Curriculum for the Master’s Programme in Vision, Graphics and Interactive Systems

Aalborg University
September 2018
Preface:
Pursuant to Act 261 of March 18, 2015 on Universities (the University Act) with subsequent changes, the following curriculum for the Master's programme in Vision, Graphics and Interactive Systems is stipulated. The programme also follows the Joint Programme Regulations and the Examination Policies and Procedures for The Technical Faculty of IT and Design.
Table of Contents

Table of Contents.................................................................................................................... 2
Chapter 1: Legal Basis of the Curriculum, etc. ........................................................................... 3
  1.1 Basis in ministerial orders.................................................................................................. 3
  1.2 Faculty affiliation............................................................................................................. 3
  1.3 Board of Studies affiliation............................................................................................ 3
  1.4 Body of external examiners ........................................................................................... 3
Chapter 2: Admission, Degree Designation, Programme Duration ........................................... 3
  and Competence Profile......................................................................................................... 3
  2.1 Admission....................................................................................................................... 3
  2.2 Degree designation in Danish and English ..................................................................... 4
  2.3 The programme’s specification in ECTS credits ............................................................. 4
  2.4 Competence profile on the diploma .............................................................................. 4
  2.5 Competence profile of the programme: ........................................................................ 4
Chapter 3: Content and Organization of the Programme............................................................. 5
  1st Semester ........................................................................................................................ 7
  2nd Semester ..................................................................................................................... 13
  3rd Semester ..................................................................................................................... 18
  4th semester ....................................................................................................................... 23
Chapter 4: Entry into Force, Interim Provisions and Revision......................................................... 25
Chapter 5: Other Provisions ......................................................................................................... 25
  5.1 Rules concerning written work, including the Master’s thesis......................................... 25
  5.2 Rules concerning credit transfer (merit), including the possibility for choice of modules that
      are part of another programme at a university in Denmark or abroad............................... 25
  5.3 Rules for examinations ................................................................................................. 25
  5.4 Exemption .................................................................................................................... 26
  5.6 Additional information ................................................................................................. 26
Chapter 1: Legal Basis of the Curriculum, etc.

1.1 Basis in ministerial orders
The Master’s programme in Vision, Graphics and Interactive Systems is organised in accordance with the Ministry of Higher Education and Science’s Order no. 1328 of November 15, 2016 on Bachelor’s and Master’s Programmes at Universities (the Ministerial Order of the Study Programmes) and Ministerial Order no. 1062 of June 30, 2016 on University Examinations (the Examination Order). Further reference is made to Ministerial Order no. 111 of January 30, 2017 (the Admission Order) and Ministerial Order no. 114 of February 3, 2015 (the Grading Scale Order) with subsequent changes.

1.2 Faculty affiliation
The Master’s programme falls under the Technical Faculty of IT and Design, Aalborg University.

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

1.4 Body of external examiners
The programme is affiliated with the body of external examiners for engineering educations: electro (In Danish: censorkorps for Ingeniøruddannelsernes landsdækkende censorkorps; elektro).

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

2.1 Admission
Applicants with a legal claim to admission (retskrav):
Applicants with one of the following degrees are entitled to admission:
- Bachelor of Science in Engineering (Electronic Engineering and IT with specialisation in Informatics), Aalborg University
- Bachelor of Science in Engineering (Internet Technologies and computer Engineering with specialisation in Informatics), Aalborg University

Applicants without legal claim to admission:
Bachelor’s programmes qualifying students for admission:
- Bachelor of Science (BSc) in Engineering (Electronic Engineering and IT with specialisation in Communication Systems) (AAU)
- Bachelor of Science (BSc) in Engineering (Electronic Engineering and IT with specialisation in Signal Processing) (AAU)
- Bachelor of Science in Engineering (Electronic Engineering and IT with specialisation in Control Engineering), Aalborg University
- Bachelor of Science (BSc) in Engineering (Internet Technologies and Computer Engineering with specialisation in Communication Systems) (AAU)
- Bachelor of Science (BSc) in Engineering (Internet Technologies and Computer Engineering with specialisation in Signal Processing) (AAU)
- Bachelor of Science (BSc) in Engineering (Internet Technologies and computer Engineering with specialisation in Control Engineering), Aalborg University
- Bachelor of Science in Engineering (Robotics); Aalborg University

All students applying must document English language qualifications comparable to an 'English B level' in the Danish upper secondary school (minimum average grade 02).
2.2 Degree designation in Danish and English
The Master’s programme entitles the graduate to the designation civilingeniør, cand.polyt. (candidatus/candidata polytechnices) i vision, grafik og interaktive systemer. The English designation is: Master of Science (MSc) in Engineering (Vision, Graphics and Interactive Systems).

