Offer #2024-07729

PhD Position F/M Signal processing based on the squared eigenfunctions of the Schrodinger operator: Mathematical analysis and application to the identification of Vulnerable Carotid Plaques using CT Scans

Contract type : Fixed-term contract

Level of qualifications required : Graduate degree or equivalent

Fonction : PhD Position

About the research centre or Inria department

The Inria Saclay-Île-de-France Research Centre was established in 2008. It has developed as part of the Saclay site in partnership with **Paris-Saclay University** and with the **Institut Polytechnique de Paris** .

The centre has **40 project teams**, 32 of which operate jointly with Paris-Saclay University and the Institut Polytechnique de Paris; Its activities occupy over 600 people, scientists and research and innovation support staff, including 44 different nationalities.

Assignment

Biomedical signals are usually characterized by the presence of peaks that provide direct or indirect information on the physiological and metabolic state. Usually, these pulse-shaped signals require preprocessing such as denoising and artifact removals. Further analysis and processing might be required in some specific situations to allow for the extraction of pertinent information from these signals. Despite the fact that the literature abounds with signal processing methods, there are still challenges that need to be overcome and further improvements can be achieved for processing pulse-shaped signals. In this context, a quantum-based signal processing method has been proposed in 1. This method called the semi-classical signal analysis (SCSA) method decomposes the signal into a set of functions given by the squared eigenfunctions of the Schrödinger operator associated to its negative eigenvalues 1. Thus, and unlike traditional signal decomposition tools, the SCSA expresses the signal through a set of functions that are signal dependent, that is, these functions are not fixed and known in advance but are computed by solving the spectral problem of the Schrödinger operator whose potential is the signal to be analyzed. Accordingly, these eigenfunctions capture more details about the signal and its morphological variations 2. The SCSA has been successfully applied in many applications for signal representation, denoising, post-processing, and feature extraction. For example, it has been used for arterial blood pressure waveform analysis in 3,4 and for magnetic resonance spectroscopy (MRS) denoising 5, for MRS water suppression 6, and for MRS lipid suppression 7. It has been also used for feature extraction in epileptic seizure detection 8 and for the characterization of PPG signals and blood pressure signals for non-invasive estimation of central pressure and arterial stiffness respectively 9. Additionally, SCSA has been extended to the 2D case for image representation and denoising 11, and more recently for image contrast enhancement.

Main activities

The objective of this research project is to study the mathematical properties of the SCSA and compare the approach qualitatively and quantitatively to state-of-the-art methods such as Wavelets and empirical model decomposition methods. A parallel between quantum and signal processing properties will be studied. Numerical properties of the algorithm will be analyzed, with a focus on the optimization of the current codes especially in 2D, which relies on an eigenvalues solver.
In addition, the student will investigate the use of the 2D-SCSA for the characterization of CT scans intending to identify vulnerable carotid plaques for asymptomatic patients. The main advantage of this method is the inherent capacity of the SCSA to filter noisy data and increase the contrast of images at the same time 11. This creates a great interest in the method since it could be potentially used as a feature extraction method that can adapt to different noise levels or contrast conditions and as a pre-processing step for deep learning methods.

For this project, we will have access to a large histopathological image collection as well as to a large amount of CT-scanner obtained with the collaboration of Dr. Jean-Michel Davaine, a vascular surgeon at AP-HP, CHU Pitié- Salpêtrière.

References:
1 Laleg et al. "Semi-classical signal analysis". MCSS Journal, Vol. 25, Issue 1, pp. 37–61, 2013.

2 P. Li et al. "Signal denoising based on the Schrodinger operator's eigenspectrum and a curvature constraint", IET Signal Processing, Vol. 15 NO. 3, 195–206, 2021
3 T.M. Laleg-Kirati, et al. "Validation of a semi-classical signal analysis method for stroke volume variation assessment: a comparison with the PiCCO technique". Annals of Biomedical Engineering, vol. 38(12), pp. 3618–3629, 2010.
4 T.M. Laleg, et al., "Arterial Blood Pressure Analysis Based on Scattering Transform II". IEEE EMBC, August 2007.
5 Laleg et al. "Spectral data de-noising using Semi Classical Signal Analysis method: Application to Localized Magnetic Resonance Spectroscopy". NMR in Biomedecine Journal, 2016.
6 A. Chahid, et al. "MRS Residual Water Suppression using the Squared Eigenfunctions of the Schrodinger Operator ", IEEE Access, 2019,
7 M. Gomez Castillo, et al. "A Novel Method for Magnetic Resonance Spectroscopy Lipid Signal Suppression Using Semi-Classical Signal Analysis and Bidirectional Long Short-Term Memory" (EMBC), 2022.
8 A. Chahid, et al. "Feature Generation and Dimensionality Reduction using the Discrete Spectrum of the Schrodinger Operator for Epileptic Spikes Detection", EMBC, 2019.
9 P. Li, et al. "Central Blood Pressure Estimation from Distal PPG Measurement using semiclassical signal analysis features", IEEE Access,2021
10 Z. Kaisserli, et al. "Image reconstruction using squared eigenfunctions of the Schrodinger operator". DSP Journal, pp. 80–87, 2015.
11J. Vargas, "Brain MRI contrast enhancement based on the schrodinger spectruspectrum,

Skills

Signal/image processing with interest in biomedical applications and Machine learning

Benefits package

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

Remuneration

Gross salary 2.100 euros/mois

General Information

- **Town/city :** GIF SUR YVETTE
- **Inria Center :** Centre Inria de Saclay
- **Starting date :** 2024-10-01
- **Duration of contract :** 3 years
- **Deadline to apply :** 2024-09-30

Contacts

- **Inria Team :** AT-SAC
- **PhD Supervisor :**
  Laleg Kirati Taous / Taous-Meriem.Laleg@inria.fr

About Inria

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

Warning : you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.

Instruction to apply

Defence Security :

This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST).Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

Recruitment Policy :
As part of its diversity policy, all Inria positions are accessible to people with disabilities.