

**BACHELOR'S PROGRAMME**

**KUNSTMATIGE INTELLIGENTIE**

FACULTY OF SCIENCE AND ENGINEERING

**UNIVERSITY OF GRONINGEN**

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Project number: Q0744

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This report was finalised on 11 March 2020.



# REPORT ON THE BACHELOR'S PROGRAMME ARTIFICIAL INTELLIGENCE OF THE UNIVERSITY OF GRONINGEN

This report takes the NVAO's Assessment Framework for the Higher Education Accreditation System of the Netherlands for limited programme assessments as a starting point (September 2018).

## ADMINISTRATIVE DATA REGARDING THE PROGRAMME

### Bachelor's programme Artificial Intelligence

Name of the programme:	Kunstmatige intelligentie (international name: Artificial Intelligence )
CROHO number:	56981
Level of the programme:	Bachelor
Orientation of the programme:	Academic
Number of credits:	180 EC
Location(s):	Groningen
Mode(s) of study:	Full-time
Language of instruction:	English
Submission deadline NVAO:	1 May 2020

The visit of the assessment panel Artificial Intelligence to the Faculty of Science and Engineering of the University of Groningen took place on 7 and 8 October 2019.

## ADMINISTRATIVE DATA REGARDING THE INSTITUTION

Name of the institution:	University of Groningen
Status of the institution:	Publicly funded institution
Result institutional quality assurance assessment:	Positive

## COMPOSITION OF THE ASSESSMENT PANEL

The NVAO has approved the composition of the panel on 25 September 2019. The panel that assessed the bachelor's programme Artificial Intelligence consisted of:

- Prof. dr. A. (Ann) Nowé. Professor at the Computer Science Department of the Faculty of Science and the Computer Science group of the Engineering Faculty at the Vrije Universiteit Brussel [chair];
- Prof. dr. C. (Cees) Witteveen. Full professor at the Algorithmics Group of the Faculty of Engineering, Mathematics and Computer Science, Delft University of Technology;
- Prof. dr. B. (Bart) de Boer. Researcher and professor at the Artificial Intelligence lab of the Vrije Universiteit Brussel;
- Dr. C.H.M. (Kees) Nieuwenhuis. Technology Manager and member of the bureau of the Chief Technology Officer at Thales Netherlands;
- M. (Maartje) Stokvis MSc. Completed the master's programme Data Science for Decision Making at Maastricht University [student member];

The panel was supported by Dr. B. (Barbara) van Balen, who acted as secretary.

## WORKING METHOD OF THE ASSESSMENT PANEL

The site visit to the bachelor's programme Artificial Intelligence at the Faculty of Science and Engineering of the University of Groningen was part of the cluster assessment Artificial Intelligence. Between October 2019 and January 2020 the panel assessed 14 programmes at 6 universities. The following universities participated in this cluster assessment: University of Groningen, Maastricht University / Transnational University Limburg, Radboud University, University of Amsterdam, Vrije Universiteit Amsterdam and Utrecht University.

On behalf of the participating universities, quality assurance agency QANU was responsible for logistical support, panel guidance and the production of the reports. Dr. Marijn Hollestelle was project coordinator for QANU. Dr. Marijn Hollestelle, Dr. Barbara van Balen, Peter Hildering MSc and Drs. José van Zwieten acted as secretaries in the cluster assessment.

During the site visit at the University of Groningen, the panel was supported by Dr. Barbara van Balen, a certified NVAO secretary.

### *Panel members*

The members of the assessment panel were selected based on their expertise, availability and independence. The panel consisted of the following members:

- Prof. dr. A. (Ann) Nowé. Professor at the Computer Science Department of the Faculty of Science and the Computer Science group of the Engineering Faculty at the Vrije Universiteit Brussel [chair];
- Prof. dr. C. (Cees) Witteveen. Full professor at the Algorithmics Group of the Faculty of Engineering, Mathematics and Computer Science, Delft University of Technology;
- Prof. dr. B. (Bart) de Boer. Researcher and professor at the Artificial Intelligence lab of the Vrije Universiteit Brussel;
- Prof. dr. W. (Wiebe) van der Hoek. Interim Executive Pro Vice Chancellor and professor at the Department of Computer Science of the University of Liverpool;
- Prof. dr. F. (Frank) Jäkel. Principal Investigator at the Centre for Cognitive Science of the Technical University Darmstadt;
- Dr. ir. J.F.M. (Hans) Tonino. Associate Professor at the Algorithmics Group of the Faculty of Engineering, Mathematics and Computer Science and Director of Studies Embedded Systems at Delft University of Technology;
- Dr. ir. E. (Edwin) de Jong. Principal Machine Learning Scientist at ScreenPoint Medical and coach A.I. startups at RockStart;
- Dr. C.H.M. (Kees) Nieuwenhuis. Technology Manager and member of the bureau of the Chief Technology Officer at Thales Netherlands;
- Dr. A. (Annerieke) Heuvelink-Marck. Senior Scientist at the Software Concepts Department of Philips Group Innovation and Research;
- Dr. A.P. (André) Meyer-Vitali. Senior Scientist Data Science group ICT department at the Netherlands Organisation for applied scientific research (TNO);
- M. (Maartje) Stokvis MSc. Completed the master's Programme Data Science for Decision Making at Maastricht University [student member];
- F. (Florence) van der Voort BSc. Master student Artificial Intelligence and master student Philosophy: Bioethics and Health at the Vrije Universiteit Amsterdam [student member].

### *Preparation*

On 10 May 2019, the panel chair was briefed by QANU on her role, the assessment framework, the working method, and the planning of site visits and reports. A preparatory panel meeting was organised on 28 August 2019. During this meeting, the panel members received instruction on the use of the assessment frameworks. The panel also discussed their working method and the planning of the site visits and reports.

The project coordinator composed a schedule for the site visit in consultation with the Faculty of Science and Engineering. Prior to the site visit, the Faculty selected representative partners for the various interviews. See Appendix 4 for the final schedule.

Before the site visit to the University of Groningen, QANU received the self-evaluation reports of the programmes and sent these to the panel members. A thesis selection was made by the panel's chair and the project coordinator. The selection consisted of 15 theses and their assessment forms for the programmes, based on a provided list of 89 graduates between November 2017 and August 2018. A variety of topics and tracks and a diversity of examiners were included in the selection. The project coordinator and panel chair assured that the distribution of grades in the selection matched the distribution of grades of all available theses.

After studying the self-evaluation report, theses and assessment forms, the panel members formulated their preliminary findings. The secretary collected all initial questions and remarks and distributed these amongst all panel members.

At the start of the site visit, the panel discussed its initial findings on the self-evaluation reports and the theses, as well as the division of tasks during the site visit.

#### *Site visit*

The site visit to the University of Groningen took place on 7 and 8 October 2019. Before and during the site visit, the panel studied the additional documents provided by the programmes. An overview of these materials can be found in Appendix 5. The panel conducted interviews with representatives of the programmes: students and staff members, the programme's management, alumni and representatives of the Board of Examiners. It also offered students and staff members an opportunity for confidential discussion during a consultation hour. No requests for private consultation were received.

The panel used the final part of the site visit to discuss its findings in an internal meeting. Afterwards, the panel chair publicly presented the panel's preliminary findings and general observations.

#### *Report*

After the site visit, the secretary wrote a draft report based on the panel's findings and submitted it to the project coordinator for peer assessment. Subsequently, the secretary sent the report to the panel members. After processing the panel members' feedback, the project coordinator sent the draft reports to the Faculty in order to have it checked for factual irregularities. The project coordinator discussed the ensuing comments with the panel's chair and changes were implemented accordingly. The report was then finalised and sent to the Faculty and University Board.

#### *Definition of judgements standards*

In accordance with the NVAO's Assessment framework for limited programme assessments, the panel used the following definitions for the assessment of the standards:

#### **Generic quality**

The quality that, from an international perspective, may reasonably be expected from a higher education Associate Degree, bachelor's or master's programme.

#### **Meets the standard**

The programme meets the generic quality standard.

#### **Partially meets the standard**

The programme meets the generic quality standard to a significant extent, but improvements are required in order to fully meet the standard.

#### **Does not meet the standard**

The programme does not meet the generic quality standard.

The panel used the following definitions for the assessment of the programme as a whole:

**Positive**

The programme meets all the standards.

**Conditionally positive**

The programme meets standard 1 and partially meets a maximum of two standards, with the imposition of conditions being recommended by the panel.

**Negative**

In the following situations:

- The programme fails to meet one or more standards;
- The programme partially meets standard 1;
- The programme partially meets one or two standards, without the imposition of conditions being recommended by the panel;
- The programme partially meets three or more standards.

## SUMMARY JUDGEMENT

The panel concluded that the final qualifications of the bachelor's degree programme Artificial Intelligence meet the Dutch qualification framework and the international standards, as indicated by the alignment with the KION framework. They sufficiently indicate the academic bachelor's level. The panel established that the programme has a scientific orientation and a specific profile aimed at Cognitive Neuroscience in relation to physical processes, as well as Computational Modelling and Robotics and Autonomous Systems.

The curriculum of the bachelor's programme Artificial Intelligence enables the students to achieve the final qualifications. The panel found the curriculum to be well developed, managed and implemented, and there is a good alignment between the curriculum and the final qualifications. The panel established that the curriculum has been built along the lines of the KION frame of reference. It allows students to obtain all necessary skills and knowledge. The structure of the curriculum is supported by the definition of the learning pathways. The panel appreciates the fine balance in the curriculum between basic skills and more advanced technology and between computational and neuro-cognitive content. A point of attention is the position of ethics in the curriculum. The panel endorses the plan to attract a staff member with a special focus and expertise on this subject. The panel agrees with the policy of the University of Groningen that considering the international character of the AI domain, and the desired balance of the national and international student and staff population, offering the programme in English ensures the best fit.

The panel very much appreciates the introduction of learning communities in the first year of the programme. The programme furthermore offers a good balance between lectures and practical assignments. The panel would nevertheless recommend the programme management to evaluate the balance between written exams, assignments and projects in the programme in regard to the study load of the students.

Although student drop-out is high and study yield can be improved, the panel concludes that the programme management has sufficient attention for these issues and is taking appropriate measures.

