Precision Algorithms: Algorithm Augmentation by Machine Learning

Jan S Hesthaven[a]

[a] *Institute of Mathematics, Ecole Polytechique Federale de Lausanne (EPFL), Switzerland*

While the success of modern simulation techniques is undisputed, many of the most successful schemes rely on the tuning of parameters, often in a nonlinear and spatio-temporal fashion to ensure optimal and efficient algorithm performance. Classic examples include the detection of bad cells and nonlinear viscosity when one solves conservation laws with high-order methods, the adaptive selection of stencils in ENO/WENO methods, the need for rapid evaluation of solutions to complex Riemann problems, or the formulation of efficient and robust reduced order models for nonlinear problems where standard projection based methods often fail. These specific elements are all characterized as playing a central role in an otherwise successful algorithm.

In this talk we, discuss the potential of using ideas of machine learning to overcome such bottlenecks and augment the algorithm to allow the choice of optimal local parameters and eliminate critical performance bottlenecks, resulting in vastly improved performance of the augmented algorithm. The central approach is to carefully identify such bottlenecks and explore data driven solutions but otherwise maintain the integrity of a well-tested method.

After a brief introduction to machine learning techniques and, in particular, neural networks, we demonstrate the success of this general idea through a number of specific examples, primarily motivated by challenges associated with the numerical solution of conservation laws. Time permitting, we also touch on advances in reduced order modeling, enabled by a similar approach.

While exemplified through specific examples, the overall philosophy is general and we conclude the talk with a more general discussion of the potential of augmenting algorithms by machine learning, resulting in a class of methods which can perhaps be referred to as precision algorithms.

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