MASTER'S PROGRAMME

ARTIFICIAL INTELLIGENCE

FACULTY OF SCIENCE

UTRECHT UNIVERSITY

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This report was finalised on 24 June 2020

REPORT ON THE MASTER'S PROGRAMME ARTIFICIAL INTELLIGENCE OF UTRECHT UNIVERSITY

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

Master's programme Artificial Intelligence

Name of the programme:	Artificial Intelligence
CROHO number:	66981
Level of the programme:	Master
Orientation of the programme:	Academic
Number of credits:	120 EC
Location(s):	Utrecht
Mode(s) of study:	Full-time
Language of instruction:	English
Submission deadline NVAO:	1 May 2020

The visit of the assessment panel Artificial Intelligence to the Faculty of Science of Utrecht University took place on 13 and 14 January 2020.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

Name of the institution:	Utrecht University
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 master'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 (Belgium) [chair];
- Prof. dr B. (Bart) de Boer, researcher and professor at the Artificial Intelligence lab of the Vrije Universiteit Brussel (Belgium);
- Prof. dr W. (Wiebe) van der Hoek, Executive Pro Vice Chancellor and professor at the Department of Computer Science of the University of Liverpool (United Kingdom);
- Dr A.P. (André) Meyer-Vitali, senior scientist Data Science group at the unit ICT of TNO;
- 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;
- F. (Florence) van der Voort BSc, master's student Artificial Intelligence and Philosophy: Bioethics & Health at the Vrije Universiteit Amsterdam [student member].

The panel was supported by Dr. Marijn Hollestelle (QANU), who acted as secretary.

WORKING METHOD OF THE ASSESSMENT PANEL

The site visit to the master's programme Artificial Intelligence at the Faculty of Science of Utrecht University 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 Utrecht University, the panel was supported by Marijn Hollestelle, a certified NVAO secretary.

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

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

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

The project coordinator composed a schedule for the site visit in consultation with the Faculty of Science. Prior to the site visit, the Faculty selected representative partners for the various interviews. See Appendix 3 for the final schedule.

Before the site visit to Utrecht University, 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 37 graduates between February and August 2019. A variety of topics, and a diversity of examiners were included in the selection. Also a mix of departments where students graduated was included (Informatics: 8/15, Philosophy: 2/15, Cognitive sciences: 4/15, Linguistics: 1/15), as well as a variety of students doing their master's research externally (6/15) at different companies. 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 Utrecht University took place on 13 and 14 January 2020. Before and during the site visit, the panel studied the additional documents provided by the programmes. An overview of these materials can be found in Appendix 5. The panel conducted interviews with representatives of the programmes: students and staff members, the programme's management, alumni and representatives of the Board of Examiners. It also offered students and staff members an opportunity for confidential discussion during a consultation hour. No requests for private consultation were received. The panel used the final part of the site visit to discuss its findings in an internal meeting. Afterwards, the panel chair publicly presented the panel's preliminary findings and general observations.

Report
After the site visit, the secretary wrote a draft report based on the panel's findings and submitted it to the project coordinator for peer assessment. Subsequently, the secretary sent the report to the panel. 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 master's programme AI is a unique cooperation between four departments and three faculties. It has a clear and unique broad profile with a model-driven and symbolic approach, with a stress on methodological, foundational and conceptual issues, focussing on concepts behind natural and artificial intelligence and on the theoretical foundations of the field. Its ILOs are well formulated and reflect the profile, academic orientation and master's level of the programme. They are aligned with the expectations of the discipline and the professional field through alignment with the full core of the domain-specific KION framework of reference. Some ILOs will not be equally applicable for all students in the broad programme. The panel suggests that the programme investigate if differentiation between the ILOs and programme directions is desirable, taking care to keep aligned with the AI component as defined by the KION framework.

The panel feels that introducing an Advisory Board of stakeholders could further strengthen the alignment with the professional field.

The panel is positive about the curriculum, the teaching-learning environment and the quality of the teaching staff, which enable the incoming students to achieve the intended learning outcomes, in its opinion. The panel is very positive about the diverse directions the students are able to take, but is also convinced that along with freedom of choice for primary (30 EC) and secondary electives (30EC), the option for a research internship, the use of study plans, the themes of areas of specialisation that align with research interest of the scientific staff, and the option to follow a profile (offered by the Faculty of Science) provides a clear structure to the programme. It recommends the programme management to investigate if more statistics of mathematics is needed in the programme. It observed that the set-up of the thesis phase, split into a proposal phase and the phase of performing and completing the planned research and writing the thesis, guides students well through the process and also should help them to complete their studies on time. It is pleased to see that the students can take an *AI Research* internship, which a lot of them do, adding to the connection with the professional field. The panel thinks that shaping the programme along course-based and research components, primary and secondary electives, sufficiently helps to retain direction and structure within the broad programme. The curriculum reflects the ILOs well.

