Curriculum for the
Master of Science (MSc) in Engineering
(Signal Processing and Computing)

1st – 4th Semester

The Faculty of Engineering and Science
Aalborg University

September 2011
Preface:
Pursuant to Act 695 of June 22, 2011 on Universities (the University Act) with subsequent changes, the following curriculum for the Master's programme is stipulated. The programme also follows the Framework Provisions and the Examination Policies and Procedures for the Faculty of Engineering and Science and The Faculty of Medicine.

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Chapter 1: Legal Basis of the Curriculum, etc.

1.1 Basis in ministerial orders
The Master’s programme is organized in accordance with the Ministry of Science, Technology and Innovation’s Ministerial Order no. 814 of June 29, 2010 on Bachelor’s and Master’s Programs at Universities (the Ministerial Order of the Study Programs) and Ministerial Order no. 857 of July 1, 2010 on University Examinations (the Examination Order) with subsequent changes. Further reference is made to Ministerial Order no. 233 of March 24, 2011 (the Admission Order) and Ministerial Order no. 250 of March 15, 2007 (the Grading Scale Order) with subsequent changes.

1.2 Faculty affiliation
The Master’s programme falls under the Faculty of Engineering and Science, Aalborg University.

1.3 Board of Studies affiliation
The Master’s programme falls under the Board of Studies for Electronics and IT.

Chapter 2: Admission, Degree Designation, Programme Duration and Competence Profile

2.1 Admission
Admission to the Master’s programme requires a Bachelor’s or Bachelor of Engineering degree in Electronic Engineering and IT, Computer Engineering or the like.

Students with another Bachelor's degree, upon application to the Board of Studies, will be admitted after a specific academic assessment if the applicant is deemed to have comparable educational prerequisites. The University can stipulate requirements concerning conducting additional exams prior to the start of study.

2.2 Degree designation in Danish and English
The Master’s programme entitles the graduate to the designation civilingeniør, cand.polyt. (candidatus/candidata polytechnices) i signalbehandling og beregning. The English designation is: Master of Science (MSc) in Engineering (Signal Processing and Computing).

2.3 The programme's specification in ECTS credits
The Master’s programme is a 2-year, research-based, full-time study programme. The programme is set to 120 ECTS credits.

2.4 Competence profile on the diploma
The following competence profile will appear on the diploma:

A graduate of the Master’s programme has competencies acquired through an educational programme that has taken place in a research environment.

The graduate of the Master’s programme can perform highly qualified functions on the labour market on the basis of the educational programme. Moreover, the graduate has prerequisites for research (a Ph.D. programme). Compared to the Bachelor’s degree, the graduate of the Master’s programme has developed her/his academic knowledge and independence, so that the graduate can independently apply scientific theory and method in both an academic and occupational/professional context.
2.5 Competence profile of the programme:

The graduate of the Master’s programme:

Knowledge

- has knowledge of stochastic processes and signals, how they are generated, their distributional characteristics, how they can be modeled mathematically, and how such models can be applied according to limitations and constraints
- has knowledge of methods for data acquisition, inclusive physical sensors and their application
- has knowledge of methods for analysis, transformation, transportation and detection of stochastic signals
- has knowledge of different classes of optimization problems typically found in signal processing, and associated methods for continuous and discrete optimization
- has knowledge of signal processing concepts applied to 1) multiple signals, 2) non-stationary signals, and 3) signals with multiple sample rates
- has knowledge of methods and tools for fast, efficient, and reliable numerical simulation of signal processing algorithms and systems on parallel computers
- has knowledge of various graph representations of digital signal processing algorithms, how to derive information on inherent parallelism, date- and control flow, as well as computational- og communication complexity in order to estimate and evaluate various types of cost function parameters
- has knowledge of theories and methods for design and implementation of resource optimal real-time digital signal processing systems on reconfigurable and/or low power hardware/software platforms

Skills

- excels in scientific methods, tools and general skills related to design, simulation, real-time implementation, test, evaluation, and documentation of signal processing systems operating on stochastic stationary or non-stationary signals
- can apply methods and tools for performance/resource optimization of signal processing algorithms and implementation platforms given specific objective functions
- can, based on given design criterions, critically assess and select among scientific theories and methods for analysis, design and implementation of signal processing algorithms and associated non real-time and real-time hardware/software platforms
- can, based on a scientifically founded working methodology, advance new solutions and analysis models for an initial problem which requires signal processing concepts and efficient computing platforms in its solution
• can assess the results and quality of a design and the applied design trajectory, including experimental test and verification of signal processing systems

