AALBORG UNIVERSITET

CIVILINGENIØR, CAND.POLYT. I REGULERING OG AUTOMATION, 2018

CIVILINGENIØR
AALBORG

MODULER SOM INDGÅR I STUDIEORDNINGEN

INDHOLDSFORTEGNELSE

NETWORKED CONTROL SYSTEMS

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds on knowledge obtained through the Bachelor of Science (BSc) in Engineering (Electronics and IT) education at Aalborg University. In particular, qualifications equivalent to those obtained through the BSc in Engineering with specialization in Control Engineering is recommended.

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

Students who complete the module: have implemented a controller for a system with multiple inputs and outputs involving the use of a network. One aim is that the student should be able to design and analyse commonly used networks and protocols with focus on their real time properties. A second aim is that the student is able to design and implement classical solutions for multivariable control along with modern state space solutions including state feedback and feedback from observed states. Special attention is given to the implication of timing and timing variations in the network on the control behavior

LEARNING OBJECTIVES

KNOWLEDGE

- Must have knowledge about common control structures
- Must have knowledge about common communication standards, protocols and network topologies
- Must be able to understand network system models

SKILLS

- Must be able to implement a control system using a selected network standard and analyse timing properties relevant for the control system behavior
- Must be able to design and implement classic and modern controllers for a multivariable system and analyse closed loop properties like pole placement, disturbance rejection and reference following.
- 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

COMPETENCES

- Must have competencies in analysis and design of control of systems in state space formulation including state feedback and observer design.
- Must have competencies in design and implementation of distributed real time systems and real time requirements for control systems.

TYPE OF INSTRUCTION

As described in the introduction to Chapter 3.

EXAM

EXAMS

Name of exam	Networked Control Systems
Type of exam	Oral exam based on a project

ECTS	15
Assessment	7-point grading scale
Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Netværksbaserede kontrolsystemer
Module code	ESNCAK1P1
Module type	Project
Duration	1 semester
Semester	Autumn
ECTS	15
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

STOCHASTIC PROCESSES

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds on knowledge of probability, statistics, linear algebra, Fourier theory, and programming

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

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 wide-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.

COMPETENCES

- Have the appropriate “engineering” intuition of the basic 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

EXAMS

Name of exam	Stochastic Processes
Type of exam	Written or oral exam
ECTS	5
Assessment	7-point grading scale
Type of grading	Internal examination

Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Stokastiske processer
Module code	ESNCAK1K1F
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

DISTRIBUTED REAL TIME SYSTEMS

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds on knowledge of Basic Network Communication and Protocols as e.g. obtained in the courses Communication in Electronic Systems (EIT 5th Semester) or Network Technologies and Distributed Systems (ITC 5th Semester)

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

- fieldbus technologies and concepts of communication
- global state protocols
- replication of systems for redundancy concerns
- application domains and their requirements, relevant Quality of Service parameters
- queuing theory, basic models
- synchronization issues
- reliability modeling, including safety, scalability, maintainability issues
- modeling tools, such as Deterministic Network Calculus
- network simulation tools (examples include ns-2/ns-3, OMNET)

SKILLS

- Service models for field bus and their limitation
- utilizing consistency between automates in a distributed system
- describing a loose coupled system with basic traffic pattern modeling
- home automation and similar domain areas in perspective of communication and safety
- quality of service
- protocol design

COMPETENCES

- identify requirements and select an appropriate communication architecture
- analyze and design complex networked systems with hard requirements such as providing real time guarantees
- model system behavior using analytical or simulation tools

TYPE OF INSTRUCTION

As described in the introduction to Chapter 3.

EXAM

EXAMS

Name of exam	Distributed Real Time Systems
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed

Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Distribuerede realtidssystemer
Module code	ESNCAK1K2F
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

MULTIVARIABLE CONTROL

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds on skills within analyses and design of classical control systems

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

To expand qualifications in classic control and to introduce modern control methods based on state space description.

LEARNING OBJECTIVES

KNOWLEDGE

- Control of large scale systems e.g. sugar production, power production, cement production
- Control of unit operations: e.g. boiler control, evaporation control, distillation control, energy transport control, reactor control, heat exchanger control.

