BACHELOR'S PROGRAMME

ARTIFICIAL INTELLIGENCE

FACULTY OF SCIENCE

UNIVERSITY OF AMSTERDAM

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CONTENTS

This report was finalised on 24 June 2020

REPORT ON THE BACHELOR'S PROGRAMME ARTIFICIAL INTELLIGENCE OF THE UNIVERSITY OF AMSTERDAM

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
CROHO number:	56981
Level of the programme:	Bachelor
Orientation of the programme:	Academic
Number of credits:	180 EC
Specializations or tracks:	-
Location(s):	Amsterdam
Mode(s) of study:	Full-time
Language of instruction:	Dutch
Submission deadline NVAO:	1 May 2020

The visit of the assessment panel Artificial Intelligence to the Faculty of Science of the University of Amsterdam took place on 9 and 10 December 2019.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

Name of the institution:	University of Amsterdam
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 (EEMCS/EWI), Delft University of Technology.
- Prof. dr. B. (Bart) de Boer. Researcher and professor at the Artificial Intelligence lab of the Vrije Universiteit Brussel.
- Dr. ir. E.D. (Edwin) de Jong. Principal Machine Learning Scientist at ScreenPoint Medical Nijmegen and mentor/coaching A.I. startups at RockStart.
- M. (Maartje) Stokvis MSc . Master graduateData Science for Decision Making at Maastricht University [student member].

The panel was supported by drs. José van Zwieten, 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 of the University of Amsterdam 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. Marijn Hollestelle, Barbara van Balen, Peter Hildering and José van Zwieten acted as secretaries in the cluster assessment.

During the site visit at the University of Amsterdam, the panel was supported by José van Zwieten, 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.D. (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 Software Concepts at 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. Master graduateData 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. 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 Amsterdam, QANU received the self-evaluation reports of the programmes and sent these to the panel. A thesis selection was made by the panel's chair and the project coordinator. The selection existed of 15 theses and their assessment forms for the programmes, based on a provided list of 52 graduates between September 2017 and August 2018. A variety of topics 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 report and the theses, as well as the division of tasks during the site visit.

Site visit
The site visit to the University of Amsterdam took place on 9 and 10 December 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 Examinations Board. 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. 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 concludes that the bachelor's programme KI from the University of Amsterdam has a clear profile. It has a strong focus on technical aspects of AI and the mathematical skills that are a foundation for this technical expertise. This profile has been translated in the curriculum. The panel does advise to be explicit on the positioning of the programme in the AI arena and to clarify its choice to deviate from the framework within the KION platform. The programme has formulated clear intended exit qualifications in line with the Dublin descriptors. The intended learning outcomes reflect the academic bachelor's level of the programme.

The panel established that the curriculum of the bachelor's programme KI of the University of Amsterdam is designed to realise its final qualifications. The Learning Trajectories create a clear and coherent curriculum that is in line with the programme's profile. The panel observed that the emphasis on the mathematical and technical aspects of AI offers the students a solid theoretical and practical foundation in the discipline. Theory and application are well-balanced in the courses. A variety of electives offer the students the opportunity to deepen their AI expertise in a direction of their choice. The panel is impressed with the efforts that are put into the *Practicum Academische Vaardigheden* by committed tutors and their coordinator. The students acquire relevant academic skills as well as skills related to teamwork. The panel appreciates the fact that all of the students come into contact with the AI industry in one of the projects. The programme is challenging but feasible. The panel supports the measures taken by the programme to promote its feasibility. It is positive about the quality and teaching skills of the teaching staff of the programme. The pressure on the teaching staff is high, but the role of super teaching assistant appears to function well in ensuring small-scale education for a large number of students.

According to the panel, assessment within the bachelor's programme Kunstmatige Intelligentie is up to standard. The assessment policies are in line with university policy and are well documented. In practice, the responsibilities concerning assessment and grading seem to be less clear. The AI assessment is varied and aligned with the learning objectives. The programme pays attention to the follow-up of fraud and plagiarism but could invest more in prevention measures. The panel concludes that within KI, the supervision and assessment of Graduation Projects are well-structured. Incorporation of the research and supervision process in the forms could improve the assessment even further. The Examinations Board has a clear view of its tasks and responsibilities. The AI subcommittee carries out its tasks in a proactive manner.

The panel is impressed with the high level of some of the bachelor's theses it studied. Overall, they demonstrated that KI graduates realise the intended learning outcomes. The graduates are able to proceed to a variety of master's programmes or the professional field. The panel is convinced KI graduates have acquired a skill set and level which render them attractive to the academic or professional field.

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, prof. dr. Ann Nowé, and the secretary, drs. José van Zwieten, of the panel 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: 24 June 2020

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

The bachelor's programme *Kunstmatige Intelligentie* (KI) is embedded in the College of Science, part of the Faculty of Science of the University of Amsterdam (UvA). It is part of the Information Science cluster, together with the bachelor's programmes Computer Science and Information Studies. It has a Programme Director, who is responsible for the quality and development of the programme. The director works together with the Programme Coordinator, who takes care of organisational matters. The bachelor's programme has a Programme committee, consisting of students and staff members. They meet five times a year. The Programme committee fulfils its legal role in the quality assurance of the programme, as well as proactively advising the programme management on the quality and development of the programme.

