ARTIFICIAL INTELLIGENCE

FACULTY OF SOCIAL SCIENCES

RADBOUD UNIVERSITY

QANU
Catharijnesingel 56
PO Box 8035
3503 RA Utrecht
The Netherlands

Phone: +31 (0) 30 230 3100
E-mail: support@qanu.nl
Internet: www.qanu.nl

Project number: Q0744

CONTENTS

This report was finalised on 19 May 2020.

REPORT ON THE BACHELOR'S AND THE MASTER'S PROGRAMMES ARTIFICIAL INTELLIGENCE OF RADBOUD 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 PROGRAMMES

Bachelor's programme Artificial Intelligence

Name of the programme:	Artificial Intelligence
CROHO number:	56945
Level of the programme:	Bachelor
Orientation of the programme:	Academic
Number of credits:	180 EC
Specialisations or tracks:	-
Location:	Nijmegen
Mode(s) of study:	Full-time
Language of instruction:	English
Submission deadline NVAO:	01-05-2020

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
Specialisations or tracks:	Neural Computation Interactive Agents[1]
Location:	Nijmegen
Mode(s) of study:	Full-time
Language of instruction:	English
Submission deadline NVAO:	01-05-2020

The visit of the assessment panel Artificial Intelligence to the Faculty of Social Sciences of Radboud University took place on 18 and 19 November 2019.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

Name of the institution:	Artificial Intelligence
Status of the institution:	Publicly funded
Result institutional quality assurance assessment:	Positive

[1] *Neural Computation* and *Interactive Agents* are the names of the specialisations until 1 September 2019. From that date the names are changed in: *Cognitive Computing* and *Intelligent Technology*.

COMPOSITION OF THE ASSESSMENT PANEL

The NVAO has approved the composition of the panel on 16 September 2019. The panel that assessed the bachelor's programme Artificial Intelligence and 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);
- Prof. dr. C. (Cees) Witteveen, full professor at the Algorithmics Group of the Faculty of Engineering, Mathematics and Computer Science (EEMCS/EWI), Delft University of Technology;
- Prof. dr. F. (Frank) Jäkel, principal investigator at the Centre for Cognitive of the Technische Universität Darmstadt (Germany);
- Dr. C.H.M. (Kees) Nieuwenhuis, Technology Manager and staff member of the CTO Office of Thales Nederland;
- 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, who acted as secretary.

WORKING METHOD OF THE ASSESSMENT PANEL

The site visit to the bachelor's and master's programmes Artificial Intelligence at the Faculty of Social Sciences of Radboud 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, Peter Hildering, Barbara van Balen and José van Zwieten acted as secretaries in the cluster assessment.

During the site visit at the Radboud University, the panel was supported by Dr. 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 (Belgium) [chair];
- Prof. dr. B. (Bart) de Boer, researcher and professor at the Artificial Intelligence lab of the Vrije Universiteit Brussel (Belgium);
- Dr. A. (Annerieke) Heuvelink-Marck, senior scientist Software Concepts at Philips Group Innovation & Research in Eindhoven;
- 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);

- Prof. dr. F. (Frank) Jäkel, principal investigator at the Centre for Cognitive Science of the Technische Universität Darmstadt (Germany);
- Dr. ir. E. (Edwin) de Jong, principal Machine Learning scientist at ScreenPoint Medical Nijmegen and mentor/coaching A.I. startups at RockStart;
- Dr. A.P. (André) Meyer-Vitali, senior scientist Data Science group at the IT-department of TNO;
- Dr. C.H.M. (Kees) Nieuwenhuis, Technology Manager and staff member of the CTO Office of Thales Nederland;
- Dr. ir. J. (Hans) Tonino, associate professor at the Algorithmics Group of the Faculty of Engineering, Mathematics and Computer Science (EEMCS/EWI) and Director of Studies Embedded Systems at Delft University of Technology;
- 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;
- M. (Maartje) Stokvis BSc, master's student Data Science for Decision Making at Maastricht University [student member];
- F. (Florence) van der Voort BSc, master's student Artificial Intelligence and Philosophy: Bioethics & 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 Social Sciences. Prior to the site visit, the Faculty selected representative partners for the various interviews. See Appendix 4 for the final schedule.

Before the site visit to Radboud 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 each of the programmes, based on a provided list of graduates between November 2018 – August 2019. A variety of topics and tracks and a diversity of examiners were included in the selection. For the bachelor's programme, a selection of 15 out of 51 theses was made. For the master's programme, a selection of 15 out of 30 theses was made. As the reorganisation took place in 2018, all current (read: 2019) master's theses are still written in the context of one of the three original specialisations: Web and Language Interaction, Robot Cognition, and Communication in Natural and Artificial Systems. The first cohort of alumni from the new programme are expected to graduate at the end of the 2019-2020 academic year. Thus, a selection was made as follows: Computation in Neural and Artificial Systems (6/8), Robot Cognition (2/4), Web and Language (6/10), and an older track Brain-Computer Interfacing (1/1). 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 reports, theses and assessment forms, the panel members formulated their preliminary findings. The secretary collected all initial questions and remarks and distributed these amongst all panel members.

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

Site visit
The site visit to Radboud University took place on 18 and 19 November 2019. Before and during the site visit, the panel studied the additional documents provided by the programmes. An overview of these materials can be found in Appendix 5. The panel conducted interviews with representatives of the programmes: students and staff members, the programme's management, alumni and

representatives of the Examination Board. It also offered students and staff members an opportunity for confidential discussion during a consultation hour. No requests for private consultation were received.

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

After the presentation of the preliminary findings, staff members and programme management participated in a development dialogue.

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

Bachelor's programme Artificial Intelligence
The bachelor's programme AI has a broad programme that combines core AI theory, methods, and techniques with solid mathematical and programming skills and insights from cognitive psychology and neuroscience. Its ILOs are well formulated and reflect its profile, academic orientation and bachelor's level. They are in line with the expectations of the discipline and the professional field through alignment with the KION domain-specific framework of reference. This connection is also strengthened by input from an external work-field committee.

The bachelor's programme and courses have a clear connection with the ILOs and address them sufficiently. In the programme, the wider context of artificial intelligence receives attention. Ethics, for example, is well represented and connected to the ILOs. The panel considers this clear connection an asset for the programme. The programme is academically oriented, with firm connections to the professional field. The panel agrees that an English language programme is suitable with regard to the international character of the field. The student projects that it reviewed showed that the students have a good command of English. It is convinced that the concept of hands-on work in the robot lab and BSI lab fits the programme. The programme could monitor the scalability of the teaching in these labs.

The bachelor's curriculum provides a broad education in mathematics, computer science and proper AI, with elements of cognitive science and neuroscience, according to the panel. The panel was impressed with the possibilities the modern software development course provides the students even in the bachelor's phase. It values the current problems brought in by external clients (companies), and the possibility of doing a 3 EC internship with a company.

The panel is convinced that the bachelor's programme is feasible. The students are well supported. Despite the large number of students, they appreciated the contact and approachability of their teachers. The panel also verified that the teaching staff is qualified for teaching in these programmes. It concluded 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 panel finds the assessment policy of the bachelor's AI programme to be adequate. The procedures to assure the quality of assessments are well described. The panel is convinced that the quality assurance of the assessments in the bachelor's degree programme AI is sufficient. It is positive about the mechanisms in place to assure the quality of the assessment, the modes of assessment, and the links of the assessments to the course contents.

The assessment procedure of the bachelor's thesis projects is well described and adequate. Rubrics are used in the grading of the bachelor's thesis projects. The panel verified that the score sheets for the bachelor's theses are adequate. They are filled in by at least two examiners in an independent way. The panel would like to encourage the programme to evaluate its use of the current forms and strengthen their use to further increase the transparency of assessment.