SKILLS

- Control of large scale systems
- Anti-integrator windup
- Reduced order observers

COMPETENCES

- Root locus design
- Digital control methods
  - Design by emulation
  - Discrete design
- Time delays
- State space control
  - Poles and zeros of state space models
  - State space transformations
  - Controllability
  - State feedback design
  - Observability
  - Observer gain design
  - Observer based control
  - Separations theorem
  - Integral state space control
  - Zero assignment
  - Reference input

TYPE OF INSTRUCTION

As described in the introduction to Chapter 3

EXAM

EXAMS

Name of exam	Multivariable Control

Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Flervariable reguleringssystemer
Module code	ESNCAK1K3
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

MULTIVARIABLE CONTROL SYSTEMS

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The project module builds on knowledge obtained during the 1st semester

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

Students who complete the module: must be able to analyze modern control methods for multi input/multi output systems and to apply modeling methods and control synthesis for mechanical or energy conversion systems.

LEARNING OBJECTIVES

KNOWLEDGE

- Stability and performance limitations in robust control
- Additive and multiplicative model uncertainty
- Robust stability
- Robust performance
- Small gain theorem
- Dynamic programming
- Riccati equation
- Elimination of steady state errors in optimal control
- Use of observer in LQG control
- Stability properties of optimal controller
- Stability properties of finite horizon control
- Solving predictive control with constraints using quadratic programming
- Dealing with uncertain and nonlinear systems in model predictive control.
- Mass- and energy balances
- Fundamental laws of thermodynamics
- Models with lumped and distributed parameters
- Model structures for system identification: AR, MA, ARMA, ARMAX, Box-Jenkins
- System identification methods: Moment method , Least squares method, Prediction error method, Maximum likelihood method, Recursive and adaptive parameter estimation
- Lagrange and Hamiltonian mechanics
- Rotation parameters, rotation matrices, quaternion
- Model representations (differential equations, state space, transfer function, differential-algebraic equations, descriptor form)

SKILLS

- Formulation of optimal control problems with references and disturbances
- Soft real time implementation
- Formulation of the standard robustness problem
- Theory and solution to the standard robust problem
- Formulation of control problems using models of constraints, disturbances and references combined with a performance function (Model Predictive Control)
- Software tools for solving constrained optimization problems
- Should be able to apply system identification methods

COMPETENCES

- Synthesis of robust control systems, model predictive control systems, and of LQG systems
- Should be able to formulate models of a basic energy conversion systems and mechanical systems.

TYPE OF INSTRUCTION

As described in the introduction to Chapter 3.

EXAM

EXAMS

Name of exam	Multivariable Control Systems
Type of exam	Oral exam based on a project
ECTS	15
Assessment	7-point grading scale
Type of grading	External examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Flervariable reguleringssystemer
Module code	ESNCAK2P1
Module type	Project
Duration	1 semester
Semester	Spring
ECTS	15
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

MODELING OF MECHANICAL AND THERMAL SYSTEMS

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds on knowledge obtained through the Bachelor of Science (BSc) in Engineering (Electronic Engineering and IT education and the 1st semester of the Master's Programme in Control and Automation (CA) at Aalborg University. In particular, qualifications equivalent to those obtained through the Bachelor of Engineering in Electronics is recommended.

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

- Mass- and energy balances
- Preservation of momentum
- Definition of control volumes, Reynolds theorem
- Empirical relations for heat transfer friction
- Properties for liquids and gasses
- Fundamental laws of thermodynamics
- Models with lumped parameters¨
- Models with distributed parameters
- Model structures for system identification: AR, MA, ARMA, ARMAX, Box-Jenkins
- System identification methods: Moment method , Least squares method, Prediction error method, Maximum likelihood method, Recursive and adaptive parameter estimation
- Lagrange and Hamiltonian mechanics
- Coordinate systems and coordinate transformation for mechanical systems.
- Rotation parameters, rotation matrices, quaternions
- Kinematics
- Satellite and Robot dynamics
- Model representations (differential equations, state space, transfer function, differential-algebraic equations, descriptor form)
- Model reduction
- Linearization
- Model properties (controllability, observability, stability)

SKILLS

- Should be able to formulate models of a basic energy conversion systems and mechanical systems.
- Should be able to apply system identification methods
- Should be able to adapt the model to a suitable representation.

COMPETENCES

- Capable of modeling a system with sufficient information level, suitable for solving a given control problem

TYPE OF INSTRUCTION

As described in the introduction to Chapter 3.

