POD-Based Adaptive Model Reduction to Accelerate Computational Fluid Dynamics

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Reduced order modeling is a popular approach that generates surrogate models [1] by using data generated by high-dimensional models (HDMs). Unfortunately, stability issues and failure to generalize beyond training make reduced order models (ROMs) unreliable in an industrial setting [1]. This is particularly the case when modeling time-dependent nonlinear problems such as those usually found in viscous or high-speed CFD problems. Generating enough training data to make ROMs generalize is often infeasible. Taking this shortcoming into consideration, adaptive reduced order methods (AROMs) [3] improve predictive capabilities by frequently updating the reduced basis with local spatial-temporal HDM data. However, AROMs have several issues still to be addressed. The computational cost of AROMs also needs to be carefully examined given that the HDM needs to be frequently locally solved.

Our work relies on several techniques to improve AROMs capabilities. First, we developed implicit HDM local surrogates with good accuracy and stability properties. The implicit time marching methods required by some problems (e.g., viscous flow) cannot provide the local solutions needed by adaptive ROMs because the numerical domain of dependence is the entire computational grid. Second, literature results [3] rely on the adaptive discrete empirical interpolation method (ADEIM) to update the reduced basis. Preliminary results show that updating the basis through proper orthogonal decomposition (POD) is superior in regards to sampling size, stability and accuracy. Third, initial results show that AROMs can go unstable. In fact, combining local HDM and ROM solutions without any further consideration leads to spurious oscillations which in turn lead to unstable solutions. Therefore, these methods benefit from explicit filtering techniques [2] used by HDMs. Additionally, we propose a residual-based adaptive sampling algorithm as opposed to a fixed-size sampling procedure. Finally, our methodology is successfully applied to two-dimensional unsteady flow problems with shock waves.

References

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