

Data-Driven Variational Multiscale Reduced Order Models

Traian Iliescu, Virginia Tech

We propose a new data-driven reduced order model (ROM) framework that centers around the hierarchical structure of the variational multiscale (VMS) methodology and utilizes data to increase the ROM accuracy at a modest computational cost. The VMS methodology is a natural fit for the hierarchical structure of the ROM basis: In the first step, we use the ROM projection to separate the scales into three categories: (i) resolved large scales, (ii) resolved small scales, and (iii) unresolved scales. In the second step, we explicitly identify the VMS-ROM closure terms, i.e., the terms representing the interactions among the three types of scales. In the third step, instead of ad hoc modeling techniques used in VMS for standard numerical methods (e.g., finite element), we use available data to model the VMS-ROM closure terms. Thus, instead of phenomenological models used in VMS for standard numerical discretizations (e.g., eddy viscosity models), we utilize available data to construct new structural VMS-ROM closure models. Specifically, we build ROM operators (vectors, matrices, and tensors) that are closest to the true ROM closure terms evaluated with the available data. We test the new data-driven VMS-ROM in the numerical simulation of a 2D flow past a circular cylinder at Reynolds numbers $Re=100$, $Re=500$, and $Re=1000$. The numerical results show that the data-driven VMS-ROM is significantly more accurate than standard ROMs.