Bachelor's programme

Artificial Intelligence

Faculty of Science,
University of Amsterdam

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Project number: Q425

CONTENTS

This report was finalized on 3 December 2013.

Report on the bachelor's programme Artificial Intelligence of the Faculty of Science, University of Amsterdam

This report takes the NVAO's Assessment Framework for Limited Programme Assessments as a starting point.

Administrative data regarding the programme

Bachelor's programme Artificial Intelligence

Name of the programme:	Kunstmatige Intelligentie
CROHO number:	56981
Level of the programme:	bachelor's
Orientation of the programme:	academic
Number of credits:	180 EC
Specializations or tracks:	-
Location(s):	Amsterdam
Mode(s) of study:	full-time
Expiration of accreditation:	December 2014

The visit of the assessment committee Artificial Intelligence to the Faculty of Science of the University of Amsterdam took place on June 12 and 13, 2013.

Administrative data regarding the institution

Name of the institution:	University of Amsterdam
Status of the institution:	publicly funded institution
Result institutional quality assurance assessment:	positive

Quantitative data regarding the programme

The required quantitative data regarding the programme are included in Appendix 6.

Composition of the assessment committee

The assessment of the bachelor's programme Artificial Intelligence was part of an assessment cluster. In total, the committee assessed 14 Artificial Intelligence programmes. The committee that assessed all of these programmes consisted of nine members:

- Prof. drs. dr. L.J.M. (Leon) Rothkrantz (chairman), Associate Professor at Delft University of Technology and Professor of Intelligent Sensor-Systems at the Netherlands Defense Academy;
- Prof. em. T. Grant, professor emeritus of Operational ICT & Communications within the Faculty of Military Sciences at the Netherlands Defence Academy (NLDA) and founder/director Retired But Active Researchers (R-BAR);

- Prof. dr. ir. D.K.J. (Dirk) Heylen, Professor of Socially Intelligent Computing, Department of Computer Science at the University of Twente;
- Dr. J. (Jimmy) Troost, Director of Thales Research & Technology, Delft.
- Drs. M.J. den Uyl, MSc, owner of SMRGroup, Senior Researcher and CEO of VicarVision, Sentient and Parabots;
- Prof. dr. L. (Luc) De Raedt is Research Professor at the Lab for Declarative Languages and Artificial Intelligence at the Department of Computer Science of the K.U. Leuven;
- Prof. dr. P. (Patrick) de Causmaecker, Professor of Computer Science at K.U. Leuven, Kortrijk Campus, Belgium, guest professor at KaHo St.-Lieven, Ghent, Belgium, and Head of the CODes research group, coordinator of the interdisciplinary research team itec at K.U. Leuven, Kortrijk Campus;
- R.H.M. (Rik) Claessens, BSc, student of the master's programme Artificial Intelligence of Maastricht University;
- Y. (Yfke) Dulek, student of the bachelor's programme Artificial Intelligence of Utrecht University.

For each site visit a subcommittee was set up, taking into account any potential conflict of interests, expertise and availability. To ensure consistency within the cluster the chairman, Prof. dr. drs. Leon Rothkranz, attended all visits.

The coordinator of the cluster visits for Artificial Intelligence was drs. Hans Wilbrink, QANU staff member. He was also the project leader for the visit to Utrecht University, Radboud University Nijmegen and the VU University Amsterdam. During the other site visits, drs. Titia Buising was the project leader. To ensure continuity, both project leaders frequently held consultations. The coordinator was also present at the final meeting of all visits within the cluster.

The committee that assessed the bachelor's programme Artificial Intelligence consisted of:

- Prof. drs. dr. L.J.M. (Leon) Rothkrantz (chairman), Associate Professor at Delft University of Technology and Professor of Intelligent Sensor-Systems at the Netherlands Defense Academy;
- Prof. em. T. Grant, professor emeritus of Operational ICT & Communications within the Faculty of Military Sciences at the Netherlands Defence Academy (NLDA) and founder/director Retired But Active Researchers (R-BAR);
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- Y. (Yfke) Dulek, student of the bachelor's programme Artificial Intelligence at Utrecht University.

The University of Amsterdam board and the Accreditation Organisation of the Netherlands and Flanders (NVAO) approved the composition of the assessment committee. Appendix 1 contains the CVs of the members of the committee.

Working method of the assessment committee

Preparation
To prepare for the site visits, the coordinator first checked the quality and completeness of the self-evaluation reports produced by the programmes and forwarded them to the participating committee members. They read the reports and formulated questions about their contents. The coordinator collected the questions and arranged them according to topic and/or interview partner. As well as the self-evaluation reports, the committee members read a total of 15 theses for each programme. The theses were randomly chosen from a list of graduates of the last two completed academic years, while covering a range of grades.

On 14 March 2013 the Artificial Intelligence committee held a preliminary meeting. During this meeting, the committee was formally installed, and its tasks and working methods were discussed. The proposed Domain-Specific Reference Framework for Artificial Intelligence was also accepted (see appendix 3).

Site visit
The coordinator prepared timetables for the visit in consultation with the committee chair and the participating institutions. The timetable for the visit for the bachelor's programme of University of Amsterdam is included as appendix 2.

Prior to the visit the committee asked the programmes to select representative interview partners. The underlying idea was to exchange thoughts with students, lecturers and supervisors of all participating programmes. Well in advance of the visit, the committee received a list of the selected interview partners for its approval. During the visit, committee members spoke to faculty and programme management staff, students, lecturers, members of the programme and examination committees, and alumni.

During the visit, the committee examined material it had requested and gave students and lecturers the opportunity – outside the set interviews – to talk informally to the committee during a consultation hour. No requests were received for this option.

The committee used the final part of the visit for an internal meeting to discuss the findings. The visit was concluded with a public oral presentation of the preliminary impressions and general observations by the chair.

Decision rules
In accordance with the NVAO's Assessment framework for limited programme assessments (6 December 2010), the committee used the following definitions for the assessment of both the standards and the programme as a whole:

- **Generic quality:** the quality that can reasonably be expected in an international perspective from a higher education bachelor's or master's programme.
- **Unsatisfactory:** the programme does not meet the current generic quality standards and shows serious shortcomings in several areas.
- **Satisfactory:** the programme meets the current generic quality standards and shows an acceptable level across its entire spectrum.
- **Good:** the programme systematically surpasses the current generic quality standards across its entire spectrum.

- **Excellent:** the programme systematically well surpasses the current generic quality standards across its entire spectrum and is regarded as an (inter)national example.

The default assessment is 'satisfactory', i.e. the programme complies adequately with the criteria.

Report
After the site visit, the project leader wrote a draft report based on the findings of the committee. It was first read and commented upon by the committee members. Then it was sent to the Faculty to check for factual irregularities. Any comments from the Faculty were discussed with the chair of the assessment committee and, if necessary, with the other committee members. After that, the report was finalised.

Summary judgement regarding the quality of the bachelor's programme Artificial Intelligence

This report reflects the findings and considerations of the committee on the bachelor's programme in Artificial Intelligence, University of Amsterdam. The evaluation is based on information provided in the self-evaluation report and the selected theses, additional documentation and interviews conducted during the site visit. The committee noted both positive aspects and some that could be improved. Taking those aspects into consideration, it decided that the programme fulfils the requirements of the criteria set by NVAO, which are the conditions for accreditation.

Standard 1: Intended learning outcomes
The committee assesses Standard 1 as **good**. The committee compared the programme to the domain-specific reference framework. It concludes that the framework gives an adequate picture of the AI domain and the basic knowledge and skills that graduates need to acquire. The intended learning outcomes of the bachelor's programme are in line with the KION framework. The programme chooses a more fundamental and technical approach to AI by focusing on applied mathematics, programming languages and software tools. The committee is very pleased to note that the programme also has a broad perspective and covers linguistic and cognitive aspects as well. It believes that this combination of a technical and at the same time broad approach to AI is quite unique.

The committee considers the intended learning outcomes to be adequately defined. It finds them suited to the objectives and appropriate for the level and orientation of an international bachelor's programme. Also, the relation with the Dublin descriptors is evident in the intended learning outcomes.

Standard 2: Programme
The committee assesses Standard 2 as **good**. The committee concludes that the programme, the personnel and the programme-specific facilities enable the students to realise the intended learning outcomes. It noted that all intended learning outcomes are cross-matched to the different components of the programme in the self-evaluation report. It is of the opinion that the learning goals as described in the course descriptions could be more uniform.

The committee concludes that the more fundamental and technical approach to AI (see standard 1) is very evident in the programme. It is reflected in the mathematical and programming courses. The committee is also very positive about the fact that in addition to the fundamental and technical approach, the broader and interdisciplinary character of the field of AI is reflected in the programme. Because students follow mandatory courses in each trajectory, they get a broad overview of the field, including the linguistic and cognitive aspects of AI.

The committee is also of the opinion that the curriculum is very coherent and that professional and academic skills are very well addressed. The five trajectories and the different projects guarantee the coherence of the programme. Academic and professional skills are integrated in the courses. The projects and the tutoring programme play an important role in the realisation of these skills.

The first semester of the third year offers student the opportunity to study abroad or to pursue an internship. The committee appreciates the opportunities the programme gives

students to do so. Also, the projects enable the students to get into contact with the professional field.

The committee is impressed by the tutoring system. Especially the deployment of senior students and the low threshold of contact for students is appreciated by the committee. The tutoring system is also greatly valued by the students. The committee concludes that the intake procedure and study load are adequate. The completion rates are relatively low, however. The committee expects that the introduction of the binding study advice will improve these rates. It also advises the programme to implement the intake interviews.

The programme is based on the principles of 'learning by doing' and 'active learning'. The committee is of the opinion that the educational format is consistently implemented, with an important role for the projects in each semester. Students also appreciate the projects and confirmed that they learn to apply theory in practice. The number of contact hours is adequate.

