Offer #2023-06308

Post-Doctoral Research Visit F/M Robust mapping of cell morphology from human diffusion MRI data combining numerical simulations and machine learning

Contract type : Fixed-term contract

Level of qualifications required : PhD or equivalent

Fonction : Post-Doctoral Research Visit

Level of experience : Recently graduated

About the research centre or Inria department

The Inria Saclay-Île-de-France Research Centre was established in 2008. It has developed as part of the Saclay site in partnership with **Paris-Saclay University** and with the **Institut Polytechnique de Paris** .

The centre has **39 project teams** , 27 of which operate jointly with Paris-Saclay University and the Institut Polytechnique de Paris; Its activities occupy over 600 people, scientists and research and innovation support staff, including 44 different nationalities.

Context

Every year Inria International Relations Department has a few postdoctoral positions **in order to support Inria international collaborations**.

This year, postdoctoral positions within the frame of **Inria London** are eligible.

The postdoc contract will have a duration of **12 to 24 months**. The default start date is November 1st, 2023 and not later than January, 1st 2024. The postdoctoral fellow will be recruited by one of the Inria Centers in France but it is recommended that the time is shared between France and the partner's country (please note that the postdoctoral fellow has to start his/her contract being in France and that the visits have to respect Inria rules for missions)

Candidates for postdoctoral positions are recruited after the end of their Ph.D. or after a first post-doctoral period: for the candidates who obtained their PhD in the Northern hemisphere, the date of the Ph.D. defense shall be later than 1 September 2021; in the Southern hemisphere, later than 1 April 2021.

In order to encourage mobility, the postdoctoral position must take place in a scientific environment that is truly different from the one of the Ph.D. (and, if applicable, from the position held since the Ph.D.); particular attention is thus paid to French or international candidates who obtained their doctorate abroad.

Assignment

The post-doc will be recruited within the Idefix Team at Inria Saclay, France and will work on a joint project between the Idefix Team and University College London, UK and Cardiff University, UK. The three supervisors are

1. *Jing-Rebecca Li, Research Scientist (DR2), Equipe IDEFIX, INRIA Saclay, UMA ENSTA Paris, France, li@inria.fr, https://perso.ensta-paris.fr/~jing-rebecca.li*
2. *Gary Zhang, Professor of Computational Imaging, Dept of Computer Science, Faculty of Engineering Science, University College London, United Kingdom, zhang@ucl.ac.uk, https://iris.ucl.ac.uk/iris/browse/profile?upi=HZHAN50*
3. *Marco Palombo, Associate Professor (Senior Lecturer), Cardiff University Brain Research Imaging Centre (CUBRIC), School of Psychology & School of Computer Science and Informatics. Cardiff University, United Kingdom, palombom@cardiff.ac.uk, https://www.cardiff.ac.uk/people/view/2571014-palombo-marco*

Main activities

MRI scanners can encode the diffusion of water protons into diffusion-weighted MRI (dMRI) signals at the resolution of around 1~mm^3 (the typical brain voxel size) by applying a time-varying magnetic field gradient. Because the movement of water protons is restricted by, for example, cell membranes, dMRI is sensitive to structures below the spatial resolution (i.e. micrometer scale) and brain voxels with varying microstructures generate different signals. Due to dMRI sensitivity to microstructure, non-invasive estimation of brain microstructure parameters, such as axon radii and neurite density, is an increasingly important area of research in the community. However, in vivo estimation is challenging due to the complex microstructure composition at the voxel scale and the intricate signal generation mechanism of dMRI.

Brain microstructure imaging often relies on ``inverting'' a forward model explaining the dMRI signal generation. Therefore, the accuracy of the forward model is of essential importance. The predominant forward models, i.e., biophysical models, typically subdivide a brain voxel into compartments described by simplified geometries such as cylinders with non-zero or zero radii (namely sticks) and spheres. Together with some additional assumptions, especially the Gaussian phase approximation (GPA), a biophysical model allows deriving an analytical signal expression as a function of the model parameters related to several microstructure parameters. A state-of-the-art biophysical model is the SANDI (Soma And Neurite Density Imaging) model [Palombo et al. NeuroImage 2020]: a compartment-based model for non-invasive apparent soma and neurite imaging by dMRI developed by the UCL and Cardiff teams. The teams have also recently pioneered machine learning-enabled parameter estimation techniques that will allow novel forward models based on numerical simulation [Gyori et al. MRM 2022 and Guerreri et al. IPMI 2023]

In the Inria team, the dMRI signal arising from neurons has been numerically simulated by solving the Bloch-Torrey partial differential equation. In the PhD of Chengran Fang ("Neuron modeling, Bloch-Torrey equation, and their application to brain microstructure imaging using diffusion MRI", Universite Paris-Saclay, 2023), high quality finite element meshes were produced for a set of 1,000 human neurons whose morphological descriptions were found in the publicly available neuron repository www.NeuroMorpho.Org. The eigenfunctions and the eigenvalues of the Laplace operators on the neuron geometries were numerically computed using P1 finite elements discretization. A preliminary statistical study on a small subset of neurons was performed to test some candidate biomarkers that can potentially indicate the soma size.

In this Postdoc project, we propose a systematic analysis of the connections between the dMRI signals and cell morphology by conducting statistical studies on a large number (around 50,000) of neurons and glial cells from different brain regions, using the Bloch-Torrey reference PDE model that accurately links the cell geometry to the dMRI signal. We will use machine learning algorithms to output selected cell morphological properties from the dMRI signals based on training and testing from the simulation dataset. Finally, we will propose a new biophysical model of cell morphological parameters that can improve the performance of SANDI and produce robust parameter maps for human imaging data. As usual, we will make resulting software and data available for public use (https://github.com/SpinDoctorMRI).

Below is a preliminary roadmap for the project.

1. *Expand the existing database of human neurons and glial cells (high quality finite elements meshes and their morphological properties);*
2. *Run and store the simulated dMRI signals under many different experimental conditions for the full set of neurons and glial cells, using the SpinDoctor Toolbox [Li et al. Neuroimage. 2019].*
3. *From the simulated dMRI signals, look for relationships between candidate biomarkers and certain morphological parameters.*
4. *Test, implement, and optimize machine learning algorithms that robustly output selected morphological properties from the dMRI signals [Gyori et al. MRM 2022].*
5. *Propose a new biophysical model based on the above results for morphological parameters map generation in human imaging data;*
6. *Compare new model to the existing model SANDI;*

Skills

Recent PhD in Applied Mathematics, Computer Science or Biomedical Engineering;

Programming skills in Matlab and Python;

Experience in mesh generation and machine learning;

Clear communication skills in speaking and writing;

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 : 2.746 Euros/month

General Information

- **Theme/Domain :** Numerical schemes and simulations
  Biologie et santé, Sciences de la vie et de la terre (BAP A)
- **Town/city :** Palaiseau
- **Inria Center :** Centre Inria de Saclay
- **Starting date :** 2023-11-01
- **Duration of contract :** 2 years
- **Deadline to apply :** 2023-08-31

Contacts

- **Inria Team :** IDEFIX
- **Recruiter :**
  Li-schlittgen Jing-rebecca / jing-rebecca.li@inria.fr

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.

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.

Instruction to apply

Defence Security :
This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST).Authorisation 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.