EXAM

EXAMS

Name of exam	Modeling of Mechanical and Thermal Systems
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Modellering af mekaniske og termiske systemer
Module code	ESNCAK2K1
Module type	Course
Duration	1 semester
Semester	Spring
ECTS	5
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

OPTIMALITY AND ROBUSTNESS

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds on knowledge obtained through the Bachelor of Science (BSc) in Engineering and the 1st semester of the Master's Programme in Control and Automation (CA) at Aalborg University. In particular, qualifications equivalent to those obtained through the Bachelor of Engineering in Electronics and the CA 1st semester course Multivariable Control is recommended.

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

The aim of this module is to obtain qualifications in formulation and solution of control problems where the objective can be formulated as an optimization problem in which the trajectories of inputs, state variables and outputs are included in an objective function and can be constrained. The formulation will include a model which describes the dynamic behavior of the physical plant with given control inputs and disturbances. Models describing disturbances and references can be included to describe predictive problems. A further aim is to provide methods to analyze robustness of closed loop stability and performance when discrepancy between the physical plant and the model is bounded by specified uncertainty bounds and to study dimensioning methods, which aim to ensure robustness of stability and performance given specified uncertainty bounds.

LEARNING OBJECTIVES

KNOWLEDGE

- Must have an understanding of basic concepts within optimal control, such as linear models, quadratic performance, dynamic programming, Riccati equations etc.
- Must have an understanding of the use of observers to estimate states in a linear dynamical system
- Must have insight into the stability properties of optimal controllers
- Must have insight into the stability properties of finite horizon control, and how to ensure stability
- Must have knowledge about performance specifications that are not quadratic
- Must have knowledge of additive and multiplicative model uncertainty
- Must have insight into the small gain theorem and its applications in robust control
- Must have insight into robust stability and robust performance

SKILLS

- Must be able to formulate linear control problems using models of disturbances and references combined with a quadratic performance function and solve them using appropriate software tools, e.g. Matlab
- Must be able to introduce integral states in control laws to eliminate steady state errors
- Must be able to design observers while taking closed-loop stability into account
- Must be able to utilize quadratic programming to solve predictive control problems with constraints.
- Must be able to use software tools such as Matlab to solve constrained optimization problems
- Must be able to formulate the standard robustness problem as a two-input-two-output problem and solve it using appropriate methods
- Must be able to assess the limitations model uncertainty sets impose on the achievable performance for systems described by linear models
- Must be able to use singular value plots and the H infinity norm of appropriate transfer function to assess robustness
- Must be able to perform H infinity norm optimization as a method to tune controllers

COMPETENCES

- Must be able to formulate and solve optimal control problems with references and disturbances
- Must understand the implications of disturbances and uncertainties in the context of linear dynamical systems, and be able to address these via robust control design

TYPE OF INSTRUCTION

As described in the introduction to Chapter 3.

EXAM

EXAMS

Name of exam	Optimality and Robustness
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Optimal- og robust regulering
Module code	ESNCAK2K2
Module type	Course
Duration	1 semester
Semester	Spring
ECTS	5
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

CONTROL OF COMPLEX SYSTEMS

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module build on knowledge obtained during the 2nd semester

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

- Must have knowledge about modeling of electromechanical and thermal systems.
- Must be able to understand methods for control of complex systems

SKILLS

- Must be able to analyze methods of state observation, parameter estimation and sensor information fusion in systems
- Must be able apply methods of supervisory control, fault tolerant control or fault detection

COMPETENCES

- Must be able to design and implement a control system for a complex system.

TYPE OF INSTRUCTION

As described in the introduction to Chapter 3.

EXAM

EXAMS

Name of exam	Control of Complex Systems
Type of exam	Oral exam based on a project
ECTS	20
Assessment	7-point grading scale
Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Regulering af komplekse systemer
Module code	ESNCAK3P1
Module type	Project
Duration	1 semester

Semester	Autumn
ECTS	20
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

ACADEMIC INTERNSHIP

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

An academic internship agreement approved by the company, an AAU supervisor and the study board for electronics and it (ESN).

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

The student stays in a company with the purpose of learning and applying theories and methods to address engineering problems in an industrial context. In addition, the student will be introduced to business procedures and policies.

LEARNING OBJECTIVES

KNOWLEDGE

- Has knowledge about the organization of the company and business procedures and policies.
- Has knowledge about performance measures in the company.
- Has developed a fundamental business sense.
- Has knowledge of the competence profile of the program and how the academic internship contributes to the competence profile.
- Has gained deepened knowledge into engineering theories and methods within the program.