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

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

A Candidatus graduate has the following competency profile:
A Candidatus graduate has competencies that have been acquired via a course of study that has taken place in a research environment.

A Candidatus graduate is qualified for employment on the labour market on the basis of his or her academic discipline as well as for further research (PhD programmes). A Candidatus graduate has, compared to a Bachelor, developed his or her academic knowledge and independence so as to be able to apply scientific theory and method on an independent basis within both an academic and a professional context.

2.5 Competence profile of the programme:

The graduate of the Master’s programme:

Knowledge
- Has knowledge on an advanced level in computer vision, computer graphics and interactive systems based on the highest international research in these areas
- Can understand and, on a scientific basis, reflect over the aforementioned subject area’s key knowledge and can identify scientific problems and propose solutions within these
- Has a comprehensive knowledge of the core subjects for computer vision, such as image recognition, visual scene analysis, object tracking, etc.
- Has knowledge about methods for computer graphics, augmented reality, 3D rendering, etc.
- Has knowledge about interactive systems design, in particular multi modal user interaction and user experience design.
- Has knowledge about machine learning methods and techniques and pattern recognition
- Has knowledge of the theories and methods for realizing complex software systems for vision, graphic and interactive systems

Skills
- Excels in scientific methods, tools and general skills related to design, simulation, real-time implementation, test, evaluation, and documentation of systems within the fields of computer vision, graphics and user interaction
- can evaluate and select among the scientific theories, methods, tools and general skills within the fields of computer
vision, graphics and user interaction and, on a scientific basis, advance new analyses and solutions
• can communicate research-based knowledge and discuss professional and scientific problems with both peers and non-specialists
• Can apply methods and tools for solving complex problems within the aforementioned domains
• Can analyze and apply state-of-the-art methods in Computer Vision
• Can analyze and apply state-of-the-art methods in Computer Graphics
• Can apply user centered design methods to design, implement and test multimodal user interaction strategies

Competencies

• Can manage work and development situations that are complex, unpredictable and require new solutions.
• Can independently initiate and implement discipline-specific and interdisciplinary cooperation and assume professional responsibility.
• Can independently take responsibility for own professional development and specialization
• Can analyze and apply appropriate theories and methods for computer vision problems within e.g. surveillance, robotics, etc.
• Can select and apply appropriate methods for solving a given problem within computer vision, graphics and interactive systems and evaluate the results regarding their accuracy and validity
• Can identify scientific problems within control and auto computer vision, graphics and interactive systems and select and apply proper scientific theories, methods and tools for their solution
• Can develop and advance new analyses and solutions within computer vision, graphics and interactive systems
• Can take responsibility for own professional development and specialization.
• Work according to a scientific method and present results in the form of a scientific article and at a seminar/scientific conference
• Formulate and explain scientific hypotheses and results achieved through scientific work
• Analyze results and draw conclusions on a scientific basis

Chapter 3: Content and Organization of the Programme

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

The programme is based on a combination of academic, problem-oriented and interdisciplinary approaches and organised based on the following work and evaluation methods that combine skills and reflection:
- lectures
- classroom instruction
- project work
- workshops
- exercises (individually and in groups)
- teacher feedback
- reflection
- portfolio work