The committee concludes that the staff consists of sufficient numbers of motivated and competent lecturers. It is of the opinion that the BKO training should be intensified.

The committee confirms that an adequate quality assurance system is in place. It especially appreciates the tutor feedback groups, which ensure that courses can be adapted immediately.

Standard 3: Assessment and achieved learning outcomes
The committee assesses Standard 3 as **good**. The committee concludes that the programme has an adequate assessment system in place. The different components of the programme are assessed in different ways, with a well-balanced mix between exams and practical assignments. Students are satisfied with the assessment in general. The committee appreciates the use of midterm exams. This not only ensures that students study throughout the whole course, it also gives the lecturers an overview of the students' level and the need to pay more attention to some topics. It is of the opinion that the Board of Examiners has sufficient insight into the quality of the assessments and takes adequate measures as necessary. The committee advises the programme however to urgently develop and implement an assessment policy. It recommends that the Board regularly assess a selection of exams, projects and graduation projects. It also advises the programme to swiftly fill the vacancy on the Board.

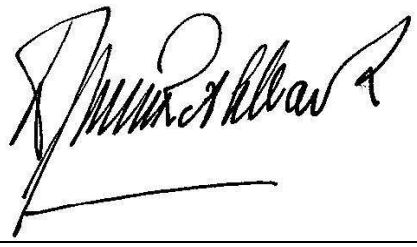
The committee concludes that the bachelor students acquire a high final level by the end of the programme. This is confirmed by the theses it evaluated. The committee realises that the assessment policy has not yet been fully implemented. It is impressed, however, by the quality of the studied theses and therefore assesses this standard as good. In addition to that, the committee noticed that students have no problems entering master's programmes of well-known European Universities.

Bachelor's programme Artificial Intelligence
The committee assessed the standards from the Assessment framework for limited programme assessments in the following way:

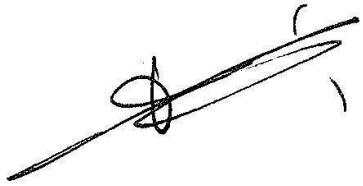
Standard 1: Intended learning outcomes	**good**
Standard 2: Teaching-learning environment	**good**
Standard 3: Assessment and achieved learning outcomes	**good**
General conclusion	**good**

The chair and the secretary of the committee hereby declare that all members of the committee have studied this report and that they agree with the judgements laid down in it. They confirm that the assessment has been conducted in accordance with the demands relating to independence.

Date: 3 December 2013.



Prof. drs. dr. L.J.M. Rothkrantz



drs. T. Buising

Description of the standards from the Assessment framework for limited programme assessments

Standard 1: Intended learning outcomes
The intended learning outcomes of the programme have been concretised with regard to content, level and orientation; they meet international requirements.

Explanation:
As for level and orientation (bachelor's or master's; professional or academic), the intended learning outcomes fit into the Dutch qualifications framework. In addition, they tie in with the international perspective of the requirements currently set by the professional field and the discipline with regard to the contents of the programme.

Findings

This first standard deals with the domain-specific reference framework (1.1), the profile and orientation of the programme (1.2) and the intended learning outcomes (1.3).

1.1 Domain-specific reference framework
Traditionally, the field of artificial intelligence (AI) is concerned with the study of cognitive processes that play a role in human perception, reasoning and action, and building intelligent systems for human modelling. This implies that the field of artificial intelligence is closely related to other disciplines such as computer science, mathematics, psychology, linguistics and philosophy. In 2006, the collaborative artificial intelligence programmes in the Netherlands (KION) delivered a domain-specific reference framework (hereafter: the framework) which presented the content and learning outcomes of the bachelor's and master's programmes in artificial intelligence. The framework forms the common basis for all programmes in artificial intelligence and for specifying the intended learning outcomes of the different programmes at various universities participating in this cluster visitation. The committee noted that in general all assessed programmes meet the intended learning outcomes described in the framework to a greater or lesser degree. For example, all programmes pay sufficient attention to the basic knowledge and skills of artificial intelligence. However, there is a variation in the extent to which the different programmes offer students deepening or broadening of the field. In addition, almost all programmes take the liberty of highlighting certain topics and adding parts of new disciplines. The committee noted that some misunderstanding arises because the different programmes give different interpretations to the concept of artificial intelligence. The concept of 'intelligence' as used in the KION framework can be interpreted in different ways. A clear operational definition, or description, is desirable according to the committee. Furthermore, the distinction in the framework between the intended learning outcomes at the bachelor's and master's level is not always clear. The gradual / incremental aspect of knowledge and skills could be better elaborated in the framework. This could also prevent the divergence of the AI programmes on this matter.

For the University of Amsterdam's bachelor's programme Artificial Intelligence, the committee concludes that it matches the KION framework. It appreciates that the programme covers multiple aspects from the framework, like more technical aspects as well as linguistic and cognitive aspects of AI.

1.2 Profile and orientation
The self-evaluation report states that the bachelor's programme focuses on building artificial intelligence systems by using the foundations of the various subdisciplines. The programme is interdisciplinary and covers the five key areas of artificial intelligence: cognitive psychology,

intelligent systems, knowledge technology, language and speech, and logic. The programme is set up in such a way that after a broad introduction to the field, students specialise in one of these areas. According to the self-evaluation report, the technical profile of the programme prepares students for a professional career as well as for a research career and graduates of the bachelor's programme are qualified for the same jobs as graduates from a bachelor's programme in computer science.

According to the self-evaluation report, the programme distinguishes itself from other bachelor's programmes in the field by offering a fundamental and technical profile and basic skills. The fundamental and technical profile is visible in the focus on applied mathematics, programming languages and software tools. The programme also offers students a broad perspective on AI, by covering the previously mentioned five key areas of AI. These areas are translated into five mandatory trajectories, which all students follow.

During the site visit, the committee discussed the profile of the programme with the management. It became clear that even though the programme has a technical profile, it also offers students a broad perspective on AI, by covering the different subdisciplines. In addition, the management confirmed that the programme also prepares students for a professional career.

The committee concludes that the programme has an academic orientation. This is reflected in the thesis, which addresses the whole research cycle. In addition, the reports that students write in the projects have the form of a conference paper. The academic orientation is also visible in the attention paid to academic skills. The committee is of the opinion that the programme is quite ambitious, offering students two different approaches to AI: a technical approach and a more broad approach. The committee also appreciates the fact that all students have to follow the five trajectories. This gives students an elaborate overview of the field and prepares students for further specialisation in one of those fields. The committee noticed that graduates have no problems entering international master's programmes.

1.3 Intended learning outcomes

The intended learning outcomes of the programme (Appendix 4) reflect its technical profile. Graduates are expected to have acquired knowledge and proficiency in the field of mathematics and logic and should be able to work with mathematical and formal models. The intended learning outcomes also reflect the qualifications mentioned in the KION framework. Graduates are expected to have gained knowledge of the methodology of the classical approach to artificial intelligence and to have experience in applying it to the design of knowledge systems and the construction of computational models. In addition, the intended learning outcomes also reflect the broader perspective of the programme. Graduates are expected to have acquired knowledge of the most important philosophical theories in the field of knowledge and cognition and in one of the five subdisciplines (knowledge technology, language and speech, intelligent systems, computational psychology, and logic). The committee concludes that the learning outcomes are of an academic nature and level. It is also of the opinion that they are in line with the KION framework.

The committee verified the relationship between the learning outcomes and the Dublin descriptors, which are considered to be general, internationally accepted descriptions of a bachelor's programme. The self-evaluation report described this match. The committee concludes that all Dublin descriptors are reflected in the intended learning outcomes.

Considerations

The committee compared the programme to the domain-specific reference framework. It concludes that the framework gives an adequate picture of the AI domain and the basic knowledge and skills that graduates need to acquire. The intended learning outcomes of the bachelor's programme are in line with the KION framework. The programme chooses a more fundamental and technical approach to AI by focusing on applied mathematics, programming languages and software tools. The committee is very pleased to note that the programme also has a broad perspective and covers linguistic and cognitive aspects as well. It believes that this combination of a technical and at the same time broad approach to AI is quite unique.

The committee considers the intended learning outcomes to be adequately defined. It finds them suited to the objectives and appropriate for the level and orientation of an international bachelor's programme. Also, the relation with the Dublin descriptors is evident in the intended learning outcomes.

Conclusion

Bachelor's programme Artificial Intelligence: the committee assesses Standard 1 as **good**.

Standard 2: Teaching-learning environment
The curriculum, staff and programme-specific services and facilities enable the incoming students to achieve the intended learning outcomes.

Explanation:
The contents and structure of the curriculum enable the students admitted to achieve the intended learning outcomes. The quality of the staff and of the programme-specific services and facilities is essential to that end. Curriculum, staff, services and facilities constitute a coherent teaching-learning environment for the students.

Findings

In this standard the design and coherence of the curriculum of the bachelor's programme Artificial Intelligence are examined (2.1). In addition, the learning outcomes (2.2), educational concept (2.3), services provided to students (2.4), intake and study progress (2.5), teaching personnel (2.6) and programme-specific internal quality assurance (2.7) are discussed.

2.1 Curriculum
The bachelor's programme is a three-year programme, consisting of 180 EC. It follows the 8-8-4 system: each semester consists of two eight-week lecture periods and one four-week block for projects. During the projects students apply the learned knowledge in assignments. The first semester of the third year consists of electives (30 EC). The last semester of the third year consists of two courses and the bachelor's thesis (18 EC).

