Module Leader
Prof S.J. Godsill

Lecturers
Prof S Godsill and Dr S.S. Singh

Lab Leader
Prof S Godsill

Timing and Structure
Michaelmas term. 16 lectures.

Prerequisites
3F1

Aims
The aims of the course are to:

- Study more advanced probability theory, leading into random process theory.
- Study random process theory and focus on discrete time methods.
- Introduce inferential methodology, including maximum likelihood and Bayesian procedures, and examples drawn from signal processing. Objectives

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

- By the end of the course students should be familiar with the fundamental concepts of statistical signal processing, including random processes, probability, estimation and inference.

Content
Lectures 1-8: Advanced Probability and Random Processes

- Probability and random variables

  - Sample space, events, probability measure, axioms.

  - Conditional probability, probability chain rule, independence, Bayes rule.
Random variables (discrete and continuous), probability mass function (pmf), probability density function (pdf), cumulative distribution function, transformation of random variables.

Bivariate: conditional pmf, conditional pdf, expectation, conditional expectation.

Multivariate: marginals, Gaussian (properties), characteristic function, change of variables (Jacobian.)

Random processes

Definition of a random process, finite order densities.

Markov chains.

Auto-correlation functions.

Stationarity–strict sense, wide sense. Examples: iid process, random-phase sinusoid.

Ergodicity, Central limit theorem.

Spectral density.

Response of linear systems to stochastic inputs – time and frequency domain.

Time series models: AR, MA, ARMA

Lectures 9-16: Detection, Estimation and Inference

Basic Linear estimation theory: BLUE, MMSE, bias, variance

Wiener filters

Matched filters

Least squares, maximum likelihood, Bayesian inference.

The ML/Bayesian linear Gaussian model

Model choice (AIC, BIC, Bayesian) and Bayes decision theory
Maximum likelihood and Bayesian detector (cf matched filter)

Example inference models: frequency estimation, AR model, Estimation of parameters for discrete Markov chain.

Coursework

[Coursework Title]

Learning objectives:

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Practical information:

- Sessions will take place in [Location], during week(s) [xxx].
- This activity [involves/doesn't involve] preliminary work ([estimated duration]).
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Full Technical Report:

Students [will/won't] have the option to submit a Full Technical Report.

Booklists

Please see the Booklist for Part IIA Courses [2] for references for this module.

Examination Guidelines

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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