JOB OFFER – INTERNSHIP

Reactive simulations on unstructured tetrahedra meshes using a high-order discontinuous method

OFFER INFORMATION

Reference: AAM-2025-DAV-04
Team: AAM

Location: 42 Avenue Gaspard Coriolis – 31057 Toulouse

Supervisors:

- Guillaume Daviller, daviller@cerfacs.fr
- Thomas Marchal, tmarchal@cerfacs.fr

Gratification : 700€ net per month - M2 level or last year at engineering school
Period : 6 months – from Février 2025 (adaptative)

Mots-clés : Combustion, CFD, High-order, Tetrahedra meshes

CERFACS

Cerfacs is a private research, development, transfer and training center for modeling, simulation and high-performance computing. Cerfacs designs, develops and proposes innovative software methods and solutions to meet the needs of its partners in the aeronautics, space, climate, environment and energy sectors. Cerfacs trains students, researchers and engineers in simulation and high-performance computing.
Cerfacs works closely with its seven partners: Airbus, Cnes, EDF, Météo France, Onera, Safran et TotalEnergies.

HOSTING TEAM - AAM

The Advanced Aerodynamic & Multiphysics (AAM) team is dedicated to developing cutting-edge numerical methods, physical modeling, and High-Performance Computing (HPC) techniques for new Computational Fluid Dynamics (CFD) solvers. The work focuses on fluid dynamics simulations for aircraft, rockets, and turbomachinery, in close collaboration with Cerfacs partners.

CONTEXT

The need for numerical simulations of unsteady multi-physical phenomena is growing rapidly in the aerospace industry. They offer a cost-effective alternative to testing and experimentation, significantly reducing development time. It also facilitates the design and optimization of aerospace systems (combustion chambers, aerodynamic structures, etc.). To be an effective tool, the underlying simulation methods must faithfully represent the physical phenomena of interest on industrial configurations.

In this context, CERFACS is working closely with ONERA to develop innovative scientific computing methods within the JAGUAR software.

JAGUAR is a high-performance computational code that solves the reactive Navier-Stokes equations in laminar and turbulent regimes, using large-scale modeling. The corresponding system of equations is discretized using a high-order numerical scheme with the Spectral Difference (SD) discretization. This scheme is an alternative to discontinuous Galerkin methods, offering the same general properties (high order, hp refinement, native handling of non-conforming and unstructured meshes) while performing better in terms of temporal stability and computational cost.

Works carried out during Adèle Veilleux's PhD thesis [1] enabled the choice of elements to be extended to triangular and tetrahedral meshes. In parallel, Thomas Marchal's PhD thesis [2] made it possible to run reactive simulations on hexahedral meshes. To make the method more robust in an industrial context, recent work has stabilized the method in the presence of shocks [3] and extended it for all polynomial orders [4] on triangles and tetrahedra. In this internship, we propose to continue this work to simulate reactive flows [5] on triangles and tetrahedra meshes.

[1] A. Veilleux, G. Puigt, H. Deniau and G. Daviller. *Stable Spectral Difference Approach Using Raviart-Thomas Elements for 3D Computations on Tetrahedral Grids*. Journal of Scientific Computing, 91, 2022.

[2] T. Marchal, H. Deniau, J.-F. Boussuge, JF., B. Cuenot and R. Mercier. *Extension of the Spectral Difference Method to Premixed Laminar and Turbulent Combustion*. Flow Turbulence and Combustion, 111, 2023.

[3] N. Messai, G. Daviller and J.-F. Boussuge. Artificial viscosity-based shock capturing scheme for the Spectral Difference method on simplicial elements. Journal of Computational Physics, 2024.

[4] N. Messai and G. Daviller. *A corrected Raviart-Thomas Spectral Difference scheme stable for arbitrary order of accuracy on triangular and tetrahedral meshes.* To appear in Computer Methods in Applied Mechanics and Engineering. 2025.

[5] L. Gicquel and G. Staffelbach and T. Poinsot. *Large Eddy Simulations of gaseous flames in gas turbine combustion chambers*. Progress in Energy and Combustion Science, 38, 2012.

MISSION

The aim of this internship will be to extend the JAGUAR reactive solver to triangular and tetrahedral elements. The candidate will develop the JAGUAR code in Fortran. The code will be tested on various academic applications. Initially, the candidate will have to familiarize himself/herself with the code and the methods dedicated to reactive simulations. Then, in collaboration with researchers from the AAM team, the candidate will propose solutions enabling the best possible integration of the envisaged approach.

DESIRED PROFILE

- Currently in the final year of an engineering degree or equivalent, specializing in Aeronautics, Aerodynamics, and Acoustics.
- Initial project-based experience in unsteady computational fluid dynamics (CFD) programming is required.
- In particular, skills in acoustics are an advantage.
- As this is a research-oriented internship, the candidate, who is preparing for a Research Master's degree, will be required to present his/her work both orally and in writing in English, in line with the standards expected in an international research laboratory.

WHAT WE OFFER AT CERFACS

- Broad access to technology, a rich interpersonal environment, in-house skills recognized nationally and internationally.
- An inclusive and equitable work environment.

- A structure accessible to people with disabilities.
- Possibility of benefiting from 1.83 days of reduced working hours per month, linked to your choice of a 39-hour rather than 35-hour working week.
- 50% reimbursement of public transport costs.

HOW TO APPLY ?

To apply, please send your CV and cover letter to daviller@cerfacs.fr, applications are open until 31/01/2025.

See you soon at CERFACS!