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

<table>
<thead>
<tr>
<th>Semester</th>
<th>Module</th>
<th>ECTS</th>
<th>P/C</th>
<th>Assessment</th>
<th>Exam</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>Computer Graphics</td>
<td>15</td>
<td>P</td>
<td>7-point scale</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Computer Graphics Programming</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Machine Learning</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>User Experience Design for Multimodal Interaction</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>Computer Vision</td>
<td>15</td>
<td>P</td>
<td>7-point scale</td>
<td>External</td>
</tr>
<tr>
<td></td>
<td>Image Processing and Computer Vision</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Robot Vision (elective)</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Algorithms, Data Structures and Software Engineering for Media Technology (elective)</td>
<td>5</td>
<td>C</td>
<td>7-point scale</td>
<td>Internal</td>
</tr>
<tr>
<td></td>
<td>Select 2</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Numerical Scientific Computing (elective)</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>Interactive Systems</td>
<td>20</td>
<td>P</td>
<td>7-point scale</td>
<td>Internal</td>
</tr>
<tr>
<td>A</td>
<td>Platforms and Methods for Multimodal Systems</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td>B</td>
<td>Research in Vision, Graphics and Interactive Systems</td>
<td>5</td>
<td>C</td>
<td>Pass/Fail</td>
<td>Internal</td>
</tr>
<tr>
<td>B</td>
<td>Academic Internship</td>
<td>20&lt;sup&gt;1&lt;/sup&gt;, 25&lt;sup&gt;2&lt;/sup&gt;, 30&lt;sup&gt;3&lt;/sup&gt;</td>
<td>P</td>
<td>7-point scale</td>
<td>Internal</td>
</tr>
<tr>
<td>B</td>
<td>Long Master’s Thesis</td>
<td>20&lt;sup&gt;4&lt;/sup&gt;</td>
<td>P</td>
<td>7-point scale</td>
<td>External</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Master’s Thesis/Long Master’s Thesis</td>
<td>30</td>
<td>P</td>
<td>7-point scale</td>
<td>External</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*) P = Project - C = Course

1 If choosing a 20 ECTS academic internship the student must earn the remaining credits on the 3<sup>rd</sup> semester by following the two courses listed under option A.
2 If choosing a 25 ECTS academic internship the student must earn the remaining credits on the 3<sup>rd</sup> semester by following one of the courses listed under option A.
3 When writing a long master’s thesis the student must earn the remaining credits on the 3<sup>rd</sup> semester by following the two courses listed under option A.
Descriptions of modules
1st Semester

Computer Graphics (P)
Computer grafik (fokus på videnskabelig kommunikation)

Workload: 15 ECTS

Objective:
The objective of this module is two-fold: 1) to provide students with core competencies within the area of real-time 3D computer graphics, enabling them to design and implement software systems that use synthetically generated images as output modality, and 2) to train students in working according to a scientific method and to report results in scientific forms, such as papers and posters.

Students who complete the module:

Knowledge
- Must be able to explain the various stages in a graphics rendering pipeline, including geometric primitives, geometric and projective transformations, local illumination models, and rasterization techniques.
- Must understand the scientific communication processes related to conference presentations and related to publishing in peer-reviewed scientific journals
- Must know how to organize a scientific publication

Skills
- Must be able to apply a graphics API such as OpenGL in the design and implementation of a system which uses real-time 3D computer graphics as an output modality in a user-interface, or a system which aims at developing a novel solution to a computer graphics related problem.
- Can explain the process of and criteria for peer reviewed scientific communications,
- Can write a paper for a scientific conference/journal
- Can prepare and give an oral and poster presentation for a scientific conference

Competencies
- Must be able to evaluate and select relevant computer graphics theories, methods, and tools, and synthesize them to produce new knowledge and solutions.
- Must be able to communicate and discuss research-based knowledge in the area of 3D computer graphics.
- Are able to judge and prioritize the validity of various sources of scientific information.
- Apply internationally recognized principles for acknowledging and citing work of others properly.
- Can formulate and explain scientific hypotheses and results achieved through scientific work
- Are able to analyze results and draw conclusions on a scientific basis

Type of instruction:
Students are organized in groups of up to six members working according to the PBL concept at Aalborg University. Each group will be supervised by at least one staff member doing research within the main topic(s) addressed in the project.

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

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

For further information see the introduction to Chapter 3.

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

**Evaluation criteria:**
As stated in the Joint Programme Regulations
Computer Graphics Programming (C)
Computergrafik programmering

Workload: 5 ECTS

Recommended academic prerequisites:
The module builds upon basic knowledge of linear algebra

Objective:
The course provides an introduction to real-time computer graphics concepts and techniques. The course focuses on programmable functionalities as offered by graphics APIs, supplemented with a presentation of the relevant underlying theories. The course also introduces the concepts of Virtual Reality and Augmented Reality, and how computer graphics is used in the context of these application areas.