The students are well guided in setting up their study plans and obtain counselling from programme coordinators and the study advisor. The programme is succeeding in reducing the workload on the teachers by recruiting teaching assistants. Courses with a high number of students are given by multiple teachers to spread the workload. The panel values the small-group learning experience and hopes the programme will be able to take measures to safeguard this system and reduce the workload further. The teachers feel and act as a community, and meet regularly to align matters concerning courses and assessment. They are accessible to the students and receive annual feedback from the students on their courses. They are proficient in teaching in English. The choice to offer the programme in English, and with an English programme name, is well justified because of the largely international labour markets for graduates, according to the panel.

The panel is positive about the feasibility of the programme. It did observe that the level of proficiency in programming varies, but this is to be expected given the interdisciplinary and broad programme, attracting a wide variety of students.

The students are enthusiastic about the guidance by the teachers and study advisor, the interdisciplinary diversity of topics and the room for electives. They value working in small and diverse groups, which enables peer learning. Keeping track of the different roles they take up in the working groups of different courses will enable them to gain experience in all different roles.

The master's programme Artificial Intelligence has a solid assessment system, guaranteeing that the students are assessed on all ILOs throughout the courses. The panel values the diversity of testing involved in the programme.

The thesis assessment is well-designed, employing two academic supervisors to assess the thesis independently, who seek consensus afterwards, but the way this is done should also be made clearly visible on the thesis forms. The intervision panel helps to ensure consistent use of the rubrics and consistent assessment of master's projects. The panel is positive about the intervision panel and the use of the rubrics. Reporting on the AI content of the work done in the theses could be incorporated in the rubrics. This would aid in making the AI component explicitly visible in the broad thesis topics.

The Executive Panel Artificial Intelligence of the Board of Examiners of the Graduate School of Natural Sciences fulfils its role in the quality assurance of assessment well and has the necessary checks and balances in place to monitor the quality of the exams as well as the theses. Because of the interdisciplinary nature of the programme, involving multiple faculties, the panel thinks the EP AI should be able to manage its own standard for quality control, including assessment forms that might diverge from the default forms of the Graduate School of Sciences.

The panel concluded that the theses of the master's programme Artificial Intelligence are of a good quality and convincingly show that the programme's ILOs have been achieved by the students. The theses showed that the students have mastered the topics within the broad area of Artificial Intelligence and have acquired good academic skills, some even to the point of publishable results. This is further demonstrated by the high employability of the graduates, in both industry and academia.

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

Master'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, dr. Marijn Hollestelle, 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

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 master's programme Artificial Intelligence at Utrecht University is a joint effort of the Department of Information and Computing Sciences of the Faculty of Science, the Departments of Philosophy and Religious Studies (Section Philosophy) and Language, Literature and Communication (Section Linguistics) of the Faculty of Humanities, and the Department of Psychology of the Faculty of Social and Behavioural Sciences, under the responsibility of the Department of Information and Computing Sciences. The master's programme is part of the Graduate School of Natural Sciences (GSNS), which encompasses eleven master's (and eight PhD) programmes in the fields of Mathematics, Physics, Chemistry, Computer Science, Information Science, Artificial Intelligence, and History and Philosophy of Sciences.

Artificial Intelligence is inherently an interdisciplinary science building on knowledge, models and tools from various scientific disciplines such as computer science, psychology, philosophy, linguistics, sociology, economy and law. The aim of the master's programme Artificial Intelligence at Utrecht University is to educate students to be optimally prepared for conducting top-level research or AI-related research projects, both in a disciplinary and interdisciplinary environment, at universities or research institutes, or in business and industry. Graduates should be able to contribute to innovative research and development in artificial intelligence, ranging from understanding human intelligence through empirical and experimental research, to building formal and computational models for intelligent phenomena and behaviour, to devising techniques and algorithms for engineering intelligent systems. The master's programme focuses on key areas in Artificial Intelligence, such as knowledge representation and reasoning, autonomous agents and multi-agent systems, natural language processing, cognitive modelling, and philosophy of artificial intelligence. The panel is positive about the broad set-up of the master's programme, which is an asset in the Dutch AI landscape. It studied the profile as well as the intended learning outcomes (ILOs). It concluded that the programme has a solid profile which is clearly visible in its ILOs, geared towards knowledge representation and reasoning, autonomous agents and multiagent systems, natural language processing, cognitive modelling, and philosophy of artificial intelligence.

Intended learning outcomes
The goals of the programme have been translated into 17 ILOs that are listed in Appendix 1. These are structured in line with the five Dublin descriptors for academic master's programmes and are formulated based on the qualifications of the KION framework.

The programme covers the full core modules of the domain-specific frame of reference of the KION (Kunstmatige Intelligentie Opleidingen Nederland), which was formulated by the Dutch Artificial Intelligence programmes in 2018. The ILOs are well formulated and correspond with the KION Framework for master's programmes in Artificial Intelligence, thus also adding to the connection to the discipline and the professional field. The structuring of the ILOs using the Dublin descriptors for academic master's programmes clearly reflects their academic orientation and master's level.

