Adjoint-Based Optimization of Time-Dependent Fluid-Structure Systems using a High-Order Discontinuous Galerkin Discretization

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ABSTRACT

The design and control of engineering and scientific systems often calls for the optimization of a system that depends on the interaction between fluid flow and structural deformation. For example, the design and control of Micro Aerial Vehicles (MAVs) is heavily dependent on the interaction between the light, flexible wings and the surrounding fluid. An optimal design that leads to a lightweight MAV and energetically optimal flapping motion can only be realized if the interaction between the fluid and structure is considered.

In this work we develop the fully discrete adjoint equations and corresponding adjoint method for a high-order discretization of Fluid-Structure Interaction (FSI). Following the work in [1, 2], a system of conservation laws are transformed to a fixed reference domain using an Arbitrary Lagrangian Eulerian formulation and discretized using a high-order discontinuous Galerkin method. The structural equations are discretized using the continuous Galerkin finite element method. The primary innovation is the use of a high-order implicit-explicit Runge-Kutta scheme for temporal discretization of the monolithic fluid-structure system that ensures both the fluid and structural solvers can be re-used without need for a specialized monolithic solver. The fully discrete adjoint equations preserve this property and, therefore, do not constitute a major implementation effort given the primal implementation. The adjoint method is used in this work to compute gradients of quantities of interest that comprise the objective and constraint functions of relevant FSI optimization model problems related to energetically optimal flapping flight and energy harvesting.

REFERENCES

[1] Bradley Froehle and Per-Olof Persson. A high-order discontinuous galerkin method for fluid–structure interaction with efficient implicit–explicit time stepping. *Journal of Computational Physics*, 272:455–470, 2014.

[2] Matthew J. Zahr and Per-Olof Persson. An adjoint method for a high-order discretization of deforming domain conservation laws for optimization of flow problems. *Journal of Computational Physics*, In press, 2016.