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Quadratic Approximation Manifold for Mitigating the Kolmogorov Barrier in Nonlinear Projection-Based Model Order Reduction

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A quadratic approximation manifold is presented for performing nonlinear, projection-based, model order reduction (PMOR). It constitutes a departure from the traditional affine subspace approximation aimed at mitigating the Kolmogorov barrier for nonlinear PMOR, particularly for convection-dominated transport problems. It builds on the data-driven approach underlying the traditional construction of projection-based reduced-order models (PROMs); is application-independent; is linearization-free; and therefore is robust for highly nonlinear problems. Most importantly, this approximation leads to quadratic PROMs that deliver the same accuracy as their traditional counterparts using however the square root of their dimension. The computational advantages of the proposed high-order approach to nonlinear PMOR over the traditional approach are highlighted for the detached-eddy simulation-based prediction of the Ahmed body turbulent wake flow, which is a popular CFD benchmark problem in the automotive industry. For a fixed accuracy level, these advantages include: a reduction of the total offline computational cost by a factor greater than five; a reduction of its online wall clock time by a factor greater than 32; and a reduction of the wall clock time of the underlying high-dimensional model by a factor greater than two orders of magnitude.

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