Master's programme

Artificial Intelligence

Faculty of Science,
University of Amsterdam

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This report was finalized on 3 December 2013.

Report on the master'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

Master's programme Artificial Intelligence

Name of the programme:	Artificial Intelligence
CROHO number:	66981
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specializations or tracks:	Gaming
	Intelligent Systems
	Learning Systems
	Natural Language Processing and Learning
	Web Information Processing
Location(s):	Amsterdam
Mode(s) of study:	full-time
Expiration of accreditation:	December 2014

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

Administrative data regarding the institution

Name of the institution:	the 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 master'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, Gent, 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 Rothkrantz, 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 UvA master'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);
- 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;
- 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 committee members.

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 approved (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 master'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 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 master's programme Artificial Intelligence

This report reflects the findings and considerations of the committee on the master's programme in Artificial Intelligence, University of Amsterdam. The evaluation of the committee 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, the committee 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 objective and intended learning outcomes of 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 master's programme are predominantly in line with the framework. The committee is of the opinion that the profile and academic orientation are very clear. The committee appreciates the explicit choices the programme has made in this. The programme chooses a more technical approach to AI. The programme focuses on developing, understanding and implementing computational processes with regard to (human) intelligence. The committee appreciates the broad opportunities students have, to specialise in one of five tracks, which represent the key areas of artificial intelligence.

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 master's programme. In addition, the relation with the Dublin descriptors is evident in the intended learning outcomes.

Standard 2: Programme
The committee assesses Standard 2 as **satisfactory**. 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 objectives as described in the course descriptions could be more uniform and more explicitly related to the intended learning outcomes.

The committee is positive about the mandatory first semester of the programme. This ensures that all international students have the same starting level for the other courses. In addition, the different tracks offer students specialisation. The committee is of the opinion that the tracks and projects provide quite a lot of coherence in the individual study programmes.

The committee concludes that the development of academic and professional skills is very well addressed within the programme. The programme does not offer any philosophical reflection on conducting research in the field of artificial intelligence, however. It recommends paying more attention to this aspect.

The committee appreciates the opportunities students have to execute the research projects for external organisations. It advises informing students more actively about the industry, for example, by inviting alumni as guest lecturers.

The committee is of the opinion that the services provided to students (both guidance and facilities) are sufficient. It also appreciates the opportunities for students to study abroad.

The programme is feasible and attracts quite a lot of international students, from a wide range of countries. The committee appreciates this. The completion rates are adequate. The committee recommends that the programme implement the academic mentors and the structuring of the thesis project mentioned in the self-evaluation report. It expects that this will contribute to an improvement of the completion rates.

The programme is based on research-oriented teaching. The committee is of the opinion that the educational principle is consistently implemented, with an important role given to the research projects. 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. It recommends increasing the involvement of full professors in the courses and lectures. It confirmed that an adequate quality assurance system is in place.

Standard 3: Assessment and achieved learning outcomes
The committee assesses Standard 3 as **satisfactory**. 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 multiple assessments in the different courses. It advises the programme to develop and implement an assessment policy. 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. It appreciates the fact that the Board is actively involved in the final presentations and grading of all theses. It advises the programme to fill the vacancy on the Board of Examiners swiftly.

The committee concludes that the master students acquire a high final level by the end of the programme. This was confirmed by the theses it evaluated.

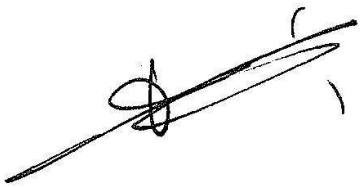
Master's programme Artificial Intelligence

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	**satisfactory**
Standard 3: Assessment and achieved learning outcomes	**satisfactory**
General conclusion	**satisfactory**

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 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 master's programme Artificial Intelligence, the committee concludes that the programme predominantly matches the KION framework. Also, the intended learning outcomes of the programme are largely in line with the qualifications mentioned in the KION framework. The committee notes that the programme's focus is primarily technical (see also next section) and that the more psychological aspects of the framework are not represented.

1.2 Profile and orientation
The self-evaluation report states that the master's programme offers high-quality training in scientific reasoning and communication to acquire knowledge and understanding of Artificial Intelligence at internationally accepted standards of academic skills at the master level. It provides an academic curriculum addressing the key areas in the field of Artificial Intelligence, including Intelligent Systems, Learning Systems, Gaming, Natural Language Processing and Learning, and Web Information Processing. These key areas are translated into five tracks. During the programme students acquire specialist knowledge in one of these tracks (or key areas).

