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Control of unsteady wake flows using local oscillation of body surface: a data assimilation study

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Abstract
Variational data assimilation (DA) can expand active flow control techniques to design wall actuators such as synthetic jets or plasma discharges which are difficult to model computationally due to ambiguous boundary conditions at the wall. Since the effectiveness of the control is largely determined by the receptivity of the flow to the imposed disturbances, these have to be of the right scale and be introduced at the right location.
A common strategy for animals to locomote through a fluid is to use the bodies or the appendages (e.g. fins and wings) to make waving, flapping and pitching motions. In particular, it was found that the wave-like swimming motion of the body is an efficient propulsion strategy.
In this study, DA will allow us to reproduce this efficient generation of vorticity wake by means of surface actuators. In that sense, a local oscillation control vector is determined to give the wake a typical propulsive-like pattern as observed behind swimmers.
Here, the control vector for the DA problem is formed by the initial flow and the solid boundary conditions for the body, that means its tangential speed at all times where no particular form is prescribed to the body motion.
In a first step, we consider a configuration of reference flow past a rotationally oscillating cylinder given by Mons *et al*. (2017).
In a second step, the proposed methodology is applied to the reconstruction of a reference flow generated by a partial control restricted to an upstream part of the cylinder surface as given by Bergmann *et al*. (2006). Physically, a partial control gives rise in the near wake to a reverse von Karman street that locally generates a significant thrust force. This unsteady flow control mechanism is similar to the drag reduction phenomenon encountered in fish-like locomotion.
In a third step, DA is employed to build wall conditions for a direct numerical simulation (DNS) of flow around an airfoil with local oscillation, from synthetic observations of the wake flow downstream a traveling wavy foil.
The results obtained in this study may both illustrate the potential of reconstructing unsteady forced flows through DA and investigate the formation and shedding of vortices by means of controlled local actuation to better explore propulsive mechanisms involved in fish-like swimming.