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
The Bachelor's programme KI aims to provide students with the fundamentals and a basic understanding of the key areas in the field of artificial intelligence (AI). The programme should prepare them to apply for a national or international master's programme in AI or a related discipline. According to the self-evaluation report, the KI programme of the UvA distinguishes itself by a strong emphasis on the fundamental and technical aspects of AI. Computer science, mathematics and logic are focal points in the curriculum. The students are expected to acquire the skills to build AI components from existing AI methods and techniques, which is considered an indication of a deep understanding of these methods and techniques. This focus is in line with the research profile of the research institutes that are involved in the AI programmes at the UvA.

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 consensus on a national frame of reference for Artificial Intelligence in the Netherlands. Graduates of bachelor's programmes 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. These 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.

The panel established that the UvA has chosen to emphasise certain aspects of the KION framework (machine learning, mathematics). In its opinion, this positioning is justified and legitimate in light of the need of the professional field and the existing research expertise of the UvA. At the same time, some of the key areas of the KION framework are not addressed in the core of the programme. This is the case for Multi-Agent Systems and Knowledge Representation. In that sense, the UvA deviates from the national frame of reference for bachelor's programmes AI. The panel believes that the

programme should be more explicit in this positioning, both to (future) students and to the KION, to better clarify what can be expected of graduates.

The objectives of the programme are elaborated in the exit qualifications of the bachelor's programme (see Appendix 1). These exit qualifications address the AI-specific knowledge and skills as well as general academic and professional skills that the students are expected to acquire. For example, exit qualification 8 deals with the ability to operate in a multidisciplinary team, and exit qualification 10 points out that the students are expected to be able to work on an empirical study under the supervision of an experienced researcher. In the self-evaluation report, the exit qualifications are related to the Dublin Descriptors for academic bachelor's programmes. This leads to a clear distinction in the knowledge, application and skills that the students are expected to develop. The programme clearly 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 programme's focus is consistently elaborated in its intended learning outcomes. They reflect the content, level and orientation of the bachelor's programme and match the professional field.

Considerations
The panel concludes that the bachelor's programme KI from the University of Amsterdam has a clear profile. It has a strong focus on technical aspects of AI and the mathematical skills that are a foundation for this technical expertise. This profile has been translated in the curriculum. The panel does advise to be explicit on the positioning of the programme in the AI arena and to clarify its choice to deviate from the framework within the KION platform. The programme has formulated clear intended exit qualifications in line with the Dublin descriptors. The intended learning outcomes reflect the academic bachelor's level of the programme.

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
The bachelor's programme KI of the University of Amsterdam has a three-year, 180 EC curriculum. It follows the university's academic 8-8-4 schedule. This schedule consists of six periods: each semester has two eight-week periods and a final four-week period.

All students take 144 EC of compulsory courses, including the 18 EC Bachelor Project. 36 EC are dedicated to the minor and other elective opportunities. At least 6 EC have to be dedicated to one of the eight KI electives. The students can use the remaining 30 EC to deepen their AI knowledge with other KI electives or broaden their expertise by following a minor taught at the University of Amsterdam. In consultation with the Examinations Board, they can also choose a minor from another university. Additionally, the minor can be an opportunity for them to study abroad. Appendix 3 contains an overview of the curriculum.

In 2016, a programme committee evaluated the curriculum of the KI programme. It consulted the ICT sector and AI master programmes to establish to what extent the curriculum was aligned with their expectations. Student evaluations were also included in their review. The conclusion of this investigation was that the curriculum would benefit from some minor changes, but major changes were not desirable. This led to a curriculum update that has been implemented. The new programme has dedicated more EC to the mathematical components, and these are explicitly connected to their applications in modern AI.

In order to establish coherence in the programme and to make the knowledge progression transparent, the programme has defined seven Learning Trajectories:

- Programming
- Mathematics
- Logic
- Natural Language Processing
- Machine Learning
- Cognitive Science
- Academic Skills

Each Learning Trajectory consists of two or more courses. In order to bridge the generic exit qualifications of the programme with the specific learning goals of individual courses, the programme has defined learning goals for each Learning Trajectory as well. It developed an ICT tool, DataNose, in which these different levels of learning goals are structured and presented.

As described under Standard 1, the educational vision for KI is concerned with the integration of theory and practice. On the one hand, the programme intends to develop a thorough understanding of the theoretical foundations of AI. It has dedicated a substantial part of the curriculum to mathematics and logic. On the other hand, it values the application of this knowledge in building AI systems. The students are trained intensively in programming skills. The KI programme uses a combination of teaching formats to realise this integration of theory and practice: lectures, lab groups, practicals and project formats. The students indicate to be satisfied with the quality of the teaching.

Courses with project formats are programmed in the 4-week periods at the end of the first, third and fourth semesters. The students work in groups on a programming assignment. They are expected to apply the knowledge they acquired in the previous courses to a practical problem. In the second year, these are external assignments: the students work on real-world problems and are expected to communicate with these stakeholders. In this course, *'Tweedejaarsproject AI'*, the students are trained to work with the SCRUM methodology for project management. The panel appreciates that with this course, the programme enables students to get into contact with the AI industry and gain practical experience.

