CEACM S4ML 2024 Conference Course (3 ECTS)

Central European Association for Computational Mechanics

Course Announcement

Short Course at CEACM S4ML 2024

Current Research on Synergy between Multiphysics/ Multiscale Modeling and Machine Learning

June 17 - 18, 2024

CTU Prague, Czech Republic

Civil Engineering, Room A228

co-organized by:

Adnan Ibrahimbegovic & Anna Kucerova

UTC-Alliance Sorbonne University & CVUT. Prague

IUF, France & ACMBH & CEACM

VENUE INFORMATION

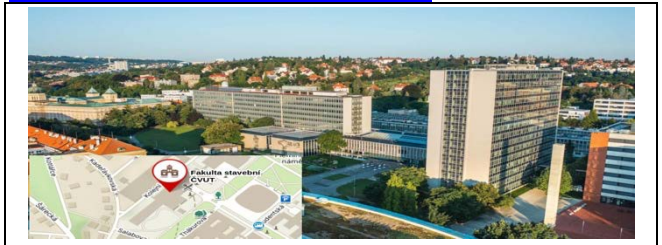
This is a multi-choice course offered to current Graduate students interested in current research in broad fields of multi-physics/multi-scale problem and machine learning with different application domains. The course is under sponsorship of Central European Association for Computational Mechanics (CEACM). The course students will also be admitted to the conference scientific program, but not to all social events. The course runs for 1,5 day, June 17-18, 2024, just before CEACM S4ML 2024 conference, which is held June 19-21, 2024 (web: https://ceacm.net/s4ml-2024/).

The course venue is **CTU Prague, Department of Civil Engineering, Room A228**.

Course venue: **CTU Prague** (see Figure below)

Address: Thákurova 2077/7, 160 00 Prague 6 - Dejvice

https://www.cvut.cz/en/welcome-to-ctu



COURSE OBJECTIVES

The main objective of this course is to provide graduate students and researchers, with an extensive review of numerical models for multi-physics/multi-scale problems, and pertinent modern developments in machine learning with respect to model reduction, probability aspects and uncertainty quantification. It presents the current state-of-the-art in finite element, finite volume and discrete element modeling of nonlinear problems in computational mechanics and coupling with machine learning current research aspects. It will illustrate the difficulties (and their solutions), which appear in a number of applications from aerospace, civil and mechanical, engineering or material science. **Different domains of Engineering Sciences are covered with specialty courses to choose from, each one coordinated by well-established experts. We propose 5 different options that cover: Bioengineering and Cancer, Identification, Computer Software, Multibody systems, Materials.**

COURSE PROGRAM OUTLINE

Day I: June 17th, 2024, 14h-18h Basics/ Identification
Multi-physics/Multi-scale 14h-15h
(Instructor: Adnan Ibrahimbegovic)
Inverse Problems/Machine Learning 15h-16h
(Instructor: Hermann Matthies)
Identification 16h-18h
(Instructors: Anna Kucerova, Noemi Friedman)
Day II June 18th, 2024, 9h-18h Applications:
Materials/Multiscale 9h-11h (Instructors: Jan Zeman, Martin Doškář)
Computer Software 11h-12h
(Instructor: Bořek Patzák)
Multibody Dynamics 13h-16h
(Instructors: Pavel Polach, Michal Hajžman, Zbyněk Šika)
Bioengineering 16h-18h
(Instructor: Nenad Filipovic)

COURSE REFERENCES

CourseNotes:Multiphysics/Multiscale-A. Ibrahimbegovic:

-Nonlinear Solid Mechanics: Theoretical Formulations and Finite Element Solution Methods, 2009, Springer, http://springer.com/978-90-481-2330-8

-Computational Methods for Solids and Fluids: Multiscale Analysis, Probability Aspects and Model Reduction, 2016, Springer, http://www.springer.com/fr/book/9783319279947

-Structural Engineering: Models and Methods for Statics, Instability and Inelasticity 2023, Springer, http://springer.com/978-3-031-23591-7

-Thermoelectromagnetics Coupling with Elasticity and Inelasticity, 2024, CRC Press, Taylor and Francis books, https://www.taylorfrancis.com/books/mono/10.1201/9781351052504/

CourseNotes: Inverse Problems/Machine Learning-H.G. Matthies:

-Uncertainty Quantification with Stochastic Finite Elements, Encyclopedia of Computational Mechanics, 2007, Wiley, https://onlinelibrary.wiley.com/doi/abs/10.1002/0470091355.ecm071

-Uncertainty Quantification and Bayesian Inversion, Encyclopedia of Computational Mechanics, 2016, Wiley, https://onlinelibrary.wiley.com/doi/abs/10.1002/9781119176817.ecm2071