According to the self-evaluation report, the programme has a technical profile. It focuses on the development and understanding of intelligent computational processes for creating useful artefacts and helping understand (human) intelligence better. Students acquire a working knowledge of efficient, robust and intelligent methods for interpreting information (sensory) of different modalities. These methods are necessary to build systems that are able to interpret and classify the various kinds of information available. They are also important for reasoning systems such as autonomous vehicles and surveillance systems, and manufacturing autonomous systems to interpret their environment and to solve decision-making tasks.

The committee concludes that the programme has an academic orientation, which is reflected in the intended learning outcomes. Graduates can formulate scientific questions and solve problems using abstraction and modelling. They are aware of the social context and consequences of doing AI research. The academic orientation is evident in the projects and the extensive thesis, which focus on research. According to the self-evaluation report, students are prepared for a career in research as well as in industry. It also states that graduates have a broad knowledge of basic and advanced theories, methods and techniques in the area of Artificial Intelligence. They can solve complex problems in a multidisciplinary way and apply the knowledge of Artificial Intelligence to design and implement complex Artificial Intelligent systems.

During the site visit, the committee discussed the profile of the programme with the management. The more technical profile of the programme was confirmed. It became clear that the cognitive and philosophical aspects of AI are not covered, mainly because they are part of the department's bachelor's programme. Also, students can use the electives if they wish to learn more about the cognitive and philosophical aspects. The students revealed during the site visit that the technical profile was an important reason for choosing the programme. Even though the committee is of the opinion that the profile and orientation of the programme are clear, it also concludes that for students coming from other bachelor's programmes, it cannot be guaranteed that the whole, broader field of AI is covered. The committee finds this however not problematic because students choose the master's programme for its more technical signature.

1.3 Intended learning outcomes
The intended learning outcomes of the programme (Appendix 4) reflect its profile, in which students specialize in a key area of AI. Graduates are expected to have specialised knowledge of at least one of the following Artificial Intelligent subfields: gaming, intelligent systems, learning systems, natural language processing and learning, web information processing, communication and education. The intended learning outcomes furthermore reflect the qualifications mentioned in the KION framework. Graduates are expected to be able to formulate a research plan, judge the quality of their own work and the work of others, and understand the key areas in Artificial Intelligence. As mentioned previously, the intended

learning outcomes also reflect the academic nature of the programme. The committee concludes that the learning outcomes are of an academic nature and level. The committee is also of the opinion that they reflect the vast majority of 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 master'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 objective and intended learning outcomes of 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 master's programme are predominantly in line with the framework. The committee is of the opinion that the profile and academic orientation are very clear. The committee appreciates the explicit choices the programme has made in this. The programme chooses a more technical approach to AI. The programme focuses on developing, understanding and implementing computational processes with regard to (human) intelligence. The committee appreciates the broad opportunities students have, to specialise in one of five tracks, which represent the key areas of artificial intelligence.

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 master's programme. In addition, the relation with the Dublin descriptors is evident in the intended learning outcomes.

Conclusion

Master'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 the 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 international master's programme is a two-year programme, consisting of 120 EC. It follows the 8-8-4 system: each semester consists of two eight-week lecture periods, followed by one four-week block for projects. The programme comprises 42 EC of mandatory courses, 18 EC of restricted electives, 18 EC of free electives and the master project of 42 EC.

The first semester of the programme aims at providing orientation and selection. During the six mandatory courses students gain an overview of the key areas in artificial intelligence and the content that will be covered in the programme. Students follow courses such as *Autonomous Agents, Machine Learning: Pattern Recognition* and *Elements of Language processing and Learning.* The first project, at the end of the first semester, is related to one of the tracks. The mandatory first semester is also intended to ensure all students have the same knowledge basis and to create a student community. During the site visit it became clear that the background of the students can be quite different. Students from the UvA bachelor's programme find the semester intensive but familiar, others find it more challenging.

In the second semester of the first year, students start with one of the five tracks: gaming, intelligent systems, learning systems, natural language processing and learning, or web information processing. All tracks consist of two mandatory courses and a profile project. The profile project is directly related to the track (courses). The five tracks cover the following topics:

1. gaming: this track offers knowledge on game programming, serious gaming and simulations, learning in games, multi-agent systems for games and multimedia analysis. The two courses are *Advanced Topics in Autonomous Agents* and *Game Programming.*
2. intelligent systems: this track covers topics such as machine learning, computer vision, autonomous systems and multi-agent systems. The two courses are *Advanced Topics in Autonomous Agents* and *Computer Vision.*
3. learning systems: in this track students learn about algorithms, models for learning, theories that explain why algorithms work, multi-agent reinforcement learning, and transfer learning for multiple modalities. The two courses are *Advanced Topics in Autonomous Agents* and *Machine Learning: Principles and Methods.*
4. natural language processing and learning: this track focuses on statistical models for complex language processing tasks such as parsing, hierarchical language modelling and machine translation. The two courses are *Statistical Structure in Language Processing* and *Unsupervised Language Learning.*

5. web information processing: this track covers data mining, natural language processing and link-based techniques. The two courses are *Applied Language Technology* and *Game Programming*.