The academic character of the programme takes shape from the beginning of the curriculum. The *'Inleiding Kunstmatige Intelligentie'* course deals with the state of the art in AI research. It consists of guest lectures by professors or associate professors who present their work and introduce the students to this academic discipline. In the first and second year, the students take the 'Practicum Academische Vaardigheden' (PAV), which is scheduled parallel to the regular courses. The practicals are delivered by a tutor, a teaching assistant who is dedicated to the group during the whole academic year. In the first year, the PAV practicals are integrated in the regular courses. They deal with generic academic skills, such as writing an essay, doing a literature search, presenting and critical thinking. There is a PAV-coordinator who coaches the tutors and oversees the course. In the second year, PAV deals with orientation towards master's programmes and careers after the bachelor's programme. It also supports the students in making relevant choices regarding the elective space in the third year of their programme. In the third year, the students follow workshops in academic English and participate in the *Filosofie en AI* course. This course addresses the philosophy of science, philosophy of mind and ethical aspects of AI. The panel concludes that the curriculum clearly has an academic focus. It appreciates the attention paid to the ethical aspects of AI.

The tutoring in PAV is also concerned with teamwork. Attention is paid to subjects related to teamwork, such as group project management, team roles, and dealing with free-riding and conflict. The tutor makes sure that during the year, all students fulfil different roles in the project teams. A rubric is designed to give feedforward and feedback on these team skills. If problems arise in the collaboration, the tutor discusses them with the project team. The panel appreciates this structured training in teamwork and supervision of the project teams.

Academic skills and project skills are integrated in the graduation project (18 EC). The students work on an individual project with a research component. They can come up with their own proposal or apply for one of the projects that are made available by the AI research institutes. This is coordinated by the graduation coordinator. Another opportunity is to participate in the Blue Student Lab, in which students from KI, Computer Science and Information Science work on projects from external clients. Although the students cooperate with other students and their client in these projects, they are expected to work individually on a research question related to the problem that is introduced by the client. The panel appreciates that the programme offers opportunities to do a graduation project with industry. The course has a strict planning during the graduation phase. It is offered twice a year: from period 2 and from period 5. Both trajectories are fulltime during two periods. The trajectory includes workshops on Academic English and setting up a research plan. A staff member acts as the daily supervisor for their specific topic and gives individual guidance and feedback on a draft report. There is also a plenary midterm presentation session. The students finish their project by writing a thesis in English.

The panel studied the curriculum as well as the content of a number of courses and projects, and spoke with students and staff about the content of the curriculum. It concludes that the curriculum is well-designed and coherent. The quality of the study materials is good. The structure of the curriculum is supported by the definition of the Learning Trajectories. The Learning Trajectories are closely related to the key areas of the KION frame of reference. However, as mentioned under Standard 1, Multi-Agent Systems and Knowledge Representation are not part of the core programme, which makes the curriculum an incomplete match with this framework. These subjects are covered in the electives of KI. The panel established that the programmes offers a wide range of AI-specific electives. The students appear to appreciate this.

The panel is very positive about the good balance of theoretical foundations and practical skills training in the curriculum. The investments in PAV are very much appreciated by the panel. It observed that the focus of the University of Amsterdam on mathematical and technical skills is manifest in the core curriculum. The projects integrate the various courses and ensure a translation of knowledge and skills into practice. According to the panel, the skills learned through these projects are very valuable for future professions, which often include working in project teams.

Student intake and feasibility
The programme has been confronted with a growth in intake of students recently from approximately 75 students in 2014-2015 to around 180 students in 2017-2018. In order to deal with this, it introduced a numerus fixus in 2018. As a consequence, the intake has decreased to around 100 students since 2018. This is substantially less than the numerus fixus of 200. The panel discussed this issue with the programme management. They appear to be satisfied with this effect. The numerus fixus seems to attract students who are more aware and capable of the requirements of the programme. Although an intake of 200 students could be handled, 100 students makes the organisation of the programme more manageable, especially regarding the staffing of final projects. The panel understands these considerations, but nevertheless it thinks that the programme could investigate whether it would be desirable to offer more enrolment opportunities. If the numerus fixus is not realised in the first enrolment period, it could be worth considering a second enrolment opportunity.

In order to improve the success rates of the students, the UvA installed a *Werkgroep Studiesucces* in 2009 that has formulated 20 recommendations. The Faculty of Science has integrated these measures in their policy and installed a taskforce that started in 2011 with the implementation of these measures. In the KI programme, this has led to several changes. First of all, implementing the academic year schedule of six periods provides a structure with normally two parallel courses. This prevents too much fragmentation of the study time and provides more study-weeks in a year. The course coordinators of courses that are scheduled in the same period are expected to discuss their course planning and, if necessary, align deadlines. Second, the programme has set a Binding Study Advice at 42 EC. This makes it possible to force weak students to leave the programme at the end

of the first year. Furthermore, courses in the first year have partial exams to make the students familiar with the level and mode of assessment. Some courses have optional lab sessions that are additional to the lectures and lab groups. In these sessions, students who struggle with the course content can get support from a teaching assistant. Another measure related to study success was the introduction of matching. This matching involves a day with lectures and lab groups at the faculty and a KI-specific test. The results of the test are not binding.

The programme committee is continuously monitoring whether there are specific course units causing study delay. It has several means to monitor the study load of individual courses and of combinations during a period: course evaluations, feedback from tutor groups and semester evaluation sessions. In some cases, this has led to a recommendation to the course coordinator to adjust the course.

The self-evaluation report mentioned that all these measures have improved the study success of the programme. The dropout rate in the first year is below 28%, and the most recent success rate of students who continue in the second year is 69% graduation within 4 years. The panel discussed the feasibility, study yield and the drop-out rates with the management, students and staff during the site visit. The students experience the programme as challenging but doable. There was no mention of specific obstacles regarding its feasibility. The yield and 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 subjects.

