Course Description

Course name	**#011 - Digital Signal Analysis Techniques: Time, Frequency, and Spatial Algorithms**
Duration	**3 days**
Format	**Public Classroom, Inhouse Event and Online**

Overview

Professor Gonzalo Seco-Granados and Professor José A. López-Salcedo are teaching this 3-day course that goes beyond available textbooks and extends these signal analysis tools to higher dimensions and multiple sensor channels.

Technical Focus

Conventional tools for analyzing and extracting the feature content of signals are filters (time content), Fourier transforms (frequency content) and beamforming (spatial content).

Alternative tools to these conventional techniques are able to produce signal analysis results with finer temporal detail and higher spectral and spatial resolution.

Course Content

This course introduces practical implementation of the latest research approaches to time series and spectral analysis.

The course uses a systematic approach based on a signal modelling theme, while focusing on fast computational procedures that make the alternative higher performance analysis techniques feasible to implement in practical applications.

Of special focus are the extensions of fast computational algorithms for high performance signal analysis techniques to multichannel, multi-dimensional, and non-stationary instantaneous time-frequency analysis applications, where there is little published implementation literature.

Who should attend?

The expected background for students is some fundamental knowledge of Fourier transforms, basic digital signal processing (filters, convolution, Fast Fourier Transform [FFT]), basic matrix mathematical operations (matrix inverse, eigenvectors), and introductory random signals (correlation, spectral density).

Some experience applying time and frequency domain techniques to signals would be helpful.

Course Daily Schedule

The daily schedule will be presented before the course start. The main topics will include:

Signal Analysis Tools and Classical Spectral Analysis

Relevant concepts of traditional temporal and frequency domain analysis of signals. We will establish some important concepts for the advanced alternative temporal and frequency (spectral) techniques

- Complex Signal Representations, Analytic Signals
- Issues in Spectral Estimation
- Tutorial Review: Fourier Transform Theory
- Tutorial Review: Random Signal Theory
- Tutorial Review: Matrix Algebra Theory
- Resolution and Time-Bandwidth Uncertainty Principle
- Autocorrelation and Cross Correlation
- Power Spectral Density
- Window Selection
- Periodogram Method
- Blackman-Tukey Method

Parametric and Autoregressive Methods

Many real-life applications are based on autoregressive and linear prediction modelling and estimation. We explore the basis for the high accuracy via a systematic modelling viewpoint, and illustrate the performance with actual data.

- Parametric Time Series Models: Autoregressive (AR)
- Moving Average (MA), and Autoregressive Moving Average (ARMA)
- Parametric Relationships
- Autocorrelation Relationships among Parametric Models (AR)
- Linear Prediction
- Levinson-Durbin Algorithm
- Maximum Entropy Analysis
- Spectral Estimation
- Order Selection

Exponential Frequency Estimation and Minimum Variance Spectra

Performance for finding signal feature extraction is achieved using minimum variance and eigenanalysis approaches, at a computational cost increase. We explore the tradeoffs.

- Prony's Method
- Damped Exponential Parameter Estimation
- Relationship to AR Methods
- Least Squares Prony Algorithms
- Noise Excision by Eigenanalysis/Principal Components Analysis
- Minimum Variance Estimation
- Pisarenko's Technique
- MUSIC and ESPRIT Algorithms
- Estimation of Number of Components

Multi-Channel and Two-Dimensional Spectral Analysis
Some of the techniques are revisited in the form of a multi-channel configuration, being representative of important applications such as array processing or the use of multiple sensors.

- Multi-Channel (MC) Spectral Analysis
- MC Classical Spectral Estimators
- Minimum Variance Spectral Analysis
- Minimum Variance Spectral Algorithm
- Autoregressive and Linear Prediction
- Relationship of Temporal and Spatial Spectral Analysis Techniques
- Spatial and Temporal Reference Beamforming
- Super-Resolution Direction Finding

Time-Frequency Analysis (TFA)
Performance tradeoffs and issues concerning time-varying signal analysis will be summarized

- Cyclostationarity,
- Time-Recursive AR Estimation,
- Short Time Fourier Transform,
- Linear and Quadratic Time-Frequency Representations,
- Short Time Fourier Transform (STFT),
- Wigner-Ville Distribution,
- 2D Methods of TFA,
- Ambiguity Functions in TFAs

Instructor´s Biography

Professor Gonzalo Seco-Granados is since 2006 Professor at the Department of Telecommunications and Systems Engineering, Universitat Autònoma de Barcelona, Spain. He coordinates the SPCOMNAV group, dedicated to research on signal processing mainly applied to wireless communications and positioning systems.

Professor Seco-Granados received his Ph.D. degree in Telecommunications Engineering from Universitat Politècnica de Catalunya and an MBA from IESE, both in Spain.

He has been a member of the technical staff of the European Space Research and Technology Center (ESTEC) of ESA in The Netherlands and held positions as coordinator of the Telecommunications Engineering degree and vice-director of School of Engineering at UAB. He has held visiting appointments at Universidad de Vigo in Spain as well as at Brigham Young University and the University of California in Irvine in the USA.

Professor Seco-Granados was granted one of the six UAB Chairs of Technology and Knowledge Transfer "UAB Research Park – Santander" in 2009, awarded an ICREA Academia Fellowship in 2014, and in 2015 he was a Fulbright Visiting Scholar at University of California, Irvine. He has authored over 150 technical papers and been principal investigator of over 25 research projects. His current research interests are distributed algorithms for estimation and detection, statistical and array signal processing, network optimization, resource management, and advanced GNSS receivers.

Professor Seco-Granados is a member of the Continuing Education Institute-Europe Faculty as of 2018.

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Dr. José A. López-Salcedo is since 2013 Professor at the Department of Telecommunication and Systems Engineering at Universitat Autònoma de Barcelona, Spain. He is the Coordinator of the Telecommunication Engineering studies at UAB.

Professor López-Salcedo received the M.Sc. and Ph.D. degrees in Telecommunication Engineering from Universitat Politècnica de Catalunya (UPC), Barcelona. He has been Research Assistant in the Department of Signal Theory and Communications, UPC and involved in R+D projects dealing with synchronization techniques for digital receivers, satellite communications and iterative decoding techniques for MIMO wireless systems, both for private industry and public administrations.

Professor López-Salcedo was a visiting scholar at the University of California, Irvine, USA, and at the Coordinated Science Laboratory (CSL), University of Illinois, Urbana-Champaign, USA. He has also held positions as a Scientific Support Officer at the European Commission, DG Joint Research Center, Ispra in Italy. His research interests are in the field of statistical signal processing, focusing on estimation theory, detection theory and applications to wireless communications and Global Navigation Satellite Systems (GNSS).

Professor López-Salcedo is a member of the Continuing Education Institute-Europe Faculty as of 2018.