The panel established that the joint Examination Board is performing its legal duties and tasks. It checks the quality of a sample of theses and a sample of courses to guarantee the quality of assessments of courses. It informs lecturers of the procedural and critical aspects of adequate testing, and systematically evaluates the quality of assessments. It also formulates proposals to improve the quality of testing and assessment if necessary. Bachelor's courses are systematically audited. The panel saw a well-functioning and proactive EB.

The panel concluded that the theses of the bachelor's programme Artificial Intelligence are of a good quality, and convincingly show that the programme's intended learning outcomes have been achieved by the students. They demonstrated that the students are on an academic level, able to analyse problems, critically review scientific results and communicate about them. The research topics are

relevant to the broad area of Artificial Intelligence. Bachelor graduates are well prepared for the master's programme AI. Because the thesis topics can be broad, the panel would like to advise the programme to ensure students make the AI component clearly visible in the theses. In its opinion, the programme provides the students with a broad basis which enables them to pursue a career in either research or industry.

Master's programme Artificial Intelligence
The master's programme AI has a clear profile focusing on developing academic and professional skills. It specialises in the development of theoretical expertise in AI (Cognitive Computing track) or the creation of optimal AI solutions to address specific problems (Intelligent Technology), while encouraging students to reflect on the societal implications of new developments in AI. Its ILOs are well formulated and reflect its profile, academic orientation and master's level. They also differentiate between the two tracks. They are in line with the expectations of the discipline and the professional field through alignment with the domain-specific framework of reference KION, and input provided by an External Advisory Board.

The master's programme and courses have a clear connection with the ILOs and address them sufficiently. In the programme, the wider context of artificial intelligence receives attention. Ethics, for example, is well represented and connected to the ILOs. The panel considers this clear connection an asset for the programme. The programme is academically oriented, with firm connections to the professional field. The panel agrees that an English language programme is suitable with regard to the international character of the field. The student projects that it reviewed showed that the students have a good command of English. It is convinced that the concept of hands-on work in the robot lab and BSI lab fits the programme. The programme could monitor the scalability of the teaching in these labs.

For the master's curriculum, the Neural Computation and Interactive Agents tracks align with the Donders Institute research profiles, which is a unique asset for the programme. The students benefit from this as it enables teaching that is tightly integrated with ongoing research, which is valued by the panel. The students are also prepared to operate as an AI professional in an entrepreneurial environment.

The panel is convinced that the master's programme is feasible. The study success of the master's programme could be improved, and the programme is exploring measures to do so, for instance by starting a pre-master. The students are well supported. Despite the large number of students, they appreciated the contact and approachability of their teachers. The panel also verified that the teaching staff is qualified for teaching in these programmes. It concluded 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 panel finds the assessment policy of the master's AI programme to be adequate. The procedures to assure the quality of assessments are well described. The panel is convinced that the quality assurance of the assessments in the master's degree programme AI is sufficient. It is positive about the mechanisms in place to assure the quality of the assessment, the modes of assessment, and the links of the assessments to the course contents.

The assessment procedure of the master's thesis projects is well described and adequate. Rubrics are used in the grading of the master's thesis projects. The panel verified that the score sheets for the master's theses are adequate. They are filled in by at least two examiners in an independent way. The panel would like to encourage the programme to evaluate its use of the current forms and strengthen their use to further increase the transparency of assessment.

The panel established that the joint Examination Board is performing its legal duties and tasks. It checks the quality of a sample of theses and a sample of courses to guarantee the quality of assessments of courses. It informs lecturers of the procedural and critical aspects of adequate

testing, and systematically evaluates the quality of assessments. It also formulates proposals to improve the quality of testing and assessment if necessary. Master's courses are systematically audited. The panel saw a well-functioning and proactive EB.

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 intended learning outcomes have been achieved by the students. They demonstrated that the students are on an academic level, able to analyse problems, critically review scientific results and communicate about them. The studied theses focus on the application of AI techniques in fields like psychology, which aligns with the goals of the programme. The panel did observe that the AI component (in particular the technical information about the students' implementation work) could be presented in more detail. The panel recommends the programme management to take additional measures to make this AI component better visible in the master thesis. It is convinced that the programme fosters both academic and critical thinking, programming and research abilities, enabling master graduates to successfully occupy positions in academia or industry.

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

Bachelor's programme Artificial Intelligence

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

Master's programme Artificial Intelligence

Standard 1: Intended learning outcomes	'meets the standard'
Standard 2: Teaching-learning environment	'meets the standard'
Standard 3: 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: 19 May 2020.

DESCRIPTION OF THE STANDARDS FROM THE ASSESSMENT FRAMEWORK FOR LIMITED PROGRAMME 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 Artificial Intelligence (AI) bachelor's and master's programmes in Nijmegen have a human-centred focus and are the responsibility of the Faculty of Social Sciences (FSW). Throughout the review period, the AI degree programme was embedded in the Institute of Psychology and AI. From a research perspective, the AI Department is embedded in the Donders Centre for Cognition (DCC), which is one of the research centres of the Donders Institute for Brain, Cognition and Behaviour (DI). The panel agrees that the connection with the Donders Institute in Nijmegen creates unique opportunities and should be fostered.

The AI department has two major objectives. First, to understand the theoretical basis of natural intelligence and to create cutting-edge AI algorithms and approaches that enable autonomous systems to think and behave naturally. This objective naturally aligns with the scientific mission of the DI to promote Cognitive AI and relates to the topic of Artificial General Intelligence (AGI), according to the panel. Second, to develop the next generation of intelligent technology to improve the well-being of people in their environment (e.g. neurotechnology, assistive technology, educational innovation, healthcare). The AI department is a driving force in the Radboud AI initiative (www.ru.nl/ai), which unites AI researchers and practitioners at Radboud University. These two major objectives of the department also align with the two master's specialisations of the degree programme.

The master's degree programme consists of course-based education in advanced theory and methods, skills training, and a thesis project. The two specialisations offer mandatory and elective courses that fit the two profiles sketched above, with the Neural Computation specialisation focusing on theoretical developments in AI and the Interactive Agents specialisation focusing on the development of optimal AI solutions to address specific problems.

Intended learning outcomes
The goals of the bachelor's programme AI have been translated into 10 intended learning outcomes (ILOs) that are listed in Appendix 2. These are structured alongside the five Dublin descriptors for academic bachelor's programmes and are formulated based on the qualifications of the KION framework, with additional emphasis on the societal implications of new developments in AI.

The panel studied the profile of the bachelor's programme AI, as well as its ILOs. It concluded that it is a broad programme that combines core AI theory, methods, and techniques with solid mathematical and programming skills and insights from cognitive psychology and neuroscience, which are consistently implemented in its ILOs. The learning outcomes explicitly include academic and professional skills, and encourage the students to reflect on the societal implications of new developments in AI.

The ILOs are well formulated and correspond with the KION Framework for bachelor's programmes in Artificial Intelligence. The connection to the discipline and the professional field is strengthened through the benchmark with this KION Framework and the input provided by lecturers, the Degree Programme Committee and the programme's external work-field committee. The structuring of the ILOs using the Dublin descriptors for academic bachelor's programmes clearly reflects their academic orientation and bachelor's level. They prepare students well for a master's programme in the field.