Students who complete the module:

Knowledge
- Must be able to describe the programmable graphics rendering pipeline as exposed for example by OpenGL.
- Must be able to explain relevant mathematical transformations, including rotations, translations and projections in terms of matrix operations in homogeneous coordinates.
- Must be able to explain real-time local illumination models, in particular the Phong reflection model, including the use of linearly interpolated attributes (colors and surface normals.)
- Must be able to explain rasterization techniques, including texture mapping (diffuse reflection maps, gloss maps, environment/reflection maps), framebuffer operations (blending, stencil tests, depth tests), and anti-aliasing techniques (super-sampling, mip-map texture filtering).
- Must be able to describe interpolation with Bezier and Hermite curves.
- Must be able to describe the concepts of Virtual Reality and Augmented Reality, including relevant display technologies.
- Must be able to discuss central issues relating to Virtual and Augmented Reality, including tracking, interaction possibilities, and degrees of realism.

Skills
- Must be able to apply a graphics API such as OpenGL for procedurally generating and interactively controlling three-dimensional content.
- Must be able to program simple vertex and fragment shaders (e.g. implementing per-vertex diffuse lighting and normal mapping)

Competencies
- Must be able to learn further graphics APIs (such as Direct3D, OpenGL ES, SVG, X3D, webGL in HTML5), game engines and APIs for user interaction

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

Exam format:
Individual oral or written examination with internal examiner.

Evaluation criteria:
As stated in the Joint Programme Regulations
Machine Learning (C)
Maskin læring

Workload: 5 ECTS

Recommended academic prerequisites:
The module builds upon basic knowledge of probability theory, statistics, and linear algebra

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

Students who complete the module:

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

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

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

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

Exam format:
Individual oral or written examination with internal examiner.

Evaluation criteria:
As stated in the Joint Programme Regulations
**User Experience Design for Multi Modal Interaction (C)**
*Design af brugeroplevelsen for multimodal interaktion*

**Workload:** 5 ECTS

**Recommended academic prerequisites:**
The module builds upon basic knowledge of interaction design and usability

**Objective:**
This course trains students to research, analyze, prototype, and conceptualize design considering all system aspects including the social and cultural contexts of use. The course gives a comprehensive knowledge about user involvement in the design process going beyond traditional methods such as usability lab testing.

The objectives are realized by presenting methods and tools in a case based framework and through the students’ active participation in workshops and assignments.

Students who complete the module:

**Knowledge**
- Must have knowledge about system design methods including the social and cultural contexts of use.
- Must have knowledge derived from sociological and ethnographic fields for user behaviour research
- Must have knowledge about qualitative research methods involving end users in the field, such as interview techniques and analysis and experience sampling
- Must have knowledge about scenario-based design methods
- Must have knowledge about principles for multi modal interaction design
- Must have knowledge about methods for multi modal evaluation and field studies

**Skills**
- Must be able to apply the taught methods to solve concrete design problems.
- Must be able to evaluate and compare and apply the methods for a specific design problem
- Must be able to facilitate the design process involving users in real-life contexts

**Competencies**
- Students will acquire the competencies to decide how to choose the appropriate method to suit different dimensions of a design problem at different stages in the process and the pitfalls of each approach
- Must have competencies in understanding the strengths and weaknesses of the methods
- Must have the competencies to facilitate the design process involving users in context

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

**Exam format:**
Individual oral or written examination with internal examiner.

**Evaluation criteria:**
As stated in the Joint Programme Regulations
2nd Semester

Computer Vision (P)

Workload: 15 ECTS

Recommended academic prerequisites:
The module builds upon knowledge obtained during the 1st semester.

Objective:
The objective of this course module is to provide students with core competencies within the field of computer vision and hereby enabling them to design and implement software systems for automatic or semi-automatic analysis of an image or sequence of images.

Students who complete the module:

Knowledge
- Must have knowledge about the terminology within computer vision
- Must be able to understand how a particular computer vision system e.g. the Semester project of the student, relates to similar systems and, if relevant, to the surrounding society

Skills
- Must be able to analyze a problem and (if possible) suggest a solution that uses relevant theories and methods from computer vision
- Must be able to analyze a system that is based on computer vision and identify relevant constraints and assessment criteria.
- Must be able to synthesize, i.e., design and implement, a system (or parts hereof) using relevant theories and methods (if possible) from computer vision
- Must be able to evaluate a computer vision system (or parts hereof) with respect to the afore mentioned assessment criteria

Competencies
- Must be able to communicate the above knowledge and skills (using proper terminology) both orally and in a written report
- Must be able to select relevant computer vision theories, methods, and tools, and synthesize them in a new context to produce new knowledge and solutions

Type of instruction:
Project work.