Teaching staff
The panel looked at the list of teaching staff provided in the self-evaluation report and interviewed a small selection of AI faculty. It concluded that the quality of the teaching staff is good. The courses are delivered by active researchers from four research institutes in the field of computer sciences and from the Faculty of Social and Behavioural Sciences. 92% has a PhD degree. The level of English proficiency of the teaching staff is good, which allows them to appropriately deliver the English-taught parts of the curriculum. The panel established that the AI staff possesses the necessary didactic skills. 62% of the lecturers holds a university teaching qualification (UTQ, in Dutch: BKO), and 33% is currently completing this qualification trajectory. There are bi-monthly teacher meetings during which the teaching staff are informed about and discuss topics such as assessment and changes in the curriculum.

The pressure on the teaching staff has increased during the last few years due to the growth in student numbers in the bachelor's and master's programmes. An increase in teaching staff is necessary but has only been partially realised. The programme management has arranged a teaching structure that is designed to realise small-scale education, despite the high number of students and scarcity of teachers. It has hired junior lecturers (usually alumni who graduated recently) and teaching assistants who deliver lab group sessions for groups of approximately 20 students. The teaching assistants receive training in didactical skills. Junior lecturers are expected to follow the UTQ trajectory. A new role has been introduced to promote the quality and coherence of the lab groups, i.e. Super Teaching Assistant. Junior lecturers can fulfil this role, as can more experienced teaching assistants. This person coordinates the communication between the teaching assistants and the lecturer of the course. He or she makes a lesson plan for the lab group sessions and coordinates the grading. The students and staff members seem to be content with this system. The panel was impressed by how the programme facilitates small-scale and well-coordinated education with this approach. The students appreciated this system as well. The teaching assistants are very approachable and can relate well to the student's perspective and needs in the courses.

Facilities
During the site visit the panel visited the RoboLab and Blue Student Lab in which the students can work on a voluntary basis and extra curricula with several robots and the associated hardware with students from other disciplines. During the programme, they also get support with obtaining access to software they need for their coursework. Individual and collaborative study facilities are available for them at the faculty, but the growth in student numbers makes it harder to gain access to these

facilities. In the near future, the programme will move to another location at which education, business partners of the faculty, and research will all have a floor. These facilities are expected to be sufficient for the current student numbers. The panel concludes that the programme offers sufficient facilities to its students.

Considerations
The panel established that the curriculum of the bachelor's programme KI of the University of Amsterdam is designed to realise its final qualifications. The Learning Trajectories create a clear and coherent curriculum that is in line with the programme's profile. The panel observed that the emphasis on the mathematical and technical aspects of AI offers the students a solid theoretical and practical foundation in the discipline. Theory and application are well-balanced in the courses. A variety of electives offer the students the opportunity to deepen their AI expertise in a direction of their choice. The panel is impressed with the efforts that are put into the *Practicum Academische Vaardigheden* by committed tutors and their coordinator. The students acquire relevant academic skills as well as skills related to teamwork. The panel appreciates the fact that all of the students come into contact with the AI industry in one of the projects. The programme is challenging but feasible. The panel supports the measures taken by the programme to promote its feasibility. It is positive about the quality and teaching skills of the teaching staff of the programme. The pressure on the teaching staff is high, but the role of super teaching assistant appears to function well in ensuring small-scale education for a large number of students.

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 within the KI programme follows the policy of the UvA as documented in the 'UvA Toetskader'. The faculty operationalised this in the policy document 'Handleiding Toetsing FNWI'. The Examinations Board produced 'The Examination Board's Rules and Guidelines' which is updated yearly. According to the first document, the relationship between the Dublin descriptors, final qualifications, learning goals and assessment must be clear. The assessment needs to be reliable, valid, transparent and manageable. These principles have been translated into 22 requirements for assessment at the UvA. Each requirement is assigned to a stakeholder: dean, programme director, examiner and/or the Examinations Board.

The programme's Assessment Plan describes how these requirements have been translated into assessment practices in the KI programme. This plan is constructed by the programme director. The panel could not find in this assessment plan an overview of when and how the final qualifications are assessed in the various courses of the programme. As described under Standard 2, the programme uses DataNose to structure and present the relationship between the final qualifications and the various courses of the programme. It also contains study guides for each course. The study guides include the modes of assessment. In daily practice, assessment is a task of the examiners. They need to work on maintaining the good quality of assessment of their courses. The examination of each course is checked by a second examiner or senior teaching assistant. There is a checklist for this peer review that addresses the quality criteria for examinations. Assignments and examinations are graded by use of a pre-established answer key. All assessment materials must be filed in the assessment dossier of the course, which includes the study guide, assignments/exams, answer models and an overview of the grades.

The panel studied the assessment system of the programme, the assessment plan, and some examples of assessment dossiers. It is positive about the university's assessment policy and the adequate requirements that are set up to stimulate and safeguard the quality of assessment.

However, the assessment dossiers that the panel studied weren't complete in all cases, and during its conversations with teachers, it gained the impression that in daily practice, the responsibilities are not always clear or strictly followed up. An example is the calibration of grading: in some cases this seems to be delegated to super teaching assistants, but it is supposed to be the responsibility of the course coordinators. Also, the assessment forms are not always filled in completely. The panel concludes that the assessment policy is well-designed, but that its implementation needs more attention.

