PROGRAM

MONDAY

1. Variational formulation in linear solid mechanics (RLT)
Strong, weak and variational forms of BVP in linear elasticity
FEM technology for 1D problems
2. Fem technology in 1d problems (MB)
Axisymmetric 1-d elasticity
Euler-Bernoulli and Timoshenko beam models
Locking numerical evidences
3. Fem technology in solids problems (MB)
Isoparametric elements and numerical integration
Incompressibility / near incompressibility
Hybrid and mixed FE
Enhanced strain FE
4. Structural finite elements (MB)
Dimensional reduction
Plate and shell models
Finite elements for thin-walled structures
5. Introduction to FEAP and problem solution (TUTORIAL)
Tutorial on FEAP command language
Tutorial on programming in FEAP environment

TUESDAY

6. Enhancing structural fem performance (MB)
Shell theory and finite elements
Assumed strain and enhanced strain FE
Reduced integration plus stabilization
7. Theoretical foundation of mixed interpolation methods (FB)
Locking phenomena
Inf-sup condition
8. Inelastic constitutive behavior at small strains (FA)
Inelasticity and plasticity models
Solution schemes (return map)
Integration of evolution equations
Operator split method and consistent tangent modulus
9. Advanced inelastic constitutive behavior at small strains (FA)
Generalized plasticity
Nonlinear kinematic hardening
Shape-memory alloys
Extension to capture soil/concrete behaviors
10. Locking problems in plasticity (TUTORIAL)
Development and debugging of inelastic constitutive models
Choice of element type for FE analysis
Tutorial on FEAP Command language
Tutorial on programming user-models in FEAP environment

WEDNESDAY

11. Nonlinear solid mechanics for large displacements (FA)
Kinematics and strain measure at large displacement
First and second Piola-Kirchhoff, Kirchhoff and Cauchy stress tensors
Finite element interpolations; consistent linearization
12. Nonlinear constitutive models for large displacements (FA)
Formulations in reference and current configurations
Finite elasticity (stored energy function forms)
13. Nonlinear constitutive models for large displacements (FA)
Plasticity at large deformations
14. Nonlinear structural mechanics and stability analysis (MB)
Nonlinear structural models
Solution methods, path following techniques
Identification of critical points, buckling and snap-through phenomena
Prebuckling analysis and nonlinear stability analysis
15. Nonlinear problems (TUTORIAL)
Example on instability issues using symbolic approach
Finite-strain problem solution in FEAP
Programming finite-strain user-models in FEAP

THURSDAY

16. Isogeometric modeling and analysis (AR)
Introduction to splines and NURBS
Basics of isogeometric analysis
Simple investigations
17. Isogeometric modeling and analysis (GS)
Properties of isogeometric fields
Local refinement by non tensor-product splines
Incompressible materials: stability and div-free exactness
Reissner-Mindlin plates and Kirchhoff–Love limit
18. Isogeometric modeling and analysis (RLT)
Computational technologies
Implementation details for displacement and mixed forms
Example applications for elastic and inelastic materials
19. Nonlinear dynamics problems (AR)
Explicit vs. implicit integration schemes
Central difference, Newmark, and generalized alpha-methods
High order approximations in structural vibration and dynamic problems
20. Tutorial on isogeometric analysis (TUTORIAL)
Simple in-house Matlab codes
Isogeometric problem solution in FEAP

FRIDAY

21. Contact problems (RLT)
Formulation of contact problems (penalty, augmented Lagrangian)
Implementation of nodal and surface methods
Impact dynamics and contact
22. Particle, meshless, and collocation schemes (AR)
An introduction to meshless methods
Smoothed particle hydrodynamics and other approaches
Some recent developments on particle methods
Isogeometric collocation methods
23. Fluid Dynamics and Fluid Structure Interaction (MB)
Phenomena of fluid flow, incompressible Navier-Stokes equations
Computational modeling of fluids
Basic remarks on coupled problems, phenomena of fluid structure interaction, solution algorithms for FSI problems
24. Multi-scale problems (RLT)
Homogenization methods
Scale bridging using representative volume elements (FE2)
Parallel implementation details
Example applications
25. Virtual Element Methods in Structural Mechanics (FB)
Poligonal and polyhedral decompositions
Applications to linear elasticity, plate bending
Application to composite and/or fractured materials