The first year of the programme offers an orientation to all five trajectories (cognitive psychology, intelligent systems, knowledge technology, language and speech, and logic). It gives students an overview of the field of artificial intelligence and the content that will be covered in the next two years. The students follow courses such as *Introduction to Artificial Intelligence, Introduction to Cognitive Psychology* and *Language Theory and Language Processing*. The before mentioned focus on applied mathematics and programming is reflected in first-year courses such as *Logic Programming and Search*, *Object-oriented Programming*, *Linear Algebra* and the *Web-programming and Databases* project. During the first year students carry out two projects.

The second year introduces students to more advanced knowledge. They attend obligatory courses such as *Calculus and Statistics, Machine Learning, Brain and Cognition* and *Natural language models and Interfaces*. The second year also includes two projects, which demand more autonomy from students.

The first semester of the third year (in total 30 EC) is flexible and offers students the chance to specialise in their direction of interest. Students can follow specialisation courses in one of the five trajectories. Or they can opt for a minor from other UvA programmes or an internship. Study abroad is also possible. Students can also conduct an individual project (for example, in relation to the international RoboCup competitions). The individual programmes for this semester have to be approved by the Board of Examiners. In the second semester of the third year, students take two mandatory courses. Their main priority during the last semester is the bachelor's thesis project (18 EC).

The committee concludes that the before mentioned technical approach to AI (see standard 1) is evident throughout the entire programme. During the programme, students follow courses such as *Linear Algebra*, *Calculus and Statistics*, *Logic Programming and Search*, *Computer Systems* and *Data Structures*. In addition, it concludes that the programme also offers students a broad perspective on AI, ensuring that all trajectories are sufficiently covered in the programme, with at least two mandatory courses per trajectory. The committee is very enthusiastic about the fact

that students not only learn relevant technical aspects but also learn linguistic and cognitive aspects of AI. This gives students a broad perspective on the field of AI.

Academic and professional skills
The self-evaluation report states that academic and professional skills are taught in the different projects and in the courses. The first-year projects are more fixed and closely supervised. Students are guided through the problem-solving process by weekly assignments and lectures. In the second year, students have more independence in choosing and executing projects. For the second-year project *Machine Learning and Decision-making*, students can choose their own project. For the last project in the second year, students can choose a project from a list or propose their own project. In the projects, skills such as project work, cooperation, writing, presenting, demonstrating leadership, critically appraising and arguing, and showing initiative are addressed. In the first project, *Web-programming and Databases,* students build a dynamic website and a relational database. The second-year project *Machine Learning and Decision-making* is conducted for an external client, where the task is to tackle a data mining problem in a practical context. All projects are concluded with a report and a presentation. Students are expected to work fulltime on their projects. The projects stress the application in a practical context and the courses the theoretical foundation.

The academic and professional skills are also addressed in the courses. The programme management recently developed learning guidelines regarding academic skills (in the ICTO project Vaardig): academic attitude, research skills, academic writing skills, presentation skills, and project skills. A skills matrix describes the learning guidelines and how and in which course the skills are assessed. In the course descriptions the skills addressed are explicitly mentioned. They are assessed during the courses by assignments. These assignments are part of the practical part of the specific course. As indicated in section 3.1, the assessment of all courses consists of a practical part. In the third year, for example, the mandatory *Philosophy and AI* course is offered. This course provides students with a basic understanding of philosophy so they can participate in debates and discussions about the field. Skills like critical argumentation, argumentative writing, presenting and critical reflection are practised and assessed in this course. In the tutoring programme (see also section 2.4), academic and professional skills are also addressed. These skills are also trained in the individual graduation project, when students execute the complete academic research cycle.

During the site visit it became clear that students value the experience of doing projects for external organisations, even though the client may not be very informed about artificial intelligence, which may make the project hard. Also, the alumni the committee spoke with during the site visit were positive about the projects. The projects prepared them for the professional field, with regard to skills such as cooperation, project work, presentation skills and general knowledge about the professional field (working in it).

Labour market
The self-evaluation report states that the projects play an important role in preparing students for working in the professional field. During the projects professional skills such as cooperation, writing and presenting are trained. Also during the second year, students are motivated to work on projects for external organisations. Students then learn to cooperate with a client and to present their results not only to academic specialists but also to clients. As mentioned before, in the first semester of the third year, students can opt for an internship. Students are also prepared for future careers in the tutoring programme (see section 2.4).

In conclusion, the committee feels that the development of academic and professional skills is

very well addressed within the programme. It especially appreciates the academic learning guidelines that have been developed in the ICTO project Vaardig. and their implementation in the regular courses. The projects and the tutoring programme (see section 2.4) also play an important role in this respect. The committee also values the projects. The projects offer students ample experience in applying the learned theory. In addition to that, the projects become more complex during the programme. In general, the committee is very positive about the structure, content and organisation of the programme. The programme shows a good balance between courses focussed on theoretical foundation and projects focussed on application aspects. It is very coherent, due to the trajectories and the projects. The trajectories ensure that all students acquire a broad knowledge of the field of AI. In the projects theory and practice are integrated. The committee also appreciates the entry requirements that are set for the different courses. This contributes to the coherence of the programme. The committee also reviewed the teaching materials used in the programme and concludes that relevant literature is studied.

2.2 Learning outcomes

The committee evaluated whether and how the intended learning outcomes formulated by the programme have been translated in the curriculum. It studied the correspondence between the learning outcomes and the curriculum, as presented in the self-evaluation report. In addition, it gained insight by examining the study guide, course books and the literature. It concluded that the intended learning outcomes are cross-matched to the different components of the programme. In the course descriptions, the learning goals are described for each course. The committee noted that the descriptions of the learning goals differ quite a lot from each other. During the site visit, the lecturers agreed with this finding but also indicated that as a result of the BKO training (Basic Teaching Qualification), more uniformity will be realised in the near future.

The committee recommends that the programme review the learning goals of all courses and their formulation.

2.3 Educational concept

The self-evaluation report states 'learning by doing' and 'active learning' as the programmes main educational principles. According to the self-evaluation report, lecturers continuously seek the integration of theory and the application of technical skills. The programme wants to provide students with a balanced mix of knowledge acquisition and application. This means that during the programme skills and knowledge are practised and applied in projects and courses. The programme explicitly distinguishes courses and projects. Courses consist of lectures, supported by a textbook or syllabus and accompanied by practical and applied work (during lab assignments and tutorials). The projects focus on research and applied problems. In the projects students integrate and apply the knowledge learned during the courses. All projects are executed in groups. During the site visit, alumni confirmed and appreciated the practical aspects of the courses.

The number of contact hours decreases over the three years, from 20.4 hours per week in the first year to 19.6 and 10.5 in the second and third years, respectively.

During the site visit, the committee discussed the educational principles with the lecturers. It was pleased to note that they are very aware of the educational principles. Students are motivated to participate actively in classes by giving assignments, asking questions and using studio classrooms (in these classrooms students have to turn away from their computer screens to see the lecturer).

Even though the educational principles are not elaborated on in the self-evaluation report, the committee is of the opinion that the educational format suits the bachelor's programme and is very well implemented. Lecturers are consciously engaged in connecting theory and practice during their lectures. It also concludes that the number of contact hours is adequate. The site visit revealed that students are satisfied with the educational format.

2.4 Services provided to students

The committee examined the supervision and guidance provided to the students. It feels that the services provided to students (both guidance and facilities) are more than sufficient and enable them to achieve the learning outcomes of the programme.

In 2011 the programme implemented the *Tutoring programme BSC KI 1 + 2*. In this tutoring programme students are divided into groups that remain together during the first two years of the programme. In the first year, the tutor groups meet on a weekly basis. In the second year, the groups meet every two weeks. A tutor, a senior student, guides each group. The tutors lead the meetings and have individual meetings with students at least once per semester. Tutors are also involved as a teaching assistant in one of the courses the students follow. A tutor is assigned for a period of six months. In the first year the guidance from the tutor groups is focused on learning to study, finding resources and training academic skills. For the last aspect, students use a portfolio for collecting assignments, assessment and reflection regarding academic skills. In the future a digital portfolio will be introduced. In the second year tutor meetings address issues like career planning, networking and orientation of the academic and professional world. The tutoring programme is mandatory, and students have to complete the first year of the tutoring programme before entering the second year. Also, the second year tutoring programme has to be completed before starting the graduation project.

A study adviser is available for students. He or she monitors the students' progress and meets with every student twice in the first year. In addition, students with a study delay are invited for a talk. The study adviser provides first-year students with a study advice after six months and at the end of the first year. During the site visit, the students confirmed this. It was also made clear that the students are quite satisfied with the tutoring programme. They appreciate the fact that they can approach their tutors for nearly everything and that they have quite a lot of contact with them. In addition, the tutors are in close contact with the lecturers and can easily discuss issues that might arise. The tutoring programme stimulates contacts with fellow students.

In addition to the regular lecture rooms, small conference rooms for groups of students, and computer facilities with dedicated software (such as MatLab, Prolog and Protégé), the programme has robotics facilities. These include a robotic arm (UMI-RTX), AIBO robots, NAO robots and AR-drone quadrocopters. Students can use the robots for projects. During the site visit students remarked that they value the facilities of the programme. The atmosphere is pleasant, and there are ample computers, study rooms and sockets for laptops available.

Excellent students are invited to join the honours programme (taking an extra 30 EC). This consists of two research projects, electives and an extended graduation project. These students also have to graduate in three years. The committee noted that most students participating in the honours programme do not finish it. The self-evaluation report states that the main reason for stopping is that students want to study longer than three years. The committee discussed this during the site visit with the students. It became clear that the courses taken in the honours programme can also be used as electives. The students revealed that the honours programme is promoted as a programme that does not have to be finished. The committee also discussed this with the management. It became clear that the relevance of the honours programme will be

promoted more in the near future and also be made more visible for students. The committee supports this and recommends that the programme explicitly label the honours programme on the bachelor's diploma.