The goals of the master's programme AI have been translated into 11 intended learning outcomes (ILOs) that are listed in Appendix 2. 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 in terms of content, level and orientation, with additional emphasis on the societal implications of new developments in AI. Two specialisations have been designed within the master's programme that focus on theoretical developments in AI (Cognitive Computing) and the development of optimal AI solutions to address specific problems (Intelligent Technology). Several ILOs differentiate between the two tracks. The panel is convinced that the tracks fit the demands of the professional field and are of a master's degree level. The programme management could give some more thought to how to focus on the unique features of the Nijmegen AI-programmes to differentiate from the AI programmes developed in Eindhoven and Tilburg.

The learning outcomes explicitly include academic and professional skills, as well as allowing students to reflect on the societal implications of new developments in AI.

Considerations
The bachelor's programme AI has a broad programme that combines core AI theory, methods, and techniques with solid mathematical and programming skills and insights from cognitive psychology and neuroscience. Its ILOs are well formulated and reflect its profile, academic orientation and bachelor's level. They are in line with the expectations of the discipline and the professional field through alignment with the KION domain-specific framework of reference. This connection is also strengthened by input from an external work-field committee.

The master's programme AI has a clear profile focusing on developing academic and professional skills. It specialises in the development of theoretical expertise in AI (Cognitive Computing track) or the creation of optimal AI solutions to address specific problems (Intelligent Technology), while encouraging students to reflect on the societal implications of new developments in AI. Its ILOs are well formulated and reflect its profile, academic orientation and master's level. They also differentiate between the two tracks. They are in line with the expectations of the discipline and the professional field through alignment with the domain-specific framework of reference KION, and input provided by an External Advisory Board.

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

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 and educational approach: bachelor
The three years of the bachelor's programme are characterised by an introductory phase in the first year, expansion phase in the second year, and a specialisation phase in the third year, including the Bachelor's Thesis Project. The programme is organised along five core learning trajectories (Transferable Skills, Brain & Cognition, Programming, Core AI, and Mathematics).

The first year introduces the basic cognitive and AI concepts and skills needed for the rest of the programme and supplies a solid mathematical and algorithmic basis. All courses in the first year are obligatory (60 EC). In the second year, the students expand their core AI & mathematical skills & knowledge, building on the skills acquired in the first year. Core AI concepts include neural networks and data mining, mathematics, and the foundations of both Frequentist and Bayesian statistics. All

courses in the second year are also compulsory (60 EC). In the third year, the students dive deeper into two core topics of AI (Brain-Computer Interfacing and Computational & Formal Modelling). Professional Skills 2 and Modern Software Development Techniques prepare them for the potential job market.

The panel was impressed with the possibilities that the modern software development course provide to students in the bachelor's phase. External clients (e.g. companies using AI) bring in current problems in this course, and there is also the possibility of doing a 3 EC internship with a company. The students can specialise in topics of their choice in the electives (18 EC) and the Bachelor's thesis (12 EC). The aim of the bachelor's thesis project is for students to show that they are able to perform a small scientific research project almost independently and communicate the results both verbally and in writing. They can also choose to go abroad. In reaction to evidence that a stay abroad often resulted in study delays, the programme management rescheduled the bachelor's third-year curriculum. It created more flexibility in the third year, concentrating the compulsory courses in the first two years. The panel is pleased to see that the programme is taking this measure to minimise study delay while also enabling international exchange.

Regarding the link to the professional practice, the programme has two meetings a year with the Work-field Committee to link real-life case studies and problems to the course work. It is exploring the option of starting an 'innovation lab' in which companies and students can find one another for research, education, and work. The students obtain feedback on their practical skills and learn to integrate and apply them in their bachelor's project, but more writing assignments are to be scheduled to improve skills practice during the programme. Academic & Professional Skills 1 and Academic Skills 2 will also be better aligned, for instance by making one lecturer responsible for the Transferrable Skills line. The panel is pleased with these measures to align the programme with the professional field.

Curriculum and educational approach: master
The Master's programme consists of course-based education, skills training and a thesis project that is closely aligned to the research agendas (both fundamental and applied) of the Donders Institute (DI) researchers affiliated with the programme.

During the accreditation period, the programme was redesigned, and mandatory courses on the societal impact of AI and training academic and professional skills were introduced. This requires every AI graduate to have taken at least one machine learning course. The programme consists of a set of foundational courses (identical for all master's students), a set of specialisation-specific courses, and a set of elective courses, complemented by the graduation phase and free elective space.

The foundational courses (18 EC) provide the general knowledge and key skills required by both specialisations. AI is immersed in our society nowadays. Every AI professional should be aware of the ethical, legal, and societal impact of AI. Therefore, the Societal Impact of AI course is mandatory for all master's students. They follow either Machine Learning in Practice or Statistical Machine Learning to obtain machine learning skills. The panel thinks this is an important asset for bolstering the professional AI skills of the students. Finally, there is a mandatory Advanced Academic & Professional Skills course, teaching the students how to plan, do, and report on AI research, how to write papers and reports, and how to operate as an AI professional in an entrepreneurial environment.

In the evaluation period 2012-2018, the programme management ascertained that graduates can be employed in both academic and non-academic/industrial environments, and structured the programme accordingly. Firstly, the programme prepares students for an academic career and delivers PhD candidates to the DI and elsewhere, both nationally and internationally. Secondly, it prepares students for a non-academic/industrial career, delivering academically trained AI professionals to the industrial workforce. To cater for both types of careers, it reorganised its three

specialisations (aligned with the DI research profiles) into two specialisations in 2018 (aligned with the fundamental vs. applied research lines of the AI researchers: Neural Computation and Interactive Agents). The Neural Computation specialisation focuses on understanding and modelling natural intelligence, providing new avenues for understanding brain and cognition and the basis for more sophisticated future AI systems. The Interactive Agents specialisation focuses on the development of human-centred intelligent technology that improves the wellbeing of humans in their environment. These specialisations align with the corresponding two research lines within the Cognitive Artificial Intelligence Department. The third research line, Societal Implications of AI, is integrated in both specialisations via a compulsory course on the societal impact of AI. The alignment of the tracks with the DI research profiles is a unique asset for the programme. The students benefit from this, as this enables teaching that is tightly integrated with ongoing research, which is valued by the panel.

Each specialisation consists of a set of core courses from which students select three (in total 18 EC). In 2018-2019 these courses were Neural Information Processing Systems, Cognition and Complexity, Theoretical Foundations for Cognitive Agents, and Advanced Brain-Computer Interfacing for the Neural Computation specialisation, and Cognitive Robotics, New Media Lab, Text and Multimedia Mining, and Neural Information Processing Systems for the Interactive Agents specialisation. In addition, a further 18 EC of 'specialisation-choice' courses can be chosen from a specialisation-specific list to deepen the knowledge within the specialisation in a preferred direction, or to broaden the background with courses from the other specialisation. Finally, students have 21 EC of free electives that can be used to take any AI-relevant course at Radboud University, another university or abroad.

During an Internship (15 EC) and Research Project (30 EC) or Extended Research Project (45 EC), the students put into practice what they have learned during the programme and demonstrate their active autonomy. The subject of the internship and thesis will generally be in line with the direction the student has chosen so far. In the Internship, the students learn to 'get their hands dirty' and apply their formal training in a professional environment, acquiring practical skills that go beyond the skills offered in the programme. About 30% of them choose to do an internship. In the Research Project, they apply their acquired knowledge and skills in an individual research project, culminating in the master's thesis as the conclusion of their training as an academic professional. Around 60% of them do research for their thesis outside the department, in other departments or at companies. The Extended Research Project allows for a more substantial research project and is the preferred option for students interested in an academic career. Apart from the increase in ECs and thereby the size of the project, the end terms are identical: a demonstration that the student is capable of applying the acquired knowledge and skills to investigate a research question independently, either in a fundamental or an applied context, that can potentially be published as a conference contribution or transformed into a scientific journal article.