The panel has noticed that the teaching staff is highly committed. Furthermore, the teaching staff is in the opinion of the panel highly qualified both in teaching as well as in domain-specific research. The level of English proficiency of the teaching is good. The panel was impressed by the efforts put into guidance of the students by the teaching staff and the teaching assistants.

The increasing student numbers have put some pressure on programme-specific facilities, such as the robot-lab. However, the panel learnt that sufficient measures are taken to improve the situation.

The panel finds the assessment policy of the AI programmes adequate. The procedures to assure the quality of assessments are well described. The panel is convinced that the quality assurance of the assessments in the degree programme AI is sufficient. The panel is positive about the introduction of the Course Unit Assessment Overviews, in which information is stored about the second examiners, the mechanisms in place to assure the quality of the assessment, the modes of assessment and the links of the assessments to the contents of the course.

The assessment procedure of the bachelor thesis project is well described and adequate. During the site visit it became obvious that the assessment procedure for bachelor's theses left some room for misunderstanding about the competences of external examiners. The programme management has immediately taken measures to resolve this.

The panel has established that the Board of Examiners is performing its legal duties and tasks. The BoE checks 10% of all theses, which is sufficient. The efficiency of the sample checks could be further improved.



The panel concludes that graduates of the bachelor's programme in Artificial Intelligence have achieved the intended learning outcomes. Bachelor graduates are well prepared for proceeding in a master's programme or a professional career in AI related industry.

The panel assesses the standards from the *Assessment framework for limited programme assessments* in the following way:

*Bachelor's programme Artificial Intelligence*

Standard 1: Intended learning outcomes	meets the standard
Standard 2: Teaching-learning environment	meets the standard
Standard 3: Student assessment	meets the standard
Standard 4: Achieved learning outcomes	meets the standard
General conclusion	positive

The chair of the panel, Prof. dr. Ann Nowé, and the secretary, Dr. Barbara van Balen, hereby declare that all panel members have studied this report and that they agree with the judgements laid down in the report. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

Date: 11 March 2020

# DESCRIPTION OF THE STANDARDS FROM THE ASSESSMENT FRAMEWORK FOR LIMITED FRAMEWORK ASSESSMENTS

The bachelor's degree programme Kunstmatige Intelligentie (formal CROHO-name. This report uses the international name: Artificial Intelligence) is offered by the Faculty of Science and Engineering (FSE) of the University of Groningen. It is part of the Undergraduate School of Science and Engineering (USSE), which includes all bachelor's programmes of the FSE. The school has a director who reports to the Faculty Board. The programme is supported by a faculty-wide Education Support Centre (ESC), which takes care of all student administration tasks.

## **Standard 1: Intended learning outcomes**

The intended learning outcomes tie in with the level and orientation of the programme; they are geared to the expectations of the professional field, the discipline, and international requirements.

## **Findings**

According to the self-evaluation report, the goal of the bachelor's programme Artificial Intelligence offered by the University of Groningen is to deliver academic individuals who can function professionally in the field of Artificial Intelligence and Cognitive Science or who can take up a master's programme at a more advanced level. The general context of the bachelor's programme profile is formed by the KION Frame of Reference which was compiled by the Dutch academic AI programmes. This document formulates the current Dutch consensus on a national reference framework for Artificial Intelligence in the Netherlands. Graduates of the bachelor's programme Artificial Intelligence are expected to have gained a basic understanding of the eight key areas of Artificial Intelligence and an advanced level of knowledge in at least one of the key areas.

The key areas are defined as:

- Cognitive Science
- Computational Linguistics
- Context of Artificial Intelligence (History, Philosophy, Ethics)
- Intelligent Autonomous Agents and Multi-Agent Systems
- Interaction (Perception, Human-Computer Interaction, Communication)
- Knowledge Representation and Reasoning
- Machine Learning
- Problem Solving (Search, Decision Making, Optimisation)

In addition to these key areas, the students must learn various skills which include, but are not limited to, programming, general academic skills (e.g. presenting, argumentation, academic writing), teamwork, mathematics (statistics and probability theory, linear algebra, calculus, discrete systems processing), and formal logic. They are also expected to acquire knowledge of several additional topics that are connected to Artificial Intelligence, such as Architectures of Cognition, Evolutionary Algorithms and Speech Technology.

The bachelor's programme of the University of Groningen focuses on three specific topics:

- Neuroscience and relation to physical processes
- Cognitive Neuroscience and Computational Modelling
- Robotics and Autonomous Systems.

The specific topics and the clustered final qualifications of the KION frame of reference are elaborated into twelve final qualifications for the bachelor's programme (see Appendix 2). The programme has a scientific orientation. This offers a basis for future careers in academia and research environments as well as in business and industry.

The panel established that the final qualifications meet the requirements of the KION reference framework and are formulated in line with the goal of the programme. They tie in with the Dublin Descriptors for bachelor's degree programmes and therefore sufficiently indicate what could be



expected from students at a bachelor's level. They reflect the content, level and orientation of the bachelor's programme and match the professional field. The panel finds the distinction between the final qualifications of the bachelor's and the master's programmes to be clear.

### **Considerations**

The panel concluded that the final qualifications of the bachelor's degree programme Artificial Intelligence meet the Dutch qualification framework and the international standards, as indicated by the alignment with the KION reference framework. They sufficiently indicate the academic bachelor's level. The panel established that the programme has a scientific orientation and a specific profile aimed at Cognitive Neuroscience in relation to physical processes, as well as Computational Modelling and Robotics and Autonomous Systems.

### **Conclusion**

*Bachelor's programme Artificial Intelligence:* the panel assesses Standard 1 as 'meets the standard'.

### **Standard 2: Teaching-learning environment**

The curriculum, the teaching-learning environment and the quality of the teaching staff enable the incoming students to achieve the intended learning outcomes.

### **Findings**

#### *Curriculum*

The bachelor's programme consists of 180 EC, of which 125 EC are compulsory courses, 15 EC are chosen from a list of practical course units, 15 EC are pre-approved electives and 15 EC are free-choice electives. The programme concludes with a 10 EC bachelor's project.

In the first year, the students receive an overview of Artificial Intelligence and are trained in basic skills such as calculus and linear algebra, logic, linguistics, research-related concepts, cognitive psychology and programming. An additional goal of the first year is selection and orientation. According to the staff and management of the programme, there are indications that students who are unable to learn the named basic skills are less likely to be suited for this programme. Students who obtain less than 45 EC in their first year receive a negative binding study advice and are not allowed to reregister and continue their AI studies within two years from being issued this negative binding study advise.

The second and third years serve as an expansion on the foundations laid in the first year. More advanced topics in the field are addressed, and knowledge gained in the first year is applied. Year 2 contains courses about Knowledge and Agent Technology, Architecture of Intelligence, Advanced Logic, Object-Oriented Programming, Language and Speech Technology, Data Analytics and Communication, Philosophy of Cognitive Science, Neural Networks for Artificial Intelligence, Statistics for AI & CS, and Signals and Systems. There is room for practicals or electives. In year 3 two compulsory courses are offered: Artificial Intelligence 2 and Neurophysics. The students choose electives and practical courses and work on their bachelor project. The programme makes a distinction between two types of electives: pre-approved (15 EC) and free-choice electives (15 EC). The pre-approved electives are courses related to Artificial Intelligence, the free-choice ones can be chosen without restriction (but the courses must be approved by the Board of Examiners).

The programme has segmented its topics into smaller groups of courses that will help the students in developing their skills: learning pathways. It has a rather applied character, so the students carry out practical assignments throughout the courses that are part of these learning pathways. The learning pathways include programming and machine learning, academia and research, mathematics and physics, logic and cognition.

The panel established that the curriculum has been built along the lines of the KION frame of reference. It allows students to obtain all necessary skills and knowledge. The structure of the curriculum is supported by the definition of the learning pathways. The panel appreciates the fine balance in the curriculum between basic skills and more advanced technology and between computational and neuro-cognitive content. It noted that all necessary subjects are covered in the bachelor's curriculum. One point of attention is the position of ethics in the curriculum. This issue was discussed with programme management and staff during the site visit. It was mentioned that ethical issues are covered in several courses in the bachelor's programme, but there is a need for a more systematic focus on ethics. The programme management wants to recruit a staff member with a special focus and expertise on this subject. The panel endorses this plan.

The programme is part of the Faculty of Science and Engineering. In 2017 the Faculty changed its name from Faculteit der Wiskunde- en Natuurwetenschappen (FWN) to Faculty of Science and Engineering (FSE) to reflect its international character. All bachelor's degree programmes and nearly all master's degree programmes at the FSE (except for the master's programme in Pharmacy and the Education track of the master's programme in Science Education and Communication) are taught in English, in an international environment.

In line with the educational approach of the University of Groningen and the programme itself, the bachelor's programme Artificial Intelligence is taught in English. This facilitates an international classroom in which students can engage in cross-cultural learning. In addition, the English language serves as a preparation for the very internationally oriented field of AI, as well as the broader field of the ICT sector. For new scientific staff, proficiency in English is one of the criteria on which candidates are selected. International students have to pass an English language test to demonstrate their proficiency.

The panel agrees with the policy of the University of Groningen that, considering the international character of the AI domain and the desired balance of the national and international student and staff population, offering the programme in English, and with an English programme name, ensures the best fit.

#### *Didactics*

The programme's teaching methods are balanced, with both lectures and practical assignments. The general didactic structure of the courses is two or four hours of lectures a week, complemented by a computer practical and/or tutorial. The practicals can range from large programming assignments to working on a presentation about a research topic. The tutorials usually consist of programming on paper, discussing reading materials, or solving mathematical problems. In the first year of the programme, each student is assigned to a Learning Community Group led by a mentor, an advanced AI student. The mentor guides the students through their first months of the study, aiming to develop their study skills, and s/he is also a teaching assistant for two courses: Introduction to AI and Basic Scientific Skills. These learning communities are much appreciated by the students. It makes them feel more secure in the new environment and part of a community.

The panel is very positive about the introduction of the learning communities. It is convinced that these learning communities have a positive influence on the development of learning skills and the study attitude of students. The students get to know each other at an early stage of their studies and keep feeling connected in the subsequent years. The panel noticed that the staff and students form an academic community, which creates a positive learning atmosphere. The didactical approach in the programme is student-centred, meaning that it is more focused on learning and less on teaching.

