

POLITECNICO DI MILANO



Course in the Structural, Seismic and Geotechnical Engineering Doctoral Program during the academic year 2023-2024

Course Title: "Inverse Problems and Finite Element Model Updating"

Date: **January/February 2024**

Duration: **25 hours; 5 CFU**

Responsible for the Course: **Prof. Eng. Roberto Fedele**,

Associate Professor, Department of Civil and Environmental Engineering (DICA)

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2 hour seminar: Prof. Paolo Dulio, Department of Mathematics, Politecnico di Milano.

Detailed Program

The course consists of a theoretical part and a few practical sessions.

1. **Theoretical part** (13 hours): Least-square problems; pseudo-inverse matrix; a probabilistical framework to inverse analyses based on information theory; Bayesian approach; Kalman filtering; Minimization algorithms and heuristic strategies; Fundamentals of nonlinear finite element models; Special purpose elements for fracture and plasticity; Sensitivity analyses by Direct Differentiation Methods (DDM); X-ray tomography reconstruction; displacement estimation on the basis of digital images by Galerkin Digital Image Correlation approach (2D and 3D-Volume DIC). In the theoretical part some case studies are also included, concerning engineering applications of finite element model updating to fracture problems, railway wheels, composites at different scales.
2. **Practical sessions** (12 hours). The novelty of the course is the presence of practical sessions: under the teacher supervision, codes for nonlinear finite elements will be developed in a Matlab environment, endowed by sensitivity analyses and identification procedures. The participants are invited to take with them their notebooks, with Matlab already installed, endowed by the Optimization toolbox.

Final examination concerns the whole course and computer programs, in the form of an oral presentation (30 minutes) developed by the student as a homework on topics selected in agreement with the teacher.

Essential Bibliography

1. Fedele, R., Raka, B., Hild, F., Roux, S., Identification of adhesive properties in GLARE laminates by Digital Image Correlation, *J Mechanics Physics of Solids*, Vol. 57, No. 7. (July 2009), pp. 1003-1016.
2. Fedele, R., Ciani, A., Galantucci, L., Bettuzzi, M., Andena, L., A regularized, pyramidal multi-grid approach to global 3D-Volume Digital Image Correlation based on X-ray micro-tomography. *Fundamenta Informaticae*, Vol. 125, pp. 361-376, 2013,

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3. Fedele, R., Galantucci, L., Ciani, A., Global 2D Digital Image Correlation for motion estimation in a finite element framework: a variational formulation and a regularized, pyramidal, multi-grid implementation, *Int. J. Numerical Methods in Engineering*, 2013, DOI: 10.1002/nme.4577.
4. Fedele, R., Maier, G., Whelan, M., Calibration of local constitutive models through measurements at the macroscale in heterogeneous media, *Computer Methods in Applied Mechanics and Engineering*, Vol.195, pp. 4971-4990, 2006
5. Bonnet M. and Frangi, A., *Analyse des solides déformables par la méthode des éléments finis*, Les Editions de l'Ecole Polytechnique, Palaiseau (France), ISBN 2-7302-1349-X, p. 320, 2006 (with downloadable Matlab programs).
6. Tarantola A., *Inverse Problem Theory and Methods for Model Parameter Estimation*, Society of Industrial and Applied Mathematics (SIAM), Philadelphia, PA (USA), 2005, ISBN 0-89871-572-5.
7. Kak A.C. and Slaney M., *Principles of Computerized Tomographic Imaging*, Society of Industrial and Applied Mathematics (SIAM), Philadelphia, PA (USA), 2001 ISBN:0-89871-494-X.

Scheduling

The course lessons will be held in presence for PhD students belonging to Politecnico, in Fassò room (Building 4, Leonardo Campus). Streaming connection will be available for the PhD students of other institutions (in this last case info about the registration, the administrative fee (25 euros) requested by Politecnico, the connection will be provided by the teacher). The course will follow the following daily program:

Dates	Morning	Afternoon
Monday 29 January 2024	<u>9:00-12:00</u>	<u>14:00-17:15</u>
Tuesday 30 January 2024	<u>9:00-12:00</u>	<u>14:00-17:15</u>
Monday 5 February 2024	<u>9:00-12:00</u>	<u>14:00-17:15</u>
Wednesday 7 February 2024	<u>9:00-12:00</u>	<u>14:00-17:15</u>

For the practical sessions, the participants should have Matlab installed on their PC/laptop, including the Optimization toolbox.

INTERESTED PERSONS ARE INVITED TO CONTACT Prof. Roberto Fedele, Tel. +39 02 23994275 E-mail: roberto.fedele@polimi.it