JÖNKÖPING UNIVERSITY
School of Engineering

PROGRAMME SYLLABUS

AI Engineering (master), 120 credits

Programmestart: Autumn 2024

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Programme code:	TAAI1	**Programmestart:**	Autumn 2024
Confirmed by:	Dean 2021-03-01	**Education Cycle:**	Second-cycle level
Revised by:	Director of Education 2023-11-01		
Version:	6		

Title of qualification

Degree of Master of Science (120 credits) with a major in Computer Science specialisation in Artificial Intelligence (AI) Engineering

Programme overview

Background

Artificial Intelligence (AI), is intelligence, in a broad sense, exhibited by machines. In computer science, an ideal intelligent machine is a flexible, yet rational, agent that perceives its environment and carries out actions that maximize the chances of success for some objective or task. Human-level machine intelligence is still in the future, but applications of deep learning and edge computing are currently transforming both industry and society. Examples of applications include medical diagnosis, personal assistants, surveillance systems, robot control, robotic manufacturing, remote sensing, machine translation, speech understanding, financial services, electronic trading, cybersecurity, combat and training simulators, mission management aids, web search, video games, code analysis, support systems for tactical decision making, product recommendations, and autonomous cars. These and other applications rely on AI techniques to interpret data that originate from a wide range of sources and use the extracted information in an intelligent and targeted behaviour.

Contemporary AI often involves self-learning systems trained on large amounts of data or interacting intelligent agents that perform distributed computing and reasoning. AI connects sensors with algorithms and human-computer interfaces and extends to large networks of intelligent devices. AI is a rapidly developing research field and it is one of the driving forces of today's economy. By combining traditional lectures with seminars and lab sessions, the AI master programme aims to teach students the basics of theory and provides hands-on experience in each subject. The acquired knowledge is applied to practical work on real applications through the development, implementation and testing of running software code.

A master's degree in AI opens up career opportunities within companies that build the next generation of AI enhanced products; for example, smart personal assistants, opinion mining systems, customer service systems, biomedical applications, games, computers, intelligent adaptive devices, robots, intelligent planning systems and so on. The programme provides the skills needed for many positions in today’s industry or research centres.

Objectives

The Master Programme in AI Engineering aims to develop the knowledge, skills and experiences

required to work in companies and organisations that develop products and services with substantial software content. The software developed and/or evaluated by the students have a focus on implementing AI solutions. The programme also covers additional special topics such as safety and security issues related to AI software solutions. During the programme, students engage in practical work and technical research.

Post-graduation employment areas
This Master's programme focuses on the development of intelligent software products and services. Specifically, AI, machine learning, and data science are covered in detail. Applications include, but are not limited to, internet-of-things, data analytics and smart cities. The programme enables graduates to aim for the more senior roles in the development of software products aimed at solving AI related problems as well as software products based on AI techniques. The education is also meant to prepare students for research in computer science, possibly within doctoral studies.

Graduates will have developed the capabilities needed to work in both large corporations and smaller specialized software shops. They will be comfortable with delivering major enterprise systems or specialized software components providing AI services across the spectrum of software development, from back-end data processing to Internet-related front-ends.

Research supporting the Programme
Computer science, including AI, Machine learning and big data analytics, is a major area of research within the School of Engineering, underpinned by the Knowledge Intensive Product Realization research environment (SPARK). Within the Department of Computing there is a strong focus on research related to data analytics, machine learning, and the creation and enhancement of algorithms that strengthen application effectiveness and efficiency.

The exponential growth of the digital society, particularly in the form of storage and computing power in recent decades, enables companies to accumulate vast amounts of data at moderate cost. Accompanying this technological shift is a widespread realisation that the collected data contain potentially valuable information. Exploiting this stored data, in order to extract useful and actionable information, is the overall goal of the generic activity termed data analytics. The AI research at Jönköping University focuses on developing machine learning algorithms for data analytics, when necessary utilising high performance computing. Most of the research is applied, and often co-produced with industry.

