MASTER'S PROGRAMME

ARTIFICIAL INTELLIGENCE

FACULTY OF SCIENCE

VRIJE UNIVERSITEIT AMSTERDAM

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This report was finalised on 9 June 2020

REPORT ON THE MASTER'S PROGRAMME ARTIFICIAL INTELLIGENCE OF VRIJE UNIVERSITEIT AMSTERDAM

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

ADMINISTRATIVE DATA REGARDING THE PROGRAMME

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:	Cognitive Science
Location(s):	Amsterdam
Mode(s) of study:	Full-time
Language of instruction:	English
Submission deadline NVAO:	1 May 2020

The visit of the assessment panel Artificial Intelligence to the Faculty of Science of the Vrije Universiteit Amsterdam took place on 11 and 12 December 2019.

ADMINISTRATIVE DATA REGARDING THE INSTITUTION

Name of the institution:	Vrije Universiteit Amsterdam
Status of the institution:	Publicly funded institution
Result institutional quality assurance assessment:	Positive

COMPOSITION OF THE ASSESSMENT PANEL

The NVAO has approved the composition of the panel on 25 September 2019. The panel that assessed the 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 [chair].
- Prof. dr. C. (Cees) Witteveen. Full Professor at the Algorithmics Group of the Faculty of Engineering, Mathematics and Computer Science (EEMCS/EWI), Delft University of Technology.
- Dr. ir. J.F.M. (Hans) Tonino. Associate Professor at the Algorithmics Group of the Faculty of Engineering, Mathematics and Computer Science and Director of Studies Embedded Systems at Delft University of Technology;
- Dr. A. (Annerieke) Heuvelink-Marck. Senior Scientist at the Software Concepts Department of Philips Group Innovation and Research;
- M. (Maartje) Stokvis MSc.. Master graduate Data Science for Decision Making at Maastricht University [student member].

The panel was supported by José van Zwieten (freelancer QANU), who acted as secretary.

WORKING METHOD OF THE ASSESSMENT PANEL

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

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

During the site visit at the Vrije Universiteit Amsterdam, the panel was supported by José van Zwieten, a certified NVAO secretary.

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

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

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

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

Before the site visit to the Vrije Universiteit Amsterdam, QANU received the self-evaluation reports of the programmes and sent these to the panel. A thesis selection was made by the panel's chair and the project coordinator. The selection existed of 15 theses and their assessment forms for the programmes, based on a provided list of 36 graduates between June 2017 and July 2019. A variety of topics and tracks and a diversity of examiners were included in the selection. In previous years, different tracks existed; recently the programme switched to just one track (Cognitive Science). In the selection, the old tracks were taken into account and from these different tracks, the following numbers of theses were selected: Socially Aware Computing (3/6), Intelligent Systems (5/10), Human Ambience (2/5), Cognitive Science (4/8), no particular track (1/6). The project coordinator and panel chair assured that the distribution of grades in the selection matched the distribution of grades of all available theses.

After studying the self-evaluation report, theses and assessment forms, the panel members formulated their preliminary findings. The secretary collected all initial questions and remarks and distributed these amongst all panel members. At the start of the site visit, the panel discussed its initial findings on the self-evaluation report and the theses, as well as the division of tasks during the site visit.

Site visit
The site visit to the Vrije Universiteit Amsterdam took place on 11 and 12 December 2019. Before and during the site visit, the panel studied the additional documents provided by the programmes. An overview of these materials can be found in Appendix 5. The panel conducted interviews with representatives of the programmes: students and staff members, the programme's management, alumni and representatives of the Board of Examiners. It also offered students and staff members an opportunity for confidential discussion during a consultation hour. No requests for private consultation were received. The panel used the final part of the site visit to discuss its findings in an internal meeting. Afterwards, the panel chair publicly presented the panel's preliminary findings and general observations.

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

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

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

Meets the standard
The programme meets the generic quality standard.

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

Does not meet the standard
The programme does not meet the generic quality standard.

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

Positive
The programme meets all the standards.

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

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

SUMMARY JUDGEMENT

The panel concludes that the master's programme AI from VU Amsterdam has a clear profile. It combines a broad perspective on AI with a focus on hybrid intelligence. This profile is in line with the strong research expertise of the VU in this approach to AI. The programme offers a track to students who wish to specialise in Cognitive Science aspects of AI. The panel suggests considering offering additional tracks that can be seen as a continuation of the *Socially Aware Computing* and *Intelligent systems* tracks in the bachelor's programme.

The programme has clear intended exit qualifications. They are in line with the KION frame of reference and with the Dublin descriptors. The intended learning outcomes reflect the academic master's level of the programme.

The panel established that the curriculum of the master's programme AI of VU Amsterdam has a good balance of core modules in AI key areas and electives that offer diverse opportunities to specialise. It is in line with the intended learning outcomes of the programme. The VU focus on hybrid intelligence is visible in dedicated courses and in the approach to AI in several generic courses. The course content is up to standard. According to the panel, formulating learning paths or tracks could make the specialistic expertise that the students can develop more transparent to both the students and the professional field. It can also create more opportunities for knowledge progression if the courses can build upon knowledge from earlier courses.

The panel appreciates that the programme is open to students from various backgrounds. Although most students with a non-AI background need to take a premaster programme, those with a bachelor's degree in psychology only take a 'Skills for AI' course in the first period of the programme. The panel thinks that they would be better prepared if they would take a premaster programme as well. This might also decrease the need for introductory lectures at the beginning of courses in the master's programme.

The students experienced the programme as challenging, but they received strong support from the teachers. The communication to the students is not always proactive and clear enough. According to the panel, the introduction of mentor groups is a good step to improve the accessibility of information for the students. The teaching methods within the programme enable and promote the students' active participation.

The students are taught by good teaching staff with a solid background in AI research. The panel noticed that the teaching staff is highly committed to their teaching responsibilities. The department has been confronted with a rise in student numbers. Although new staff members have been hired and more vacancies have been posted, the panel advises the programme to keep a close eye on the staff-student ratio and workload of the teaching team.