The committee is of the opinion that the programme offers good guidance and facilities to students. It is impressed by the tutoring programme and the easy contact between tutors and students. The tutor-system helps to create a community between students, where students can find each other for help. The small scale of the programme also leads to an informal atmosphere.

2.5 Student intake and study progress

Student intake
The committee concludes that the programme applies adequate admission criteria. Students can enrol in the programme with a vwo diploma (with Mathematics A or B). The self-evaluation report revealed that the number of enrolling students has increased over the last years to 49 students in the 2012-2013 academic year. According to the self-evaluation report, this increase is due to the new building and the Science Park ambiance. The number of female students enrolling in the programme has also increased, to 15% in the 2011–2012 academic year.

Study load
The committee confirmed that the programme is feasible, based on the information provided and the interviews it conducted with students, lecturers and alumni. In addition, it noted that measures are taken when parts of the programme are discovered to be impeding the students' study progress. The self-evaluation report states that the 8-8-4 system creates a clear and consistent structure, with an even spread of the workload. Using a fixed structure for examinations also helps spread the workload. Each course consists of two interim exams: in the fourth and in the eight week. Coursework also forms part of the assessment. During the site visit students indicated that they study 40 hours per week on average.

The self-evaluation report reveals that the programme uses entry requirements for courses, to ensure that in each course the knowledge taught in earlier courses can be assumed and build upon. During the site visit the committee discussed this system of entry requirements with students. They indicated that in general they support this system. When it is not possible to follow a certain course (because of a failed entry course), students can take electives. Students also indicated that it is rather tough that the first two courses of the programme are also required courses for other programmes. Students remarked that these two courses are quite difficult, and in addition they have to get used to studying at university level. The committee also appreciates the entry requirements that are set for the different courses. This contributes to the coherence of the programme.

Completion rates
The self-evaluation report remarks that the completion rates vary widely and are quite low in general. A slight increase has been noted. From the 2006–2007 cohort 33% of the students completed the programme after three years, 50% after four years and 58% after five years. From the 2007–2008 cohort 50% completed the programme after three years and 67% after four years. The self-evaluation report remarks that the implementation of the above-mentioned tutor programme is intended to increase the completion rates to above 70% after four years.

The percentage of students dropping out of the programme is variable and relatively high. For

example, from the 2007–2008 cohort 54% dropped out after the first year, from the 2008–2009 cohort 25% dropped out after the first year. The self-evaluation report makes reference to the exit interviews held with students. The main reasons for dropping out are the difficulty of the programme, the difference between what the programme offers and what students expect, and the challenges of studying in a big city. The programme expects the implemented tutoring programme to positively influence the dropout rates. It also expects that the strict rules regarding exams and resits will influence the rates. In the 2014-2015 academic year, a binding study advice (BSA) will be implemented in the first year of the bachelor's programme. In September 2013 an urgent study advice will be introduced, to assess the BSA readiness of the programme. The programme also expects the introduction of the BSA to influence the dropout rates. The self-evaluation report states that intake interviews with enrolling students are being considered, to check the student's motivation and to manage their expectations.

The committee is of the opinion that the completion rates are rather low. It expects that the introduction of the tutoring programme and the binding study advice will contribute to an improvement of these rates. It recommends that the programme introduces the intake interviews mentioned in the self-evaluation report. This will give enrolling students a realistic overview of the programme and its expectations.

2.6 Staff

There are 26 lecturers involved in the bachelor's programme, with a total amount of 3.5 FTE in the 2011–2012 academic year. The committee ascertained that there is currently an acceptable staff: student ratio of 1:25. In addition, it understood from students during the site visit that lecturers are accessible and approachable (in person or by email).

The committee studied an overview of the core staff members involved in the programme, their position, level of education, and expertise. It recognises the staff's good scientific quality, (inter)national academic reputations, and teaching experience. According to the self-evaluation report, all staff members are involved in research and education. The core of the teaching staff consists of one professor, one associate professor, seven assistant professors and one lecturer. The core team is responsible for administering the programme and teaches most of the key courses in the programme. In addition, two professors, three associate professors, six assistant professors, four lecturers, one PhD student and nine teaching assistants are involved in the programme. Most staff members spend 60% of their time on research and 40% on education. Of the 26 lecturers involved in the programme, 89% have a doctorate and 99% have a master's degree.

The self-evaluation report mentions that 36% of the lecturers has a BKO certificate. The programme expects all lecturers to have acquired their BKO certificate within three years. The committee urges the programme to ensure this happens, since it is of the opinion that the number of BKO registrations is quite low.

The site visit revealed that the team of core lecturers plays an important part in the quality assurance of the programme. The team meets on a monthly basis and discusses the content and coherence of the programme. The site visit also revealed that students are positive, in general, about the didactical skills of their lecturers. In addition to that some lecturers have an open door policy, others prefer students to make an appointment by email. The students appreciate the small scale of the programme. Students are also positive about the teaching assistants, who are considered accommodating and helpful in connecting the different courses and disciplines, for example. During the site visit, the committee talked with the management about the relation between educational tasks and promotions. It became clear that educational

tasks do not influence the chances of getting a promotion. Promotions are primarily based on research qualities and the outcomes. Management remarked that there should be a balance between research and teaching activities. The committee concludes however that teaching activities are still underestimated in the career profiles.

2.7 Programme-specific quality assurance
The committee ascertained the extent to which students and lecturers are involved and heard in the evaluation and improvement of the quality of the teaching. All courses and projects are evaluated, and the results are discussed by the programme committee. The latter is responsible for safeguarding the quality of the programme. It consists of five students and five lecturers. In addition, a so-called tutor feedback group evaluates all courses. This is a group of students that discusses the course-related issues with the lecturer, halfway during the course and after the course has been completed. A lecturer and a student also attend these meetings from the programme committee. Every other year, evaluations of a whole year are held (for each year of the programme). During the site visit it became clear that every three years the whole programme is evaluated.

The committee is of the opinion that the design and functioning of the quality assurance system are adequate. During the site visit both lecturers and students stated that they are involved and their opinions are heard in reference to the quality of the teaching. Students also appreciate the tutor feedback groups and indicated that lecturers are open to suggestions for improving the courses, even halfway through it. The committee also had the opportunity during the site visit to talk to members of the programme committee. It noted that full professors do not participate in it. It also became clear that the programme committee is quite reactive. It reviews the evaluations and gives students feedback regarding their comments on the evaluation forms. The committee realises that the programme is quite small in scale, which makes discussions between the director, lecturers and programme committee easy. This also creates an informal atmosphere, from which students and lecturers can benefit. The committee recommends that the programme committee write an annual plan and an annual report. This will provide more structural information for the programme management.

During the site visit, the committee also discussed the imminent merger with VU University Amsterdam. It became clear that the discussions about structure and organisation are held at the level of the Boards of the universities. Despite the unknown outcome of these discussions, the lecturers of the AI programmes from both universities are already working together and discussing the content of their programmes. The management remarked that the more technical approach to AI at the University of Amsterdam can complement the human-machine focus of VU University.

Improvements in response to the previous site visit
In the self-evaluation report, no reference is made to the recommendations of the previous assessment committee. Nevertheless, the committee notes that the programme has implemented quite a few changes in the last few years. For example, the tutoring programme has been introduced, academic skills have a more prominent place in the programme, and the number of EC for the graduation project has increased (from 6 to 18 EC).

The committee concludes that the programme pays sufficient attention to measures for improvement. It ascertained that the programme properly monitors and checks the quality of the education provided.

Considerations

The committee concludes that the programme, the personnel and the programme-specific facilities enable the students to realise the intended learning outcomes. It noted that all intended learning outcomes are cross-matched to the different components of the programme in the self-evaluation report. It is of the opinion that the learning goals as described in the course descriptions could be more uniform.

The committee concludes that the more fundamental and technical approach to AI (see standard 1) is very evident in the programme. It is reflected in the mathematical and programming courses. The committee is also very positive about the fact that in addition to the fundamental and technical approach, the broader and interdisciplinary character of the field of AI is reflected in the programme. Because students follow mandatory courses in each trajectory, they get a broad overview of the field, including the linguistic and cognitive aspects of AI.

The committee is also of the opinion that the curriculum is very coherent and that professional and academic skills are very well addressed. The five trajectories and the different projects guarantee the coherence of the programme. Academic and professional skills are integrated in the courses. The projects and the tutoring programme play an important role in the realisation of these skills.

The first semester of the third year offers student the opportunity to study abroad or to pursue an internship. The committee appreciates the opportunities the programme gives students to do so. Also, the projects enable the students to get into contact with the professional field.

The committee is impressed by the tutoring system. Especially the deployment of senior students and the low threshold of contact for students are appreciated by the committee. The tutoring system is also greatly valued by the students. The committee concludes that the intake procedure and study load are adequate. The completion rates are relatively low, however. The committee expects that the introduction of the binding study advice will improve these rates. It also advises the programme to implement the intake interviews.

The programme is based on the principles of 'learning by doing' and 'active learning'. The committee is of the opinion that the educational format is consistently implemented, with an important role for the projects in each semester. Students also appreciate the projects and confirmed that they learn to apply theory in practice. The number of contact hours is adequate.

The committee concludes that the staff consists of sufficient numbers of motivated and competent lecturers. It is of the opinion that the BKO training should be intensified.

The committee confirms that an adequate quality assurance system is in place. It especially appreciates the tutor feedback groups, which ensure that courses can be adapted immediately.

Conclusion

Bachelor's programme Artificial Intelligence: the committee assesses Standard 2 as **good**.

Standard 3: Assessment and achieved learning outcomes
The programme has an adequate assessment system in place and demonstrates that the intended learning outcomes are achieved.