KI assessment takes the form of written examinations, practical work, written assignments, reports and oral presentations. Most courses are assessed in a combination of formats. In the first year of the programme, all courses have two partial exams spread over the course period, in order to acquaint the students with the level and mode of examination. Lab groups contain formative assessments, such as programming assignments. The students also receive formative feedback on their projects and thesis. During the project work, groups of students are supervised by a teaching assistant. They are asked to present updates on their projects from time to time. The assessment plan of the programme states that at least 75% of the final grade of a course should be assessed individually. It describes several ways to assess individual contributions to project work. If there appear to be problems or a major imbalance in the individual contributions to projects, this is discussed between the students and supervisor. He or she decides on appropriate measures.

The panel is satisfied with the variety of assessment formats. In some courses, the students can compensate practical assignments with written exams. The panel recommends reconsidering this practice.

The panel also discussed the policy regarding fraud. This subject has the attention of both the Examinations Board and the teaching staff. They mentioned several means to deal with fraud. The programme uses Turnitin for written assignments. Coding assignments are also automatically checked for plagiarism. During the introduction course of the programme, there are usually a lot of plagiarism cases as the students seem ignorant of the different standards at the university, in comparison to high school assignments. This has been discussed with the teacher of this course. The subject is addressed in the course and in the tutoring sessions of PAV. The students sign a form there, stating that they won't commit plagiarism. The Examinations Board agreed with the panel that additional prevention activities could be useful in order to make sure the students are familiar and compliant with plagiarism regulations.

Thesis trajectory
The Graduation Project is an individual research project that is executed under the responsibility of an experienced researcher who acts as the supervisor. This supervisor is the first examiner, with another AI researcher taking the role of second examiner. The appointment of supervisors is done by the graduation coordinator. The Examinations Board has made a list of the staff members who are available for graduation supervision. The graduation process includes midterm presentation sessions that are chaired by a member of the Examinations Board. When the research is completed, the student writes a bachelor's thesis.

Theses are assessed by the supervisor and a second assessor. They perform their assessment independently using their own marking form. These forms indicate the different assessment criteria, including the weighting of these criteria. There is also a more holistic description of criteria related to specific grades. The process of the graduation project is not included as a criterion. After their individual assessment of the thesis, the assessors establish the final mark. This is the average of the two grades, unless the difference between them is more than 1 point or if the final mark is just under 5.5. In these cases, the two assessors discuss their grades and decide on a final grade. If they cannot come to an agreement, a third assessor is involved. The final grade is then the average of the three grades. From 2019, this grading process has been digitalised and is transparent to the students.

The panel thinks that the assessment procedure for the Graduation Project is appropriate. It is positive about the procedure that there are always two academic examiners involved in the grading, and that they form their opinion separately before establishing the grade together. It could be beneficial to include a more independent reader to establish if the thesis can pass or not, in case of disagreement between the two assessors. According to the panel, the incorporation of the research and supervision process could be included in the grading form; this is currently not a criterion for the final grade. This matter was discussed with the programme management. They wish to ensure that the final product is of sufficient quality and therefore do not want the process to compensate for inadequate products. The panel thinks that this objection can be overcome by requiring that both the process and the end result receive a satisfactory grade.

The panel studied a number of assessment forms as part of the thesis check conducted prior to the site visit. The weighting of the scoring criteria ensures that the substantiation of the final grades are clear to students. However, not all forms contain a written substantiation of the final grade, even though this is mandatory for grades above 8. The panel recommends providing more qualitative substantiation for the grading.

Examinations Board
The quality of the AI assessment is safeguarded by an Examinations Board appointed for all programmes within the Faculty of Science. This Board has an external member and is advised by an assessment expert. It has installed an assessment committee that advises programmes on exam-related matters. There is also a subcommittee that is dedicated to dealing with policy and the handling of fraud and plagiarism. The Board has programme-specific subcommittees, one of which is the subcommittee for the bachelor's programme KI and the master's programme Artificial Intelligence. The panel interviewed members of the Examination Board and the AI subcommittee. It concluded that they have a clear view of their tasks and responsibilities and that they work hard to guarantee the quality of assessment faculty-wide.

This subcommittee has four members and meets once a month. It deals with students' requests concerning changes in their individual study programme and requests for exemptions, as well as with fraud cases. A secretary supports the subcommittee with its work. The subcommittee appoints the programme's examiners and monitors the quality of assessment within the programmes. The self-evaluation report stated that the subcommittee has recently introduced meetings with course coordinators. In these meetings, a course coordinator is invited to discuss the assessment and grading of their course. These conversations seem to be appreciated by the staff members, as this gives them an opportunity to discuss difficult considerations in the assessment process and to exchange best practices. Each year, a sample of course coordinators is invited to have such a meeting. The selection is made based on pass rates and student evaluations. The results of these meetings are reported to the Programme Director. The subcommittee intends to monitor each course at least once every five years. For the Graduation Project, it takes regular samples of theses to monitor the grading process and the level of the theses.

Considerations
According to the panel, assessment within the bachelor's programme Kunstmatige Intelligentie is up to standard. The assessment policies are in line with university policy and are well documented. In practice, the responsibilities concerning assessment and grading seem to be less clear. The AI assessment is varied and aligned with the learning objectives. The programme pays attention to the follow-up of fraud and plagiarism but could invest more in prevention measures. The panel concludes that within KI, the supervision and assessment of Graduation Projects are well-structured. Incorporation of the research and supervision process in the forms could improve the assessment even further. The Examinations Board has a clear view of its tasks and responsibilities. The AI subcommittee carries out its tasks in a proactive manner.