The programme has a broad set-up with much flexibility. The way the ILOs are currently set up obviously suggests that in this broad programme, the students will not address all ILOs to an equal extent. The panel confirmed this when reading the theses (see Standard 4) that sometimes less emphasis is placed on ILOs 6 and 7 (capable of creating innovative software and information system designs, taking account of feasibility issues; mastery of the necessary skills in theoretical analysis, modelling and experimentation). These ILOs will not be equally applicable to all students in the broad

programme. The panel suggests that the programme investigates whether differentiation between the ILOs and programme directions is desirable, taking care to keep aligned with the AI component as defined by the KION framework. To make the specific expertise of the alumni clear, also to the professional field, the programme could opt for shaping programme-specific master profiles (other than the ones offered by the Faculty of Science), aligning with differentiated ILOs.

Connecting to the KION framework ensures alignment of the master's programme with the field, but to keep the programme aligned with the expectations of the rapidly changing academic and professional field, the panel advises the programme management to introduce an Advisory Board of stakeholders, including representatives of companies in data science and AI, other academic programmes in AI, and alumni of the programme. This board could advise on the content and goals of the programme.

Considerations

The master's programme AI is a unique cooperation between four departments and three faculties. It has a clear and unique broad profile with a model-driven and symbolic approach, with a stress on methodological, foundational and conceptual issues, focussing on concepts behind natural and artificial intelligence and on the theoretical foundations of the field. Its ILOs are well formulated and reflect the profile, academic orientation and master's level of the programme. They are aligned with the expectations of the discipline and the professional field through alignment with the full core of the domain-specific KION framework of reference. Some ILOs will not be equally applicable for all students in the broad programme. The panel suggests that the programme investigate if differentiation between the ILOs and programme directions is desirable, taking care to keep aligned with the AI component as defined by the KION framework.

The panel feels that introducing an Advisory Board of stakeholders could further strengthen the alignment with the professional field.

Conclusion

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

Standard 2: Teaching-learning environment

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

Findings

Curriculum

The master's programme in Artificial Intelligence consists of two main components: a course-based component and a research component. The research component (thesis phase) can start once all mandatory courses have been successfully passed and 60 EC in total have been obtained. The course-based component consists of 76 EC, including 16 EC mandatory courses, 30 EC primary electives, and 30 EC secondary electives. The 16 EC mandatory courses are: Methods in AI Research (7.5 EC), Philosophy of AI (7.5 EC), Introducing Natural Sciences (0.5 EC), Dilemmas of the scientist (0.5 EC). The last two are special broadening courses. The first one introduces students to the education offered by the Graduate School of Natural Sciences and this master's programme. They get an overview of the courses and interdisciplinary options. The second one discusses dilemmas of integrity in the practice of doing academic research. The students learn what such dilemmas are and how they can deal with them in practice. The panel is very positive about this addition to the AI programme, as this will add to the interdisciplinary approach. Also, integrity and ethics are currently pressing topics within AI. The 30 EC primary electives consist of 4 courses that can be chosen from the following pool of 10 courses (each 7.5 EC): Intelligent Agents, Multi-agent Systems, Multi-agent Learning, Social Simulation, Cognitive Modelling, Experimentation in Psychology and Linguistics, Advanced Topics in Cognitive Science, Logic and Language, Common-sense Reasoning and

Argumentation, Logic and Computation. Courses that are provided by other master's programmes in Utrecht University may also be chosen. Within their elective space, the students can opt for a profile, offered by the Faculty of Science. Profiles are similar to minors in the bachelor's programmes: they consist of four courses of 7.5 EC each that form a unit. The three profiles that can be chosen are *Complex Systems*, *Applied Data Science*, and *Educational*. They do not extend the study load. For the master's programme AI, a profile replaces the four secondary electives, enabling a student to further expand their selected direction of study or broaden their knowledge by choosing courses that are more distant from their core. The panel thinks that shaping the programme along course-based and research components, primary and secondary electives, sufficiently helps to retain direction and structure within the broad programme. The curriculum reflects the ILOs well, although the programme could investigate whether differentiation between the ILOs and programme directions is desirable (see standard 1).

Students are provided with a guideline to help compose their individual study plans. The guideline suggests various areas of specialisation, with an associated package of primary and secondary electives. The themes of the areas of specialisation are aligned with the research interests of the scientific staff involved in the master's programme and with potential areas for employment. The panel is positive about the structure this provides to the student, and thinks these guidelines could be a start for shaping potential programme-specific master profiles, to clarify the specialisation of the graduates, as discussed under standard 1.

Various courses such as *Methods in AI Research*, *Philosophy of AI*, *Intelligent Agents*, *Cognitive modelling*, and *Experimentation in Psychology and Linguistics* prepare the students for their final research projects. In these courses, they are trained to develop their academic and practical skills, including reading and evaluating scientific work, performing empirical and experimental research, developing and programming systems, and writing reports and short essays. It is possible to perform an *AI Research Internship* as a secondary elective for either 7.5 EC or 15 EC depending on the duration and scope of the project, as judged by the supervisor in consultation with the programme coordinator. The students can choose, for example, to develop intelligent software, investigate a theoretical problem related to artificial intelligence, or perform experimental research. These individually supervised projects can be done internally or externally at other universities, knowledge institutes, companies, or industry. The panel is pleased to see that internships are possible and that the option is taken up by approximately 50% of the students. This strongly adds to the connection to the professional field.

For the academic year 2019/2020, three new primary elective courses have been introduced. They are *Social Computing*, *Advanced Machine Learning,* and *Natural Language Processing*. Moreover, the *Advanced Topics in Cognitive Science* course has been redesigned to include a significant component on machine learning, and renamed *Machine learning for human vision and language*. The panel is pleased to see that the programme keeps pace with recent developments in academic and professional AI settings in this way.

Didactic concept
The didactic model for the master's programme AI is to provide the students with a small-group, interdisciplinary learning experience, provide specialised and interdisciplinary knowledge in lectures, allow freedom of choice based on personal interests, and utilise different teaching and training forms for knowledge and skills. The students are well guided in setting up their study plans and are counselled by programme coordinators and the study advisor.

A flexible, small-group learning model with freedom of choice based on interests is part of the Utrecht University educational model. Because of rising student numbers, most master's courses currently have an enrolment of about 40-60 students, and recently there were even a few courses with an enrolment of 100 students. The panel sees this as a concern and is pleased that the programme has addressed this by hiring new staff, increasing the number of student assistants assigned to these courses, and introducing new courses on popular topics such as Advanced Machine Learning and

Natural Language Processing. It is very positive about the small-group learning model, which is a strength of the programme. It would advise the programme management to ensure this concept remains intact.

All courses have additional assignments that may involve presentations, writing reports, reading scientific literature and reviewing it, programming and experimentation, data analysis, and brainstorming, providing variety to the learning experience. Most of the activities are done in small teams. The students follow only two courses at once. They are divided by the teachers into working groups, resulting in the mixing of students with different backgrounds and skills, enabling them to learn from each other. The panel values this and suggests that the programme keep track of the different roles that the students take up in the working groups for different courses, encouraging them to gain experience in all different roles. It is positive about the course work and the assignments.

Thesis
The research component (thesis phase) can start when all mandatory courses have been successfully passed and 60 EC in total have been obtained. The research component of the master programme (44 EC) consists of two phases. The programme coordinator approves the research topic and checks whether it aligns with the programme's domain. The first phase (14 EC) is intended as a preliminary study (usually in the form of a literature study) to propose and plan a research project. The project proposal phase is concluded with a document that contains at least an extensive literature review, a set of research questions, and a planning for the master's thesis phase. An assessment with an explicit go/no-go decision takes place at the end of the proposal phase. The second phase of the research component consists of performing and completing the planned research and writing the thesis. Supervisors typically meet with their master's students every two or three weeks, depending on the phase of the master project and the project's progress. If there is a serious need of counselling, the supervisor will redirect the student to an experienced study advisor, who advises on the kind of help that could be necessary. The panel is positive about the set-up of the thesis phase, as splitting it into two components helps to signal potential problems in an early phase.

The nominal study success for the 2016/2017 cohort was 30%. The programme management indicated that most of the delay was caused by the thesis phase. The programme has taken measures to improve this, by setting up the thesis application as an agreement with deadlines and consequences for missing deadlines, splitting the thesis phase (as described above) into two parts with a go/no-go decision in between, and more regular meetings between the student and supervisor. Following these measures, the preliminary numbers for the 2017/2018 cohort indicated an increase to at least 35%. The panel is positive about the proactive measures taken by the programme management and encourages them to keep monitoring the study delay and take appropriate measures when necessary.

Teaching staff
The courses in the master's programme AI are taught by lecturers who are appointed in one of the four departments involved. A team of dedicated AI teachers for both the bachelor's and master's programmes, the core teachers ("kerndocenten"), ensures the coherence of the teaching. The team of core teachers consists of course coordinators of all compulsory courses and the major track courses. The core teachers meet five times per year in a teachers' meeting, at which issues relating to the bachelor's and master's programme in AI are on the agenda. Currently, all staff who teach in an Artificial Intelligence master's programme have the University Teaching Qualification (UTQ, or BKO in Dutch) or are in the process of obtaining it. Several of the staff are also in possession of the Senior Teaching Qualification (STQ). Each staff member responsible for a master's course or supervising a master's project has a PhD. In annual Assessment and Development meetings, each staff member evaluates their performance in teaching as an important component in their assessment. The involved departments in the programme stimulate the teachers to participate in the Centre for Academic Teaching. This centre provides teachers with information, knowledge sharing,

support and training aimed at their own development and the renewal of their education, offering courses ranging from basic teaching to advanced educational leadership programmes.

The students are enthusiastic about the accessibility and involvement of their teachers. The panel gathered, in talking to students and teachers, that despite the involvement of four different 'blood types' within the programme, there is a real community feeling amongst the teachers, who meet regularly to align matters concerning the courses and assessment.

The students provide quantitative and qualitative feedback on the courses annually. The Education Advisory Committee (OAC) Artificial Intelligence uses this feedback to evaluate the courses and provide input for the next edition of courses. The lecturers also respond to the comments made by the students, so the students are informed about what happens with their feedback.

In some of the involved departments, the staff has a typical teaching percentage that is considered too high. To bring down the teaching load, the departments have hired extra staff, but since the student numbers have been increasing significantly over the last years, the extra staff has not yet led to a reduced workload of the current staff. The panel is pleased to see that the programme is succeeding in reducing the pressure somewhat by recruiting teaching assistants. Courses with a high number of students are given by multiple teachers to spread the workload. The panel heard from the programme management that further hiring is planned, and hopes that this will help reduce the workload effectively in the future.

English language
In reading the self-evaluation and talking to the programme management and teachers, the panel gained insight into the reasons for conducting the teaching in English. Research is conducted in an international context, and the language of communication in artificial intelligence is English. English language skills are a necessity given that the labour markets are largely international. Also, the student pool is international, given the objective to attract students both from inside and outside the Netherlands. For educational reasons, attracting international students also creates an international student population, which – in combination with a strict admission procedure – contributes to the quality of the programmes. The panel agrees with this and is convinced an international classroom adds to the quality of the programme. Teaching in English also enables the programme to recruit top international candidates for faculty positions. The policy within the Graduate School of Natural Sciences is that all master's and PhD programmes are taught in English. Course evaluations indicate that the students are satisfied with the English proficiency of their teachers. New lecturers are assessed for their proficiency in English during their interviews. The panel agrees that an English language programme, with an English programme name, is suitable with regard to the international character of the field and the goals of the programme. It concludes that sufficient measures are in place to safeguard the English language proficiency of the staff, the quality of which was positively evaluated by the students. The student projects that the panel saw showed that the students have a good command of English.

Feasibility
The panel is positive about the feasibility of the programme. The students are in general satisfied with its feasibility. They value the interdisciplinary diversity of topics and the room for electives. The programme management indicated that due to its interdisciplinary nature, the master's programme AI at Utrecht University is of interest to students coming from an AI or computer science bachelor's programme, but also to those with a bachelor's degree in linguistics, cognitive psychology, philosophy and professional education (HBO) related to computing science. These students often lack sufficient training in either logic, programming, or artificial intelligence, according to the management. The panel is positive about the possibility for these students to enrol, adding to the diverse set-up of the programme, and is positive about the pre-master that is in place to remedy their deficiencies. Offering the pre-master courses in English could help reach out to foreign students who want to enter the programme, according to the panel.

The panel believes that the students entering the programme have thus effectively remedied their deficiencies. The students indicated to the panel that some experience the programme as rather demanding, and some believe the level of difficulty could be raised. A variation remains between the pre-existing skills of the diverse students, such as programming. The panel observed that the level of proficiency in programming does vary, but this is to be expected from a broad programme. Students with basic programming skills are able to complete the programme. Keeping track of the different roles taken up by the students can help the programme to monitor the progress of the students in the different skills, such as programming.

Several students and alumni indicated a desire for more statistics and mathematics in the programme. It recommends that the programme explores options to incorporate this.

Considerations
The panel is positive about the curriculum, the teaching-learning environment and the quality of the teaching staff, which enable the incoming students to achieve the intended learning outcomes, in its opinion.

The panel is very positive about the diverse directions the students are able to take, but is also convinced that along with freedom of choice for primary (30 EC) and secondary electives (30EC), the option for a research internship, the use of study plans, the themes of areas of specialisation that align with research interest of the scientific staff, and the option to follow a profile (offered by the Faculty of Science) provides a clear structure to the programme. It recommends the programme management to investigate if more statistics of mathematics is needed in the programme. It observed that the set-up of the thesis phase, split into a proposal phase and the phase of performing and completing the planned research and writing the thesis, guides students well through the process and also should help them to complete their studies on time. It is pleased to see that the students can take an *AI Research* internship, which a lot of them do, adding to the connection with the professional field. The panel thinks that shaping the programme along course-based and research components, primary and secondary electives, sufficiently helps to retain direction and structure within the broad programme. The curriculum reflects the ILOs well.

The students are well guided in setting up their study plans and obtain counselling from programme coordinators and the study advisor. The programme is succeeding in reducing the workload on the teachers by recruiting teaching assistants. Courses with a high number of students are given by multiple teachers to spread the workload. The panel values the small-group learning experience and hopes the programme will be able to take measures to safeguard this system and reduce the workload further. The teachers feel and act as a community, and meet regularly to align matters concerning courses and assessment. They are accessible to the students and receive annual feedback from the students on their courses. They are proficient in teaching in English. The choice to offer the programme in English, and with an English programme name, is well justified because of the largely international labour markets for graduates, according to the panel.