-Predictive Computational Science: Computer Predictions in the Presence of Uncertainty, 2017, Wiley, https://onlinelibrary.wiley.com/doi/abs/10.1002/9781119176817.ecm2101

CourseNotes: Identification - A. Kucerova

-Efficient probabilistic multi-fidelity calibration of a damage-plastic model for confined concrete. Comp. Methods Applied Mechanics Eng., 412, 1 (2023), 116099, https://doi.org/10.1016/j.cma.2023.116099

-Comparison of Numerical Approaches to Bayesian Updating. In: Computational Methods for Solids and Fluids. Cham: Springer International Publishing, 2016. p. 427-462. Computational Methods in Applied Sciences. vol. 41, ISBN 978-3-319-27996-1, https://link.springer.com/chapter/10.1007/978-3-319-27996-1_16

-Artificial neural networks in calibration of nonlinear mechanical models. Advances in Engineering Software, 95: 68-81, 2016, https://arxiv.org/abs/1502.01380

CourseNotes: Identification – N. Friedman

-A Worked-out Example of Surrogate-based Bayesian Parameter and Field Identification Methods. In: Bayesian Inverse Problems. CRC Press,155-203.(2021) ISBN 9781315232973 10.1201/b22018-10

-Bayesian updating of tall timber building model using modal data. Eng. Structures, 266. (2022) ISSN 0141-0296 10.1016/j.engstruct.2022.114570

CourseNotes: Materials/Multiscale –J.Zeman, M.Doskar

-Computational Homogenization of Heterogeneous Materials with Finite Elements, 2019,. Springer, https://link.springer.com/book/10.1007/978-3-030-18383-7

-Effective properties of composite materials with periodic microstructure: a computational approach. Computer Methods in Applied Mechanics and Engineering 172, 109–143, 1999, https://doi.org/10.1016/S0045-7825(98)00227-8

-Micromechanics in Practice, 2013, WIT Press, https://www.witpress.com/books/978-1-84564-682-0

CourseNotes: Computer Software – B. Patzak

-EMMS Digitalisation & Interoperability in Materials modelling, 2023, https://emmc.eu/focus-areas/digitalisation-interoperability/

-Integration of material and process modelling in a business decision support system: Case of COMPOSELECTOR H2020 project. Composite Structures, 204, 778-790, 2018, https://www.sciencedirect.com/science/article/pii/S0263822318315551

-MuPIF Integration platform, 2023, www.mupif.org

CourseNotes: Multibody Dynamics – P. Polach, M. Hajzman, Z. Sika

-Dynamics of Multibody Systems, 2013, Cambridge University Press https://doi.org/10.1017/CBO9781107337213

-Flexible Multibody Dynamics: Review of Past and Recent Developments,MultibodyDynamics, 1,189–222,1997 https://link.springer.com/article/10.1023/A:1009773505418

-Kinematics and Dynamics of Machinery, 1996, Taylor & Francis https://books.google.cz/books/about/Kinematics_and_Dynamics_of_Machinery.html?id=x312QgAACAAJ&redir_esc=y

CourseNotes: Bio-Engineering - N.D. Filipovic

-Computational Modeling in Bioengineering and Bioinformatics, 2020, Academic Press, https://www.sciencedirect.com/book/9780128195833/computational-modeling-in-bioengineering-and-bioinformatics

-Computational Modeling and Simulation Examples in Bioengineering, 2022, Wiley, https://onlinelibrary.wiley.com/doi/book/10.1002/9781119563983

-Computer simulation of three-dimensional plaque formation and progression in the coronary artery, Computers & Fluids 88 (2013) 826–833, http://dx.doi.org/10.1016/j.compfluid.2013.07.006

-Electromagnetic field investigation on different cancer cell lines, Cancer Cell Int., 14, 84 (2014), https://doi.org/10.1186/s12935-014-0084-x

-Modeling of liver metastatic disease with applied drug therapy, Comput. Methods Programs Biomed, 115 (2014)162–170, http://dx.doi.org/10.1016/j.cmpb.2014.04.013

-SILICOFCM platform, multiscale modeling of left ventricle from echocardiographic images and drug influence for cardiomyopathy disease, Comput. Methods Programs Biomed, (2022),227:107194, doi: 10.1016/j.cmpb.2022.107194

-Huxley muscle model surrogates for high-speed multi-scale simulations of cardiac contraction, Computers in Biology and Medicine 149 (2022) 105963, https://doi.org/10.1016/j.compbiomed.2022.105963

-Machine learning and physical based modeling for cardiac hypertrophy, Heliyon 9 (2023) e16724, https://doi.org/10.1016/j.heliyon.2023.e16724