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

According to the panel, assessment within Artificial Intelligence is up to standard. Assessment practices and policies are in line with faculty policy. AI assessment is varied. The programme pays sufficient attention to the prevention and follow-up of fraud. The introduction of scoring rubrics and separate grading forms for first and second examiners and their consensus contribute to the quality of the assessment process. More clarity on the weighing of subscores and more discipline in filling and signing forms are points for improvement The Examination Board has a clear view of its tasks and responsibilities. Its subcommittees and assessment committee carry out their tasks in a proactive manner.

The panel concluded from the theses it studied and the performance of alumni that AI graduates realise the intended learning outcomes. The level of the theses was adequate and in line with the expectations of academic master graduates. They are able to proceed with their career in academia or in the professional field.

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

Master's programme Artificial Intelligence

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

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

Date: 9 June 2020

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

The master's programme Artificial Intelligence (AI) is offered by the Department of Computer Science, part of the Science Faculty of Vrije Universiteit Amsterdam. It is organised in the College and Graduate School of Information Sciences, together with four other master's programmes. To coordinate organisational matters that concern all programmes, the Science Faculty organises monthly meetings with the Educational Director of the Faculty, all Programme Directors and the Head of the Education Office.

The programme has a Programme Director, who is responsible for its quality and development. She works together with the Programme Coordinator, who takes care of organisational matters of the bachelor's and master's programmes AI. The Master's programme has a joint Programme committee with the bachelor's programme AI, consisting of three students and three staff members. They meet five times a year. The Programme committee fulfils its legal role in the quality assurance of the programme, as well as pro-actively advising the programme management on the quality and development of the programme.

Standard 1: Intended learning outcomes
The intended learning outcomes tie in with the level and orientation of the programme; they are geared to the expectations of the professional field, the discipline, and international requirements.

Findings
The master's programme AI of the VU aims to provide students with a solid foundation in the technical and algorithmic aspects of AI, combined with a thorough understanding of human functioning from human-oriented sciences. According to the self-evaluation report, the VU master's programme in AI distinguishes itself by a focus on hybrid intelligence. In this human-centred approach to AI, AI systems and humans collaborate. Attention is paid to the social awareness of intelligent systems and the interaction between humans and machines. According to the panel, this focus is well-chosen in the light of the research profile of the VU. All three AI research groups of the department of Computer Science contribute to this focus: *Social AI, Computational Intelligence* and *Knowledge Representation & Reasoning.* The panel also thinks that the focus on hybrid intelligence makes the programme attractive for students who are interested in this human-centred approach to AI.

The general context of the master's programme profile is formed by the KION Frame of Reference which is compiled by the Dutch academic AI programmes. This document formulates the current Dutch consensus on a national frame of reference for Artificial Intelligence in the Netherlands. Students at the VU master's programme are trained in all relevant disciplinary areas within the broad field of AI, as formulated in this KION frame of reference. A large part of the programme is dedicated to core courses in the eight key areas of AI. In several parts of the programme, these areas are related to hybrid intelligence.

In line with the profile of the programme, and utilising the strong ties with the Cognitive Science section of the Behavioural and Movement Sciences faculty, the programme organises a *Cognitive Science* track (CS) that aims to provide students with a solid knowledge base of the cognitive aspects and applications of AI. The panel thinks that this track is interesting for students who wish to specialise in this area. At the same time, it is striking that there are no other tracks defined in the programme. It is worth considering the creation of tracks that offer a specialised follow-up of the two tracks in the bachelor's programme AI at the VU: *Socially Aware Computing* and *Intelligent Systems*. Although the current core programme and electives offer opportunities in this direction, the panel thinks that offering predefined tracks makes this more recognisable for students who are comparing master's programmes in AI.

In addition to this content focus of the programme, VU Amsterdam intends to attract a broad target group of students in line with its policy. By making it an English-taught programme, it can welcome international students. The programme is also open to students with a background in psychology. With the explicit attention paid to the social aspects of AI and its applications in the life sciences, the programme has managed to attract a substantial percentage of female students. During the site visit, it became clear that the programme takes pride in this openness and the diversity that it has realised. The panel appreciates this intention of the programme and the congruence of choices that have been made in line with this intention.

To keep the programmes aligned with the expectations of the academic and professional field, the VU programmes in AI have recently introduced an Advisory Council of Professionals. The Council currently has four members, employees of companies representing different subfields within AI. It aims to meet once per year and advises on the vision and content of the programmes.

The focus of the programme, together with the clustered final qualifications of the KION frame of reference, are elaborated into the final qualifications for the master's programme (see Appendix 1). The programme has adopted the final qualifications of the KION frame of reference and added two VU-specific qualifications related to knowledge and insight in hybrid intelligence and the required knowledge of human functioning that can be exploited in socially aware AI systems. For the CS track, four additional qualifications have been formulated for the knowledge and application abilities that students in this track should acquire.

The panel established that the final qualifications meet the requirements of the KION framework and are formulated in line with the goal of the programme. They tie in with the Dublin Descriptors for master's degree programmes and therefore sufficiently indicate what could be expected from students at a master's level. They reflect the content, level and orientation of the master's programme. The panel finds the distinction between the final qualifications of the bachelor's and the master's programmes to be clear.

Considerations
The panel concludes that the master's programme AI from VU Amsterdam has a clear profile. It combines a broad perspective on AI with a focus on hybrid intelligence. This profile is in line with the strong research expertise of the VU in this approach to AI. The programme offers a track to students who wish to specialise in Cognitive Science aspects of AI. The panel suggests considering offering additional tracks that can be seen as a continuation of the *Socially Aware Computing* and *Intelligent Systems* tracks in the bachelor's programme.

The programme has clear intended exit qualifications. They are in line with the KION frame of reference and with the Dublin descriptors. The intended learning outcomes reflect the academic master's level of the programme.

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

Standard 2: Teaching-learning environment
The curriculum, the teaching-learning environment and the quality of the teaching staff enable the incoming students to achieve the intended learning outcomes.

Findings
The master's programme AI of VU Amsterdam has a two-year, 120 EC curriculum. It follows the university's academic 8-8-4 schedule. This schedule consists of six periods: each semester has two eight-week periods and a final four-week period.

