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Advanced computational and deep learning algorithms for the automated modeling of materials with complex microstructures

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12:00pm – 1:00pm

Lunch Presentation

E100 Scott Laboratory

Dr. Soheil Soghrati is an Associate Professor of Mechanical and Aerospace Engineering at The Ohio State University. He earned his Ph.D. in Structural Engineering with a minor in Computational Science in Engineering from the University of Illinois at Urbana-Champaign, during which he held a graduate research assistantship at the Beckman Institute for Advanced Science and Technology. Dr. Soghrati joined the Department of Mechanical and Aerospace Engineering at OSU in June 2013 with a joint appointment in the Department of Materials Science and Engineering. Dr. Soghrati's research interests lie in the area of computational solid mechanics, with a special focus on the development and implementation of advanced numerical and AI algorithms for the automated modeling and design of materials. Some of the past and ongoing research problems being investigated in Dr. Soghrati's research group, the Automated Computational Mechanics Laboratory (ACML), include the development of new microstructure reconstruction and mesh generation algorithms, using AI to predict material performance, simulating localized corrosion and corrosion-assisted failure of alloys, digital manufacturing, finite element simulation of the multiscale failure response of composites, computational design of Lithium-ion battery electrodes, and computational biomechanics. These projects have been supported by several federal agencies and industrial companies, including the National Science Foundation, Air Force Office of Scientific Research, Department of Defense, Honda, Ford, Owens Corning, and OSU's Center for Cancer Engineering.

Abstract:

An integrated computational framework, which relies on virtual microstructure reconstruction, parallel mesh generation, and deep learning algorithms, is presented for predicting and simulating the multiscale failure response of materials. A NURBS-based virtual reconstruction algorithm is developed to synthesize heterogeneous material microstructures by packing arbitrarily shaped inclusions, whose morphologies are extracted from imaging data such as micro-computed tomography images. A genetic algorithm (GA)-based optimization phase is then utilized to replicate target statistical microstructural descriptors such as the volume fraction, spatial arrangement, and orientations of embedded inclusions. Additionally, a new AI-based approach is introduced that relies on Deep Convolutional Degenerative Adversarial Networks (DCGAN) for the virtual reconstruction of complex biomaterial microstructures. Conforming finite element (FE) meshes are generated using a non-iterative meshing algorithm, coined Conforming to Interface Structured Adaptive Mesh Refinement (CISAMR), which transforms an initial structured mesh into a high-quality conforming mesh. CISAMR can handle problems with highly intricate geometries, including material interfaces with sharp edges/corners, as well as mixed-mode fracture problems involving crack merging. Several applications of this integrated reconstruction-meshing framework are presented for predicting the failure response and fatigue life of a wide variety of materials, including particulate composites, fiber-reinforced composites, chopped fiber composites, entangled nonwoven materials, and textile composites. Furthermore, it is demonstrated how these algorithms can be used in the realm of computational biomechanics to create digital twins of the human vertebra and predict the risk of vertebral compression fracture in cancer patients with spinal metastasis. Last but not least, the application of deep learning for the accelerated prediction of the failure response of corroded steel pipes is presented, which enables real-time health monitoring of these pipelines.

Hosted by Prof. Marcelo Dapino

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