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Data-Driven Multi Fidelity Physics-Informed Constitutive Meta-Modeling of Complex Fluids

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We present a Multi-Fidelity Neural Network (MFNN) architecture to construct a rheological constitutive meta-model and compare its predictions for the rheological response of a complex multi-component system with those of a simple Deep Neural Network (DNN) and experimental measurements. The proposed MFNN allows for inclusion of underlying physics in form of synthetic data, while taking advantage of high-fidelity experimental data. Generation of the low fidelity data are done using different constitutive models at hand. The high-fidelity network in contrast is trained on limited experimentally measured data. The goal is to establish the framework that will preserve the essential physical and rheological underpinnings of the problem, and accurate predictions of rheological response of a given complex multi-component system. The MFNN is found to be capable of successfully predicting the steady state shear viscosity of a multi-component complex fluid consisting of several different colloidal particle, worm-like micelles and other aromatic particles over a wide range of applied shear rates based on fluid's primary constituting components. We investigate the role of constitutive model employed in data generation on overall performance of the MFNN algorithm. We show that the MFNN can be used to provide a rather accurate prediction of an entirely new sample with only known components and their compositions. Furthermore, we seek to determine the applicability of the physics-based neural networks on predicting the rheology of a complex fluid with respect to more complex parameters such as experiment temperature, salinity of the mixture, and sample aging. We show that by incorporating the appropriate physical intuition into the neural network, the MFNN algorithm provides a reasonable prediction of the experimentally measured viscosity data. In contrary, due to the fact that an abundance of data is required in purely data-driven methods, the DNN without a physical basis is not able to reflect on real behavior of the material.