Exam format:
Oral examination with external examiner based on a written report.

Evaluation criteria:
As stated in the Joint Programme Regulations
**Image Processing and Computer Vision (C)**  
*Billedbehandling og computervision*

**Workload:** 5 ECTS

**Recommended academic prerequisites:**  
The module builds upon basic knowledge of linear algebra and statistics

**Objective:**  
Cameras capture visual data from the surrounding world. Building systems which can automatically process such data requires computer vision methods. Students who complete the module will understand the nature of digital images and video and have an inside into relevant theories and methods within computer vision and an understanding of their applicability.

Students who complete the module:

**Knowledge**
- Must have knowledge about the primary parameters of a camera system
- Must have knowledge about the representation and compression of digital images and video signal
- Must be able to understand the general framework of image processing as well as the basic point and neighborhood operations, i.e., binarization, color processing, BLOB analysis and filtering
- Must be able to explain the principles behind invariant feature point descriptors such as SIFT and Harris corners.
- Must have knowledge of different motion analysis methods, such as background subtraction and optical flow
- Must be able to understand the tracking frameworks such as the Kalman filter, mean-shift and the particle filter
- Must be able to understand different shape analysis methods such as active-shape models, procrustes, Hungarian method

**Skills**
- Must be able to apply stereo vision to generate 3D data from two or more cameras. This implies projective geometry, camera calibration, epipolar geometry, correspondence and triangulation
- Must be able to apply advanced 2D segmentation methods such as Hough transform, compound morphology, and histogram-of-oriented histograms.
- Must be able to demonstrate understanding of error propagation techniques as a tool for performance characterization of computer vision based solutions

**Competencies**
- Must be able to learn further computer vision methods and theories, and select an appropriate solution for a given problem

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

**Exam format:**  
Individual oral or written examination with internal examiner.

**Evaluation criteria:**  
As stated in the Joint Programme Regulations
Robot Vision (C) (Elective)

Robot vision

Workload: 5 ECTS

Recommended academic prerequisites:
The module builds upon basic knowledge of linear algebra and statistics

Objective:
Students who complete the module will gain knowledge, skills and competences as follows:

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.

Competencies

- 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 format:
Individual oral exam on the basis of a small report and a practical demonstration. An internal censor participates in the exam.

Evaluation criteria:
As stated in the Joint Programme Regulations.
Objective: The goal of this module is to strengthen a student’s ability to use efficient and appropriate algorithms, data structures and software engineering techniques in the design, implementation and analysis of media technology software. The topics covered in the course may include: efficient data structures (e.g., trees and heaps), advanced algorithmic techniques (e.g., divide-and-conquer, dynamic programming, greedy algorithms), methods for analysing software (e.g., analysis of time and space complexity), machine-learning algorithms (e.g., k-NN, SVM, neural networks), and advanced software engineering concepts (e.g., generics, closures, reflection, GPU programming).

Students who complete the module will gain knowledge, skills and competences as follows:

Knowledge

- Must understand the fundamentals of algorithm design and analysis.
- Must understand methods for analysing time and space complexity.
- Must understand basic and advanced data structures used in various computational problems.
- Must understand advanced algorithmic techniques such as recursion and dynamic programming.
- Must have knowledge of basic machine learning algorithms and techniques.
- Must understand advanced software engineering concepts and programming techniques.

Skills

- Must be able to select and implement efficient and appropriate algorithms, data structures and software engineering techniques to solve programming problems in media technology.
- Must be able to work in a group to build a substantial media-technological product that uses state-of-the-art programming techniques.

Competencies

- Ability to analyse multimedia software engineering problems and select and implement efficient and appropriate algorithms, data structures and software engineering techniques to develop successful solutions.
- Ability to analyse solutions and quantify their resource requirements in terms of time and space complexity.

Type of instruction: Refer to the overview of instruction types listed in the start of chapter 3.

Exam format: Oral or written examination with internal censor. The assessment is performed in accordance with the 7-point scale.

Evaluation criteria: Are stated in the Joint Programme Regulations.
Numerical Scientific Computing(C) (Elective)
Numerisk videnskabelig beregning

Workload: 5 ECTS

Objective:
Students who complete the module:

Knowledge
- Must have knowledge about hardware and software platforms for scientific computing.
- Must have knowledge about the possible speedup by using parallelization (Amdahl's law / Gustafson-Barsis' law) under different conditions.
- Must have knowledge about message and data passing in distributed computing.
- Must have knowledge about programming techniques, profiling, benchmarking, code optimization etc.
- Must have knowledge about numerical accuracy in scientific computing problems.
- Must have knowledge about what typically characterizes problem-specific scientific computing software vs. general, user-oriented commercial software.
- Must have knowledge about one or more software development methods of relevance to development of scientific computing software.

