

Ph.D. research topic

- Title of the proposed topic: **“Multimodal machine learning for patient-tailored catheter ablation of persistent atrial fibrillation”**
 - Research axis of the 3iA: IA for integrative computational medicine
 - Supervisor (name, affiliation, email): Vicente Zarzoso
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 - Potential co-supervisor (name, affiliation):
 - The laboratory and/or research group: Signals, Images, Systems (SIS) Team, I3S Lab.
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Apply by sending an email directly to the supervisor.

The application will include:

- Letter of recommendation of the supervisor indicated above
 - Curriculum vitæ.
 - Motivation Letter.
 - Academic transcripts of a master's degree(s) or equivalent.
 - At least, one letter of recommendation.
 - Internship report, if possible.
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- Description of the topic:

Background

Atrial fibrillation (AF) is the most common sustained arrhythmia encountered in clinical practice, especially affecting the elderly and held responsible of up to 25% of strokes. With the ageing of the Western population, this arrhythmia is becoming a major public health concern taking epidemic proportions: between 6 and 12 million people will be affected in the USA in 2050, and up to 18 million in Europe in 2060 [MOR17]. AF is indeed "the last great frontier of cardiac electrophysiology" as it continues to puzzle cardiologists [JAN14]. Physiological signal analysis and machine learning arise a key tools to improve the understanding and management of this challenging cardiac condition. Despite its cost and risk of complications, catheter ablation is currently the most attractive therapeutic option in terms of long-term recurrence rate for the treatment of persistent AF. However, this therapy depends heavily on the practitioner's subjectivity, with rather variable protocols and success rates reported by different centers. The development of robust, widely accepted intervention protocols remains an open challenge.

Medical diagnosis and decision support in radiology, dermatology, ophthalmology and cancer detection, among others, are application areas where deep networks have already proven their interest [CHI18]. The use of deep learning techniques in cardiology has been relatively less explored. Automatic

classification techniques based on deep learning could help cardiologists to perform ablation in an efficient, cost-effective manner, increasing its chances of long-term success while reducing its limitations.

Goals

The present thesis aims at developing new machine learning techniques to aid the cardiologist in the catheter ablation therapy by means of a multimodal approach taking into account both invasive and noninvasive recordings. The project will have the following specific goals and proposed methodology:

- *Novel quantitative measures of AF complexity:* Despite the growing interest in noninvasive tools such as the electrocardiogram (ECG) to assess the complexity of persistent AF due to their simplicity and cost-effectiveness, their use in the characterization of the ablation therapy remains rather limited [MEO18]. To fill this gap, this part of the thesis aims to exploit deep learning techniques to identify the features of the surface signal that evolve significantly during the intervention, thereby reflecting the evolution of the atrial substrate during catheter ablation procedures and pointing the atrial zones where ablation shots are likely to be most effective to terminate the arrhythmia.
- *Exploiting data multimodality:* Different data modalities, including invasive (intracardiac electrograms, electroanatomic maps) and noninvasive (ECG, echocardiography), are acquired in the management of persistent AF patients. This part of the project will explore suitable data processing and machine learning techniques for exploiting multimodality in a robust manner in order to better characterize this cardiac disorder and adapt the catheter ablation therapy to each patient.
- *Robust detection of ablation zones:* Capitalizing on the results obtained in the previous parts of the thesis, the project will aim at automatically detecting the most suitable tissue areas for successful AF ablation. Emphasis will be laid on the recent ablation protocol developed at Nice University Hospital (CHU) using multi-spline catheters [SEI17]. Promising initial results based on intracardiac electrograms have recently been reported in [GHR20].

This multidisciplinary thesis is expected to take a significant step forward towards a patient-tailored management of persistent AF, helping to improve the success rate of catheter ablation while reducing its duration, cost and risks of complications.

Collaborations

This interdisciplinary thesis will be carried out in close collaboration with cardiologists from Nice CHU and industrial partners.

Pre-requisites

Prospective candidates must hold a MSc diploma or equivalent in data science, signal processing, applied mathematics or biomedical engineering, and will require a strong background in theoretical as well as computational aspects of machine learning, statistics and signal processing. Previous experience with biomedical signals and familiarity with cardiac electrophysiology will also be interesting assets.

Bibliography

[CHI18] T. Ching, D. S. Himmelstein, B. K. Beaulieu-Jones, A. A. Kalinin, B. T. Do, *et al.*, "[Opportunities and obstacles for deep learning in biology and medicine](#)", *Journal of the Royal Society Interface*, vol. 15, no. 141, 2018.

[GHR20] A. Ghrissi, D. Almonfrey, R. C. de Almeida, F. Squara, J. Montagnat and V. Zarzoso, "[Data augmentation for automatic identification of spatiotemporal dispersion electrograms in persistent atrial fibrillation ablation using machine learning](#)", in: *Proc. EMBC-2020, 42nd Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Montreal, Canada, July 20-24, 2020.

[JAN14] C. T. January, L. S. Wann, J. S. Alpert, *et al.*, "[2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: A report of the American College of Cardiology/American Heart Association Task Force on practice guidelines and the Heart Rhythm Society](#)", *Circulation*, vol. 64, no. 21, pp. 2246-2280, Dec. 2014.

[MEO18] M. Meo, T. Pambrun, N. Derval, C. Dumas-Pomier, S. Puyo *et al.*, "[Noninvasive assessment of atrial fibrillation complexity in relation to ablation characteristics and outcome](#)", *Frontiers in Physiology*, vol. 9, Jul. 2018.

[MOR17] C. A. Morillo, A. Banerjee, P. Perel, D. Wood, and X. Jouven, "[Atrial fibrillation: the current epidemic](#)", *Journal of Geriatric Cardiology*, vol. 14, no. 3, pp. 195–203, Mar. 2017.

[SEI17] J. Seitz, C. Bars, G. Théodore, S. Beurtheret, N. Lellouche, *et al.*, "[AF ablation guided by spatiotemporal electrogram dispersion without pulmonary vein isolation. A wholly patient-tailored approach](#)", *Journal of the American College of Cardiology*, vol. 69, no. 3, pp. 303–321, Jan. 2017.