Adjoint-Based Optimal Control of Incompressible Flows with Energy-Stable Boundary Conditions

Problems arising in computational fluid dynamics often require artificially truncating the domain and posing appropriate open boundary conditions. However, these are known to suffer from backflow instability – when the flow at the boundary reverses, the simulation can blow up altogether. In order to eliminate this phenomenon, so-called energy-stable open boundary conditions have been devised.

Optimal control of systems involving fluids is an active field of research. A popular strategy is open-loop control – the problem is posed as the minimization of some objective functional and various optimization procedures are employed to iteratively search for the desired control signals. These algorithms can be much more computationally efficient when they are supplied with information about the gradient of the objective w.r.t. the control variables. In order to compute the gradient effectively, the adjoint problem can be solved.

First, we will explain the rationale behind the energy stable open boundary conditions and provide examples of flows where their use can significantly reduce the computational cost of a simulation. Second, we will present the continuous adjoint method and discuss the advantages it offers, as well as some of its drawbacks. Finally, we will discuss some challenges associated with the application of the continuous adjoint method to optimal control problems involving flows with energy-stable boundary conditions.