Computational Mathematics Seminar Series

Nonlocal operator is all you need

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Professor

Digital Media Center 1034
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Abstract:

During the last 20 years there has been a lot of progress in applying neural networks (NNs) to many machine learning tasks. However, their employment in scientific machine learning with the purpose of learning physics of complex system is less explored. Differs from the other machine learning tasks such as the computer vision and natural language processing problems where a large amount of unstructured data are available, physics-based machine learning tasks often feature scarce and structured measurements.

In this talk, we will take the learning of heterogeneous material responses as an exemplar problem, to investigate the design of neural networks for physics-based machine learning. In particular, we propose to parameterize the mapping between loading conditions and the corresponding system responses in the form of nonlocal neural operators, and infer the neural network parameters from high-fidelity simulation or experimental measurements. As such, the model is built as mappings between infinite-dimensional function spaces, and the learnt network parameters are resolution-agnostic: no further modification or tuning will be required for different resolutions in order to achieve the same level of prediction accuracy. Moreover, the nonlocal operator architecture also allows the incorporation of intrinsic mathematical and physics knowledge, which improves the learning efficacy and robustness from scarce measurements.

To demonstrate the applicability of our nonlocal operator learning framework, three typical scenarios in physics-based machine learning will be discussed: the learning of a material-specific constitutive law, the learning of an efficient PDE solution operator, and the development of a foundational constitutive law across multiple materials. As an application, we learn 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.

Speaker's 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 full professor in 2023. Her research lies in the area of applied mathematics and computational mechanics, 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.

This lecture has refreshments @ 03:00 pm