All students take 54 EC in total: 42 EC of compulsory courses and 12 EC of constrained choice electives. This compulsory core addresses all the key areas of AI. It also contains a methodology course and an 'AI & Society' course, which addresses the ethical, normative and social consequences of AI. The students also take 36 EC of elective courses. There is a broad range of electives that offer opportunities to specialise in a subarea of AI, such as symbolic approaches or machine learning. The students can also specialise in a particular application domain, such as health or criminology. In order to complete the Cognitive Science track, students use 18 EC of their elective space to follow three specialised CS courses. For all students, 30 EC is dedicated to the Master Project. Appendix 3 contains an overview of the curriculum.

The panel studied the curriculum as well as the content of a number of courses and projects, and spoke with students and staff about the content of the curriculum. It concluded that the curriculum is up to standard. The compulsory part addresses the key areas of the KION frame of reference. It also deals with generic academic knowledge and skills. The panel observed that the focus of VU Amsterdam on hybrid intelligence is present in several courses of the core curriculum, for example in the 'Social Intelligent Robotics' and 'Knowledge Engineering' courses. The study materials of the courses that the panel reviewed are of good quality and represent the level that would be expected from master's courses.

The panel appreciates the broad basis that the curriculum offers, together with a diverse range of electives. However, for the students as well as the industry, it could be good to define certain specializing study paths. The curriculum offers possibilities to specialise in specific areas of AI or specific applications, but without labelling them, these specialisations may not be recognisable for students or employers. Defining learning paths or tracks would make these routes more visible for the students. This will help them to choose a coherent set of courses. It may also be beneficial in making clear to future employers what kind of AI professional they are.

The students also expressed a wish regarding this matter. They would appreciate more specializing tracks in the programme, especially if it would be possible to specialise earlier in the programme and if this would lead to more coherence and knowledge accumulation between courses in the same track. The panel also sees this beneficial point of defining learning paths or tracks. Most courses are now stand-alone introductions in a subject that can be followed at any point in a student's programme. Learning paths would allow for knowledge progression between the courses.

Regarding the CS track, the panel thinks that this track could benefit from a more substantial position in the curriculum. Currently, it involves three courses (18 EC) in the elective space of the curriculum. According to the panel, it would be worthwhile increasing this. One possibility could be to require students in this track to do a CS-related master project. This will provide a clear focus in their programme to develop specialised knowledge and research skills in this aspect of AI.

Didactical approach
In the self-evaluation report two key concepts were mentioned that characterise the didactic vision. Education is community-based and problem-driven. During the site visit, the panel discussed this approach with the students and teachers. It became clear that the approach is operationalised in project-based courses and assignments. In several courses, the students work on a group assignment. An example of this is the 'Knowledge Engineering' course, during which the students need to identify their own problems and domain experts and develop a knowledge-based system from acquisition phase until implementation, using the CommonKADS methodology. Elsewhere in the programme, the students are challenged to design solutions for specific problems. They also mentioned that many courses have guest lectures at which researchers and professionals from the AI industry introduce them to the projects and problems that they are working on.

The panel discussed the guidance that students receive when working on group assignments. It became clear that attention is paid to good and equal collaboration in the project groups. The students mentioned that they all have experience in teamwork from their bachelor programme, so

co-working comes naturally to them, and they are usually able to resolve issues themselves. Therefore, the supervision can focus on the content of the project, rather than on their collaboration process. The panel thinks that this experience in group work with a problem-based approach can prepare students well for the professional field of AI, where they are expected to work in teams. The students also appreciated these projects, although some mentioned that they would prefer to have more individual assignments, where they can work on a challenging task that they can approach in their own way. The programme could consider introducing individual student portfolios to monitor that the students fulfil all different roles throughout the group assignments.

The second didactical key concept of the programme is research-embedded teaching. The courses are organised by staff members who are active in one of the research groups of the department. The students mentioned several examples of courses in which the teachers address or use their own research projects; they stated that they obtain a good overview of the AI research expertise of VU Amsterdam. During their master project, they work on research projects that are supervised by the research groups and in some cases initiated by these groups.

The programme uses a combination of traditional teaching formats: lectures, practicals and project formats. The students seemed to be satisfied with the quality of the teaching. The teachers mentioned several examples of innovative approaches in their courses. For instance, in the Knowledge Representation course, the students need to peer-review each other's work using EasyChair. During staff meetings, the teachers share experiences and ideas on educational innovation. The panel is pleased with this commitment to developing the didactical approach in the AI programmes. In its opinion, this development could be formalised more in order to stimulate alignment with the educational vision of the department and to make it more transparent for new teachers.

Language and internationalisation
The master's programme AI has adopted English as the language of instruction. The programme management and teaching staff are convinced that internationalisation of the programme should be pursued, in order to prepare the students for developments in the academic and professional field of AI. The rising number of international students contributes to a stimulating learning environment in their opinion. In 2018/2019, around 15% of the total intake of the programme had an international background. To maintain the quality of English as the language of instruction, all non-native English teaching staff is required to reach at least the C1 (near native) level. Staff members who do not perform at that level are offered a qualification programme.

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

Intake and feasibility
Students can enter the programme from a variety of academic backgrounds. The majority has a BSc degree in AI, from VU Amsterdam or another Dutch University. VU Amsterdam also allows students with a BSc in computer science or psychology directly into the programme. Students with a relevant bachelor diploma from a university of applied sciences (in Dutch: HBO)or with an academic bachelor's degree in a related discipline (e.g. philosophy) can take a premaster programme of 30 EC, which is tailored to their specific background. The panel gathers that students are responsible for their own choices considering minors and electives, which is appropriate as long as it is clear to enrolling students what kind of background is expected of them in terms of subjects and level.