COURSE PROFESSORS (Day I):

Adnan Ibrahimbegovic is Professor Classe Exceptionnelle, Member IUF-Institut Universitaire France and Chair for Computational Mechanics at UT Compiègne - Alliance Sorbonne Université, member of the Academy of Arts and Sciences of Bosnia-Herzegovina and of the Academy of Europe. He has obtained his engineering education in Sarajevo, PhD at the University of California Berkeley and Habilitation at University Pierre Marie Curie in Paris, France. He has held professorships and research positions at five different universities in four countries (including UC Berkeley, USA; EPFL, Switzerland; ENS-Paris-Saclay and UTC, France and University of Sarajevo, BH). He has received a number of international distinctions, including IACM Fellow Award, Humboldt Research Award for Germany, Research Award for Slovenia, International Fellow NSERC Award for Canada, 'Claude Levy-Strauss' Chair for Univ. Sao Paulo, Brazil, 'Asgard' Chair for NTNU, Norway, KAIST Professor, South Korea, 'Hôte Académique' Award for EPFL, Switzerland. He has published over 200 papers in scientific journals, 400 conference papers and 10 textbooks and monographs**.**

Hermann G. Matthies is Professor Emeritus in Scientific Computing at TU Braunschweig and member of the academy "Braunschweigische Wissenschaftliche Gesellschaft". He has obtained his first degree at TU Berlin, Germany; and his PhD degree in mathematics at MIT, Cambridge, USA in 1978. Subsequently he has worked in Research Division of Germanischer Lloyd, Hamburg, Germany, dealing with industrial research and engineering in diverse fields such as wind, offshore, and ice engineering. Since 1995 he joined academia as the Head of the Institute of Scientific Computing at the TU Braunschweig, Germany; and from 1996 to 2006 he served as the director of the University Computing Centre. His current research is oriented towards the uncertainty quantification, Bayesian identification and updating, coupled and interaction problems, plasticity and scientific computing. He has received several international distinctions, among them the Fellowship Award of the IACM and Gay-Lussac-Humboldt Award for France. He has published over 150 papers in scientific journals, and close to 300 conference publications.

Anna Kučerová is associate professor at the Department of Mechanics, Faculty of Civil Engineering, Czech Technical University (CTU) in Prague. She has 20 years of experience in development optimisation and machine learning tools for solving inverse problems in engineering. After her PhD in cotutelle at ENS Cachan, France and CTU in Prague focused on identifying nonlinear material model parameters using evolutionary algorithms and artificial neural networks, she worked as a post-doc at TU Braunschweig on reformulating the inverse problems in a probabilistic framework, applying Bayesian inference and numerical tools for uncertainty quantification. In 2008, she was appointed an assistant professor at CTU and more recently promoted to associate professor. In 2017, her work was rewarded by L'Oréal - UNESCO For Women in Science Award for the project on Inverse problems in probabilistic engineering mechanics. She recently spent 9 months as a Fulbright visiting professor at the Department of Aeronautics and Astronautics, MIT, USA as a member of the Uncertainty Quantification Group led by Prof. Marzouk.

Noemi Friedman is Senior Scientist @Institute for Computer Science and Control (SZTAKI), Hungary. Noémi Friedman has earned her Master degree in structural engineering at the Budapest University of Technology and Economics (BME), and her PhD in parallel at ENS de Cachan, France and at the Budapest University of Technology and Economics. Her Ph.D.

focused on deployable structures, structures that can go through large deformations and displacements. Following her PhD, she was a postdoc at TU Braunschweig, Germany for six years, where she has started to shift her skills to stochastic computations, data science, and machine learning (SZTAKI). Her main research focus is to quantify uncertainties of engineering simulations and to reduce these uncertainties using measured data. She has a demonstrated history of working in the cross-disciplinary fields of computational science, artificial intelligence, and civil engineering.

COURSE PROFESSORS (Day II):

Jan Zeman is a Full Professor in the Theory of Materials and Structures at the Department of Mechanics, Faculty of Civil Engineering, Czech Technical University (CTU) in Prague, and a core member of the CTU Open Mechanics Group. He earned his Ph.D. in 2003 from CTU in Civil Engineering with a specialization in Structural Mechanics. He received the 2000 Hlavka Talent Foundation prize and the Ivo Babuška Award for the best Ph.D. thesis in Applied and Computational Mathematics and Mechanics in 2003. His research interests are in applied mechanics and mathematics, focused on modeling and simulation of deterministic and stochastic microstructured material. His work was supported by a Marie-Curie Intra-European Fellowship the Czech Science Foundation. He is currently the principal investigator of a five-year EXPRO project on the computer-aided design of modular architectured materials.

