2019-01446 - Post-Doctoral Research Visit F/M (BN19)
Non-invasive electrical imaging of the heart: regularization of the inverse problem by projection on the set of admissible data, and assuming time-smoothness

A propos du centre ou de la direction fonctionnelle
The team Carmen develops mathematical models and numerical methods in order to simulate the propagation of the cardiac action potential, from the cellular scale to the scale of the body. It is part of the IMU LIRYC, the electrophysiology and heart modeling institute in Bordeaux. It collaborates actively with the clinical, imaging, cellular electrophysiology, and signal processing groups within the LIRYC. Carmen aims at improving:

- our knowledge and the treatment of electrical cardiac pathologies;
- the exploitation of all available electrical signals.

The overall objectives of Carmen pertain both to the fields of numerical sciences, and to medical sciences through close collaborative research. The objectives in numerical sciences concern the progress to be made on data- and image-based modeling of cardiac electrophysiology, and model-based inverse problems and constructions of solutions in both medical and scientific fields in order to contribute to the objectives of LIRYC concerning atrial fibrillation, sudden cardiac death due to ventricular fibrillation, and heart failure. Software tools are important for the success of this research.

Contexte et atouts du poste
Scientific priorities:
Cardiovascular diseases are the first cause of mortality in the whole world accounting for 29% of deaths (750 000 deaths per year in Europe alone). The heart electrical dysfunction is the main reason behind cardiac diseases. Computational medicine is a priority in the strategic plan of Inria, which has been involved for years in modeling and simulation in life sciences and in particular in cardiac electrophysiology. This project aims at improving non-invasive electrical imaging of the heart, and finally providing innovative algorithms and methods in order to address real life clinical issues.

Scientific Research context:
Liryc is a research, treatment, innovation and teaching institute, wholly dedicated to the study, diagnosis and treatment of cardiac electrical disorders. These electrical disorders are responsible for various cardiovascular diseases and sudden deaths and cause, directly or indirectly, around one third of all deaths in the world. Understanding these complex pathologies requires a multidisciplinary approach. In regrouping a large number of national and international experts at the same center, the Liryc fully responds to these 21st century demands.

In this context, the team Carmen investigates mathematical and computational issues underlying this research, for instance the modeling of cardiac electrophysiology or the inverse problem associated to imaging the cardiac electrical signals. This inverse problem consists in reconstructing functional information on the heart from the geometry of the heart and torso, and electrical recordings on the torso. This highly ill-posed problem already has several practical solutions, though they allow only for limited, coarse reconstructions. As shown in our recent comparative study (Frontiers in Physiology, vol. 9 2018), based on our own experimental recordings on porcine hearts, there remain room for innovative methods providing cardiologists with more precise and reliable information.

The person recruited will be a member of the team Carmen and the Liryc Institute, and have access to all corresponding facilities, e.g. computing facilities, access to experimental data, pluridisciplinary interactions.

Mission confiée
The methodological research proposed for this postdoctoral project is twofold. Firstly, we would like to explore the method of projection on admissible data of Pr A. Fragaule Collar (Mathematical Modelling of Natural Phenomena 2010): the exact data, Dirichlet and Neumann boundary conditions on the torso should satisfy some compatibility conditions that are not explicitly known. Fragaule's method allows to project numerically the actual data on this set of compatible data, which increases the stability of the inverse problem. This approach may be combined with the theory of factorization of elliptic boundary value problems, developed by J. Henry and A. Ramos (J Henry, AM Ramos, ISTE 2016). This theory allows to derive the operator giving the estimate of the heart potential from the measurements at the continuous level. It allows to master the effects of the discretization and to compute off-line some heavy calculations (J Bouyssier & al, ISBI 2015).

Secondly, we plan to consider the time dependent problem, assuming some regularity in time. It has been shown that this problem may also be factorized in two evolution problems forward and backward. This allows for an additional regularization of the inverse problem. The method of projection will be applied also to this situation

Collaboration: the person recruited will be in connection in particular with N. Zemzemi and J. Henry who will be responsible for supervising his work.

Responsibilities: the person recruited will be responsible for developing her or his own, individual, research program based on the main research directions given by the supervisors.

Steering/Management: the person recruited will have to participate to the team activities. She or he

Informations générales
- Thème/Domaine : Modélisation et commande pour le vivant
- Ville : Talence
- Centre Inria : CR Bordeaux - Sud-Ouest
- Date de prise de fonction souhaitée : 2019-09-01
- Durée de contrat : 1 an
- Date limite pour postuler : 2019-03-31

Contacts
- Équipe Inria : CARMEN
- Recruteur : Zemzemi Nejib / nejib.zemzemi@inria.fr

A propos d’Inria
Inria, l’institut national de recherche dédié aux sciences du numérique, promeut l’excellence scientifique et le transfert pour avoir le plus grand impact. Il emploie 2400 personnes. Ses 200 équipes-projets agiles, en général communes avec des partenaires académiques, industriels et d’organisations non gouvernementales, travaillent sur plus de 3000 scientifiques pour relever les défis des sciences informatiques et mathématiques, souvent à l’interface d’autres disciplines. Inria travaille avec de nombreuses entreprises et a accompagné la création de plus de 160 start-up. L’institut s’efforce ainsi de répondre aux enjeux de la transformation numérique de la science, de la société et de l’économie.

L’essentiel pour réussir
References:

Keywords: inverse problem, scientific computing, mathematical models, cardiac electrophysiology.

Consignes pour postuler
Thank-you to send :
- CV
- Cover letter
- Support letters (mandatory)
- List of publication

Sécurité défense :
Ce poste est susceptible d’être affecté dans une zone à régime restrictif (ZRR), telle que définie dans le décret n°2011-1425 relatif à la protection du potentiel scientifique et technique de la nation (PPST). L’autorisation d’accès à une zone est délivrée par le chef
may participate to the teaching activities of the team, or be in charge of supervising master students.

Principales activités
Main activities (5 maximum):
- Summarize the state-of-the-art of the ECGI problem methods.
- Work with mathematicians, engineers, and clinicians on the identification of the suitable methods taking into account the mathematical complexity and the medical relevance.
- Formalize the mathematical problem of the ECGI taking into account the dynamic of the electrical wave.
- Write reports, papers.

Additional activities (3 maximum):
- Presenting the results obtained in local seminars and international conferences
- Participate to events for the popularization of Mathematics based on the work developed in the postdoc.

Compétences
The candidate should have a strong background in numerical methods for PDEs, numerical simulations, working on new numerical methods and good programming skills.
Knowledge/experience on the electrocardiography imaging problems will be appreciated.

Avantages
- Subsidized meals
- Partial reimbursement of public transport costs
- 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

Rémunération
2653€ / month (before taxs)