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Physics-informed Attention-based Neural Network for Solving Non-linear Partial Differential Equations

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Physics-Informed Neural Networks (PINNs) have enabled significant improvements in modeling physical processes described by partial differential equations (PDEs). PINNs are based on simple architectures, and learn the behavior of complex physical systems by optimizing the network parameters to minimize the residual of the underlying PDE. Current network architectures share some of the limitations of classical numerical discretization schemes when applied to non-linear differential equations in continuum mechanics. A paradigmatic example is the solution of hyperbolic conservation laws that develop highly localized nonlinear shock waves. Learning solutions of PDEs with dominant hyperbolic character is a challenge for current PINN approaches, which rely, like most grid-based numerical schemes, on adding artificial dissipation. Here, we address the fundamental question of which network architectures are best suited to learn the complex behavior of non-linear PDEs. We focus on network architecture rather than on residual regularization. Our new methodology, called Physics-Informed Attention-based Neural Networks, (PIANNs), is a combination of recurrent neural networks and attention mechanisms. The attention mechanism adapts the behavior of the deep neural network to the non-linear features of the solution, and break the current limitations of PINNs. We find that PIANNs effectively capture the shock front in a hyperbolic model problem, and are capable of providing high-quality solutions inside and beyond the training set.