UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Overview of methods for spectrum analysis"

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Short Abstract: In signal processing, spectrum analysis plays a key role to characterize and understand many phenomena. For instance, in biomedical applications, some features such as the ratio between the powers in low and high frequencies can be the basis of a physiological interpretation. Having a visual representation of how the spectrum of an audio signal varies over time can help the practitioner. Different families of methods have been developed for spectrum analysis. When dealing with stationary signals, several approaches exist. They differ on two main features: they can be parametric or not, with low or high resolution. Among the low-resolution non-parametric methods, the periodogram and the correlogram are based on the short-time Fourier transform (STFT). As an alternative, high-resolution non parametric methods such as the ones proposed by Capon and Borgiotti-Lagunas consist in designing very-selective frequency filters, whose finite impulse response depends on the input signal covariance matrix, and then in looking at the filter output power. Among the other solutions, parametric methods based on an *a priori* model such as the autoregressive with moving average (ARMA) can be used. The last class includes subspace methods such as MUSIC and ESPRIT and their variants. It should be noted that some links can be drawn between all these methods. When dealing with non-stationary signal, the above methods can be used by designing "sliding" methods, which consist in using a sliding window and then in applying a stationary-signal spectrum analysis on each signal frame. Nevertheless, the whole non-stationary signal can be studied directly by using alternative approaches such as the Cohen class which includes the Wigner-Ville distribution and its variants, the wavelet-based method or the empirical mode decomposition, to cite a few.

The purpose of this PhD course is to present an overview of these different families of approaches, their advantages and drawbacks.

Course Contents in brief:

- Stationary case

    - Fourier based methods (periodogram, correlogram, etc.)
    - Filtering based methods (Capon, Borgiotti-Lagunas algorithm)
    - ARMA-model based methods
    - Subspace methods (Music, Esprit, etc.)
- Non-stationary case
    - Sliding-window methods
    - Whole-signal analysis
        - Cohen classes
        - Wavelet methods
        - EMD
- Some illustrations
    - Speech analysis
    - Biomedical applications

Total # of hours of lecture: 16 hours

References:

[1] Modeling, estimation and optimal filtering in signal processing, Mohamed Najim, ISTE WILEY.

[2] Discrete Random Signals and Statistical Signal Processing, Charles W. Therrien, Prentice Hall.

CV of the Teacher

Eric Grivel received the diploma of engineer in electronics and the Ph.D. degree in signal processing from the University of Bordeaux. Currently, he is Professor in the field of signal processing at ENSEIRB-MATMECA, Bordeaux INP, France. He is with the Signal & Image research group at IMS laboratory, a joint research unit for the French National Center for Scientific Research (CNRS), University of Bordeaux and Bordeaux INP. His research interests include the design of signal processing approaches, from recursive estimation methods (including Kalman filtering and its variants, H-infinity filtering, particle filter, multiple-model approaches, etc.) to time-frequency analysis. The algorithms are then mainly applied in speech processing, mobile communication systems, GPS navigation, health and radar processing. He was the supervisor of 16 PhD students, 13 engineers and 36 students for their internships. He was the head of the Telecommunications dpt at ENSEIRB-MATMECA from 2010 to 2017. Since 2014, he has been in charge of the scientific network "Albatros" between THALES, University of Bordeaux, University of Limoges, University of Poitiers, Bordeaux INP, INRIA and CNRS. For two years, he has been involved in the scientific cluster Aerospace Valley. Since 2020, he has been the representative of University of Bordeaux in the European project ASSETS+, which aims at reinforcing the human resource supply chain in the defence-related sector by focusing on digital technologies (robotics, autonomous systems, artificial intelligence, C4ISTAR and cybersecurity).

Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell'Informazione, Via G. Caruso 16, Pisa – Ground Floor*

(Suggestion of) schedule:

Day1 - 2 slots of 2 hours dedicated to some prerequisites (if it is necessary), Fourier-based methods and filtering-based methods.
Day2 - 2 slots of 2 hours dedicated to ARMA-model based methods and subspace methods.
Day3 - 2 slots of 2 hours dedicated to examples and illustrations (if possible *Matlab* laboratory).
Day4 - 2 slots of 2 hours dedicated to examples and a brief overview of the non-stationary case.