Explanation:
The level achieved is demonstrated by interim and final tests, final projects and the performance of graduates in actual practice or in post-graduate programmes. The tests and assessments are valid, reliable and transparent to the students.

Findings

In this standard the findings regarding the assessment methods in the bachelor's programme are given (3.1), and then the question is addressed of whether students actually realize the intended learning outcomes (3.2).

3.1 Assessment method
The committee explored whether the programme has an adequate system of assessment. It examined the functioning of the Board of Examiners, the procedures involved with assessment, the forms of assessment, and the thesis procedure. It confirmed that there is an adequate system in place.

Examination Board
According to the self-evaluation report, the Board of Examiners is responsible for safeguarding the quality of the diploma, based on all courses and projects (of both the bachelor's and master's programme Artificial Intelligence). In addition, the Board is responsible for processing the requests for exceptions, the execution of the university's examination policy, acting as a first judge of appeal, processing cases of fraud and plagiarism and extraneous admissions. Since 2011, it has been drawing up an annual report. The self-evaluation report reveals that currently a department-wide examination policy is being implemented. Part of the implementation is refining learning objectives for each course, setting guidelines for creating exams and criteria for assessing projects and skills, and making assessment matrices and criteria for exams. According to the self-evaluation report, the Board of Examiners relies on student's complaints and course evaluations to measure the quality of exams. It is not involved in evaluating the graduation projects of the bachelor's programme. In 2013, it wants to replace the current (rather general) marking criteria of the graduation project with a new, more explicit marking system (and scoring form).

During the site visit the committee spoke with representatives of the Board of Examiners about its role in monitoring the quality of assessment, and it became clear that the Board is currently understaffed. The committee noted that full professors do not participate on it. In addition, it finds the board quite reactive and the Board does not actively monitor the assessment of graduation projects by, for example, reviewing already assessed theses. A standard form is used for the assessment of theses. The Board members confirmed that the assessment policy is currently being developed and implemented. It also became clear that peer review of assessments is not a common practice in the programme. The Board members revealed that the BKO certificate (see also section 2.6) plays an important role in the implementation of the assessment policy. Lecturers who have attained their BKO certificate are less hesitant about defining learning goals and assessment criteria, for example.

The committee urges the programme to fill the current vacancy (preferably with a full professor). It also urges the Board to implement the examination policy and to regularly review a selection of exams, projects and graduation projects.

Assessment policy, process and forms
The self-evaluation report states that, as a rule, all courses of the bachelor's programme have two exams (the mid-term exam in the fourth week and the final exam in the eight week). They form the examination of the theoretical part of the course. In addition, all courses use lab assignments or homework to assess the practical part of the course. The final grade is determined by weighing both parts. The weighing takes into account that at least 75% of the grade is based on the student's individual input. This implies that the theoretical part accounts for at least 50% of the grade.

Most exams consist of written exams with open questions. All exams are individual. The lab assignments can be done in small groups. A written essay is used in the *Introduction to Cognitive Psychology* and *Philosophy and AI* courses. The *Introduction to Artificial Intelligence* course uses weekly individual online assessments. The *Language Theory and Language Processing* course is assessed with a group project (along with the two exams and homework exercises). The weighing attached to the assignments is specified in the course descriptions. Students are informed about the assessments and criteria in the course descriptions and the study guide.

Projects are usually assessed by the end result (the product), a report and a presentation. The first-year *Search, Navigate and Activate* project also uses an exam and practicals as assessment. According to the self-evaluation report, lecturers set deadlines and clear assessment criteria before the start of the project. As part of the previously mentioned new examination policy, grading forms are being developed.

The site visit made it clear that students are satisfied, in general, with the level and the form of the assessments used. They also remarked that the mid-term exam is always discussed in each course. During the site visit and in preparation for it, the committee also looked at the different forms of assessment. It confirmed that the assessments seem adequate in terms of level and content. It is positive about the mid-term exams. The mid-term exams keep students motivated and give lecturers insight into the student's level. The committee also appreciates the fact that the mid-term exams are discussed with the students.

Graduation project
The committee examined the procedure for the graduation project and is of the opinion that it is adequate. It gives individual students the opportunity to show that they have achieved the intended learning outcomes. In addition to that, two staff members, using standardized assessment criteria, assess the graduation project.

The graduation project is individual and results in a scientific report in academic English. Students present their project and paper in a plenary session. Students are free to propose a graduation project but a list of potential projects is available. The self-evaluation report states that the projects can range from theoretical or philosophical to technical, focusing on implementation. The graduation project has to match one of the trajectories of the programme. It was also mentioned that all graduation projects cover the intended learning outcomes related to skills. The relation with the more substantive (AI) intended learning outcomes depends on the subject of the graduation project.

During the graduation project, students attend several lectures and carry out assignments regarding finding the relevant literature, executing the research, doing academic reading and writing in English. A supervisor, in general the lecturer who proposed the project, guides students. Students who propose their own project have to find a supervisor themselves. During the whole project students present their results three times: first, the research question

and research plan; second, the midterm results; and third, the final presentation.

The supervisor and a second independent staff member assess the thesis. The self-evaluation report states that the grade is based on the report, using basic assessment criteria. The final presentation can influence the grade only marginally. As mentioned earlier, the assessment criteria of the graduation project will be refined in the coming period.

3.2. Achievement of the learning outcomes
The committee assessed the achieved learning outcomes by inspecting a selection of the theses from the programme (see Appendix 7), 15 in total. Consideration in selecting the theses was given to the grading (low, average and high grades). The committee members read the theses and assessed their presentation of the problem and review of the literature, methods and justification, conclusion and discussion, structure, legibility and verification.

In general, the committee is of the opinion that the theses are of good quality and that graduates of the bachelor's programme clearly achieve the required level. The studied theses discussed quite complex topics and were very well written in general. They were characterized by a logical structure, a clear and relevant problem definition and adequate use of research methods.

Considerations

The committee concludes that the programme has an adequate assessment system in place. The different components of the programme are assessed in different ways, with a well-balanced mix between exams and practical assignments. Students are satisfied with the assessment in general. The committee appreciates the use of midterm exams. This not only ensures that students study throughout the whole course, it also gives the lecturers an overview of the students' level and the need to pay more attention to some topics. It is of the opinion that the Board of Examiners has sufficient insight into the quality of the assessments and takes adequate measures as necessary. The committee advises the programme however to urgently develop and implement an assessment policy. It recommends that the Board regularly assess a selection of exams, projects and graduation projects. It also advises the programme to swiftly fill the vacancy on the Board.

The committee concludes that the bachelor students acquire a high final level by the end of the programme. This is confirmed by the theses it evaluated. The committee realises that the assessment policy has not yet been fully implemented. It is impressed, however, by the quality of the studied theses and therefore assesses this standard as good. In addition to that, the committee noticed that students have no problems entering master's programmes of well-known European Universities.

Conclusion

Bachelor's programme Artificial Intelligence: the committee assesses Standard 3 as **good**.

General conclusion

The committee assesses the *bachelor's programme Artificial Intelligence* as **good**.

Appendices

Appendix 1: Curricula Vitae of the members of the assessment committee

Prof. dr. Leon Rothkrantz studied Mathematics at the University of Utrecht from 1967-1971. Next he started his PhD study at the University of Amsterdam under supervision of Prof Freudenthal and Prof. Van Est. He finished his PhD study in 1980. In the meantime he worked as a teacher Mathematics at "de Nieuwe Lerarenopleiding" at Delft. From 1980 he worked as a student counselor at Delft University of Technology. From that time he started a second study psychology at the University of Leiden and finished this study in 1990. From that time he worked as an Assistant Professor and later as an Associate Professor Artificial Intelligence at Delft University of Technology (DUT) in the group Knowledge Based Systems headed by Prof Koppelaar. Since 1998 he worked as a Professor Sensor Systems at The Netherlands Defence Academy (NLDA). In 2011 he retired from DUT and in 2013 also from the NLDA.
Leon Rothkrantz supervised more than 150 MSc. students and 15 PhD students. He published more than 200 scientific papers in Journals and Conference Proceedings. He was involved in many National and European Research and Educational Projects. He is honoured with golden medals from the Technical University of Prague and the Military Academy from Brno.

Yfke Dulek obtained her Bsc degree in Artificial Intelligence at Utrecht University in 2013, and is currently working towards an Msc degree in Logics at the same university. She graduated in 2009 from the Stedelijk Gymnasium Leiden. During her school years she obtained a Certificate in Advanced English at Cambridge University, and participated in the Leiden Advanced Pre-university Programme for Top Students in Molecular Science and Technology at Leiden University. She has teaching experience at the 'pre-gymnasium College' teaching Latin and Chemistry to primary school children; as remedial teacher at Stichting Studiebegeleiding Leiden and a student assistant for various bachelor courses at the UU Artificial Intelligence bachelor's programme. She was the secretary in the executive committee of the Artificial Intelligence student society USCKI Incognito, and continues to be an active member of this society.

Prof. em. Tim Grant is retired but still an active scientific researcher in the fields of network-enabled Command & Control systems, offensive cyber operations, and agent-based simulation. His last appointment was as full professor of Operational ICT & Communications within the Faculty of Military Sciences at the Netherlands Defence Academy. Tim's research takes a socio-technical viewpoint, across the military, manned spaceflight, emergency management, and motorway control domains, in collaboration with other researchers and subject matter experts worldwide. He currently co-supervises two PhD students. His career covered 20 years as a military officer in the (British) Royal Air Force, 17 years experience in Atos Origin (IT industry), and 10 years experience in academia (including a visiting professorship at the University of Pretoria, South Africa). Tim Grant has a BSc in Aeronautical Engineering (Bristol University, UK), a Masters-level Defence Fellowship (Brunel University, UK), and a PhD in Artificial Intelligence (Maastricht University, NL).

