### Module Template for New and Revised Modules

<table>
<thead>
<tr>
<th>Module Code</th>
<th>EEP55C03</th>
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</thead>
<tbody>
<tr>
<td>Module Name</td>
<td>STATISTICAL SIGNAL PROCESSING</td>
</tr>
<tr>
<td>ECTS Weighting</td>
<td>10 ECTS</td>
</tr>
<tr>
<td>Semester taught</td>
<td>Semester 1</td>
</tr>
<tr>
<td>Module Coordinator/s</td>
<td>Associate Professor ANTHONY QUINN</td>
</tr>
</tbody>
</table>

**Module Learning Outcomes** with reference to the [Graduate Attributes](#) and how they are developed in discipline

On successful completion of this module, students should be able to:

- **LO1** Elicit and estimate parametric probability models for information-bearing signals and stochastic systems
- **LO2** Choose a data transform analysis that is matched to (i.e. consistent with) the probability model
- **LO3** Derive prescriptive (Bayesian) solutions for key signal processing tasks, such as prediction, classification, (auto)regression and state-space filtering, in the context of a fully audited stochastic model
- **LO4** Derive the state-of-the-art classical solutions (least squares, Wiener and/or maximum likelihood) to these tasks, and compare them critically to the consistent Bayesian solutions of LO3
- **LO5** Derive signal and system model selection criteria within countable sets of such models
- **LO6** Track nonstationary signals via Bayesian stabilized forgetting, and compare with classical adaptive Wiener solutions
- **LO7** Derive and implement (in Matlab) recursive, finite-dimensional signal processing algorithms based on the classical and Bayesian frameworks above, for use in on-line applications, and in nonstationary environments, and drawing on available open-source datasets

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1. [An Introduction to Module Design](#) from AISHE provides a great deal of information on designing and re-designing modules.
2. [TEP Glossary](#)
Graduate Attributes: levels of attainment
To act responsibly - Attained
To think independently - Attained
To develop continuously - Enhanced
To communicate effectively - Enhanced

Module Content

OBJECTIVES
The main purpose of this module is to provide students with the theory and methods necessary for the design of optimal signal processing algorithms for information-bearing sequences ('signals'). Classical optimization methods are reviewed, but a central pillar is the design of optimal statistics (i.e. data transformations) that are consistent with the observer’s (generative) signal model. In this way, the module explores the role of probability modelling in the development of robust and consistent (matched) signal transformations. The intention is to provide a principled pathway linking deterministic signal processing with a range of context-specific areas that require the processing of information-bearing signals.

The module is organized in a way that constantly emphasizes the connection between the formal design approaches and the key algorithms comprising the modern signal processing toolbox. The assumptions that underlie these algorithms are revealed. Thus, the module reviews a range of frequency transforms and spectrum estimation techniques, exploring the limited conditions under which they perform well, and ways in which they can be evolved to cope with more realistic conditions. Parametric (Wold-type) modeling of random processes is reviewed as a basis for signal prediction and compression. Wiener-type estimation strategies are compared to probabilistic (maximum likelihood and Bayesian) approaches. Classification and regression problems – as canonical machine learning tasks - are a major focus. A priority is to derive principled techniques for the design of recursive, finite-dimensional estimation strategies for on-line signal processing, and to adapt them consistently in nonstationary environments.

This philosophy of reviewing classical methods, auditing their assumptions, and using probability modelling to adapt them for consistency if need be, encourages the engineering student to be critical and creative in their choice of signal processing algorithm for their application; it primes them for design innovation in application domains; and it points them to opportunities for novel contributions to signal processing at research level.
SYLLABUS

• Review of transform analysis strategies for deterministic signals

• Parametric modelling of regular random processes, and their transform analysis

• Classical frequency and power spectrum estimation methods

• Wiener – and related – optimization strategies for estimation: contexts in prediction, filtering and smoothing

• Classical approaches to adaptive signal processing in nonstationary contexts

• Probabilistic design of signal processing algorithms: maximum likelihood and Bayesian strategies

• Contexts in the design of matched transforms, classification and regression

• Conjugate design of recursive, finite-dimensional signal processing algorithms, and adaptive variants

• Inference of hidden fields: classical and Bayesian (Kalman) filtering

Teaching and Learning Methods

The module will be delivered via about 44 real-time sessions, delivered in a hybrid manner via Blackboard Collaborate Ultra, and also from College lecture rooms. A 3:1 ratio is maintained between theory and tutorial content during the contact sessions. Problem-solving experience is vital, and gained primarily via the tutorial exercises and the in-session discussions, and also via the approximately six homework sheets distributed uniformly across the semester.

A priority of the module is to demonstrate how statistical signal processing theory enables the design of implementable algorithms. Therefore, Matlab-based computational implementations will be developed during a series of five two-to-three-hour laboratories later in the semester.

Attendance at all module contact sessions is compulsory, and necessary for the acquisition of the learning outcomes.

70% of the final mark is determined via the formal post-module examinations. They comprise a Theory paper, and a Matlab-based Practice paper. The remaining 30% is reserved for continuous assessment, by means
of two in-semester continual assessments, and a one-hour end-of-
semester quiz.

<table>
<thead>
<tr>
<th>Assessment Details</th>
<th>Assessment Component</th>
<th>Assessment Description</th>
<th>LO Addressed</th>
<th>% of total</th>
<th>Week due</th>
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<tbody>
<tr>
<td></td>
<td>Two in-semester</td>
<td>Written tests (between 30-</td>
<td>1-4</td>
<td>15</td>
<td>4, 8</td>
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<td></td>
<td>assessments</td>
<td>50 minutes apiece)</td>
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<tr>
<td></td>
<td>End-of-term quiz</td>
<td>Written test (1 hour)</td>
<td>1-7</td>
<td>15</td>
<td>12</td>
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<td></td>
<td>Theory examination</td>
<td>Written paper (2 hours)</td>
<td>1-7</td>
<td>40</td>
<td>Semester-1 assessment period</td>
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<td>Practice examination</td>
<td>Matlab-programming-</td>
<td>1-7</td>
<td>30</td>
<td>Semester-2 assessment period</td>
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<td>based examination (2 hours)</td>
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Reassessment Requirements

Contact Hours and Indicative Student Workload

<table>
<thead>
<tr>
<th>Contact hours:</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Independent Study (preparation for course and review of materials):</td>
<td>59</td>
</tr>
<tr>
<td>Independent Study (preparation for assessment, incl. completion of assessment):</td>
<td>95</td>
</tr>
<tr>
<td>Independent Study:</td>
<td>67</td>
</tr>
</tbody>
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Recommended Reading List

The primary learning resource will be the full set of lecture notes developed in real time during the live contact sessions, providing a unique record of the module. The live audiovisual lectures will be archived for consultation by students in BbCU. Tutorial sheets, self-study resources, etc., will also be distributed within the module in Blackboard.

The following books can also support the student’s learning in this module:

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3 TEP Guidelines on Workload and Assessment

### Module Pre-requisite

Digital Signal Processing (e.g. 4C5); Probability and Statistics (e.g. 3E3); Signals and Systems (e.g. 3C1); Engineering Mathematics (up to Year 3 incl.)

### Module Co-requisite

None

### Module Website

See module in Blackboard

### Are other Schools/Departments involved in the delivery of this module?
If yes, please provide details.

No

### Module Approval Date


### Approved by


### Academic Start Year


### Academic Year of Date


