Evolve Smoothly, Fit Consistently: Learning Smooth Latent Dynamics For Advection-Dominated Systems

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ABSTRACT

We present a data-driven, space-time continuous framework to learn surrogate models for complex physical systems described by partial differential equations (PDEs). Our approach involves constructing hypernetwork-based latent dynamical models directly on the parameter space of a compact representation network specially tailored to the state space of the target system. We leverage the expressive power of the network with a specially designed consistency-inducing regularization to obtain latent trajectories that are both low-dimensional and smooth. These properties render our surrogate models highly efficient at inference time.

We demonstrate the effectiveness of our approach on advection-dominated systems. These systems have slow-decaying Kolmogorov n-widths that hinders standard methods, including reduced order modeling, from producing high-fidelity simulations at low cost. We show that our method is able to generate accurate multi-step rollout predictions at high efficiency, for several challenging one- and two-dimensional PDEs. The resulting rollouts are shown to be stable indefinitely and reflect statistics which are consistent with the ground truths.

REFERENCES

[1] Z. Y. Wan, L. Zepeda-Núñez, A. Boral and F.Sha.Evolve Smoothly, Fit Consistently: Learning Smooth Latent Dynamics For Advection-Dominated Systems, ICLR 2023.