Skills
- Must be able to translate the covered principles regarding scientific computing and software development to practice in the programming language(s) utilized in the course.
- Must be able to implement software programs to solve scientific computational problems using parallel computing.
- Must be able to implement software programs to solve scientific computational problems using distributed computing units or high-performance specialized computing units (such as GPU).
- Must be able to debug, validate, optimize, benchmark and profile developed software modules.
- Must be able to assess the performance of different hardware architectures for scientific computing problems.

Competencies
- The student must be able to apply the proper terminology in oral and written communication and documentation within the scientific domains of numerical scientific computing.
- Must be able to assess and weigh resources spent on software development against total subsequent computing time for concrete scientific computing problems.
- Must be able to reflect on different software development methods and independently select and combine elements thereof for use in concrete scientific computing problems.
- Must be able to independently adapt and apply the covered methods and principles for complex scientific computing problems within the students' professional field.

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

Exam format:
Individual oral or written examination with internal examiner.

Evaluation criteria:
As stated in the Joint Programme Regulations
3rd Semester

Interactive Systems (P)
*Interaktive systemer*

**Workload:** 20 ECTS

**Recommended academic prerequisites:**
The module builds on the knowledge obtained during the 1st and 2nd semester

**Objective:**
The objective of this project module is to equip students with the abilities to design, build and test advanced interactive system integrating the more traditional information sources with information derived from e.g. computer vision techniques, speech recognition, and contextual knowledge, such as location. Information visualization and presentation can also be considered in an integrated way as well.

The students can freely choose the focus within the above-mentioned fields, however interaction design issues must be considered and elements of user involvement, such as user requirements gathering and/or end user tests must be treated.

Students who complete the module:

**Knowledge**
- Must be able to understand how a particular system e.g. the Semester project of the student, relates to similar systems and, if relevant, to the surrounding society
- Must be able to understand different aspects of user involvement in a particular system
- Must have knowledge about methods and architectures for fusion of information
- Must have knowledge about context-aware interaction.

**Skills**
- Must be able to analyze how a particular problem, e.g. the Semester project of the student, relates to an end-user
- Must be able to analyze a problem and, when relevant, suggest a solution that utilizes information derived from relevant modalities, such as vision, tactile or speech
- Must be able to design and develop a system- partly or in full - that fuses information from several information sources.
- Must be able to analyze the required response time of a given system and assess its potential for a realtime responsive implementation

**Competencies**
- Must be able to communicate the above knowledge and skills (using proper terminology) both orally and in a written report
- Must be able to select relevant theories, methods, and tools, and synthesize them in a new context to produce new knowledge and solutions

**Type of instruction:**
Project work.

**Exam format:**
Oral examination with internal examiner based on a written report.

**Evaluation criteria:**
As stated in the Joint Programme Regulations
Workload: 5 ECTS

Recommended academic prerequisites:
The module builds upon basic knowledge of human-computer interaction and software design

Objective:
The course will enable the student to understand the principles of multi modal user interaction, including speech based interaction and computer vision, and to extend the methods for HCI GUI design to analyze, design and synthesize multi modal user interaction

Students who complete the module:

Knowledge
- Must have knowledge about integration of sensory information from non-standard signal sources.
- Must have knowledge about methods and architectures for fusion of multi modal information from e.g. speech, gaze, sound and gesture modalities.
- Must have knowledge about context-aware multimodal interaction.

Skills
- Must be able to apply the taught platforms and methods to analyze and design multi modal user interfaces.
- Must be able to evaluate and compare interaction modalities relevant to a specific application.

Competencies
- Must have competencies in analyzing a given problem and identifying appropriate modalities and their fusion to the problem.
- Must have competencies in understanding the pros and cons of the modalities of relevance

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

Exam format:
Individual oral or written examination with internal examiner.

