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Domain decomposition physics-data combined neural network for parametric reduced order modelling of fluids

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Reduced Order Modelling (ROM) is a widely used method in various engineering such as fluids, porous media, reservoir modelling and so on. This paper proposes a novel domain decomposition physics-data combined neural network(DPDCNN) approach to construct a ROM. In this method, Proper Orthogonal Decomposition (POD) is applied to each sub-domain to reduce dimensionality. Neural network is then used to predict POD coefficients of each sub-domain. The physical equations are incorporated into the loss function. In this domain decomposition method, several additional conditions are enforced at the interferes to ensure the overall continuity of physical solutions such as averaging solutions at neighbourhood, next time levels' values and derivative terms of the PDEs. The performance of this newly domain decomposition method is compared against the model without domain decomposition. The capability of this method is tested using a number of parametric nonlinear problems such as KDV equation in a regular domain, two-dimensional Kovasznay flow, and the two-dimensional Incompressible Navier–Stokes equation.

The results indicate that the proposed methods offer an economically effective means of constructing a reduced model for parameterized PDEs through machine learning. Particularly in specific parameter ranges, especially when distinct physical phenomena regions are prominent, the method outperforms the model without domain decomposition, demonstrating excellent performance on several challenging problems.

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