Machine Learning for electroencephalography data analysis

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Abstract:
This thesis proposal has two main objectives, both related to EEG data analysis.
The firs one is to propose a method to jointly handle two specific problems in EEG data analysis: source localization and temporal analysis. These two problems are usually solved independently depending on the target application and analysis strategy. A deep learning-based method will be proposed.
The second objective is to propose a deep learning method to jointly analyze EEG data with other modalities such as ECG, and this for drowsiness detection. Indeed, when biomedical signals are considered, drowsiness is generally analyzed using a single modality. Combining different modalities raises specific problems mainly related to incoherence in temporal and spatial resolution. The target method will account for this specificity.

Thesis proposal:

This thesis proposal aims to study the problem of analyzing electroencephalography (EEG) signals, for various applications such as epilepsy [1,2] or drowsiness [3].
Indeed, reading and analyzing an EEG recording is a complicated task for doctors, because of the complexity of the signals and the large volume of data recorded for a single subject: number of electrodes (spatial dimension) and recording time (time dimension). The scientific community has worked for several years on the development of automatic tools to process and analyze these signals. Several techniques have been proposed in the literature, generally based on analytical models [4,5].
More recently, exploratory works based on machine learning have been proposed for applications such as epilepsy [6,7,8] or drowsiness [9,10]. These works made it possible to test the performance of existing techniques for analyzing EEG signals in the time domain.

In this thesis, we propose to first handle the problem of source localization with sparsity constraints. It has already been shown that sparse localization of sources improves signal analysis, and therefore allows better diagnosis for diseases such as epilepsy [2].
We will tackle here the resolution of this specific ill-posed inverse problem using spatio-temporal data, by proposing an approach based on deep learning. The method to be proposed will include an architecture capable of taking into account the sparsity constraints at the level of the target sources. This sparsity will be formulated simultaneously according to the spatial and temporal dimensions.
Secondly, we plan to develop an approach to perform joint analysis the temporal signal (classify time windows to detect an epileptic seizure, for example) with source localization.

For doing so, a hybrid architecture will be proposed to combine the two above-mentioned problems which are usually solved independently. Particular attention will be paid to the optimization problem implemented for network learning.
This first research avenue combines therefore methodological research (resolution of source localization jointly with temporal signals analysis) with applied one linked to the analysis of EEG signals for diagnostic aid.

The second goal will be drowsiness detection for subjects under control (drivers,…). A number of studies have already addressed the problem by analyzing temporal EEG signals [11].
We propose here to develop a method allowing joint analysis of EEG with other physiological signals such as electrocardiography (ECG). We propose here to develop a method allowing to combine EEG with other physiological signals such as electrocardiography (ECG). Indeed, combining other modalities with EEG may improve the characterization of the physiological state of subjects under control. An appropriate architecture will therefore be proposed, accounting for potential temporal and spatial resolution differences. Given that some drowsiness-related applications require implementation on an embedded terminal, particular attention will be paid to the computational complexity of the proposed method, especially during the test phase.

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