PhD position open for recruitment in Creatis, Lyon, France

Application. Send to philippe.delachartre@insa-lyon.fr your resume, a cover letter stating your interests and goals, and contacts of two references, preferably including your MSc project supervisor.

Title: Weakly-supervised learning for emboli characterization with Transcranial Doppler (TCD) monitoring

Work place: Creatis research unit, INSA Lyon (https://www.creatis.insa-lyon.fr/site7/en)

PhD thesis supervisor: Pr. Philippe Delachartre (Creatis, Lyon)
Supervising board: Maciej Orkisz (Creatis, Lyon), Kevin Guepié (LM2S, Troyes)
Partners: Atys Medical company, hospitals in Lyon, Lille and Bordeaux

Context

The detection of emboli is a major topic as regards prevention of stroke. The cause of a stroke can be multiple, but in most cases, a Doppler monitoring (figure 1) of the middle cerebral artery (MCA) can help diagnosis and prevent stroke risk. The classification of emboli is essential to improve the reliability of diagnosis.

For more than 20 years, Atys Medical has been developing Doppler monitoring systems that can detect HITS (High Intensity Transient Signal) and classify them as emboli or artifacts (probe movement, eye blinking, voice artifact, etc...).

Atys latest device - unique in the world - is a Holter (figure 2) equipped with robotized probes (***TCD-X***), allowing long monitoring session, on ambulatory patients, thanks to automatic probe adjustments all along recording to assure optimal signal maintain.

One major topic to help doctors identify the cause of stroke is to focus on the nature of the emboli. During cardiac surgery or in stroke units, knowing that emboli is solid or gaseous may give essential clues to the doctor to better take in charge their patients. Also more precise information on the origin of emboli might be helpful.

The main aim of this project is to extract specific features for each emboli - based on a set of labeled and unlabeled Doppler archive- and use deep learning to classify events in an efficient way to give more accurate diagnosis and optimize time for data analysis.

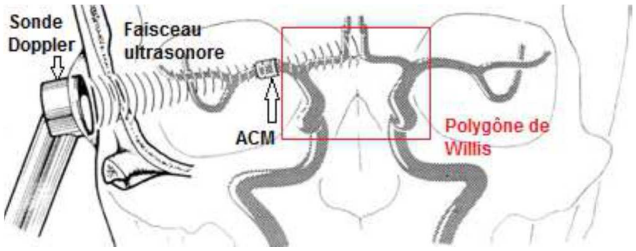

Figure 1. MCA.

Figure 2. Holter TCDx.

Key words: statistical machine and deep learning, unsupervised and weakly-supervised learning, Bayesian framework

Aim of the thesis

The goal of this PhD project is to develop methods and tools, to validate new research concepts in the aim to integrate value-added algorithms in Atys devices.

The aim of the thesis is twofold:

Characterization of emboli

(i) Develop and apply the suitable deep learning algorithm to extract specific features from all available ways to analyze Doppler signal (spectrum, audiogram, M-Mode) and identify the more relevant representation mode to apply deep learning

(ii) Identify features sufficient to find emboli cause or nature, by correlating this feature with patient pathology or treatment

Classification of emboli

(iii) Develop and apply the suitable deep learning algorithm to discriminate solid from gaseous emboli,

(iv) Extend algorithm to HITS found always at same position in cardiac cycle, especially on young patient

Scientific challenges

On one hand, the small amount of labelled data and the uncertainty on the labels (intra and inter expert variability) make the task of characterization and classification particularly difficult. On the other hand, acquisition and processing of Doppler and brain ultrasound data stills are challenging due to the speckle nature of ultrasound, a limited field of view and the outpatient monitoring. Therefore, finding solutions for data processing present major challenges in transcranial ultrasound.

Expected original contributions

In this project, an original method of combining time information (complex Doppler signal) with spatial information (sonogram and M-mod) is expected to optimize the computer-aided diagnosis system. Thanks to these challenging topics, we expect to produce new efficient algorithms for emboli discrimination, identification of new patterns with the aim to give more information to doctors as regards the nature of emboli and the cause of stroke. We expect to improve the estimation of Doppler angle and consequently provide more precise blood flow velocities.

Research Program

This thesis proposal is structured around three different axes:

- Design and apply of deep learning algorithm in a Bayesian framework to discrimination emboli, selection of neural network inputs
  The constraints to be taken into account are the followings: the small size of the database, the difficulty for an expert to define a precise boundary between classes and the evolution of the number of classes

as and when knowledge is improved. We propose the implementation of unsupervised and weakly supervised methods to facilitate the work of labelling, by predicting the belonging of an embolic event to a super class, then a more and more precise class as the PhD thesis work progresses.
Combination of several networks are envisaged for emboli classification: recurrent networks directly using Doppler signal information and convolutional networks using spectrogram images for different device settings which correspond to several resolution scales. In all cases it will be desirable to introduce a score at the input of the network, reflecting the expert's confidence in the assignment of an embolic event to a class. The Bayesian framework will help us to detect out-of-distribution samples and to implement selective classification techniques, i.e., with reject option.

- Validation on new archive
  The neural network will be developed using a fixed archive dataset already existing.
  So as to validate neural network algorithm, we propose to apply the emboli detection algorithm on a new archive dataset for both types of emboli:
    - Gaseous emboli archive may be generated using a Doppler phantom in which bubbles are still remaining in the blood flow
    - Solid emboli may be retrieved from running clinical studies on carotid stenosis.

- Integration in Atys device
  The main goal of this thesis is to integrate relevant research improvements on emboli detection into Atys device to give a real value-added, responding to physician's needs.
  So as to do that, time should be reserved at the end of thesis to transfer the algorithm validated with research tools into algorithms directly usable in Atys TCD devices (Qt projects). Input/outputs should be clearly identified at the beginning of the development to save time for integration. Performance and usability criteria should be taken into account.

Scientific supervision

The PhD student will be supervised by Philippe Delachartre (Prof, INSA Lyon) and Marilys Almar (Ingénieure, Atys Medical). The PhD student will benefit from the expertise of:

- Philippe Delachartre in image and signal processing, machine and deep learning at CREATIS
- Maciej ORKISZ … reconstruction algorithm
- Kevin GUEPIE … machine learning, statistical analysis, signal processing
- Marilys ALMAR in TCD/emboli knowledge and ATYS device functionalities
- All partners in medical field (as referred below) for clinical knowledge

Use of research results

The results of this project will be presented at top machine learning and medical imaging venues as well as at the dedicated workshops concerning their intersections. The extended experimental evaluations will be submitted to top peer machine learning and medical imaging journals. On the other hand, the developed algorithms will be implemented and made available on dedicated software to be developed allowing users to perform their own clinical research using the algorithms on the collected data sets or on their own database.
We expect these new methods to have a strong impact on the work of the scientists involved from the medical imaging community to analyze different kinds of ultrasound data they routinely

acquire and that is clearly in demand for quantitative results of emboli data set and help for diagnosis.

Pre-requisite qualifications of the applicant

A successful candidate will have strong knowledge in the following fields:
Signal and image processing, statistical learning (machine/deep learning), applied mathematics.
Programming skills: Python, deep learning libraries (tensorflow and/or Pytorch), Qt, C++.

Skills developed by the successful candidate during the PhD project

The successful candidate will develop strong skills in statistical machine learning, medical imaging analysis and their applications. Due to the theoretical and applicational aspects of this proposal, the successful PhD student will be able to join research departments in both industry and academia.

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