DynAMO: Dynamic Anticipatory Mesh Optimization for Hyperbolic PDEs using Reinforcement Learning

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ABSTRACT

Adaptive Mesh Refinement (AMR) is a popular technique for improving efficiency of finite element simulations by selectively modifying resolution in different regions of the mesh based on some error estimate. For nonlinear time dependent problems (e.g., Euler equations), existing AMR techniques typically rely on error estimates that are indicative of current simulation state, while being agnostic to error propagation in future. As a result, these reactive AMR techniques require frequent mesh refinement to maintain accuracy in the solution as error cannot be removed once it has been introduced.

We propose DynAMO, a dynamic anticipatory mesh optimization framework to address this issue. In current work, we power DynAMO with multi-agent Reinforcement Learning (RL) to anticipate nonlinear error propagation across the spatial domain at future times [1]. Using instantaneous error estimates and a non-dimensional measure of error propagation derived from Flux Jacobians, time-step size, and relative element spacing, DynAMO determines regions that must be preemptively refined to keep the error in the solution below a prescribed threshold. Additionally, using physics insights, we make design choices that help the RL policy generalize with respect to initial conditions, domain size, and regridding duration used during training. We present several examples where the proposed approach outperforms existing AMR techniques by achieving higher solution accuracy with relatively fewer degrees of freedom.

REFERENCES

[1] J. Yang, K. Mittal, S. Petrides, B. Keith, B. Petersen, R. Anderson, et al., Multi-agent reinforcement learning for adaptive mesh refinement, in: AAMAS, 2023.

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