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 optimization (with priority given to energy).

The 480 researchers and engineers from Inria and its partners who work in the research centre’s 28 teams, the 60 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.

Context

Studying tissue microstructure non-invasively is a key application of diffusion MRI (dMRI). In the feasibility of analyzing cellular size in live tissue with time-dependent diffusion MR was demonstrated. However, the use of such analyses on human cohorts has been confined to characterizing the anisotropy and direction of tissue due to MR scanner limitations. In this work, we go beyond the characterization of anisotropy by exploiting the multi-shell dMRI acquisition for the characterization of tissue microstructure at the cellular level.

The Bloch-Torrey partial differential equation (PDE) describes the time evolution of the transverse spin magnetization at the voxel level, where the interface conditions for the PDE inside voxel model the hindrances to water diffusion due to the presence of cell membranes. This PDE can be solved using finite elements discretization coupled to an appropriate ODE solver for the resulting system of discretized equations. The PhD candidate will use a toolbox developed in the Defi team that solves the Bloch-Torrey PDE and adapt it to solve on geometrical configurations relevant to the VENs. The challenges of this work include:

1) Geometry and mesh creation for multi-scale and anisotropic cell membranes distributions in the relevant brain regions;
2) Reducing the computational complexity of the numerical PDE solution by parameterizing certain input parameters (such as the average lengths of the dendrites segments, the angle distributions of the dendrite tree branches, and the size distribution of the somas);
3) Optimizing the MRI acquisition protocol for the detection of the VENs;
4) Invert the parameterized model above with the optimized MRI acquisition protocol to estimate the presence and density of VENs;
5) Confronting the numerical simulations and reduced model with in-vivo data.

Assignment

Sensing microstructural characteristics of human brain tissue with clinical MRI scanners has been an area of heated debate in the diffusion MRI (dMRI) community. We have recently presented evidence that, if we focus on the cortex, specifically in the insula and anterior cingulate cortex (ACC), the unique characteristics of the cellular population in these gyri allow using clinical-grade scanners to sense the presence of VENs (VENs). VENs, uniquely localized in the insula and ACC, are large neurons thought to play an important role in goal-directed behaviors and emotional regulation. However, there is a lack of tools enabling studies on VENs population characteristics and their link to brain function and behavior.

The proposed project attacks a new frontier in dMRI for microstructure quantification by focusing on specific areas in the cortex, rather than the heretofore much studied white matter areas. There has been tremendous progress made in the past decades in white matter fiber tracking and fiber structure quantification. The study of such problems in the white matter is facilitated by the cylindrical nature of the bundled axons in the white matter. Such “simple” structure, unfortunately, does not exist in the gray matter. The multiple-scale and anisotropic nature of cellular components in the gray matter (soma, dendrite trees, etc.) makes the microstructure quantification problem much more difficult than in the white matter where the geometrical objects are predominantly cylindrical axons.

However, in an exciting preliminary work, we have shown that using multiple shell diffusion acquisitions has the potential to give quantitative information about the VENs.

Main activities

In this PhD project, we will use numerical and analytical tools to study the feasibility and optimize the design of multiple shell dMRI acquisitions with the specific goal of targeting VENs quantification. In particular, we will perform numerical simulations of the dMRI signal in the relevant brain regions on the voxel level and then analyze the behavior of the dMRI signal as a function of the neuronal structure and the acquisition protocols, and finally optimize the protocols for sensitivity to VENs.

We foresee the following challenges in this project:

1) Geometry and mesh creation for multi-scale and anisotropic cell membranes distributions in the relevant brain regions;
2) Reducing the computational complexity of the numerical PDE solution by parameterizing certain input parameters (such as the average lengths of the dendrites segments, the angle distributions of the dendrite tree branches, and the size distribution of the somas);
3) Optimizing the MRI acquisition protocol for the detection of the VENs subject to constraints imposed by SNR and clinical scanner limitations;
4) Invert the parameterized model above with the optimized MRI acquisition protocol to estimate the presence and density of VENs in a way that is robust with respect to un

About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

Instruction to apply

Defence Security:

This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2017-425 relating to the protection of national scientific and technical potential (PPST). Authorization to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

Recruitment Policy:

As part of its diversity policy, all Inria positions are accessible to people with disabilities.

General Information

- Theme/Domain: Computational Neuroscience and Medicine
- Scientific computing (BAP E)
- Town/City: PALaiseau
- Inria Center: CRI Saclay - Île-de-France
- Starting date: 2019-10-01
- Duration of contract: 3 years
- Deadline to apply: 2019-07-31

Contacts

- Inria Team: PARIETAL
- PhD Supervisor: Wassermann Demian / demian.wassermann@inria.fr

Warning: you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.
Skills
The desired profile is someone who has obtained a Master's degree in Applied Mathematics or Computer Science and has the ability to program in Matlab or Python. This candidate should have a good level of understanding of methods of numerical solution of partial differential equations and the physics of diffusion in heterogeneous media.

Benefits package
- 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

Remuneration
Monthly gross salary: 1,982 euros (1st and 2nd year) - 2,085 euros (3rd year)