M2 Internship / Numerical computation of Green’s kernel and associated layer potential integrals in helioseismology

Contract type: Internship agreement

Level of qualifications required: Master’s or equivalent

Fonction: Internship Research

Assignment

We propose an M2 internship in computational helioseismology in the context of project Butterfly which aims to develop numerical tools for use in seismological investigation of surface magnetic activity of Sun and solar-like stars. The objective of the internship is to compute numerically the quiet Sun Green’s kernel and implement numerical integration involving this kernel to be employed in boundary integral equation (BIE) methods. The Green’s kernel forms a key ingredient in forward modeling as well as inversion in helioseismology and asteroseismology which employ seismological techniques to reconstruct the interior structure and dynamics of the Sun and solar-like stars. Radially symmetric standard solar models, such as model S [2], represent the Sun at minimum magnetic activity, called ‘quiet’ Sun. Effects of magnetic activity on solar acoustic modes can be represented as near-surface 3D perturbations in wave speed, and in this way, wave propagation in the Sun is modeled by a time-harmonic scalar wave equation with sound speed coefficient containing these perturbations. Adding these perturbation breaks the radial symmetry of standard models, thus resolution is carried out in 3D but can be prohibitively costly. In the case of compact perturbations, we will construct a more computing-resource frugal alternative, employing a BIE method coupled with Hybridizable Discontinuous Galerkin (HDG) method.

Main activities

The program will be divided into two main phases. All software development and numerical implementation will be performed in the open-source code hawen [3] developed in the team Makutu.

Phase 1: Computation of the Green’s kernel exploiting its axis-symmetry, with the following tasks:

(1.a) Implement and validate the 2.5D scalar equation in software hawen which employs HDG method and direct solver MUMPS. Validating test cases include backgrounds with analytic solutions and solar background. The latter comparison is done with the kernel in [4].

(1.b) Use the validated code to compute the 3D quiet sun Green’s kernel and its derivative for all positions of source and receiver. The 3D problem is reduced to one in the 2D meridional plane by exploiting rotational invariance.

Phase 2: With coupling BIE to HDG in mind, we will consider Garlekin boundary element method rather than collocation method. We will need double layer integrals associated with the kernel and its derivatives. The technical difficulty comes from the weak singularity of the kernel along its diagonal. The tasks here consist of:

(2.a) Familiarize with existing techniques in Galerkin BEM literature to compute double integrals with weakly singular kernels. We will employ Sauter–Schwab quadrature as our reference, but keep in mind other approaches that provide more precision, cf., e.g., the introduction of [5].

(2.b) For regular pairs of integrals, we will ‘tensorize’ the quadrature routines in the code hawen. For singular pairs, we implement the Sauter–Schwab quadrature, cf., [6, Section 5.2], [7, 1].

References


Skills

The applicant must have a solid background in applied mathematics, in particular in partial differential equations for wave propagation; knowledge in boundary element methods and finite elements is recommended. Numerical implementation will be part of the internship, within the open-source platform hawen, it is necessary that the applicant is familiar with programming, including parallel computer architecture to launch experiments. In addition, the applicant is expected to review scientific bibliography and write reports/documentation for its progress, hence a good level in English for all aspects of communications is required.

Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)

General Information

- Theme/Domain: Numerical schemes and simulations
  Scientific computing (BAP E)
- Town/city: Pau
- Inria Center: Centre Inria de l'université de Bordeaux
- Starting date: 2024-03-01
- Duration of contract: 6 months
- Deadline to apply: 2024-01-31

Contacts

- Inria Team: MAKUTU
- Recruiter: Faucher Florian / florian.faucher@inria.fr

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