The students reported that they have many assignments and carry out many projects during their studies. They acknowledged the value of these projects for their skills development and study progress, but they complained about the amount of time these projects cost them. The panel thinks that project work and assignments are a valuable method to support the development of study skills and a successful study attitude, but it would nevertheless recommend that the programme



management evaluate the balance between written exams, assignments and projects in terms of the students' study load. The timing of the different deadlines should also be carefully monitored.

#### *Student intake, yield and feasibility*

The student intake has grown from 78 in 2012 to 212 in 2018. From the first year that the programme was offered entirely in English, the percentage of international students has been growing. It stabilised in the last few years at around 45-50%.

Due to restrictions on the numbers, the intake in 2019 decreased to 129. The total number of registered students in 2019-2020 is 658. The student drop-out during the first year has in the past been more than 50%, which is considered too high, despite the fact that the first year is also aimed at orientation and selection. The programme has taken several measures to improve its feasibility. The drop-out rate after one year has been gradually reduced to 44% for cohort 2017, which is still high but comparable to other Dutch programmes. Preliminary data shown during the site visit indicate a further reduction to 35% drop-out during the first year of cohort 2018. One of the measures taken is the improvement of promotional activities and information about the content and orientation of the AI programme in particular in regard to the expected level of mathematics. Another measure was the introduction of matching. This matching involves an AI-specific test in addition to general matching for aspiring students introduced by the FSE. The test has proven to provide a good prediction of whether students will pass the first year. The results of the test are not binding.

The programme committee is continuously monitoring whether there are specific course units causing study delay. It noticed that most resits are for course units related to either programming or mathematic skills, which therefore receive continuous attention in relation to study programme feasibility. The panel discussed the feasibility, study yield and drop-out rates with the management, students and staff during the site visit. The yield and the drop-out rates of this programme are comparable to those of other academic degree programmes at Dutch universities. The panel concluded that the programme management is paying sufficient attention to these aspects.

#### *Teaching Staff*

The self-evaluation report of the AI bachelor programme reports a student-staff ratio of about 69 students / 1 teaching fte. The ratio has increased during the last years due to the growth in student numbers. An increase of teaching staff is necessary but cannot be realised in a short time. The expansion of staff always lags a few years behind. The panel observed in speaking with the teaching staff that they manage to teach and guide the increasing student numbers thanks to their strong commitment. The formal and programme management informed the panel that they are exploring several measures to recruit more teaching staff.

During the site visit interviews, the staff demonstrated that they are motivated, enthusiastic and dedicated to providing a high-quality teaching-learning environment. In the panel's opinion, the teaching staff is highly qualified in both teaching and domain-specific research. Their level of English proficiency is good.

The panel was impressed by the efforts put into the guidance of the students by the teaching staff and the teaching assistants.

#### *Facilities*

During the site visit the panel visited the robot labs and computer rooms which are used for and by the AI students. The growth of the student numbers has put some pressure on the facilities, in particular on the use of the robot labs. The programme management has already discussed the capacity problems with the Faculty management, and an extension of the robot lab is planned, which is expected to be sufficient for the current student numbers.

The panel held some discussions with the students about the accessibility and capacity of the study advisors. International students spoke highly of the amount of support they receive in this degree programme. The learning communities are very supportive in this regard.

### **Considerations**

The curriculum of the bachelor's programme Artificial Intelligence enables the students to achieve the final qualifications. The panel found the curriculum to be well developed, managed and implemented, and there is a good alignment between the curriculum and the final qualifications. It established that the curriculum has been built along the lines of the KION frame of reference. This allows students to obtain all necessary skills and knowledge. The structure of the curriculum is supported by the definition of the learning pathways. The panel appreciates the fine balance in the curriculum between basic skills and more advanced technology and between computational and neuro-cognitive content. A point of attention is the position of ethics in the curriculum. The panel endorses the plan to recruit a staff member with a special focus and expertise on this subject. It agrees with the policy of the University of Groningen that considering the international character of the AI domain, and the desired balance of the national and international student and staff population, offering the programme in English ensures the best fit.

The panel very much appreciates the introduction of learning communities in the first year of the programme. The programme furthermore offers a good balance between lectures and practical assignments. The panel would nevertheless recommend that the programme management evaluate the balance between written exams, assignments and projects in the programme in regard to the students' study load.

Although the student drop-out is high and the study yield could be improved, the panel concludes that the programme management pays sufficient attention to these issues and is taking appropriate measures.

The panel noticed that the teaching staff is highly committed. In its opinion they are highly qualified both in teaching and in domain-specific research. Their level of English proficiency is good. The panel was impressed by the efforts put into the guidance of the students by the teaching staff and the teaching assistants.

The increasing student numbers have put some pressure on programme-specific facilities, such as the robot lab. However, the panel learnt that sufficient measures are being taken to improve the situation.

### **Conclusion**

*Bachelor's programme Artificial Intelligence:* the panel assesses Standard 2 as 'meets the standard'.

### **Standard 3: Student assessment**

The programme has an adequate system of student assessment in place.

### **Findings**

#### *Assessment procedures*

The assessment procedures of the bachelor's programme Artificial Intelligence are in line with the assessment policy of the FSE, which is based on the university-wide assessment policy. The programme has an assessment plan, which is an overview of all assessments and contains information about the way students are evaluated throughout the degree programme. A variety of assessment types are used, ranging from assignments, interim tests and multiple-choice examinations to reports, oral examinations, presentations and practical work. Examinations take place in two separate examination weeks, after the regular teaching weeks. Re-examinations/resits



take place a week before the examination weeks. During this specific week there are no scheduled programme elements to allow the students the opportunity to take the resit.

The students finish their bachelor degree programme by conducting a 10 EC bachelor's project. This project is a specific form of assessment. Each project is headed by two supervisors, with the first one being an examiner approved by the Board of Examiners. The students start their project by filling in a contract with their supervisors. In this contract the student and supervisor clarify agreements on the deadlines, on the expected output from the project, and who the second supervisor of the project will be. The students have to hand in a proposal. The project should result in a thesis that clearly outlines the relevant literature and describes the results and the methods used.

The procedure prescribes that both supervisors individually assess the student's work and come to a conclusion on its quality. The panel discussed this procedure with the Board of Examiners during the site visit. It came to the conclusion that when students do their thesis work externally, it was possible that an external supervisor who is not appointed as an examiner could be an assessor of the thesis. In reaction to the remarks on this issue, the programme management changed the assessment procedure immediately. External supervisors can advise about the quality of the student's work to an assessor, but the BoE will explicitly check if two formally appointed examiners in fact assess the theses. After checking this procedure, the panel is pleased about the measures taken and concludes that this ensures a correct and independent procedure in all cases.

#### *Quality assurance*

Examinations of each course are checked by a second examiner. Assignments and examinations are graded with a pre-established answer key. The programme also makes use of grading criteria for presentations and papers.

A faculty-wide method to assure the quality of assessment is the Course Unit Assessment Overview (CUAO). In the CUAO, information is stored about the second examiners, the mechanisms in place to assure the quality of the assessment, the modes of assessment, and the links of the assessments to the contents of the course.

The panel studied the Quality Assurance Manual FSE, the assessment plan and some CUAOs. It is convinced that the quality assurance of the assessments in the AI programme is sufficient. The assessment policy is adequate. The panel is positive about the introduction of the CUAOs.

#### *Board of Examiners*

The bachelor's programme AI, the master's programme AI and the master's programme Human-Machine Communication share one Board of Examiners, consisting of four staff members from the Artificial Intelligence Department and an external member. The external member is an employee of the Undergraduate School of Science and Engineering. The Board of Examiners (BoE) is responsible for topics relating to the qualitative assessment of the programme of individual students and the assessment quality of the degree programme itself. It deals with student requests concerning changes in their individual study programme and requests for exemptions, as well as with students who show fraudulent behaviour.

In order to be able to guarantee the quality of assessments of courses and graduation, the BoE checks the quality of a sample of theses and a sample of courses. The panel noticed that the assessment procedures are adequately described and executed, and that the BoE checks 10% of all theses obtained the ILOs, but that the efficiency of the sample checks could be further improved by, for instance, making use of support by the ESC to perform administrative checks and asking the ESC to report to the BoE.

#### **Considerations**

The panel finds the assessment policy of the AI programmes to be adequate. The procedures to assure the quality of assessments are well described. The panel is convinced that the quality

assurance of the assessments in the AI programme is sufficient. It is positive about the introduction of the CUAOs.

The assessment procedure of the bachelor's thesis project is well described and adequate. During the site visit it became obvious that the assessment procedure for bachelor's theses left some room for misunderstanding about the competences of external examiners. The programme management has immediately taken measures to resolve this.

The panel established that the Board of Examiners is performing its legal duties and tasks. The BoE checks 10% of all theses, which is sufficient. The efficiency of the sample checks could be further improved.

### **Conclusion**

*Bachelor's programme Artificial Intelligence:* the panel assesses Standard 3 as 'meets the standard'.

### **Standard 4: Achieved learning outcomes**

The programme demonstrates that the intended learning outcomes are achieved.

### **Findings**

In order to establish whether the graduates of the bachelor's programme AI demonstrate that the final qualifications are achieved, the panel checked whether all final qualifications are covered in the courses and accompanying assessments that make up the curriculum. It concluded that the curriculum ensures that the graduates have achieved the final qualifications.

The panel studied a selection of fifteen bachelor's theses and the assessment forms. It agreed with the assessments of all theses. It concluded that the theses showed that the students are on an academic level, able to analyze problems, critically review scientific results and communicate about them. The theses show that the students have the capability to perform a theoretically founded experiment or produce a design and report on this. The graduates are well prepared for the master's programme AI, which was confirmed by the master's students in the interview during the site visit. The panel concluded that the quality of the studied bachelor's theses indicates that the graduates have achieved the final qualifications of the bachelor's programme. It was impressed by the number of bachelor's theses (23 between 2013-2018) that resulted in co-authored publications. This illustrates the good academic level the graduates have achieved.

The self-evaluation report indicates the percentage of graduates who proceed to the master's degree programme in Groningen is decreasing. From the graduated students in the period 2008-2015, 64% continued with the master's programme AI or HMC at Groningen, 3.2% started one of these master's but dropped out, 19% choose to do a master's programme at another university, and 13.8% did not continue with a master's programme.

