2019-01361 - PhD Position F/M (BN19) Shock embedding: a new paradigm to handle discontinuities in hyperbolic systems

Type de contrat : CDD de la fonction publique
Niveau de diplôme exigé : Bac + 5 ou équivalent
Fonction : Docteurant

A propos du centre ou de la direction fonctionnelle

From PDEs to certified computational models: this is the motto of CARDAMOM. We aim at providing a robust model development methodology, as well as a quantitative approach to model certification, allowing to assess the robustness of the model w.r.t. each of its components (equations, numerical methods, etc), and to assess the variability of the outputs w.r.t. random variations of the data.

We will achieve this objective working toward a unified set of tools for the engineering analysis of complex flows involving moving fronts. Examples of such flows be found in civil, industrial, and aerospace engineering: industrial hazards (explosions), free surface hydraulics (coastal hydrodynamics, floods, etc), energy conversion facilities (gas-vapour, liquid-vapour systems, wave energy conversion, etc), space-reentry (chemically reacting fronts, ablating walls, rarefied/continous flows), wing de-icing systems (ice-air flow).

Simulating, optimising and controlling these systems in a robust manner is far from being a simple task, especially in a real life. There is still a large number of open scientific challenges. These are related to the intrinsic nature of these flows necessitating:

- an appropriate PDE formulation taking into account the physics relevant to the engineering applications while remaining computationally affordable in an operational context,
- efficient adaptive discretizations allowing to optimise the computational effort, while providing a sharp and accurate resolution of the physics;
- a certification step quantifying the uncertainty in engineering outputs due to all modelling choices, both physical and mathematical (continuous and discrete).

To develop a robust and accurate model means to be able to quantify and control the effects of the choices made in each of the above steps. The development of robust models tailored to the applications mentionned above is the objective of CARDAMOM.

Contexte et atouts du poste

The research stems from ideas developed in a collaboration between the CARDAMOM team, Prof. R. Piacentini (U. Roma La Sapienza), and Prof. A. Bonfanti (U. della Basilicata) in Italy, and with some of the results of the associated team Hamster (https://team.inria.fr/hamster/).

The focus is the simulations of fluid flows in which a major role is played by shocks, as e.g. in propulsion systems or space re-entry, and also in some free surface flows as e.g. in river flows (bore, marascati). Shock capturing methods, currently the standard approach to handle these phenomena, introduce a strong numerical dissipation, which is greatly dependent on the structure of the computational grid. This leads to many undesired spurious effects downstream of the shock. The typical (but not the only) example is the failure in predicting the heating of bodies present downstream of the shock. An approach to remove these effects is shock fitting: an exact tracking and meshing of the shock surface. This approach, dating back to the 70s, has become feasible due to advances in re meshing. It remains however a complex method, especially in 3D, due to the re meshing constraints, and impossible to use when the underlying grid is structured. The objective of this work is to develop a new method going beyond these limitations.

Mission confiée

The approach developed here is based on a combination of shock fitting with high order extrapolation techniques typically used in immersed boundary methods. This is an entirely new paradigm in between shock fitting and shock capturing. Its preliminary implementation has already been shown to have accuracy comparable to that of a classical fitting method, without the need of exactly re-meshing. This idea opens the path to many additional simplifications as well as to the use of fitting in a more general context, including existing structured flow solvers which would be an enormous advantage for users already having a well validated/verified numerical code. The initial implementation has shown the method to have accuracy comparable to that of a classical shock fitting method, without the need of exactly remeshing.

The objective of the PhD is to further develop the idea, an bring it to realistic applications on geometries relevant in propulsion and space re-entry systems. This research will continue within the same international collaborations, strengthening the ties between Inria B50, UI Roma La Sapienza and UI della Basilicata. The recruited PhD will thus regularly interact with and visit these partners.

Principal activitètés

The milestones of the work to be performed are the following:

1. Improve fundamental formulation to account more for the directionality of wave propagation in the shocked cells by investigating:
   a. The impact of extrapolation direction
   b. The type of boundary/coupling condition imposed on the surrogate mesh boundary (mesh edges closest to the shock)
2. Implementation and benchmarking on Cartesian grids
3. Evaluation of mixed embedding/capturing on adapted grids approach
4. Extension to 3D and benchmarking on complex geometries

For more information please see http://team.inria.fr/cardamom/files/2019/02/PhD-ESF.pdf

Compétences
Candidates are expected to have a strong background in numerical methods for compressible flows on unstructured grids, as well as in compressible fluid mechanics. Some background on the management of unstructured grids, as well as good programming skills are also required.

Avantages
- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking (after 6 months of employment) and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

Rémunération
Duration: 36 months

Gross Salary: 1982€ / month (before taxes) during the first 2 years, 2085€ / month (before taxes) during the third year