The panel is positive about the feasibility of the programme. It did observe that the level of proficiency in programming varies, but this is to be expected given the interdisciplinary and broad programme, attracting a wide variety of students.

The students are enthusiastic about the guidance by the teachers and study advisor, the interdisciplinary diversity of topics and the room for electives. They value working in small and diverse groups, which enables peer learning. Keeping track of the different roles they take up in the working groups of different courses will enable them to gain experience in all different roles.

Conclusion
Master'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 system
The Graduate School of Natural Sciences has outlined an Assessment Plan, which includes the school's assessment policy and assessment plans per master's programme, that ensures the connection between the curriculum and the content, quality and grading of the exams. To realise the aim that students develop multiple competences (e.g., ability to complete practical work or assignments, or give a presentation), the mandatory courses and primary electives all have multiple assessment methods: written exams, homework assignments, practical assignments, reports and projects. Consequently, passing a course typically relies on components that test different aspects of knowledge and skills. The panel values the diversity of testing involved in the programme, which it deems fitting to obtain the ILOs.

Thesis assessment
The research component of the master's programme (44 EC) consists of two phases. The first phase (14 EC) is intended as a preliminary study, at the end of which the supervisor(s) will make a go/no-go decision. The second phase consists of performing and completing the planned research, writing the thesis that presents the performed research and its results, and finally presenting and defending the results and conclusions of the performed research. The master's thesis is an individual research project that is conducted under the supervision of a staff member.

The programme evaluates the master's theses using standardised assessment forms and rubrics used by all programmes in the Graduate School of Natural Sciences. The theses are always assessed by two examiners, who initially assess the thesis separately and then, after joint consultation, decide on a definitive mark and corresponding reasoning.

An intervision panel of four AI staff members checks samples of theses every one or two years to ensure a consistent use of the rubrics for the master's theses, and hence ensure a consistent assessment of master's projects. The panel is positive about the set-up of the intervision panel and the use of the rubrics. It studied a number of assessment forms and is positive about this arrangement. It believes that it should always be made clear on the forms how the two assessors arrive at their independent and final assessment. This was not the case for the sample of theses it studied. The panel would like to suggest that the reporting in the theses on the AI content of the work done is incorporated in the rubrics. This would aid in making the AI component explicitly visible in the broad thesis topics (see also Standard 4).

The panel does want to mention that, because of the interdisciplinary nature of the programme, involving multiple faculties, the Executive Panel Artificial Intelligence (EP AI) should be able to manage their own standard for quality control, including assessment forms that might diverge from the default forms of the Graduate School of Sciences.

The research part of the curriculum is performed under the direct supervision of a member of the scientific staff involved in the master's programme Artificial Intelligence. In addition, another member of the scientific staff acts as the second examiner. This second examiner is involved in reading and assessing both phases of the research component. It is possible to perform the thesis project externally at other departments of Utrecht University, at other universities, or at an external organisation such as a company or a government institute. In all cases, also for internships, two staff members involved in the master programme Artificial Intelligence approve the project and serve as examiners. In case of an internship, the supervisor from the company has an advisory role. The panel is positive about this, and with the fact that the student and the external daily supervisor are in regular contact with the supervisor. It is convinced that the assessment system of the research part is sufficient.

Board of Examiners
The Board of Examiners (Examencommissie) upholds the quality of the tests and exams within the Graduate School of Natural Sciences. It consists of a central board and executive panels for each of the six disciplinary fields. The chairs of the executive panels form the central board, which acts as a framework-setting and supervisory body. It determines the examination policy and sets frameworks in the form of regulations and procedures, which are updated annually. In its supervisory role, it also monitors the quality of the decisions and the implementation of the examination policy by the panels.

The Executive Panel Artificial Intelligence (EP AI or in Dutch: Kamer AI) implements the examination policy for the master's programme Artificial Intelligence. Its members determine whether the master's degree and the distinction cum laude can be awarded to students in the master's programme Artificial Intelligence. The EP AI selects and evaluates courses by studying the assessment methods, passing rates, distribution of grades, student feedback, and checking whether the relevant regulations are respected. The assessment of eight courses is evaluated annually, including secondary electives. The findings are communicated to both the director of master's education and the programme leader, and archived by the EP AI.

The panel interviewed the EP AI and studied a number of the BoE's annual reports. In its opinion, the system with a central Board and domain-specific Executive Panels functions adequately, and the Board properly fulfils its role in the quality assurance of assessment within the programme. It thinks that the structure fits the educational philosophy of the university, with students often following courses in other programmes. A more centralised system of assessment and a central Board of Examiners would allow for more coherence in assessment between the individual programmes.

Considerations
The master's programme Artificial Intelligence has a solid assessment system, guaranteeing that the students are assessed on all ILOs throughout the courses. The panel values the diversity of testing involved in the programme.