The remainder of the first year is filled with electives. During the second year, students follow several electives and focus mainly on their master's thesis.

The site visit revealed that students choose a track based on the courses in the first semester. The first semester courses address all tracks. Students also indicated that it is possible to follow more than one track, for example by using the free electives for track-specific courses. They are informed about the profile project during a session in which possible projects are presented.

The self-evaluation report made it clear that students can additionally choose to follow two majors: in Management, Policy Analysis and Entrepreneurship or in Science Communication. During the site visit the committee discussed these majors with the lecturers. It became clear that these are faculty-wide programmes followed by only one or two students from the master's programme Artificial Intelligence per year. Students follow one year of AI courses and one year of courses in the chosen major. The thesis is 12 EC. It was also remarked that next year the majors will be reviewed and will decrease from 60 to 30 EC. The committee supports this, for it will give more guarantees that the intended learning outcomes directly related to the field of artificial intelligence can be realised.

During the site visit it became clear that students were very disappointed in the design of the *Game Programming* course. They welcome the appointment of a new lecturer for gaming (see also section 2.7).

The committee concludes that the before mentioned technical approach to AI (see Standard 1) is evident throughout the programme. During the site visit, it discussed the lack of cognitive and philosophical aspects in the programme with the students. Students revealed that they appreciate the technical character of the programme and do not miss the cognitive aspects. In addition to that, for students from the UvA's this is covered in the bachelor's programme Artificial Intelligence. They also indicated that the free electives can be used for courses on those aspects not present in the core programme. A few years ago, the track that existed on this subject was transformed into a separate master's programme, namely: Cognitive Science. The lecturers confirmed the technical character of the programme and that it is possible for students to graduate in artificial intelligence without knowledge of the cognitive and philosophical aspects. Interested students can choose electives in these subjects. The committee recommends the programme to motivate students (with a background other than the UvA's bachelors' programme) to choose electives that ensure that the broader field of AI is covered.

The committee appreciates the mandatory first semester of the programme. It ensures that all students achieve the same level for the other courses. The tracks give students ample room for specialisation.

Academic and professional skills
Students acquire academic skills during the projects and the master's thesis. In both cases, students study literature and develop and implement computational methods. The projects are concluded with a written report and a presentation. In the projects, students learn academic skills, project management skills and communication skills. Projects are done in small groups (2–3 students). In the master's thesis, according to the self-evaluation report, students develop skills and understanding of a sub-discipline and an overview of the current state of the art of

that sub-discipline. In some courses students work on projects, in which academic and professional skills are practised. During the site visit students confirmed that projects are done in small groups. At the end of the *Autonomous Agents* course, the lecturer held individual interviews with the students to prevent freeriding. Due to an increase in student numbers, however, this was not possible this academic year.

The committee noted that even though research and research skills are an important part of the programme, the programme does not offer any philosophical reflection on conducting research in the field of artificial intelligence. The committee is of the opinion that this is an important aspect of being a researcher and recommends incorporating this in the programme.

Labour market
The self-evaluation report states that it is possible to do projects for companies or external research institutes. Graduation projects can be also done for external organisations. The self-evaluation report remarks that lecturers collaborate with industrial partners such as IBM, Philips, Logica, TomTom, Thales Nederland, Unilever, Guerilla Games and Lost Boys. There are also collaborations with the Stedelijk Museum and the Dutch Forensic Laboratory. During the site visit it became clear that even though students confirmed that they are encouraged to do external projects, they also would like to be informed more about the industry, for example, during extra-curricular activities.

Alumni indicated during the site visit that the acquired project and presentation skills are valuable for their work in the professional field. They also appreciated the combination of theoretical and practical aspects in the programme. They revealed that the contacts with the professional field were limited in the programme and depended on the student's own initiative.

