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Numerical simulation of bioinspired fluid-structure interaction problems using a multi-body structural model

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The development of efficient micro-air vehicles or swimming robots requires a proper understanding of underlying physical mechanisms, which is still currently lacking. A major problem is that, in these devices, there is an intimate coupling between fluid forces, structural forces and vehicle's inertia, resulting in difficult fluid-structure interaction (FSI) problems. The present work introduces a versatile methodology that couples a multi-body algorithm to a fluid solver, so that a large variety of bioinspired FSI problems can be tackled.

The robotic algorithm developed by Felis [1] is used to solve for the dynamics of the multi-body systems. These systems are composed by a collection of rigid bodies connected between them using kinematic joints that allow and constrain certain degrees of freedom. The Navier-Stokes equations for an incompressible flow are directly solved using the immersed boundary method of Uhlmann [2] to model the presence of rigid bodies in the fluid.

The coupling between the multi-body and the fluid solvers is weak, allowing for cost-effective computations. A recursive dynamic algorithm in reduced coordinates is employed to compute the dynamic equations of the multi-body systems, allowing for computations of different systems using an arbitrary number and types of joints with no code modification.

To validate and illustrate the performance of the proposed methodology in bioinspired fluid-structure interaction problems, we present here results for two three-dimensional problems at low Reynolds numbers. First, we will discuss the results obtained for the passive flapping of a highly-flexible flag ($Re = 200$). Second, we will analyse the problem of the self-propulsion of a flexible swimmer ($Re = 20$).

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