Educational concept at the School of Engineering
All degree programmes at the School of Engineering at Jönköping University (JTH) follow an education concept. The concept consists of several aspects that must be included in the programmes in order to guarantee quality and appeal as well as their ability to create professionally skilled, in-demand students. The concept places special emphasis on collaboration with industry and internationalisation as two essential tools to develop successful programmes and to attract national and international applicants. Furthermore, all the master’s programmes offered by the School of Engineering follow common guidelines that indicate the number of credits per each course (7,5, 15 or 30), the need of cross disciplines courses, and the Industrial Placement Course as mandatory or elective.

Objectives
After the completion of the programme, students must meet the intended learning outcomes, as described in The Higher Education Ordinance by Degree of Master (1-9), and also the intended learning outcome, as described by JTH:
Common learning outcomes
Knowledge and Understanding

1. demonstrate knowledge and understanding in the main field of study, including both broad knowledge of the field and a considerable degree of specialised knowledge in certain areas of the field as well as insight into current research and development work
2. demonstrate specialised methodological knowledge in the main field of study

Competence and skills

3. demonstrate the ability to critically and systematically integrate knowledge and analyse, assess and deal with complex phenomena, issues and situations even with limited information
4. demonstrate the ability to identify and formulate issues critically, autonomously and creatively as well as to plan and, using appropriate methods, undertake advanced tasks within predetermined time frames and so contribute to the formation of knowledge as well as the ability to evaluate this work
5. demonstrate the ability in speech and writing both nationally and internationally to clearly report and discuss his or her conclusions and the knowledge and arguments on which they are based in dialogue with different audiences
6. demonstrate the skills required for participation in research and development work or autonomous employment in some other qualified capacity

Judgement and Approach

7. demonstrate the ability to make assessments in the main field of study informed by relevant disciplinary, social and ethical issues and also to demonstrate awareness of ethical aspects of research and development work
8. demonstrate insight into the possibilities and limitations of research, its role in society and the responsibility of the individual for how it is used
9. demonstrate the ability to identify the personal need for further knowledge and take responsibility for his or her ongoing learning

JTH. prove ability to embrace interdisciplinary approaches

Programme-specific learning outcomes

Upon completion of the program, the intended learning outcomes provided for programme must also be met.

Knowledge and Understanding

10. display knowledge of the fundamental tasks, methods and algorithms for data analysis
11. display knowledge of the current state-of-the-art in AI, machine learning and data science
12. demonstrate an understanding of the basic algorithms and methods in machine learning
13. demonstrate an understanding of the development of software utilizing AI or machine learning

Competence and skills

14. demonstrate the ability to implement and test basic learning algorithms based on pseudocode or formal specifications
15. display an ability to use established tools for ontology development, for the processing, storage, and querying of linked data, and for the validation and visualization of linked data and ontologies
16. demonstrate the ability to explain the ways some of the ethical concerns of AI are being addressed, both practically and theoretically
17. demonstrate the ability to implement various machine learning and deep learning architectures, including feed-forward, convolutional, recurrent and generative neural networks

Judgement and Approach

18. demonstrate a skill to compare and evaluate different representations and algorithms for intelligent agents
19. demonstrate a skill to suggest suitable AI and machine learning approaches to real-world problems

Contents

Programme principles

A key principle for the programme is the treatment of AI as both an integrated part in systems and products and a tool to be used for Computer Science and decision support. The program builds upon theoretical knowledge on AI to help acquire practical skills in applying machine learning for data analysis and skills on programming machine learning as well as knowledge on how to utilize the strengths of different hardware platforms. The AI perspective is complemented by the programme's emphasis on growing the competence of the students as professional engineers. The CDIO Initiative™ underpins a new vision for engineering education. By mapping to the Curriculum Guidelines for Graduate Degree Programs in AI Engineering and to the AI Engineering Body of Knowledge, the degree builds upon the work of professional software bodies. A commitment to "evidence-based AI engineering" helps students to understand the importance of sound research over hype and myth in the AI field.