In conclusion, the committee feels that the development of academic and professional skills is very well addressed within the programme. However, it recommends that the programme pay more attention to the philosophical aspects of research in the field of artificial intelligence. Even though the committee appreciates the opportunities for doing projects for external organisations, it advises informing students more actively about working in industry. For example, by inviting alumni as guest lecturers. The committee is positive about the different tracks, the coherence and specialisation they provide in the individual study programmes. In general, it is also positive about the content and organisation of the programme. The lectures provide state of the art information in the five specialisations, presented by lecturers who are recognised research authorities in the given fields. The committee reviewed the literature used in the programme and concludes that the 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 by the programme in the self-evaluation report. In addition, it gained insight into the way the learning outcomes are translated within the programme by examining the study guide, textbooks and literature used in the programme. In the course descriptions, the objectives are described for each course. The committee concludes that the intended learning outcomes are cross-matched to the different components of the programme. It noted, however, that no direct reference is made to the intended learning outcomes in the course descriptions. It also noted that the descriptions of the objectives from different courses 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 (Basis Kwalificatie Onderwijs), more uniformity will be realised in the near future.

The committee recommends that the programme critically review the objectives and their formulation, and to match the course objectives directly to the intended learning outcomes.

2.3 Educational concept
The self-evaluation report states that the programme aims to train students to the level at which they can independently execute research and develop projects in the field of artificial intelligence. During the site visit, the management confirmed that the educational concept is based on academic research. Students are trained for PhD positions, and courses are directly related to the lecturer's research.

The programme uses different types of didactical formats: courses and projects. In general, the courses aim to achieve a proper balance between theory and practice. They usually consist of weekly lectures, workshops and practicals for exercises and practical work. During practicals and lab sessions, students get hands-on experience by doing mathematical exercises, for example, or developing and testing computer software. According to the self-evaluation report some courses have a more technical character while other courses pay more attention to communication skills. In the *Computer Vision* and *Advanced Topics in Autonomous Agents* courses, small groups of students report on a scientific paper.

The self-evaluation report states that the development and testing of software in real-world applications is important in order to acquire better insight into practical problems. In the projects students apply the knowledge provided by the previous lectures, preferably in a real-world context. The first-year AI project consists of a literature study, developing and implementing computational models, a written report, a presentation and a demonstration of the software. The profile project prepares students for their graduation project. It contains an in-depth study of different research topics taught during the various courses, which have to be put into practice.

The number of contact hours decreases over the programme, from 9.5 hours per week in the first year to 4.9 in the second year.

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 master's programme. The research-based educational concept is also adequately implemented. It concludes that the number of contact hours is sufficient.

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

The self-evaluation report states that new students are welcomed the week before the lectures start. During an introductory programme they are informed about practical matters and the programme and meet their lecturers, study advisors and fellow students. The first six months of mandatory courses determine whether the programme is suited for the student (and vice versa). This period is also used to allow the international students to work together and create a community. After this period, the students will make several choices regarding the electives and the graduation project. Students are guided in this process by student advisors, who offer

course-specific supervision and information. Student advisors also monitor the student's progress, set targets for improving study results and organise mentoring for students (by lecturers or students).

In addition to the regular lecture rooms, small conference rooms are available for groups of students, plus computer facilities with dedicated software, and the programme has robotics facilities. The committee was impressed by the facilities for students. The activities in the framework of Robocup are highly appreciated by the committee.

2.5 Student intake and study progress

Student intake
The committee concludes that the programme applies adequate admission criteria. The self-evaluation report revealed that on average 30 students enrolled in the programme in the last few years. In 2010-2011 academic year, 25 students enrolled. Students can enroll twice a year, in September and in February. Students with a bachelor's degree in Artificial Intelligence or Computer Science are automatically admitted. All other applications are evaluated on an individual basis. Students have to submit an application form, accompanied by diplomas, a motivation letter, two letters of recommendation and proof of English proficiency. For students who do not yet meet the requirements (but are expected to be able to do so within a reasonable period of time), a pre-master's programme is available. The international character of the programme is reflected in the nationalities of the students. The programme attracts quite a lot of international students, from a wide range of countries. The committee appreciates this.

Study load
The committee confirmed that the programme is feasible, based on the information provided by the programme and the interviews conducted with students, lecturers and alumni. In addition, the committee noted that measures are taken when parts of the programme are discovered to be impeding the students' study progress. During the site visit students indicated that they study 30 to 40 hours per week on average.

Completion rates
The self-evaluation report states that from the 2009 cohort, 61% of the students completed the programme after three years. The drop-out rate is on average 16% per cohort. For the 2009–2010 cohort, the average duration of the programme is 28 months. The self-evaluation report states that international students are more inclined to finish the programme within 24 months. According to the self-evaluation report, the delay is caused by the student's financial situation and extra time spent on the thesis. Thesis supervisors, who check the time frame and project management of the thesis, monitor the latter. To improve the completion rates, the programme plans to assign a mentor to the students. The mentor (a core lecturer of the programme) guides students in the choices to be made and offers help regarding study difficulties and career opportunities. In addition, the programme plans to structure the thesis project and to install a computer room for students working on their thesis project. This should increase the time students spend on their thesis.

