2018-00525 - [CORDIS2018-MATHNEURO]
Multi-scale mathematical modeling of Cortical Spreading Depression (CSD)

Contract type : Public service fixed-term contract
Level of qualifications required : Graduate degree or equivalent
Fonction : PhD Position

About the research centre or Inria department
The Inria Sophia Antipolis - Méditerranée center counts 37 research teams and 9 support departments. The center's staff (about 600 people including 400 Inria employees) is composed of scientists of different nationalities (250 foreigners of 50 nationalities), engineers, technicians and administrators. 1/3 of the staff are civil servants, the others are contractual. The majority of the research teams at the center are located in Sophia Antipolis and Nice in the Alpes-Maritimes. Six teams are based in Montpellier and a team is devoted to extend the model to a spatially-extended system taking the form of a slow-fast dynamical system. This will then enable a full timescale analysis of the model and its bifurcation structure. The second part of the PhD will be devoted to extend the model to a spatially-extended system taking the form of a slow-fast neural field model, where both a theoretical analysis and link with experimental data will be part of the work.

Context
The MathNeuro team at the Inria centre of Sophia Antipolis Méditerranée focuses on applications of multi-scale dynamics to neuroscience. This involves the modelling and analysis of systems with multiple time and space scales as well as stochastic effects. We look both at single-cell models, microcircuits and large networks. In terms of neuroscience, we are mainly interested in questions related to synaptic plasticity, neuronal excitability and memory. In particular, we focus our modelling efforts towards questions related to pathological states such as migraine and epileptic seizures, and neurodegenerative diseases such as Alzheimer.

The team evolves in a rich scientific environment with six permanent members, three postdocs, four phd students and one junior chair, as well as a large network of international collaborators regularly visiting us and giving talks. More infos on our team webpage here. The successful candidate will be given access to a wide range of computing facilities (laptop computer, an account on the local cluster) and will receive training from the supervisory team as well as from dedicated summer and winter schools that he/she will be encouraged to attend.

Assignment
Summary of the project. Cortical Spreading Depression (CSD) refers to a wave of depolarized electrical activity that is generated in specific brain regions and propagates through large parts of the cortex (see e.g. here). This is associated with pathophysiological processes that can be relevant to migraines or stroke. Our team for this project consists of three mathematicians/modelers and one experimental neurologist. We have already derived a model accounting for the initiation of CSD, following a biological hypothesis for which the experimentalist of the team has preliminary data. This is a micro-circuit composed of two neural populations (each of which is represented by one average neuron), one excitatory and one inhibitory. We also consider evolution equations for pump dynamics and slowly-varying ionic concentrations, which are known to play an important role in this ignition process. The successful candidate will have the task to investigate numerically the current model and derive a mathematical reduction under the form of a slow-fast dynamical system. This will then enable a full timescale analysis of the model and its bifurcation structure. The second part of the PhD will be devoted to extend the model to a spatially-extended system taking the form of a slow-fast neural field model, where both a theoretical analysis and link with experimental data will be part of the work.

Team. This PhD will be co-supervised by Mathieu Desroches (Inria Sophia Antipolis, mathneuro team, website) and Martin Krupa (UCA, JAD laboratory, website). The work will be done in close collaboration with electrophysiologist Massimo Mantegazza.

General Information
- Theme/Domain : Computational Neuroscience and Medicine
- Scientific computing (BAP E)
- Town/city : Sophia Antipolis
- Inria Center : CRI Sophia Antipolis - Méditerranée
- Starting date : 2018-09-01
- Duration of contract : 3 years
- Deadline to apply : 2018-04-15

Contacts
- Inria Team : MATHNEURO
- Recruiter : Desroches Mathieu / mathieu.desroches@inria.fr

The keys to success
Candidates should be motivated by a multi-disciplinary project involving applied mathematics (dynamical systems, bifurcation theory), scientific computing (numerical simulation, numerical continuation) and computational modeling at various temporal and spatial scales (microcircuits, networks, field models). Candidates should be interested in applying mathematical theories and techniques to a given biological problem, interact with a biologist and manipulate experimental data.

Conditions for application
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.

Warning : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted
The project will benefit from an interaction with our collaborator Daniele Avitabile from the University of Nottingham (UK).

**Main activities**
The main objectives of this PhD project are

1. to study computationally a network model based on our preliminary work (here),
2. to reduce the model to a minimal dynamical systems for a thorough bifurcation analysis,
3. to derive and study a multi-timescale neural field version of the model,
4. to compare both the local ODE model and the spatially-extended model with experimental data from the Mantegazza lab, in link with both healthy and pathological states, so as to further enlighten the mechanisms underpinning CSD in the case of certain forms of migraine.

**Skills**
Candidates should be familiar with dynamical systems theory: differential equations, equilibria, stability, limit cycles, invariant manifolds, etc.. Some notions of bifurcation theory are desirable but could be learnt during the early phase of the project. A background knowledge in neuronal modeling (conductance formalism) will be seen as very positive, as well as some notions of programming (e.g. in matlab, C++, python, julia, etc..). In any case, candidates should be interested in deepening their preliminary knowledge in all the above topics.

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

**Remuneration**
Duration: 36 months
Location: Sophia Antipolis, France
Gross Salary per month: 1982€ brut per month (year 1 & 2) and 2085€ brut/month (year 3)