The thesis assessment is well-designed, employing two academic supervisors to assess the thesis independently, who seek consensus afterwards, but the way this is done should also be made clearly visible on the thesis forms. The intervision panel helps to ensure consistent use of the rubrics and consistent assessment of master's projects. The panel is positive about the intervision panel and the use of the rubrics. Reporting on the AI content of the work done in the theses could be incorporated in the rubrics. This would aid in making the AI component explicitly visible in the broad thesis topics.

The Executive Panel Artificial Intelligence of the Board of Examiners of the Graduate School of Natural Sciences fulfils its role in the quality assurance of assessment well and has the necessary checks and balances in place to monitor the quality of the exams as well as the theses. Because of the interdisciplinary nature of the programme, involving multiple faculties, the panel thinks the EP AI should be able to manage its own standard for quality control, including assessment forms that might diverge from the default forms of the Graduate School of Sciences.

Conclusion
Master'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
The panel studied a selection of fifteen master's theses and their assessment forms. It agreed that all theses reflected the required degree level and demonstrated that the graduates have achieved the programme's intended learning outcomes. It concluded that the theses showed that the students are on an academic level, able to analyse problems, critically review scientific results and

communicate about this. It is convinced that the graduates are able to contribute to innovative research and development in artificial intelligence, ranging from understanding human intelligence through empirical and experimental research, to building formal and computational models for intelligent phenomena and behaviour, to devising techniques and algorithms for engineering intelligent systems. The theses show sufficient academic skills and command of the English language. Sometimes theses lead to joint publications, which underlines their general quality. The panel observed that some of the studied theses were relatively short, and it would like to suggest that the programme management keep an eye on this, to ensure the final products retain the character of a thesis. It concluded that the quality of the studied master's theses indicated that the graduates have achieved the final qualifications of the master's programme.

Notwithstanding the fact that all of the theses demonstrated the minimum level required by the programme's ILOs, the panel noted that the thesis topics showed a large variation. Some topics were relatively far from the technical core of AI, dealing for instance with topics of ethics, education and psychology. Although this is in line with the distinctive interdisciplinary nature of the programme, this also means that the acquired knowledge and skills can vary significantly between the programme's graduates. Some theses showed very deep and profound technical work, while others only lightly touched upon technical topics. The previous accreditation panel noticed the same divergence in thesis topics, and recommended improving the AI content of the theses. The current panel feels that this is partly covered by the broad definition of AI that the programme uses, but thinks that variation in skills between graduates should still be addressed. It suggests that the programme could make the various specialisation directions in the programme more explicit, for instance by introducing tracks. This would make the specific profile of a graduate more visible, also with regard to the professional field (see Standard 1).

Alumni have no trouble finding employment, as there is a severe shortage of professionals with AI capabilities and skills. The panel is pleased to see that most of the alumni find jobs, for instance as developer (23%), data scientist (20%), or researcher or PhD candidate in an academic setting (20%), or as consultant (8%) or machine learning engineer (4%).

Considerations
The panel concluded that the theses of the master's programme Artificial Intelligence are of a good quality and convincingly show that the programme's ILOs have been achieved by the students. The theses showed that the students have mastered the topics within the broad area of Artificial Intelligence and have acquired good academic skills, some even to the point of publishable results. This is further demonstrated by the high employability of the graduates, in both industry and academia.

Conclusion
Master's programme Artificial Intelligence: the panel assesses Standard 4 as 'meets the standard'.

GENERAL CONCLUSION

The panel judged that the master's programme Artificial Intelligence offered by Utrecht University meets all the standards of the NVAO Assessment Framework for Limited Programme Assessment. It therefore gives a positive advice on the accreditation of the programme.

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

3.2 Common Requirements

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

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

Knowledge and understanding

1. Has mastery of artificial intelligence at an advanced academic level. This means mastery of a number of advanced general subjects in the areas of agents, cognitive processing and reasoning, and in depth-knowledge and ability in at least one advanced subject (such as agent design, multi-agent communication, multi-agent learning, cognition and language, psychology of perception, conceptual semantics, logic and computation, logic and language, or argumentation). Mastery of the necessary logical, computational and experimental tools;
2. Has thorough experience with research in (pure or applied) artificial intelligence and complete awareness of the applicability of research in technological developments and organisational contexts;
3. Is able to read research articles in artificial intelligence.

Understanding knowledge and understanding

4. Is capable of understanding a wide variety of different research problems in artificial intelligence and being able to formulate these at an abstract level. To see, from the abstract level, the relation between diverse problems and to contribute creatively to their solution focused on practical applications;
5. Is able to point at solutions for identified problems using the most advanced techniques from artificial intelligence;
6. Is capable of creating innovative software and information system designs, taking account of feasibility issues;
7. Has mastery of the necessary skills in theoretical analysis, modelling and experimentation;
8. Understands the potential dilemmas related to scientific integrity in his/her research field.

Making judgements

9. Is capable of assessing and discussing research results and of taking part in discussions within the research group;
10. Is able to evaluate research results in the context of similar research on artificial intelligence. Is capable of assessing the practical feasibility and usefulness of artificially intelligent designs;
11. Is capable of reflecting on his/her own activities as a researcher and being aware of social and ethical responsibilities concerning application of research.