SKILLS

- Can initiate and ensure the completion of an agreement for the academic internship, with learning objectives corresponding to the semester at the master's program.
- Can apply analytic, methodological and/or theoretic skills to address advanced engineering problems in an industrial context.
- Can contribute in a professional manner to company objectives as an individual and in teams in accordance with the project management model applied in the company.
- Can collaborate and communicate with peers, managers and others.
- Can document the academic internship in a report and defend it orally.

COMPETENCES

- Can discuss and reflect on the learning outcomes of the academic internship.
- Can discuss the need for knowledge transfer between academia and industry.
- Has a deepened understanding of the academic interests to pursue in the master's thesis and possible job positions to aim at after graduation.

TYPE OF INSTRUCTION

Project work

EXAM

EXAMS

Name of exam	Academic Internship
Type of exam	Oral exam based on a project
ECTS	20

Assessment	7-point grading scale
Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Projektorienteret forløb
Module code	ESNCAK3P2
Module type	Project
Duration	1 semester
Semester	Autumn
ECTS	20
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

ACADEMIC INTERNSHIP

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

An academic internship agreement approved by the company, an AAU supervisor and the study board for electronics and it (ESN).

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

The student stays in a company with the purpose of learning and applying theories and methods to address engineering problems in an industrial context. In addition, the student will be introduced to business procedures and policies.

LEARNING OBJECTIVES

KNOWLEDGE

- Has knowledge about the organization of the company and business procedures and policies.
- Has knowledge about performance measures in the company.
- Has developed a fundamental business sense.
- Has knowledge of the competence profile of the program and how the academic internship contributes to the competence profile.
- Has gained deepened knowledge into engineering theories and methods within the program.

SKILLS

- Can initiate and ensure the completion of an agreement for the academic internship, with learning objectives corresponding to the semester at the master's program.
- Can apply analytic, methodological and/or theoretic skills to address advanced engineering problems in an industrial context.
- Can contribute in a professional manner to company objectives as an individual and in teams in accordance with the project management model applied in the company.
- Can collaborate and communicate with peers, managers and others.
- Can document the academic internship in a report and defend it orally.

COMPETENCES

- Can discuss and reflect on the learning outcomes of the academic internship.
- Can discuss the need for knowledge transfer between academia and industry.
- Has a deepened understanding of the academic interests to pursue in the master's thesis and possible job positions to aim at after graduation.

TYPE OF INSTRUCTION

Project work

EXAM

EXAMS

Name of exam	Academic Internship
Type of exam	Oral exam based on a project
ECTS	25

Assessment	7-point grading scale
Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Projektorienteret forløb
Module code	ESNCAK3P3
Module type	Project
Duration	1 semester
Semester	Autumn
ECTS	25
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

ACADEMIC INTERNSHIP

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

An academic internship agreement approved by the company, an AAU supervisor and the study board for electronics and it (ESN).

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

The student stays in a company with the purpose of learning and applying theories and methods to address engineering problems in an industrial context. In addition, the student will be introduced to business procedures and policies.

LEARNING OBJECTIVES

KNOWLEDGE

- Has knowledge about the organization of the company and business procedures and policies.
- Has knowledge about performance measures in the company.
- Has developed a fundamental business sense.
- Has knowledge of the competence profile of the program and how the academic internship contributes to the competence profile.
- Has gained deepened knowledge into engineering theories and methods within the program.

SKILLS

- Can initiate and ensure the completion of an agreement for the academic internship, with learning objectives corresponding to the semester at the master's program.
- Can apply analytic, methodological and/or theoretic skills to address advanced engineering problems in an industrial context.
- Can contribute in a professional manner to company objectives as an individual and in teams in accordance with the project management model applied in the company.
- Can collaborate and communicate with peers, managers and others.
- Can document the academic internship in a report and defend it orally.

COMPETENCES

- Can discuss and reflect on the learning outcomes of the academic internship.
- Can discuss the need for knowledge transfer between academia and industry.
- Has a deepened understanding of the academic interests to pursue in the master's thesis and possible job positions to aim at after graduation.

TYPE OF INSTRUCTION

Project work

EXAM

EXAMS

Name of exam	Academic Internship
Type of exam	Oral exam based on a project
ECTS	30

Assessment	7-point grading scale
Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Projektorienteret forløb
Module code	ESNCAK3P4
Module type	Project
Duration	1 semester
Semester	Autumn
ECTS	30
Location of the lecture	Campus Copenhagen
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

MASTER'S THESIS

2018/2019

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

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.

