Biomedical Informatics Grand Rounds

Wednesday, October 12th, 2022 3:00 pm – 4:00 pm

Learning Physics-Guided Neural Operators for Biological Tissue Modeling

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In-Person talk
Medical and Research Translation (MART) Building, Room location 7M-0602
Remote Access
Join Zoom Meeting https://stonybrook.zoom.us/j/95617197636?pwd=KytzZ2pVRG9SZGpKZUtpNXJISjNjZz09
Meeting ID: 956 1719 7636 Passcode: 924293

Bio: Yue Yu received her B.S. from Peking University in 2008, and her Ph.D. from Brown University in 2014. She was a postdoc fellow at Harvard University after graduation, and then she joined Lehigh University as an assistant professor of applied mathematics and was promoted to associate professor in 2019. Her research lies in the area of applied and computational mathematics, with recent projects focusing on nonlocal problems and scientific machine learning. She has received an NSF Early Career award and an AFOSR Young Investigator Program (YIP) award.

Abstract: For many decades, physics-based PDEs have been commonly employed for modeling the mechanical responses of soft biological tissues, then traditional numerical methods were employed to solve the PDEs and provide predictions. However, these classical models may become inaccurate due to the high degrees of material heterogeneity, and often suffer from high computational cost in long-term prediction tasks. In this talk we present a data-driven workflow to biological tissue modeling, which aims to predict the displacement field under unseen loading scenarios, without postulating a specific constitutive model form nor possessing knowledge on the material microstructure. In particular, we develop PDE-inspired neural operator architectures, to learn the mapping between loading conditions and the corresponding tissue mechanical responses. By parameterizing the increment between layers as an integral operator, our neural operator can be seen as the analog of a time-dependent nonlocal equation, which captures the long-range dependencies in the feature space and is guaranteed to be resolution-independent. Moreover, when applying to (hidden) PDE solving tasks, our neural operator provides a universal approximator to a fixed point iterative procedure, and partial physical knowledge can be incorporated to further improve the model's generalizability and transferability. As an application, we learn the material models directly from digital image correlation (DIC) displacement tracking measurements on a porcine tricuspid valve leaflet tissue, and show that the learnt model substantially outperforms conventional constitutive models.

Educational Objects: Upon completion, participants should be able to:

- Understand neural operators and how they can solve PDEs in challenging settings via neural networks.
- Understand how neural operators apply to solving physical problems, incorporating physics knowledge into learning, and improving the transparency of learning.
- Understand how neural operators can be applied to model the physics of porcine tricuspid valve leaflet tissue.

Disclosure Statement: The faculty and planners have no relevant financial relationship with ineligible companies whose primary business is producing, marketing, selling, re-selling, or distributing health care products used by or on patients.

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