Students can choose to proceed with any AI master's programme in the Netherlands or can choose a master's programme in a different discipline. They also very easily find employment on the labour market in their line of expertise and at their achieved level. According to the panel, the programme provides the students with a broad basis which enables them to pursue a career in both research and industry.

### **Considerations**

The panel concludes that graduates of the bachelor's programme in Artificial Intelligence have achieved the intended learning outcomes. They are well prepared for a master's programme or a professional career in an AI-related industry.



**Conclusion**

*Bachelor's programme Artificial Intelligence:* the panel assesses Standard 4 as 'meets the standard'.

**GENERAL CONCLUSION**

The panel judged that the bachelor's programme in Artificial Intelligence offered by the University of Groningen meets all standards of the NVAO assessment framework for limited programme assessment. It therefore advises positively about the re-accreditation of the programme.

**Conclusion**

The panel assesses the *bachelor's programme Artificial Intelligence* as 'positive'.

# APPENDICES



# APPENDIX 1: DOMAIN-SPECIFIC FRAMEWORK OF REFERENCE

## Frame of Reference: Bachelor's and Master's Programmes in Artificial Intelligence

*The Dutch Perspective*

[For author names and article, see:

[https://pure.uva.nl/ws/files/29809664/KION\\_FoR\\_2018\\_Final.pdf](https://pure.uva.nl/ws/files/29809664/KION_FoR_2018_Final.pdf) ]<sup>1</sup>

October 16th, 2018

This document is an update of the 2013 Frame of Reference as developed by the KION<sup>2</sup> task force on Curricula for Artificial Intelligence, which was based on:

- Artificial Intelligence Academic Programmes in the Netherlands - A State of the Art report, Quality Assurance Netherlands Universities, 2015<sup>3</sup>
- Computer Science Curricula 2013: Curriculum Guidelines for Undergraduate Degree Programs in Computer Science, The Joint Task Force on Computing Curricula, Association for Computing Machinery (ACM), & IEEE Computer Society, December 20, 2013, p. 221-229<sup>4</sup>
- The Onderwijs- en Examenregelingen (OER) of the bachelor's and master's programmes in Artificial Intelligence administered by the Dutch Universities.
- Tuning Educational Structures in Europe<sup>5</sup>, European project, 2000-2004.

### 1 | INTRODUCTION

This document is an update of the 2013 frame of reference for the Dutch University programmes included in the category Artificial Intelligence of the Dutch register of higher education programmes (CROHO)<sup>6</sup> This frame of reference defines the fields covered by the term Artificial Intelligence as well as the common goals and final qualifications of these programmes.

Artificial Intelligence is a relatively young field. The birth of Artificial Intelligence research is often dated in 1956, when the founding fathers of AI met at the Dartmouth Conference. The history of teaching Artificial Intelligence as a separate discipline is much shorter still, starting in the Netherlands in the early '90's. Consequently, a frame of reference for Artificial Intelligence is still actively developing both in the national and the international context. This document formulates the current Dutch consensus on a national frame of reference for Artificial Intelligence in the Netherlands.

Intelligence is often defined as the ability to reason with knowledge, to plan and to coordinate, to solve problems, to perceive, to learn and to understand language and ideas. Originally these are typical properties and phenomena associated with the human brain, but they can also be investigated without direct reference to the natural system. Both ways of studying intelligence either can or must use computational modelling. The term Artificial Intelligence as used in this document refers to the study of intelligence, whether artificial or natural, by computational means.

#### 1.1 KION: Artificial Intelligence in the Netherlands

The current Dutch Artificial Intelligence programmes were mostly started in the nineties in an interdisciplinary context. Originally they were known under a variety of names such as Cognitive Science (Cognitiewetenschap), Applied Cognitive Science (Technische Cognitiewetenschap), Knowledge Engineering (Kennistechnologie), Cognitive Artificial Intelligence (Cognitieve Kunstmatige Intelligentie) as well as Artificial Intelligence (Kunstmatige Intelligentie).

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<sup>1</sup> The authors like to acknowledge the authors of the 2006 and 2013 Frame of Reference for their work; major parts of this document are still built on their original vision.

<sup>2</sup> Kunstmatige Intelligentie Opleidingen Nederland

<sup>3</sup> [www.qanu.nl/en/state-of-the-art-reports](http://www.qanu.nl/en/state-of-the-art-reports) (last visited in March 2018)

<sup>4</sup> [www.acm.org/education/curricula-recommendations](http://www.acm.org/education/curricula-recommendations) (last visited in March, 2018)

<sup>5</sup> [www.unideusto.org/tuning/](http://www.unideusto.org/tuning/) (last visited in February 2018)

<sup>6</sup> Centraal Register Opleidingen Hoger Onderwijs



In 1999, the number of recognised labels in the CROHO was reduced, and the aforementioned study programmes were united under the name Artificial Intelligence<sup>7</sup>. Initially, this was an administrative matter that did not influence the content of the curricula. It did mean, however, that from then on cognitive science (as the study of natural intelligence) and artificial intelligence (as a formal approach to intelligence) were shared under the heading of Artificial Intelligence. The above mentioned definition of Artificial Intelligence as the study of natural and/or artificial intelligence by computational means was then agreed upon. The KION (Kunstmatige Intelligentie Opleidingen in Nederland) was formed as a discussion and cooperation platform for the united programmes.

Starting in 2002, all university-level study programmes in the Netherlands were divided into a bachelor's and a master's phase. KION took this as an opportunity to agree upon a common kernel of subjects that would be constituent of every Dutch Artificial Intelligence bachelor's programme, with the aim of advancing an adequate fit of all Dutch bachelor's programmes to all Dutch master's requirements.

Since then, some degree programmes have changed their names for specification and/or marketing purposes. The Human-Machine Communication degree programme in Groningen joined the KION framework soon after the start, in 2004. In 2013, the VU changed the name of its bachelor's in Kunstmatige Intelligentie to Lifestyle Informatics, to better fit their human-oriented approach to AI, which helped to attract a new population of students (including a higher proportion of female students). However, from 2019 on, the bachelor's programme will be taught in English under the name Artificial Intelligence (with a track in Intelligent Systems and a track in Socially Aware Computing). Furthermore, in 2017, Maastricht renamed its bachelor's programme to Data Science & Knowledge Engineering, and changed its master's programme in Operations Research programme to Data Science for Decision Making, to enable more synergy with its master's AI programme. A full list of the degree programmes that are a member of the KION can be found in section 1.2.

During the last decade new developments in Artificial Intelligence (AI) have become increasingly visible to society and the general public. Most appealing successes like IBM's Watson performance and Google's DeepMind victory in AlphaGo, have globally drawn attention. In business, AI's impact on massive data-mining applications in consumer markets may even more revolutionise the use of AI in everyday life.

The successes in the field of AI have not gone unnoticed in the Dutch educational AI programmes. There has been a substantial increase in the intake of virtually all Dutch AI programmes, reflecting the awareness of the growing potential of AI by talented students. In addition, several Dutch programmes are now taught in English, attracting students from all over the world. At some Universities, the substantial growth has led to measures to maintain quality, e.g. by introducing a Binding Study Advice or even by imposing a Numerus Fixus (Radboud University and University of Amsterdam in September 2018; other Universities are likely to follow in 2019).

The prospects of a career in AI, directly or via business-related spin-offs, are very promising; we therefore have to be prepared to face the challenge of keeping quality of our AI programmes during upcoming years, while offering enough capacity to train professionals to fulfil the future needs of society in implementing AI-based solutions.

The following degree programmes are a member of the Kunstmatige Intelligentie Overleg Nederland:

### **1.2.1 Bachelor's Programmes of the KION**

The following Bachelor's programmes are a part of the KION:

- B Artificial Intelligence, Radboud Universiteit Nijmegen (CROHO: 56945)
- B Data Science and Knowledge Engineering, Universiteit Maastricht (CROHO: 50300)
- B Kunstmatige Intelligentie, Rijksuniversiteit Groningen (CROHO: 56981)
- B Kunstmatige Intelligentie, Universiteit van Amsterdam (CROHO: 56981)

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<sup>7</sup> In Dutch: Kunstmatige Intelligentie

- B Kunstmatige Intelligentie, Universiteit Utrecht (CROHO: 56981)
- B Artificial Intelligence, Vrije Universiteit Amsterdam (CROHO: 56983)

### 1.2.2 Master's Programmes of the KION

- The following Master's degree programmes are a part of the KION:
- M Artificial Intelligence, Radboud Universiteit Nijmegen (CROHO: 66981)
- M Artificial Intelligence, Rijksuniversiteit Groningen (CROHO: 66981)
- M Artificial Intelligence, transnationale Universiteit Limburg (CROHO: 66981)
- M Artificial Intelligence, Universiteit Utrecht (CROHO: 66981)
- M Artificial Intelligence, Universiteit van Amsterdam (CROHO: 66981)
- M Artificial Intelligence, Vrije Universiteit Amsterdam (CROHO: 66981)
- M Data Science for Decision Making, transnationale Universiteit Limburg (CROHO: 60125)
- M Human-machine Communication, Rijksuniversiteit Groningen (CROHO: 60653)

### 1.3 Aim of this Document

Now that the Dutch Artificial Intelligence programmes are coming up for accreditation in 2019, KION feels that the essence of the 2013 Frame of Reference is still valid, but in definite need of an update. However, this document is not intended purely as a description of the current status quo. Rather, it aims to provide an account of what an Artificial Intelligence programme should provide as a minimum (the communal requirements for every study programme called Artificial Intelligence), and how it can extend this basis to distinguish itself from other Artificial Intelligence programmes.

Agreement among the Dutch Artificial Intelligence programmes upon the contents of this document will advance both the equivalence of these programmes, and the understanding on existing and possible profiles within Artificial Intelligence programmes. Moreover, it is hoped that this document will also be a starting point for defining international standards for Artificial Intelligence programmes.

## 2 | PROGRAMME CHARACTERISTICS

This section describes definitions regarding the build-up of bachelor's and master's programmes.

### 2.1 Areas, Courses, Modules and Topics

A bachelor's programme in Artificial intelligence is organised hierarchically into three levels. The highest level of the hierarchy is the area, which represents a particular disciplinary subfield. The areas are broken down into smaller divisions called modules, which represent individual thematic units within an area. A module may be implemented as a complete course, be covered in part of a course, or contain elements from several courses. Each module is further subdivided into a set of topics, which are the lowest level of the hierarchy. The modules that implement the particular programme (or curriculum) are together referred as the 'body of knowledge'.

