Engineering Tripos Part IIA, 3F3: Statistical Signal Processing, 2017-18

Module Leader

Prof S.J. Godsill [1]

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.
  - Multivariates: 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

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

D4

Ability to generate an innovative design for products, systems, components or processes to fulfil new needs.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

P8

Ability to apply engineering techniques taking account of a range of commercial and industrial constraints.

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

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