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PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **DAADA-2025-32**
(à rappeler dans toute correspondance)

Lieu : Chatillon

Département/Dir./Serv. : DAAA / DEFI

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DESCRIPTION DU STAGE

Thématique(s) : High-resolution numerical scheme, Aeroacoustics, HPC

Type de stage : ☒ Fin d'études bac+5 ☐ Master 2 ☐ Bac+2 à bac+4 ☐ Autres

Intitulé : Large Eddy Simulation of compressible turbulent flow on octree mesh for aeroacoustics.

Sujet :

The simulation of turbulent phenomena by methods allowing the reproduction of rich spectral content (Large Eddy Simulation) is attracting growing interest in the industrial world to understand particular physical mechanisms or study aeroacoustic phenomena. As the LES simulation must represent a large part of the spatio-temporal scales of the turbulence directly on the mesh, this approach relies on a particular numerical method, which achieves a precision/robustness compromise to obtain a satisfactory solution of **N**avier-**S**tokes (NS) equations at the best calculation cost. Initially reserved for simple geometric configurations and moderate Reynolds numbers, LES is used nowadays more and more often in an industrial context with the progress of supercomputers. This "democratization" was made possible by:

- The development of wall law (Wall Model LES) which considerably reduces calculation time
- meshing techniques (chimera method, automatic Octree meshes) which drastically reduces the preparatory phase of the calculation

This new framework (wall law and meshing technique), the current radical change in the architecture of supercomputers (GPU) and the possible substitution of the NS equations by the **L**attice **B**oltzmann **M**ethod (LBM) over the past 4 or 5 years invalidate the previous conclusions regarding the proper implementation of a LES simulation for compressible flows in an industrial setting:

- LBM, which is based on Octree meshes and wall laws, gains a strong interest in athermal flows as soon as we become interested in aeroacoustics. Very recent developments make it possible to study compressible flows, but the approach lacks of maturity and its competitiveness compared to the classic NS approach is not yet proven.
- The NS approach has great maturity for compressible flows. As aeroacoustic studies are an important purpose, it is necessary to be able to implement high order schemes better suited to the propagation of sound waves. This leads to favoring the use of structured mesh, which requires the use of automatic Octree meshes in areas that are difficult to mesh to limit engineering time.

For 20 years, ONERA has developed a numerical method in a CFD research solver for LES adapted to the constraints of high-performance computing, the main characteristics of which have been widely distributed in the elsA software, used at Safran. The method is based on finite volumes 2nd order schemes and structured meshes. Recent calculations have highlighted a weakness of this method: it sometimes generates micro disturbances which can distort the development of transition instabilities and/or excite low-amplitude parasitic acoustic waves. For the latter, the phenomenon is exacerbated in the case of the use of Octree Cartesian meshes.

The main objective of the internship will be to improve and reassess the choice of the numerical method to be used for LES calculations based on NS equations for aeroacoustics on structured meshes comprising Octree patches:

- By implementing in a Python/C/Fortran framework a conservative connections for octree meshes in a high-performance computing context.
- By modifying the current spatial scheme to limit the amplitude of spurious waves, while maintaining a good accuracy for the vortices advection.

The current method will be adapted and evaluated using elementary test cases (acoustic waves, vortex advection, ...). A more in-depth aeroacoustic validation will be performed on an academic case involving 3D unsteady flow around a naca0012 wing profile by comparing the results with experimental data and **L**attice **B**oltzmann **S**imulation obtained with commercial ProLB software.

Est-il possible d'envisager un travail en binôme ? **Non**

Méthodes à mettre en œuvre :

☒ Recherche théorique	☐ Travail de synthèse
☒ Recherche appliquée	☐ Travail de documentation
☐ Recherche expérimentale	☒ Participation à une réalisation

Possibilité de prolongation en thèse : **Oui**

Durée du stage : Minimum : 4 mois Maximum : 5 mois (sauf dérogation)

Période souhaitée : mars-septembre 2024

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :
Méthode numérique, Mécanique des fluides, Programmation (Python, C, Fortran)	Master en mécanique des fluides