**Authors of the research proposal**: Laura Bear, Rémi Dubois and Lisl Weynans

**Title of the research proposal**: Numerical methods for solving the electrocardiographic imaging inverse problem with structurally abnormal tissue.

**Scientific objectives:** The aim of this project is to improve the performance and the accuracy of the electrocardiographic imaging inverse problem to enable accurate reconstruction of cardiac electrical activity in the presence of structurally abnormal tissue.

**Scientific Background and State of the Art**

Ventricular tachy-arrhythmias are responsible for 80% of the 350 000 sudden cardiac deaths occurring each year in Europe. Most ventricular tachy-arrhythmias occur on a structurally diseased myocardium, and are therefore a fatal complication of chronic cardiac diseases. The mechanisms involved in the cardiac rhythmic disorders are still poorly understood. Thus, while efficient curative therapies exist these patients, such as catheter ablation for cardiac arrhythmia, or implantable defibrillators for patients at risk of sudden cardiac death, they are currently not effectively offered as patients are either incorrectly characterized or cannot be pre-emptively identified. Detailed characterization with the use of intra-cardiac catheters can be obtained with current methods, but such an invasive strategy is not applicable on a wide scale for the diagnosis, risk stratification or therapy guidance of these extremely prevalent diseases.

The inverse problem, also known as non-invasive electrocardiographic imaging (ECGI), has been proposed as a tool to overcome these limitation. This approach enables the non-invasive reconstruction of cardiac electrical activity from densely sampled electrical measurements on the torso using a mathematical model of the volume conductor between the heart and body surface. Unfortunately, while this approach has been shown to be highly efficient in mapping focal arrhythmias in structurally normal hearts, critical issues remain in heterogeneous hearts showing fibrotic scars. Large margins of improvements can be anticipated through a closer integration with imaging data, and the use of models of cardiac electrophysiology.

**Project Outline**

The primary object of this thesis is to improve current ECGI methods to enable the accurate reconstruction of cardiac electrical activity in the presence of fibrotic scar. The outcome of this thesis has applications towards the diagnosis/risk stratification and guidance of catheter ablation therapies for cardiac arrhythmias.

The development of ECGI methods will take place under the supervision of Lisl Weynans within the Scientific Computing Team at IMB and the Carmen Team at INRIA, which investigates mathematical and computational issues underlying cardiac clinical electrophysiology, from the modeling of cardiac electrophysiology to inverse problems associated with the functional imaging of electrical activity. The mathematical problem behind ECGI 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.

The validation of ECGI methods, and derivation of diagnostic and/or prognostic information from reconstructed electrophysiological data will take place under the supervision of Rémi Dubois and Laura Bear within the Signal Processing Team at the IHU LIRYC. The IHU LIRYC is a collaborative research center dedicated to the complete understanding of clinical cardiac electrophysiology and ablation therapy. The institute has state of the art facilities for conducting experimental research, including an ex-vivo torso tank experimental set up. The set up consists of a Langendorff-perfused heart suspended within a human torso-shaped tank filled with electrolytic solution, allowing easy intervention compared to an *in-vivo* setting. Simultaneous electrical mapping is performed from the heart (epicardial sock, transmural needles, endocardial arrays) and the tank surface (256 embedded electrodes). This allows not only the complete validation of ECGI methods and post-processing tools, but will help us to understand the mechanisms underlying cardiac arrhythmias associated with scar tissue. The IHU LIRYC also, holds close ties with the neighboring CHU (Hôpital Haut Lévêque), and with CardioInsight, a commercial enterprise with an ECGI mapping system used regularly at the Hospital. The accuracy of the developed approaches will be assessed on three types of data: *in-silico* simulated signals (INRIA), *ex-vivo* experimental data (IHU LIRYC) and *in-vivo* patient data (CHU).

**Required Knowledge and background**

Major requirements: The candidate should have a strong background in scientific computing or signal processing with the option of further training in the other.

Minor requirements: Computational electrophysiology, finite element methods, statistical optimization.

**Transverse training during PhD**

Depending of the background of the student, signal processing and/or statistical optimization , computational electrophysiology, finite element methods.

**Advisors:** Lisl Weynans, Rémi Dubois and Laura Bear.

**References**

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**Keywords:**

Scientific Computing, Inverse Problems , Electrocardiography Imaging, Statistical Optimization, Monte-Carlo Algorithms , Myocardial Infarction , Ventricular Arrhythmia

**Duration**: 3 years