CRUNCH Seminars at Brown, Division of Applied Mathematics

Friday - October 13, 2023

Nonlinear Mode Decomposition via Physics-Assimilated Neural Network

Bo Zhang, University of Notre Dame

A physics-assimilated convolutional autoencoder (CAE) neural network, namely, PhyAENet, has been developed to perform nonlinear mode decomposition of the unsteady flow field around a NACA 4412 airfoil near stall conditions. The flow field snapshots are mapped into latent modes by the encoder part of the well-trained CAE, which are used for dynamic mode decomposition (DMD) analysis. The computed DMD modes are split into modes covering different frequency ranges. These high and low-frequency DMD modes are used to form reconstructed encoded sequences, which are then mapped back to generate the nonlinear decomposed spatiotemporal modes by the decoder of the CAE. As such, physics is assimilated into the neural network by incorporating the frequencies of the DMD modes into the latent modes in the latent space. The proposed PhyAENet is capable of extracting the dominant features of the flow fields, accounting for the nonlinearity of the underlying dynamics. Furthermore, the extracted nonlinear modes are evolving with time and physically interpretable. It is revealed that the nonlinear modes can be well represented when using more DMD modes for reconstruction of the encoded sequences. The energy spectrum of the nonlinear modes is obtained by ranking the Frobenius norm of the mode vector. Additionally, I will briefly talk about my present developments of differentiable neural solvers for cavitating flows and fin field effect transistor (FinFET) in the framework of JAX.