SECRETARIAT

NL14 Secretariat — Via Ferrata,1 - 27100 Pavia, Italy
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REGISTRATION

Participants should communicate by e-mail a statement of participation to the Secretariat and, after the payment, a scan copy of the bank transfer receipt. Registration is considered completed only after the scan copy of the bank has been received by email by the secretariat.
Course fees are established as follows:

Participants from industry:	**1300€ (early)**	**1500 €**
Faculty members:	**850€ (early)**	**1000 €**
PhD students & Post-Docs:	**700€ (early)**	**850 €**

The method of payment is by bank transfer to:
Dipartimento di Ingegneria Civile e Architettura
Banca Popolare Commercio e Industria - Strada Nuova 61/C - 27100 Pavia
IBAN: IT27V0504811302000000046622
SWIFTCODE: BLOPIT22
indicating as **purpose of payment: “NL14” and the attendee's name**.

Early registration is kindly recommended. For the **early registration**, a scan copy of the bank transfer receipt should be sent **before 31.01.2014**. Registration is transferable to another member of the same organization. To get the reduced rate PhD students and post-docs should send a proof of status.
The fee comprises fixed-menu lunches, coffee breaks and course material.
For cancellations communicated prior to March 1st 2013, 70% of the registration fee will be refunded. No refund will be made for cancellation after that date.

ORGANIZING COMMITTEE

Prof. Ferdinando Auricchio — auricchio@unipv.it
Prof. Alessandro Reali — alessandro.reali@unipv.it
Mrs. Elisa Reali — elisa.reali@unipv.it

COURSE SCHEDULE

9.00-10.00	*Lecture 1*	*14.00-15.00*	*Lecture 4*
10.00-10.15	*Coffee break*	*15.00-15.15*	*Coffee break*
10.15-11.15	*Lecture 2*	*15.15-16.30*	*Tutorial*
11.15-12.15	*Lecture 3*	*16.30-17.00*	*Open discussion*
12.15-14.00	*Lunch*		

COURSE LOCATION

The course will be held at the **conference room of IMATI** – CNR (Institute of Applied Mathematics and Information Technologies) in **via Ferrata 3, 27100 Pavia**, Italy.

ACCOMMODATION

Participants have to proceed with **personal reservations**. Please refer to the course website for a list of possible hotels in Pavia.

COURSE OBJECTIVES

The main objective of this course is to provide engineers who use computer codes, graduate students, and researchers with an **review of numerical techniques and solution algorithms for nonlinear mechanics**. It presents the current state-of-the-art in finite element modeling of nonlinear problems in solid and structural mechanics and illustrates difficulties (and possible solutions) which appear in a number of applications.

Different sources of nonlinear behavior are presented in a systematic manner. Special attention is paid to nonlinear constitutive behavior of materials, large deformations and rotations of structures, contact and instability problems with either material (localization) or geometric (buckling) nonlinearities, which are needed to fully grasp weaknesses of structural design.

The course will also provide insight both on advanced mathematical aspects as well as into the practical aspects of several computational techniques, such as the finite element method, isogeometric analysis, meshless techniques, mimetic differences.

The objective is thus to provide the participants with a solid basis for using computational tools and software in trying to achieve the optimal design, and/or to carry out a refined analysis of nonlinear behavior of structures.

The course finally provides a basis to account for multi-physics and multi-scale effects, which are likely to achieve a significant break-through in a number of industrial applications.

