



ST7 – 80 – SOURCE SEPARATION FOR OPTIMAL SIGNAL PROCESSING

Department : MDS (Mathematics, Data Science)

Language of instruction: Français

Campus : Campus de Metz

Engineering problematic

In order to increase productivity, to reduce ecological impact or to improve the quality of services, manufacturers and research centers must respond to the issues of data analysis made up of overlapping signals. Indeed, in many applications, sensor signals are mixtures of several sources that emit at the same time, and the information carried by these signals can only be exploited if we manage to separate what comes from each source. For example, in oil exploration, companies are now carrying out acquisition campaigns in simultaneous source mode (several sources emit at the same time). It is then necessary to distinguish in the signals of the geophones the echoes due to the various sources to obtain an image of the subsoil. Or in a "hi-tech" store, a robot that has started a conversation with a person may be disturbed by other customers or by ambient noise, while it must continue its conversation with the same person. Or in electrocardiograms, to separate the signal of the fetus' heart from that of its mother. Or for sound recording in a conference or round table with several speakers, rather than giving a microphone to each speaker, it would be practical to separate what each speaker says from recordings of microphones placed in fixed positions. The solutions to these problems are based on the same mathematical concepts:

- The knowledge of a data representation space adapted to the problem, where data have a sparse representation (in other words the data can be represented by a vector which has a few non-zero coordinates, in a space of great dimension);
- the minimization of a criterion that depends on the data; and
- a learning and testing stage to verify that the obtained solution generalizes and thus avoid overfitting.

Necessary prerequisites

First year courses in probability, statistics, signal processing and algorithms; good skills in a programming environment (Matlab, Python, ...).

Context and issues modules: These modules include an introductory lecture on the theme, presentations on environmental and societal issues and on



technological and scientific challenges, as well as a presentation of related projects.

Specific course (60 HEE): *Sparse representations of signals*

- **Brief description:** This course presents the mathematical tools of signal analysis and their properties (complements on the Fourier transform, subsampling/oversampling, harmonic signal, STFT, multiresolution analysis, Paley-Littlewood and bi-orthogonal wavelet decompositions, perfect reconstruction filter banks) as well as signal decomposition methods (Matching Pursuit, Basis Pursuit, Independent Component Analysis).

Projet n°1 : *Tracking a speaker by a robot*

- **Associated partner:** ORANGE, Cognitive Computing
- **Campus:** Campus de Metz
- **Brief description:** Robots are increasingly present in our environment. When a robot has started a conversation with a speaker, the problem is to keep the focus on the interlocutor while several people are talking around the robot, or another interlocutor is talking to it. ORANGE wants to solve this problem by using a monophonic audio signal recorded by the robot, without adding other modalities.

The issue is therefore to find one or more data representation spaces well adapted to the problem of speaker tracking; to learn from a small number of samples (i.e. over a small recording duration) the features of the speaker to be tracked; to avoid overfitting which may occur if the learned features depend on the words spoken by the speaker.

Projet n°2 : *Separation of sound sources from recordings of several microphones*

- **Associated partner:** CentraleSupélec, audio platform of the « smartroom
- **Campus:** Campus de Metz
- **Brief description:** There are many concrete situations in which you want to capture a sound so you can either record it for replay or amplify it live so that all participants have a good perception. Dans certaines de ces situations, plusieurs sources peuvent intervenir (par exemple, une conférence ou table ronde dans laquelle plusieurs locuteurs sont présents).

In order to allow good intelligibility in the case of several speakers, a microphone is usually placed in front of each speaker, or, in the theater, a radio transmitter microphone is placed directly on the actors. A significant improvement could be to use a fixed microphone array and to have a



processing algorithm to separate the sources, thus giving the illusion of having an individual microphone per speaker or actor.

The problem is therefore, starting from a fixed microphone array and assuming a finite number of sources (e.g. speakers), to ensure the separation of the sources and to provide an output channel per source (speaker), which channel would also contain the position information of this source. For simplicity, we will start by assuming that the speakers are at fixed positions known in advance. This is the case, for example, for speakers at a round table. In this case, the system could be calibrated beforehand using white noise generators, and then could operate using the fixed parameters determined in this way.

Projet n°3 : *Non-invasive foetal electrocardiogram extraction*

- **Associated partner:** INSERM
- **Campus:** Campus de Metz
- **Brief description:** Non-Invasive foetal electrocardiography (NI-FECG) represents an alternative foetal monitoring technique to traditional Doppler ultrasound approaches, that is non-invasive and has the potential to provide additional clinical information. However, despite the significant advances in the field of adult ECG signal processing over the past decades, the analysis of NI-FECG remains challenging and largely unexplored. This is mainly due to the relatively low signal-to-noise ratio of the FECG compared to the maternal ECG, which overlaps in both time and frequency.

The issue is to find one or several data representation spaces well adapted to the problem of foetal ECG extraction. It will be a question of applying and testing one or several methods starting from an article that reviews recent advances in NI-FECG research including: publicly available databases, NI-FECG extraction techniques for foetal heart rate evaluation and morphological analysis, NI-FECG simulators and the methodology and statistics for assessing the performance of the extraction algorithms..