Knowledge Engineering

Faculty of Humanities and Sciences,
Maastricht University

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This report was finalized on 10 November 2013.

Report on the bachelor's programme Knowledge Engineering of the Faculty of Humanities and Sciences, Maastricht University

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

Administrative data regarding the programme

Bachelor's programme Knowledge Engineering

Name of the programme:	**Knowledge Engineering**
CROHO number:	50300
Level of the programme:	bachelor's
Orientation of the programme:	academic
Number of credits:	180 EC
Specializations or tracks:	-
Location(s):	Maastricht
Mode(s) of study:	full-time
Expiration of accreditation:	December 31st 2014

The visit of the assessment committee Artificial Intelligence to the Faculty of Humanities and Sciences at Maastricht University took place on May 28 and 29, 2013.

Administrative data regarding the institution

Name of the institution:	Maastricht University
Status of the institution:	publicly funded institution
Result institutional quality assurance assessment:	applied (pending)

Quantitative data regarding the programme

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

Composition of the assessment committee

The assessment of the bachelor's programme Knowledge Engineering 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. dr. drs. 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 Catholic University of 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 Rothkranz attended all visits.

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

The committee that assessed the bachelor's programme Knowledge Engineering 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. 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 Thales Research & Technology Delft;
- 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;
- Y. (Yfke) Dulek, student of the bachelor's programme Artificial Intelligence at Utrecht University.

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

Working method of the assessment committee

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

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

Site visit
The coordinator prepared timetables for the visit in consultation with the committee chair and the participating institutions. The timetable for the visit for the bachelor's programme of Maastricht University 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, it spoke to faculty and programme management staff, students, lecturers, members of the programme and examination committees, and alumni.

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

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

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

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

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

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

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

Summary judgement regarding the quality of the bachelor's programme Knowledge Engineering

This report reflects the findings and considerations of the committee on the bachelor's programme in Knowledge Engineering, Maastricht University. 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, which 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 **satisfactory**. The committee compared the programme to the domain-specific reference framework. It concludes that the framework gives an adequate picture of the AI domain and the basic knowledge and skills that graduates need to acquire. The intended learning outcomes of the programme are, in general, in line with the framework. The programme chooses a more technical approach to AI, however, by focusing on applied mathematics and computer science. In addition, linguistic and cognitive aspects are not covered. The committee is of the opinion that because of this, the programme is not a classical AI programme. It operates on the borders of the AI domain.

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

Even though the committee values the international and academic level and orientation of the programme, it advises the programme to define its position in the field of AI more clearly, so the choices made can be better accounted for.

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 also concludes that the match between the intended learning outcomes and the projects could be more balanced. This would enable monitoring of the realisation of the intended learning outcomes and ensure that the intended learning outcomes fit the increasing complexity of the projects.

The committee concludes that the more technical approach to AI (see standard 1) is evident in the programme. It is of the opinion that the curriculum is coherent and academic and that professional skills are adequately addressed. The projects play an important role in this. For courses directly related to the projects, the coherence is distinct. Courses that are not related to projects are more isolated. The committee finds that reflective skills could receive more attention in the programme. Students learn to analyse and solve complex problems but do not learn how to reflect on the scientific relevance of their work or the relation with the broader field of AI.

The committee appreciates the international character of the programme and the opportunities it gives students to study abroad. It is also pleased to see that students take advantage of these opportunities. It concludes that the intake procedure and study load are adequate. The completion rates are relatively low, however. The committee expects that the introduction of a binding and matching procedure and the binding study advice will improve these rates.

The programme is based on a Project-Centred Learning concept. The committee is of the opinion that the educational format is consistently implemented. Students also appreciate this and confirmed that they learn to apply theory in practice. The number of contact hours is also 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 can be intensified. Regarding the training of lecturers, the committee recommends formalising the didactical training of new lecturers regarding the PCL concept.

The committee confirms that an adequate quality assurance system is in place. It notes that the programme is quite small in scale and informal. To provide more structural management information, the programme committee will start drawing up annual reports. The committee supports this step.

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. Students are content with the assessment in general. The committee 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 recommends that the programme instruct lecturers to fill out all the aspects of the thesis assessment forms systematically. In addition, it advises the Board of Examiners to regularly assess a selection of theses and to actively monitor the relationship between the thesis and the field of AI.

Even though the studied theses do not all have a direct relationship with the field of AI, the committee is of the opinion that their overall quality and level are good. Therefore, it concludes that graduates of the bachelor's programme achieve the required level.

Bachelor's programme Knowledge Engineering

The committee assessed the standards from the Assessment framework for limited programme assessments in the following way:

Standard 1: Intended learning outcomes	Satisfactory
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: 10 November 2013

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

drs. T. Buising

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

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

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

Findings

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

1.1 Domain-specific reference framework
Traditionally, researchers in the field of artificial intelligence (AI) are 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) composed a domain-specific reference framework (hereinafter: 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. The committee noted that in general all programmes that were assessed 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 to highlight certain topics and add parts of new disciplines. The committee noted that some misunderstanding arises because the different programmes give different interpretations of 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 elaborated on more in the framework. This could also prevent the divergence of the AI programmes on this matter.

According to the self-evaluation report, the intended learning outcomes of the international bachelor's programme at Maastricht University overlap considerably with the KION framework. However, some topics such as computational linguistics and cognitive aspects are barely covered. The self-evaluation report states that this results from the programme's emphasis on mathematics. The committee is of the opinion that the programme operates on the borders of the AI field. The fact that linguistic and cognitive aspects are not part of the profile confirms this suspicion.

