Data Science Seminar Series

From Neural PDEs to Neural Operators: Blending data and physics for fast predictions

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We will review physics-informed neural network and summarize available extensions for applications in computational mechanics and beyond. We will also introduce new NNs that learn functionals and nonlinear operators from functions and corresponding responses for system identification. The universal approximation theorem of operators is suggestive of the potential of NNs in learning from scattered data any continuous operator or complex system. We first generalize the theorem to deep neural networks, and subsequently we apply it to design a new composite NN with small generalization error, the deep operator network (DeepONet), consisting of a NN for encoding the discrete input function space (branch net) and another NN for encoding the domain of the output functions (trunk net). We demonstrate that DeepONet can learn various explicit operators, e.g., integrals, Laplace transforms and fractional Laplacians, as well as implicit operators that represent deterministic and stochastic differential equations. More generally, DeepOnet can learn multiscale operators spanning across many scales and trained by diverse sources of data simultaneously.

George Karniadakis is from Crete. He received his S.M. and Ph.D. from the Massachusetts Institute of Technology (1984/87). He was appointed Lecturer in the Department of Mechanical Engineering at MIT and subsequently, he joined the Center for Turbulence Research at Stanford / Nasa Ames. He joined Princeton University as an Assistant Professor in the Department of Mechanical and Aerospace Engineering and as Associate Faculty in the Program of Applied and Computational Mathematics. He was a Visiting Professor at Caltech in 1993 in the Aeronautics Department and joined Brown University as Associate Professor of Applied Mathematics in the Center for Fluid Mechanics in 1994. After becoming a full professor in 1996, he continued to be a Visiting Professor and Senior Lecturer of Ocean/Mechanical Engineering at MIT. He is a member of the National Academy of Engineering.