• can communicate research-based knowledge and discuss professional and scientific problems with both peers and non-specialists using the correct terminology defined for signal processing and computing

Competencies

• excels in scientific methods, tools and general skills related to design, simulation, real-time implementation, test, evaluation, and documentation of signal processing systems operating on stochastic stationary or non-stationary signals

• can apply methods and tools for performance/resource optimization of signal processing algorithms and implementation platforms given specific objective functions

• can, based on given design criterions, critically assess and select among scientific theories and methods for analysis, design and implementation of signal processing algorithms and associated non real-time and real-time hardware/software platforms

• can, based on a scientifically founded working methodology, advance new solutions and analysis models for an initial problem which requires signal processing concepts and efficient computing platforms in its solution

• can assess the results and quality of a design and the applied design trajectory, including experimental test and verification of signal processing systems

• can communicate research-based knowledge and discuss professional and scientific problems with both peers and non-specialists using the correct terminology defined for signal processing and computing

Chapter 3: Content and Organization of the Programme

The programme is structured in modules and organised as a problem-based study. A module is a programme element or a group of programme elements, which aims to give students a set of professional skills within a fixed time frame specified in ECTS credits, and concluding with one or more examinations within specific exam periods. Examinations are defined in the curriculum.

The programme is based on a combination of academic, problem-oriented and interdisciplinary approaches and organised based on the following work and evaluation methods that combine skills and reflection:

• lectures
• classroom instruction
• project work
• workshops
• exercises (individually and in groups)
• teacher feedback
• reflection
• portfolio work
**Overview of the programme:**

All modules are assessed through individual grading according to the 7-point scale or Pass/Fail. All modules are assessed by external examination (external grading) or internal examination (internal grading or by assessment by the supervisor only).

<table>
<thead>
<tr>
<th>Semester</th>
<th>Module</th>
<th>ECTS</th>
<th>P/C *)</th>
<th>Assessment</th>
<th>Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td><strong>Select</strong>&lt;br&gt;Signal analysis</td>
<td>20</td>
<td>P</td>
<td>7-point scale</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>PBL and Signal analysis</td>
<td>20</td>
<td>P</td>
<td>7-point scale</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Stochastic processes</td>
<td>5</td>
<td>C</td>
<td>7-point scale</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Optimization methods</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td><strong>Select</strong>&lt;br&gt;Scientific computing (elective)</td>
<td>20</td>
<td>P</td>
<td>7-point scale</td>
<td>External</td>
</tr>
<tr>
<td></td>
<td>Reconfigurable computing (elective)</td>
<td>20</td>
<td>P</td>
<td>7-point scale</td>
<td>External</td>
</tr>
<tr>
<td></td>
<td>Scientific computing and sensor modelling</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Reconfigurable and low energy systems</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>Signal processing and computing</td>
<td>20</td>
<td>P</td>
<td>7-point scale</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Machine learning</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Array and sensor signal processing</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Master's thesis</td>
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<td>P</td>
<td>7-point scale</td>
<td>External</td>
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<td>Total</td>
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<td>120</td>
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</tbody>
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*) P = Project -  C = Course
Descriptions of modules

Signal Analysis (P)

Signalanalyse

Prerequisites:
Competencies in Project-Oriented and Problem-Based Learning.

Objective:
Students who complete the module:

Knowledge
- Must have knowledge about stationary and quasi-stationary signals, how they can be modeled mathematically, as well as the possibilities provided and the constraints imposed by such models.
- Must have knowledge about non-parametric and parametric based spectral analysis methods, how they compare in terms of spectral accuracy and computational complexity, and how essential parameters such as time-frequency duality and model order impact their respective performances.
- Must have knowledge about the nature of signals impaired by noise, such as additive noise, convolution noise, and non-linear noise.
- Must have knowledge about fundamental signal detection theories and methods.
- Must understand the scientific communication processes related to conference presentations and related to publishing in peer-reviewed scientific journals
- Must know how to organize a scientific publication

Skills
- Must be able to specify and design models for (quasi-) stationary stochastic signals.
- Must be able to apply fundamental methods for parametric spectral analysis in order to derive the spectral content of a stochastic signal. Furthermore, be able to compare and evaluate the result against non-parametric methods, e.g., based on Fourier analysis.
- Must be able to apply fundamental methods for either 1) signal detection in order to extract information from a signal with finite signal-to-noise-ratio or 2) optimization problems related to signal processing or signal analysis
- Can explain the process of and criteria for peer reviewed scientific communications,
- Can write a paper for a scientific conference/journal
- Can prepare and give an oral and poster presentation for a scientific conference

Competencies
- Must be able to read and understand selected scientific literature and next apply the theories, methods, and/or tools in order to solve a problem which needs signal analysis in its solution.
- Are able to judge and prioritize the validity of various sources of scientific information.
- Apply internationally recognized principles for acknowledging and citing work of others properly.
- Can formulate and explain scientific hypotheses and results achieved through scientific work
- Are able to analyze results and draw conclusions on a scientific basis.
Type of instruction:
Students are organized in groups of up to six members working according to the POPBL concept at Aalborg University. Each group will be supervised by at least one staff member doing research within the main topic(s) addressed in the project.

On this semester the project has to be documented in the following forms (all in English):

• A scientific article
• An oral presentation
• A poster
• Edited worksheets, providing all relevant project details

For further information see the introduction to Chapter 3.

Exam format:
Individual oral examination based on written documentation including: a scientific article, slides from the oral presentation at the student conference (SEMCON), a poster and edited worksheets.

Evaluation criteria:
As stated in the Framework Provisions
Problem Based Learning and Signal Analysis (P)

Prerequisites:
None

Objective:
Students who complete the module:

Knowledge
- Must have knowledge about stationary and quasi-stationary signals, how they can be modeled mathematically, as well as the possibilities provided and the constraints imposed by such models.
- Must have knowledge about non-parametric and parametric based spectral analysis methods, how they compare in terms of spectral accuracy and computational complexity, and how essential parameters such as time-frequency duality and model order impact their respective performances.
- Must have knowledge about the nature of signals impaired by noise, such as additive noise, convolution noise, and non-linear noise.
- Must have knowledge about fundamental signal detection theories and methods.
- Has knowledge of the phases that a project will go through
- Understand various theories and methods applied in problem based learning and group organized project work

Skills
- Must be able to specify and design models for (quasi-) stationary stochastic signals.
- Must be able to apply fundamental methods for parametric spectral analysis in order to derive the spectral content of a stochastic signal. Furthermore, be able to compare and evaluate the result against non-parametric methods, e.g., based on Fourier analysis.
- Must be able to apply fundamental methods for either 1) signal detection in order to extract information from a signal with finite signal-to-noise-ratio or 2) optimization problems related to signal processing or signal analysis
- Are able to plan and take part in a small group of students working on a problem based project
- Can reflect on experiences obtained through problem based learning and group project work
- Can communicate the result of the project work in an appropriate form
- Are able to demonstrate skills in project management

Competencies
- Must be able to read and understand selected scientific literature and next apply the theories, methods, and/or tools in order to solve a problem which needs signal analysis in its solution.
- Can organize and contribute to a team based project work
- Has competencies in project work and problem based learning in a global/multicultural environment
- Can manage work and development situations that are complex, unpredictable and require new solutions.
- Can independently initiate and implement discipline-specific and interdisciplinary cooperation and assume professional responsibility.
• Can independently take responsibility for own professional development and specialization
• Can find, evaluate and reference literature within the professional field
• Apply internationally recognized principles for acknowledging and citing work of others properly.

**Type of instruction:**
Project work.

**Exam format:**
Individual oral examination based on the written report.

**Evaluation criteria:**
As stated in the Framework Provisions
Stochastic Processes (C)
Stokastiske processer

Prerequisites:
Solid knowledge in probability, statistics, linear algebra, Fourier theory, and programming

Objective:
Students who complete the module:

Knowledge
- Have knowledge about the theoretical framework in which stochastic processes are defined.
- Be able to understand the properties of the stochastic processes introduced in the course, such as white-sense stationary (WSS) processes, Auto Regressive Moving Average (ARMA) processes, Markov models, and Poisson point processes.
- Be able to understand how WSS processes are transformed by linear time-invariant systems.
- Be able to understand the theoretical context around the introduced estimation and detection methods ((non-parametric and parametric) spectral estimation, Linear Minimum Mean Square Error (LMMSE) estimation, Wiener filter, Kalman filter, detection of signals, ARMA estimation, etc.)

Skills
- Be able to apply the stochastic processes taught in the course to model real random mechanisms occurring in engineering problems.
- Be able to simulate stochastic processes using a standard programming language.
- Be able to apply the taught estimation and detection methods to solve engineering problems dealing with random mechanisms.
- Be able to evaluate the performances of the introduced estimation and detection methods.

Competencies
- Have the appropriate “engineering” intuition of the basics concepts and results related to stochastic processes that allow – for a particular engineering problem involving randomness – to design an appropriate model, derive solutions, assess the performance of these solutions, and possibly modify the model, and all subsequent analysis steps, if necessary

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral or written examination

Evaluation criteria:
As stated in the Framework Provisions
Optimization Methods (C)
Optimeringsmetoder

Prerequisites:
Basic linear algebra and numerical methods

Objective:
Students who complete the module:

Knowledge
- Must have knowledge about different classes of optimization problems.
- Must have knowledge about objective function, global/local minima, constrained/unconstrained, convex/non-convex functions and sets.
- Must have knowledge about the consequences of dimensionality.
- Must have knowledge about gradient and optimal gradient methods.
- Must have knowledge about Newton and interior-point methods for constrained optimization.
- Must have knowledge about sine search methods and stop criteria.
- Must have knowledge about tools for non-linear optimization.
- Must have knowledge about methods for solving combinatorial optimization problems, such as Simulated Annealing (SA), Genetic Algorithms (GA), ant colony optimization, and Integer Linear Programming (ILP).

Skills
- Must be able to identify problem classes.
- Must be able to apply optimization methods in order to design and implement algorithms for continuous and discrete optimization.
- Must be able to evaluate the performance of optimization algorithms.
- Must be able to transform optimization problems to standard form and use off-the-shelf optimization software.
- Must be able to evaluate and understand numerical aspects of optimization algorithms.

Competencies
- Must have an understanding of how to formulate optimization problems in signal processing.
- Must have competencies in applying optimization in signal processing applications.

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral or written examination

Evaluation criteria:
As stated in the Framework Provisions
Scientific Computing (P)
Videnskabelig beregning

Prerequisites:
Corresponding to having passed 1st semester.

Objective:
Students who complete the module:

Knowledge
- Must have knowledge of computer architecture classification (Flynn's taxonomy).
- Must have knowledge about typical scientific computing problems with non-real-time constraints.
- Must have knowledge of parallel computing techniques.
- Must have knowledge of the relation between physical world problems and mathematical models.
- Must have knowledge of different computational platforms for different types of scientific computing problems.

Skills
- Must be able to select suitable hardware platforms for different computational problems.
- Must be able to program solutions for scientific computing problems by use of various computational platforms (single and multi-core processing units, graphics processing units, compute clusters etc.).
- Must be able to debug and performance optimize (e.g., time and/or memory consumption) the developed software.
- Must be able to use various computing platforms to solve different scale computational problems.
- Document the developed software including validation of the desired functionality.

Competencies
- Must be able to work in groups to solve problems where scientific computing is applied and where sub-parts are done individually.
- Using the above mentioned knowledge and skills, the student must be able to identify, prioritize, and apply in a structured manner the set of tasks needed for solving a scientific computing problem, which in its solution naturally involves or require high-performance simulation capabilities.
- The student must be able to create and plan the work and development processes as needed for solving systematically such a problem.
- The student must be able to select the most appropriate project management method(s) and tool(s) for solving the problem.
- Must be able to initiate the above mentioned task independently, critically, and responsibly.

Type of instruction:
Project work.

Exam format:
Individual oral examination based on a written report.

Evaluation criteria:
As stated in the Framework Provisions
Reconfigurable Computing (P)
Rekonfigurerbare systemer

Prerequisites:
Corresponding to having passed 1st semester.

Objective:
Students who complete the module:

Knowledge
- Must have knowledge about methodologies applied for resource optimal mapping of Digital Signal Processing (DSP) algorithms onto application specific reconfigurable hardware/software (HW/SW) platforms.
- Must have knowledge about analytical, numerical, experimental and simulation based methods for assessing selected cost function parameters typically associated with such real-time systems.

Skills
- Must be able to apply analysis/design/implementation/test methods and -tools for the optimization of 1) performance and 2) resource usage when mapping DSP algorithms onto dedicated real-time HW and/or SW architectures.
- Must be able to apply theories, methods, and techniques for analysis, design, implementation, and test of reconfigurable real-time hardware systems.
- Must be able to evaluate, compare, and optimize the quality of selected parts of the overall system in terms of e.g., chip area, execution time, memory usage, energy consumption, and/or numerical properties.
- Must be able to present, justify, and argue for the methodological, structural (system component related), and physical (technological) choices made when analyzing, designing, implementing, and testing reconfigurable and/or low energy DSP systems.

Competencies
- Using the above mentioned knowledge and skills, the student must be able to identify, prioritize, and apply in a structured manner the set of tasks needed for solving a DSP problem which in its solution naturally involves or require a reconfigurable real-time HW/SW platform.
- The student must be able to create and plan the work and development processes as needed for solving systematically such a problem.
- The student must be able to select the most appropriate project management method(s) and tool(s) for solving the problem.
- Must be able to initiate the above mentioned task independently, critically, and responsibly.

Type of instruction:
Project work.

Exam format:
Individual oral or written examination

Evaluation criteria:
As stated in the Framework Provisions
Scientific Computing and Sensor Modeling (C)
Videnskabelige beregninger og sensor modellering

Prerequisites:
None

Objective:
Students who complete the module:

Knowledge
- Must have knowledge about hardware and software platforms for scientific computing.
- Must have knowledge about the possible speedup by using parallelization (Amdahl's law / Gustafson-Barsis' law) under different conditions.
- Must have knowledge about message and data passing in distributed computing.
- Must have knowledge about programming techniques, profiling, benchmarking, code optimization etc.
- Must have knowledge about numerical accuracy in scientific computing problems.
- Must have knowledge about selected sensors and sensor signal processing devices and their basic working principle (examples of sensors: temperature, pressure, frequency, phase and position; examples of sensor signal processing devices: low noise amplifiers, power amplifiers, mixers and logical gates).
- Must have knowledge about how sensors and sensor signal processing devices can be modeled and how model parameters can be extracted from e.g. measurements or data sheets.
- Must have knowledge about how to simulate single and multiple connected sensors.

Skills
- Must be able to implement software programs to solve scientific computational problems using parallel computing.
- Must be able to debug, validate, optimize, benchmark and profile developed software modules.
- Must be able to assess the performance of different hardware architectures for scientific computing problems.
- Must be able to use sensor models in system simulations.

Competencies
- The student must be able to apply the proper terminology in oral and written communication and documentation within the scientific domains of scientific computing and sensor modeling.
- The student must be able to study and later understand and model sensors, which have not been treated in the course.

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral or written examination

Evaluation criteria:
As stated in the Framework Provisions
Reconfigurable and Low Energy Systems (C)
Rekonfigurerbare systemer og energi-minimale systemer

Prerequisites:
Fundamental hardware/software components for embedded systems, programming languages and design methodologies.

Objective:
Students who complete the module:

Knowledge
Must have knowledge about;
- computational complexity theory
- cost functions and models of computation
- graph representation and -analysis of Digital Signal Processing (DSP) algorithms
- interaction between DSP algorithms and real-time Hardware/Software (HW/SW) architectures
- design and optimization of dedicated HW architectures/co-processors
- scheduling methodologies for multiple processors/functional units
- hardware/software metric-estimation and partitioning
- static and dynamic reconfiguration management
- technologies and methods for partial reconfiguration
- models for power consumption in digital circuits
- power/energy optimization techniques in HW/SW architectures
- essential issues of probabilistic embedded computing
- battery models and management
- energy harvesting methodologies

Skills
- Must be able understand advanced terms, concepts, and methods, their application as well as limitations in the context of time-, area-, or energy optimal/constrained mapping of DSP algorithms onto real-time HW/SW architectures.

Competencies
- The student must be able to apply the proper terminology in oral and written communication and documentation within the scientific domains of DSP algorithms, and application specific HW/SW architectures.

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral or written examination

Evaluation criteria:
As stated in the Framework Provisions
Signal Processing and Computing (P)
Signalbehandling og beregning

Prerequisites:
Corresponding to having passed 2nd semester

Objective:
Students who complete the module:

Knowledge
Knowledge in one or more of the following domains:
- Must have knowledge about methods and algorithms for signal estimation, including appropriate simulation or real-time implementation.
- Must have knowledge about methods and algorithms for parametric spectral estimation of one-dimensional and two-dimensional signals, including appropriate simulation or real-time implementation.
- Must have knowledge about methods and algorithms for adaptive filtering, including appropriate simulation or real-time implementation.
- Must have knowledge about methods and algorithms for multi-rate signal processing, including appropriate simulation or real-time implementation.
- Must have knowledge about methods and algorithms that allow computers to evolve behaviors based on empirical data from sensors or from databases, including appropriate simulation or real-time implementation.

Skills
- Must be able to analyze theoretically complex problems for which signal processing methods must be employed, and next select among and apply the methods and algorithms mentioned above in order to suggest efficient system solutions in terms of computational performance, and -complexity, as well as numerical robustness.
- Must be able to conduct a detailed and structural analysis of the complete set of applied algorithms, including the data acquisition functionality, in order to assess the overall system performance against the initial specifications.
- Must be able to apply the results from the performance analysis in order to plan how the complete system can be ported to a suitable computing platform, either for simulation purposes or for real-time resource optimal hardware/software implementation.
- Must be able to organize, schedule, conduct, evaluate, and document a thorough test- and validation procedure for the complete system.

Competencies
- Must be able to read, understand, and apply theories, methods, algorithms, and tools published in the relevant scientific literature.

Type of instruction:
Project work.

Exam format:
Individual oral examination based on a written report.

Evaluation criteria:
As stated in the Framework Provisions.
Machine Learning (C)
Maskin læring

Prerequisites:
Basic knowledge in probability theory, statistics, and linear algebra.

Objective:
The course gives a comprehensive introduction to machine learning, which is a field concerned with learning from examples and has roots in computer science, statistics and pattern recognition. The objective is realized by presenting methods and tools proven valuable and by addressing specific application problems.

Students who complete the module:

Knowledge
- Must have knowledge about supervised learning methods including K-nearest neighbors, decision trees, linear discriminant analysis, support vector machines, and neural networks.
- Must have knowledge about unsupervised learning methods including K-means, Gaussian mixture model, hidden Markov model, EM algorithm, and principal component analysis.
- Must have knowledge about probabilistic graphical models, variational Bayesian methods, belief propagation, and mean-field approximation.
- Must have knowledge about Bayesian decision theory, bias and variance trade-off, and cross-validation.
- Must be able to understand reinforcement learning.

Skills
- Must be able to apply the taught methods to solve concrete engineering problems.
- Must be able to evaluate and compare the methods within a specific application problem.

Competencies
- Must have competencies in analyzing a given problem and identifying appropriate machine learning methods to the problem.
- Must have competencies in understanding the strengths and weaknesses of the methods.

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral or written examination

Evaluation criteria:
As stated in the Framework Provisions
Prerequisites:
Stochastic processes, basic estimation theory, and optimization methods.

Objective:
Students who complete the module:

Knowledge
- Must have knowledge about the Cramér-Rao lower bound (CRLB) as well as (asymptotic) optimal unbiased estimators such as minimum variance unbiased estimator, maximum likelihood, and least-squares.
- Must have knowledge about 1- and 2-dimensional spectral estimation methods such as the period gram, the Yule-Walker equations, subspace-based methods (MUSIC and ESPRIT), and filter-bank methods (Capon’s method and Amplitude and Phase Estimation (APES)).
- Must have knowledge about fundamental terms and methods applied for design and analysis of adaptive filter such as Steepest descent, least-mean-square (LMS), normalized LMS (NLMS), affine projections (AP), recursive least-squares (RLS), transient and steady-state performance.
- Must have knowledge about terms and methods applied for design and analysis of multi-rate signal processing systems, such as Hilbert transform, Noble identities, poly-phase decomposition, commutators, re-sampling, as well as up- and down-sampling.

Skills
- Must be able to compare the estimation performance of unbiased estimators by using the CRLB.
- Must be able to apply methods and algorithms for parametric and non-parametric spectral estimation on 1- and 2-dimensional signals.
- Must be able to implement fundamental adaptive filters such as the (normalized) least-mean-square filter, the affine projection filter, and the recursive least-squares filter.
- Must be able to apply fundamental methods for analysis, design, and implementation of poly-phase filters.

Competencies
- Must have competencies in analyzing a given problem which in its solution requires advanced signal processing methodologies and next identify appropriate methods and algorithms to solve the problem.
- Must have competencies in understanding the strengths and weaknesses of the methods.

Type of instruction:
As described in the introduction to Chapter 3.

Exam format:
Individual oral or written examination

Evaluation criteria:
As stated in the Framework Provisions
Prerequisites:
Passed three previous semester or the like

Objective:
Students who complete the module:

Knowledge
- have knowledge, at the highest international level of research, of at least one of the core fields of the education
- have comprehension of implications of research (research ethics)

Skills
- are able to reflect on a scientific basis on their knowledge,
- can argue for the relevance of the chosen problem to the education including specifically account for the core of the problem and the technical connections in which it appears
- can account for possible methods to solve the problem statements of the project, describe and assess the applicability of the chosen method including account for the chosen delimitation and the way these will influence on the results of the product
- can analyze and describe the chosen problem applying relevant theories, methods and experimental data
- are able to describe the relevant theories and methods in a way that highlights the characteristics and hereby document knowledge of the applied theories, methods, possibilities and delimitations within the relevant problem area
- have the ability to analyze and assess experimental data, including the effect the assessment method has on the validity of the results.

Competencies
- are able to communicate scientific problems in writing and orally to specialist and non-specialist.
- are able to control situations that are complex, unpredictable and which require new solutions,
- are able to independently initiate and to perform collaboration within the discipline and interdisciplinary as well, and to take professional responsibility,
- are able to independently take responsibility for his or her own professional development and specialization.

If the project is carried out as a long master's thesis the learning objectives include those defined for the 3rd semester of the education.

Type of instruction:
As described in the introduction to Chapter 3.

Problem based project oriented project work individual or in groups of 2-3 persons

Exam format:
Individual oral examination based on a written report.

Evaluation criteria:
As stated in the Framework Provisions
Chapter 4: Entry into Force, Interim Provisions and Revision

The curriculum is approved by the Dean of the Faculty of Engineering and Science.

Students who wish to complete their studies under the previous curriculum from 2008 must conclude their education by the summer examination period 2012 at the latest, since examinations under the previous curriculum are not offered after this time.

In accordance with the Framework Provisions and the Handbook on Quality Management for the Faculty of Engineering and Science and The Faculty of Medicine at Aalborg University, the curriculum must be revised no later than 5 years after its entry into force.

Chapter 5: Other Provisions

5.1 Rules concerning written work, including the Master's thesis
In the assessment of all written work, regardless of the language it is written in, weight is also given to the student's spelling and formulation ability, in addition to the academic content. Orthographic and grammatical correctness as well as stylistic proficiency are taken as a basis for the evaluation of language performance. Language performance must always be included as an independent dimension of the total evaluation. However, no examination can be assessed as ‘Pass’ on the basis of good language performance alone; similarly, an examination normally cannot be assessed as ‘Fail’ on the basis of poor language performance alone. The Board of Studies can grant exemption from this in special cases (e.g., dyslexia or a native language other than Danish).

The Master’s thesis must include an English summary.\(^1\) If the project is written in English, the summary must be in Danish.\(^2\) The summary must be at least 1 page and not more than 2 pages. The summary is included in the evaluation of the project as a whole.

5.2 Rules concerning credit transfer (merit), including the possibility for choice of modules that are part of another programme at a university in Denmark or abroad
In the individual case, the Board of Studies can approve successfully completed (passed) programme elements from other Master’s programmes in lieu of programme elements in this programme (credit transfer). The Board of Studies can also approve successfully completed (passed) programme elements from another Danish programme or a programme outside of Denmark at the same level in lieu of programme elements within this curriculum. Decisions on credit transfer are made by the Board of Studies based on an academic assessment. See the Framework Provisions for the rules on credit transfer.

5.3 Rules for examinations
The rules for examinations are stated in the Examination Policies and Procedures published by the Faculty of Engineering and Science on their website.

5.4 Exemption
In exceptional circumstances, the Board of Studies study can grant exemption from those parts of the curriculum that are not stipulated by law or ministerial order. Exemption regarding an examination applies to the immediate examination.

\(^1\) Or another foreign language (upon approval from the Board of Studies.
\(^2\) The Board of Studies can grant exemption from this.
5.5 Completion of the Master's programme
The Master's programme must be completed no later than four years after it was begun.

5.6 Rules and requirements for the reading of texts
It is assumed that the student can read academic texts in his or her native language as well as in English and use reference works etc. in other European languages.

5.7 Additional information
The current version of the curriculum is published on the Board of Studies' website, including more detailed information about the programme, including exams.