COMPETENCES

- 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.

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

EXAMS

Name of exam	Master's Thesis
Type of exam	Oral exam based on a project
ECTS	50
Assessment	7-point grading scale
Type of grading	External examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Kandidatspeciale
Module code	ESNCAK4P2
Module type	Project
Duration	1 semester
Semester	Spring
ECTS	50
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

MASTER'S THESIS

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The master's thesis builds on knowledge obtained during the 1st – 3rd semester

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

The master thesis can be conducted as a long master thesis. If choosing to do a long master thesis, it has to include experimental work and has to be approved by the study board. The amount of experimental work must reflect the allotted ECTS.

LEARNING OBJECTIVES

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.

COMPETENCES

- 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.

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

EXAMS

Name of exam	Master's Thesis

Type of exam	Oral exam based on a project
ECTS	30
Assessment	7-point grading scale
Type of grading	External examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Kandidatspeciale
Module code	ESNCAK4P1
Module type	Project
Duration	1 semester
Semester	Spring
ECTS	30
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

FAULT DETECTION, ISOLATION AND MODELLING

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds on knowledge of basic probability theory, dynamical systems formulated in state space and frequency, and the module Stochastic Processes

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

Every real life system will at some point or another experience faults. Students who complete this course will be able to, in a systematic manner, to analyze dynamic systems as well as distributed, network coupled systems. For each of the two system types the student will be able to:

- List the different considered faults, how they propagate through the system and assess their severity and occurrence likelihood.
- Develop methods for estimating if a given fault is present or not.
- Develop fault tolerant strategies for ensuring the continuation of the system in the presence of faults.

LEARNING OBJECTIVES

KNOWLEDGE

- Of the taxonomy of fault tolerant systems
- Of simulation tools for testing and verification

SKILLS

- In analyzing a system for possible faults and modeling these
  - Failure Mode and Effect Analysis
  - Structural analysis
  - Faults in TCP/IP based Networks
- In evaluating the severity of different faults and prioritizing
  - By means of simulations
  - Stochastic models for components and their availability
- In designing detectors for selected faults
  - Structural analysis
    - Analytical Redundancy Relations
  - Passive fault detection
    - Unknown input observers
    - Parameter estimators
    - Parity space filters
  - Active fault detection
    - Design of perturbation signals
    - Neighbor discovery
    - Round-trip time
    - Heartbeats
    - Acknowledged transmissions
  - Decision ruling
    - Threshold based
    - Stochastic based
- In designing strategies for handling faults
  - Passive fault tolerance
    - Robust controllers
    - Reliable message broadcasting
    - Multipath routing
  - Active fault tolerance
    - Control strategy change

- Redundant systems with backup components

COMPETENCES

- In designing fault tolerance strategies for a given system

TYPE OF INSTRUCTION

As described in the introduction to Chapter 3.

EXAM

EXAMS

Name of exam	Fault Detection, Isolation and Modelling
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Fejldetektion, -isolation og -modellering
Module code	ESNNDSK2K1
Module type	Course
Duration	1 semester
Semester	Spring
ECTS	5
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

ROBOT VISION

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds upon basic knowledge of linear algebra and statistics

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

LEARNING OBJECTIVES

KNOWLEDGE

- Must have gained an understanding of fundamental concepts related to robotics.
- Must have an understanding of how vision and other sensors can be integrated with a robot
- Must have an understanding of relevant technologies enabling the design of intelligent machines (artificial intelligence).
- Must have an understanding of highly flexible and integrated automation technologies.
- Must have an understanding of the business potential of intelligent manufacturing.

SKILLS

- Must be able to use various technologies to provide manufacturing systems with intelligent capabilities (reasoning, knowledge, planning, learning, communication, perception and the ability to move and manipulate objects).
- Must be able to model the direct and inverse kinematics of a robot.
- Must be able to design simple trajectory planners, including Cartesian and joint interpolators
- Must be able to program an industrial robot to carry out various tasks
- Must be able to integrate vision with an industrial robot.
- Must be able to integrate and implement intelligent machines into a small and limited manufacturing system.

COMPETENCES

- Must have the foundation to participate in projects aiming at designing intelligent manufacturing systems which more or less autonomously can adapt to variations in its environment and, over time, improve its performance.