### 2.2 Core and Elective Courses

By insisting on a broad consensus in the definition of the core, we hope to keep the core as small as possible, giving institutions the freedom to tailor the elective components of the curriculum in ways that meet their individual needs. The core is thus not a complete programme. Because the core is defined as minimal, it does not, by itself, constitute a complete undergraduate curriculum. Every undergraduate programme must include additional elective courses relating to the body of knowledge. This report does not define what those courses should be, but does enumerate options in terms of modules.

### 2.3 Assessing the Time Required to Cover a Course

To give readers a sense of the time required to cover a particular course, a metric must be defined that establishes a standard of measurement. No standard measure is recognised throughout the world, but within the European Community agreement has been reached upon a uniform European Credit Transfer System<sup>8</sup> (ECTS) in which study load is measured in European Credits (ECs). One EC

<sup>8</sup> [https://ec.europa.eu/education/resources/european-credit-transfer-accumulation-system\\_en](https://ec.europa.eu/education/resources/european-credit-transfer-accumulation-system_en) (last visited on May 4, 2018)



stands for 28 hours of study time and a full year of study is standardised at 60 EC. In this document, we shall use the EC metric as the standard of measurement for study load.

## **2.4 Coping with Change**

An essential requirement of any Artificial Intelligence degree is that it should enable graduates to cope with-and even benefit from-the rapid change that is a continuing feature of the field. But how does one achieve this goal in practice? At one level, the pace of change represents a challenge to academic staff who must continually update courses and equipment. At another level, however, it suggests a shift in pedagogy away from the transmission of specific material, which will quickly become dated, toward modes of instruction that encourage students to acquire knowledge and skills on their own.

Fundamentally, teaching students to cope with change requires instilling an attitude that promotes continued study throughout a career in those students. To this end, an Artificial Intelligence curriculum must strive to meet the following challenges:

- Adopt a teaching methodology that emphasises learning as opposed to teaching, with students continually being challenged to think independently.
- Assign challenging and imaginative exercises that encourage student initiative.
- Present a sound framework with appropriate theory that ensures that the education is sustainable.
- Ensure that equipment and teaching materials remain up to date.
- Make students aware of information resources and appropriate strategies for staying current in the field.
- Encourage cooperative learning and the use of communication technologies to promote group interaction.
- Convince students of the need for continuing professional development to promote lifelong learning.
- Provide students with awareness of potential ethical and legal issues the field of Artificial Intelligence.

## **3 | SHARED IDENTITY**

### **3.1 Common Role**

Apart from the roles academics usually perform in society students of Artificial Intelligence are educated to enrich society with the benefits a formalization of intelligence and intelligent phenomena can provide. In particular this entails that an alumnus of Artificial Intelligence can contribute to the understanding and exploitation of natural and artificial intelligence. This may lead to new technologies but it may also enrich designs, products, and services with intelligence so that they are more effective, more reliable, more efficient, safer, and often require less natural resources. This role, in combination with the interdisciplinary nature of the field, requires the Artificial Intelligence alumnus to be able to contribute to interdisciplinary teams and, in many cases function as an intermediate who facilitates the interaction of (other) domain specialists.

### **3.2 Common Requirements**

Artificial Intelligence is a broad discipline and many approaches to the study of intelligent phenomena are justified and fruitful. Curricula are therefore often different from their siblings in emphasis, goals, and capabilities of their graduates. Yet they have much in common. Any reputable Artificial Intelligence programme should include each of the following aspects.

1. Essential and foundational underpinnings of the core aspects of intelligence. These must be founded on empirical efforts and based on a formal theory, and they may address professional values and principles. Regardless of their form or focus, the underpinnings must highlight those essential aspects of the discipline that remain unaltered in the face of technological change. The discipline's foundation provides a touchstone that transcends time and circumstances, giving a sense of permanence and stability to its educational mission. Students must have a thorough grounding in that foundation.

2. A foundation in the core concepts of modelling and algorithms for implementing intelligence. The construction and use of models (simplified, abstracted and dynamic representations of some phenomenon in reality) is common to many sciences. In Artificial Intelligence, however, model building is central: the field of Artificial Intelligence may actually be defined as trying to model aspects of (formal or natural) intelligence and knowledge. Moreover, models within Artificial Intelligence have specific characteristic: they are computational and therefore necessarily mathematical or formal. Artificial Intelligence-graduates must therefore be able to work with (computational) models at different levels of abstraction and understand the recursive nature of models in Artificial Intelligence. This foundation has a number of layers:

- An understanding of, and appreciation for, many of the diverse aspects of intelligence, models of intelligent phenomena, and of algorithms that describe intelligent processes.
- Skills to model intelligent phenomena and appreciate the abilities and limitation of these models, if appropriate in comparison with a natural intelligence counterpart.
- Skills to model and implement intelligent phenomena on a computer, in particular skills to work with algorithms and data-structures in software.
- Skills to design and build systems that are robust, reliable, and appropriate for their intended audience.

3. An understanding of the possibilities and limitations of what intelligent systems can and cannot do. This foundation has a number of levels:

- An understanding of what current state-of-the-art can and cannot accomplish, if appropriate in combination with the accomplishment of the natural system that inspired it;
- An understanding of the limitations of intelligent systems, including the difference between what they are inherently incapable of doing versus what may be accomplished via future science and technology;
- The impact of deploying technological solutions and interventions on individuals, organizations, and society.

4. The identification and acquisition of non-technical skills, including interpersonal communication skills, team skills, and management skills as appropriate to the discipline. To have value, learning experiences must build such skills (not just convey that they are important) and teach skills that are transferable to new situations.

5. Exposure to an appropriate range of applications and case studies that connect theory and skills learned in academia to real-world occurrences to explicate their relevance and utility.

6. Attention to professional, legal and ethical issues such that students acquire, develop and demonstrate attitudes and priorities that honour, protect, and enhance the profession's ethical stature and standing.

7. Demonstration that each student has integrated the various elements of the (under)graduate experience by undertaking, completing, and presenting a capstone project.

### **3.3 Shared Background for Bachelor's Programmes**

Similar to alumni of programmes such as Physics, Computer Science, and Psychology, all Artificial Intelligence bachelors are expected to share a certain amount of support knowledge, domain specific knowledge, specialised domain knowledge, and a set of skills. The content mentioned below ensures a firm common basis that enables AI bachelors of any Dutch university admission to any Dutch master's programme in AI. At the same time, it allows for a wide range of individual and/or institute specific specialisations. The list is an update (extension) of the shared programme agreed upon by the KION platform in 2013.

#### **3.3.1 Core Modules (shared between AI Bachelor's Degree Programmes)**

The following topics and skills are part of each of the bachelor's programmes, either as a dedicated course or as a substantial topic within one or more courses. The core modules define the 8 key areas of Artificial Intelligence.

##### **3.3.1.1 Artificial Intelligence (Core) Modules**

- Algorithmic Problem Solving (Search, Decision Making, Optimisation)
- Cognitive Science



- Computational Linguistics
- Context of Artificial Intelligence (History, Philosophy, Ethics)
- Intelligent Autonomous Agents and Multi-Agent Systems
- Interaction (Perception, Human-Computer Interaction, Communication)
- Knowledge Representation and Reasoning
- Machine Learning

### **3.3.1.2 Support Module**

- Computer Science
  - Algorithms and Data Structures
  - Programming
- Logic
  - Propositional Logic
  - Predicate Logic

### **3.3.1.3 Academic Skills**

- Mathematics
  - Calculus
  - Discrete Mathematics
  - Linear Algebra
  - Probability Theory
  - Statistics

Apart from curriculum specific skills, the bachelor's programmes support the development of a set of general academic skills. Even though they can be topics in specific modules, they are generally addressed by the appropriate choice of work and assessment methods throughout the curriculum.

- Analytic Skills
- Empirical Methods
- Modelling
- Teamwork
- Written and Oral Communication, Argumentation and Presentation

### **3.3.2 Elective Modules (within Artificial Intelligence)**

The following list of modules is considered as representative of the AI field at this moment. Given that the different AI programs have different priorities in selecting topics, and assigning topics to either the bachelor's or master's, each bachelor's should offer a substantial subset of the following list as part of their bachelor's programme, either as specific course, or as a substantial part of a broader course (i.e. a module).

- Architectures of Cognition and Cognitive Modelling
- Computational and Cognitive Neuroscience
- Computational Intelligence
- Computer Vision
- Data Mining
- Deep Learning
- ELSA (Ethical, Legal and Social Aspects of AI)
- Evolutionary Algorithms (Genetic Algorithms, Evolutionary Computing)
- Language and Speech Technology
- Neural Networks
- Perception (Computational and Natural)
- Reasoning under Uncertainty
- Reinforcement Learning
- Robotics
- Text Mining and Information Retrieval
- Virtual Reality and Gaming
- Web and Artificial Intelligence

## **4 | BACHELOR'S PROGRAMME ARTIFICIAL INTELLIGENCE**

This section is divided into two parts. Section 4.1 describes the roles that a bachelor ought to be able to perform in society. Section 4.2 describes the final qualifications that bachelors in Artificial Intelligence possess in order to fulfil these roles.

### **4.1 Objectives**

The objective of the bachelor's programme is to provide students with a suitable basis for a further career, both in education as well as in employment. The bachelor must be prepared for a number of different roles and opportunities.

#### **4.1.1 Access to Master's Programmes**

The bachelor provides the student with the specific knowledge and abilities, exemplified in the form of a bachelor's diploma that allows the bachelor to apply for any master's programme in Artificial Intelligence or other national or international master's programmes, particularly in related disciplines.

#### **4.1.2 Professional Career**

The bachelor prepares for a position in which the student can earn his or her own subsistence. In particular it prepares for:

- Supervised work on a national and international academic level;
- Positions in the modern high-tech society, such as functions in knowledge-intensive companies and knowledge intensive parts of the non-profit sector.

#### **4.1.3 Academic Skills**

The bachelor provides sufficient training in (scientific) reasoning, conduct, and communication to reach internationally accepted standards of academic skills at that level.

