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A finite volume method on NURBS geometries and its application in isogeometric fluid–structure interaction

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Abstract

A finite volume method for geometries parameterized by Non-Uniform Rational B-Splines (NURBS) is proposed. Since the computational grid is inherently defined by the knot vectors of the NURBS parameterization, the mesh generation step simplifies here greatly and furthermore curved boundaries are resolved exactly. Based on the incompressible Navier–Stokes equations, the main steps of the discretization are presented, with emphasis on the preservation of geometrical and physical properties. Moreover, the method is combined with a structural solver based on isogeometric finite elements in a partitioned fluid–structure interaction coupling algorithm that features a gap-free and non-overlapping interface even in the case of non-matching grids.

Keywords: Finite volume method; NURBS; Exact geometry; Navier–Stokes equations; Fluid–structure interaction; Matching interface

1. Introduction

In numerical partial differential equations, the role of the geometry description has been mostly neglected or underestimated for many years. Only recently, with the advent of isogeometric analysis [18], it has been demonstrated that geometry and numerics may go hand in hand with substantial mutual benefits. In this contribution we discuss the class of finite volume methods (FVM) from the same perspective and introduce a discretization technique for geometries parameterized by Non-Uniform Rational B-Splines (NURBS). The discretization is able to preserve free-form surfaces and is particularly attractive for the combination with an isogeometric solver in fluid–structure interaction problems.

The isogeometric approach extends isoparametric finite elements to more general basis functions such as B-splines and NURBS [8]. In this way, exact geometries at the coarsest level of discretization are obtained and geometry errors are eliminated from the very beginning. The resulting discretization still fits into the variational framework of the finite element method (FEM), and it is possible to equip established FEM codes with isogeometric elements [4].

In computational fluid dynamics, however, the FVM is still the method of choice. It can be interpreted as a discontinuous Galerkin method of lowest order, i.e., with constant approximations in each cell or control volume. A major

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