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Model reduction of dynamical systems by proper orthogonal decomposition: error bounds and comparison of methods using snapshots from the solution and the time derivatives

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Abstract

We consider two proper orthogonal decomposition (POD) methods for dimension reduction of dynamical systems. The first method (M1) uses only time snapshots of the solution, while the second method (M2) augments the snapshot set with time-derivative snapshots. The goal of the paper is to analyze and compare the approximation errors resulting from the two methods by using error bounds. We derive several new bounds of the error from POD model reduction by each of the two methods. The new error bounds involve a multiplicative factor depending on the time steps between the snapshots. For method M1 the factor depends on the second power of the time step, while for method 2 the dependence is on the fourth power of the time step, suggesting that method M2 can be more accurate for small between-snapshot intervals. However, three other factors also affect the size of the error bounds. These include (i) the norm of the second (for M1) and fourth derivatives (M2); (ii) the first neglected singular value and (iii) the spectral properties of the projection of the system's Jacobian in the reduced space. Because of the interplay of these factors neither method is more accurate than the other in all cases. Finally, we present numerical examples demonstrating that when the number of collected snapshots is small and the first neglected singular value has a value of zero, method M2 results in a better approximation.

Keywords: Model reduction, Proper Orthogonal Decomposition, Error bound

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