Laboratoire POEMS, CNRS, Inria, ENSTA Paris, Institut Polytechnique de Paris, Palaiseau (France)
In collaboration with ACE team, Université de Liège (Belgium)

Postdoctoral fellowship
in Computational Engineering/Applied Mathematics

Acceleration of a HDG finite element solver for time-harmonic wave problems

Keywords: discontinuous finite elements (DG), domain decomposition methods (DDM), iterative solvers, wave propagation, high-performance computing, C++ programming

Host laboratory:	POEMS *(CNRS, Inria, Ensta Paris)* at Palaiseau (France)
Mentors:	Dr Axel Modave *(POEMS, CNRS, France)* [website] *(main contact)*
	Prof. Christophe Geuzaine *(Liège University, Belgium)* [website]
Duration:	1 year *(potentially extended)*
Starting:	Ideally September/October 2024
Funding:	ANR WavesDG project

Context

Numerical tools that simulate wave propagation phenomena are widely used to address major industrial and societal challenges such as aircraft noise reduction, electromagnetic compatibility testing, and seismic risk assessment. Numerical schemes based on finite element methods (FEMs) have proven their ability to address realistic problems. However, the discretization of time-harmonic problems with FEMs leads to large sparse algebraic systems that are difficult to solve.

The postdoc will be part of the ANR WavesDG project [website]. In this project, we study and extend discontinuous Galerkin (DG) finite element schemes tailored for the iterative solution of time-harmonic problems. Our ultimate goal is to develop time-harmonic finite element solvers that are able to efficiently exploit the computational power of modern parallel architectures consisting of many-core processors accelerated by GPUs. The postdoc will contribute to a research axis dedicated to the acceleration of an existing 3D DG solver using domain decomposition methods and high-performance computing (HPC).

Description of the postdoctoral research project

A new hybridizable discontinuous Galerkin (HDG) finite element approach [2] has been recently proposed for solving scalar wave problems. This method relies on a standard DG scheme hybridized by using transmission variables at the interface between the elements. The resulting algebraic system has interesting properties for efficient iterative solution procedures, and we believe that the method is a good candidate to address large-scale realistic problems. A 3D parallel C++ prototype code is currently under development.

The goal of the postdoctoral research project is to investigate techniques to accelerate the 3D solver for efficient computations on modern computing architectures. Two research directions are proposed. The first is to develop a GPU version of the prototype code by adapting techniques already used for time-dependent

DG GPU solvers, *e.g.* [1] and [3]. For the second axis, we will investigate domain decomposition methods (DDMs) to speed up the convergence of the solver. In particular, we would like to use iterative operations at all levels and exploit the specificity of the system.

The balance between the two axes can vary depending on the interests and abilities of the candidate!

Research teams

This position is proposed in the framework of a collaboration between the POEMS team *(Palaiseau, France)* and the ACE team *(Liège, Belgium)*. The postdoctoral researcher will be based at Palaiseau.

The POEMS team [website] is a joint laboratory of the CNRS, Inria and ENSTA Paris with 16 academic permanent and about 20 non-permanent researchers. The research activities of POEMS are mainly dedicated to the mathematical and numerical study of wave propagation problems, including aspects related to mathematical analysis, numerical simulation and high-performance computing.

The ACE team [website] participates in research projects in applied physics *(electromagnetic and acoustic wave scattering, electromagnetic compatibility, bio-electromagnetism, non-destructive testing, material modeling)*, applied mathematics *(partial differential equations, fast solvers)* and computer science *(finite element mesh generation, high performance scientific computing)*.

Profile of the candidate

We are looking for a candidate with a **PhD in Computational Engineering or Applied Mathematics** *(recent, less than 2 years)* with strong practical skills/interest in numerical methods and high-performance computing (HPC).

Practical knowledge of finite element methods and scientific programming is expected. Knowledge of DDM and/or GPU programming is preferred but not required.

Don't hesitate to contact us for further information!

Practical information for application

Interested candidates should send a letter of application together with a curriculum vitae, copies of doctoral theses and letters of reference *(if any)* to Axel Modave [axel.modave@ensta-paris.fr].

References

[1] Cicuttin, Royer, Binde, Geuzaine (2022). Electrostatic Discharge Simulation Using a GPU-Accelerated DGTD Solver Targeting Modern Graphics Processors. IEEE Transactions on Magnetics, 58 (9) [link]

[2] Modave, Chaumont-Frelet (2023). A hybridizable discontinuous Galerkin method with characteristic variables for Helmholtz problems. Journal of Computational Physics, 493, 112459 [preprint] [link]

[3] Modave, St-Cyr, Warburton (2016). GPU performance analysis of a nodal discontinuous Galerkin method for acoustic and elastic models. Computers & Geophysics, 91, 64-76 [link]

Version: 21/04/2024