#### **4.1.4 Place in Society**

The bachelor's programme provides the bachelor with the knowledge and tools needed to form an informed opinion of the meaning and impact of Artificial Intelligence, and an informed notion of the responsibilities of a specialist in this area.

### **4.2 Final Qualifications**

The objectives of the bachelor can be specified into final qualifications. To comply with international standards these qualifications are presented below in terms of the Dublin descriptors for the bachelor's profile<sup>9</sup>. Together these final qualifications must lead to alumni that exemplify the shared identity defined in section 3.

#### **4.2.1 Knowledge and Understanding**

The bachelor demonstrates knowledge and understanding in a field of study that builds upon and supersedes their general secondary education. Knowledge and understanding is typically at a level at which the bachelor, whilst supported by advanced textbooks, is able to include some aspects at the forefront of their field of study.

We distinguish two levels of qualification: a basic understanding, corresponding to knowledge of the essentials and fundamentals of the field in question, such as knowing what the field is, knowing how to apply knowledge in said field, and knowing how to further develop oneself in the field in question, and an advanced understanding, corresponding to in-depth knowledge about a topic in question.

Qualifications:

1. Basic understanding of the (8) key areas in Artificial Intelligence in accordance with the shared identity.
2. Advanced knowledge of at least one of the key areas in Artificial Intelligence, up to a level that without further requirements grants access to a master programme in this area.

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<sup>9</sup> "A Framework for Qualifications of the European Higher Education Area", 2005. (last visited on May 4, 2018)



#### **4.2.2 Applying Knowledge and Understanding**

Bachelors can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation, and have competences typically demonstrated through devising and sustaining arguments and solving problems and/or designing systems within their field of study. They are able to analyse and model prototypical Artificial Intelligence problems by using known Artificial Intelligence methods and techniques.

Qualifications:

1. The ability to understand, apply, formulate, and validate models from the domains of Artificial Intelligence.
2. The ability to apply knowledge from the key areas of Artificial Intelligence. (as outlined in 3.3.1.1)
3. The ability to apply knowledge from the support modules of Artificial Intelligence (as outlined in 3.3.1.2)
4. Analytical approach to problem solving and design:
  - Ability to comprehend (design) problems and abstract their essentials.
  - Ability to construct and develop logical arguments with clear identification of assumptions and conclusions.
5. The ability to submit an argument in the exact sciences (or humanities) to critical appraisal.
6. Analytical and critical way of thought and ability to apply logical reasoning.
7. Openness to interdisciplinary cooperation and ability to effectively participate therein as an academic professional.
8. The ability to create an effective project plan for solving a prototypical Artificial Intelligent problem in a supervised context.
9. Manage one's own learning and development, including time management and organizational skills.
10. The ability to transpose academic knowledge and expertise into (inter)national social, professional and economic contexts.
11. Readiness to address new problems in new areas, emerging from scientific and professional fields.

#### **4.2.3 Making Judgments**

The bachelor has the ability to gather and interpret relevant data (typically within the field of study) and to formulate judgments that include reflection on relevant social, academic or ethical issues.

Qualifications:

1. Ability to critically review results, arguments and problem statements from accepted perspectives in the field of Artificial Intelligence and neighbouring disciplines.
2. Initial competence in search and critical processing of professional literature in Artificial Intelligence.
3. Acquaintance with the standards of academic criticism.
4. Awareness of, and responsible concerning, the ethical, normative and social consequences of developments in science and technology, particularly resulting from Artificial Intelligence.

#### **4.2.4 Communication**

The bachelor can communicate information, ideas, problems and solutions to audiences of both domain-specialist and a general audience.

Qualifications:

Academically appropriate communicative skills; the bachelor can:

- Communicate ideas effectively in written form and through the use of Information and Communication Technology,
- Make effective oral presentations, both formally and informally,
- Understand and offer constructive critiques of the presentations of others.

#### **4.2.5 Learning Skills**

The bachelor has developed those learning skills that are necessary for a successful further study characterised by a high degree of autonomy (typically in the context of a master or a specialist profession).

Qualifications:

1. Reflection on one's own style of thought and working methods and readiness to take the necessary corrective action.
2. Recognise the need for continued learning throughout a professional career

### **5 MASTER'S PROGRAMME ARTIFICIAL INTELLIGENCE**

This section is divided into two parts. Section 5.1 describes the roles that a master ought to be able to perform in society. Section 5.2 describes the final qualifications that masters in Artificial Intelligence possess in order to fulfil these roles.

#### **5.1 Objectives**

The objective of the master programme is to provide students with a suitable basis for a further career, both in research as well as in the rest of society. The master must be prepared for a number of different roles and careers at key positions in society.

##### **5.1.1 Access to PhD Programmes**

The master programme provides the student with the specific knowledge and abilities, exemplified in the form of a master diploma that allows the master access to a PhD programme in a broad range of disciplines, especially in Artificial Intelligence related disciplines.

##### **5.1.2 Professional Career**

The master programme prepares for a position in which the student can earn his or her own subsistence. In particular, it prepares for:

- Independent work on an academic level, especially at positions where many of the problems have not been addressed before and where solutions require scientific training
- Key positions in the modern high-tech society, such as higher functions in knowledge-intensive companies and knowledge-intensive parts of the non-profit sector

##### **5.1.3 Academic Skills**

The master programme provides sufficient training in independent scientific reasoning, conduct, and communication to reach internationally accepted standards of academic skills at that level. Masters can communicate original ideas in their own language and in English to a public of specialists and non-specialists.

##### **5.1.4 Place in Society**

The programme provides the master with the knowledge and tools needed to formulate an informed opinion about the meaning and impact of Artificial Intelligence in society. Masters are able to enrich society with results from contemporary research and oversee the consequences of proposed measures to society and are aware of their responsibility towards society.

#### **5.2 Final Qualifications**

The objectives of the master can be specified into final qualifications. To comply with international standards these qualifications are presented below in terms of the Dublin descriptors for the master's profile<sup>10</sup>. Together these final qualifications must lead to alumni that exemplify the shared identity defined in section 3.

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<sup>10</sup> Framework\_for\_Qualifications\_of\_the\_European\_Higher\_Education\_Area (last visited on May 4, 2018)



### **5.2.1 Knowledge and Understanding**

The Master demonstrates knowledge and understanding in a field of study that builds upon and supersedes their bachelor's degree. Knowledge, understanding, and abilities are typically at a level at which the master is able to formulate a feasible research plan in one's own specialisation.

We distinguish three levels of qualification: a basic understanding, corresponding to the minimal level of knowledge that is expected of a Bachelor student, an advanced understanding, meaning students must have in-depth knowledge about a topic that they could easily develop to become a specialist, and specialist knowledge, meaning students are highly skilled (and specialised) in the key area in question.

Qualifications:

1. Basic understanding of all (8) key areas of Artificial Intelligence.
2. An advanced understanding in some of the key areas of Artificial Intelligence.
3. Specialist knowledge of at least one of the key areas in Artificial Intelligence, up to a level that the master can appreciate the forefront of research in that field.

### **5.2.2 Applying Knowledge and Understanding**

Masters can apply their knowledge and understanding in a manner that indicates a scientific approach to their work or vocation. They are able to handle complex and ill-defined problems for which it is not a priori known if there is an appropriate solution, how to acquire the necessary information to solve the sub-problems involved, and for which there is no standard or reliable route to the solution.

Qualifications:

1. The ability to formulate a project plan for an open problem in a field related to Artificial Intelligence in general and the own specialisation in particular.
2. The ability to determine the feasibility of a proposal to lead to a solution or design as specified.
3. The ability to contribute autonomously and with minimal supervision to an interdisciplinary project team and to profit from the abilities, the knowledge, and the contributions of other team members.
4. The ability to choose, apply, formulate, and validate models, theories, hypotheses, and ideas from the key areas of Artificial Intelligence.
5. The ability to submit an argument in the exact sciences (or humanities) to critical appraisal and to incorporate its essence in the solution of Artificial Intelligence problems.
6. The ability to translate academic knowledge and expertise into social, professional, economic, and ethical contexts.
7. Awareness of, and responsibility concerning, the ethical, normative and social consequences of developments in science and technology, particularly resulting from original contributions.

### **5.2.3 Making Judgments**

The master is able to formulate an opinion or course of action on the basis of incomplete, limited and in part unreliable information.

Qualifications:

1. Competence in the search and critical processing of all sources of information that help to solve an open and illdefined problem.
2. The ability to demonstrate a professional attitude conform the (international) scientific conduct in Artificial Intelligence.
3. The ability to provide and receive academic criticism conform the standards in one specialism of Artificial Intelligence-research.
4. The ability to formulate an opinion and to make judgments that include social and ethical responsibilities related to the application of one's own contributions.
5. The master is able to judge the quality of his or her work or the work of others from scientific literature.

### 5.2.4 Communication

The Master can communicate information, ideas, problems and solutions to audiences of specialist in (other) research areas and to a general audience.

Qualifications:

The Master has academically appropriate communicative skills; s/he can:

- Communicate original ideas effectively in written form,
- Make effective oral presentations, both formally and informally, to a wide range of audiences
- Understand and offer constructive critiques of the presentations of others.

### 5.2.5 Learning Skills

The master has developed those learning skills that are necessary for a successful further career at the highest professional level. The master is able to detect missing knowledge and abilities and to deal with them appropriately.

Qualifications:

1. Being able to reflect upon one's competences and knowledge and, if necessary, being able to take the appropriate corrective action.
2. The ability to follow current (scientific) developments related to the professional environment.
3. Showing an active attitude towards continued learning throughout a professional career.

## 6 | INTERNATIONAL PERSPECTIVE

As stated in the introduction, this frame of reference is intended not only for the Dutch national context, but also to put the Dutch Artificial Intelligence programmes into an international perspective, and possibly to serve as a starting point for an internationally agreed frame of reference. The latter possibility is of course dependent upon international debate and agreement, and at this moment it is not clear how to bring this about, or whether it will in fact be possible. What we can and will do in this document is provide a comparison between the frame of reference as developed in the previous sections and a number of known related study programmes in other countries. In doing this, we hope to show that the developed frame of reference is up to par from an international perspective as well as the Dutch national one.

