Physics-Informed Neural Networks (PINNs): An alphabet of Algorithms for Diverse Applications

Abstract

We will present a new approach to develop a data-driven, learning-based framework for predicting outcomes of physical and biological systems and for discovering hidden physics from noisy data. We will introduce a deep learning approach based on neural networks (NNs) and generative adversarial networks (GANs). We also introduce new NNs that learn functionals and nonlinear operators from functions and corresponding responses for system identification. Unlike other approaches that rely on big data, here we "learn" from small data by exploiting the information provided by the physical conservation laws, which are used to obtain informative priors or regularize the neural networks. We will also make connections between Gauss Process Regression and NNs, and discuss the new powerful concept of meta-learning. We will demonstrate the power of PINNs for several inverse problems in fluid mechanics, solid mechanics and biomedicine including wake flows, shock tube problems, material characterization, brain aneurysms, etc, where traditional methods fail due to lack of boundary and initial conditions or material properties. There are many versions of PINNs, e.g., variational (VPINNs), stochastic (sPINNs), conservative (cPINNs), nonlocal (nPINNs), generalized (xPINNs), etc, and we will provide some highlights. In addition, we will present our recent theoretical results on the convergence and generation of PINNs.

Presenter: George Em Karniadakis (GS h-index 102)

The Charles Pitts Robinson and John Palmer Barstow Professor
of Applied Mathematics, Brown University;
Also @MIT & PNNL

https://www.brown.edu/research/projects/crunch/home

Bio: George Karniadakis is from Crete. He received his S.M. and Ph.D. from 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 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 continues to be a Visiting Professor and Senior Lecturer of Ocean/Mechanical Engineering at MIT. He is an AAAS Fellow (2018-), Fellow of the Society for Industrial and Applied Mathematics (SIAM, 2010-), Fellow of the American Physical Society (APS, 2004-), Fellow of the American Society of Mechanical Engineers (ASME, 2003-) and Associate Fellow of the American Institute of Aeronautics and Astronautics (AIAA, 2006-). He received the Alexander von Humboldt award in 2017, the Ralf E Kleinman award from SIAM (2015), the J. Tinsley Oden Medal (2013), and the CFD award (2007) by the US Association in Computational Mechanics. **His h-index is 102 and he has been cited over 51,000 times.**