Engineering Tripos Part IIB, 4F7: Digital Filters & Spectrum Estimation, 2016-17

Module Leader
Dr S Singh

Lecturers
Dr S Singh and Dr H Buchner

Timing and Structure
Michaelmas term. 16 lectures (including examples classes). Assessment: 100% exam

Aims
The aims of the course are to:

- continue the study of digital signal processing (DSP) systems, from the basics studied in 3F1/3F3.
- introduce the fundamental concepts and methods of adaptive filtering.
- develop the basic techniques for estimating the power spectrum of a random signal.

Objectives
As specific objectives, by the end of the course students should be able to:

- understand the theory and objectives of optimal (Wiener) filtering in an adaptive setting.
- recognise and describe the classes of problem where adaptive filtering might be applied.
- describe the implementation of the LMS and RLS adaptation algorithms, and understand their convergence properties. Understand the basic principles of Kalman filtering and filtering for Hidden Markov Models.
- understand the principles of spectrum estimation, windowing, resolution.
- apply non-parametric spectral analysis methods.
- specify data requirements in order to achieve specified spectral analysis criteria.
- formulate signal processing tasks in a model-based framework, and to estimate the model parameters.

Syllabus
The first aim of the course is to introduce the fundamental concepts and methods of adaptive filtering, i.e. filters which attempt to adapt their parameters automatically on-line to the data at hand - good examples of this are echo cancellation in telephony or background noise cancellation for aircraft pilots. Modern filtering theory will be introduced for state-space models (i.e. the Kalman filter.) This part of the course is an extension of the basic filter design material combined with the optimal filtering material from 3F3. In the second part of the course optimal spectrum estimation is studied. The aims are to develop the basic techniques for estimating the power spectrum of a random signal, i.e. what is the average frequency content of a signal, based just on a set of measured signal values. The course introduces both non-parametric (Fourier transform-based) and parametric model-based methods for this.
Adaptive Filters (8L, Prof S Godsill)

- Optimal linear Filter: Wiener Filter
- LMS Algorithm and its variants
- RLS Algorithm
- State-space models and the Kalman filter
- Applications

Spectral estimation (8L, Dr H Buchner)

- Non-Parametric Methods: Data Windows; Frequency resolution; Correlogram; Periodogram; Bartlett; Blackman-Tukey; Welch methods
- Parametric Methods; Autogressive Moving Average (ARMA) models; Yule-Walker Equations; Maximum Likelihood;

Lectures will be supported by interactive computer demonstrations using MATLAB.

Booklists

Please see the Booklist for Group F Courses [2] for references for this module.

Assessment

Please refer to Form & conduct of the examinations [3].

UK-SPEC

The UK Standard for Professional Engineering Competence (UK-SPEC) [4] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the 'Accreditation of Higher Education Programmes' (AHEP) document [5] which sets out the standard for degree accreditation.

The Output Standards Matrices [6] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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