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 bachelor's programme AI demonstrates that the final qualifications are achieved, the panel studied a selection of fifteen bachelor theses and their assessment forms. It agreed with the assessments of these theses. It concluded that the theses showed that the students are on an academic level. The theses confirmed that the graduates have the capability to perform a theoretically founded project and report on it. Some theses could be called outstanding. This is reflected in the fact that a number of them have served as the basis for a journal or conference publication. All in all, the panel is pleased with the level of the theses. The bachelor graduates are well prepared for the master's programme AI, which was confirmed by the master's students and alumni in the interview during the site visit. The panel concluded that the quality of the studied bachelor's theses indicated that the graduates have achieved the final qualifications of the bachelor's programme.

Recent data on what students do after obtaining their bachelor's degree were not presented in the self-evaluation report. The curriculum evaluation report of 2016 presented data of the preceding cohorts. Approximately 65% of the graduates proceeded directly after graduation to a master's programme. The report indicated that the percentage of graduates who proceed to the master's degree programme AI at the University of Amsterdam is low: approximately 30%. The graduates are welcome at any AI master's degree programme in the Netherlands. Alumni can also choose a master's programme in a related discipline or enter the favourable job market for AI professionals. After studying the programme and talking to graduates, the panel is convinced the programme provides the students with a broad basis which enables them to pursue an academic or business career.

Considerations
The panel is impressed with the high level of some of the bachelor's theses it studied. Overall, they demonstrated that KI graduates realise the intended learning outcomes. The graduates are able to proceed to a variety of master's programmes or the professional field. The panel is convinced KI graduates have acquired a skill set and level which render them attractive to the academic or professional field.

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 Kunstmatige Intelligentie offered by the University of Amsterdam 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
For author names and article: https://pure.uva.nl/ws/files/29809664/KION_FoR_2018_Final.pdf[1]

October 16th, 2018

This document is an update of the 2013 Frame of Reference as developed by the KION[2] 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[3]
- 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[4]
- 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[5], 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)[6] 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).

In 1999, the number of recognised labels in the CROHO was reduced, and the aforementioned study programmes were united under the name Artificial Intelligence[7]. Initially, this was an administrative

[1] 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.
[2] Kunstmatige Intelligentie Opleidingen Nederland
[3] www.qanu.nl/en/state-of-the-art-reports (last visited in March 2018)
[4] www.acm.org/education/curricula-recommendations (last visited in March, 2018)
[5] www.unideusto.org/tuning/ (last visited in February 2018)
[6] Centraal Register Opleidingen Hoger Onderwijs
[7] In Dutch: Kunstmatige Intelligentie

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)
- 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[8] (ECTS) in which study load is measured in European Credits (ECs). One EC 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.

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

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 formalisation 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 athorough 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, Optimalisation)
- 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[9]. 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.

[9] "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[10]. Together these final qualifications must lead to alumni that exemplify the shared identity defined in section 3.

[10] 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.[11]

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

[11] 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 exit qualifications are enumerated in Dutch in the OER. Here is their equivalent in English:

A student obtaining the degree of Bachelor in Artificial Intelligence is able:

1. to apply the methodology of the classical approach on AI, which uses a symbolic representation of knowledge, for the construction of computational models of cognitive processes like problem solving, machine learning and natural language processing.

2. to apply the techniques based on the numerical, non-symbolic approach in applications, in particular natural language processing, computer vision and pattern recognition.

3. to describe the most influential philosophical and psychological theories in the field of knowledge and cognition, which are needed to contribute to the discussion of the foundations and (ethical) implications of the developments inside the field of AI.

4. to use his/her knowledge and proficiency in the field of mathematics and logic to work with the mathematical and formal models relevant in the field of AI.

5. to distinguish the features of the different programming languages and environments used inside the field of AI and to use those tools to solve research problems with a AI component.

6. to use his/her insight in his/her talents to make a deliberate choice on his/her future career and has acquired the learning skills to further specialize in a research master or a professional programme.

7. to find relevant literature for a research question and to critically reflect on how this literature could support a hypothesis. The student is able to report on such a literature study both verbally and in writing.

8. to operate on an academic level inside a multidisciplinary team, with adequate communicative and collaborative skills.

9. to use his/her insight in the societal significance of AI field and the responsibilities of an AI expert to advise on professional decisions which have to balance the interest of different stakeholders.

10. to design, perform and analyze an individual empirical study, supervised by an experienced researcher, by applying AI methods and techniques and critically reflect on his/her acquired knowledge and understanding in order to further consolidate, expand and apply this knowledge.

The Curriculum Commission already analyzed the connection between courses along these trajectories, which are now formalized and amended with the Academic Skills learning trajectory:
- Mathematics
- Programming
- Logic
- Language
- Machine Learning
- Cognition

For each of the learning trajectories the following goals are defined:

Logic
The student is able to apply the formal methods of logic to AI problems and applications.
1. The student is able to interpret the fundamental logical machinery, such as propositional calculus and predicate logic.
2. The student is able to create logical models for various AI problems to reason about knowledge, planning, and communication.

3. The student is able to take an informed position in debates on the principles and consequences of AI.
4. The student is able to recognize the importance of logic for qualitative AI.

