Space-Time Finite Volume Method with Anisotropic Mesh Adaptation for Numerical Fluid Mechanics

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In numerical simulations of fluid mechanics, achieving higher accuracy can be approached in sever always : refining the physical modeling of flows, increasing the resolution of discretization, or improving the precision of numerical methods. To balance computational cost and accuracy, anisotropic metric-based Adaptive Mesh has demonstrated its effectiveness for steady problems. However, extending this approach to unsteady flows remains a significant challenge due to the complexities introduced by time dependence. One key issue is the lagging of the mesh relative to the evolving solution. When a mesh is optimized for a solution at specified time, it quickly becomes suboptimal as the solution advances. Several methods in the literature address this issue [2], but they require introducing complex interpolation techniques to transfer the solution between meshes, as well as intricate metric definitions to ensure accuracy. In this work, we introduce a novel numerical method designed for unstructured meshes, ensuring conservation in both space and time, while mitigating these challenges in an efficient way.
Unlike classical time-marching approaches for unsteady problems, which typically rely on a single global time step imposed over the entire spatial domain, the present space-time setting naturally accommodates locally varying time increments [1].

[1] A. A. Ahmad, F. Blachère, B. Portelenelle, T. Grosges, E. Rouhaud. *Space-time formulation of finite volume scheme for conservation laws.* Computers and Mathematics with Applications, **26**, 2026. Submitted manuscript.

[2] F. Alauzet, A. Loseille, G. Olivier. *Time-accurate multiscale anisotropic mesh adaptation for unsteady flows in CFD.* Journal of Computational Physics, **36(3)**, 2018.

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