Prof. dr. Luc De Raedt studied and worked at the KU Leuven between 1986 and 1999. He completed his PhD in Computer Science at that same university in 1991. From 1999 to 2006 he was professor Machine Learning and Natural Language Acquisition at the Albert Ludwigs University in Freiburg, Germany. Since 2006 he is back at his *alma mater* the KU Leuven as research professor. His research concerns Artificial Intelligence, specifically the dealing with structured information, the use of declarative logic and probabilistic languages and the constraint programming of machine learning and data mining. De Raedt was a coordinator of

various European projects, concerning 'probabilistic inductive logical programming' and 'inductive constraint programming'. He was chairman of various international conference, among which the European and International Machine Learning Conference (1994, 2001, 2005) and the European Conference on Artificial Intelligence (2012). He is a member of the editorial board of journals in the domain of Artificial Intelligence. He was nominated Fellow of the European Coordinating Committee for Artificial Intelligence in 2005. De Raedt is an experienced teacher, having taught at the universities of Leuven, Freiburg, Basel, Namur and Sienna. At the University of Freiburg, he was the director of the international Master of Science Master's programme in Applied Computer Science.

Marten den Uyl MSc obtained an MSc in cognitive psychology in 1978 from University of Amsterdam. From 1978 till 1987 Den Uyl worked in various areas of psychological research at University of Amsterdam and Stanford University, including text understanding, psychophysics and judgment theory, ethnic attitude, emotion theory, connectionist modeling.
In 2001, Den Uyl founded VicarVision, a company active in computer vision, and ParaBots which focuses on websearch and tesmining. In 2007, VicarVision introduced the FaceReader, the first vision system able to evaluate basic emotional expressions –even for unknown persons- in real time. FaceReader is currently in use in well over 200 academic research groups. VicarVision coordinates the TNO SBIT project "Patroonherkenning voorkomt loos alarm" and is a coordinating partner in the "Watching people Security Services" project which is field testing the integration of advanced intelligent camera surveillance technologies from a number of partners, including TNO. In 2004, ParaBots introduced the Xenon system for fiscal web search and inspection, which is currently used by tax authorities in more than half a dozen countries in Europe and America for inspection of e-commerce activities on the web. Den Uyl's companies have participated in well over 20 EU and nationally granted R&D projects in AI and Den Uyl has (co-)authored many dozens of papers and reports on AI technologies.

Appendix 2: Domain-specific framework of reference

Frame of reference Bachelor and Master programmes in Artificial Intelligence
The Dutch perspective
January 16, 2013

This document is an update of the 2006 Frame of Reference as developed by the KION[1] task force on Curricula for Artificial Intelligence, which was based on:

- Computing Curricula 2013 Strawman Draft for Computer Science developed by the Joint Task Force on Computing Curricula, IEEE Computer Society and the Association for Computing Machinery[2].
- The Onderwijs- en Examenregelingen (OER) of the bachelor and master programmes in Artificial Intelligence administered by the Dutch Universities.
- Tuning Educational Structures in Europe[3].

1 Introduction

This document is an update of the 2006 frame of reference for the Dutch University programmes included in the category Artificial Intelligence of the Dutch register of higher education programmes (CROHO)[4]. 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.

1.2 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 Technology (Kennistechnologie), Cognitive Artificial

[1] Kunstmatige Intelligentie Opleidingen Nederland
[2] http://www.acm.org/education/ (last visited on November 1st, 2012)
[3] http://www.unideusto.org/tuning/ (last visited on November 1st, 2012)
[4] Centraal Register Opleidingen Hoger Onderwijs

Intelligence (Cognitieve Kunstmatige Intelligentie) as well as Artificial Intelligence (Kunstmatige Intelligentie).

In 1999, the number of recognized labels in the CROHO was reduced, and the aforementioned study programmes were united under the name *Artificial Intelligence*[5]. 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 abovementioned 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 and a master 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 programme, with the aim of advancing an adequate fit of all Dutch bachelor programmes to all Dutch master requirements.

1.2 Aim of this document

Now that the Dutch Artificial Intelligence programmes are coming up for accreditation in 2013, KION feels that the essence of the 2006 Frame of Reference is still valid, but an update is called for. 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 setting international standards for Artificial Intelligence programmes that, to our knowledge, do as yet still not exist.

2. Programme characteristics

This section describes definitions regarding the build-up of bachelor and master programs.

2.1 Areas, courses, modules, and topics

A bachelor programme in Artificial intelligence is organized 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'.

[5] In Dutch: Kunstmatige Intelligentie

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 from 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 recognized throughout the world, but within the European Community agreement has been reached upon a uniform European Credit Transfer System[6] (ECTS) in which study load is measured in European Credits (ECs). One EC stands for 28 hours of study time and a full year of study is standardized 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 in those students an attitude that promotes continued study throughout a career. To this end, an Artificial Intelligence curriculum must strive to meet the following challenges:

- Adopt a teaching methodology that emphasizes 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.

[6] http://ec.europa.eu/comm/education/programmes/socrates/ects/index_en.html (last visited on September 1st, 2012)

3. Shared identity

3.1 Common role

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

3.2 Common requirements

Artificial Intelligence is a broad discipline and many approaches to the study of intelligent phenomena are justified and fruitful. Curricula are therefore often different from their siblings in emphasis, goals, and capabilities of their graduates. Yet they have much in common. Any reputable Artificial Intelligence program 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 formal. Artificial Intelligence-graduates must therefore be able to work with (computational) models at different levels of abstraction and understand the recursive nature of models in Artificial Intelligence. This foundation has a number of layers:
    a. An understanding of, and appreciation for, many of the diverse aspects of intelligence, models of intelligent phenomena, and of algorithms that describe intelligent processes.
    b. Skills to model intelligent phenomena and appreciate the abilities and limitation of these models, if appropriate in comparison with a natural example.
    c. Skills to model and implement intelligent phenomena on a computer, in particular skills to work with algorithms and data-structures in software.
    d. Skills to design and build systems that are robust, reliable, and appropriate for their intended audience.
3. An understanding of the possibilities and limitations of what intelligent systems can and cannot do. This foundation has a number of levels:

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

4. The identification and acquisition of non-technical skills, including interpersonal communication skills, team skills, and management skills as appropriate to the discipline. To have value, learning experiences must build such skills (not just convey that they are important) and teach skills that are transferable to new situations.
5. Exposure to an appropriate range of applications and case studies that connect theory and skills learned in academia to real-world occurrences to explicate their relevance and utility.
6. Attention to professional, legal and ethical issues such that students acquire, develop and demonstrate attitudes and priorities that honour, protect, and enhance the profession's ethical stature and standing.
7. Demonstration that each student has integrated the various elements of the undergraduate experience by undertaking, completing, and presenting a capstone project.

3.3 Shared background for bachelor 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, specialized 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 programme in AI. At the same time, it allows for a wide range of individual and/or institute specific specialisation. The list is an update (extension) of the shared programme agreed upon by the KION platform in 2006.

3.3.1 Common core between AI bachelor degree programmes

The following topics and skills are part of each of the bachelor programmes, either as a dedicated course or as a substantial topic within one or more courses.

Artificial Intelligence modules

- Autonomous systems
- Cognitive psychology
- Computational linguistics
- History of Artificial Intelligence
- Human-computer interaction
- Knowledge representation and reasoning
- Machine learning
- Multi-agent systems
- Philosophy for Artificial Intelligence

Support modules

- Computer science
  - Programming
  - Data structures and algorithms
- Logic
- Mathematics

- Calculus
- Probability theory
- Linear algebra
- Statistics

Academic skills
Apart from curriculum specific skills, the bachelor program supports 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 Artificial Intelligence elective courses
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 or Master, each Bachelor should offer a substantial subset of the following list as part of their Bachelor programme, either as specific course, or as a substantial part of a broader course.

- Cognitive modelling anArchitectures of cognition
- Data mining
- Information retrieval
- Language and speech technology
- Neural nets
- Genetic algorithms
- Probabilistic models
- Cognitive and computational neuroscience
- Perception (Computational and Natural)
- Robotics
- Reasoning under uncertainty
- Virtual reality and Gaming
- Web Intelligence
- Bio-informa

4. Bachelor 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 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 programmes

The bachelor provides the student with the specific knowledge and abilities, exemplified in the form of a bachelor diploma that allows the bachelor access to a master programme in Artificial Intelligence or other national or international masters, 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 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[7]. 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.

Qualifications:

1. Basic understanding of 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.
3. Knowledge of the symbolic approach to Artificial Intelligence.
4. Knowledge of the numerical, non-symbolic, approach to Artificial Intelligence.
5. Knowledge of the most important philosophical theories regarding the fundamental questions of AI as well as its ethical, legal and societal implications.
6. Knowledge of the most important theories developed in the area of empirical sciences, particularly psychology.
7. Expertise in constructing and evaluating computational models of cognitive processes and intelligent systems.

[7] http://www.jointquality.org/ (last visited on September 1st, 2012)

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 the symbolic approach to Artificial Intelligence.
3. The ability to apply non-symbolic approaches to Artificial Intelligence.
4. The ability to design, implement, and evaluate knowledge-intensive.
5. The ability to apply tools from mathematics and logic.
6. The ability to apply important programming languages used in Artificial Intelligence.
7. 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.
8. The ability to submit an argument in the exact sciences (or humanities) to critical appraisal.
9. Analytical and critical way of thought and ability to apply logical reasoning.
10. Openness to interdisciplinary cooperation and ability to effectively participate therein as an academic professional.
11. The ability to create an effective project plan for solving a prototypical Artificial Intelligent problem in a supervised context.
12. Manage one's own learning and development, including time management and organizational skills.
13. The ability to transpose academic knowledge and expertise into (inter)national social, professional and economic contexts.
14. Readiness to address new problems in new areas, emerging from scientific and professional fields.

