

# Abstract

Fluid-structure interaction is a ubiquitous phenomenon with significant implications in both engineering and biological applications. In many instances, solvers for fluid-structure interactions employ a partitioned approach, where separate, standalone fluid and solid solvers are coupled together using a coupling algorithm. To accurately simulate real-life situations, the fluid and solid solvers must be general and free of restricting approximations. The most general solid solver should be capable of handling geometrically and materially nonlinear scenarios, allowing for large deformation and strain as well as large displacement and rotation, while also taking into account nonlinear constitutive relations.

The present work focuses on the development of a standalone fluid solver based on the Lattice Boltzmann Method and a standalone solid solver based on the Finite Element Method, both tailored for two-dimensional scenarios. These solvers were rigorously validated using results available in the literature and through comparison with commercial solvers like COMSOL Multiphysics. However, it is important to note that the coupling of the two solvers is beyond the scope of this work.

The developed fluid solver leverages the Lattice Boltzmann Method, an unconventional yet powerful computational fluid dynamics technique. This method employs a uniform Cartesian grid to simulate unsteady incompressible laminar fluid flow using the D2Q9 discrete velocity set. It utilizes Zou-He boundary conditions for the inlet and outlet, while also incorporating other straight and curved boundary conditions as required. The fluid solver's accuracy was validated by simulating flow around a cylinder with an attached downstream flap. The resulting data for overall drag and lift was found to be in excellent agreement with existing literature.

On the other hand, the developed structural solver is a time-dependent, geometrically-nonlinear large deformation solver based on the Finite Element Method. This solver employs the total Lagrangian formulation - an incremental approach used to solve the equilibrium equations. The dynamic response of the structure is captured using the standard Newmark time integration scheme, which has been adapted for the total Lagrangian formulation. The present structural solver has been validated for both static and dynamic cases. Different loading conditions, including volume, surface, and point loads, were simulated to verify the solver's wide applicability. Furthermore, the variation in the solver's accuracy was studied with respect to the number of elements, the aspect ratio of the elements, and the order of the elements. These studies also included an analysis of non-uniform stiffness, which was incorporated and validated within the solver.

In addition, the computational cost of the developed solver was evaluated with respect to the number and order of elements. The challenges associated with extending the solver to three-dimensional scenarios were also examined and discussed in detail which highlighted the increased complexity and computational demand that comes with three-dimensional simulations.