1.2 Profile and orientation
The self-evaluation report states that the international bachelor's programme aims to provide students with a solid foundation in knowledge engineering by training them in artificial intelligence, computer science, and applied mathematics. The programme apparently differs in two respects from other Dutch AI programmes. First, the programme has a stronger emphasis on exact sciences, i.e., it provides a different coverage of AI-related topics. Second, the programme uses the educational concept of Maastricht University, in which groupwise collaboration and problem-based education (PGO) are emphasised (see also Standard 2).

The programme has an academic orientation. This is reflected in the thesis, which takes the form of a scientific paper. The academic orientation is also visible in the five goals of the programme:

1) to educate students at an academic level in Knowledge Engineering based upon Mathematics and Computer Science;
2) to teach students how to analyse and solve Knowledge Engineering problems in a variety of application domains;
3) to prepare students to work in teams by organizing the education in Knowledge Engineering according to the Project-Centred Learning system;
4) to prepare students for further study, in particular the master programmes in Artificial Intelligence, Operations Research, Knowledge Engineering and Computer Science or for a career in business (IT industry or IT-related application domains);
5) to stimulate students to acquire an international academic orientation.

According to the self-evaluation report, the programme prepares students for a professional career as a Knowledge Engineer in a variety of application domains in industry or society (governmental as well as non-governmental institutes) as well as for master programmes.

During the site visit, the committee discussed the profile of the programme with the management. Representatives from the management indicated that the programme is not a classical AI programme, for it focuses more on applied mathematics and computer science. They remarked that graduates from the bachelor's programme in Knowledge Engineering can enrol in several master programmes, such as the master programme in Artificial Intelligence and the master programme in Operations Research. They also stated that bachelor students are motivated to specialise in either operations research or artificial intelligence. It also became clear that the historical context plays an important role in the current profile of the programme. It originates from two other programmes, in mathematics and operations research. During the site visit it became apparent that this profile of applied mathematics and computer science is recognised by both students and lecturers. The students admitted that this was even the main reason for choosing this programme.

Even though the committee concludes that the interdisciplinary profile and academic orientation of the programme are appropriate for a bachelor's programme in the field of AI, it also recommends specifying its position further. For example, by defining what AI contains and what this means for the choices made in the profiling of the programme.

1.3 Intended learning outcomes
The intended learning outcomes of the programme (Appendix 4) reflect the five specified goals of the programme. They also reflect the qualifications mentioned in the KION framework. Graduates are expected, for example, to have gained knowledge of artificial intelligence, computer science and applied mathematics. Also, they are able to assess the

suitability of models, theories, formulated hypotheses and ideas in the domain of knowledge engineering. The committee concludes that the learning outcomes are of an academic nature and level. It is also of the opinion that they reflect the most important aspects of the framework.

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

Considerations

The committee compared the programme to the domain-specific reference framework. It concludes that the framework gives an adequate picture of the AI domain and the basic knowledge and skills that graduates need to acquire. The intended learning outcomes of the programme are, in general, in line with the framework. The programme chooses a more technical approach to AI, however, by focusing on applied mathematics and computer science. In addition, linguistic and cognitive aspects are not covered. The committee is of the opinion that because of this, the programme is not a classical AI programme. It operates on the borders of the AI domain.

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

Even though the committee values the international and academic level and orientation of the programme, it advises the programme to define its position in the field of AI more clearly, so the choices made can be better accounted for.

Conclusion

Bachelor's programme Knowledge Engineering: the committee assesses Standard 1 as **satisfactory**.

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 Knowledge Engineering are examined (2.1). In addition, the learning outcomes (2.2) educational concept (2.3), services provided to students (2.4), intake and study progress (2.5), teaching personnel (2.6) and programme-specific internal quality assurance (2.7) are discussed.

2.1 Curriculum
The bachelor's programme is a three-year programme, consisting of 180 EC. In its first two years the programme follows the 8-8-4 system: each semester consists of two eight-week blocks and one four-week block. In the first semester of the third year, students compose their own programme. The last semester consists of one regular block and the bachelor's thesis.

The first year of the programme consists of courses mainly concerned with mathematical and computer science subjects. The students also follow courses such as *Introduction to Knowledge Engineering* course and *Knowledge representation and Cognitive Psychology*. In the first year, students also take the *Introduction to Business Management* course. This course aims to give students an understanding of the organization of businesses, business processes and the most common business fields (such as strategy, logistics, marketing, finance, etc.). During the first year students also carry out four smaller projects.

The second year introduces students to the more application-centred mathematical and computer sciences subjects. The students attend courses such as *Philosophy of Science*, *Reasoning Techniques*, *Linear Programming* and *Machine Learning*. The second and third year include respectively two and one project. These projects are larger and more complex than the first-year projects.

The third year offers students deepening in the application of AI and business mathematics. The first semester of the third year (in total 30 EC) is flexible and offers students specialisation in their direction of interest. The individual programmes for this semester have to be approved by the Board of Examiners. The students have to choose at least four optional courses. They can opt for elective courses offered by the department or courses (or a minor) from other programmes or faculties. An educational minor is also possible. Students can also participate in a honours research programme (students have to be selected for this programme). Study abroad is also possible. In the second semester of the third year, students take four mandatory courses. Their main priority during the last semester is the bachelor's thesis project (18 EC). During the site visit students remarked that in choosing optional courses, they follow their own interest. They also revealed that the relevance of some courses (especially the ones that are not linked to a project or that do not have a follow-up course) is not always clear.