4.2.3. Making judgements

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

Qualifications:

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

4.2.4.Communication

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

Qualifications:
1. Academically appropriate communicative skills; the bachelor can:
    - Communicate ideas effectively in written form and through the use of Information and Communication Technology,
    - Make effective oral presentations, both formally and informally,
    - Understand and offer constructive critiques of the presentations of others.

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

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

5. Master 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[8]. 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 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.

Qualifications:

1. Advanced understanding of key areas in Artificial Intelligence.
2. 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.
3. The master is able to judge the quality of his of her work or the work of others from scientific literature.

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 domains 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;

[8] http://www.jointquality.org/ (last visited on September 1st, 2012)

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 judgements

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 judgements that include social and ethical responsibilities related to the application of one's own contributions.

5.2.4. Communication

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

Qualifications:

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

5.2.5. Learning skills

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

Qualifications:

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

6. International perspective

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

Having said this, we must immediately recognize that the Dutch national context appears to be rather special in that we only know of specialized 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 programmes of study programmes in a related field, notably Cognitive Science. Furthermore, we will compare the Dutch bachelor 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 programmes, there are several well-known specialized Artificial Intelligence master programmes outside the Netherlands, study programmes at the master level are much more divergent than at the bachelor level. A comparison can therefore only be provided in global, subject-independent, terms.

We have drawn up both the bachelor and master 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 programmes

6.1.1. The Artificial Intelligence bachelors in Edinburgh

Edinburgh University (United Kingdom) offers a range of bachelor degrees related to Artificial Intelligence, one of them in Artificial Intelligence as such, the others in combination with other disciplines (AI & Computer Science, AI & Mathematics, Cognitive Science). An ordinary bachelor degree consists of 3 years, however admittance to the (1-year) master programme can only be obtained by an honours degree, which takes a fourth year of study. In order to compare this system with the European standard of a 3-year bachelor and a 1-2-year master, we will take the honours year of the Edinburgh bachelor programme to be equivalent to the first year of a 2-year master degree in other European countries, and base our comparison of bachelor programmes on the first three years.

6.1.2. Comparison with the Dutch frame of reference

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 communality between the Edinburgh Artificial Intelligence bachelors is smaller than communality within the Dutch framework. It seems that the wide variation in Edinburgh Artificial Intelligence related bachelor degrees actually means that the degrees themselves are much more specialized than the Dutch framework proposes, some of them having little or no (cognitive) psychology, others having no mathematics, etcetera. Areas such as philosophy appear not to be obligatory at all.

6.1.3. The Cognitive Science bachelors in Osnabrück and Linköping

Both the University of Osnabrück (Germany) and the University of Linköping (Sweden) offer 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.

6.1.4. Comparison with the Dutch frame of reference
Based on studying both programmes, we conclude that the Dutch frame of reference recognizes 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.

6.2 Comparison of master programmes

6.2.1. 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
- Knowledge management, representation and reasoning
- Learning from data
- Natural language processing

6.2.2. Comparison with the Dutch frame of reference
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 degree.
- The Edinburgh system knows a 'Diploma' whereas the Dutch system does not. As described above, this Diploma can be awarded after completing only the taught part of the course.
- 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.

6.2.3. Stanford
Stanford has four majors in computer science: Computer Science, Computer System Engineering, Mathematical and Computational Sciences and Symbolic Systems. Symbolic Systems most closely relates to the Artificial Intelligence programmes in the Netherlands.

Symbolic Systems is an interdisciplinary program 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 program explores the ways computers and people reason, perceive, and act. Within the Symbolic Systems major, there is a core set of required classes; beyond this core, students choose an area of concentration in order to gain depth.[9]

6.2.4. Comparison with the Dutch frame of reference

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

- It is surprisingly difficult to find programme objectives, final qualifications etcetera in the available information. This information is mainly of subject-independent, administrative nature. For example "This programme prepares for entering a PhD programme".
- It was already 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. But still, this variety is on the Computer Science level rather than the Artificial Intelligence level.
- The Stanford programmes seem to have a large freedom in elective courses. In other words, the core of compulsory courses is limited and students have select many elective courses.
- The Dutch framework has more formal subjects (logic etcetera) than the Symbolic Systems programme.

7. Concluding remarks

Artificial Intelligence is a developing field. Due to its relatively recent start as a coherent field of research, the term Artificial Intelligence does not have the stature of Physics, Psychology, or even Computer Science. Internationally, the study of natural and artificial intelligence with computational means is firmly, but usually not very visibly, 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. Future challenges will force products, services, and even societies to react faster but remain reliable, to be both flexible and effective, be both efficient and versatile, and to utilize natural resources with maximal benefit. Making the most of this combination of conflicting demands, which is very much at the core of in the concept of *intelligence*.

The Dutch situation is special because of the existence of Artificial Intelligence bachelor and master programs 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 and master programmes in Artificial Intelligence of Dutch universities contribute to educate alumni that will take a leading role in meeting these future challenges.

[9] http://symsys.stanford.edu/courses (last visited on September 5th, 2012)

Appendix 3: Intended learning outcomes

Doel van de opleiding en eindtermen

1. Met de opleiding wordt beoogd studenten op te leiden tot een bachelordiploma dat toegang geeft tot de aansluitende masteropleiding Artificial Intelligence van de UvA of tot een masteropleiding aan een universiteit in Nederland of daarbuiten. De opleiding biedt tevens een gedegen voorbereiding op een positie op de arbeidsmarkt.

2. De afgestudeerde van de opleiding:

- is op de hoogte van de methodiek die gevolgd wordt in de klassieke Kunstmatige Intelligentie, die uitgaat van een symbolische representatie van informatie, en van de toepassing van deze methodiek bij het ontwerpen van kennissystemen en de constructie van computationele modellen van cognitieve processen als probleemoplossen, leren, en natuurlijke taalverwerking;
- heeft kennis gemaakt met de technieken die een numerieke, niet-symbolische aanpak met zich meebrengt en weet hoe die toegepast kan worden in met name beeldherkenning, spraakherkenning en synthese, sensordataverwerking, planning en regelen;
- is op de hoogte van de meest belangrijke filosofische theorieën op het gebied van kennis en cognitie, en ook van de theorieën die op dit gebied ontwikkeld zijn binnen de empirische wetenschappen, met name de psychologie;
- beschikt over voldoende kennis en vaardigheid op het gebied van de wiskunde en logica om te kunnen werken met de wiskundige en formele modellen die binnen de Kunstmatige Intelligentie een rol spelen;
- is op de hoogte van de verschillende soorten programmeertalen en programmeeromgevingen die binnen de Kunstmatige Intelligentie worden gebruikt, en heeft praktische ervaring opgedaan met de belangrijkste daarvan;
- bezit een meer gedegen kennis van minstens één van de volgende (sub)disciplines: (a) kennistechnologie, (b) taal en spraak, (c) intelligente systemen (d) computationele psychologie, (e) logica; dit tot een niveau dat zonder nadere ingangseisen toegang geeft tot een Masteropleiding op het gebied van een van deze (sub)disciplines;
- beschikt over adequate vaardigheden inzake het opsporen en de kritische verwerking van relevante vakliteratuur en inzake de schriftelijke en mondelinge rapportage daarover;
- beschikt over voldoende communicatieve- en samenwerkingsvaardigheden om als academicus in een multidisciplinair teamverband te functioneren;
- heeft inzicht in de maatschappelijke betekenis van de Kunstmatige Intelligentie en de verantwoordelijkheden van deskundigen op dit gebied in de samenleving

Appendix 4: Programme

First year

	EC	Semester	Periode
Logisch Programmeren en Zoektechnieken	6	1	a
Inleiding Kunstmatige Intelligentie	6	1	a
Objectgeoriënteerd Programmeren	6	1	b
Inleiding Logica	6	1	b
Webprogrammeren en Databases	6	1	c
Lineaire Algebra KI/INF	6	2	a
Taaltheorie en Taalverwerking	6	2	a
Computationele Logica	6	2	b
Inleiding Cognitieve Psychologie	6	2	b
Zoeken, Sturen en Bewegen	6	2	c
Tutoraat Kunstmatige Intelligentie 1		1+2	ab

Second year

	EC	Semester	Periode
Continue Wiskunde en Statistiek	6	1	a
Computersystemen	6	1	a
Beeldverwerken	6	1	b
Leren	6	1	b
Leren en Beslissen	6	1	c
Datastructuren	6	2	a
Brein en Cognitie	6	2	a
Natuurlijke Taalmodellen en Interfaces	6	2	b
Kennissystemen	6	2	b
Tweedejaarsproject BSc KI	6	2	c
Tutoraat Kunstmatige Intelligentie 2		1+2	a

Third year

	EC	Semester	Periode
Verplichte onderdelen			
Filosofie en Artificial Intelligence	6	2	a
Kennisgebaseerde Media	6	2	a
Afstudeerproject BSc KI	18	2	bc
Aanbevolen keuzeonderdelen			
Intensionele logica's en onzekerheid	6	1	a
Discourse	6	1	a
Autonome Mobiele Robots	6	1	b
Spraakherkenning en -synthese	6	1	c
Connectionistische modellen 1 – Theorie (eventueel + Connectionistische Modellen 2 – Practicum)	6 (9)	1	bc

Appendix 5: Quantitative data regarding the programme

Data on intake, transfers and graduates

Tabel 1: Uitval na 1, 2, en 3 jaar

Cohort	2006	2007	2008	2009	2010	2011
Uitval na 1jr	24%	54%	25%	33%	33%*	…%
Uitval na 2jr	36%	54%	35%	36%*	…%	
Uitval na 3jr	40%	54%	40%*	…%		

