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Time-parallel reduced-order models via forecasting

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Many-query and real-time scenarios demand reduced-order models (ROMs) for tractability. For the many-query case, the relevant notion of simulation cost is *core-hours*, which dictates how many queries are possible given fixed computing resources. In this sense, nonlinear ROMs have already demonstrated significant savings, as ROMs can be simulated using a 'sample mesh' that necessitates far fewer computing cores. In contrast, the relevant cost for real-time scenarios is *wall time*. Nonlinear ROMs have been less effective at reducing this cost, as spatial parallelism is quickly saturated. For example, on a compressible flow problem, the GNAT ROM yielded a 452X improvement in core-hours, but only a 6.86X improvement in wall time [1]. Spatial parallelism was saturated with only 12 cores.

Time-parallel methods (e.g., parareal [3], PITA) constitute one approach to improve wall-time performance. However, speedups are often modest (i.e., less than five), in part because typical time integrators are often employed for the coarse propagator. As the coarse time step is usually outside the asymptotic range of convergence, the coarse propagator can be inaccurate, yielding slow convergence.

The main idea of this work is to enable efficient time parallelism for ROMs by employing an accurate coarse propagator that exploits *time-evolution data* available from offline training simulations. In particular, we propose adopting the forecasting method introduced in Ref. [2] as a data-driven coarse propagator. As shown in Fig. 1, the forecasting method can provide a much more accurate coarse propagation than traditional time integrators, leading to significantly faster convergence.

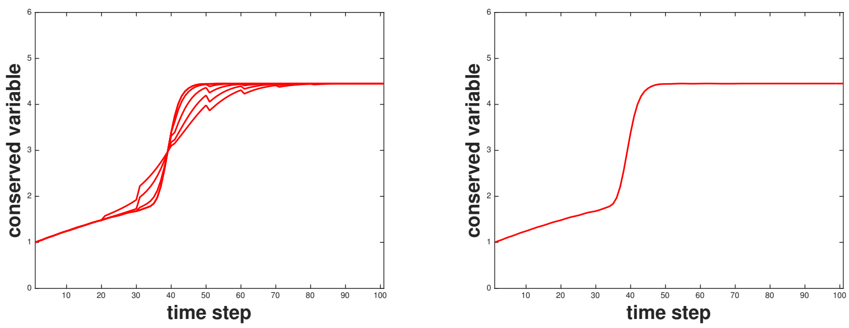

Figure 1: Time evolution of a state variable across time-parallel iterations for a ROM applied to the inviscid Burger's equation for two coarse propagators (left: backward Euler; right: forecasting).

References

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