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Variational Multiscale error estimator for anisotropic adaptive fluid mechanic simulations: application to convection-diffusion problems

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Abstract

In this work, we present a new a posteriori error estimator based on the Variational Multiscale method for anisotropic adaptive fluid mechanics problems. The general idea is to combine the large scale error based on the solved part of the solution with the sub-mesh scale error based on the unresolved part of the solution. We compute the latter with two different methods: one using the stabilizing parameters and the other using bubble functions. We propose two different metric tensors $\mathcal{H}_{iso}$ and $\mathcal{H}^{new}_{aniso}$. They are both defined by the recovered Hessian matrix of the solution and rely on the sub-grid scale error estimator. Thus, we develop a new anisotropic local error indicator and we test it for mesh adaptation on convection-dominated benchmarks in 2D and 3D. The results show that the proposed error indicator leads to enhanced and accurate solutions while using a drastically reduced number of elements.

Keywords: CFD; VMS; Error Estimator; Mesh Adaptation; Convection-Diffusion.

1. Introduction

The use of Computational Fluid Dynamics (CFD) for industrial applications has been in constant increase for the last decades. Researchers are continuously developing new techniques to reach higher level of precision. Nevertheless, to comply with industrial expectations, a trade-off has to be found between high precision results and high computational costs [1]. Different strategies can be found in the literature. Most of them are related to high order elements (see [2, 3, 4]), parallel computing (see [5, 6, 7, 8]) or, in particular, adaptive methods (see [9, 10, 11, 12]).

Indeed, adaptive methods make it possible to improve the accuracy and the efficiency of numerical methods. In particular, anisotropic mesh adaptation has proved to be powerful in capturing dynamically the heterogeneities that can appear in numerous physical applications including those having boundary or inner layers [13, 14]. In these cases, gradients of the solution are highly directional and can be captured with a good accuracy using fewer additional elements. These mesh adaptation techniques are based on local modifications of an existing mesh. Usually, it consists in a local stretching of the elements which is defined by a metric field. This metric field is built from an error analysis

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