

2D Discontinuous Galerkin Methods for Acoustic and Electromagnetic Waves on CPUs and GPUs

MATH0471 – Spring 2020

v1 (03/02/2020)

This project consists in studying a hyperbolic system of equations in its conservative form. Spatial discretization will be performed using the Discontinuous Galerkin (DG) method and Lagrange nodal basis functions on unstructured meshes. An explicit time-marching method will be chosen. The book of J.S. Hesthaven and T. Warburton entitled *Nodal Discontinuous Galerkin Methods*¹ (Springer 2008) will be the main reference for the project.

Since the DG method requires a more elaborated mesh data structure than the classical finite element method, the numerical scheme will be implemented with the help of the Gmsh SDK² so that meshing, computation of surface integrals and postprocessing of results will be simplified.

The numerical scheme will first be developed, tested and validated for the solution of three uncoupled scalar transport equations. Then, the coupled systems describing the propagation of acoustic or electromagnetic waves will be considered. For each of these two phases, the acceleration on GPUs using OpenACC will be studied.

The project is organized as follows:

1. Students will be divided in 2 groups. Each group will write its own solver.
2. Three intermediate deadlines are given, with a mandatory (but not graded) 8-page progress report that should detail the computer implementation and the mathematical, numerical and physical experiments.
3. The final report (about 60 pages) will present the method and numerical results, the computer implementation and a detailed analysis of physical experiments on non-trivial configurations.
4. An oral presentation of the main project results will be organized during the June exam session (tentative date: June 10th 2020); individual theoretical and practical questions will be asked to each member of the 2 student groups.

¹<https://link.springer.com/book/10.1007%2F978-0-387-72067-8>

²<http://gmsh.info>

Important dates:

1. **Wednesday March 11th: Intermediate deadline #1: DG method for transport equations on CPUs:** Implementation of the DG method using Lagrange shape functions of arbitrary order for three uncoupled scalar conservation equations in 2D. The implementation should take advantage of the Gmsh library for creating and/or reading the mesh, computing values of shape functions and Jacobians, as well as exporting results. At this stage, the code should run on CPUs, either sequentially or (optionally) multi-threaded using OpenMP, and the time integration should be performed using a simple forward-Euler method.
2. **Wednesday April 1st: Intermediate deadline #2: Acceleration on GPUs using OpenACC:** Implementation, testing and performance analysis of the GPU-accelerated version of the solver.
3. **April 29th: Intermediate deadline #3: Extension to a realistic problem:** Modification of the code for solving either acoustic or electromagnetic wave problems.
4. **May 15th: Final deadline:** Final report and code.
5. **June 10th: Exam:** Oral presentation of the projects.

The full source code should be tagged in the ULiège Gitlab for each deadline, and should be directly configurable and compilable on the designated machines. The reports in PDF format should also be associated to this tag on Gitlab for each deadline.