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Physics-Informed Machine Learning for Displacement Estimation in Solid Mechanics Problem

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Abstract : Machine learning (ML), especially deep learning (DL), has been extensively applied to many applications in recently years and gained great success in solving different problems, including scientific problems. However, conventional ML/DL methodologies are purely data-driven which have the limitations, such as need of ample amount of labelled training data, lack of consistency to physical principles, and lack of generalizability to new problems/domains. Recently, there is a growing consensus that ML models need to further take advantage of prior knowledge to deal with these limitations. Physics-informed machine learning, aiming at integration of physics/domain knowledge into ML, has been recognized as an emerging area of research, especially in the recent 2 to 3 years. In this work, physics-informed ML, specifically physics-informed neural network (NN), is employed and implemented to estimate the displacements at x, y, z directions in a solid mechanics problem that is controlled by equilibrium equations with boundary conditions. By incorporating the physics (i.e. the equilibrium equations) into the learning process of NN, it is showed that the NN can be trained very efficiently with a small set of labelled training data. Experiments with different settings of the NN model and the amount of labelled training data were conducted, and the results show that very high accuracy can be achieved in fulfilling the equilibrium equations as well as in predicting the displacements, e.g. in setting the overall displacement of 0.1, a root mean square error (RMSE) of $2.09 \times 10{-}4$ was achieved.

Keywords : deep learning, neural network, physics-informed machine learning, solid mechanics
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