The committee is of the opinion that the completion rates are adequate. It welcomes the proposal for academic mentors and the structuring of the thesis project mentioned in the self-evaluation report. It expects that this will contribute to an improvement of the completion rates.

2.6 Staff

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. It is of the opinion that the staff is equipped to provide the programme.

There are 29 lecturers involved in the master's programme, with a total amount of 3.82 FTE in the 2012-2013 academic year. The committee ascertained that there is currently an acceptable staff: student ratio of 1:22.

According to the self-evaluation report, all courses are taught by lecturers actively involved in research in the topics of the course. The self-evaluation report states that this ensures that students receive state-of-the-art knowledge in the key areas of AI during the courses. It also states that lecturers work in close cooperation with the industry, which gives students insight into the application of knowledge in real-life, practical situations. The lecturers are also involved in international summer schools and international conferences and have received several research grants.

The teaching staff consists of three professors, five associate professors, eleven assistant professors, five lecturers, two post-docs and three technical staff members. The core team is responsible for administering the programme and teaches most of the key courses. Post-docs and PhD students in general teach study groups and practical assignments. Most staff members spend 60% of their time on research and 40% on teaching. Of the 29 lecturers involved in the programme, 94% have a PhD degree.

The self-evaluation report mentions that 42% of the lecturers has a BKO certificate (Basic Teaching Qualification). New lecturers are required to complete the BKO training within two years of their employment. The programme expects all lecturers to have acquired their BKO certificate within three years. The committee urges the programme to encourage this, since it is of the opinion that the number of BKO registrations is quite low.

The self-evaluation report states furthermore that a team of lectures is formed for each track, chaired by a track coordinator. This team is responsible for developing and executing the education. The team formation is based on the required expertise and a balance between the different research fields. In the annual performance review for each staff member, the teaching activities are also evaluated, using his/her digital portfolio. The digital portfolio contains information about the courses, the evaluation of the courses, the individual supervision of students, educational activities and research.

The site visit revealed that students are in general satisfied with their lecturers. It became clear, however, that the contact with professors is limited. Students are aware of the research topics addressed by their thesis supervisor. The committee recommends that the programme increase the involvement of full professors in the courses and lectures. This will inspire students and give them ample state-of-the-art knowledge.

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 explored the extent to which students and lecturers are involved and heard in the evaluation and improvement of the quality of the teaching. The self-evaluation report refers to the faculty's Quality Assurance Manual. It describes the actors involved in the quality assurance process, the steps of this process and the teaching evaluations. During the site visit the committee studied this manual. It is of the opinion that the manual is quite accurate and elaborate. All of the courses are evaluated on a yearly basis, 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 and discusses the courses, their evaluation, the examination regulations and the collaboration with other parties. In addition, the results of the National Student Survey are used to acquire information about student satisfaction. During the site visit it became clear that students are not immediately informed about the results of the evaluations, unless a lecturer explicitly refers to the changes made due to last year's evaluations.

The site visit revealed that alumni are not yet actively involved in the quality assurance of the programme. Alumni are invited for to give guest lectures, and an alumni association is currently being set up.

The committee is of the opinion that the design of the quality assurance system is adequate. During the site visit it became clear that both lecturers and students are involved in general, and their opinions are heard in reference to the quality of the teaching. The committee also had the opportunity to talk to members of the programme committee during the visit. It noted that full professors do not participate in the programme committee. 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 being 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 the 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, reference is made to the recommendations of the previous assessment committee. For example, the AI aspects in the gaming track are more closely monitored, by focusing on AI techniques in games. A researcher on serious games has recently been appointed, who is involved in supervising the gaming-related projects. Furthermore, the Web Information Processing track was introduced in 2009.

The committee concludes that the programme is paying sufficient attention to measures for improvement suggested by the previous assessment committee. 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 objectives as described in the course descriptions could be more uniform and more explicitly related to the intended learning outcomes.

The committee is positive about the mandatory first semester of the programme. This ensures that all international students have the same starting level for the other courses. In addition, the different tracks offer students specialisation. The committee is of the opinion that the tracks and projects provide quite a lot of coherence in the individual study programmes.

The committee concludes that the development of academic and professional skills is very well addressed within the programme. The programme does not offer any philosophical reflection on conducting research in the field of artificial intelligence, however. It recommends paying more attention to this aspect.

