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Leading Units with Artificial and Common Intelligence

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ABSTRACT:

We are strongly motivated to develop models from a first-principles approach to explaining physical phenomena. In this talk, multi-scale modeling of 3D composite structures of complex architectures will be discussed at the intersection of mechanobiology, computational solid mechanics, and interfacial mechanics. To provide perspective, traumatic axonal injury occurs when loads experienced on the tissue scale are transferred to the individual axons. Mechanical characterization of axon deformation, especially under dynamic loads, is challenging owing to its viscoelastic properties. Our research efforts focus on creating a histology-informed computational framework that depicts, analyzes, and determines dynamic axonal damage. Given the fragility and inaccessibility of the central nervous system, there has been a growing emphasis on non-invasive techniques, like magnetic elastography (MRE). Interpretation of MRE measurements depends on efficient mathematical representations of examined tissues' architecture and properties. The white matter's geometry and material anisotropy are scale-dependent; thus, a direct numerical simulation of its viscoelastic response is arduous.We developed orthotropic Representative Volume Elements (RVE) of the microstructure of the brain white matter (BWM) using frequency domain viscoelasticity and the finite element method. Anisotropic mesoscale models that are informed by the microscale RVEs are thus derived. Producing full-scale finite element models that accurately represent the relationship between the micro and macroscale BWM is computationally expensive. The behavior of the RVE is expressed by a viscoelastic constitutive material model where the frequency-related viscoelastic properties are imparted as storage modulus and loss modulus of the individual components, namely, the axonal fibers and extracellular glia. Thus, the resulting anisotropic properties comprise individual constants for the loss and storage moduli. Additionally, it is very testing to build every single RVE using finite elements since the architecture of each RVE is arbitrary in an infinite data set. The above challenges are overcome by developing a deep 3D convolution neural network (CNN) model that utilizes a voxelization method to obtain geometry information from 3D RVEs. The architecture information encoded in the voxelized location is employed as input data to the CNN, which cross-references the RVEs' material properties (output data). Using simulation results of RVEs as training data, the CNN is trained to predict the stiffness tensor of an input RVE. The training process compares the full FE simulations of the RVEs with predicted results by the CNN. An optimization process updates the neural network model. This novel methodology combining data-informed CNN with FE simulations of RVE dramatically reduces computational effort and time compared to full-scale finite element models. The efficacy of the CNN model depends on the number of data points used in the training dataset. However, it is observed that with the number of simulation results used here, the CNN model yielded a coefficient of determination, R2=0.8225. A coefficient of determination value of 0 implies a poor fit, while 1 implies a perfect fit. In addition to vastly speeding up the process of predicting the material properties of the microstructure of the BWM, this method also overcomes mesh failure issues that arise in capturing the arbitrary and random distribution of axons in BWM. The model markedly predicts the dynamic response of histology-informed white matter tissue compared to models that do not directly represent cell-level architecture. This framework produces a computational model of trauma-damaged tissue while preserving a geometrically accurate representation.

BIOGRAPHY:

Dr. Assimina (Mina) Pelegri is a Professor and Chairwoman of the Mechanical and Aerospace Engineering Department at Rutgers University. She is an aerospace engineer with research interests in composite materials design, modeling, and characterization. Her current research projects span from super-hard materials' response on ballistic loads to modeling neuron degradation during Alzheimer's and traumatic brain injury. An NSF Career award recipient, she has forged funding and research relationships with NSF, ONR, AFOSR, DARPA, NJ Space Grant Consortium, NJ Commission of Brain Injury Research, and industrial partners. By forming strategic collaborations with companies, she founded and currently directs the Advanced Materials and Structures Laboratories and the Tissue Characterization and Modeling Laboratories at Rutgers. As an advocate and supporter of student activities, Mina initiated MESA, a student leadership organization to better connect professors with the student body, and RU Girls Connect, which focuses on mentoring and championing females in underrepresented STEM fields such as aerospace and physics. In service to the students, Mina established the Aerospace Engineering degree at Rutgers University, one of her proudest achievements.

Before joining Rutgers, she interned at Cisco Systems, Coca-Cola Inc., Kenco Ltd., and Public Power Corp., GR. As a volunteer, Mina conceptualized and currently leads the Space: Habitats and Exploration Technology Group