2018-00389 - PhD - Monte-Carlo techniques for solving the electrocardiographic imaging inverse problem

Level of qualifications required: Graduate degree or equivalent
Function: PhD Position

About the research centre or Inria department

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 IHU LIRYC, the electrophysiology and heart modeling institute in Bordeaux. It collaborates actively with the clinical, imaging, cellular electrophysiology, and signal processing groups within the LIYRC. 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 reconstruction or interpretation of electrical signals. The goal in medical sciences is to contribute to the objectives of LIYRC concerning atrial fibrillation, sudden cardiac death due to ventricular fibrillation, and heart failure. Software tools are important for the success of this research.

Context

Scientific priorities:

This project is in the framework of the third axis of Inria Bordeaux Sud-Ouest strategic plan: “Modélisation et simulation pour la santé et la biologie”. The aim of this project is to improve the performance and the accuracy of an electrocardiography device for clinical use.

Scientific research context:

The IHU LIRYC is a collaborative research center dedicated to the complete understanding of normal and abnormal cardiac electrical excitation. In this context, the team Carmen investigates the mathematical and computational issues underlying this research, from the modeling of cardiac electrophysiology to the inverse problems associated to the functional imaging of electrical excitation. This inverse problem consists in retrieving functional information on the heart from electrical measurements on the torso. The IHU LIYRC has many industrial partners, including the company Cardiolnsight. This company provides a vest with 250 electrodes and a commercial tool used to reconstruct intra-cardiac activation maps. The mathematical approach used in this commercial tool is still limited in many ways. For instance, a quasi-static problem is solved while the electrical propagation is highly unsteady, the repolarization signal cannot be identified. Models of cardiac electrophysiology, like those developed in our team, will provide significant improvements of this non-invasive imaging technique.

Assignment

Our main goal is to improve the current non-invasive electrocardiography imaging (ECGI) methodology. This would help cardiologist in better targeting cardiac arrhythmias, mainly atrial fibrillation and ventricular tachycardia. The mathematical problem behind this technology is represented by a Cauchy problem for the Laplace equation. This problem is known by its ill-posedness. The state-of-the-art approach to solve this problem is to minimize a least square functional with regularization term. The obtained solution is then unique. However, this solution would depend on the regularization parameter, the discretization approach, the choice of the least square functional to minimize, the regularization operator, ... etc. First, the Monte-Carlo algorithm would allow generating a family of solutions by varying all these parameters. Our aim is to extract the most probable statistical solution, which would be the one that minimizes the mean of the least square functional residuals of the different discretization approaches. Second, we will refine this solution using genetic algorithms by looking for a more accurate solution in a set centered on the statistical solution. A challenge will be to devise a genetic algorithm able to take into account the physical constraints of the model. In order to validate the algorithm, we will assess the accuracy of the developed approaches on three types of data: in silico simulated signals, in vitro experimental data from the IHU-LIRYC and in vivo real life patients data from the CHU. The experimental and clinical data are available for all the teams of the IHU-LIRYC.
Main activities

Keywords:
Scientific Computing, Inverse problems, Electrocardiography imaging, Statistical Optimization, Monte-Carlo algorithms

References:
- Mosegaard and M. Sambridge, Monte Carlo Analysis of inverse problems, Inverse Problems 18 (2002), R29-R54

Skills

Required knowledge and background
Major requirements: The candidate should have a strong background in scientific computing and/or statistical optimization
Minor requirements: Computational electrophysiology, finite element methods and optimization techniques

Benefits package
- Subsidised catering service
- Partially-reimbursed public transport

Remuneration
1982€ / month (before taxes) during the first 2 years, 2085€ / month (before taxes) during the third year.