Collaboration with businesses and institutions ensures that the programme reflects "real-world" Computer Science needs while lectures from external AI software engineers provide a counterpoint to the academic view of software development. The programme embraces the Agile Manifesto philosophy which favours a flexible approach to the frequent delivery of working code over a rigid adherence to processes and plans.

Instruction is in the form of lectures, seminars, exercises, laboratory sessions and project work. All courses are held in English. All final course examinations are in English.

Programme progression

Year 1

First semester

The course *Artificial Intelligence (AI)* is a fundamental course in artificial intelligence with a focus on traditional AI, i.e., GOFAI (Good Old-Fashioned Artificial Intelligence). The course covers many different basic and intermediate topics in the field, alternating theory with practice, it introduces students to the basic knowledge representation, problem solving, and learning methods of artificial intelligence. Upon completion of the course, the students should be able to develop basic intelligent systems and understand the role of knowledge representation, inference, search and learning in intelligent- system engineering. Those students who have already taken the course *Artificial Intelligence* (TAIK19) must select an alternative course on advanced level within the fields of computer engineering, informatics, or mathematics. In parallel the course *Mathematics for Intelligent Systems* contains elements from various fields of mathematics and mathematical statistics used when intelligent systems and machine learning are developed, used and analyzed.

The course *Knowledge Representation and the Semantic Web* teaches students to develop and utilize linked data graphs and semantic ontologies for purposes of knowledge modelling, enabling homogenous knowledge representations and data integration across distributed underlying systems. Such knowledge representations can be utilized in a multitude of domains, including document management and search, intelligent agents, smart buildings, biomedical research, web searching, e-retailing, etc. The course *Data Science* introduces students to fundamental topics in data analysis and skills in performing data analysis. Software tools and techniques and their application to different business domains.

Second semester

The *Machine Learning* course introduces the basics of machine learning, focusing on basic building blocks, families of machine learning algorithms and how to evaluate performance. In parallel the course *Ethics of Artificial Intelligence* this course gives an introduction to the ethics of AI, discussing ethical concerns that arise from the use and development of AI.

The course *Deep Learning* covers basic and state-of-the-art algorithms for training various deep neural network architectures, alternating theory with practice. The course includes assignments where the students both implement various deep learning algorithms from scratch and use modern deep learning software. The course *Data Science Programming* is fundamental basic course in data science programming with Python and R. The course covers basic language features and concepts, including core libraries for data science programming, such as data management and augmentation, data analysis and visualization, machine learning and model evaluation, alternating theory with practice.

Year 2

First Semester

The course *Research Methods for Intelligent Systems* covers the theoretical foundations of typical research approaches in artificial intelligence and related areas as well as common research methods and ways of reporting research findings. In parallel, in the *Industrial Placement Course* (NFK), students will gain real workplace experience with a collaborating organisation.

The course *State-of-the-Art in AI Research* discusses selected topics and methods within AI, machine learning and their applications. Examples may include areas, such as computational intelligence algorithms in search, optimization and classification, natural language processing and FAT (fairness, accountability, transparency) aspects. Examples of relevant applications could include robotics, music, health and medicine.

The course *Embedded and Distributed AI* creates an overall understanding of knowledge representation and processing in AI, covering the span from the semantic web through distributed systems all the way to deep learning and edge computing.

Second semester

The fourth and final semester focuses on further developing the students' analytical skills and ability to perform independent and critical research in the area of Computer Science, specialization in AI. Students spend the semester writing a 30 credit *Master Thesis in Computer Science* on a topic related to AI.