Excellent students have the opportunity to apply to the Examination Board for a double-degree programme. In such a programme, they combine the Master in Artificial Intelligence with a Research Master in Cognitive Neuroscience or with a Master in Computer Science, specialisation Data Science, with a maximum of 60 EC of overlap in both programmes. They write a separate thesis for each degree. About five to ten students per year apply for a double-degree programme. The panel is positive about the possibility of a double degree, and the prerequisite of a separate thesis is especially appreciated.

Orientation and connection with the ILOs
The programme and courses have a clear connection with the ILOs and address them sufficiently. A particularly interesting aspect is that the wider context of artificial intelligence receives attention in both the bachelor's programme and the master's programme. For instance, ethics is well represented in both programmes. This is part of the ILOs on philosophy and societal impact (ILO 7 of the bachelor's programme and ILO 4 of the master's) and present in the courses.

The bachelor's curriculum provides a broad education in mathematics, computer science and fundamental AI, with elements of cognitive science and neuroscience, preparing the students well for a master's programme, according to the panel. The master's programme prepares the students for an academic career as well as for a non-academic/industrial career.

Feasibility and workload
In talking to the students, the panel gathered that the bachelor's and master's programmes are feasible and that the students are well supported through counselling and advice where necessary. In the written self-evaluation report, the students mentioned that the study load is unevenly distributed in the first year of the bachelor's programme, making for an especially busy end of the second semester. The panel was informed about the way in which the programme tackled this problem: it created an Excel spreadsheet in which the lecturers fill in the study load for their courses. This tool provides better insight into the work distribution for the students and enables a better spread of assignment deadlines. Care should be taken that someone should take ownership of this information, so action can be taken if the workload turns out not be well distributed.

In the bachelor's programme, the number of students taking longer than 3 years to complete their studies is relatively large, as was already pointed out by the previous accreditation panel. The programme has taken measures to increase study success: it organised the bachelor's thesis project within teams, introduced restrictions on the number of ECs students must acquire before starting their bachelor's thesis, set stricter prerequisites for entering a course, and introduced more flexibility in the third year to counteract delays as a result of a study abroad. The panel is positive about these measures and encourages the programme to keep monitoring study success. The numerus fixus limited the student influx for 2018-2019 to 170 bachelor students.

The study success of the master's programme could be improved as well. The programme is exploring the possibility of starting a pre-master, to bridge the gap in background knowledge (for instance, in programming or mathematics) for students coming from other bachelor's programmes than Artificial Intelligence or Computer/Data Science. The panel applauds this suggestion.

Lecturers
The teaching is primarily provided by staff members of the AI Educational Institute (7.0 FTE) and supported by other lecturers in DCC and BSI (0.6 FTE). Additional teaching is provided by staff members of Computing Science (0.5 FTE) at the Institute of Computing Sciences & Information Sciences of the Faculty of Science, with whom the collaboration is organised in a formal agreement signed by the deans of FSW and FNWI. The DCC and BSI staff members are members of the Psychology staff. They are involved in the Bachelor's and Master's programmes.

Teaching Assistants (TAs) are recruited from the student population, and Junior teachers are appointed to provide guidance. The students are positive about the contribution TAs and Junior teachers make to courses. The panel thinks this is a clever and sound way to deal with the growing student numbers. The teaching staff often participates in teacher meetings, and several teachers are experimenting actively with new educational concepts.

There is a large number of students, but the panel observed when talking to them that they still appreciate the contact with their teachers. They regard their teachers as approachable and easy to contact. The teachers seem open to feedback and demonstrably try to improve on points mentioned by the students. The students expressed worries about the workload of the teachers. They appreciate their lecturers and the sense of community between lecturers and students in the programmes.

Language and programme name
The language of instruction in both the bachelor's and the master's programme is English. The English proficiency of the lecturers is benchmarked by an Oxford Placement Test or a course in lecturing in English. Their level of English is sufficient according to the students. The English level of the teaching staff is monitored annually. The panel agrees that these English language bachelor's and master's AI

programmes are suitable with regard to the international character of the field. In talking to the staff and students, it was convinced that the international influx benefits the motivation of all the students. International students have to pass an English language test demonstrating their proficiency. The panel concluded that sufficient measures are in place to safeguard the English language proficiency of the staff, the quality of which is positively evaluated by students. The student projects that the panel has seen show that the students have a good command of English. In addition, the English language serves as a preparation for the very internationally oriented field of data science and artificial intelligence, as well as the broader field of the ICT sector.

Facilities
For experiments with robots, the students can use the dedicated AI Robot Lab. The lab is large enough to conduct serious experiments. The floor and lighting are suited for visual tasks. In the flight lab, the students can simulate VR aircrafts and/or driving simulations. Because of the close affiliation of AI with the DCC and the Donders Institute and the Behavioural Science Institute (BSI), they have access to several of the unique facilities for brain imaging using EEG, fMRI and MEG, and make use of the Virtual Reality Laboratory to study the social interaction between humans and avatars or make use of the available 3D recording equipment. The panel is positive about the facilities and the support it gives to enable students to complete the programme; the concept of hands-on work in the robot lab and BSI lab fits the programme. The programme should monitor if the facilities remain sufficient when student numbers rise.

Considerations
The bachelor's and master's programmes and courses have a clear connection with the ILOs and address them sufficiently. In both programmes, the wider context of artificial intelligence receives attention. Ethics, for example, is well represented in both programmes and connected to their ILOs. The panel considers this clear connection an asset for these programmes. The programmes are academically oriented, with firm connections to the professional field. The panel agrees that an English language programme is suitable with regard to the international character of the field. The student projects that it reviewed showed that the students have a good command of English. It is convinced that the concept of hands-on work in the robot lab and BSI lab fits the programme. The programme could monitor the scalability of the teaching in these labs.

The bachelor's curriculum provides a broad education in mathematics, computer science and proper AI, with elements of cognitive science and neuroscience, according to the panel. The panel was impressed with the possibilities the modern software development course provides the students even in the bachelor's phase. It values the current problems brought in by external clients (companies), and the possibility of doing a 3 EC internship with a company.

For the master's curriculum, the Neural Computation and Interactive Agents tracks align with the Donders Institute research profiles, which is a unique asset for the programme. The students benefit from this as it enables teaching that is tightly integrated with ongoing research, which is valued by the panel. The students are also prepared to operate as an AI professional in an entrepreneurial environment.

The panel is convinced that the bachelor's and master's programmes are feasible. The study success of the master's programme could be improved, and the programme is exploring measures to do so, for instance by starting a pre-master, The students are well supported. Despite the large number of students, they appreciated the contact and approachability of their teachers. The panel also verified that the teaching staff is qualified for teaching in these programmes. It concluded 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.

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

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
The testing and assessment system of both the bachelor's and master's programmes in Artificial Intelligence are described in the Education and Examination Rules (EER, in Dutch: OER), which documents the organisation, procedures, restrictions, and student rights regarding assessment, and in the rules and regulations of the Examination Board (EB), which specify the function and procedures of the EB, and the Rules and Regulations specifying the procedures for performing and assessing bachelor's and master's graduation projects, including the theses. The quality criteria for the assessments are described in the assessment policy of the Educational Institute of Psychology and Artificial Intelligence. AI has its own assessment programme for the bachelor's and master's programmes, recently updated in the academic year 2018-2019.

Course evaluations are carried out on a regular basis and are discussed by the Degree Programme Committee (DPC, in Dutch: Opleidingscommissie (OC)). The bachelor's programme and the master's programme have their own DPC. The students evaluate the quality of the testing and assessment in course evaluations, and this makes them actively involved in the quality assurance.

