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Learning Physics-based Galerkin models of turbulence with Neural Differential Equations ARVIND MOHAN, Los Alamos National Laboratory, Los Alamos, NM, USA, KAUSHIK NAGARAJAN, National Aerospace Laboratories, Bengaluru, India, DANIEL LIVESCU, Los Alamos National Laboratory, Los Alamos, NM, USA — Turbulent flow control has numerous applications and building reduced order models (ROMs) of the flow and its associated feedback control laws is extremely challenging. Despite the complexity of building data-driven ROMs for turbulence, the superior representational capacity of Deep neural networks have demonstrated considerable success in learning ROMs. However, these strategies are typically devoid of physical foundations and often lack interpretability. Conversely, the Proper Orthogonal Decomposition (POD) based Galerkin projection (GP) approach for ROM has been a popular approach with successes in many problems. A key limitation is that ordinary differential equations (ODEs) arising from GP ROMs are highly susceptible to instabilities due to truncation of POD modes and lead to deterioration in temporal predictions. In this work, we propose a deep learning approach that blends the strengths of both these strategies, by incorporating neural networks directly into the GP ODE formulation. Given the structure of the projected equations, the resulting Neural Galerkin approach implicitly learns stable ODE coefficients from POD data and demonstrates significantly longer time horizon predictions. Finally, we demonstrate various applications of the Neural Galerkin projection approach compared to traditional GP ROMs, including learning stable ODEs when only the partial structure of the equation is known.

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