The committee concludes that the above-mentioned technical approach to AI (see standard 1) is evident in the programme. During the programme, students follow courses such as *Introduction to Computer Science*, *Discrete Mathematics*, *Linear Algebra*, *Calculus*, *Probability and Statistics* and *Chaos and Fractals*.

Academic and professional skills
The self-evaluation report states that the academic and professional skills are taught in the different projects. In the projects, skills such as writing, presenting, demonstrating leadership, cooperation, critically appraising and arguing, and showing initiative are addressed. The knowledge and insights learned during the courses are implemented in the projects. To acquire all the relevant skills, students take different roles in the projects. They receive feedback from their tutor and two examiners. For each project, a block book is available for students. The block book gives a description of the project and its setting, the different phases and the assessment of the project. Also, the relation with relevant courses is highlighted. In the second and third year, the projects are more closely related to the business community. The academic and professional skills are also trained in the bachelor's thesis project.

The site visit revealed that students are positive about the projects. The students also confirmed that the projects are related to the courses taught in the same block. During the projects students learn to apply their acquired knowledge and to search for more knowledge and insights. The students also confirmed that the projects increase in complexity and that independence is expected from students throughout the programme. Students have weekly meetings with the project coordinator during the project.

In the second year, the *Philosophy of Science* course is offered. This course provides students with a basic understanding of the different theories of scientific knowledge. They learn to reflect on fundamental issues with regard to science. During the course students practice their critical argumentation skills.

Labour market
The self-evaluation report states that the projects play an important role in preparing students for the professional field. During the projects students apply their acquired knowledge and insights, knowledge and skills from different disciplines are integrated, they work and reason on an academic level and acquire professional skills. The optional third year summer school at Manchester University offers students a four-week internship during which they design their own information-based company. The students acquire basic knowledge about entrepreneurship and how to make business and marketing plans, etc. The site visit revealed that the study association also organises activities such as a business day and a café meeting with PhD students.

The committee reviewed the literature used in the programme and concluded that relevant literature is studied. It feels that the development of academic research skills and professional skills is adequately addressed within the programme. The projects play an important role in this aspect. In general, the committee also approves the structure, content and organisation of the programme. It is coherent, which is also partly due to the projects. The relation between the courses and the projects is clear, especially when the knowledge of the course is used in the project. The relevance of courses that are not related to projects is not always obvious. Even though the *Philosophy of Science* course is taught in the second year, the committee is of the opinion that reflective skills could be addressed more in the programme. Students learn to analyse and solve complex problems but do not learn how to reflect on the scientific relevance of their work or the relation with the broader field of AI.

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, course books and the literature. It concluded that the intended learning outcomes are cross-matched to the different components of the programme. In the course descriptions, the content of each course is related to the Dublin descriptors. For each course the knowledge and insights learned are described, as well as the use of this knowledge. Also, the skills to be acquired (such as applying appropriate algorithms, designing and building a database or arguing critically) are defined per course.

The matrix in the self-evaluation report shows which intended learning outcomes are addressed in the projects. The vast majority of them are part of the projects, even the first-year ones. During the site visit, the committee spoke with several representatives of the programme about the realisation of the intended learning outcomes in the projects. It became clear that even though the projects are discussed on a weekly basis within the project groups and with the project coordinator, the realisation of the intended learning outcomes is not measured (or assessed) in a formal and structural manner. The committee is of the opinion that not all intended learning outcomes can be realised in all projects. It advises the programme to make the matrix in which intended learning outcomes are matched with the courses more balanced so that the increasing complexity of the projects is reflected in the intended learning outcomes addressed.

Internationalisation
The committee examined to what extent internationalisation is a part of the programme. Like all programmes at Maastricht University, it is taught in English. In 2001 the Transnational University of Limburg (TUL) was started, in which Maastricht University and Hasselt University cooperate. The master's programmes are embedded in this structure. The bachelor's programme is embedded in Maastricht University. The programme started cooperating with Aachen University in 2008, and courses have been developed for the Maastricht bachelor's programme and for related programmes in Aachen. Some of the courses of the programme are taught by staff from Aachen University. As mentioned before, the first semester of the third year can also be used to study abroad. In 2011 four students studied abroad. Third-year students can also participate in a summer school at Manchester University. The programme furthermore cooperates with several international universities such as Aarhus University, Université de Montreal, Singapore Management University and Hobart & William Smith College (New York). The programme attracts students from the Netherlands, Belgium, Germany and other EU and non-EU countries. Half of the students in the programme are non-Dutch.

The committee appreciates the international character of the programme and the opportunities it gives students to study abroad. The committee is also pleased to see that students use these opportunities.

2.3 Educational concept
The programme uses the Project-Centred Learning (PCL) concept. According to the self-evaluation report, students learn to apply their acquired knowledge in realistic and challenging projects. During each project students work in small groups (three to four students), execute all tasks of the project, write a report and present the results. The first year of the programme contains four smaller projects. In the second and third year the projects are larger. The committee noticed that even though the universities unique PCL concept is a very important part of the programme, it is not elaborated on in the self-evaluation report.

In addition to the projects, the programme uses lectures, practicals and skills training as the main teaching methods. The first-year *Introduction to Business Management* course employs a global business game. During this game students become acquainted with the basic decision-making skills for the relevant business subjects. The programme covers on average 18 contact hours per week. The students are also expected to participate in project groups for 3 hours per week. During the bachelor's thesis, students receive individual guidance, on average 1 hour per week.

The committee is of the opinion that the educational format suits the bachelor's programme and is adequately implemented. It also concludes that the number of contact hours is sufficient. The site visit revealed that students are satisfied with the educational format and its focus on connecting theory and practice.