Communication

12. Is capable of presenting one's own research in both written and spoken English to diverse audiences. Is able to adapt to the background and interest of the audience;
13. Is capable of working in a (possibly interdisciplinary) team of experts performing the aforementioned activities and communicating easily in both written and oral English.

Learning skills

14. Is capable of working independently and of taking initiatives where necessary; is capable of identifying areas where expertise is lacking and remedying the situation;
15. Is capable of writing a research proposal and independently carrying out research in an area of technical artificial intelligence;
16. Has the qualification to obtain a PhD position in the area of specialisation or a key position outside of academia in the area of specialisation. This includes but is not limited to working at R&D departments, working in (software) industry, consultancy and government institutions.
17. Has a realistic idea of the career opportunities after graduating, and of the skills that he/she needs to successfully start a career.

APPENDIX 3: OVERVIEW OF THE CURRICULUM

Course	ec	type	block	Learning outcomes degree programme																
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Introducing Natural Sciences	0.5	M	1,3						x		x							x		
Dilemmas of the Scientist	0.5	M	3						x		x						x	x		
Methods in AI Research	7.5	M	1	x	x	x	x	x	x			x	x	x		X	x			
Philosophy of AI	7.5	M	3			x	x					x		x	x	X				
Intelligent Agents	7.5	PE	2	x		x			x	x		x	x		x	x		x	x	
Multi-agent Systems	7.5	PE	3	x	x	x	x	x		x		x			x	X				
Multi-agents Learning	7.5	PE	4	x	x	x	x	x	x	x		x	x	x	x	X	x	x	x	
Social Simulation	7.5	SE	4	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Cognitive Modelling	7.5	PE	2	x	x	x	x	x	x	x		x	x		x	X			x	
Experimentation in Psychology and Linguistics	7.5	PE	3	x	x	x	x	x	x	x		x	x	x	x	X			x	
Advanced Topics in Cognitive Science	7.5	PE	4	x	x	x	x	x	x	x		x	x	x	x	X	x	x	x	
Logic and Language	7.5	PE	2	x	x	x	x	x		x		x	x		x		x		x	
Commonsense Reasoning and Argumentation	7.5	PE	3	x	x	x						x	x	x			x	x	x	
Logic and Computation	7.5	PE	2	x	x	x	x	x		x		x	x		x	X	x		x	
Research Internship AI	7.5/15	SE	-	x	x	x			x	x			x	x			x	x		X
Thesis part 1 – Artificial Intelligence	14	M	-		x	x	x	x		x			x				x	x	x	X
Thesis part 2 – Artificial Intelligence	30	M	-	x	x	x	x	x	x	x			x		x	X	x	x	x	X

APPENDIX 4: PROGRAMME OF THE SITE VISIT

Dag 1 - 13 januari 2020
08.30 – 09.00 Aankomst en welkom
09.00 – 10.00 Intern overleg
10.00 – 10.45 Interview inhoudelijk verantwoordelijken [English]
10.45 – 11.00 Uitloop / intern overleg
11.00 – 11.45 Interview studenten bachelor
11.45 – 12.00 Uitloop / intern overleg
12.00 – 12.45 Interview docenten bachelor
12.45 – 13.45 Lunch + inloopspreekuur
13.45 – 14.15 leestijd
14.15 – 15.00 Interview studenten master [English]
15.00 – 15.15 Uitloop / intern overleg
15.15 – 16.00 Interview docenten master [English]
16.00 – 16.15 Uitloop / intern overleg
16.15 – 17.00 Interview alumni bachelor en master
17.00 – 17.15 Uitloop en dagafronding

Dag 2 - 14 januari 2020
08.30 – 09.30 Aankomst en voorbereiding
09.30 – 10.00 Interview examencommissie bachelor
10.00 – 10.15 Uitloop / intern overleg
10.15 – 10.45 Interview examencommissie master
10.45 – 11.15 Uitloop / intern overleg
11.15 – 12.00 Interview formeel verantwoordelijken
12.00 – 14.15 Opstellen oordelen (incl. lunch)
14.15 – 14.30 Mondelinge terugkoppeling
14.30 – 14.45 Pauze
14.45 – 15.45 Ontwikkelgesprek twee opleidingen (2x half uur) [MA: English]
15.45 – 16.00 Afronding

APPENDIX 5: THESES AND DOCUMENTS STUDIES BY THE PANEL

Prior to the site visit, the panel studied 15 theses of the master'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):

- Assessment Plan & Assessment Forms
- Master Introduction GSNS and Brochure Master Program AI
- Courses Materials
    - Cognitive Modelling
    - Logic and Computation
    - Methods in AI Research
    - Multiagent Systems
- Education Board (OC and OAC) Documents
- Examination Board (EC) Documents
- Education & Examinations Regulation (OER) Documents
- AI Colloquium
- Governance KI / AI 2016
- International Office Information GSNS
- AI Thesis Info