The programme components in the bachelor's and master's programmes combine papers, research reports, essays, multiple-choice exams, open-question exams, projects, presentations, and assignments and testing methods. The assessment methods that are used in a course are dependent on its learning objectives and teaching methods, as well as on practical arguments such as the number of course participants. The general policy is that, especially in the case of the bachelor's programme, the assessment types should evolve from more directed and specific (focused questions, small assignments) to more open and integrated (essays, reports, larger projects). The panel is pleased that the structure of assessment is well organised. The difficulty increases during the bachelor's programme with the final bachelor's thesis project as the capstone. The relative weighting of the test results for calculating the final grade can be found in the prospectus and the course manual. The latter also includes other testing rules that apply, such as compensation involved in testing results, resits for failing grades for partial exams, and maximum grades after a resit.

The assessment programme of the bachelor's and master's programme shows the links between the course objectives and the programme's final qualifications and the links between the course objectives and the testing methods. Every three years, this assessment programme is updated. The last update was in the academic year 2018- 2019 (before that, in 2015-2016).

Course testing matrices
At the course level, the course testing matrices preserve the consistency of the learning objectives, testing methods, and assessment criteria. During the construction of the exams, the lecturers check each other's exams, thus applying the so-called four-eyes principle. The Examination Board checks the course testing matrices, the assessment methods used in relation to the posited learning objectives, and the content of the methods. The department of Educational Support, a central RU department, was also asked to check a number of courses regarding assessment quality last year. The outcome of this review was positive. It has been indicated that the validity of the testing in the AI programmes is generally favourable. In some cases, the formulation of the learning objectives could be formulated in more active, student-relevant competency terms and less focused on just knowledge reproduction because the assessments are often already formulated at a higher level.

All course qualifications are tested multiple times, and the panel learned from the students that they experience that testing sometimes takes place too many times. Some courses want to test a lot of the final qualifications in a single course, and this may cause an unnecessary workload for the lecturers and students. In the coming period, the programme management will take measures to prevent such a risk. The panel feels that the DPC should monitor the distribution of assessments and deadlines, and help spread the assessment load over time. It suggests reducing the number of assessments, which could help in reducing the students' workload. Another measure could be to introduce more formative instead of summative assessments.

Assessment of group work
The educational institute's assessment policy states that it is important to assess the students' individual performance, including during group assignments. At least 50% of the grading for each course has to be based on individual testing. The students sometimes regret that they are not able to work on all aspects in a course when they have to do a group assignment. To improve and align peer grading, a student from the DPC developed a peer assessment form in 2018, which was adopted by the programme for use during peer grading in the Bachelor's and Master's programmes. A pilot was started and due to the positive results and effects of this programme improvement, more and more AI lecturers are starting to use this form. The panel is positive about this measure taken and suggests that it could be a good idea to have a portfolio for group work to monitor the roles the student has taken over time. It is convinced of the balance between individual assessment and group assessment.

Assessment of thesis projects
Every assessor uses the same grading scheme to grade the bachelor's and master's thesis project and makes use of rubrics developed by the bachelor's and master's coordinator. The panel examined the score sheet for the bachelor's and master's theses and is convinced they are adequate. They are filled in by at least two examiners in an independent way. The original scores of all examiners are kept in an archive. The panel observed that not all score forms are filled in consistently, and that the amount of written feedback supporting the scores varies, depending on the examiner. It would like to encourage the programme management to monitor the completion of the qualitative assessment boxes in the bachelor's and master's theses assessment forms, and to establish that the independent examiners clearly present their individual scores and the way in which the final score came about. The assessment process could also benefit from a clearer correspondence between the scoring of the rubrics and the scoring of the final grade, and using grades consistently to score criteria instead of the now sometimes used +/- scoring.

A default weighting of the different parts in the rubrics should be a clear part of the standard form. Deviation from the weighting remains possible, for instance between tracks, but should be made explicit under certain terms. It was not always clear to the panel whether a thesis was linked to an internship; this could be made clearer in the thesis form as well.

Examination Board (EB)
There is one joint Examination Board for both the bachelor's and the master's programme AI. Its primary goal is to secure the quality of assessments and examinations, thereby ensuring that everyone who receives a diploma meets the final qualifications of the degree programmes. Its role is laid down in the Rules and Regulations for the Examination Board. This role is proactive as well as reactive. The EB is responsible for topics related to the qualitative assessment of the programme of individual students and the assessment quality of the degree programmes themselves. It deals with student requests concerning changes in their individual study programmes and requests for exemptions, as well as with cases of fraud.

In order to be able to guarantee the quality of assessments of courses and graduation, the EB checks the quality of a sample of theses and a sample of courses. It informs the lecturers of the procedural and critical aspects of adequate testing, and systematically evaluates the quality of assessments. It also formulates proposals to improve the quality of testing and assessment if necessary.

The EB is in charge of the quality control of assessments. The testing and assessment system as a whole, and the quality control in particular, form an integral part of the overall educational quality assurance process, and fall under the final responsibility of the Director of AI.

The EB controls assessment at the programme and course levels. Bachelor's and master's courses are systematically audited. The EB forms its opinion by evaluating learning and assessment materials and formulates its conclusions as advice for the head of the programme. It operates independently and has an external board member to strengthen its independence.

Considerations
The panel finds the assessment policy of the bachelor's and master's AI programmes to be adequate. The procedures to assure the quality of assessments are well described. The panel is convinced that the quality assurance of the assessments in the bachelor's and master's degree programmes AI is sufficient. It is positive about the mechanisms in place to assure the quality of the assessment, the modes of assessment, and the links of the assessments to the course contents.

The assessment procedure of the bachelor's and master's thesis projects is well described and adequate. Rubrics are used in the grading of the bachelor's and master's thesis projects. The panel verified that the score sheets for the bachelor's and master's theses are adequate. They are filled in by at least two examiners in an independent way. The panel would like to encourage the programme to evaluate its use of the current forms and strengthen their use to further increase the transparency of assessment.

The panel established that the joint Examination Board is performing its legal duties and tasks. It checks the quality of a sample of theses and a sample of courses to guarantee the quality of assessments of courses. It informs lecturers of the procedural and critical aspects of adequate testing, and systematically evaluates the quality of assessments. It also formulates proposals to improve the quality of testing and assessment if necessary. Bachelor's and master's courses are systematically audited. The panel saw a well-functioning and proactive EB.

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

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

Bachelor's programme Artificial Intelligence
The panel studied a selection of fifteen bachelor's theses and their assessment forms. It agreed that all theses reflected the required degree level. They demonstrated that the intended learning outcomes are achieved. The panel concluded that the theses showed that the students are on an academic level, able to analyse problems, critically review scientific results and communicate about them. The research topics are relevant to the broad area of Artificial Intelligence, which ranges from theoretical explorations of the social and ethical implications of AI, via computational modelling of aspects of human cognition and brain functioning, to more engineering types of projects in which smart systems, robots, or interfaces are designed and evaluated. The theses showed that the bachelors have the capability to perform a theoretically founded experiment or produce a design and report on it.

The panel did observe that in two of the selected theses, the reporting did not reflect the AI component in their multidisciplinary set-up. It would like to advise the programme to take additional

measures to make the AI component more clearly visible in the theses. It concluded that the quality of the studied bachelor's theses indicate that the graduates have achieved the final qualifications of the bachelor's programme.

Graduates can proceed to any AI master's degree programme in the Netherlands or can choose a master's programme in a different discipline. Bachelor graduates also find employment on the labour market very easily in the line of their expertise and level. According to the panel, the programme provides the students with a broad basis which enables them to pursue a career in either research or industry. It considers the bachelor graduates to be well prepared for the master's programme AI; this impression was confirmed by the master's students and alumni interviewed during the site visit.

Master's programme Artificial Intelligence
In 2018, a reorganisation of the tracks took place. All current master's theses are still written in the context of one of the three original specialisations: Web and Language Interaction (aligned with the Donders Institute Language and Communication theme), Robot Cognition (aligned with the Perception, Action & Control theme) and Communication in Natural and Artificial Systems (aligned with the Brain Networks & Neuronal Communication theme). The programme expects the first cohort of alumni to graduate from the new curriculum at the end of the 2019-2020 academic year.

The panel studied a selection of fifteen master's theses and their assessment forms, covering all three original tracks. It agreed that all theses reflected the required degree level. They demonstrated that the intended learning outcomes are achieved. The panel deems the quality of the examined theses to be good. They focus on the application of AI techniques in fields like psychology, which aligns with the programme's goals. The panel did observe that the AI component (in particular the technical information about the students' implementation work) could be presented in more detail. The theses showed that the students have the ability to perform independent research in Artificial Intelligence. They can utilise the acquired knowledge and skills and professionally report on their work. They demonstrated an ability to analyse problems on an international academic level, and critically and constructively review both their own and other scientific results and communicate about this. The theses showed that the students have the capability to reflect on their working methods and knowledge and to understand the scientific developments within the field of Artificial Intelligence.

The master's programme graduates are well prepared to continue in a PhD trajectory and for a position on a master's level in the work field that is in line with their expertise. About 30% of the alumni pursues a PhD, while 70% starts a professional career or becomes an entrepreneur. The panel interviewed alumni during the site visit. They confirmed that they felt well prepared for their function in the work field. The knowledge, skills and competences they developed during their AI studies provide a good broad background for their present positions in a variety of companies. They particularly mentioned their ability to look at the AI problems to be solved from a critical perspective, aligning with the goal of the programme to incorporate the societal implications of new developments in AI. The alumni were satisfied with the programme, and they found the academic and critical thinking, programming and research abilities they learnt to be valuable.

The contact with the alumni could be improved, since the panel is of the opinion that alumni input could be very valuable for the programme. It would like to encourage the programme management to implement their current plans to involve more alumni in the programme, for instance by planning more alumni activities and starting an alumni association together with the student association CognAC.

The panel is pleased to see that the work-field committee meets twice a year to discuss the quality of the Bachelor's and Master's programmes regarding the final level, amongst other topics. This ensures that the final attainment levels of the programmes keep on track with the demands of industry. The programme management aims to expand the connection with industry, and keep track of how alumni are doing and how valued they are in industry.

Considerations
The panel concluded that the theses of the bachelor's programme Artificial Intelligence are of a good quality, and convincingly show that the programme's intended learning outcomes have been achieved by the students. They demonstrated that the students are on an academic level, able to analyse problems, critically review scientific results and communicate about them. The research topics are relevant to the broad area of Artificial Intelligence. Bachelor graduates are well prepared for the master's programme AI. Because the thesis topics can be broad, the panel would like to advise the programme to ensure students make the AI component clearly visible in the theses. In its opinion, the programme provides the students with a broad basis which enables them to pursue a career in either research or industry.

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 intended learning outcomes have been achieved by the students. They demonstrated that the students are on an academic level, able to analyse problems, critically review scientific results and communicate about them. The studied theses focus on the application of AI techniques in fields like psychology, which aligns with the goals of the programme. The panel did observe that the AI component (in particular the technical information about the students' implementation work) could be presented in more detail. The panel recommends the programme management to take additional measures to make this AI component better visible in the master thesis. It is convinced that the programme fosters both academic and critical thinking, programming and research abilities, enabling master graduates to successfully occupy positions in academia or industry.

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

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

GENERAL CONCLUSION

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

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

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
The Dutch Perspective

[For author names and article, see:https://pure.uva.nl/ws/files/29809664/KION_FoR_2018_Final.pdf][2]

October 16th, 2018

This document is an update of the 2013 Frame of Reference as developed by the KION[3] 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[4]
• 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[5]
• 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[6], 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)[7] 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).

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

In 1999, the number of recognised labels in the CROHO was reduced, and the aforementioned study programmes were united under the name Artificial Intelligence[8]. Initially, this was an administrative matter that did not influence the content of the curricula. It did mean, however, that from then on cognitive science (as the study of natural intelligence) and artificial intelligence (as a formal approach to intelligence) were shared under the heading of Artificial Intelligence. The above mentioned definition of Artificial Intelligence as the study of natural and/or artificial intelligence by computational means was then agreed upon. The KION (Kunstmatige Intelligentie Opleidingen in Nederland) was formed as a discussion and cooperation platform for the united programmes.

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

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

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

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.

[8] In Dutch: Kunstmatige Intelligentie

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[9] (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.

2.4 | Coping with Change

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

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

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

3 | SHARED IDENTITY

3.1 | Common Role

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

3.2 | Common Requirements

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

1. Essential and foundational underpinnings of the core aspects of intelligence. These must be founded on empirical efforts and based on a formal theory, and they may address professional values

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

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:

    a. An understanding of, and appreciation for, many of the diverse aspects of intelligence, models of intelligent phenomena, and of algorithms that describe intelligent processes.
    b. Skills to model intelligent phenomena and appreciate the abilities and limitation of these models, if appropriate in comparison with a natural intelligence counterpart.
    c. Skills to model and implement intelligent phenomena on a computer, in particular skills to work with algorithms and data-structures in software.
    d. 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:

    a. 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;
    b. 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;
    c. The impact of deploying technological solutions and interventions on individuals, organisations, 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 and Programming
Logic: Propositional Logic and Predicate Logic
Mathematics: Calculus, Discrete Mathematics, Linear Algebra, Probability Theory and Statistics

3.3.1.3 | Academic Skills

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[10]. 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.

[10] "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 organisational 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:
1. 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[11]. Together these final qualifications must lead to alumni that exemplify the shared identity defined in section 3.

[11] 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:
1. 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.[12]

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

[12] http://symsys.stanford.edu/courses (last visited on May 4, 2018)