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) provided to students are sufficient and enable them to achieve the learning outcomes of the programme.

First-year students are supervised by an academic mentor (a lecturer of the programme, one per three or four students) and the study advisor. In the second and third year the study advisor is available for guidance. During the introduction week, students meet their mentor. All first-year students meet with their mentor four times per semester. After each block the student's progress is monitored, and students are called for additional meetings with their study advisor. At the start of the 2012 academic year, the programme organised an interactive team dynamic workshop. During this workshop students of different backgrounds and nationalities worked together. The self-evaluation report states that students were very positive about this event. During the site visit it became clear that the study advisor also meets first-year students at least twice in the first year.

In addition to the regular lecture rooms, project rooms, computer facilities, etc., the programme has a Kecs cluster, robot lab and a swarm lab at its disposal. The Kecs cluster consists of 12 nodes and is available 24x7 for computations for the student's bachelor's thesis. The robot lab includes four humanoid robots (NAO). The swarm lab includes e-puck robots, turtlebot robots (I and II), a quad and one octocopter, a custom-built telepresence robot (MITRO) and a KUKA youbot (robocup competition).

The committee is of the opinion that the programme offers good facilities and guidance to students. The small scale of the programme also leads to an informal atmosphere.

2.5 Student intake and study progress

Student intake

The committee concludes that the programme applies adequate admission criteria. Each application is reviewed by the university's Student Service Centre. The self-evaluation report states that if necessary the programme's admission board reviews the applications.

The self-evaluation report revealed that the number of enrolling students has increased over the last years to approximately 50 per year. This increase is mainly due to the growing number of international students (from other countries than Belgium and Germany). About half of the enrolling students have an international background. Students can enrol in the programme with a vwo diploma (with Mathematics B or Mathematics D or Mathematics A and physics) or a relevant propaedeutic hbo-diploma. For international students similar admission requirements have been set. International students also need to submit proof of English language proficiency. The programme aims at 60 - 70 students enrolling each year. To increase the number of students, the information activities for incoming students have been intensified.

Study load

The committee confirmed that the programme is feasible, based on the information provided and the interviews it conducted with students, lecturers and alumni. In addition, it noted that measures are taken when parts of the programme are discovered to be impeding the students' study progress. The self-evaluation report states that the study load can differ depending on the choices students make in the first semester of the third year. Reference is also made to student evaluations. These indicate that students study on average 35 hours per week.

Completion rates

The self-evaluation report remarks that the drop-out rates are below the university's average, but higher than most exact programmes (see also Appendix 6). The self-evaluation report states that there is a mismatch between the requirements of the programme and the level of some (international) students. Of the 2006 cohort, 38% completed the programme in three years, 63% in four years, and 67% in five years. The success rate after three years varies from 30% to 42%.

The programme wants to decrease the drop-out rate in the first year to 25% (33% in 2011) and to increase the success rate to 80%. To do so, it wants to implement a binding and matching procedure that predicts the study success of candidate students. In addition, all courses in the first year are mandatory, and attendance is required. In 2012 the programme initiated several activities to decrease the number of international students dropping out. An interactive website has been developed for students who cannot visit the open day. A project has also been initiated to set up job opportunities for international students. In the 2013-2014 academic year, a binding study advice will be implemented in the first year of the bachelor's programme.

The committee is of the opinion that the completion rates are indeed relatively low. It expects that the introduction of a binding and matching procedure and the binding study advice will contribute to an improvement of these rates.

2.6 Staff

There are 25 lecturers involved in the bachelor's programme, with a total amount of 7.0 fte in the 2011–2012 academic year. The committee ascertained that there is currently an acceptable staff:student ratio of 1:17. In addition, it understood from students during the site visit that lecturers are in general accessible and approachable.

The committee studied an overview of the core staff members from the Knowledge Engineering Department (DKE), their position, level of education, and expertise. It recognises the staff's scientific quality, (inter)national academic reputations, and teaching experience. According to the self-evaluation report, all staff members are involved in the bachelor's programme. The staff is also involved in the master's programmes of the Department and in courses at Aachen University. The staff consists of three professors, four associate professors and thirteen assistant professors. External lecturers (professors, assistant professors and a teacher) are also involved in the coordination of courses. Guest lecturers and PhD students play a role in courses, projects and the supervision of theses. The self-evaluation report states that for each job profile, the norm hours for teaching are defined. A full professor for example is involved in teaching 45% of his time, an assistant professor 50% and PhD students 15%. Also, 92% of staff has a doctorate.

The international character of the programme is also reflected in the staff, with twelve different nationalities. The self-evaluation report mentions that 48% of the staff members has a BKO certificate (Basis Kwalificatie Onderwijs). This is below the university's standard of 67%. According to the self-evaluation report, the faculty wants to increase the number of BKO registrations in the coming year. The committee supports this, since it is of the opinion that the number of BKO registrations is quite low.

The site visit revealed that students are, in general, satisfied with the lecturers. Some lecturers have an open door policy, others prefer students to make an appointment by email. During the site visit, the committee talked with lecturers about the Project-Centred Learning concept. To its surprise, it became clear to the committee that new lecturers do not receive any formal training regarding this didactical concept. New lecturers always team up with a more experienced lecturer, however, and receive training on the job. The committee realises that this can work in such a small-scale and informal programme. It advises the programme to elaborate on the didactical concept in a manual, however, for lecturers to use as a reference.

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 courses and projects of each block are evaluated, and the programme committee discusses the results. The latter is responsible for advising the faculty board, director and Board of Examiners about the programme. It can also provide advice on any subject regarding the programme. It consists of four members (two students and two lecturers) and three advisory members (the director, the quality officer and the study advisor).