The committee appreciates the opportunities students have to execute the research projects for external organisations. It advises informing students more actively about the industry, for example, by inviting alumni as guest lecturers.

The committee is of the opinion that the services provided to students (both guidance and facilities) are sufficient. It also appreciates the opportunities for students to study abroad.

The programme is feasible and attracts quite a lot of international students, from a wide range of countries. The committee appreciates this. The completion rates are adequate. The committee recommends that the programme implement the academic mentors and the structuring of the thesis project mentioned in the self-evaluation report. It expects that this will contribute to an improvement of the completion rates.

The programme is based on research-oriented teaching. The committee is of the opinion that the educational principle is consistently implemented, with an important role given to the research projects. 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. It recommends increasing the involvement of full professors in the courses and lectures. It confirmed that an adequate quality assurance system is in place.

Conclusion

Master's programme Artificial Intelligence: the committee assesses Standard 2 as **satisfactory**.

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 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 graded (of both the bachelor's and master's programme Artificial Intelligence). It is also responsible for processing requests for exceptions, executing the 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 Board of Examiners consists of four members. The self-evaluation report reveals that a department-wide examination policy is currently being developed and implemented. Part of this policy involves setting learning goals for each course, guidelines for creating exams, criteria for assessing projects and skills, and assessment matrices and criteria for exams. According to the self-evaluation report, the Board relies on student's complaints and course evaluations to measure the quality of exams. It also states that the programme is considering appointing an examination assessment committee, to report to the Board of Examiners and assess the quality of the exams. In 2013, the Board wants to develop a more explicit marking system for the theses (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 remarked that full professors do not participate on the board. It also noted that the Board is quite reactive. It became clear however, that the Board is actively involved in assessing the theses of the master's programme: a member of the Board chairs all committees assessing the theses. The understaffing of the Board and the increase in tasks jeopardize this process, however. The Board members also confirmed that the assessment policy is currently being developed and implemented. It became evident that peer review of assessments is not 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.

Based on the information provided in the self-evaluation report and the interviews held during the site visit, the committee is of the opinion that the Board of Examiners has

sufficient insight into the quality of the examinations and takes adequate measures when necessary. It notes, however, that the Board is understaffed and urges the programme to fill the current vacancy (preferably with a full professor). It also urges the Board to implement the examination policy. The committee is positive about the involvement of the Board in the assessment of the theses, even though it recognises that this is quite a time-consuming process. It supports the plans to appoint an examination assessment committee and to develop more explicit criteria for assessing the thesis. It recommends implementing these plans quickly.

Assessment policy, process and forms
The self-evaluation report states that written exams are the standard form of assessment. Other forms such as homework, presentations, practical assignments, project work, developing prototypes and discussion of papers are also used. All courses use multiple forms of assessment. The *Advanced Topics in Autonomous Agents* course, for example, uses weekly paper responses, class participation, a paper presentation and a research project report. The *Advanced Information Retrieval* course uses a midterm exam, practical assignments and a final exam. The final grade of a course is determined by weighing the different forms of assessment used. The committee noted that the different forms of assessment are mentioned in the course descriptions. The weighing is not covered, though. The committee recommends that the programme describe this for all courses. Projects are usually assessed by a report and a presentation.

Students are informed about the assessments and criteria in the course descriptions and the study guide. The results of the exams are announced within 15 working days. Students can inspect their corrected exams within 30 days after the results are known.

During the site visit students remarked that the level of assessments differs per course. The assessment of some courses is very challenging, others required less effort. Students especially appreciate the challenging assessments of the *Machine Learning* courses and the *Autonomous Agents* 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 are adequate in terms of level and content. It is positive about the use of multiple assessment forms in each course. This ensures that not only theoretical aspects but also application of the theory are assessed.

Graduation project
The committee examined the procedure for the graduation project and also read and assessed a total of 15 theses. It is of the opinion that the thesis procedure is adequate. It gives individual students the opportunity to show that they have achieved the intended learning outcomes. In addition to that three staff members, including a representative from the Board of examiners, using standardized assessment criteria, assess the graduation project.

The graduation project (42 EC) is individual and provides students with further specialisation in one area of the field of Artificial Intelligence. Students are expected to advance the state-of-the-art and to evaluate their results. In addition, the graduation project should provide a research contribution or innovation. Lecturers, companies, research industries or students propose topics for theses. Students can find a supervisor themselves or can be assisted in this by the track coordinator. The graduation project results in a thesis written in the form of a scientific paper in academic English and a presentation.

The self-evaluation report states that students can combine the graduation project with an external traineeship. They are also allowed to follow additional courses, which address the

topic of the graduation project.