TUTORIALS AND COURSE MATERIAL

Tutorials are organized as a final section each day and they are meant not as a standard lecture but as an **interactive part of the course**. In fact, tutorials are based on addressing simple problems to be solved during the class on the fly and they are meant as a basis for an interactive discussion between the teaching body and the course attendees. We strongly encourage students to bring their own laptops and we plan to distribute files, so that students can run examples, interact, and participate lively to the tutorials. Depending on the specific topic, the tutorials will be managed by one or more of the teachers and they will be based on using different software. Special emphasis will be given to FEAP personal version (http://www.ce.berkeley.edu/projects/feap/feappv/) or programs written in Matlab, or Maple.

The **course material** will consist of electronic copies of lecture materials and survey papers. Copies of Finite Element Analysis Program (FEAP) computer codes, written by Prof. Robert L. Taylor at UC Berkeley, and the complete volume of notes will be made available to all attendees.

LECTURERS

Franco Brezzi (FB). Full Professor of Mathematical Analysis since 1976 and of Numerical Analysis since 2008, he is Director of CeSNA IUSS-center. Awarded as ISI Highly cited researcher in Mathematics, his scientific contribution counts more than 150 papers in international journals, 5 books and many book chapters. His scientific interests are mainly concentrated in the field of Numerical Methods for Partial Differential Equations. In particular, from the point of view of methodological tools, he works mainly on Finite Element Methods (of various kinds). From the applicative point of view, he is mostly interested in problems arising from various Engineering fields, such as Structural Mechanics, Fluid Mechanics, and Electromagnetics.

Robert L. Taylor (RLT). Professor in the Graduate School, Department of Civil & Environmental Engineering, University of California, Berkeley, he is also member of US National Academy of Engineers since 1992, and has received a number of distinctions (including the von Neumann Medal of IACM) and honorary doctorates, (e.g., from University of Wales at Swansea, UK and University of Hannover, Germany). His scientific contribution counts more than 200 papers in scientific journals, co-authorship with Prof. Olek Zienkiewicz of the most well-known books on finite element method, as well as the finite element computer program FEAP.

Ferdinando Auricchio (FA). Full Professor of Mechanics of Solids at the University of Pavia, Italy since 1998. He is Research Associate at IMATI CNR-institute, member of CeSNA scientific committee and Department of Civil Engineering and Architecture Head. His main research topics span over constitutive modeling of innovative materials, biomechanics and finite element methods. He has published more than 110 papers in international journals and has been invited to give about 50 seminars at international institutions.

Manfred Bischoff (MB). Since 2006 he is Full Professor and head of the Institute of Structural Mechanics at the University of Stuttgart. In 2000 he won the EUROMECH European Young Scientist Award and in 2008 the IACM Young Investigator Award. In 2012 he was elected fellow of the International Association for Computational Mechanics (IACM). His main research topics span over nonlinear computational structural mechanics and dynamics, modeling and analysis of shells with finite elements, finite element technology, structural optimization, contact problems, isogeometric analysis and computational material modeling.

Alessandro Reali (AR). Associate Professor of Mechanics of Solids at Department of Civil Engineering and Architecture of the University of Pavia. His main research interests are isogeometric analysis, advanced material constitutive modeling, mixed finite elements, and particle methods. He authored more than 40 papers on international journals with more than 40 invited lectures and 30 plenary/keynote lectures at international conferences. He is the recipient of the 2010 ERC Starting Grant "ISOBIO – Isogeometric Methods for Biomechanics".

Giancarlo Sangalli (GS). Associate Professor at Mathematics Department of the University of Pavia since 2005, He is also Research Associate at IMATI-CNR and member of CeSNA at IUSS. His main research interests are isogeometric analysis for solid and fluid mechanics and for electromagnetics; numerical methods for domain decomposition, for multiscale and transport-dominated problems. He has published more than 40 papers in international refereed journals. He is recipient of the 2013 ERC Consolidator Grant.

Università di Pavia
Dipartimento di Ingegneria Civile e Architettura
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NL14 COURSE

First announcement

NONLINEAR COMPUTATIONAL SOLID & STRUCTURAL MECHANICS

Theoretical formulations, technologies, and computations

Pavia
May 5-9, 2014

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