The committee is of the opinion that the design and functioning of the quality assurance system are adequate. During the site visit both lecturers and students stated that they are involved and their opinions are heard in reference to the quality of the teaching. The committee also had the opportunity during the visit to talk to members of the programme committee. It became clear that the programme committee reviews the evaluations and also gives students feedback regarding their comments on the evaluation forms. It was also remarked that in the near future the programme committee will be expanded to six members (three students and three lecturers). 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 supports the resolution of the programme committee to write an annual report. This will provide structural information for the programme management.

Improvements in response to the previous site visit

In the self-evaluation report, reference is made to the recommendations of the previous assessment committee. The number of projects in the first year has increased, to offer students experience with more project topics and project groups. Also, student mentoring and mandatory attendance have been implemented, and several new optional courses have been developed and introduced. The bachelor's thesis has increased from 14 to 18 EC, and even though the internships have been omitted from the programme, students can still follow an internship for their thesis.

The committee concludes that the programme is paying sufficient attention to the measures for improvement suggested by the previous visit. 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 also concludes that the match between the intended learning outcomes and the projects could be more balanced. This would enable monitoring of the realisation of the intended learning outcomes and ensure that the intended learning outcomes fit the increasing complexity of the projects.

The committee concludes that the more technical approach to AI (see standard 1) is evident in the programme. It is of the opinion that the curriculum is coherent and academic and that professional skills are adequately addressed. The projects play an important role in this. For courses directly related to the projects, the coherence is distinct. Courses that are not related to projects are more isolated. The committee finds that reflective skills could receive more attention in the programme. Students learn to analyse and solve complex problems but do not learn how to reflect on the scientific relevance of their work or the relation with the broader field of AI.

The committee appreciates the international character of the programme and the opportunities it gives students to study abroad. It is also pleased to see that students take advantage of these opportunities. It concludes that the intake procedure and study load are adequate. The completion rates are relatively low, however. The committee expects that the introduction of a binding and matching procedure and the binding study advice will improve these rates.

The programme is based on a Project-Centred Learning concept. The committee is of the opinion that the educational format is consistently implemented. Students also appreciate this and confirmed that they learn to apply theory in practice. The number of contact hours is also 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 can be intensified. Regarding the training of lecturers, the committee recommends formalising the didactical training of new lecturers regarding the PCL concept.

The committee confirms that an adequate quality assurance system is in place. It notes that the programme is quite small in scale and informal. To provide more structural management information, the programme committee will start drawing up annual reports. The committee supports this step.

Conclusion

Bachelor's programme Knowledge Engineering: 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 in the bachelor's programme are given (3.1), and then the question is addressed of whether students actually realize the intended learning outcomes (3.2).

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

Examination Board
According to the self-evaluation report, the Board of Examiners is responsible for the organisation and supervision of the examinations. The board consists of three members. 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 programme does not have an assessment policy or plan. The lecturers are responsible for the assessment of the courses. There is a feedback system, however, in which lecturers get feedback about the level of their assessments and the relationship with the intended learning outcomes.

The Board of Examiners does not yet actively monitor the assessment of theses by, for example, reviewing already assessed theses. A standard form is used for the assessment of theses. The committee noted, however, that lecturers do not always fill out all aspects of the form. Also, the information provided on the form does not always reflect the grade given. During the site visit this was discussed with the representatives from the Board of Examiners. It became clear that lecturers are responsible for filling out the forms, and the Board does not check the completed thesis assessment forms. This was confirmed during the interviews with the management.

The committee also discussed the assessment of the projects with the representatives from the Board of Examiners. Projects are graded by using a standard form. In addition, students discuss the projects on a weekly basis with the project coordinator, and the groups receive feedback after each block. The committee noted that even though the projects are graded and evaluated, whether the learning goals and intended learning outcomes related to the projects are realised is not systematically measured. This is done in a rather informal manner. The committee recommends formalising this procedure, for example by introducing a portfolio in which students can prove they have realised the specific learning outcomes.

The relationship of the theses to the field of AI was also discussed with the representatives from the Board of Examiners. Even though the theses read were of an adequate level, the relation with AI was not always evident. The Board of Examiners reviews every thesis proposal with regard to the research questions and the relationship with the programme. The committee believes that monitoring the relationship between the theses and the field of AI is an important part of the quality assurance of the assessment of AI programmes. It therefore recommends explicitly giving this task to the Board of Examiners.

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 advises the Board to pay attention to the transparency of the thesis assessment for students by consistently filling out the thesis assessment forms. It also recommends that the Board of Examiners regularly review a selection of theses and actively monitor the relationship with the field of AI in the theses. Finally, it recommends that the programme develop and implement an assessment policy and plan.

Assessment policy, process and forms
The self-evaluation report states that, as a rule, all courses of the bachelor's programme are assessed by a written exam at the end of the block. Most exams consist of open questions and are either open or closed book exams. For some courses, the assessment also includes practical assignments (for example, the *Computer Sciences* courses, the *Semantic web* course and the *Intelligent Systems* course). The *Philosophy of Science* course is assessed by means of an essay and the *Human Computer Interaction & Social Media* course by a small group assignment. The *Knowledge Management* course is assessed by a written exam, a paper and a presentation. For some courses students can acquire one bonus point by making optional bonus assignments. When assignments are used, the weighting attached to the assignments is specified in the course descriptions. Students are informed about the assessments and criteria in the course descriptions and the study guide.