Having said this, we must immediately recognise that the Dutch national context appears to be rather special in that we only know of specialised bachelor-level Artificial Intelligence study programmes at one university outside the Netherlands, namely at Edinburgh (United Kingdom), which have a rather different programme structure than the Dutch (and general European) one. In our discussion of the Dutch frame of reference in international perspective, we will therefore add to our comparison with the Edinburgh study programme by a comparison with bachelor's programmes of study programmes in a related field, notably Cognitive Science. Furthermore, we will compare the Dutch bachelor's qualifications with the requirements for enrolment in Artificial Intelligence master programmes in other countries.

A comparison of master programmes is tricky as well. Although, contrary to bachelor's programmes, there are several well-known specialised Artificial Intelligence master programmes outside the Netherlands, study programmes at the master level are much more divergent than at the bachelor's level. A comparison can therefore only be provided in global, subject-independent, terms.

We have drawn up both the bachelor's and master's degree programme comparisons based on the programme descriptions and course lists received from the involved Universities. However, for the purpose of conciseness, we have left out particular details of the programmes that are largely time-dependent and often change from year to year.



## **6.1 Comparison of Bachelor's Programmes**

### **6.1.1 The Artificial Intelligence Bachelor's Programme in Edinburgh**

Edinburgh University (United Kingdom) offers a range of bachelor's degrees related to Artificial Intelligence, one of them in Artificial Intelligence as such, the others in combination with other disciplines (AI & Computer Science, Cognitive Science). An ordinary bachelor's degree consists of 4 years. In order to compare this system with the European standard of a 3-year bachelor's and a 2-year master's programme, we will take the fourth year of the Edinburgh bachelor's programme to be equivalent to the first year of a 2-year master's degree in other European countries, and base our comparison of bachelor's programmes on the first three years.

It should be pointed out that the (first three years of the) AI-related bachelors in Edinburgh show a large variation between them, and an extensive amount of (usually restricted) choices for particular courses within them. In fact, the commonality between the Edinburgh Artificial Intelligence bachelors is smaller than commonality within the Dutch framework. It seems that the wide variation in Edinburgh Artificial Intelligence related bachelor's degrees actually means that the degrees themselves are much more specialised than the Dutch framework proposes, some of them having little or no (cognitive) psychology, others having no mathematics, etcetera.

### **6.1.2 The Cognitive Science Bachelor's Programme in Osnabrück**

The University of Osnabrück (Germany) offers a three-year (180 EC) bachelor's programme in Cognitive Science. The discipline of Cognitive Science is related to Artificial Intelligence, and may in fact be seen as a flavour of Artificial Intelligence, focused somewhat more towards Cognitive Psychology, and somewhat less towards Engineering. The same key knowledge and skills apply in Artificial Intelligence and in Cognitive Science.

Based on studying both programmes, we conclude that the Dutch frame of reference recognises the same AI-specific areas as both Cognitive Science programmes outside the Netherlands. The Dutch frame of reference devotes as much or more attention to any of these areas as any of those Cognitive Science programmes, with the exception of Cognitive Psychology in Linköping. Moreover, the recognition, in the Dutch frame of reference, that each individual study programme has a specific profile in addition to the communal areas appears to hold for both inspected study programmes outside the Netherlands as well.

### **6.1.3 The Symbolic Systems Bachelor's Programme in Stanford**

The University of Stanford offers a programme in Symbolic Systems that has a variant in Artificial Intelligence. The list of core requirements of this programme includes, but is not strictly limited to: single and multivariable calculus, probability theory and statistics, discrete fundamentals, programming, philosophy, cognition and neuroscience, natural language and computation and cognition. Students in Artificial Intelligence should also take courses from the topics of knowledge representation and reasoning, natural language processing, learning and robotics and vision. They offer several courses in these topics. They offer a more in-depth application of numerous of these topics as non-core cognate courses, such as machine learning, motion planning, modal logic, automated reasoning, and more advanced levels of philosophy/linguistics (in reality, they offer a wide variety of supplemental courses).

The course units that are denoted are the core of Symbolic Systems and are supplemented by their Artificial Intelligence variant are very similar to the Dutch framework of reference - all of the topics in the core list of Stanford's programme + variant are reflected in our common core to some degree. There seems to be a slightly bigger focus on Philosophy (3/12th of the Symbolic Systems bachelor's core consists of philosophical foundations). The nature of the setup of compulsory core courses in Stanford does allow students to 'somewhat' skip topics that are important in the eyes of the Dutch framework - for example, the framework in Stanford calls for knowledge on 'Computation and Cognition', which ask of the student to take one course from a list ranging from Theoretical

Neuroscience to Neural Networks and Machine Learning. All in all, the frameworks are similar, but the core of Symbolic Systems appears to be a bit less technical than the Dutch framework.

#### **6.1.4 The Bachelor's Programme Artificial Intelligence at Carnegie Mellon**

The Carnegie Mellon University in Pittsburgh has introduced in Fall 2018 the first full Artificial Intelligence bachelor programme of the USA. Their curriculum consists of three cores: a mathematical, computer science and artificial intelligence core. The artificial intelligence core consists of Introductions in AI Representations, Problem Solving, Machine Learning, Natural Language Processing and/or Computer Vision. As electives, one course has to be selected from four clusters: Decision Making & Robotics, Machine Learning, Perception & Language and Human-AI Interaction.

The main difference with the Dutch Framework is the role of Logic; in this framework Propositional Logic and Predicate Logic are explicitly mentioned as support modules, in Pittsburgh logic is part of the Decision Making & Robotics cluster, with courses as Strategic Reasoning for AI and Planning Techniques for Robotics. This is a far more practical approach compared to the theoretical approach of the Dutch Framework.

### **6.2 Comparison of Master's Programmes**

#### **6.2.1 The Artificial Intelligence Master's Programme in Edinburgh**

The Artificial Intelligence master programme in Edinburgh spans a full 12-month period and consists of two parts: taught and research. During the taught part (8 months), lectures, tutorials and group practicals are followed. The research part (4 months) consists of a major individual research project on which a dissertation is written. There is also the option of completing only the taught part, in which case, a Diploma will be awarded. MSc courses in Artificial Intelligence in Edinburgh are grouped in four major areas of specialisation:

- Intelligent robotics
- Agents, Knowledge and Data
- Machine Learning
- Natural language processing

Comparing the Edinburgh programmes to the Dutch frame of reference, we can draw the following conclusions:

- The main Artificial Intelligence topics that are in the Dutch framework are also represented in the Edinburgh programmes (as shown in the four different identified areas of specialisation).
- The Edinburgh programmes are 1-year, whereas most Dutch Artificial Intelligence master programmes are 2-year programmes. However, the Edinburgh master programme requires a 4-year honours bachelor's degree.
- The Edinburgh programme knows relatively little study load for practical work. Whereas the minimum length of a Dutch master-thesis ('afstudeerproject') is 30 ECs (half a year), the Edinburgh programme has 4 months for doing practical assignments.
- However, the practical work seems to be more research oriented, whereas in the Dutch programme there is also the option to do a final project in industry.
- The Edinburgh program has an entry requirement on mathematics (During the bachelor degree 60 credits have completed of mathematics.)

#### **6.2.2 The Machine Learning and Machine Intelligence Master's Programme in Cambridge**

At the University of Cambridge the master is called Machine Learning and Machine Intelligence. It is a very selective (20 places) two year programme (120 ECTS credits). To apply, the applicants should have a UK First class Honours Degree (equivalent with overall grade of 8/10).

Their programme includes courses such as:

- Deep Learning and Structured Data
- Probabilistic Machine Learning
- Speech Recognition



- Weighted Automata
- Computer Vision

Comparing the Cambridge study programme to the Dutch frame of reference, we can draw the following conclusions:

- the programme has clear programme objectives (9 in total)
- the programme only covers 3 of the 8 core areas (Computational Linguistics, Perception, Machine Learning)
- There is not much choice: the programme consists of eleven core modules
- the programme has only two optional modules: Computer Vision or Natural Language Processing
- As elective the students can pick one elective module from 4th year undergraduate

### **6.2.3 The Symbolic Systems and Computing Science Master's Programmes in Stanford**

Stanford offers two variants that are similar to Artificial Intelligence in the Netherlands: the Symbolic Systems Master and an Artificial Intelligence variant in the Computer Science degree programme. Symbolic Systems is an interdisciplinary programme that combines Computer Science, Psychology, Philosophy, and Linguistics in order to better understand cognition in both humans and machines. Viewing people and computers as symbol processors, the Symbolic Systems programme explores the ways computers and people reason, perceive, and act. Within the Symbolic Systems major, there is a core set of required classes with respect to the aforementioned fields; beyond this core, students choose an area of concentration in order to gain depth.<sup>11</sup>

The variant that is actually named Artificial Intelligence offers a subset of the disciplines in the Dutch framework, mostly those related to Computer Science. This master's programme focuses on solving problems using computers, and as such mainly contains course units that address topics in Machine Learning, Computer Vision, Natural Language Processing, Data Mining, Robotics and Bioinformatics. There is a framework of courses students can choose from, but this framework is fairly loosely defined (with only very few guidelines), making it hard to distinguish a core beyond the specific attention for the applied computational side of Artificial Intelligence.

Comparing the Stanford study programme to the Dutch frame of reference can only be done by evaluating both the Symbolic Systems Master and the Computer Variant at the same time:

1. The Dutch framework has more formal subjects (such as a stronger focus explicit focus on logic and computer science related topics) than the Symbolic Systems programme. The Dutch framework has more topics related to Cognitive Science and the context of Artificial Intelligence than the Computer Science AI variant.
2. It has already been mentioned that there is much variety between the master programmes
  - Both in the Netherlands and abroad. This is also the case for the programmes at Stanford.
  - The Stanford programmes seem to have a lot of freedom in their choice for electives. In other words, the core of compulsory courses is limited and students have to select many elective courses - thus rejecting the idea behind a broad common core of the programme.

### **6.2.4 The Cognitive Science Master's Programme in Osnabrück**

The university of Osnabrück offers a two-year (120 ec) master of science programme in Cognitive Science. Apart from a 30 ec individual thesis project and a 22 ec team project, students take predominantly elective courses in Cognitive Psychology, Artificial Intelligence, (Computational) Linguistics, Robotics, Neuroscience, Neuroinformatics and Philosophy of Mind and Cognition. The choice of courses largely follows the research group structure. The programme offers a double degree option together with the Cognitive Science programme in Trento.

