Flux reconstruction solver for arbitrarily unstructured grids with r-refinement

R. Dhib[*], F. Ben Ameur[*,**], R. Vandenhoeck[*,**], A. Lani[*,**] and S. Poedts[*,***]
Corresponding author: rayan.dhib@kuleuven.be

[*] Centre for Mathematical Plasma-Astrophysics, KU Leuven
[**] Von Karman Institute for Fluid Dynamics
[***] Institute of Physics, University of Maria Curie-Skłodowska

Abstract: The present paper will address the development and implementation of the high-order Flux Reconstruction (FR) schemes for high-speed flows on both straight and curved edged simplex elements within the open-source COOLFluiD (Computational Object-Oriented Libraries for Fluid Dynamics) platform. While the FR method potentially provides a more accurate detection of complex flow features over relatively coarser mesh, when compared to their low-order peers, the approach suffers from the same pacing items as the other high-order methods such as the slow convergence to steady state and the lack of robust shock capturing capabilities. To overcome such deficiencies, Adaptive Mesh Refinement (AMR) represent a robust procedure for improving the quality of the physical results, especially shock capturing capabilities, due to a local increase of the grid resolution and mesh/shock alignment. Particularly, spring-based and physics-driven r-refinement requires a compact stencil and is suitable for parallel computing. This fact goes hand in hand with the FR method since the latter can obtain arbitrary high orders of accuracy without requiring a wide stencil at higher orders. In this work, a concise overview of the Flux Reconstruction method and spring-based AMR techniques will be given, followed by some promising results of r-AMR applied to benchmark high-order supersonic flow simulations.

Keywords: Flux Reconstruction, r-AMR, high-speed flows, Spring analogy, simplex meshes.

1 Introduction

Due to their flexibility, robustness and relatively low computational cost, low-order CFD methods have been and are still extensively used in either industrial or academic applications. However offering at best second-order accuracy in space, the limits of these schemes begin to appear when facing more and more complex problems such as in aeroacoustics, vortex-dominated flows, thermochemical non-equilibrium and astrophysical simulations. In order to overcome the obstacles faced by low-order schemes, a promising approach is to employ high-order methods. Recently, an implicit high-order Flux Reconstruction (FR) solver for high-speed compressible flows on quadrilateral and hexahedral meshes, has recently been implemented within the COOLFluiD platform [4]. Following the steps of [3], the COOLFLuiD FR solver is currently being extended to deal with triangular and tetrahedral meshes. In addition, as in [4], the shock capturing will be based on a modified Localized Laplacian Artificial Viscosity (LLAV) scheme combined with a positivity preservation method in order to alleviate oscillations caused by the Gibbs phenomenon as well as harsh transient effects characterizing high-speed flow calculations. Furthermore, a robust and efficient r-AMR module was developed within the COOLFLuiD platform for Finite Volume (FV) [1] and FR [2]. The existing FR-AMR algorithms works on quadrilateral straight and curved edged, is parallel and physics-independent, letting the user decide which monitor physical quantity to use for driving the adaptation according to the application. As in [2], the sub-cell order-dependent spring analogy will be implemented for the high-order simplex mesh elements.

2 Work status

Within this section, we show the preliminary promising work that was done and we intent to present a wider range of FR-AMR results on simplex elements for the final version of the paper. Figure 1(left) shows the density contour plots of the Mach 0.38 inviscid flow over a cylinder of radius 0.5[m] using the second-order FR polynomial solution (P2) on second-order triangular mesh (Q2). Figure 1(right) shows preliminary results for P2Q1 density contour plots of a Mach 2 inviscid steady wedge channel flow. We can clearly observe that the oblique shock is widely spread and indeed, and a r-AMR tool will be beneficial for better capturing the shock.

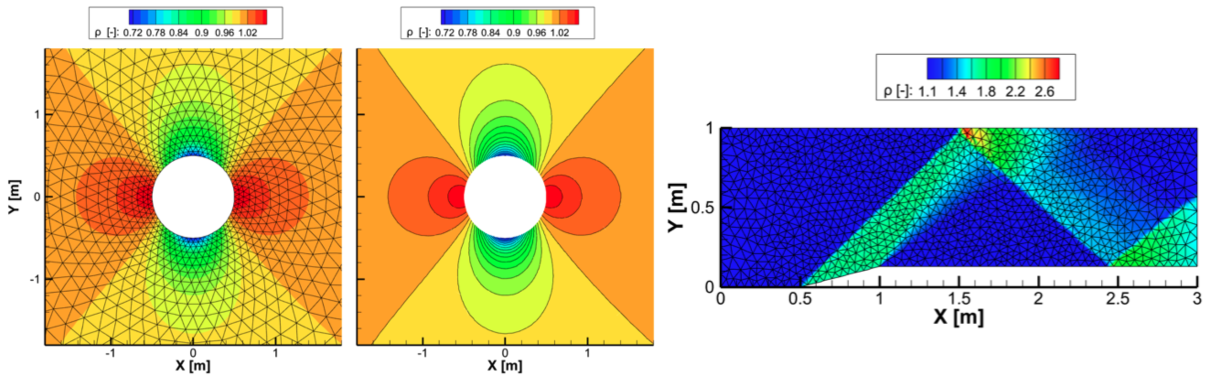

Figure 1: Density contour plots : (left) the cylinder (right) the wedge

References

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