Courses

Mandatory courses

Course Name	Credits	Main field of study	Specialised in	Course Code
Artificial Intelligence	7.5	Computer Science	A1N	TARI29
Data Science	7.5	Computer Science	A1N	TDSR22
Data Science Programming	7.5	Computer Science	A1F	TDPS22
Deep Learning	7.5	Computer Science	A1F	TDIS22
Embedded and Distributed AI	7.5	Computer Science	A1F	TEDS22
Ethics of Artificial Intelligence	7.5	Computer Science	A1N	TAIR22
Final Project Work in Computer Science	30	Computer Science	A2E	TEXV23
Knowledge Representation and the Semantic Web	7.5	Computer Science	A1N	TSWR21
Machine Learning	7.5	Computer Science	A1F	TMLS22

Mathematics for Intelligent Systems	7.5		A1N	TMAR21
Industrial Placement Course in Computer Science	7.5	Computer Science	A1F	TNDS22
Research Methods for Intelligent Systems	7.5	Computer Science	A1F	TRIS22
State-of-the-Art in AI Research	7.5	Computer Science	A1F	TSFS22

Programme overview

Year 1

Semester 1		Semester 2	
Period 1	Period 2	Period 3	Period 4
Artificial Intelligence, 7.5 credits	Data Science, 7.5 credits	Ethics of Artificial Intelligence, 7.5 credits	Data Science Programming, 7.5 credits
Mathematics for Intelligent Systems, 7.5 credits	Knowledge Representation and the Semantic Web, 7.5 credits	Machine Learning, 7.5 credits	Deep Learning, 7.5 credits

Year 2

Semester 3		Semester 4	
Period 1	Period 2	Period 3	Period 4
Industrial Placement Course in Computer Science, 7.5 credits	Embedded and Distributed AI, 7.5 credits	Final Project Work in Computer Science, 30 credits	
Research Methods for Intelligent Systems, 7.5 credits	State-of-the-Art in AI Research, 7.5 credits		

Teaching and examination

Throughout the academic year, typically, two courses are taken in parallel. Examination forms and grades are given by each course module, respectively. The programme overview shows the programme structure for both years and may be changed during the programme. For updated programme overview visit http://www.ju.se

Prerequisites

The applicant must hold the minimum of a bachelor's degree (i.e the equivalent of 180 ECTS credits at an accredited university) with at least 90 credits in computer engineering, computer science or electrical engineering (with relevant courses in computer engineering), or equivalent. The bachelor's degree should comprise a minimum of 15 credits in mathematics. Proof of English proficiency is required.

Continuation Requirements

In order to begin the second year, at least 30 credits from the programme's first year must be completed.

Qualification Requirements

To obtain a Degree of Master of Science (120 credits) with a major in Computer Science, specialisation in AI Engineering, students must complete a minimum of 120 higher education credits in accordance with the current programme syllabus, at least 60 of which must be in the main field of study Computer Science and 21 credits in Mathematics.
In addition a Degree of Bachelor of Science in Engineering/Degree of Bachelor of Science or an equivalent Swedish or foreign qualification is required.

Quality Development

Management councils, Head of Programmes, teachers and students work together with the development of the programmes and courses. All students get the opportunity to do a course evaluation after each completed course and before graduation time. The results of the evaluation

are presented to the Head of Programmes, Head of Departments, Course Coordinators and to the Director of Education for further development.
Head of Departments, or corresponding, and Head of Programmes raise questions regarding the programme development within the Council of Programmes. Representatives of students and programme managers gather continuously to discuss the recently completed programme courses.
The chairman of students Educational Committee is a regular member in Council of Education.

Other Information

Information regarding eligibility

If formal competence is missing, the applicant's substantial competence is tested if the applicant has acquired equivalent knowledge in some other way. The aim is to assess the collective competence and if the applicant has the opportunity to meet selected training. Substantial competence can be about knowledge and experience from working life, long-term mobility or other courses.

Course included in the programme can be read as a separate course, subject to availability. Prerequisites are stated in the syllabus.

Admission is under "Admission arrangements for first and second level" at Jönköping University.

This syllabus is based on "Regulations and guidelines for education at undergraduate, postgraduate and doctoral studies at Jönköping University"