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Variational multiscale error estimators for the adaptive mesh refinement of compressible flow simulations

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Abstract

This article investigates an explicit a-posteriori error estimator for the finite element approximation of the compressible Navier-Stokes equations. The proposed methodology employs the Variational Multi-Scale framework, and specifically, the idea is to use the variational subscales to estimate the error. These subscales are defined to be orthogonal to the finite element space, dynamic and non-linear, and both the subscales in the interior of the element and on the element boundaries are considered. Another particularity of the model is that we define some norms that lead to a dimensionally consistent measure of the compressible flow solution error inside each element; a scaled L^2-norm, and the calculation of a physical entropy measure, are both studied in this work. The estimation of the error is used to drive the adaptive mesh refinement of several compressible flow simulations. Numerical results demonstrate good accuracy of the local error estimate and the ability to drive the adaptative mesh refinement to minimize the error through the computational domain.

Keywords:
Compressible Navier-Stokes equations, Variational Multi-Scale (VMS) method, Orthogonal Sub-Grid Scales (OSGS), A-posteriori local error estimation, Adaptive Mesh Refinement (AMR)

1. Introduction

The compressible Navier-Stokes equations, namely the conservation of mass, momentum, and energy, together with constitutive and thermodynamical relations, constitute a physical model that describes the compressible fluid flow phenomena. This model is able to represent the wide range of spatial and temporal flow scales typically encountered in engineering cases of interest. When numerically approximating these equations, the smallest flow scales (in turbulence or aeroacoustics, for example) must be modeled

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