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The Cost-Accuracy Trade-Off In Operator Learning With Neural Networks

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Summary for general readers:

The term ‘surrogate modeling’ in computational science and engineering refers to the development of computationally efficient approximations for expensive simulations, such as those arising from numerical solutions of partial differential equations (PDEs).
These surrogate models capture the behavior of these expensive models so that scientists and engineers can quickly study the dominant effects of the described system and use them for many-query computations, which include iterative methods in optimization and sampling methods in uncertainty quantification.

Over the last few years, several approaches to surrogate modeling for PDEs using neural networks have emerged, motivated by successes in using neural networks to approximate nonlinear maps in other areas. In principle, the relative merits of these different approaches can be evaluated by understanding, for each one, the cost required to achieve a given level of accuracy. However, the absence of a complete theory of approximation error for these approaches makes it difficult to assess this cost-accuracy trade-off. The purpose of the paper is to provide a careful numerical study of this issue, comparing a variety of different neural network architectures for operator approximation across a range of problems arising from PDE models in continuum mechanics.

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