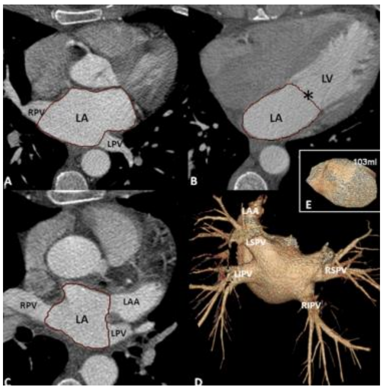
PhD Project Physiology-based Learning for Computational Cardiology

within *3IA Côte d’Azur Interdisciplinary Institute for Artificial Intelligence*

Clinical Context

Cardiac Arrhythmias are a major healthcare issue. For instance, atrial fibrillation (AF) is the most common cardiac arrhythmia, characterized by chaotic electrical activation of the atria, preventing synchronized contraction. More than 6 million Europeans suffer from it and age is the most powerful predictor of risk. Life-threatening complications and fast progression to persistent or permanent forms call for as early as possible diagnosis and effective treatment. Arrhythmias are often treated with anti-arrhythmic drugs, with limited efficacy and safety. Catheter ablation, an invasive procedure, is more effective. This procedure is by no means optimized, however, and arrhythmias may reoccur. The efficacy of first time ablation may range from 30%-75% depending on the individual patient and disease, such that multiple ablation procedures may be recommended.

It is critical to understand whether an ablation procedure is likely to benefit a particular patient, and whether the arrhythmia is likely to reoccur in this patient, to maximize positive patient outcomes and ensure judicious resource allocation in our healthcare systems. Currently, there are no decision support tools enabling clinicians to access integrated patient data together with predictive models to facilitate prognosis and treatment planning.



Position Description

AI and more precisely machine learning have obtained impressive results in several domains like vision, natural language processing, bioinformatics. However, this data intensive paradigm leads to model that often lack interpretability and robustness. Also it does not allow an easy integration of prior knowledge available in many scientific fields. This can explain its difficult adoption in domains like healthcare. On the other hand, biophysical modelling of the human body is a well-posed mathematical framework to introduce physiology into predictive analysis of clinical data. Moreover, it provides a natural mechanistic framework to interpret results. However, there is often a large computational cost, even more when the quantification of uncertainty has to be performed. And it is sometimes difficult to circumvent model approximations. A major scientific challenge today consists in combining the versatility of data intensive approaches with the physically grounded modelling approaches developed in scientific fields like biophysics.

The scientific objective of this project is then to combine the advantages of biophysics and machine learning, more specifically deep learning methods, and to develop hybrid models exploiting the complementarity of the two approaches. We propose to introduce physiological priors in learning systems through biophysical modelling by learning spatiotemporal dynamics from simulations and by introducing physically motivated constraints relative to these dynamics. The objective is to exploit optimally the large amounts of data available in this field together with well-known properties of biophysical cardiac dynamics. Besides, this would also enable us to propose a data-driven correction of biophysical models error. Finally, we will seek a principled integration of uncertainty quantification within this framework. This will encompass both uncertainty on the training data and in the prediction.

This project will be done in collaboration with cardiologists and radiologists to access clinical databases in order to evaluate the proposed methods on diagnosis, therapy planning and prognosis for cardiac pathologies.

Preliminary results on this topic were obtained through the initiation of a collaboration between Inria Epione team specialist of computational physiology and cardiology and Machine Learning and Information Access team LIP6, Sorbonne University, specialist of machine learning and deep learning. These results were presented at the *"Functional Imaging and Modelling of the Heart Conference"* and published within the Springer LNCS proceedings of the conference:
Ibrahim Ayed, Nicolas Cedilnik, Patrick Gallinari, Maxime Sermesant. EP-Net: Learning Cardiac Electrophysiology Models for Physiology-based Constraints in Data-Driven Predictions. In *Functional Imaging and Modeling of the Heart*, Bordeaux, France, June 2019. https://hal.inria.fr/hal-02106618

This PhD position will be at Inria, the French Institute for Research in Computer Science and Mathematics, in the Epione research team of the Inria Sophia Antipolis - Méditerranée Research Centre, located on the French Riviera. It will be co-supervised by Pr. Patrick Gallinari from the Machine Learning and Information Access team LIP6, Sorbonne University and done in collaboration with the IHU Liryc, Bordeaux University Hospital, a world leading centre in the treatment of cardiac arrhythmias.

Searched profile

- MSc Level in data science or applied mathematics
- Motivated by machine learning and mathematical modelling
- Eager to work in the medical field
- Good coding skills in Python
- Fluent in English (Reading, Writing, Speaking)

Remuneration: 3IA PhD thesis candidates will be remunerated 2 650 euros gross, which corresponds to a remuneration of approximately 2 150 euros net for the doctoral student.
Teaching obligation: the 3IA PhD scholarships are subject to a teaching obligation of 64 hours per year.

Send your resume and motivation letter:
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