The projects are evaluated three times by two examiners: intermediate presentations at the end of the first and second block and the final presentation at the end of the third block. The intermediate presentations are given to the examiners and the tutor, who provide students with feedback. The final presentations are given to the other groups of students. The grading of the projects is based on the presentations, the written report and the implemented software product. A grading form is used, which specifies these aspects and includes the weighing of the different aspects. The self-evaluation report states that the project groups also receive a written justification of the assessment from the examiners. Grades are applicable for the whole group. It is possible for examiners to give an individual grade if necessary. This was confirmed by the students during the site visit. The students also remarked that during the weekly meetings with the project coordinator, the individual contribution of each group member is visible. At the end of the project, a peer review is held.

The self-evaluation report states that students are informed about the results of the exams within 15 working days. Students also can inspect their corrected exams within 30 days after the results are known, by making an appointment with the examiner. The results of the projects are discussed by the tutor with each project group. During that meeting the project is also evaluated.

The site visit made it clear that students, in general, are content with the level and the form of the assessments used. During the site visit and in preparation for it, the committee also looked at the different forms of assessment. It confirmed that the assessments seem adequate in terms of level and content.

Thesis procedure
The committee examined the thesis procedure and also read and assessed a total of 15 theses. It is of the opinion that the thesis procedure is adequate. The thesis is individual and has the form of a scientific paper of eight to ten pages. Relevant appendices and software can be added to it. Students have to present the thesis in a conference, and a submission form is used for this. The research can be either empirical or theoretical, and the topic is open but has to match the programme. A list of topics is available for students.

The programme distinguishes six phases in the thesis procedure. First, students attend a preparatory thesis writing class. During this class students learn to select a topic, formulate a problem statement and hypothesis, find the relevant literature, execute the research, draw conclusions and design the research paper. During the second phase students select a topic (and problem statement). Based on the topics, groups of students are formed. The groups are guided by a thesis supervisor with expertise in the relevant field. The student groups meet on a weekly basis with the thesis supervisor. During this phase, students write a project plan, which has to be handed in to the bachelor thesis coordinator. The Board of Examiners approves the project plan. The research is conducted during the third phase. Additional individual support can be given. The fourth phase runs in parallel with the third phase and involves writing the thesis in the form of a scientific paper. During the fifth and sixth phases, the presentation is prepared and given.

The thesis is assessed by the thesis supervisor and a second assessor, using a thesis grading form. Students receive their final grade after the presentations.

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

In general, the committee is of the opinion that the theses are of good quality and that graduates of the bachelor's programme do achieve the required level. The theses studied 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 intended format of a scientific paper is reflected in the theses. Some theses could be (and have been) accepted for international conferences.

Even though the level of the theses is more than sufficient, the committee noted that they did not always have a clear relationship with the field of AI. It discussed this point during the site visit with several representatives of the programme. The Board of Examiners stressed that it reviews all thesis proposals. During this review the relationship between the proposal and the programme is assessed. Management remarked that the programme is not a classical AI programme and emphasises applied mathematics and computer science. Therefore, the theses also do not reflect (classical) AI topics. As mentioned in Standard 1, the committee recommends that the programme formulate its relationship with the field of AI more explicitly. This can also benefit the students writing theses and the positioning of these theses in the field of AI.

The committee realises, however, that there will always be tension in a broad discipline such as AI with the chosen topic of a thesis. Nevertheless, it believes that the AI character of the theses should be visible. It recommends that the Board of Examiners should actively monitor this.

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. Students are content with the assessment in general. The committee 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 recommends that the programme instruct lecturers to fill out all the aspects of the thesis assessment forms systematically. In addition, it advises the Board of Examiners to regularly assess a selection of theses and to actively monitor the relationship between the thesis and the field of AI.

Even though the studied theses do not all have a direct relationship with the field of AI, the committee is of the opinion that their overall quality and level are good. Therefore, it concludes that graduates of the bachelor's programme achieve the required level.

Conclusion
Bachelor's programme Knowledge Engineering: the committee assesses Standard 3 as **satisfactory**.

General conclusion

The committee assesses the *bachelor's programme Knowledge Engineering* 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 Lerarenlopleiding" 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 honored with golden medals from the Technical University of Prague and the Military Academy from Brno.

Prof. dr. ir. Dirk Heylen is Professor Socially Intelligent Computing at the University of Twente. After his studies of Linguistics, Computer Science and Computational Linguistics at the University of Antwerp he moved to the Institute of Dutch Lexicology in Leyden, to develop tools for enriching natural language databases. After a couple of years he went on to the Utrecht University and got involved in the big European project Eurotra on Machine Translation. After coordinating a follow-up EU project, he started his PhD project on a logical approach to natural language analysis and parsing (Type Logical Grammar). At the University of Twente he started working on embodied dialogue systems (aka virtual agents or embodied conversational agents). This made his interests shift from pure linguistic analysis to body language, from text analysis to real-time human-machine interaction, and from the logical analysis to a much broader concern with emotion and social relations in interaction. His research interests cover both the machine analysis of human (conversational) behaviour and the generation of human-like (conversational) behaviour by virtual agents and robots. He is especially interested in the nonverbal and paraverbal aspects of dialogue and what these signals reveal about the mental state (cognitive, affective, social). These topics are explored both from a computational perspective and as basic research in the humanities, reflecting my training as a computational linguist.

Dr. Jimmy Troost is Director Research & Technology at the Thales in Delft. After compleding his studies at Radboud University Nijmegen and obtaining his PhD in cognitive science at the same university, he worked as a researcher for the Dutch Royal Army. Between 1993 and 1994 he had a past doc. Position at the University of York, working in the field of visual perception. Since then, he has worked at various companies in the Research and Science industries, and has occupied various positions at Thales. His specialities include Innovation Management, Research & Development, Change Management and Behaviour Change.