Evaluation criteria:
As stated in the Joint Programme Regulations
Research in Vision, Graphics and Interactive Systems (C)
Forskning inden for vision, grafik og interaktive systemer

Workload: 5 ECTS

Recommended academic prerequisites:
The module builds on basic skills within the fields of machine learning, computer graphics, computer vision and user interaction

Objective:
The goal of this course is to introduce the student to state-of-the-art theories and methods within the core topics of the program, i.e., vision, graphics and interactive systems.

Students who complete the module will gain knowledge, skills and competences as follows:

Knowledge
• Must have an overview over theories for automatic detection and recognition of objects in natural scenes
• Must have an overview of fundamental real-time and non-real-time techniques for computer graphics rendering
• Must have an overview over theories for statistical user modeling and profiling
• Must have an understanding of selected methods for automatic detection and recognition of objects in natural scenes
• Must have an understanding of selected methods for advanced realistic graphics rendering of natural scenes
• Must have an understanding of selected methods for theories for data mining, statistical user modeling and profiling

Skills
• Must be able to analyse research papers related to the three main topics of this course and discuss these with peers in a structured manner
• Must be able to identify relevant state-of-the-art theories and methods given a concrete research problem related to Vision, Graphics or Interactive Systems
• Must be able to apply a relevant state-of-the-art method to a concrete research problem related to Vision, Graphics and Interactive Systems

Competencies
• Must have the competences to devise and implement systems based on advanced topics in vision, graphics, and interactive systems, including AI and deep learning based systems for interaction as well as detection and recognition of objects, and image-based modelling, lighting, and radiometry.

Type of instruction:
The course will first use lectures to introduce the students to core theories and methods. Hereafter the students will be assigned essential research papers that are discussed in the following lectures. The process will be lecturer-guided, but the initiative will be the students. Lastly students are given state-of-the-art research problems and asked to identify and implement relevant solution methods. Results are presented and discussed.

Exam format:
Individual oral or written examination with internal examiner.
Evaluation criteria:
As stated in the Joint Programme Regulations
Academic internship
Projetoriertert forløb i en virksomhed

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

The academic internship must have a scope that correspond the ECTS load.

Purpose:
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.

Objectives:
After completing the module, the student should have the following knowledge, skills and competencies:

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.

Competencies
- 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 format:
Oral examination based on a written report.

Evaluation criteria:
As stated in the Joint Programme Regulations.
4th semester

Master's Thesis (P)
Kandidatspeciale

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.

Workload: 30 ECTS (possibly 50 if conducted as a long Master’s Thesis)

Recommended academic prerequisites:
The module builds on knowledge obtained from the 1st to the 3rd Semester

Objective:
Students who complete the module:

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

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

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

Type of instruction:
As described in the introduction to Chapter 3.
Problem based project oriented project work individual or in groups of 2-3 persons

Exam format:
Oral examination with external examiner based on a written report.

**Evaluation criteria:**
As stated in the Joint Programme Regulations
Chapter 4: Entry into Force, Interim Provisions and Revision

The curriculum is approved by the Dean of the Technical Faculty of IT and Design and enters into force as of September 2018.

Students who wish to complete their studies under the previous curriculum from 2017 must conclude their education by the summer examination period 2019 at the latest, since examinations under the previous curriculum are not offered after this time.

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. If the project is written in English, the summary must be in Danish. The summary must be at least 1 page and not more than 2 pages. The summary is included in the evaluation of the project as a whole.

5.2 Rules concerning credit transfer (merit), including the possibility for choice of modules that are part of another programme at a university in Denmark or abroad
The Board of Studies can approve successfully completed (passed) programme elements from other Master’s programmes in lieu of programme elements in this programme (credit transfer). The Board of Studies can also approve successfully completed (passed) programme elements from another Danish programme or a programme outside of Denmark at the same level in lieu of programme elements within this curriculum. Decisions on credit transfer are made by the Board of Studies based on an academic assessment. See the Joint Programme Regulations 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 Technical Faculty of IT and Design on their website.

All students who have not participated in Aalborg University’s PBL introductory course during their Bachelor’s degree must attend the introductory course “Problem-based Learning and Project Management”. The introductory course must be approved before the student can participate in the project exam. For further information, please see the School of Information and Communication Technology’s website.

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4 Or another foreign language (upon approval from the Board of Studies)
5 The Board of Studies can grant exemption from this.
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.

5.5 Rules and requirements concerning the reading of texts in foreign languages and a statement of the foreign language knowledge this assumes
It is assumed that the student can read academic texts in modern English and use reference works and similar.

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