The Osnabrück programme has a similar focus on cognitive (and neuroscience) aspects of AI as Nijmegen. Nijmegen has a tradition of attracting graduated bachelor students from Osnabrück who are typically directly admitted to the master programme in Nijmegen; in addition, several graduated master students from Osnabrück found a PhD position at the Radboud University. Student mobility

<sup>11</sup> <http://symsys.stanford.edu/courses> (last visited on May 4, 2018)

thus suggests that the programmes are relatively comparable in content and quality to the Dutch Framework.

## **7 | NATIONAL PERSPECTIVE**

At its core, the framework of reference serves as a foundation for every Artificial Intelligence degree programme in the Netherlands. This is also what differentiates the degree programmes that are a member of the KION from similar degree programmes: at its very heart, the KION programmes aim to provide a broad foundation that respects the roots of the field, rather than merely offer a specialistic application of Artificial Intelligence. With the growing popularity and diversity of Artificial Intelligence as a field, the need for programmes to adhere to a framework founded in both history and modern-day application is more important than ever.

We have drawn up an analysis that compares AI-related degree programmes in the Netherlands, to see whether they fit the frame of reference. In this way, we hope to highlight the unique position the KION degree programmes hold in the field of Artificial Intelligence: both with respect to delivering broadly educated Artificial Intelligence students, but also with respect to the consistency of the quality and background future employers can expect.

### **7.1 Bachelor's Programmes**

Tilburg University and TU Eindhoven offer a joint BSc degree in Data Science. The focus of this bachelor's degree is on mathematical tools for dealing with big data; there is less emphasis on programming and no broad introduction in Artificial Intelligence. Tilburg University also offers a bachelor in Cognitive Science and Artificial Intelligence; this is part of the School for Humanities. Currently, the programme is under development; the relationship with the KION frame of reference is still open at the time of writing. Finally, TU Delft offers a bachelor Computer Science & Engineering (intelligent data analysis variant). This programme does not offer the broad introduction in Artificial Intelligence that the KION degree programmes do.

### **7.2 Master's Programmes**

Several universities offer a specialisation in Data Science as part of the Computer Science or Information Studies MSc degree. Tilburg University and TU Eindhoven offer a joint MSc degree Data Science and Entrepreneurship. TU Delft offers a MSc degree in Data Science & Technology. These master programmes do not offer the broad overview on AI that the KION degree programmes do, but focus specifically on data science. Tilburg University also offers a one-year MSc degree (in contrast to the two-year KION programmes) in Cognitive Science and Artificial Intelligence.

## **8 | CONCLUDING REMARKS**

Artificial Intelligence is a rapidly developing field. The term Artificial Intelligence does not have the stature of Physics, Psychology, or even Computer Science, due to its relatively recent start as a coherent field of research. Despite this, the recent attention for the successes of the field have ascertained that the field of Artificial Intelligence has made its mark. Internationally, the study of natural and artificial intelligence with computational means is firmly embedded in the fabric of modern Universities.

Modern topics such as gaming, ambient intelligence, ambient awareness, and believable-agent systems are fashionable manifestations of Artificial Intelligence and these and future fashionable spin-offs of Artificial Intelligence will increasingly affect humans. A particularly popular focus of Artificial Intelligence can currently be found in the field of Machine Learning, where possibilities for data analysis provide the world with useful patterns in all sorts of data. These possibilities have helped popularise Artificial Intelligence in the media, but have also raised ethical and legal questions about the field. Future challenges will force products, services, and societies to react faster but remain reliable, to be both flexible and effective, be both efficient and versatile, and to utilise natural resources with maximal benefit. The biggest challenge of all is making the most of this combination of conflicting demands, a challenge that lies very much at the core of in the concept of intelligence.



The Dutch situation is special because of the existence of Artificial Intelligence bachelor's and master's programmes on most of the general universities. This offers the Netherlands a competitive advantage, consistent with its main economic strategy to remain one of the leading "knowledge intensive" economies. This frame of reference explicates how the bachelor's and master's programmes in Artificial Intelligence of Dutch universities contribute to educate alumni that will take a leading role in meeting these future challenges.

## APPENDIX 2: INTENDED LEARNING OUTCOMES

*The bachelor demonstrates knowledge, understanding, and the ability to evaluate, analyze and interpret relevant data in the field of*

1. the symbolic approach to Artificial Intelligence and has the ability to apply this;
2. the numerical, non-symbolic approach to Artificial Intelligence and has the ability to apply this;
3. computational models of cognitive processes and has expertise in constructing and applying these;
4. autonomous systems and robotics and has the ability to apply these;
5. linguistics and language technology and has the ability to apply these;
6. knowledge and agent systems and has expertise in designing, implementing and applying these.

*The bachelor has knowledge and understanding of*

7. the most important philosophical concepts developed in the areas of artificial intelligence and cognition;
8. relevant theories developed in the area of empirical sciences, psychology, biology and physics and has experience applying and analyzing results thereof.

*The bachelor has relevant knowledge and ability*

9. to apply methods and techniques from mathematics and logic used in Artificial Intelligence;
10. to use algorithms, data structures and important programming languages used in Artificial Intelligence.

*The bachelor has the ability*

11. on an academic level, to analyze problems, critically review scientific results and communicate about this both individually as well as in a group, both oral and in written form, also in a broader societal context;
12. to critically reflect on one's own working method and to recognize the need for continued learning on a high degree of autonomy, also in the context of preparing for a master's or a specialist profession.

The bachelor has knowledge and understanding of Artificial Intelligence and Cognitive Science, in combination with formal skills required to work in these fields. The bachelor has learned, via lectures, tutorials, writing essays, giving presentations, practical assignments and the final bachelor's project, to perform a theoretically founded experiment or to produce a design and to report on this. Specifically in the final bachelor project, the bachelor has to utilize the acquired knowledge and skills, to professionally report on this with a final thesis and to be able, via participation in the final bachelor colloquium, to present to a wider audience. After successfully completing the programme at the level of the first cycle, the bachelor is qualified to enroll in programmes of the second cycle or specialist profession (see Dublin descriptors, Qualifications Framework of the European Higher Education Area).



## APPENDIX 3: OVERVIEW OF THE CURRICULUM

Year 1			
Term 1a	Term 1b	Term 2a	Term 2b
Autonomous Systems	Basic Scientific Skills	Algorithms and Data Structures	Artificial Intelligence 1
Imperative Programming for AI	Calculus for AI	Cognitive Psychology	Introduction to the Brain
Introduction to AI	Introduction to Logic (AI & MA)	General Linguistics	Linear Algebra & Multivariable Calculus

Year 2			
Knowledge and Agent Technology	Architectures of Intelligence	Advanced Logic	Object-Oriented Programming
Language and Speech Technology	Data Analytics and Communication	Philosophy of Cognitive Science*	Neural Networks for Artificial Intelligence
Statistics for AI & CS	Signals and Systems	<i>Practical or Elective Course Unit</i>	<i>Practical or Elective Course Unit</i>

Year 3			
Artificial Intelligence 2	<i>Practical or Elective Course Unit</i>	Bachelor's Project	Bachelor's Project
Neurophysics (Physics for AI)	<i>Practical or Elective Course Unit</i>	<i>Practical or Elective Course Unit</i>	Bachelor's Project (starting 2021 - 2022; prev. Biopsychology)
<i>Elective Course Unit</i>	<i>Practical or Elective Course Unit</i>	<i>Practical or Elective Course Unit</i>	<i>Practical or Elective Course Unit</i>

Term 1a	Term 1b	Term 2a	Term 2b
	Knowledge Technology Practical	Autonomous Systems Practical	Autonomous Systems Practical Extension
		Cognitive Science Practical	Language Technology Practical

Each course field represents 5 EC



## APPENDIX 4: PROGRAMME OF THE SITE VISIT

<b>7 October 2019</b>	
08.30 – 09.00	Arrival panel and welcome by the programme management
09.00 – 10.00	Preparatory panel consultation
10.00 – 10.45	Interview programme management
10.45 – 11.00	Break / panel consultation
11.00 – 11.45	Interview students bachelor
11.45 – 12.00	Break / panel consultation
12.00 – 12.45	Interview teachers bachelor
12.45 – 13.30	Lunch + open consultations
13.30 – 14.00	Tour of the robot-lab
14.00 – 14.45	Break / panel consultation
14.45 – 15.30	Interview students master AI
15.30 – 15.45	Break / panel consultation
15.45 – 16.30	Interview students master HMC
16.30 – 16.45	Break / panel consultation
16.45 – 17.30	Interview alumni bachelor, master AI & HMC

<b>8 October 2019</b>	
08.30 – 09.30	Arrival of the panel and preparation for day 2
09.30 – 10.15	Teachers Master AI and HMC
10.15 – 10.30	Break / panel consultation
10.30 – 11.15	Interview board of examiners
11.15 – 11.30	Break / panel consultation
11.30 – 12.00	Interview formal responsible management
12.00 – 14.00	Panel composes their findings & lunch
14.00 – 14.15	Public verbal feedback of the preliminary findings by the panel chair
14.15 – 15.00	Break
15.00 – 15.45	Development dialogue
15.45 – 16.00	End of the site visit



## APPENDIX 5: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied 15 theses of the bachelor's programme Artificial Intelligence. Information on the selected theses is available from QANU upon request.

During the site visit, the panel studied, among other things, the following documents (partly as hard copies, partly via the institute's electronic learning environment):

- Self-evaluation Report - Artificial Intelligence and Human-Machine Communication
- Assessment plan BSc Artificial Intelligence
- KION frame of reference
- Staff overview
- Minutes meetings:
  - Heidag
  - Curriculum Committee
  - Staff Meetings
  - Raad van Advies
- FSE Quality Assurance Manual
- Programme Committee Handbook
- Manual Board of Examiners
- Quality Assurance Board of Examiners
- Rules and Regulations by the Board of Examiners
- Education Primer
- FSE Quality Assurance Manual 2017-2017
- Instellingstoets Kwaliteitszorg RUG 2014
- Teaching and Examination Regulations + appendices Bachelor Artificial Intelligence
- NSE results 2016 and 2017
- Annual reports Board of Examiners
- Annual reports Programme Committee
- Education Monitor
- Minutes Midterm
- Publications (co-)authored by bachelor- and/or master students