Patrick De Causmaecker is a Full Professor in Computer Science and the head of the CODeS group at KU Leuven. He holds a master in mathematics and a PhD in theoretical physics from the University of Leuven (1983). The subject of his PhD was a calculus for particle collisions at high energies, which is still in use today. After thirty years, his papers on this subject are still regularly cited. After he switched to the field of information processing in

1984, he has successfully conducted research in heuristic combinatorial optimization and constraint solving, specifically for planning, scheduling and rostering problems. He is particularly interested in combinatorial optimisation at the interface with data interpretation and knowledge discovery. This research was in close cooperation with a multitude of small and medium sized companies specialized in planning and scheduling for production, transport, education and medical care. Special attention goes to developments in meta heuristics and hyper heuristics. Apart from this research program, he spends about half of his time in teaching at the undergraduate level. Subjects include programming, data structures and algorithms and operating systems. He coordinates project development training in the second year of bachelors in engineering studies and he is responsible for research training in the third year of the bachelor in computer science. He supervised 10+ PhD students.

Yfke Dulek obtained her Bsc degree in Artificial Intelligence at Utrecht University in 2013, and is currently working towards a 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 assistent 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.

Appendix 2: Domain specific framework of reference

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

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

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

1 Introduction

This document is an update of the 2006 frame of reference for the Dutch University programmes included in the category Artificial Intelligence of the Dutch register of higher education programmes (CROHO)[4]. This frame of reference defines the fields covered by the term Artificial Intelligence as well as the common goals and final qualifications of these programmes.

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

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

1.2 KION: Artificial Intelligence in the Netherlands

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

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[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.

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

Qualifications:
1. Competence in the search and critical processing of all sources of information that help to solve an open and ill-defined problem.
2. The ability to demonstrate a professional attitude conform the (international) scientific conduct in Artificial Intelligence.
3. The ability to provide and receive academic criticism conform the standards in one specialism of Artificial Intelligence-research.
4. The ability to formulate an opinion and to make judgements that include social and ethical responsibilities related to the application of one's own contributions.

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

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

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

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

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

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

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

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

6.1 Comparison of bachelor programmes

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

6.1.2. Comparison with the Dutch frame of reference
It should be pointed out that the (first three years of the) AI-related bachelors in Edinburgh show a large variation between them, and an extensive amount of (usually restricted) choices for particular courses within them. In fact, the communality between the Edinburgh Artificial Intelligence bachelors is smaller than communality within the Dutch framework. It seems that the wide variation in Edinburgh Artificial Intelligence related bachelor degrees actually means that the degrees themselves are much more specialized than the Dutch framework proposes, some of them having little or no (cognitive) psychology, others having no mathematics, etcetera. Areas such as philosophy appear not to be obligatory at all.

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

6.1.4. Comparison with the Dutch frame of reference
Based on studying both programmes, we conclude that the Dutch frame of reference recognizes the same AI-specific areas as both Cognitive Science programmes outside the Netherlands. The Dutch frame of reference devotes as much or more attention to any of these areas as any of those Cognitive Science programmes, with the exception of Cognitive

Psychology in Linköping. Moreover, the recognition, in the Dutch frame of reference, that each individual study programme has a specific profile in addition to the communal areas appears to hold for both inspected study programmes outside the Netherlands as well.

6.2 Comparison of master programmes

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

- Intelligent robotics
- Knowledge management, representation and reasoning
- Learning from data
- Natural language processing

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

- The main Artificial Intelligence topics that are in the Dutch framework are also represented in the Edinburgh programmes (as shown in the four different identified areas of specialisation).
- The Edinburgh programmes are 1-year, whereas most Dutch Artificial Intelligence master programmes are 2-year programmes. However, the Edinburgh master programme requires a 4-year honours bachelor degree.
- The Edinburgh system knows a 'Diploma' whereas the Dutch system does not. As described above, this Diploma can be awarded after completing only the taught part of the course.
- The Edinburgh programme knows relatively little study load for practical work. Whereas the minimum length of a Dutch master-thesis ('afstudeerproject') is 30 ECs (half a year), the Edinburgh programme has 4 months for doing practical assignments.
- However, the practical work seems to be more research oriented, whereas in the Dutch programme there is also the option to do a final project in industry.

6.2.3. Stanford
Stanford has four majors in computer science: Computer Science, Computer System Engineering, Mathematical and Computational Sciences and Symbolic Systems. Symbolic Systems most closely relates to the Artificial Intelligence programmes in the Netherlands. Symbolic Systems is an interdisciplinary program that combines Computer Science, Psychology, Philosophy, and Linguistics in order to better understand cognition in both humans and machines. Viewing people and computers as symbol processors, the Symbolic Systems program explores the ways computers and people reason, perceive, and act. Within the Symbolic Systems major, there is a core set of required classes; beyond this core, students choose an area of concentration in order to gain depth.[9]

[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

The qualifications of the programme are as follows:

I. Knowledge and understanding
The recipient of a bachelor degree in Knowledge Engineering should have:

1. Basic understanding of key areas in Knowledge Engineering, in Artificial Intelligence, in Computer Science, and in Applied Mathematics;
2. Advanced knowledge of a specific area in Knowledge Engineering, in Artificial Intelligence, in Computer Science, or in Applied Mathematics, up to a level that without further requirements grants access to a master programme in this area. The specific areas are listed below as qualifications 3 to 6;
3. Knowledge of the symbolic and (numerical) sub-symbolic approaches to Artificial Intelligence and their mathematical underpinnings;
4. Knowledge of the most important theories in the areas of knowledge and cognition;
5. Knowledge of the most important methods in Operations Research;
6. Knowledge of Mathematical Modelling and Simulation for Knowledge Engineering;
7. Expertise in constructing and evaluating mathematical and computational methods for a wide range of application domains.

