Deep learning inference of cardiac arrhythmias

Duration: 6 months of Masters' internship **When**: Spring-Summer 2024
Where: *Tau* team (previously Tao), Inria Paris-Saclay.
Bits2beat, Startup emanating from Inria Bordeaux, 37 cours Clémenceau, Bordeaux.
Expected background: Master in computer science or statistical physics, machine learning.
Keywords: Inverse problem, deep learning, heart disease, model identification, disordered systems

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The increasing incidence of cardiovascular diseases constitutes a public health problem, due to their impact on vital prognosis and quality of life. Accident prevention through early detection and therapeutic monitoring must be done in a medical office or at home. It is today hampered by the lack of medical equipment, for acquiring cardiac signals, as well as interpretation experts. The abundance of smart devices promises to compensate for that, if algorithms make poor quality acquisition and automation of interpretation more reliable. Because of its ergonomy, the recording of rhythmic sequences is unavoidable.

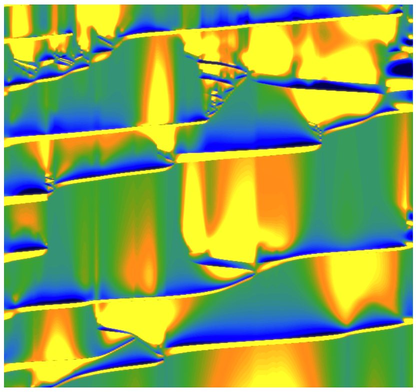

Figure 1: Space-time map of action potential current for the 1-D model of atrial fibrillation.

Rhythmic patterns have been shown to represent quite well some classes of health states and diseases, obviously arrhythmias but also the beat-to-beat variations of normal rhythm [1]. However, this knowledge is partial and lacks accuracy, especially when discriminating from noise.

In an effort to push forward our understanding of the heart beats sequences resulting from heart diseases and associated comorbidities, an important tool is the inference of models from rhythmic sequences. One may use gradually more complex models ranging from stochastic ordinary equations generating sequences of pulses to coupled partial differential equations hierarchically describing the dynamical systems from inside the heart up to the pulse beating response.
To achieve such complexity, an inverse problem has to be solved for inferring the inner electrical activity of the heart (at least its class) from the pulse beat-to-beat sequences.

This internship will focus on developing and implementing deep learning tools for model discovery of the heart dynamics in different regimes including atrial fibrillation, the most common and less understood arrhythmia. Inspiration from optimal control and reinforcement learning [2] could lead to important new insights for rate and rhythm control therapeutic strategies. Ground truth electrical measurements on the chest and inside the heart, as well as numerical simulations [3], will be available as supporting data.

References

[1] Ivanov P., Amaral L., Goldberger A. *et al.*, Multifractality in human heartbeat dynamics, *Nature*, **399**, p. 461–465, 1999.
[2] Bucci M.A., Semeraro O., Allauzen A., Wisniewski G., Cordier L. & Mathelin L., Control of chaotic systems by deep reinforcement learning, *Proceedings of the Royal Society A*, **475**, 2019.
[3] Attuel G., Gerasimova-Chechkina E., Argoul F., Yahia H. & Arneodo A., Multifractal Desynchronization of the Cardiac Excitable Cell Network During Atrial Fibrillation. II. Modeling, *Frontiers in Physiology*, **10**, 2019.