A supervisor, a member of the staff, guides students. The site visit revealed that students are in general positive about the thesis guidance. Supervisors are easily accessible, and appointments can be made in response to the student's need.

The thesis is assessed by a committee consisting of the supervisor, a second independent staff member and a member of the Board of Examiners (chairman). When the graduation project is done for an external organisation, supervisors from the organisation are added to the assessment committee. The grade is based on the report, the presentation and the oral defence (questions from the assessment committee right after the presentation). As mentioned earlier, the assessment criteria of the graduation project will be refined in the coming period.

The self-evaluation report shows that many theses have resulted in scientific publications. In addition, four UvA theses have won the KION thesis prize in recent years.

During the site visit, the committee discussed the length of the thesis project (42 EC) with the lecturers. Even though the committee is of the opinion that the level of the studied theses is quite high, it also realises that students can spend quite a lot of time writing their thesis. Lecturers remarked that the thesis is focused on academic research and seen as a small PhD thesis. They also indicated that the number of credits is different from other programmes, but the theses produce more research results. In addition, theses sometimes lead to scientific articles or conference papers.

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 master's programme do achieve the required level. The theses were written in the form of a scientific paper, and some theses also were published as scientific papers. The committee concludes that the form of a scientific paper guarantees a logical and coherent composition. The examined theses discussed quite complex topics and were in general very well written. They were characterized by a logical structure, a clear and relevant problem definition, and adequate use of research methods.

The committee reviewed the job positions of graduates of the master's programme and whether they were adequately prepared for them. The self-evaluation report refers to a survey among alumni. It revealed that alumni find a job within a month after graduation. All graduates found jobs that match the content and level of the programme. Popular functions are PhD positions, (scientific) programmer, software/web developer and start-ups (creating their own business). The survey also revealed that alumni are in general satisfied with the programme. They value its academic character, the teamwork, the cohesion and the subject knowledge offered. The survey revealed that the development of personal and professional skills and feedback and guidance could be improved. The previously mentioned mentoring system and the introduction of assessment criteria can help amend this. During the site visit

alumni indicated that especially the combination of theoretical and practical aspects (projects) prepared them for their current jobs.

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 multiple assessments in the different courses. It advises the programme to develop and implement an assessment policy. 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. It appreciates the fact that the Board is actively involved in the final presentations and grading of all theses. It advises the programme to fill the vacancy on the Board of Examiners swiftly.

The committee concludes that the master students acquire a high final level by the end of the programme. This was confirmed by the theses it evaluated.

Conclusion

Master's programme Artificial Intelligence: the committee assesses Standard 3 as **satisfactory**.

General conclusion

The committee assesses the *master's programme Artificial Intelligence* as **satisfactory**.

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

[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

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'.

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

[5] In Dutch: Kunstmatige Intelligentie

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.

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

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

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.

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.

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

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;
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:

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

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]

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

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.

Appendix 3: Intended learning outcomes

Objectives
A student who has obtained the degree of Master in Artificial Intelligence will have extensive knowledge and understanding of Artificial Intelligence. The Master programme is designed according to the following objectives:

1. Knowledge and understanding, the student is able to formulate a research plan, able to judge the quality of his/her own work and the work of others, and is able to understand the key areas in Artificial Intelligence.
2. Applying knowledge and understanding, the student is able to solve complex problems and applies his/her knowledge and understanding of this in a scientific manner.
3. Making judgements, the student is able to formulate an opinion or judgement on the basis of possibly incomplete information.
4. Communication, the student can communicate information to audiences of specialists as well as nonexperts.
5. Learning skills, the student is able to detect and adjust missing knowledge accordingly.

The objectives of the programme correspond to the definition of Artificial Intelligence by Kunstmatige Intelligente Opleidingen Nederland (KION) as reported in the frame of reference.

Exit qualifications
Anyone who has obtained a master degree in AI:

1. has thorough knowledge of the current theories, methods and techniques in the field of Artificial Intelligence;
2. has specialized knowledge of at least one of the following Artificial Intelligent subfields:
   - gaming
   - intelligent systems
   - learning systems
   - natural language processing and learning
   - web information processing
   - communication and education
3. has the capability to apply this knowledge to analyse, design and develop AI systems;
4. can formulate scientific questions and is able to solve problems with the aid of abstraction and modelling;
5. is able to contribute to further developments of the theories, methods and techniques of the AI in a scientific context;
6. is able to express him/herself clearly on a technical/mathematical and general level;
7. is aware of the social context and consequences of conducting AI research;
8. can obtain an academic position at a university or research centre or scientific/applied position in the industry.