* = voorlopige cijfers op peildatum 1 oktober

Tabel 2: Rendement (vwo-instroom)

Cohort	2006	2007	2008	2009
Rendement na 3 jaar	32%	50%	40%	…%
Rendement na 4 jaar	53%	67%	…%	
Rendement na 5 jaar	63%	…%		
Rendement na 6(1) jaar	…%			

Tabel 3: Rendement (totale instroom)

Cohort	2006	2007	2008	2009
Rendement na 3 jaar	33%	50%	33%	…%
Rendement na 4 jaar	50%	64%	…%	
Rendement na 5 jaar	58%	…%		
Rendement na 6(1) jaar	…%			

Quality of the teaching staff

Graad	Master	PhD	BKO
Percentage	99 %	89 %	36 %

Teacher-student ratio

Ratio	24,7

Average amount of face-to-face instruction per stage of the study programme

Studiejaar	1	2	3
Contacturen	20,4	19,6	10,5

Appendix 6: Programme of site visit

Woensdag 12 juni		
10.30	13.00	**Startbijeenkomst en lunch** (event. + inloopspreekuur) (alleen commissie)
13.00	14.00	**Management (inhoudelijk verantwoordelijken**) Bert Bredeweg (Opleidingsdirecteur bacheloropleiding) Babette Sluijter (Opleidingscoördinator bacheloropleiding) Theo Gevers (Opleidingsdirecteur masteropleiding) Kristien van Lunen (Opleidingscoördinator masteropleiding) Maarten de Rijke (Track coördinator Learning Systems, Web Information Processing) Khalil Simaan (Track coordinator Natural Language Processing and Learning)
14.00	14.45	**Studenten Bachelor** Lotte Weerts 1e jaars Sebastien Negrijn 1e jaars Steve Nowee 2e jaars Mick van 't Nederend 2e jaars Bart Vredebregt 3e jaars Inge Becht 3e jaars
14.45	15.30	**Docenten Bachelor (Gesprek in het Engels)** Raquel Fernandez Rovira Arnoud Visser Annemie Ploeger Frank Nack Susanne Hendrickx Leo Dorst Bert Bredeweg
15.30	*15.45*	***Break***
15.45	16.30	**Opleidingscommissie (gedeeld voor Bachelor en Master):** Theo Janssen OC voorzitter Casper van Hout OC secretaris Maarten van Someren OC docent lid Henk Zeevat OC docent lid Camiel Verschoor OC student lid
16.30	17.15	**Alumni (zowel van Bachelor als Master**) Ba: Maarten van der Velden Sander Latour Robrecht Jurriaans Ba en Ma: Aziz Baibabaev Masters: Janneke van der Zwaan Fares Alnajar Nicholas Piël
18.30	*21.00*	**Diner**
Donderdag 13 juni		

9.00	9.45	**Studenten Master** Bertram de Boer 1st year Thomas Jongstra 1st year Stijn de Gooijer 1st year Hoda Alemi 2nd year Kristin Rieping (nog niet zeker) 2nd year Wenjin Wang 2nd year Mihai-Adrian Morariu 2nd year Morris Franken 2rd year
9.45	10.30	**Docenten Master** Gwen Englebienne Frank Aldershoff Shimon Whiteson Maarten v. Someren Khalil Simaan Jan van Gemert
10.30	*10.45*	**Break**
10.45	11.30	**Examencommissies en studieadviseur (gedeeld voor Bachelor en Master**): Leo Dorst Voorzitter EC Piet Rodenburg Lid EC Richard Kellermann Studieadviseur
11.30	12.00	**Rondleiding** Arnoud Visser (docent)
12.00	14.00	**Voorbereiden eindgesprek en lunch**
14.00	15.00	**Eindgesprek (formeel verantwoordelijken**) Decaan (prof. Dr Kareljan Schoutens) Directeur Onderwijs (mr. Jeanine Meerburg, formeel per 1 juni 2013 opgevolgd door prof. Dr. Michel Haring) Directeur Graduate School of Informatics (dr. Andy Pimentel) Directeur College of Science (dr. Jeroen Goedkoop) Directeur Bacheloropleiding Kunstmatige Intelligentie (dr. Bert Bredeweg) Directeur Masteropleiding Artificial Intelligence (dr. Theo Gevers)
15.00	17.00	**Vaststellen bevindingen (alleen commissie)**
17.00	17.15	**Presentatie bevindingen en informele afsluiting (in het Engels)**
17.15		**Borrel voor panelleden en de toehoorders van de presentatie**

Appendix 7: Theses and documents studied by the committee

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

- Information material;
- Books and syllabi, readers, study guides;
- Examples of projects, portfolios, research reports of students;
- Thesis regulations and guidelines for completing assignments;
- Regulations/manuals;
- Examination regulations;
- Key materials (exams, test instructions, key policies, etc.) with model answers;
- Recent reports of the Programme Committee, Examination Committee, annual education, bachelor-master transitional arrangements;
- Teaching and curriculum evaluations, student satisfaction monitor(s), etc.;
- Alumni surveys;
- Material of the study associations;
- Annual reports (education, research, last three years).

Theses studied:

0321907	5974100	6036031
5749468	5756545	9305017
5967651	6071392	0439541
5647177	5640318	10017321
0553018	5743028	6036163

Appendix 8: Declarations of independence

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ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: León Rothkrantz

PRIVÉ ADRES: Ir. Werffstraat 19
2722 AR Zoetermeer

IS ALS DESKUNDIGE / ~~SECRETARIS~~ GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

Kunstmatige Intelligentie

AANGEVRAAGD DOOR DE INSTELLING:

RUG/UU/RU/UT/UvA/VU

VERKLAART HIERBIJ GEEN (FAMILIE)RELATIES OF BANDEN MET BOVENGENOEMDE INSTELLING TE ONDERHOUDEN, ALS PRIVÉPERSOON, ONDERZOEKER / DOCENT, BEROEPSBEOEFENAAR OF ALS ADVISEUR, DIE EEN VOLSTREKT ONAFHANKELIJKE OORDEELSVORMING OVER DE KWALITEIT VAN DE OPLEIDING TEN POSITIEVE OF TEN NEGATIEVE ZOUDEN KUNNEN BEÏNVLOEDEN;

1

nvao
nederlands-vlaamse accreditatieorganisatie

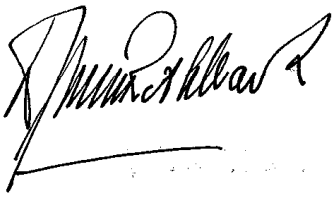
VERKLAART HIERBIJ ZODANIGE RELATIES OF BANDEN MET DE INSTELLING DE AFGELOPEN VIJF JAAR NIET GEHAD TE HEBBEN;

VERKLAART STRIKTE GEHEIMHOUDING TE BETRACHTEN VAN AL HETGEEN IN VERBAND MET DE BEOORDELING AAN HEM/HAAR BEKEND IS GEWORDEN EN WORDT, VOOR ZOVER DE OPLEIDING, DE INSTELLING OF DE NVAO HIER REDELIJKERWIJS AANSPRAAK OP KUNNEN MAKEN.

VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Utrecht DATUM: 14 maart 2013

HANDTEKENING:



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nederlands-vlaamse accreditatieorganisatie

ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: Timothy John Gralt

PRIVÉ ADRES: Koningin Wilhelminastraat 13
3405 XP Benschop

IS ALS DESKUNDIGE / ~~SECRETARIS~~ GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

Kunstmatige Intelligentie

AANGEVRAAGD DOOR DE INSTELLING:

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VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Benschop

DATUM: 14 maart 2013

HANDTEKENING: T.J. Bracht

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nederlands-vlaamse accreditatieorganisatie

ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: M. J. den Uyl

PRIVÉ ADRES: Courbetstraat 29
1077 ZS Amsterdam

IS ALS DESKUNDIGE / ~~SECRETARIS~~ GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

Kunstmatige Intelligentie

AANGEVRAAGD DOOR DE INSTELLING:

UU / UvA / VU

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VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Utrecht DATUM: 14 maart 2013

HANDTEKENING:

nvao
nederlands-vlaamse accreditatieorganisatie

ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: DE RAEDT, Luc

PRIVÉ ADRES: LEDEBEEKHOF 4
9070 Destelbergen
BELGIË

IS ALS DESKUNDIGE / ~~SECRETARIS~~ GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

Kunstmatige Intelligentie

AANGEVRAAGD DOOR DE INSTELLING:

UU/UvA/VU

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VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Deskelbrugge

DATUM: 13/3/2013

HANDTEKENING:

nvao
nederlands-vlaamse accreditatieorganisatie

ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: Yfke Marie Dulek

PRIVÉ ADRES: Cambridgelaan 617

3584 DM

Utrecht

IS ALS DESKUNDIGE / ~~SECRETARIS~~ GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

kunstmatige intelligentie

AANGEVRAAGD DOOR DE INSTELLING:

UU / UvA / VU

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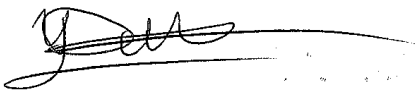
VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Utrecht DATUM: 14-03-2013

HANDTEKENING:



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ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: T. Bubacz

PRIVÉ ADRES: De Ondde Wlaren beek 20
7339 GZ Ugchelen

IS ALS DESKUNDIGE / SECRETARIS GEVRAAGD VOOR HET BEOORDELEN VAN DE OPLEIDING:

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AANGEVRAAGD DOOR DE INSTELLING:

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PLAATS: Utrecht

DATUM: 14-3-2013

HANDTEKENING: