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Reduced-Order Models for Fluid Flow: A Physics-Preserving Approach

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Model order reduction (MOR) is a method designed to simplify high-dimensional systems by representing their states using a low-dimensional parametrization. It enhances computational efficiency and reduces memory usage but can lead to reduced simulation accuracy and difficulties in preserving system properties, such as sparsity, positivity, and incompressibility. Consequently, choosing an appropriate MOR approach with an optimal latent dimension is critical to achieving a balance between accuracy and efficiency.

In this work, we introduce autoencoders that reconstruct latent states using actual states sampled from a dataset. This method is compared against two well-known approaches: proper orthogonal decomposition and proper CUR decomposition. We develop reduced-order models of the wake flow around a single cylinder, governed by the incompressible Navier-Stokes equations, and evaluate their simulation accuracy and ability to preserve fundamental physical principles such as incompressibility.

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