In order to deal with the diverse backgrounds of students entering the programme, the students take an introductory course in the first period that is meant to bring them all to a comparable entry level regarding human AI. Students with a technical background, such as AI, take a course in cognitive psychology. Those with a background in psychology follow the 'Skills for AI' course. This course was introduced in 2019-2020. In the experience of the students and staff members, the course is

beneficial for students with a non-AI background, but 6 EC is not sufficient to get them to the same level as their AI-peers. The students mentioned that in more technical courses, they need to work very hard to bridge the knowledge gap with AI-peers. Some mentioned that these students tend to avoid programming roles in projects.

As an additional measure, the programme introduced a programming test for students with a background in psychology in 2019. The result of this test is non-binding, but the students are instructed that they are expected to meet the level of this test in order to succeed in the programme. They are urged to take a programming course if they fail the test. The panel observed that in other courses of the curriculum as well, the programme strives to get all of the students to the same level of knowledge in the relevant subject. Core courses often start with a few lectures that cover the required foreknowledge.

The panel praises the programme for its efforts to support a diverse group of students. It allows people from various backgrounds to become AI professionals. They might not become programming experts in this field, but there is a growing need for AI professionals who play a different role in teams that develop and implement AI applications. This interdisciplinary character of the programme with its focus on hybrid intelligence fulfils this need well. At the same time, the panel thinks that the level of the programme could increase with stricter entry requirements. It advises requiring students with a background in psychology to take a premaster programme, possibly in the minor space of their bachelor's programme. This would support them better in becoming AI experts. At the same time, the core courses of the master's programme can build on a more advanced knowledge level of all of its students.

In the self-evaluation report, the statistics on student success are presented. The first-year dropout rate was between 6% and 24% in the period 2012-2017. Of the 2015 cohort, 71% graduated within three years. According to the panel, these numbers are comparable to other AI master's programmes.

The panel discussed the feasibility of the programme with the students and alumni. They experienced the programme as challenging but feasible. The study load approaches a fulltime work week, although they perceived some differences between courses. The students mentioned that the information on the programme, for example on electives, could be improved. However, they stressed that the teachers are very approachable and open to receiving feedback. When they bring up a problem, their experience is that the teachers follow up on this as soon as possible. The programme has introduced mentor groups as a means of student support. Groups of approximately 15 students meet with each other under the supervision of a staff member and a second-year AI student. They discuss their experiences in the programme and can pose questions. The panel thinks that this is a good measure to improve the accessibility of information and support to the students.

Teaching staff

The panel looked at the list of teaching staff provided in the self-evaluation report and interviewed a small selection of AI faculty. It concluded that the quality of the teaching staff is good. Most lecturers have a PhD degree. According to the department's policy, each staff member is required to teach one graduate course per year. The panel believes that this is a good measure to realise the intended research-based education. Half of the staff members hold a university teaching qualification (UTQ, or BKO in Dutch), and approximately 10% is in the course of completing this qualification. The panel established that the AI staff possesses the necessary didactic skills.

The department also organises monthly teacher-team meetings, during which the teaching staff is informed about and discusses topics such as assessment quality, scalable education and the programme's educational vision. During the site visit, the teachers spoke enthusiastically about these meetings. The discussions are lively and inspiring. They reported that the meetings have high attendance rates, partly because they are scheduled at fixed moments around lecture hours. The

panel was impressed by the way the department realises commitment to these informal teacher-team meetings.

During the site visit, the panel met a selection of lecturers from the programme. It observed a lot of commitment and dedication concerning their teaching responsibilities. The teachers seem to form a close team. The appreciation of students and alumni regarding the accessibility and involvement of their teachers is high.

The student-staff ratio in the department of Computer Science is 49 to 1. The department has hired a new professor and five assistant professors to cope with the increasing number of students in the AI programmes. In addition, more vacancies have been posted. For the supervision of practicals, the programme uses teaching assistants and junior lecturers, who are supervised by staff members. The teachers reported to the panel that in their experience, increases in student numbers in a course are supported by the allocation of additional teaching assistants. The panel concluded that the staff quantity is sufficient to successfully run the programme.

Facilities
During the site visit, the panel visited the new building where the department and the AI programmes will be housed from the beginning of 2020. Although the students did not report any complaints about the current facilities of the programme, it was impressed with the new building. There are high-quality seminar rooms planned, as well as substantially more space for self-study than is currently the case. The panel thinks this rehousing is a major improvement of the teaching facilities.

Considerations
The panel established that the curriculum of the master's programme AI of VU Amsterdam has a good balance of core modules in AI key areas and electives that offer diverse opportunities to specialise. It is in line with the intended learning outcomes of the programme. The VU focus on hybrid intelligence is visible in dedicated courses and in the approach to AI in several generic courses. The course content is up to standard. According to the panel, formulating learning paths or tracks could make the specialistic expertise that the students can develop more transparent to both the students and the professional field. It can also create more opportunities for knowledge progression if the courses can build upon knowledge from earlier courses.

The panel appreciates that the programme is open to students from various backgrounds. Although most students with a non-AI background need to take a premaster programme, those with a bachelor's degree in psychology only take a 'Skills for AI' course in the first period of the programme. The panel thinks that they would be better prepared if they would take a premaster programme as well. This might also decrease the need for introductory lectures at the beginning of courses in the master's programme.

The students experienced the programme as challenging, but they received strong support from the teachers. The communication to the students is not always proactive and clear enough. According to the panel, the introduction of mentor groups is a good step to improve the accessibility of information for the students. The teaching methods within the programme enable and promote the students' active participation.

The students are taught by good teaching staff with a solid background in AI research. The panel noticed that the teaching staff is highly committed to their teaching responsibilities. The department has been confronted with a rise in student numbers. Although new staff members have been hired and more vacancies have been posted, the panel advises the programme to keep a close eye on the staff-student ratio and workload of the teaching team.

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

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

Standard 3: Student assessment
The programme has an adequate system of student assessment in place.

Findings
Assessment within the AI programmes follows the VU policy as documented in the 'Handboek Onderwijskwaliteit' (2019). The faculty operationalised this in the policy document 'Toetsbeleid' (2019). According to this document, assessment must be transparent on the level of the faculty, programme and course. It is seen as an integral part of education and therefore must be related to the learning objectives and final qualifications. In daily practice, it is a task of the examiners. They need to work with their second examiner on a good quality of assessment of their courses. The Examination Board produced 'The Examination Board's Rules and Guidelines', which is updated annually.