TYPE OF INSTRUCTION

The form(s) of teaching will be determined and described in connection with the planning of the Semester. The description will account for the form(s) of teaching and may be accompanied by an elaboration of the roles of the participants. The course/project theme is performed in either English or Danish dependent of the language skills of the participants.

EXAM

EXAMS

Name of exam	Robot Vision
Type of exam	Written or oral exam Individual oral exam on the basis of a small report and a practical demonstration. An internal censor participates in the exam.
ECTS	5
Assessment	Passed/Not Passed

Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Robot vision
Module code	ESNVGISK2K2
Module type	Course
Duration	1 semester
Semester	Spring
ECTS	5
Language of instruction	English
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

SYSTEMS OF SYSTEMS/COMPLEX SYSTEMS

2018/2019

PREREQUISITE/RECOMMENDED PREREQUISITE FOR PARTICIPATION IN THE MODULE

The module builds on knowledge within the areas of systems and control theory, network theory, distributed systems and embedded systems

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

The students will be introduced to methodologies for design of a system of systems in terms of designing the properties of the individual systems as well as their interconnecting behavior, establishing the system of systems. A systematic approach to the design of network architectures and local behavior rules, which together constitute systems of systems that are optimal with respect to objectives formulated at a macroscopic level, will be presented.

LEARNING OBJECTIVES

KNOWLEDGE

- The formalized concept of systems of systems
- A systematic approach to the design of network architectures and local behavior rules, which together constitute systems of systems that are optimal with respect to objectives formulated at a macroscopic level.

SKILLS

- To combine the areas of systems and control theory, network theory, distributed systems and embedded systems into design principles for systems of systems

COMPETENCES

- The ability to design of the properties of the individual systems, as well as their interconnecting behavior, establishing the system of systems
- Identify systems as being complex and/or to fit the Systems of systems paradigm
- Identify appropriate tools for the analysis of complex systems/ Systems of systems
- Predict how overall design decisions impact behavior and performance of complex systems /system of systems

TYPE OF INSTRUCTION

As described in the introduction to Chapter 3.

EXAM

EXAMS

Name of exam	Systems of Systems/Complex Systems
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations

	http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Komplekse systemer
Module code	ESNCAK3K1F
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

NON-LINEAR CONTROL

2018/2019

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

Students who complete the module will obtain skills within Nonlinear Control including analysis of controllability, observability, and stabilizability and stability, along with control synthesis for non-linear systems, hybrid systems covering dynamical system with both discrete and continuous components, the optimal linear estimator - the Kalman filter - as well as non-linear estimation and sensor fusion.

LEARNING OBJECTIVES

KNOWLEDGE

- Lyapunov stability
- Backstepping
- Linear Kalman Filters and their limitations
- The extended Kalman filterThe unscented Kalman filter
- Particle filtering
- Kalman filters as parameter estimators
- The influence of (coloured) sensor and model noise on the filter estimate.
- Must be able to understand…
- The invariance principle
- Feedback linearization

SKILLS

- Controllability
- Observability
- Online estimation techniques to a given system
- Understand and analyze systems with multiple sensors for the purpose of fusing sensor information to control-relevant information
- Stabilizability

COMPETENCES

- Synthesis of non-linear control systems
- Synthesis of hybrid control systems
- Synthesis of estimators for non-linear systems

TYPE OF INSTRUCTION

As described in the introduction to Chapter 3.

EXAM

EXAMS

Name of exam	Non-linear Control
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination

Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Ikke-lineære kontrolsystemer
Module code	ESNCAK3K2F
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design

MACHINE LEARNING

2018/2019

CONTENT, PROGRESS AND PEDAGOGY OF THE MODULE

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.

LEARNING OBJECTIVES

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.

COMPETENCES

- 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

EXAMS

Name of exam	Machine Learning
Type of exam	Written or oral exam
ECTS	5
Assessment	Passed/Not Passed
Type of grading	Internal examination
Criteria of assessment	As stated in Joint Programme Regulations http://www.en.tech.aau.dk/education-programmes/Education+and+Programmes/

FACTS ABOUT THE MODULE

Danish title	Maskinlæring
Module code	ESNSPAK3K2F
Module type	Course
Duration	1 semester
Semester	Autumn
ECTS	5
Empty-place Scheme	Yes
Location of the lecture	Campus Aalborg
Responsible for the module	Ove Kjeld Andersen

ORGANISATION

Study Board	Study Board of Electronics and IT
Department	Department of Electronic Systems
Faculty	Technical Faculty of IT and Design