Natural Language Processing
The student is able to apply underlying techniques to create natural language processing systems.
1. The student is able to identify and describe the formal structures of natural language.
2. The student is able to distinguish between applicability of NLP methods depending on the structure of the language.
3. The student is able to apply computational processing (including statistical models) to extract syntax, semantics, and morphology.
4. The student is able to use common programming languages for NLP.

Cognition
The student can apply his/her knowledge of cognitive theories to work with computational models of cognitive processes.
1. The student is able to relate and apply the fundamental concepts and methods of the cognitive psychology and cognitive neuroscience.
2. The student is able to understand and apply the computational models used to simulate and interpret cognitive processes.
3. The student is able to creatively adjust existing cognitive models and translate a psychological hypothesis into a computational model.

Machine Learning
The student is able to understand the fundamentals of modern Machine Learning techniques.
1. The student is able to develop AI specific applications.
2. The student is able to acquire, clean, analyze, explore, and visualize data in order to make data driven inferences and decisions.
3. The student is able to distinguish between different machine learning methods.
4. The student is able to explain the importance of dimension reduction for a classification task.
5. The student is able to demonstrate a classification task on given example data and apply it to other related problems.
6. The student is able to distinguish and explain the differences between supervised and unsupervised learning.
7. The student is able to describe and implement graph-search techniques.
8. The student is able to rewrite local structures in images data into effective features.

Programming
The student can independently implement an algorithm.
1. The student is able to represent and process data with the provided datastructures & methods of a programming language and construct new datastructures on basis of the available classes and other abstraction methods.
2. The student is able to improve the conceptual abstraction of code by using functional decomposition, control-flow and other programming constructs.
3. The student is able to translate a problem description into functional and non-functional requirements, and to translate these requirements into tests to verify and validate the program.
4. The student can trace an error in a program on basis of error messages, exceptions, failed test or unexpected results, and devise a strategy to rectify this error.
5. The student is able to document his/her program to make this solution accessible to other developers, and to share this solution effectively by making use of version-control.
6. The student is able to make an informed choice on the usage of several (new) programming languages, on the basis of the problem description and the documentation of the language.
7. The student is able to determine the computational complexity of an algorithm and/or implementation and could propose a number of possible adjustments to reduce the complexity.

8. The student is able to trace how program code is represented and interpreted in machine code, and the consequences on the abstraction level of the program.
9. The student is able to apply his knowledge from the elementary web technologies, infrastructure and protocols to collect, interpret and dissolve information over the internet.

Mathematics
The student can use the mathematical tools needed for the problems typically encountered in AI.
1. The student is able to perform elementary calculation (by hand and using a software) and construction (including differential and integral calculus) with functions in one or more variables.
2. The student is able to formulate and solve problems using the basic notions of probability and statistics (by hand and using a software) with applications in AI, such as regression, classification.
3. The student is able to formulate and solve problems using more specific statistics tools (on a conceptual and also technical levels) that are needed for the basics of Statistical Machine Learning, with an emphasis on the Bayesian statistics framework.
4. The student is able to formulate and solve problems (by hand and using a software) using coordinate transformations, convolutions and Taylor series.
5. The student is able to formulate and solve problems of linear algebra, ranging from Gaussian elimination via matrices (including important subclasses like orthogonal and symmetrical) to eigenstructure, ability to bring quadratic forms to principal axes, and singular value decomposition.

Academic Skills
The student can write, present, cooperate and perform a scientific study at an academic level. In addition, he/she has reflected on a future career path.
1.The student has gained an independent and academic attitude with respect to acquiring knowledge, sound argumentation and critical thinking.
2. The student is able to design a scientific study, perform the study, analyze the results and evaluate the conclusion that can be drawn from this study.
3. The student is able to write an essay and to report on a research project with a scientific argumentation, structure and style.
4. The student is able to report on the outcome of a research project in a structured way to an audience.
5. The student is both able to work independently and in a team on a project.
6. The student is able to reflect on a future career path in AI-related professions based on his/her capabilities, talents and interests.

APPENDIX 3: OVERVIEW OF THE CURRICULUM

Het programma van de bacheloropleiding Kunstmatige Intelligentie bestaat uit:

- een verplicht gedeelte (144 EC), waaronder het Afstudeerproject BSc KI
- en een vrije keuzeruimte (36 EC) in het derde studiejaar.

Jaar 1
Het eerste studiejaar kent een verplicht programma van 60 EC.

Academische vaardigheden
Gedurende het gehele eerste studiejaar wordt er gewerkt aan academische vorming. Hieronder wordt begrepen: vaardigheden en oriëntatie op studie en beroep. Het onderwijs vindt plaats in practica academische vaardigheden die onderdeel uitmaken van verschillende vakken in het eerste jaar.

Bindend Studieadvies (BSA)
Iedere eerstejaarsstudent ontvangt aan het eind van diens eerste jaar van inschrijving, doch uiterlijk 31 augustus, een bindend studieadvies over de voortzetting van de studie. Het BSA houdt in dat de student aan het einde van het eerste jaar van inschrijving minimaal 42 EC aan eerstejaars vakken van de opleiding dient te hebben behaald.