The faculty's assessment system includes assessment plans for each programme. Each plan is constructed by the programme director. It describes when and how the final qualifications are assessed in the various courses of the programme. The exams are created by at least two staff members, under the responsibility of the course coordinator. He or she is obliged to use an assessment matrix in order to realise alignment between the assessment and the learning objectives of the course. This matrix is part of the assessment dossier of the course, which also includes the assignments/exams, answer models and an overview of the grades.

The panel studied the assessment system of the programme, the assessment plan, and some examples of assessment dossiers. It was impressed with the faculty's assessment system and the adequate measures that are in place to stimulate and safeguard the quality of assessment. The assessment dossiers that the panel studied weren't complete in all cases, but the format is good, and the Examinations Board is encouraging the course coordinators to complete them. From its conversations with the management, staff and students of the programme, the panel concluded that these stakeholders are satisfied with the assessment system.

AI assessment takes the form of written examinations, practical work, written assignments, reports and oral presentations. Most courses are assessed with a combination of formats. Practical sessions contain formative assessments, such as programming assignments. The students also receive formative feedback on their projects and their thesis. The panel is satisfied with the variety of assessment formats. A point of attention is the weighting of the assessment forms. In some courses, unsatisfactory grades (between 4.5 and 5.5) for practical assignments can be compensated with higher grades on the written exam. The panel noted that it is important to ensure that all students develop the required skills during the programme. Compensation should therefore be impossible if the skills are not assessed in other core courses. The panel advises the programme management to keep an eye on this aspect of assessment.

The panel also discussed the policy regarding fraud. Both the Examination Board and the teaching staff pay attention to this topic. They mentioned several means to prevent and deal with fraud. The Examination Board has published a flyer that shows examples of what is acceptable and what is not. One teacher designed a plagiarism quiz that all students need to pass at the beginning of the course. The Examination Board recently changed its policy on the follow-up of fraud. When a teacher spots a potential fraud case, he or she is asked to discuss the case with the student in question. The result of this discussion is reported to the Examination Board, including a recommendation of how the case should be handled. The Examination Board then decides if it needs to speak to the student or whether the case may be handled by the teacher. The panel concluded that the programme dedicates sufficient attention to this matter.

Thesis trajectory
The Master Project AI marks the end of the programme and aims to cover all of its intended final qualifications. It is an individual research project that is conducted under the responsibility of a thesis supervisor. The project can be done at a company or in one of the research groups of the department of Computer Sciences or the Cognitive Science section at the department of Psychology. The MSc project coordinator publishes the available projects and supervisors on the Canvas course page and supports matching them with individual students. After finding a research project, the students start writing a research proposal. This consists of a literature overview, the research problem and question, the intended methodology, and a project plan that includes project planning and risk assessment.

The thesis supervisor is the first examiner, with another AI researcher taking the role of second examiner. In the case of an external project, there is a third supervisor at the external organisation. Most supervision is individual, but there are group sessions as well: Kunstmatige Intelligentie Middagen (KIM). These sessions are compulsory for all students in their thesis phase and also attended by supervisors. During their Master Project, the students present their work twice in these meetings. The first presentation is after one or two months, and the second one is at the end of the project. The last one is graded and counts for 10% of the final grade.

Once the research is completed, the students write a master's thesis. The final grades are based on the quality of the executed work (40%), attitude and professional development, thesis (30%) and presentation (10%). The theses are assessed by the supervisor and a second assessor. When an external supervisor is involved, he or she gives input on the assessment, but the grading is done by the two assessors. They perform their assessment independently using their own marking form. These forms indicate the different assessment criteria, including rubrics that describe the quality levels required to obtain a certain mark. After their individual assessment of the thesis, both assessors discuss their findings and come to a consensus on the grading. The results of this discussion are recorded on a third marking form. This consensus process is appreciated by the staff members; they feel that it stimulates good substantiation of the grading and at the same time contributes to calibration of the standards that the examiners use.

In general, the panel thinks that the assessment procedure for the Master Project is appropriate. It is positive about always having two academic examiners involved in the grading, and the fact that they form their opinion separately from each other before discussing the grade together. It suggests formulating a guideline and procedure for the assignment of first and second supervisors. This should clarify the procedure, for instance to avoid hierarchical relationships between the first and second examiners, which could impede the independence of the grading. The panel studied a number of assessment forms as part of the thesis check conducted prior to the site visit. It concluded that the rubrics are a good improvement compared to the marking form that had been used until 2018. The rubrics help to substantiate the grades per category. Attaching a fixed weight to the partial grades will make it easier to follow how the final grade was composed of the partial grades. Also, a written motivation of the final grade could add to the motivation of the grading. The panel suggests including the relative weights of each category on the assessment form for each thesis and providing a qualitative motivation for the grading. Alternatively, the programme could include a fixed weight for the partial grades on the assessment form. Finally, the panel observed that several forms did not include signatures and/or signing off plagiarism checks. It noted that the programme has made well-chosen improvements to the assessment procedure. With rising student numbers, improving on the points mentioned above will take the quality of assessment to the next level.

Examination Board
The quality of AI assessment is safeguarded by an Examination Board appointed for all programmes within the Faculty of Science. Members of the Examination Board have received training in their tasks and responsibilities. There are domain-related subcommittees, one of which is the subcommittee for all bachelor and master programmes of the Computer Science department. This subcommittee has three members and meets once a month. It deals with students' requests concerning changes in

their individual study programme and requests for exemptions, as well as with fraud cases. A secretary supports the subcommittee with their work.

The Board appoints the programme's examiners and monitors the quality of assessment within the programmes. The Examination Board has installed an assessment committee with a member from each of the subcommittees. This assessment committee investigates the quality of assessment and theses. Each year, a sample of courses and theses is studied. The selection is made based on pass rates and student evaluations. The results of this investigation are reported to the Programme Director. The panel interviewed members of the Examination Board. It concluded that it has a clear view of its tasks and responsibilities and that it works hard to guarantee the faculty-wide quality of assessment.

