Energy-conserving reduced order models for incompressible fluid flows
Dr. B. Sanderse, CWI Amsterdam

The simulation of complex fluid flows is an ongoing challenge in the scientific community. The computational cost of Direct Numerical Simulation (DNS) or Large Eddy Simulation (LES) of turbulent flows quickly becomes imperative when one is interested in control, design, optimization and uncertainty quantification. For these purposes, simplified models are typically used, such as reduced order models, surrogate models, low-fidelity models, etc.

In this work we will study reduced order models (ROMs) that are obtained by projecting the fluid flow equations onto a lower-dimensional space. Classically, this is performed by using a POD-Galerkin method, where the basis for the projection is built from a proper orthogonal decomposition of the snapshot matrix of a set of high-fidelity simulations. Ongoing issues of this approach are, amongst others, the stability of the ROM, handling turbulent flows, and conservation properties [1,2].

We will address the stability of the ROM for the particular case of the incompressible Navier-Stokes equations. We propose to use an energy-conserving finite volume discretization of the Navier-Stokes equations [3] as full-order model (FOM), which has the important property that it is energy conserving in the limit of vanishing viscosity and thus possesses non-linear stability. We project this FOM on a lower-dimensional space in such a way that the resulting ROM inherits the energy conservation property of the FOM, and consequently its non-linear stability properties. The stability of this new energy-conserving ROM is demonstrated for various test cases, and its accuracy as a function of time step, Reynolds number, number of modes, and amount of snapshot data is assessed.

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