Sophia Antipolis, le 7 mars 2018

Internship proposal:

Inverse problems in electroencephalography (EEG), treatment of time independent topographies for dipolar sources estimation.

Location INRIA Sophia Antipolis Méditerranée.
Expected duration: 5-6 months.

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Electroencephalography (EEG) is one of the non invasive imaging techniques used in medical engineering for functional or clinical brain exploration. Electrical currents occurring in the brain produce an electrical potential which is recorded at a finite number of pointwise electrodes located on the scalp. From these measures, we approach the inverse problem of localizing in the brain the primary currents (sources) which have produced the records [2]. A dedicated software FindSources3D (http://www-sop.inria.fr/apics/FindSources3D) is currently being developed at INRIA that solves the inverse EEG problem spherical head models and for pointwise dipolar brain sources. It runs two main consecutive steps:

1. EEG records are the superposition of several main time independent activities that first have to be properly separated.

2. Next, each independent time activity (topography) can be seen as a static vector modulated by a time dependant signal. This static vector can be explained as the potential produced at the electrodes locations by one or several pointwise dipolar sources.

Step 1 is relevant of MUltiple SIgnal Classification (MUSIC) techniques. Step 2 is a time harmonic potential inverse problem.

The aim of the internship is to develop the step 1.

Multi-channels sampled EEG records are stored in a data matrix. Classification relies on approximate factorization of this matrix, the approximate rank being the number of activities we are looking for. This is classically done using singular values decompositions (SVD). Linear combinations between these activities are then searched in a finite dimensional subspace. Methods may differ on the way to explore this subspace. The way we want to proceed is to look for the linear

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combinations that minimize the error between the potential generated on the scalp by the associated localized sources and the available EEG measurements. Indeed, from a given static vector, FindSources3D is able to perform dipolar source estimation (solutions to problem 2), for spherical layered models of heads [1]. This can be viewed as a change of basis performed on the static part of the SVD. At present step 1 is solved by dipole fitting, and this may not be optimal as a single activity may be caused by several dipolar sources. During the internship, a bibliographical study will be pursued concerning principal components analysis techniques and algorithms of MUSIC type [3].

Algorithmical and numerical aspects of the change of basis described above will be studied, while computational developments should be added to the software FindSources3D. The obtained results should be compared with those obtained by more classical combinations of the time independant components. Observe that a similar protocol can be used for magnetoencephalography (MEG) recordings, which may also be considered, if time allows. Note that quite many softwares and databases are available on the internet such as anywave, eeglab, fieldtrip , brainstorm, and others. They provide free access to some well tested tools for data manipulation and filtering, independant component analysis, and dipole fitting.

Co-advisement: Centre de Mathématiques Appliquées, Mines ParisTech, Athena INRIA team (Sophia Antipolis), Institut Neurosciences de la Timone (INT, Marseille).

Candidate profile

- Second year of Master degree or Engineers School (PFE).
- Strong background in applied mathematics.
- Good knowledge of physics, algorithms and numerical analysis,
- Involvement in numerical simulation (Matlab) and in applications.

Bibliographical references

[1] M. Clerc, J. Leblond, J.-P. Marmorat, T. Papadopoulo, Source localization using rational approximation on plane sections. Inverse Problems, 28(5):055018, 2012
[2] O. Faugeras, et al., The inverse EEG and MEG problems: the adjoint state approach; I: continuous case, INRIA Research Report 3673, 1999.
[3] J. C. Mosher, R. M. Leahy, Recursive MUSIC: A Framework for EEG and MEG Source Localization. IEEE Trans. Biomedical Engineering, 45(11), 1998.