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

Bachelor's programme Artificial Intelligence

1. Relevant level: Bachelor's graduates (henceforth graduates) have a basic understanding of the key areas in AI, as well as more advanced knowledge in at least one of these areas.
2. Relevant disciplines: Graduates possess essential knowledge and understanding regarding relevant aspects of psychology, informatics, mathematics, logic, linguistics, philosophy and neuroscience. This enables them to develop and apply original ideas, with supervision.
3. Cognition: Graduates possess essential knowledge and understanding regarding human cognition, such as problem-solving, perception, language and motor skills.
4. Methods and technology: Graduates have essential knowledge and understanding regarding methods and techniques in artificial intelligence, such as search techniques, deduction methods, machine learning methods and logic.
5. Analytical skills: Through supervision, graduates are able to analyse a computational problem, formalise theoretical solutions to such problems, translate theoretical solutions into an algorithm or model, and formalise and validate the theoretical predictions.
6. Paradigms: Graduates are able to describe and comment on relevant aspects of current research, for example similarities and differences in architecture and functionality of different models such as symbolic, connectionist and probabilistic models. They also understand the theoretical implications of these aspects, and understand the relevance of different types of models for different areas of application.
7. Philosophy: Graduates have an eye for the philosophical foundations and implications of the influential paradigms and model types in artificial intelligence, as well as the social and ethical implications of developments in the field, for instance regarding topics like autonomy, agency and social implications of robotics.
8. Communication: Graduates are able to express themselves in writing in accordance with the acceptable norms within artificial intelligence for scientific publications, relating to both form and content. They are able to effectively process articles in relevant journals. Additionally, they should be equipped to express themselves orally with accurate terminology to such an extent that they can report on conducted research and can communicate clearly with specialists in artificial intelligence and non-specialists alike.
9. Research: Graduates are able to design, conduct and analyse empirical research through the application of the acquired methods and techniques, as well as observing, consolidating, expanding and applying their knowledge and understanding acquired through this research. The product is potentially suitable for publication in peer-reviewed forums such as the BNAIC.
10. Practical application: Graduates are able to think and act in a practical manner. They can translate practical requirements into design of and improvements to a computer program. They are able to apply the acquired competences in different practical applications, such as major programming tasks that demand a working product to be tested through demonstration sessions, or designing empirical or theoretical research projects regarding the design, implementation and testing of software products.
11. Critical attitude: Graduates have a critical scientific attitude towards research in artificial intelligence in particular. They are able to critically evaluate and assess arguments, assumptions, abstract concepts and (possibly incomplete) data in terms of reliability and validity. They have the ability to integrate and develop (partially under supervision) multidisciplinary knowledge and scientific research questions and to tackle these questions largely independently and autonomously.
12. Learning skills: Graduates have obtained the necessary learning skills to reflect on one's own style of thought and working methods. To recognise the need for continued learning. And to reflect on the job market to build the basis of one's own career path.

Master's programme Artificial Intelligence

1. Relevant level: Master's graduates (henceforth graduates) have general knowledge in the full breadth of the field, detailed knowledge with respect to either the use of AI as a means of studying natural intelligence or the application of state-of-the-art AI in technology, and specialist knowledge on the topic of the Master's thesis.
2. Relevant disciplines: Graduates have obtained relevant knowledge and understanding in the fields of psychology, computer science, mathematics, logic, linguistics, philosophy and/or neuroscience, at a level at which they can actively relate AI to those fields, and are able to incorporate the contributions of scientists in different fields into AI projects.
3. Cognition: Graduates have obtained relevant knowledge and understanding of several human cognitive functions and skills, such as problem solving, perception, language processing and motor behaviour, at a level that enables an original contribution to the computational modelling of such a functionality.
4. Societal implications: Graduates have obtained knowledge and understanding of the ethical and societal implications of recent developments in AI at a level that allows them to form an independent opinion on these aspects.
5. Methodology: Graduates have obtained knowledge and understanding of the similarities and differences in AI methodology, ranging from empirical research, algorithm design and comparison, computational and formal modelling, to conceptual analysis. Graduates also have an understanding of the theoretical implications thereof, and of the relevance of different AI methods for different application domains.
6. Critical attitude: Graduates have a critical, scientific attitude towards research in general and AI in particular, and is able to form a well-founded opinion about the latest developments in several areas of AI.
7. Communication: Graduates are able to express themselves in writing according to the accepted norms for scientific AI publications and to effectively digest articles in relevant journals. In addition, graduates have obtained oral skills that enable reporting on performed research, and communicating on an equal basis with specialists in AI and the fields mentioned in the second point, as well as with non-specialists.
8. Independent learning skills: Graduates have obtained the necessary learning skills to enable further learning in an independent self-directed manner.

Next to these general final qualifications, we identify the following specialisation-specific final qualifications:

Cognitive Computing specialisation

9. Analytical skills: Graduates are able to independently translate a theory, approach, or hypothesis into a formal or computational model, identify inconsistencies or ambiguities in the theory, deduce model predictions, and test those predictions.
10. Research skills: Graduates are able to independently design, execute and analyse fundamental scientific research in a methodologically correct way.
11. Practical application: Graduates are able to both develop and apply new techniques in AI to increase understanding in natural intelligence, as well as incorporate insights from cognitive (neuro)science and related areas into new AI techniques and models.

Intelligent Technology specialisation

12. Analytical skills: Graduates are able to make an independent analysis of an abstract problem that is complex and underspecified, in such a way that a solution can be sought or implications can be evaluated by means of a working application, computational model, guideline, design, or artefact, and, if relevant, a theoretical generalisation can be made.
13. Research skills: Graduates are able to use state-of-the-art AI methods and techniques in applied research and development.
14. Practical application: Graduates are able to translate complex and/or extensive practical requirements into a work plan for developing, improving or extending a computer program, design or artefact.

APPENDIX 3: OVERVIEW OF THE CURRICULUM

Bachelor's programme Artificial Intelligence

Year 1

B1 for cohort 2018 (academic year 2018-2019)

Course code	Course Title	EC
SOW-BKI126	Academic and Professional Skills - 1	4
SOW-BKI123	Academic Skills - 2	3
SOW-BKI108	Brain for AI	6
SOW-BKI121	Introduction Artificial Intelligence A	4
SOW-BKI122A	Introduction Artificial Intelligence B: Practical	3
SOW-BKI110A	Introduction Cognitive Psychology	4
NWI-IPK001	Introduction to Formal Reasoning	6
SOW-BKI114	Introduction Human-Computer Interaction	6
SOW-BKI115A	Introduction Robotics	6
SOW-BKI124	Linear Algebra	3
SOW-BKI104	Mathematics 1A	3
NWI-IPI005	Object Oriented Programming	6
SOW-BKI31	Programming for AI - 1	3
SOW-BKI32	Programming for AI - 2	3
	TOTAL	**60**

Course schedule

Period 1	Period 2	Period 3	Period 4
SOW-BKI126 Ac.&Prof.Skills-1 (4ec)		NWI-IPI005 Object Oriented Programming (6ec)	
SOW-BKI31 Programming 1 (3ec)	SOW-BKI32 Programming 2 (3ec)	SOW-BKI114 Intro HCI (6ec)	
NWI-IPK001 Introduction to Formal Reasoning (6ec)		SOW-BKI115A Intro Robotics (6ec)	
SOW-BKI110A Intro Cogn. Psychology (4ec)	SOW-BKI121 Intro AI-A (4ec)	SOW-BKI108 Brain for AI (6ec)	
SOW-BKI104 Mathematics - 1A (3ec)	SOW-BKI124 Linear Algebra (3ec)	SOW-BKI122A Intro AI-B Practical (3ec)	SOW-BKI123 Ac. Skills - 2 (3ec)

Year 2

B2 for cohort 2017 (academic year 2018-2019)

Course code	Course name	EC
SOW-BKI212A	AI: search, planning and machine learning	6
SOW-BKI203	Bayesian Statistics	6
NWI-IBI008	Data Mining	6
SOW-BKI107	Frequentist Statistics	6
NWI-IBC015	Functional Programming for AI	3
SOW-PSB3BC20E	Language in Progress	4
NWI-IPI004	Logic and Applications	6
SOW-BKI316	Mathematics 2 for AI	6
SOW-BKI230A	Neural Networks	6
SOW-BKI329	Representation and Interaction	6
SOW-BKI244	TCS1: Foundations and implications	5
	TOTAL	**60**

B2 for cohort 2018 (academic year 2019-2020)

Course code	Course name	EC
SOW-BKI212A	AI: search, planning and machine learning	6
NWI-IPI004	Logic and Applications	6
SOW-BKI203	Bayesian Statistics	6
NWI-IBI008	Data Mining	6
SOW-BKI107	Frequentist Statistics	6
NWI-IBC015	Functional Programming	3
SOW-PSB3BC20E	Language in Progress	4
SOW-BKI316	Mathematics 2 for AI	6
SOW-BKI230A	Neural Networks	6
SOW-BKI329	Representation and Interaction	6
SOW-BKI244	TCS1: Foundations and implications	5
	TOTAL	**60**

Period 1	Period 2	Period 3	Period 4
SOW-BKI316 Mathematics-2 (6ec)		SOW-BKI329 Representation and Interaction (6ec)	
SOW-BKI212A ASPML (6ec)		SOW-BKI230A Neural Networks (6ec)	
SOW-BKI107 Frequentist Statistics (6ec)		SOW-BKI203 Bayesian Statistics (6ec)	
NWI-IBC015 Functional Programming (3ec)	SOW-PSB3BC20E Language in Progress (4ec)	NWI-IPI004 Logic and Applications (6ec)	
NWI-IBI008 Data Mining (6ec)		SOW-BKI244 TCS-1 (5ec)	

Year 3

Course code	Course name	EC
SOW-BKI300	Bachelor Thesis	12
SOW-BKI323	Brain-computer Interfacing (BCI)	6
SOW-BKI211	Computational and Formal Modeling	6
SOW-BKI324	Modern Software Development Techniques	6
SOW-PSB3BC25E	Neurophysiology of Cognition and Behaviour	4
SOW-BKI328	Professional Skills - 2	2
SOW-BKI329	Representation and Interaction	6
Free-Choice Electives	See for recommended electives	18
	TOTAL	**60**

Period 1	Period 2	Period 3	Period 4
SOW-BKI324 Modern Software Development Techniques (6ec)		SOW-BKI300 Bachelor Thesis (12ec)	
SOW-BKI323 BCI (6ec)		SOW-BKI329 Representation & Interaction (6ec)	
SOW-BKI211 Computational & Formal Modeling (6ec)		Choice (12ec)	
SOW-BKI328 Prof.Skills-2 (2ec)	SOW-PSB3BC25E Neurophysiology (4ec)		
Choice(6ec)			

Master's programme Artificial Intelligence

Neural Computation - Specialisation programme

Course code	Course name	EC
	***Compulsory Courses** - 18 EC*	
SOW-MKI66	Advanced Academic & Professional Skills	6
SOW-MKI67	Societal Impact of AI	6
NWI-IMC030 or NWI-IMC056	Machine Learning in Practice Statistical Machine Learning	6
	***Final Project** - 45 EC*	
SOW-MKI83 SOW-MKI92 or SOW-MKI94	Internship, and Research Project Extended Research Project	15 30 45
	Specialisation courses *Selection of 18 EC*	
SOW-MKI40	Cognition and Complexity	6
SOW-MKI46	Advanced Brain-Computer Interfaces	6
SOW-MKI49	Neural Information Processing Systems	6
SOW-MKI56	Theoretical Foundations for Cognitive Agents	6

	Specialisation electives *- 18 EC*	
	Any compulsory or specialisation course	
NWI-FFIL202A	Evolution and the mind	3
NWI-IMC012	Bayesian Networks	6
NWI-IMC042	Natural Computing	6
NWI-NM047C	Computational Neuroscience	9
SOW-DGCN02	Neuroimaging I	6
SOW-DGCN03	Neurophilosopy	6
SOW-DGCN23	Motor Control	6
SOW-DGCN25	Cognitive Control and Decision Making	6
SOW-DGCN44	Perception	6
SOW-DGCN45	Attention and Performance	6
	Free electives *- 21 EC*	
SOW-MKI10	Capita Selecta	3
SOW-MKI20	Capita Selecta	6
SOW-MKI62	Research Seminar	6
SOW-MKI54	Matlab Skills	3
	Any Master course	
TOTAL		**60**

Interactive Agents - Specialisation programme

Course Code	Course name	EC
	Compulsory Courses *- 18 EC*	
SOW-MKI66	Advanced Academic & Professional Skills	6
SOW-MKI67	Societal Impact of AI	6
NWI-IMC030 or NWI-IMC056	Machine Learning in Practice Statistical Machine Learning	6
	Final Project *- 45 EC*	
SOW-MKI83 SOW-MKI92 or SOW-MKI94	Internship, and Research Project Extended Research Project	15 30 45
	Specialisation Courses Selection of 18 EC	
LET-REMA-LCEX06	Text and Multimedia Mining	6
SOW-MKI49	Neural Information Processing Systems	6
SOW-MKI52	New Media Lab	6
SOW-MKI68	Cognitive Robotics	6

	Specialisation Electives - 18 EC	
	Any compulsory or specialisation course	
LET-REMA-LCEX10	(Automatic) Speech Recognition	6
NWI-FFIL215	Upgrading the Human2	3
NWI-I00041	Information Retrieval	6
NWI-IMC037	Intelligent Systems in Medical Imaging	6
NWI-NM102	Auditory Perception and Technology	3
SOW-DGCN23	Motor Control	6
SOW-DGCN26	Social Neurocognition	6
SOW-DGCN44	Perception	6
SOW-MKI55	Artificial & Natural Music Cognition	6
SOW-MKI59	Robotlab Practical	3
	Free Electives - 21 EC	
SOW-MKI10	Capita Selecta	3
SOW-MKI20	Capita Selecta	6
SOW-MKI62	Research Seminar	6
SOW-MKI54	MatLab Skills	3
	Any Master course	
TOTAL		**60**

APPENDIX 4: PROGRAMME OF THE SITE VISIT

Monday November 18, 2019		
08.15	08.30	Taxi from hotel
08.30	09.00	Arrival and welcome committee
09.00	10.00	Internal consultation committee
10.00	10.45	Interview content responsible director and coordinators
10.45	11.00	Internal consultation committee
11.00	11.45	Interview Bachelor students
11.45	12.00	Internal consultation committee
12.00	12.45	Interview Bachelor lecturers
12.45	13.45	Lunch / walk in hour (only if notified in advance at QANU secr.)
13.45	14.15	Tour
14.15	14.30	Break
14.30	15.15	Interview Master students
15.15	15.30	Internal consultation committee
15.30	16.15	Interview Master lecturers
16.15	16.30	Internal consultation committee
16.30	17.15	Interview Alumni
17.15	17.30	End of day 1

Tuesday, November 19, 2019		
08.15	08.30	Taxi from hotel
08.30	09.30	Arrival, welcome and preparation committee
09.30	10.15	Interview Examination Board
10.15	10.30	Internal consultation committee
10.30	11.15	Interview Formal Responsible
11.15	13.15	Formulation judgement by committee
13.15	13.30	Presentation provisional results/oral feedback
13.30	14.15	Development meeting (back in room A03.06)
14.15	14.30	End of visit – Drinks

APPENDIX 5: THESES AND DOCUMENTS STUDIED BY THE PANEL

Prior to the site visit, the panel studied 15 theses of the bachelor's programme Artificial Intelligence and 15 theses of the master's programme Artificial Intelligence. Information on the selected theses is available from QANU upon request. The panel also studied the self-evaluation report provided by the programme, and the report of the previous accreditation panel.

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 (Brightspace)):

- Introduction Robotics, 1st year
- Introduction Computer – Human interaction, 1st year
- Bayesian Statistics – 2nd year
- Cognition and Complexity – master course
- Academic and Professional skills (1st year) and Advanced Academic and Professional skills (master course)

- Literature, examinations, assignments and demo's of the above courses
- Book used for Introduction AI-A
- Supplementary:
    - Posters Computational and formal modeling (3rd year)
    - Tablet demo of Modern Software Development Techniques (3rd year)
- Minutes, advice and other documents from the EC, BoE, and work field committee.
- Assessment programme bachelor and master
- Course evaluations
- Procedures of bachelor and master projects