Considerations
According to the panel, assessment within Artificial Intelligence is up to standard. Assessment practices and policies are in line with faculty policy. AI assessment is varied. The programme pays sufficient attention to the prevention and follow-up of fraud. The introduction of scoring rubrics and separate grading forms for first and second examiners and their consensus contribute to the quality of the assessment process. More clarity on the weighing of subscores and more discipline in filling and signing forms are points for improvement The Examination Board has a clear view of its tasks and responsibilities. Its subcommittees and assessment committee carry out their tasks in a proactive manner.

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

Standard 4: Achieved learning outcomes
The programme demonstrates that the intended learning outcomes are achieved.

Findings
In order to establish whether the master's programme AI demonstrates that the final qualifications are achieved, the panel studied the programme's assessment plan that shows the relationship between the individual courses and the final qualifications. It concluded that the curriculum ensures that the graduates have achieved the final qualifications.

The panel studied a selection of fifteen master theses and the assessment forms. Overall, it agreed with their assessments. It observed that there are different formats with which the students report on their project, ranging from a technical note and a scientific paper to a traditional thesis. In its view, it would be preferable to have a uniform format. This would enable grading based on comparable products. The panel concluded that the theses showed that the students are on an academic master's level. They demonstrated that the graduates have the capability to perform a theoretically founded in-depth research project and to report on it. In some cases, these projects resulted in publications. The panel concluded that the quality of the studied theses indicated that the graduates have achieved the final qualifications of the master's programme.

The panel observed that the lowest mark of the graduates of the last two academic years was a 7. It discussed this aspect with the thesis supervisors. They explained that in general, the students are ambitious, and the supervisors try to support them until their thesis has reached a more than satisfactory level. The panel understands and appreciates that the students and supervisors are motivated to get a good result, but there are downsides to this. First of all, it affects the workload of the supervisors when the students need more time and effort to reach this level. With the rise in student numbers, this may become a critical issue. Furthermore, students coming from abroad usually do not have the time to extend their Master Project. This may create inequality between national and international students.

The panel interviewed a couple of alumni and employers of AI alumni. They are enthusiastic ambassadors of the programme. Alumni especially appreciated the diverse range of topics they could study in their programme. The results of an alumni survey indicated that graduates easily find a job: 92% of the respondents found a job in less than 3 months after graduating. The panel concluded that the programme prepares students well for a career in the academic or business field of AI.

Considerations
The panel concluded from the theses it studied and the performance of alumni that AI graduates realise the intended learning outcomes. The level of the theses was adequate and in line with the expectations of academic master graduates. They are able to proceed with their career in academia or in the professional field.

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

GENERAL CONCLUSION

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

Conclusion
The panel assesses the *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, see: https://pure.uva.nl/ws/files/29809664/KION_FoR_2018_Final.pdf[1]

16 October 2018

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

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

1 | INTRODUCTION

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

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

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

1.1 KION: Artificial Intelligence in the Netherlands

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

[1] The authors like to acknowledge the authors of the 2006 and 2013 Frame of Reference for their work; major parts of this document are still built on their original vision.
[2] Kunstmatige Intelligentie Opleidingen Nederland
[3] www.qanu.nl/en/state-of-the-art-reports (last visited in March 2018)
[4] www.acm.org/education/curricula-recommendations (last visited in March, 2018)
[5] www.unideusto.org/tuning/ (last visited in February 2018)
[6] Centraal Register Opleidingen Hoger Onderwijs

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

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

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

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

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

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

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

1.2.1 Bachelor's Programmes of the KION

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

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

[7] In Dutch: Kunstmatige Intelligentie

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

1.2.2 Master's Programmes of the KION

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

1.3 Aim of this Document

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

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

2 | PROGRAMME CHARACTERISTICS

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

2.1 Areas, Courses, Modules and Topics

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

2.2 Core and Elective Courses

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

2.3 Assessing the Time Required to Cover a Course

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

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

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

2.4 Coping with Change

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

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

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

3 | SHARED IDENTITY

3.1 Common Role

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

3.2 Common Requirements

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

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

and circumstances, giving a sense of permanence and stability to its educational mission. Students must have a thorough grounding in that foundation.

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

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

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

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

3.3.1.3 Academic Skills

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

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

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

3.3.2 Elective Modules (within Artificial Intelligence)

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

- Architectures of Cognition and Cognitive Modelling
- Computational and Cognitive Neuroscience
- Computational Intelligence
- Computer Vision
- Data Mining
- Deep Learning
- ELSA (Ethical, Legal and Social Aspects of AI)
- Evolutionary Algorithms (Genetic Algorithms, Evolutionary Computing)
- Language and Speech Technology

- Neural Networks
- Perception (Computational and Natural)
- Reasoning under Uncertainty
- Reinforcement Learning
- Robotics
- Text Mining and Information Retrieval
- Virtual Reality and Gaming
- Web and Artificial Intelligence

4 | BACHELOR'S PROGRAMME ARTIFICIAL INTELLIGENCE

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

4.1 Objectives

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

4.1.1 Access to Master's Programmes

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

4.1.2 Professional Career

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

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

4.1.3 Academic Skills

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

4.1.4 Place in Society

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

4.2 Final Qualifications

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

4.2.1 Knowledge and Understanding

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

[9] "A Framework for Qualifications of the European Higher Education Area", 2005. (last visited on May 4, 2018)

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.

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:
Academically appropriate communicative skills; the bachelor can:

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

4.2.5 Learning Skills

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

Qualifications:

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

5 | MASTER'S PROGRAMME ARTIFICIAL INTELLIGENCE

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

5.1 Objectives

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

5.1.1 Access to PhD Programmes

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

5.1.2 Professional Career

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

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

5.1.3 Academic Skills

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

5.1.4 Place in Society

The programme provides the master with the knowledge and tools needed to formulate an informed opinion about the meaning and impact of Artificial Intelligence in society. Masters are able to enrich

society with results from contemporary research and oversee the consequences of proposed measures to society and are aware of their responsibility towards society.