Appendix 4: Overview of the programme

Obligatory Courses AI

	EC	Semester	Period
Information Retrieval	3	1	b
Autonomous Agents	6	1	a
Intelligent Multimedia Systems	6	1	b
Machine Learning: Pattern Recognition	6	1	a
Elements of Language Processing and Learning	3	1	b
Project AI	6	1	c

Programme Track Gaming

	EC	Semester	Period
Advanced Topics in Autonomous Agents	6	2	a
Game Programming	6	2	b
Profile Project AI-Gaming	6	2	c
AI Courses	18		
Free choice courses	12		
Master Thesis AI	42		

Programme Track Intelligent Systems

	EC	Semester	Period
Computer Vision	6	1	b
Advanced Topics in Autonomous Agents	6	2	a
Profile Project AI-IS	6	2	c
AI Courses	18		
Free choice courses	12		
Master Thesis AI	42		

Programme Track Learning Systems

	EC	Semester	Period
Machine Learning: Principles and Methods	6	1	a
Advanced Topics in Autonomous Agents	6	2	a
Profile Project AI-LS	6	2	c
AI Courses	18		
Free choice courses	12		
Master Thesis AI	42		

Programme Track Natural Language Processing and Learning

	EC	Semester	Period
Statistical Structure in Language Processing	6	2	b
Unsupervised Language Learning	6	2	a
Profile Project AI-NLPL	6	2	c
AI Courses	18		
Free choice courses	12		
Master Thesis AI	42		

Programme Track Web Information Processing

	EC	Semester	Period
Web Text Mining	6	1	a
Advanced Information Retrieval	6	2	a
Profile Project AI-WIP	6	2	c
AI Courses	18		
Free choice courses	12		
Master Thesis AI	42		

AI Courses

	EC	Semester	Period
Courses (18 EC):			
Scientific Visualization and Virtual Reality*	6	1	a
Speech Perception and Production*	5	1	a
Pragmatics and the Lexicon*	6	2	a
Reasoning with Uncertainty*	6	2	b
Information Visualization*	6	2	a
Neural Nets and Symbolic Reasoning*	6	2	b
Advanced Topics in Autonomous Agents	6	2	a
Computer Vision	6	1	b
Web Text Mining	6	1	a
Advanced Information Retrieval	6	2	a
Game Programming	6	2	b
Machine Learning: Principles and Methods	6	1	a
Statistical Structure in Language Processing	6	2	b
Unsupervised Language Learning	6	2	a

*: Restricted to one course from this list as a constrained choice course, in all other cases as a free choice course.

Appendix 5: Quantitative data regarding the programme

Efficiency of the programme

Cohort	**2009**
Rendement	61 %

Quality of the teaching staff

Graad	**Master**	**PhD**	**BKO**
Percentage	100 %	94 %	42 %

Teacher-student ratio

Ratio	21,68

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

Studiejaar	1	2
Contacturen	9,5	4,9

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:

5939607	5840503	6108741
6111602	9946667	10027564
6110002	6018718	0438944
5765277	0512605	10004410
9865403	0251968	5622670

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

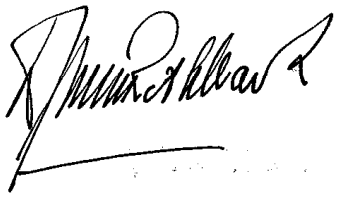
VERKLAART HIERBIJ ZODANIGE RELATIES OF BANDEN MET DE INSTELLING DE AFGELOPEN VIJF JAAR NIET GEHAD TE HEBBEN;

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:



nvao
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:

UU / UvA / VU

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

PLAATS: Beneschot

DATUM: 14 maart 2013

HANDTEKENING: T-J Gratt

nvao
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

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;

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nederlands-vlaamse accreditatieorganisatie

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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

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;

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nederlands-vlaamse accreditatieorganisatie

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

PLAATS: Deskelbrug

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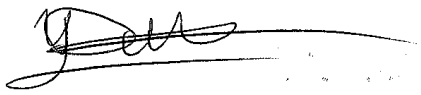
VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Utrecht DATUM: 14-03-2013

HANDTEKENING:



nvao
nederlands-vlaamse accreditatieorganisatie

ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: T. Bouwy

PRIVÉ ADRES: De Ondde Wlaverbeek 20
7339 GZ Ugchelen

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

Kunstmatige Intelligentie

AANGEVRAAGD DOOR DE INSTELLING:

RUG / UM / U.A

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

PLAATS: Utrecht

DATUM: 14-3-2013

HANDTEKENING: