



Curriculum for Master of Science in Intelligent Reliable Systems

Aalborg University
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Preface

Pursuant to Act 367 of March 25, 2013 on Universities (the University Act) with subsequent changes, the following curriculum for the Master's program in Intelligent Reliable Systems is stipulated. The program also follows the Framework Provisions and the Examination Policies and Procedures for the Faculties of Engineering, Science and Medicine.

Table of Contents

Chapter 1: Legal Basis of the Curriculum, etc.	2
1.1 Basis in ministerial orders	2
1.2 Faculty affiliation	2
1.3 Board of Studies affiliation	2
Chapter 2: Admission, Degree Designation, Program Duration and Competence Profile	2
2.1 Admission.....	2
2.2 Degree designation in Danish and English	2
2.3 The program's specification in ECTS credits	2
2.4 Competence profile on the diploma	3
Chapter 3: Content and Organization of the Program	4
3.2 Descriptions of modules	6
Chapter 4: Entry into Force, Interim Provisions and Revision	31
Chapter 5: Other Provisions.....	31
5.1 Rules concerning written work, including the Master's thesis	31
5.2 Rules concerning credit transfer (<i>merit</i>), including the possibility for choice of modules that are part of another program at a university in Denmark or abroad	31
5.3 Rules for examinations.....	31
5.4 Exemption	31
5.5 Additional information.....	32
5.6 Completion of the Master's program	32

Chapter 1: Legal Basis of the Curriculum, etc.

1.1 Basis in ministerial orders

The Master's program in Intelligent Reliable Systems is organized in accordance with the Ministry of Science, Innovation and Higher Education's 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. 666 of June 24, 2012 on University Examinations (the Examination Order) with subsequent changes. Further reference is made to Ministerial Order no. 1488 of December 16, 2013 (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 program falls under the Faculty of Engineering and Science, Aalborg University.

1.3 Board of Studies affiliation

The Master's program falls under the Board of Studies for Electronics and Information Technology

Chapter 2: Admission, Degree Designation, Program 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 (AAU)
- Computer Engineering (AAU)
- Electronic and Computer Engineering (AAU)
- Electrical Engineering (DTU)

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 one of the following designations:

Civilingeniør, cand.polyt. (candidatus/candidata polytechnices) i intelligente pålidelige systemer.
The English designation is: Master of Science (MSc) in Engineering (Intelligent Reliable Systems).

2.3 The program's specification in ECTS credits

The Master's program is a 2-year, research-based, full-time study program. The program 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 program has competencies acquired through an educational program that has taken place in a research environment.

The graduate of the Master's program can perform highly qualified functions on the labor market on the basis of the educational program. Moreover, the graduate has prerequisites for research (a Ph.D. program). Compared to the Bachelor's degree, the graduate of the Master's program 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 program:

The graduate of the Master's program:

Knowledge:

- Has knowledge in one or more subject areas that, in selected areas within intelligent reliable systems, is based on the highest international research in a subject area
- Can understand and, on a scientific basis, reflect over subject area's related to information technology and identify scientific problems within that area
 - Demonstrate an understanding of research work and be able to become a part of the research environment
 - Has knowledge and comprehension within advanced control theory and its applications
 - Has a thorough understanding of probabilistic, statistics and stochastic theories and methods, and their application in the reliability modeling and analysis
 - Has understanding of fault detection, diagnosis and fault tolerant control of engineering systems

Skills:

- Excels in scientific methods, tools and general skills within information technology
- Can evaluate and select among the subject area's(s') scientific theories, methods, tools and general skills and, on a scientific basis, advance new analyzes and solutions
- Can communicate research-based knowledge and discuss professional and scientific problems with both peers and non-specialists
- Have obtained skills which are related to the employment area within intelligent information and control technology
- Can design and develop intelligent reliable systems using state of the art theories and methods within control engineering
- Able to apply systematic methods for modelling complex mechanical structures dynamically in both planar and spatial cases.

Competencies

- Can manage work and development situations that are complex, unpredictable and require new solutions within the area of information technology
- Can independently initiate and implement discipline-specific and interdisciplinary cooperation and assume professional responsibility.
- Can independently take responsibility for own professional development and specialization

- Has competencies in design, development and test of intelligent and reliable automation systems
- Has competencies within system identification, fault detection, reliability and diagnosis
- Can contribute to the scientific development within intelligent reliable systems
- Can prioritize and build optional competencies in: modeling of mechanical structures, Kalman filtering, adaptive control, supervised/unsupervised learning and artificial intelligence.

Chapter 3: Content and Organization of the Program

The program is structured in modules and organized as a problem-based study. A module is a program element or a group of program 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 program is based on a combination of academic, problem-oriented and interdisciplinary approaches and organized 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

3.1 Overview of the program:

An overview of the ECTS credit breakdown for the various semesters by modules is shown in the table below.

Sem.	P/C	Module	IRS	ECTS	Assessment	Exam
1st	C	Stochastic Processes	Mandatory	5	7-point scale	Internal
	C	System Identification and Diagnosis	Mandatory	5	7-point scale	Internal
	C	Advanced Modelling of Dynamic Systems	Elective ¹	5	7-point scale	Internal
	C	Kalman Filter Theory and its Applications	Elective ¹	5	7-point scale	Internal
	C	Structural Mechanics and Dynamics	Elective ¹	5	7-point scale	Internal
	P	System Identification and Estimation	Mandatory	15	7-point scale	External
2nd	C	Control and Surveillance Processes and Systems	Mandatory	5	7-point scale	Internal
	C	Fault Detection and Diagnosis Techniques	Mandatory	5	7-point scale	Internal
	C	Reliability Modeling and Analysis	Mandatory	5	7-point scale	Internal
	P	Fault Diagnosis and Reliability Analysis	Mandatory	15	7-point scale	External
3 rd	C	Adaptive and Optimal Control	Elective ²	5	7-point scale	Internal
	C	Intelligent Control and Reliability Oriented Design	Elective ²	5	7-point scale	Internal
	C	Machine Learning	Elective ²	5	Pass/Fail	Internal
	P	Design of Intelligent Reliable Systems	Elective	20	7-point scale	Internal
	P	Advanced control and estimation	Elective	20	7-point scale	Internal
4 th	P	Master's Thesis	Mandatory ³	30/50	7-point scale	External
Total				120		

C/P: Course/Project module

¹: One course must be chosen (total: 5 ECTS)

²: Two courses must be chosen (total: 10 ECTS)

³: Students may choose either a 30 ECTS or a 50 ECTS thesis project. In the latter case the learning objectives for the thesis include both the learning objectives for the projects on 3rd and 4th semester!

Table 1 Structure of Master's program

3.2 Descriptions of modules

Course module Stochastic Processes Stokastiske processer
Prerequisites: Solid knowledge in probability, statistics, linear algebra, Fourier theory, and programming
Objective: Students who complete the module must: Knowledge <ul style="list-style-type: none">• 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 process are transformed by linear-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 <ul style="list-style-type: none">• 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 performance of the introduced estimation and detection methods Competencies <ul style="list-style-type: none">• 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

Course module**System Identification and Diagnosis****Systemidentifikation og diagnosticering****Prerequisites:**

Numerical methods, control theory, probability, statistics and stochastic processes, state-space methods.

Objective:

Students who complete the module must:

Knowledge

- Have comprehension of the fundamental principles of typical methods of system identification
- Have comprehension of the fundamental concepts, terms and methodologies of abnormal diagnosis
- Have comprehension of some typical model-based and signal-based diagnosis

Skills

- Be able to apply the learned knowledge to handle some simple system identification problems under assistance of a commercial software
- Be able to apply and analyze different diagnosis methods

Competencies

- Independently be able to define and analyze scientific problems within the area of system identification and diagnosis.
- Independently be able to be a part of professional and interdisciplinary development work within the area of system identification and diagnosis.

Contents:*System Identification*

- General introduction to modelling and system identification
 - Typical modeling methods: physics-based and experiment-based
 - Parametric and non-parametric models
 - General procedures of system identification
- Non-recursive methods
 - Least-Square method and its variants
 - Instrumental variable methods
 - Prediction error methods
- Recursive methods
 - Recursive Least-Square methods
 - Recursive instrumental variable methods
 - Recursive prediction error methods
 - Forgetting factor techniques and time-varying systems identification
- Introduction to subspace methods
- MIMO system identification
- Practical considerations
 - Input signals and persistent excitation
 - Model structure selection
 - Model validation
- Commercial software and examples

Fault Detection and Diagnosis

- Fundamental concepts, terms and principles of FDD
 - Terminology
 - Fundamental principles
 - General overview of typical methods
- FDD modelling and analysis

- Fault types and classification
- Fault modelling
- Fault delectability
- Fault diagnosability
- Parameter identification based diagnosis methods
- State estimation based diagnosis 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

Course module**Advanced Modeling of Dynamic Systems****Avanceret modellering af dynamiske systemer****Prerequisites:**

Mathematics and physics from a relevant Bachelor of Science.

Purpose:

- to contribute to students' attainment of knowledge and comprehension of systematic methods for modelling complex mechanical structures and non-rigid (flexible) mechanical structures, and further to achieve knowledge and comprehension about advanced dynamics equations and solutions for motion of systems with rigid or non-rigid bodies.
- to contribute to students' attainment of knowledge and comprehension of fluid power systems and components and enable them to analyze and model such systems.

Objective:

Students who complete the module must:

Knowledge

- Have knowledge and comprehension for complex mechanical structures
- Have knowledge of modelling non-rigid (flexible) mechanical structures and friction between two moving parts.
- Have knowledge and comprehension for advanced dynamics for motion of systems with rigid or non-rigid bodies.
- Have knowledge and comprehension for 3-dimensional kinematic problems.
- Have comprehension of the characteristics of the pressure media and its influence on the system dynamics

Skills

- Be able to apply systematic methods for modelling complex mechanical structures dynamically in both planar and spatial cases.
- Be able to analyze and model the dynamics of fluid power components and systems
- Be able to judge the usefulness of the set up methods
- Be able to relate the methods to applications in the industry

Competencies

- Independently be able to define and analyze scientific problems within the area of advanced mechanic systems
- Independently be able to be a part of professional and interdisciplinary development work within fluid power and advanced mechanic systems.

Contents:*Advanced mechanic systems:*

- Planar and spatial rigid body kinematics
- Cartesian coordinates and Euler parameters
- Transformation matrices
- Cinematic constraints for plane and spatial joints and actuators
- Cinematic constraints for a cinematically determined system
- Position, velocity and acceleration analysis
- Energy methods
- Lagrange multipliers
- Reaction forces and torques
- Rigid body motion (equations of motion) for planar and spatial cases
- Modelling flexible mechanical bodies and joints
- Advanced friction models

Fluid power:

- Introduction to dynamic hydraulic systems
- Properties of the pressure media and the stiffness influence on the system dynamics
- Continuity and momentum equations
- Systematic approach for deriving dynamic lumped parameter models of system components such as: cylinders, pumps, motors, valves and flow and pressure regulating components
- Flow forces in valves
- Fluid power (servo) drives
- Modelling and simulation of selected characteristic component(s)
- Examples of control system design for fluid power systems

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

Course module**Kalman Filter Theory and its Application****Kalman filterteori og anvendelse****Prerequisites:**

Numerical methods, probability, statistics and stochastic processes

Purpose:

- to contribute to students' attainment of knowledge and comprehension of Kalman filter theory.
- to contribute to students' attainment of knowledge and comprehension of how to apply Kalman filter theory for engineering problems, such as abnormal diagnosis and multiple target tracking etc..

Objective:

Students who complete the module must:

Knowledge

- Have knowledge and comprehension for Kalman filter theory
- Have knowledge and comprehension for extended Kalman filter techniques
- Have knowledge and comprehension for vector-based Kalman filter theory.
- Have comprehension of the application of Kalman filter theory to abnormal scenario diagnosis
- Have comprehension of the application of Kalman filter theory to multiple target tracking

Skills

- Be able to apply Kalman filter theory for state estimation problem in the presence of noises.
- Be able to apply Kalman filter theory for abnormal diagnosis problem
- Be able to apply Kalman filter theory for multiple target tracking problem
- Be able to judge the usefulness of the set up methods
- Be able to relate the methods to applications in the industry
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Competencies

- Independently be able to define and analyze scientific problems using Kalman filter theory
- Independently be able to apply Kalman filter theory for different engineering problems

Contents:*Conventional Kalman filter theory:*

- Scale Kalman filter
- Vector-based Kalman filter
- Convergence and preconditions
-

Extended Kalman filter theory:

- Extended Kalman filter (EKF)
- Uncended Kalman filter (UKF)
- Multi-mode Kalman filter

Application of KF theory

- Fault detection using KF theory
- Fault diagnosis using KF theory
- Multiple target tracking
- Multi-mode system estimation

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

Course module**Structural Mechanics and Dynamics***Strukturel mekanik og dynamik***Prerequisites**

Electronic and/or mechanic engineering in BSc level.

Objective:

Students who complete the module:

Knowledge:

- Understand how kinematics of different structural elements are related to general continuum mechanics
- Have an understanding of fundamental properties of structural systems with emphasis on their impact on the dynamic response
- Have knowledge about fundamental theories and methods for analysis of dynamic structural response
- Have an understanding of the solution procedure in Finite Element Analysis of linear elastic dynamic problems
- Have a basic knowledge and understanding of experimental work related to dynamic testing of structures

Skills:

- Use correct terminology for structural dynamic analysis
- Based on general continuum mechanics, be able to formulate a model for a given structural problem and based on the assumed kinematics, to establish a finite element formulation with the aid of the principle of virtual work
- Be able to analyze the dynamic response of single-degree-of-freedom systems
- Be able to analyze the dynamic response of structures in time domain and frequency domain
- Be able to conduct modal analysis of structures
- Develop and implement a Finite Element Software code for analyzing the dynamic response of a given structure
- Be able to plan and set up a test for determining dynamic structural response

Competence:

- Be able to analyze the dynamic response of a structure
- Be able to select appropriate analysis methods for the analysis of dynamic structural response
- Be able to compare results obtained from different analysis methods and be able to judge the quality of the results
- Be able to quantify errors associated with different types of analysis and evaluate the methods regarding assumptions and simplifications

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

Project module**System Identification and Estimation*****Systemidentifikasjon og estimering*****Prerequisites**

Bachelor of Science in EE, CSE or alike.

Objective:

Students who complete the module:

Knowledge

- Have knowledge and comprehension for the system identification techniques.
- Have fundamental knowledge and comprehension of probability, statistics and stochastic processes.
- Have knowledge of the phases that an engineering project go through
- Understand various theories and methods applied in problem based learning and group organized project work.
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Skills

- Be able to choose different system identification/estimation methods and algorithms for different identification and/or estimation engineering problems.
- Be able to evaluate the results using the probabilistic and/or statistic sense.
- Be able to verify the analytical and numerical approaches by means of simple laboratory experiments
- Be able to communicate scientific results by use of papers, posters and oral presentations
- 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 organized project work
- Can discuss various approaches to project management.

Competencies

- Be able to control the working and development process within the project theme, and be able to develop new solutions within identification/estimation technology
- Independently be able to define and analyze scientific problems of identification /estimation for engineering systems, and based on that make and state the reasons for decisions made for selecting corresponding method.
- Independently be able to continue own development in competences and specialization
- Can find, evaluate and reference literature within the professional field
- Can apply internationally recognized principles for acknowledging and citing work of others

Content:

The project unit focuses on the identification and/or estimation of engineering systems for the control design purpose. The considered systems can come from (petro-)chemical process industry, offshore oil and gas industry, mechanical systems, robots or other engineering systems with the requirements for identification and/or estimation. The considered problem should be formulated and analyzed, then some proper identification/estimation method needs to be selected and implemented. The designed/constructed system is assessed through simulation and practical test as well.

Type of instruction: Project work
Exam format: Individual oral examination based on a project report
Evaluation criteria: As are stated in the Framework Provisions

Course module**Control and Surveillance Processes and Systems****Regulerings og overvågningsprocesser og -systemer****Prerequisites**

Control theory and digital microprocessors.

Objective:

- to contribute to students' attainment of knowledge and comprehension of typical industrial automation systems
- to contribute to students' attainment of knowledge and comprehension of basic nonlinear control theory

Purpose:

The course purpose consists of two parts:

- To contribute to students' attainment of comprehension of some typical industrial control and surveillance processes/systems, such as control of AC-machines, PLC programming and implementation and SCADA systems.
- To contribute to students' attainment of comprehension of fundamental knowledge of non-linear control systems and the feedback linearization design method

Students who complete the module:

Knowledge

- Have comprehension of some typical industrial automation processes/systems including the control of AC-machines, PLC systems and SCADA systems
- Have comprehension of fundamental concepts and terms of nonlinear control theory.
- Have comprehension of Lyapunov's methods for stability analysis and stabilization control design.

Skills

- Be able to apply the learned knowledge to handle some small-sized industrial automation systems.
- Be able to apply the feedback linearization method for non-linear control design.
- Be able to judge the usefulness of the set up methods
- Be able to relate the methods to applications in the industry

Competencies

- Independently be able to define and analyze scientific problems within the area of control and surveillance systems.
- Independently be able to be a part of professional and interdisciplinary development work within the area of control and surveillance systems.

Contents:*Industrial automation systems:*

- Introduction to industrial automation systems
 - Overview of typical energy- industrial automation systems
- Control of AC machines
 - AC machine models, e.g., dynamic models, space-vector models
 - AC machine stationary characteristics
 - Motoring vs. generating mode
 - Speed-torque-current-voltage-flux characteristics
 - Induction machine control
 - Variable frequency operation (V/Hz control)
 - Small-signal stability analysis during V/Hz control
 - Voltage-vector control

- Compensation for resistive voltage drops
 - Load compensation (slip frequency)
- Permanent-magnet machine control
 - Torque production mechanisms
 - Rotor-flux oriented control principles
 - Current control
 - Principles of field-weakening operation
- Programmable Logic Controllers (PLC's)
 - Architecture of PLC systems, includes the microprocessor unit, I/O modules, communications and user interface
 - PLC programming using IEC 61131-3 standard
 - Introduction to Programmable Automation Controllers (PAC's)
 - Examples of vendor PLC's and fieldbus interfaces to PLC's
- Supervisory Control And Data Acquisition (SCADA) systems
 - System concepts and features
 - Human Machine Interface (HMI)
 - Remote Terminal Unit (RTU)
 - Supervisory station
 - Communication infrastructure and methods
 - SCADA architectures, e.g., monolithic, distributed, networked configurations
 - Reliability and security issues
 - Redundancy
 - Reliability statistic calculation
 - Network security
 - Application examples of SCADA in energy systems

Nonlinear control Theory

- Introduction to nonlinear control
- Phase plane analysis
- Lyapunov stability theory
 - Lyapunov Stability
 - Linearization and local stability
 - Lyapunov's direct method
 - Stabilization control design based on Lyapunov method
- Feedback linearization
 - Lie derivatives and Lie brackets
 - Diffeomorphisms and state transformations
 - Frobenius theorem
 - Input-state linearization of SISO systems
 - Input-output linearization of SISO systems

Type of instruction:

As described in the introduction to Chapter 3.

Exam format:

Individual oral or written examination

Evaluation criteria:

As are stated in the Framework Provisions

Course module**Fault Detection and Diagnosis Techniques****Fejlfinding og diagnosticeringsteknikker****Prerequisites**

Probability, statistics and stochastic processes, system identification and estimation,

Purpose:

- To contribute to students' attainment of comprehension of some typical fault detection and diagnosis techniques.

Objective:

Students who complete the module:

Knowledge

- Have comprehension of some typical model-free fault detection and diagnosis methods
- Have comprehension of some typical model-based fault detection and diagnosis methods

Skills

- Are able to apply the learned knowledge to handle some fault detection and diagnosis problems.
- Are able to judge the usefulness of the set up methods
- Are able to relate the methods to applications in the industry

Competencies

- Independently be able to define and analyze scientific problems within the area of fault detection and diagnosis.
- Independently be able to be a part of professional and interdisciplinary development work within the area of fault detection and diagnosis.

Contents:

- Fundamental concepts, terms and principles of FDD
- Fault modelling and analysis
 - Fault types and classification
 - Fault modelling
 - Fault detectability
 - Fault diagnosability
- Residual generation (I): Observer based FDD methods for deterministic systems
 - Review of observer theory
 - Fault detection using single observer
 - Fault diagnosis using a bank of observers
- Residual generation (II): Kalman filter based FDD methods for stochastic systems
 - Review of probability and stochastic processes
 - Kalman filter theory
 - Extended Kalman filter
 - Fault detection using single Kalman filter
 - Fault diagnosis using a bank of Kalman filters (Multiple Model (MM) method)
 - Fault diagnosis using a bank interactive Kalman filters (Interactive Multiple Model (IMM) method)
 - Fault diagnosis using a two-stage Kalman filter for additive and multiplicative faults
- Robust residual generation (I): Unknown Input Observer (UIO) method
 - (complete) Disturbance decoupling principle
 - UIO theory
 - Robust FDD using UIO method

- Robust residual generation (II): Robust filtering method
 - Disturbance attenuation principle
 - Modelling uncertainties
 - Introduction to robust filtering theory (H_∞ optimal control theory)
 - Robust FDD using H_∞ filtering method
- Residual evaluation
 - Simple voting techniques
 - Statistical testing approaches
 - Likelihood function methods
 - Probabilities of false alarm and miss
- FDD using Parity space approaches
 - Detectability and diagnosability
 - Parity space methods for FDD
- Parameter estimation based FDD methods
 - Parametric fault characteristics
 - FDD using parameter estimation (least-square methods)
 - FDD using recursive system identification methods
- Signal-based (model-free) FDD methods
 - FDD using spectrum analysis
 - FDD using short-timed Fourier transform and wavelet transform
 - FDD using some artificial intelligence methods

Type of instruction:

As described in the introduction to Chapter 3.

Exam format:

Individual oral or written examination

Evaluation criteria:

As are stated in the Framework Provisions

Course module**Reliability Modeling and Analysis****Påideliighedsmodellering og analyse****Prerequisites**

Probability, statistics and stochastic processes

Purpose:

The course purpose consists of two parts:

- To contribute to students' attainment of comprehension of fundamental principles for reliability modelling
- To contribute to students' attainment of comprehension of fundamental principles for reliability analysis

Objective:

Students who complete the module:

Knowledge

- Have comprehension of fundamental principles for reliability modelling and analysis
- Have comprehension of reliability analysis using logic diagrams
- Have comprehension of Bayesian methods for simple reliability modelling and analysis

Skills

- Be able to apply probabilistic methods for reliability modelling and analysis.
- Be able to judge the usefulness of the set up methods
- Be able to relate the methods to applications in the industry

Competencies

- Independently be able to define and analyze scientific problems within the area of reliability modelling and analysis.
- Independently be able to be a part of professional and interdisciplinary development work within the area of reliability modelling and analysis.

Contents:

- Principles of reliability modelling
 - Quality and reliability
 - Creating reliability vs. measuring reliability
 - Failure modes, causes and mechanisms
- Probabilistic models of failure phenomena
 - Essentials of probability theory
 - Probabilistic definition of reliability
- Component reliability
 - Common distribution in component reliability
 - Component reliability model selection
- System reliability analysis
 - Structure analysis and design
 - Reliability block diagram method
 - Fault modes and effects analysis
 - Fault tree analysis
- Hazard and risk analysis

- Reliability analysis of dynamic systems
 - Markov theory and applications
 - Simulation methods (Monte Carlo methods)
 - Analysis of fault tolerant systems

- Bayesian analysis
 - Foundations of Bayesian statistical inference
 - Bayesian inference in reliability
 - Performing Bayesian reliability analysis
 - Bayesian decision and estimation theory

- Uncertainty analysis and propagation methods
 - Measuring uncertainty
 - Uncertainty propagation

- Reliability in computer systems
 - Hardware reliability vs. software reliability
 - Software reliability improvement methods
 - Software reliability assessment methods

Type of instruction:

As described in the introduction to Chapter 3.

Exam format:

Individual oral or written examination

Evaluation criteria:

As are stated in the Framework Provisions

Project module**Fault Diagnosis and Reliability Analysis*****Fejldiagnosticering og pålidelighedsanalyse*****Prerequisites**1st Semester**Purpose:**

The purpose of the project unit is to contribute to students' attainment of knowledge about fault detection, diagnosis and relevant reliability analysis of engineering systems

Objective:

Students who complete the module:

Knowledge

- Have knowledge and comprehension for how to design, analyze and model different fault diagnosis systems for different typical engineering systems
- Have knowledge and comprehension of fundamental reliability analysis and modelling

Skills

- Be able to apply probabilistic methods for reliability modelling, analysis and assessment.
- Be able to apply different fault diagnosis methods for developing monitoring and surveillance system.
- Be able to verify the analytical and numerical approaches either by means of laboratory experiments or simulation study

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within monitoring and surveillance system.
- Independently be able to define and analyze monitoring/diagnosis problems from the reliability point of view, and based on that make and state the reasons for decisions made for method selection.
- Independently be able to continue own development in competences and specialization

Content:

The project is based on a problem to monitor a process system, which can be a chemical process, mechanical system, or any other safety-critical systems. The reliability of the considered system as well as individual components should be analyzed and assessed using the probabilistic methods. The strategies and methods for Fault Detection and Diagnosis (FDD) should be determined for the considered system by taking some intelligent methods into consideration. The chosen FDD solution has to be implemented on a real-time platform and tested, either by the computer simulations or a dedicated hardware

Type of instruction:

Project work

Exam format:

Individual oral examination based on a project report

Evaluation criteria:

As are stated in the Framework Provisions

Course module**Adaptive and Optimal Control****Adaptiv og optimal regulering****Prerequisites**

Linear control theory, numerical methods, optimization theory

Purpose:

The course purpose is to contribute to students' attainment of knowledge and comprehension of the fundamental knowledge of advanced control with adaptive mechanisms and optimal control techniques.

Objective:

Students who complete the module:

Knowledge

- Have comprehension of the fundamental principles of typical adaptive control methods
- Have comprehension of the fundamental principles of typical optimal control methods

Skills

- Be able to use different adaptive and optimal control algorithms.
- Be able to apply some typical adaptive/optimal control methods to solve some specific linear control problems under the assistance of available computation software

Competencies

- Independently be able to define and analyze scientific problems within the area of adaptive and optimal control.
- Independently be able to be a part of professional and interdisciplinary development work within the area of adaptive and optimal control.

Contents:*Adaptive control:*

- Introduction to adaptive control
- Typical adaptive control principles and methods
 - Feed-forward adaptive control and feedback adaptive control
- Feedback adaptive control
 - Gain scheduling
 - Model Reference Adaptive Control (MRAC)
 - Gradient optimization MRAC's
 - Stability optimized MRAC's
 - Model identification adaptive control
 - Parametric adaptive control
 - Explicit parameter adaptive control
 - Implicit parameter adaptive control
 - Multiple model adaptive control
 - Self-tuning regulators

Optimal Control:

- Review of optimal control principles
- Infinite horizon optimization: Linear Quadratic (LQ) control
 - Standard problem formulation
 - Solutions and Riccati equations
 - Discrete-time LQ control
 - Linear quadratic Gaussian (LQG) control
 - Application examples
- Finite horizon optimization (I): Minimum Variance Control (MVC)

- Problem formulation for SISO systems
- Solution and its properties
- Generalized MVC
- Offset problem
- Self-tuning MVC
- Finite horizon optimization (II): Model predictive Control (MPC)
 - Principles of MPC
 - Typical MPC schemes based on different models
 - Numerical computation algorithms
 - Nonlinear MPC
 - Commercial software and examples
- Adaptive MPC
 - Principles of adaptive MPC
 - Typical algorithms

Type of instruction:

As described in the introduction to Chapter 3.

Exam format:

Individual oral or written examination

Evaluation criteria:

As are stated in the Framework Provisions

Course module**Intelligent Control and Reliability Oriented Design*****Intelligent regulering og design af pålidelige systemer*****Prerequisites**

Linear control theory, numerical methods, optimization theory

Purpose:

The course purpose is to contribute to students' attainment of knowledge about some typical intelligent control methods with consideration of reliability

Objective:

Students who complete the module:

Knowledge

- Have comprehension of the fundamental principles of typical intelligent control methods
- Have comprehension of the fundamental principles of reliability oriented design

Skills

- Be able to apply different intelligent control algorithms for different engineering problems
- Be able to apply reliability oriented design to solve some specific reliable control problems under the assistance of available computation software

Competencies

- Independently be able to define and analyze scientific problems within the area of intelligent and reliable control
- Independently be able to be a part of professional and interdisciplinary development work within the area of intelligent and reliable control.

Contents:

- Intelligent control based on fuzzy logic and neural networks
 - Boolean logic, fuzzy theory of sets, membership functions, fuzzy logic
 - Fuzzy relations, fuzzy rule bases, defuzzication
 - Fuzzy modelling and fuzzy control
 - Neuron model, learning, back propagation error, gradient methods,
 - The coherence between regression and defuzzification, neural-fuzzy systems, learning in rule bases, extraction of rules from neural network
- Supervisory control
 - Discrete event systems and models
 - Languages and automata
 - Safety, blocking, state estimation and diagnosis
 - Controllability theorem
 - Supervisory control problem and their solutions
- Hybrid control systems
 - Terminology of hybrid systems
 - Control architectures of hybrid systems
 - Modelling of hybrid systems, Hybrid automaton and its operation
 - Reachability and controllability analysis
 - Stability of hybrid systems
 - Multiple Lyapunov function method
 - Control synthesis for linear switched hybrid systems
- Active fault-tolerant (reconfigurable) control

- General structure of active FTCS
- Classification of existing design strategies
- Incorporation of performance degradation in designing FTCS
- Reliability assessment of FTCS
- Reconfigurable controller design techniques
- Statistic estimation of reliability
- Reliability evaluation of FDD methods

Type of instruction:

As described in the introduction to Chapter 3.

Exam format:

Individual oral or written examination

Evaluation criteria:

As are stated in the Framework Provisions

Course Module
Machine Learning
Maskinl ring

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 neighbor's, 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:

Are stated in the Framework Provisions

Elective Project module**Design of Intelligent Reliable Systems*****Design af intelligente pålidelige systemer*****Prerequisites**

2nd semester at the Master of Science in Intelligent Reliable Systems or alike.

Purpose:

The purpose of the project unit is to contribute to students' attainment of knowledge about how to design intelligent control-, diagnostic- or surveillance systems with the consideration of reliability.

Objective:

Students who complete the module:

Knowledge

- Have knowledge and comprehension for how to design control-, diagnostic- and surveillance systems by taking the reliability into consideration.
- Have knowledge and comprehension of different advanced control methods and their potential application in intelligent reliable system development.

Skills

- Be able to judge the usefulness of the used different scientific methods for the design of intelligent control-, diagnostic- and surveillance systems for engineering systems.
- Be able to apply quantitative and qualitative, intelligent and/or model-based methods for reliable system design

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within intelligent control-, diagnostic- and surveillance of engineering systems.
- Be able to show entrepreneurship to define and analyze scientific problems in the area of control-, diagnostic- and surveillance of engineering systems, and based on that make and state the reasons for decisions made.
- Be able to set up innovative ideas within the area of control-, diagnostic- and surveillance of engineering systems
- Independently be able to continue own development in competences and specialization

Content:

The project is based on a design problem for reliable control system. The considered physical system can be a (petro-) chemical process, mechanical system, or any other safety-critical systems. The control system design should take fault tolerant control into consideration. The strategies and methods for fault tolerant design is determined for the considered system possibly using some intelligent approaches as support tools. The chosen solution has to be implemented on a real-time platform and tested, either by the computer simulations or a dedicated hardware system. The students in the project work shall demonstrate their ability to handle complex problems by scientific methods.

Type of instruction:

Project work

Exam format:

Individual oral examination based on a project report

Evaluation criteria:

As are stated in the Framework Provisions

Elective Project module**Advanced control and estimation****Avanceret kontrol og estimering teknologi****Prerequisites**

2nd semester at the Master of Science in Intelligent Reliable Systems or alike.

Purpose:

The purpose of the project unit is to contribute to students' attainment of knowledge about advanced control and estimation technologies and their engineering applications

Objective:

Students who complete the module:

Knowledge

- Have the knowledge and comprehension of fundamental principles, characteristics and limitations of some advanced control and estimation techniques, such as model-based adaptive control, optimal control, model predictive control as well as model -based/-free intelligent control.
- Have knowledge and comprehension of different advanced control methods and their potential applications in engineering systems.

Skills

- Be able to judge the usefulness of the selected different scientific methods for the design of advanced control and estimation for engineering systems.
- Be able to analyze, realize and test the selected control and estimation method in a professional manner

Competences

- Be able to control the working and development process within the project theme, and be able to develop new solutions within advanced control and estimation of engineering systems.
- Be able to show entrepreneurship to define and analyse scientific problems in the area of advanced control and estimation of engineering systems, and based on that make and state the reasons for decisions made.
- Be able to set up innovative ideas within the area of advanced control and estimation of engineering systems
- Independently be able to continue own development in competences and specialization

Content:

The project is based on a design problem for advanced control and/or estimation system. The considered physical system can be a (petro-) chemical process, mechanical system, or any other safety-critical systems. The control and/or estimation design should take advanced technology into consideration instead of employing fundamental control and/or estimation solution. The strategies and methods for this design are encouraged to consider using some intelligent approaches as support tools. The chosen solution has to be implemented on a real-time platform and tested, either by the computer simulations or a dedicated hardware system. The students in the project work shall demonstrate their ability to handle complex problems by scientific methods.

Type of instruction:

Project work

Exam format:

Individual oral examination based on a project report

Evaluation criteria:

As are stated in the Framework Provisions

Project module
Master's Thesis
Kandidatspeciale

Prerequisites

3rd semester at the Master of Science in Intelligent Reliable Systems or alike

Objective:

Purpose:

The purpose of the project unit is to contribute to students' documentation of his/her obtained skills and the level at which he/she is able to exploit these skills in solving a specified task within the specialization of Intelligent Reliable Systems.

Students who complete the module:

Knowledge

- Have knowledge and comprehension within the area of Intelligent Reliable Systems at the highest international level
- Be able to critically judge knowledge and identify new scientific problems within the area of Intelligent Reliable Systems
- Have comprehension for the implications within the research work (research ethics)

Skills

- Be able to judge the usefulness of different scientific methods and tools for analysis and problem solving within the field of Intelligent Reliable Systems
- Be able to use advanced laboratory set ups, data analysis methods and analysis and modelling methods within the field of Intelligent Reliable Systems.
- Be able to communicate about scientific problems both to specialist and the public.
- Have obtained skills related to the industrial area within Intelligent Reliable Systems technology

Competences

- Be able to control complex/unexpected working and development situations within the Intelligent Reliable Systems area, and be able to develop new solutions.
- Independently be able to define and analyze scientific problems, and based on that make and state the reasons for decisions made.
- Independently be able to continue own development in competences and specialization
- Independently be able to be the head of professional and interdisciplinary development work and be able to undertake the professional responsibility.

Content:

The final project may study new subjects or be an extension of the project work from previous semesters. The subject matter will remain in the area of Intelligent Reliable Systems. The project may be of theoretical or experimental nature, and will often be in collaboration with an industrial company or other research institution performing research in the area of Intelligent Reliable Systems technology.

Type of instruction:

Project work

Exam format:

Individual oral examination based on a project report

Evaluation criteria:

As are 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 and enters into force as of September 2014.

Students who wish to complete their studies under the previous curriculum from Intelligent Information Systems must conclude their education by the summer examination period Summer 2015 at the latest, since examinations under the previous curriculum are not offered after this time.

In accordance with the Framework Provisions for the Faculty of Engineering and Science 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 program at a university in Denmark or abroad

In the individual case, the Board of Studies can approve successfully completed (passed) program elements from other Master's programs in lieu of program elements in this program (credit transfer). The Board of Studies can also approve successfully completed (passed) program elements from another Danish program or a program outside of Denmark at the same level in lieu of program 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 Additional information

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

5.6 Completion of the Master's program

The Master's program must be completed no later than four years after it was begun.