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**Multi-scale Deep Neural Network (MscaleDNN) Methods for
Oscillatory Stokes Flows in Complex Domains
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In this paper, we study a multi-scale deep neural network (MscaleDNN) as a meshless numerical method for computing oscillatory Stokes flows in complex domains. The MscaleDNN employs a multiscale structure in the design of its DNN using radial scalings to convert the approximation of high frequency components of the highly oscillatory Stokes solution to one of lower frequencies. The MscaleDNN solution to the Stokes problem is obtained by minimizing a loss function in terms of L 2 norm of the residual of the Stokes equation. Three forms of loss functions are investigated based on vorticity-velocity-pressure, velocity-stress-pressure, and velocity gradient-velocity pressure formulations of the Stokes equation. We first conduct a systematic study of the MscaleDNN methods with various loss functions on the Kovasznay flow in comparison with normal fully connected DNNs. Then, Stokes flows with highly oscillatory solutions in a 2-D domain with six randomly placed holes are simulated by the MscaleDNN. The results show that MscaleDNN has faster convergence and consistent error decays than normal fully connected DNNs in the simulation of Kovasznay flow for all four tested loss functions. More importantly, the MscaleDNN is capable of learning highly oscillatory solutions while the normal DNNs fail to converge.