Martin Doškář is an assistant professor at the Department of Mechanics, Faculty of Civil Engineering, Czech Technical University (CTU) in Prague. He obtained his master and doctoral degrees at CTU in Prague in 2014 and 2019, respectively. In 2014, he received Hlavka Talent Foundation prize for top university students in the Czech Republic. His Ph.D. thesis was awarded Rector's prize for the best doctoral thesis at CTU in 2019 and best PhD thesis award by CEACM. His scientific interests are driven by identifying and understanding the key mechanisms through which the material composition at a microstructural scale (including its inherent randomness) affects the effective behaviour of a material at larger scales, both from the perspective of describing existing materials microstructures and designing new advanced (meta)materials.

Bořek Patzák is a full professor in charge of the theory of materials and structures at the Department of Mechanics, Faculty of Civil Engineering, Czech Technical University (CTU) in Prague. He earned his Ph.D. in 1997 from CTU in Civil Engineering with a specialization in Structural Mechanics. In 2000-2002 he worked as research engineer at EPFL, ENAC, Laboratory of Structural and Continuum Mechanics (LSC) in Lausanne, Switzerland, on a project with HILTI on adaptive techniques for strain-softening materials. At present he is also a Vice-Dean for science and research at the Faculty of Civil Engineering. His research interests are in applied mechanics and design and development of simulation software, focused on modeling and simulation of multiphysics problems. He is the original author of open-source FE code OOFEM and of multiphysics simulation platform MuPIF.

Pavel Polach is Associate Professor at Research and Testing Institute Plzen, Czech Republic. He obtained his engineering education at CTU in Prague, PhD and Habilitation at University of West Bohemia in Plzen. He is past president of CEACM. He is of R&D projects manager at Research and Testing Institute Plzen, a senior researcher at Faculty of Applied Sciences, University of West Bohemia and an Associate Professor at Faculty of Mechanical Engineering, Jan Evangelista Purkyně University in Ústí nad Labem. His scientific research is focused on computational mechanics and dynamics, especially multibody dynamics, vehicle dynamics, rotating machines dynamics, robotics and power engineering. He is the author of over 400 scientific works (over 50 journal papers, over 200 conference papers and 150 research reports). He has served as the principal investigator for a large number of research projects.

Michal Hajžman is associate professor at University of West Bohemia in Pilsen. He has obtained his initial degree and his doctoral degree in Applied mechanics at University of West Bohemia in 2006. Parallelly, he works as a researcher in Research and Testing Institute Plzen. He is a member of CEACM, the Board member of Czech Society for Mechanics and he served as a secretary of CEACM in years 2012 to 2017. His PhD thesis was awarded by honorable mention of Prof. Babuška in the annual competition organized by Czech Society for Mechanics. His scientific activities are focused on the field of multibody system dynamics and kinematics, rotordynamics, vibration and dynamics of machines and mechanical structures, vehicle dynamics and optimization in general. He has been the principal investigator or co-investigator of several research projects of basic and applied research.

Zbyněk Šika has obtained his engineering education, PhD and Habilitation at CTU in Prague. He is full professor at FME CTU in Prague, Member of Scientific Council – FME, CTU in Prague. He is chairman of the Board of the master's study program "Applied sciences in mechanical engineering" and of the doctoral study program "Design engineering and mechatronics" at FME, CTU in Prague. His scientific activity is focused on the field of parallel redundantly actuated robots and manipulators; cable driven robots and manipulators; active and semi-active vibration control; synthesis and optimization of mechanical and mechatronical systems; and multibody system dynamics and kinematics. He was and is the principal investigator of a large number of research projects dealing with basic and applied research.

Nenad D. Filipovic is Professor and Rector of University of Kragujevac, Serbia and Head of Center for Bioengineering at University. He was Research Associate at Harvard School of Public Health in Boston, USA. His research interests are in the area of computational mechanics, biomedical engineering, cardiovascular disease, fluid-structure interaction, biomechanics, bioinformatics, biomedical image processing, machine learning, medical informatics, multi-scale modeling, software engineering, parallel computing, computational chemistry and bioprocess modeling. He is co-author of 11 textbooks and 10 monographies, over 400 publications in peer review journals and over 10 software products for fluid mechanics and multiphysics. He is Editor in Chief for EAI Endorsed Transaction on Bioengineering and Bioinformatics, Managing Editor for Journal of Serbian Society for Computational Mechanics, President of Serbian Society of Mechanics and member of European Society of Biomechanics (ESB), European Society for Artificial Organs (ESAO) and IEEE member.