	Sem. 1	Sem. 2	EC
Inleiding Kunstmatige Intelligentie			6
Problem Solving and Search			6
Introductie in Programmeren			6
Lineaire algebra KI/INF			6
Webtechnologie voor KI/INF			6
Inleiding Cognitieve Psychologie			6
Inleiding Logica			6
Calculus en Optimalisatie			6
Taaltheorie en Taalverwerking			6
Informatievisualisatie			6

Jaar 2
Het tweede studiejaar kent een verplicht programma van 60 EC.

Academische vaardigheden: Oriëntatie
Gedurende het tweede studiejaar wordt er gewerkt aan oriëntatie op het afnemende veld van kunstmatige intelligentie, door het bespreken van onderzoeken binnen en buiten de eigen universiteit en het interviewen van een alumnus die werkzaam is in het werkveld. Dit onderwijs vindt plaats in practica academische vaardigheden die onderdeel uitmaken van het Afstudeerproject BSc KI. Deze practica gaan van start in periode 1 van jaar 2, en lopen door tot periode 6 in jaar 2.

Blokkade-regeling

1. Voor cohort 2014-2015 en later, op wie de BSA regeling van toepassing is, geldt het volgende: indien een student na twee jaar studeren het eerste studiejaar nog niet heeft gehaald, heeft de student geen toegang meer tot onderdelen van het tweede of het derde studiejaar, hetgeen resulteert in een blokkade van de student voor de genoemde onderdelen. De student krijgt hiervan schriftelijk bericht. Indien een student in de loop van het studiejaar alle EC van het eerste studiejaar heeft gehaald, wordt de genoemde blokkade opgeheven.
2. Voor studenten van cohort 2013-2014 en eerder, op wie de BSA-regeling niet van toepassing is, geldt het volgende:
   a) het is de student slechts toegestaan onderdelen uit het tweede en het derde studiejaar van de opleiding te volgen indien de student na het eerste studiejaar minstens 42 EC heeft behaald. De student krijgt hiervan schriftelijk bericht;
   b) indien een student na twee jaar studeren het eerste studiejaar nog niet heeft gehaald, heeft de student geen toegang meer tot onderdelen van het tweede of het derde studiejaar, hetgeen resulteert in een blokkade van de student voor de genoemde onderdelen. De student krijgt hiervan schriftelijk bericht. Indien een student in de loop van het studiejaar alle EC van het eerste studiejaar heeft gehaald, wordt de genoemde blokkade opgeheven.

	Sem. 1	Sem. 2	EC
Bayesian Statistics for Machine Learning			6
Computersystemen			6
Computationele logica			6
Leren			6
Leren en Beslissen			6
Datastructuren en Algoritmen voor KI/INF			6
Natuurlijke Taalmodellen en Interfaces			6
Cognitive Modelling			6
Introduction to Computer Vision			6
Tweedejaarsproject BSc KI			6

Jaar 3

Het derde studiejaar kent een verplicht programma van 24 EC en een keuzeruimte van 36 EC. In semester 1 heeft de student ruimte voor 30 EC vrije keuze. In periode 4 van semester 2 ruimte voor 6 EC keuze en volgt de student een verplicht programma van 6 EC. In periode 5 en 6 van semester 2 volg je een verplicht programma van 18 EC: het Afstudeerproject BSc KI.

Van het totaal van 36 EC keuzeruimte in studiejaar 3 moet minstens 6 EC een KI-gerelateerd keuzevak zijn.

	Sem. 1	Sem. 2	EC
Filosofie en AI			6
Afstudeerproject BSc KI			18
Vrije keuze: Aangeraden keuzevakken			0

APPENDIX 4: PROGRAMME OF THE SITE VISIT

9 December 2019

08.30 – 09.00	Arrival committee and welcome
09.00 – 10.00	Internal deliberation by the committee
10.00 – 11.00	Board and programme management Bachelor KI and Master AI
11.00 – 11.15	Internal deliberation by the committee
11.15 – 12.00	Students bachelor and alumni KI
12.00 – 12.15	Internal deliberation by the committee
12.15 – 13.00	Didactical staff bachelor KI (English)
13.00 – 14.00	Lunch
14.00 – 14.45	Rondleiding Robolab
14.45 – 15.00	Internal deliberation by the committee
15.00 – 15.45	Exam committee (English)
15.45 – 16.00	Internal deliberation by the committee
16.00 – 17.00	Students and alumni master AI and advisory board (English)
17.00 – 17.15	Internal deliberation by the committee

10 December 2019

08.30 – 09.00	Arrival committee
09.00 – 09.30	Internal deliberation by the committee
09.30 – 10.00	Inloopspreekuur
10.00 – 10.45	Didactical staff master AI (English)
10.45 – 11.00	Internal deliberation by the committee
11.00 – 11.45	Interview formeel verantwoordelijken
11.45 – 13.45	Opstellen oordelen + lunch
13.45 – 14.00	Feedback by the committee
14.00 – 14.15	Short break
14.15 – 15.00	Ontwikkelgesprek
15.00 – 15.15	Afronding

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
- Assessment plan BSc Kunstmatige Intelligentie
- KION frame of reference
- Staff overview
- Rapport Curriculum Commissie
- Rapport Evaluatie Studiesucces
- Teaching and Examination Regulations
- Description of Course components
- Exam protocol
- Rules and guidelines of the Examinations Board
- Annual reports Examinations Board
- Annual reports Programme Committee
- Assessments dossiers and study materials of courses, including Study guides, assessment, results, and evaluation results of the following courses:
    - Inleiding KI
    - Lineare Algebra
    - Natuurlijke Taalmodellen en Interfaces