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. **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.
10. **Locking problems in plasticity (TUTORIAL)**
    Development and debugging of inelastic models.
    Choice of element type for FE analysis.
    Tutorial on FEAP Command language.
    Tutorial on programming user-models in FEAP environment.

WEDNESDAY

11. **Isogeometric modeling and analysis (AR)**
    Introduction to splines and NURBS.
    Basics of isogeometric analysis.
    Simple investigations.
12. **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 Kirchoff-Love limit.
13. **Isogeometric modeling and analysis (RLT)**
    Computational technologies.
    Implementation details for displacement and mixed forms.
    Examples applications for elastic and inelastic materials.
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. **Tutorial on isogeometric analysis (TUTORIAL)**
    Simple in-house Matlab codes.
    Isogeometric problem solution in FEAP.

THURSDAY

16. **Advanced inelastic constitutive behavior at small strains (FA)**
    Generalized plasticity.
    Nonlinear kinematic hardening.
    Shape-memory alloys.
    Extension to capture soil/concrete behaviors.
17. **Nonlinear constitutive models for large displacements (FA)**
    Formulations in reference and current configurations.
    Finite elasticity (stored energy function forms).
18. **Nonlinear constitutive models for large displacements (FA)**
    Plasticity at large deformations.
19. **Nonlinear dynamics problems (AR)**
    Explicit vs. implicit integration schemes.
    Central difference, Newmark, and generalized alpha-methods.
    High order approximations in structural vibration and dynamics.
20. **Nonlinear problems (TUTORIAL)**
    Example on instability issues using symbolic approach.
    Finite-strain problem solution in FEAP.
    Programming finite-strain user-models 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

NL16 Secretariat — Via Ferrata,1 - 27100 Pavia, Italy
Phone: + 39-0382-985016 — Fax: + 39-0382-528422
E-mail: sonia.padovan@unipv.it
Web-site: **www.unipv.it/compmech/nl16_home.html**

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 €**

For private registration 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: "NL16" and the attendee's name**.

For public institutions the method of payment is by bank transfer to:
Dipartimento di Ingegneria Civile e Architettura
Banca D'italia
Institution Code: 81001
Current account: 37198
indicating as **purpose of payment: "NL16" 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 31.01.2016**. 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, 2016**, 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. Sonia Padovan — sonia.padovan@unipv.it

COURSE SCHEDULE

09.00-10.00	*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 **Palazzo Vistarino** in **via sant'Ennodio, 26, Pavia**, Italy.
Palazzo Vistarino's website: http://www-wp.unipv.it/vistarino/

ACCOMMODATION

The Palace hosting the course has several **guest rooms** that can be **booked by sending an email to the Secretariat**. **Other accommodations** are available, but they need to be **personally booked by participants**. 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, graduate students, and researchers with a **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) appearing 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, virtual element method.

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 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 on the fly 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 simple "in-house" codes 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). Professor of Mathematical Analysis since 1976 and of Numerical Analysis since 2008. 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 and Environmental Engineering, University of California, Berkeley. His main research areas cover several areas of computational mechanics including: element technology, contact problems, solution algorithms and software development. He is well known for his co-authored books on the finite element method (with O.C. Zienkiewicz et al.) and development of the finite element program FEAP.

Ferdinando Auricchio (FA). Professor of Mechanics of Solids at the University of Pavia, Italy. FA main research topics span over constitutive modeling of innovative materials, biomechanics and finite element methods. He is currently leading one of the five strategic project for the whole University of Pavia, project entitled "3D@UniPV: Virtual Modeling and Additive Manufacturing (3D printing) for Advanced Materials".

Manfred Bischoff (MB). Professor and head of the Institute of Structural Mechanics at the University of Stuttgart. Winner in 2000 of the EUROMECH European Young Scientist Award and in 2008 of the IACM Young Investigator Award, elected in 2012 fellow of the International Association for Computational Mechanics (IACM). His main research topics are nonlinear computational structural mechanics and dynamics, modeling and analysis of shells, finite element technology, structural optimization, contact problems, isogeometric analysis, computational material modeling.

Alessandro Reali (AR). Professor of Mechanics of Solids at the Department of Civil Engineering and Architecture of the University of Pavia, and "Fischer" Fellow at the Institute of Advanced Study of the Technical University of Munich. His main research interests are isogeometric analysis, advanced constitutive modeling, mixed finite elements, and strong-form (particle and collocation) methods. He is an ISI "Highly Cited Researcher" and the recipient, among other honors, of the ERC "Ideas" Starting Grant, of the IACM "Argyris" Award, and of the ECCOMAS "Zienkiewicz" Award.

Giancarlo Sangalli (GS). Professor of Numerical Analysis at the Mathematics Department of University of Pavia, GS has worked on multiscale numerical methods, domain decomposition methods and, more recently, on isogeometric methods, with application in solid, fluid mechanics, and electromagnetism. In particular, he has contributed to the analysis of isogeometric methods in several directions, ranging from basic elliptic problems, to eigenvalue analyses, complex geometry parametrizations (e.g., T-splines), and efficient inplementation (quadrature, linear solvers).

UNIVERSITÀ DI PAVIA

Ordine Ingegneri provincia di Pavia

ECCOMAS

NL16 COURSE

Third announcement

An ECCOMAS Advanced Course on

NONLINEAR COMPUTATIONAL SOLID & STRUCTURAL MECHANICS

Theoretical formulations, technologies, and computations

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