2018-00578 - [CORDIS2018-EPIONE] PhD: Statistical Dimension Reduction in Non-Linear Manifolds for Brain Shape Analysis, Connectomics & Brain-Computer Interfaces

Level of qualifications required: Graduate degree or equivalent
Fonction: PhD Position

About the research centre or Inria department

The Inria Sophia Antipolis - Méditerranée center counts 37 research teams and 9 support departments. The center's staff (about 600 people including 400 Inria employees) is composed of scientists of different nationalities (250 foreigners of 50 nationalities), engineers, technicians and administrators. 1/3 of the staff are civil servants, the others are contractual. The majority of the research teams at the center are located in Sophia Antipolis and Nice in the Alpes-Maritimes. Six teams are based in Montpellier and a team is hosted by the computer science department of the University of Bologna in Italy. The Center is a member of the University and Institution Community (ComUE) "Université Côte d'Azur (UCA)."

Context

The PhD will take place in the Epione team at the Inria centre of Sophia Antipolis Méditerranée, in collaboration with other teams at Inria Sophia and at Inria Saclay. The Epione team aims at contributing to the development of what we call the e-patient (digital patient) for e-medicine (digital medicine). The e-patient (or digital patient) is a set of computational models of the human body able to describe and simulate the anatomy and the physiology of the patient's organs and tissues, at various scales, for an individual or a population.

In computational anatomy as in many other applications, data belong to non-linear sub-manifolds of a high dimensional space. The natural invariance properties of the space in which the data live often encode informative priors that turn out to be key features to improve the results of analyses. This is the case in Computational Anatomy (CA), Brain Computer Interfaces (BCI) and Brain Connectomics where data naturally belong to shape spaces, Lie groups and symmetric positive definite matrices. Since these data live in very high dimension, (this could even be infinite dimensional spaces for diffeomorphisms), any correlation analysis or interpretation requires first reducing the dimension of the space. However, a difficulty is not to lose the original structure, i.e. to find a submanifold in a manifold. Moreover, the assumption that data live in a submanifold of fixed dimension is often too strong: we rather aim at finding a consistent series of nested subspaces that better and better approximate the original data. This is a significantly harder problem than classical manifold learning in Euclidean or Hilbert spaces.

Assignment

The research approach investigated in this PhD will explore the power of the concept of sequences of properly nested affine subspaces (flags) in manifolds. In linear spaces, such sequences belong to flag manifolds and it has been shown that Principal Component Analysis can be rephrased as the optimization of the accumulated unexplained variance criterion in that space (Pennec 2016). The generalization to flags of affine subspaces of Riemannian manifolds, called barycentric subspace analysis, is raising an increasing interest in the geometric statistics community. Exploring other criteria on flags spaces will certainly allow more robust and more adaptive subspace approximation algorithms that will provide novel strategies for big data analysis. In order to demonstrate the generality of the methods, this PhD will investigate three applications of this framework to the brain. First, we expect to improve the statistical modelling of the variability of the anatomical shape (computational anatomy) of the brain; Second, anatomical and functional connectivity properties coming from diffusion or functional MRI are often encoded through symmetric positive definite (SPD) matrices. Here, the use of principled methods respecting the natural structure of that space should improve the consistency current results in brain connectomics. Thirdly, the natural structure of SPD matrices was also shown to enhance the classification of mental tasks from EEG signals for brain-computer interfaces (BCI). Consistent and hierarchical dimension reduction methods are likely to bring further improvements.

Main activities
Skills
Technical skills and level required: Candidates should have a good knowledge of differential geometry and statistics and be familiar with medical signal and image processing. Other valued appreciated: Machine learning, optimization, programming in python.

Languages: French and/or English

Benefits package
- Subsidised catering service
- Partially-reimbursed public transport
- Social security
- Paid leave
- Flexible working hours
- Sports facilities

Remuneration
Duration: 36 months
Location: Sophia Antipolis, France
Gross Salary per month: 1982€ brut per month (year 1 & 2) and 2085€ brut/month (year 3)