

Multivariate synchrosqueezing: Application to the analysis of EEG and ECG signals

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PhD Thesis : yes

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1 Basics on time-frequency analysis and synchrosqueezing

Time-frequency analysis is widely used to localize in time the frequency information contained in a signal. The most commonly used time-frequency representations are the short-time Fourier and the wavelet transforms. Unfortunately, the filtering processes associated with these transforms smear the information in the time-frequency (TF) plane. A technique to reassign and sharpen the representation in the TF plane has been developed, and is known as *synchrosqueezing* [1]. The reassignment is performed, with such a technique, in a way that the synchrosqueezed representation is invertible.

This transform is of particular interest when one wants to retrieve the modes of multicomponent signals, which can be viewed as the superimposition of AM/FM (amplitude and frequency modulated) modes. This type of signals are ubiquitous in audio, biomedical or biological (mammals echolocation for instance) applications, for instance. From a mathematical point of view, it was initially shown that when the modes are slightly modulated these can be retrieved with little error [1], and more recent works showed that this could be generalized to a wider class of modes [2].

The extension to multivariate signals where the data are associated with recordings corresponding to the same information but slightly varying, typically like in ECG or EEG recordings related to the same patient, has recently been introduced in [3]. A recent application of such a new transform to the study of emotional states has shown promising results available in [4]. In a nutshell, the idea that withstands the multivariate synchrosqueezing technique is a new definition of mode which is viewed as a common oscillation that better fits the different channels, e.g. the different EEG recordings. In the case of the study of the emotional states, this common oscillation can then be viewed as the feature of interest.

2 Objectives of the internship

The goal of the internship will be first to understand the literature on time-frequency and synchrosqueezing techniques in the univariate case. In this regard, several softwares are available which will help the student to start with. Then, the main part of the project will be devoted to the design of the multivariate synchrosqueezing inspired by the work of Stankovic et al. [3], and to the mathematical study of proposed transform. Finally, applications of the transform to the study of emotional states using an open access database will also be looked at.

3 Prerequisite

The student should be skilled (and keen) on mathematical signal processing and familiar with Matlab.

References

- [1] I. Daubechies, J. Lu, and H.-T. Wu, *Synchrosqueezed wavelet transforms: An empirical mode decomposition-like tool*, Appl. Comput. Harmon. Anal., vol. 30, no. 2, pp. 243–261, 2011.
- [2] D-H. Pham and S. Meignen, *High-Order Synchrosqueezing Transform for Multicomponent Signals Analysis - With an Application to Gravitational-Wave Signal*, IEEE Transactions on Signal Processing, vol. 65, no. 12, pp. 3168–3178, 2017.
- [3] L. Stankovic, D. Mandic, M. Dakovic, and M. Brajovic, *Time-frequency decomposition of multivariate multicomponent signals*, Signal Processing, vol. 142, pp. 468–479, 2018.
- [4] A. Mert, Ahmet and A. Akan, *Emotion recognition based on time-frequency distribution of EEG signals using multivariate synchrosqueezing transform*, Digital Signal Processing, vol. 81, pp. 106–115, 2018.