2018-00304 - Comparison of time stepping methods for the Bloch-Torrey equation in diffusion MRI

Level of qualifications required: Master's or equivalent
Function: Internship Research

About Inria

Inria, the French National Institute for computer science and applied mathematics, promotes "scientific excellence for technology transfer and society". Graduates from the world's top universities, Inria's 2,700 employees rise to the challenges of digital sciences. With its open, agile model, Inria is able to explore original approaches with its partners in industry and academia and provide an efficient response to the multidisciplinary and application challenges of the digital transformation. Inria is the source of many innovations that add value and create jobs.

About the research centre or Inria department

Located at the heart of the main national research and higher education cluster, member of the Université Paris Saclay, a major actor in the French Investments for the Future Programme (Idex, LabEx, IRT, Equipex) and partner of the main establishments present on the plateau, the centre is particularly active in three major areas: data and knowledge; safety, security and reliability; modelling, simulation and optimisation (with priority given to energy).

The 450 researchers and engineers from Inria and its partners who work in the research centre's 31 teams, the 100 research support staff members, the high-level equipment at their disposal (image walls, high-performance computing clusters, sensor networks), and the privileged relationships with prestigious industrial partners, all make Inria Saclay Île-de-France a key research centre in the local landscape and one that is oriented towards Europe and the world.

Assignment

Diffusion Magnetic Resonance Imaging (dMRI) has been used extensively to image the brain and other organs such as the heart. The Bloch-Torrey Partial Differential Equation (PDE) governs the evolution of the water proton magnetization in a heterogeneous medium and can be used to model the dMRI signal in an imaging voxel.

Main activities

In this internship project, the student will use an existing Matlab code that solves the above equations with the finite element method (FEM) and compare several time stepping approaches for the resulting semi-discretized equations that are in the form of a large system of coupled ordinary differential equations (ODEs). There are several Matlab-implemented ODE solvers as well as the Runge-Kutta Chebyshev method to be compared. Numerical issues such as the stiffness of the resulting ODEs and rapid oscillations due to high gradient strength will need to be considered and evaluated for each of the ODE solvers.

Skills

This project requires the knowledge of basic partial differential equations (diffusion equation properties), numerical analysis (ODE solvers, numerical stiffness), and finite elements (constructing finite element matrices). Very importantly, it is necessary that the student can write good code in "Matlab" (correct and fast to run, i.e., using vector operations rather than loops, etc.).

Benefits package

- Subsidised catering service
- Partially-reimbursed public transport
- Social security
- Paid leave
- Flexible working hours
- Sports facilities