Structural Engineering Seminar Series

CEE 595 S/SO

Modeling traffic jam and growth process of neurons using isogeometric analysis and physics-informed neural network

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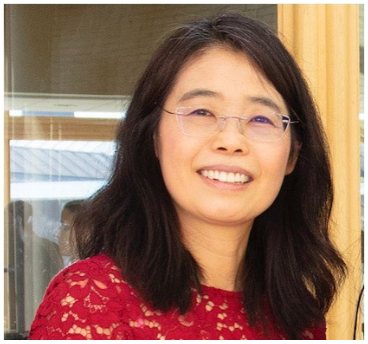
Abstract:

The motor-driven intracellular transport plays a crucial role in supporting a neuron cell's survival and function. The disruption of transport may lead to the onset of neurodegenerative diseases. To study how neurons regulate the material transport process and have a better understanding of the traffic jam formation, we develop a PDE-constrained optimization model and an isogeometric analysis (IGA) solver to simulate traffic jams induced by MT reduction and swirl. We also develop a novel IGA-based physics-informed graph neural network (PGNN) to quickly predict normal and abnormal transport phenomena in different neuron geometries. The IGA-based PGNN model contains pipe and bifurcation simulators as well as a GNN assembly model. The well-trained model effectively predicts the distribution of transport velocity and material concentration during traffic jam and normal transport with an average error <10% compared to IGA simulations. To model neuron growth, we develop a new computational framework and an open-source software package "NeuronGrowth_IGAcollocation." We propose a novel phase field model with isogeometric collocation to simulate different stages of neuron growth by considering the effect of tubulin, including lamellipodia formation, initial neurite outgrowth, axon differentiation, and dendrite formation. Through comparison with experimental observations, we demonstrate similar reproduction of neuron morphologies at different stages of growth and allow extension towards the formation of neurite networks. Based on the IGA simulation data, a CNN model is built to efficiently predict the growth process.

Bio:



Jessica Zhang is the George Tallman Ladd and Florence Barrett Ladd Professor of Mechanical Engineering at Carnegie Mellon University with a courtesy appointment in Biomedical Engineering. She received her B.Eng. in Automotive Engineering, and M.Eng. in Engineering Mechanics from Tsinghua University, China; and M.Eng. in Aerospace Engineering and Engineering Mechanics and Ph.D. in Computational Engineering and Sciences from Institute for Computational Engineering and Sciences (now Oden Institute), The University of Texas at Austin. Her research interests include computational geometry, isogeometric analysis, finite element method, data-driven simulation, image processing, and their applications in computational biomedicine, materials science and engineering.

Zhang has co-authored over 200 publications in peer-reviewed journals and conference proceedings and received several Best Paper Awards. She published a book entitled "Geometric Modeling and Mesh Generation from Scanned Images" with CRC Press, Taylor & Francis Group. Zhang is the recipient of Simons Visiting Professorship from Mathematisches Forschungsinstitut Oberwolfach of Germany, US Presidential Early Career Award for Scientists and Engineers, NSF CAREER Award, Office of Naval Research Young Investigator Award, and USACM Gallagher Young Investigator Award. At CMU, she received David P. Casasent Outstanding Research Award, George Tallman Ladd and Florence Barrett Ladd Professorship, Clarence H. Adamson Career Faculty Fellow in Mechanical Engineering, Donald L. & Rhonda Struminger Faculty Fellow, and George Tallman Ladd Research Award. She is a Fellow of AIMBE, ASME, SMA, USACM and ELATES at Drexel. She is the Editor-in-Chief of Engineering with Computers.

Monday, November 28, 2022 4:00 – 5:20 p.m.

1310 Yeh Student Center