Abstract Submitted
for the DFD19 Meeting of
The American Physical Society

Surrogate Modeling for Fluid Flows Using Physics-Constrained, Label-Free Deep Learning JIAN-XUN WANG, LUNING SUN, HAN GAO, University of Notre Dame, SHAOWU PAN, University of Michigan, Ann Arbor — Numerical simulations on fluid dynamics problems can often be computational prohibitive for most real-time and many-query applications, and developing a cost-effective surrogate model is of great practical significance. Deep learning (DL) has shown new promises for surrogate modeling due to its capability of handling strong nonlinearity and high dimensionality. However, the off-the-shelf DL architectures fail to operate when the data becomes sparse, which is often the case in most parametric fluid dynamics problems since each data point in the parameter space requires an expensive numerical simulation. In this paper, we provide a physics-constrained DL approach for surrogate fluid modeling without relying on any simulation data. Specifically, a structured deep neural network (DNN) architecture is devised to enforce the boundary conditions, and the Navier-Stokes equations are used to drive the training. Numerical experiments are conducted on a number of vascular flows and forward propagation of uncertainties in fluid properties and domain geometry is studied as well. The results show excellent agreement on the flow field and propagated uncertainties between the DL surrogate approximations and the first-principle numerical simulations.

Jian-Xun Wang
University of Notre Dame

Date submitted: 22 Jul 2019 Electronic form version 1.4