5.2 Final Qualifications

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

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.

[10] Framework_for_Qualifications_of_the_European_Higher_Education_Area (last visited on May 4, 2018)

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

5.2.4 Communication

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

Qualifications:
The Master has academically appropriate communicative skills; s/he can:
- Communicate original ideas effectively in written form,
- Make effective oral presentations, both formally and informally, to a wide range of audiences
- Understand and offer constructive critiques of the presentations of others.

5.2.5 Learning Skills

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

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

6 | INTERNATIONAL PERSPECTIVE

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

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

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

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

6.1 Comparison of Bachelor's Programmes

6.1.1 The Artificial Intelligence Bachelor's Programme in Edinburgh

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

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

6.1.2 The Cognitive Science Bachelor's Programme in Osnabrück

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

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

6.1.3 The Symbolic Systems Bachelor's Programme in Stanford

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

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

6.1.4 The Bachelor's Programme Artificial Intelligence at Carnegie Mellon

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

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

6.2 Comparison of Master's Programmes

6.2.1 The Artificial Intelligence Master's Programme in Edinburgh

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

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

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

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

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

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

Their programme includes courses such as:

- Deep Learning and Structured Data
- Probabilistic Machine Learning
- Speech Recognition
- Weighted Automata
- Computer Vision

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

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

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

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

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

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

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

6.2.4 The Cognitive Science Master's Programme in Osnabrück

The university of Osnabrück offers a two-year (120 ec) master of science programme in Cognitive Science. Apart from a 30 ec individual thesis project and a 22 ec team project, students take

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

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.

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

I

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. At all events, a graduate of the study programme will have:

A. 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. The 8 key areas are:
   a) Cognitive Science Computational Linguistics;
   b) Context of Artificial Intelligence (History, Philosophy, Ethics);
   c) Intelligent Autonomous Agents and Multi-Agent Systems;
   d) Interaction (Perception, Human-Computer Interaction, Communication);
   e) Knowledge Representation and Reasoning;
   f) Machine Learning;
   g) Problem Solving (Search, Decision Making, Optimisation).
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;
4. Has a solid academic knowledge of and insight in the field of hybrid artificial intelligence, including the required background knowledge of socially aware artificial intelligence, ambient intelligence, and ubiquitous computing, which builds upon and goes beyond the level of a Bachelor degree in any of those disciplines;
5. Has basic knowledge of physiological, psychological, or social aspects of human functioning that can be exploited in socially aware artificially intelligent systems.

B. 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.

C. 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 ill-defined 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.

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

E. 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.

II

Without prejudice to the provisions of paragraph I, a graduate of the specialisation Cognitive Science will have the following additional knowledge and understanding:

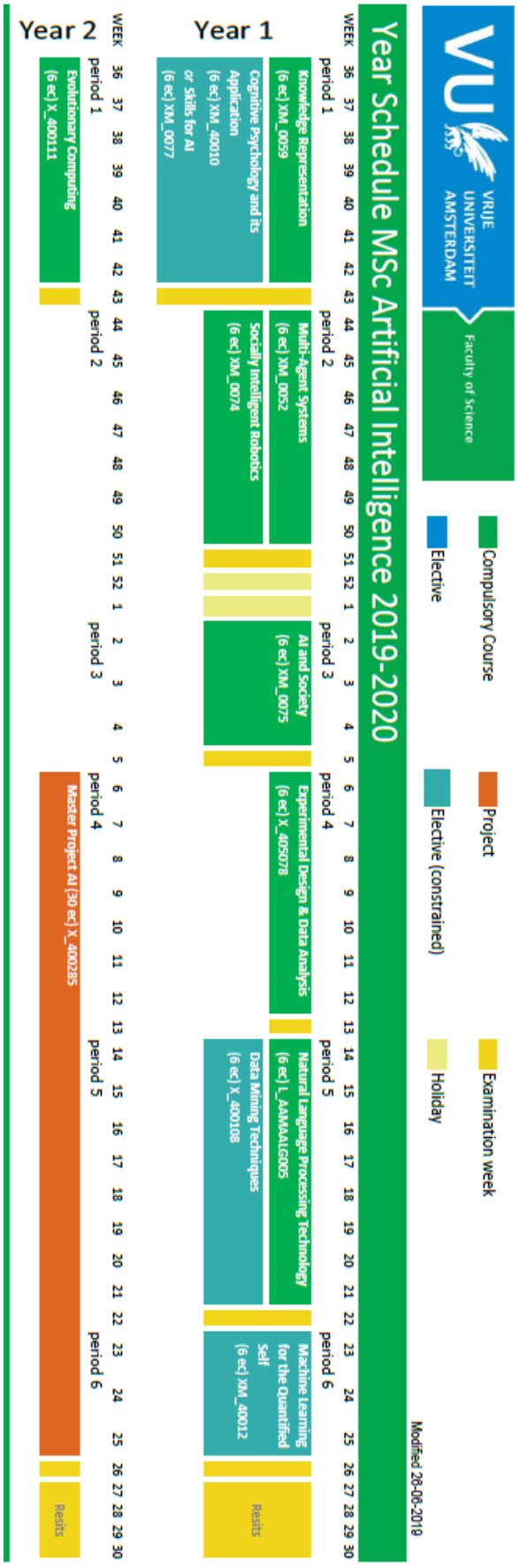
A. Knowledge and Understanding

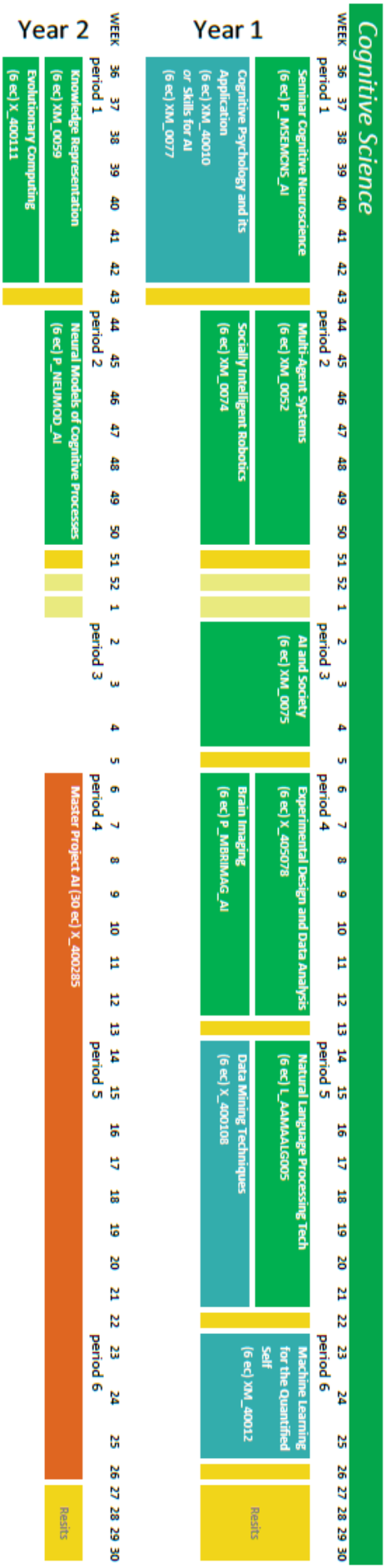
1. Has advanced understanding of Cognitive Science;
2. Has knowledge of the experimental methods and findings from research into the cognitive psychology of behavior;

B. Applying Knowledge and Understanding

1. Can apply empirical methods to improve the understanding of neurobiological processes and phenomena;
2. Is capable of modelling behavior to create opportunities for simulation and further analysis, exploiting the potential and limits of various representations, coupled with studies of computational mechanisms.

APPENDIX 3: OVERVIEW OF THE CURRICULUM




Cognitive Science
Year 1
Year 2
WEEK 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
period 1
period 2
period 3
period 4
period 5
period 6
Seminar Cognitive Neuroscience (6 ec) P_MSEMCNS_AI
Cognitive Psychology and its Application (6 ec) XM_40010 or Skills for AI (6 ec) XM_0077
Multi-Agent Systems (6 ec) XM_0052
Socially Intelligent Robotics (6 ec) XM_0074
AI and Society (6 ec) XM_0075
Experimental Design and Data Analysis (6 ec) X_405078
Brain Imaging (6 ec) P_MBRIMAG_AI
Natural Language Processing Tech (6 ec) L_AAMAALG005
Data Mining Techniques (6 ec) X_400108
Machine Learning for the Quantified Self (6 ec) XM_40012
Resits
Knowledge Representation (6 ec) XM_0059
Evolutionary Computing (6 ec) X_400111
Neural Models of Cognitive Processes (6 ec) P_NEUMOD_AI
Master Project AI (30 ec) X_400285
Resits

APPENDIX 4: PROGRAMME OF THE SITE VISIT

11 December 2019
08.30 – 09.00 Aankomst en welkom
09.00 – 10.00 Intern overleg
10.00 – 10.45 Interview inhoudelijk verantwoordelijken
10.45 – 11.00 Uitloop / Intern overleg
11.00 – 11.45 Interview studenten bachelor
11.45 – 12.00 Uitloop / Intern overleg
12.00 – 12.45 Interview docenten bachelor
12.45 – 13.45 Lunch + inloopspreekuur
13.45 – 14.30 Interview studenten master
14.30 – 14.45 Uitloop / Intern overleg
14.45 – 15.30 Interview docenten master
15.30 – 15.45 Uitloop / Intern overleg
15.45 – 16.30 Interview examencommissie
16.30 – 16.45 Uitloop / Intern overleg
16.45 – 17.30 Interview alumni bachelor/master en werkveldadviesraad

12 December 2019
09.00 – 09.15 Aankomst panel
09.15 – 09.45 Intern overleg
09.45 – 10.45 Interview formeel verantwoordelijken
10.45 – 12.45 Opstellen oordelen
12.45 – 13.00 Mondelinge terugkoppeling
13.00 – 14.00 Lunch + ontwikkelgesprek
14.00 – 14.30 Afronding

APPENDIX 5: THESES AND DOCUMENTS STUDIED BY THE PANEL

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

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

- Self-evaluation Report - Artificial Intelligence and Human-Machine Communication
- Assessment plan BSc artificial Intelligence and assessment matrix
- Assessment forms (new and old) master thesis BSc Artificial Intelligence
- Master thesis guidelines
- KION frame of reference
- Staff overview
- VU Educational Vision
- Teaching and Examination Regulations
- Description of Course components
- NSE Results 2018
- Handbook Quality on education
- Assessment policy Bèta VU
- Exam protocol
- Examination Board Assessment 2018-2019
- Alumni Survey
- Rules and Guidelines by the Board of Examiners
- Annual reports Board of Examiners NSM-IS 2018-2019 (Natural Sciences and Mathematics & Information Sciences)
- Minutes sub-Examination Board Informatics:
  - 22 August 2019
  - 16 September 2019
  - 14 October 2019
  - 18 November 2019
- Annual reports Programme Committee
- Policy document *Kwaliteitszorg Onderwijs Bèta*
- Annual report opleidingscommissie (OLC) 2018-2019 bachelor + master
- Annual programme report 2017-2018
- Data:
  - Influx programme, divided in previous education and gender
  - student drop-out rate
  - Efficiency of the programme
  - Alumni
  - Flow routes from bachelor AI VU to master AI VU
- Assessments dossiers and study materials of courses, including Study guides, assessment, results, and evaluation results of the following courses:
  - Knowledge Representation – year 1 and 2 + Exam with open-ended questions
  - Data Mining Techniques – year 1 + Exam: Two assignments
  - Machine Learning for the Quantified self – year 1 + Exam with open-ended questions
  - Cognitive Psychology and its applications – year +: Exam with open-ended questions
  - Evolutionary Computing – year 2 + Exam: Multiple-choice exam
  - Brain Imaging – year 1 +Exam with open-ended questions
  - Neural Models of Cognitive Processes for AI – year 2 + Exam with open-ended questions, multiple-choice questions and fill in the gap