II. Applying knowledge and understanding for problem solving and design
The recipient of a bachelor degree in Knowledge Engineering should have at least the following twelve abilities:

1. The ability to understand, apply, formulate, and validate models from the domains of Knowledge Engineering;
2. The ability to apply the symbolic approach to Artificial Intelligence;
3. The ability to apply non-symbolic approaches to Artificial Intelligence;
4. The ability to design, implement, and evaluate knowledge systems;
5. The ability to apply methods and tools from mathematics and logic;
6. The ability to apply important programming languages used in Knowledge Engineering;
7. The ability to submit an argument in the exact sciences to critical appraisal;
8. The ability to think analytically and critically, and to apply logical reasoning;
9. The ability to cooperate in a group and to participate effectively as an academic professional;
10. The ability to create an effective project plan for solving a Knowledge Engineering problem in a supervised context;
11. The ability to apply KE methods and techniques in a business-related practice;
12. The ability to transpose academic knowledge and expertise in a variety of application domains.

III. Making judgments
The recipient of a bachelor degree in Knowledge Engineering should have:

1. The ability to review critically (a) results, (b) arguments, and (c) problem statements from accepted perspectives in the field of Knowledge Engineering;
2. A reasonable level of competence in searching and critically processing the professional literature in Knowledge Engineering;
3. A reasonable familiarity with the standards of academic criticism;

4. An awareness of and responsibility for ethical, normative and social consequences of developments in science and technology, particularly resulting from Knowledge Engineering.

IV. Communication
The recipient of a bachelor degree in Knowledge Engineering should have:

1. Academically appropriate communicative skills, i.e. (a) communicate ideas effectively in written form, (b) give effective presentations, both formally and informally, and (c) understand and offer constructive criticism of the presentations of others;
2. International communication skills;
3. Elementary effectiveness in leading group-wise communication.

V. Learning skills
The recipient of a bachelor degree Knowledge Engineering should be able to:

1. Reflect on (a) one's own style of thought, (b) one's own working methods, and (c) one's own readiness to take the necessary corrective action;
2. Recognize the need for continued learning throughout a professional career;
3. The ability to manage one's own learning and development.

Appendix 4: Programme

Year 1	EC
Period 1.1	
Introduction to Knowledge Engineering (KEN1110)	4
Introduction to Computer Science 1 (KEN1120)	4
Discrete Mathematics (KEN1130)	4
Project 1-1 (*)	-
Period 1.2	
Knowledge Representation and Cognitive Psychology (KEN1210)	4
Introduction to Computer Science II (KEN1220)	4
Linear Algebra (KEN1410)	4
Project 1-1 (*)	-
Period 1.3	
Project 1-1 (KEN1300)	6
Period 1.4	
Calculus (KEN1440)	4
Data Structures and Algorithms (KEN1420)	4
Introduction to Business Management (KEN1430)	4
Project 1-2 (*)	-
Period 1.5	
Numerical Mathematics (KEN1540)	4
Software Engineering (KEN1520)	4
Logic (KEN1530)	4
Project 1-2 (*)	-
Period 1.6	
Project 1-2 (KEN1600)	6

(*) Project 1-1 will start in Period 1.1 and Period 1.2; Project 1-2 will start in Period 1.4 and Period 1.5. The credits for the projects will become available at the end of Period 1.3 and Period 1.6, respectively.

Year 2	**EC**
Period 2.1	
Databases (KEN2110)	4
Philosophy of Science (KEN2120)	4
Probability and Statistics (KEN2130)	4
Project 2-1 (*)	-
Period 2.2	
Reasoning Techniques (KEN2230)	4
Machine Learning (KEN2240)	4
Graph Theory (KEN2220)	4
Project 2-1 (*)	-
Period 2.3	
Project 2-1 (KEN2300)	6

Period 2.4

Mathematical Modelling (KEN2430)	4
Human Computer Interaction and Social Media (KEN2410)	4
Theoretical Computer Science (KEN2420)	4
Project 2-2 (*)	-

Period 2.5

Linear Programming (KEN2520)	4
Mathematical Simulation (KEN2530)	4
Knowledge Management (KEN2510)	4
Project 2-2 (*)	-

Period 2.6

Project 2-2 (KEN2600)	6

(*) Project 2-1 will start in Period 2.1 and Period 2.2 with weekly meetings; Project 2-2 will start in Period 2.4 and Period 2.5 with weekly meetings. The credits for the projects will become available at the end of Period 2.3 and Period 2.6 respectively.

Year 3	**EC**
Period 3.1 *	
Semantic Web (KEN3140)	4
Game Theory (KEN3130)	4
Prolog (KEN3234)	4
Chaos and Fractals (KEN3233)	4
Project 3-1 (**)	

Period 3.2 *

Logic for AI (KEN3231)	4
Parallel Programming (KEN3235)	4
Robotics (KEN3236)	4
Data Analysis (KEN3450)	4
Project 3-1 (**)	

Period 3.3

Project 3-1 (KEN3300)	6

Period 3.4

Operations Research Case Studies (KEN3410)	4
Intelligent Systems (KEN3430)	4
Introduction to Bio-Informatics (KEN3440)	4

Period 3.5 and 3.6

Bachelor Thesis (KEN3500)	18

** Third year students choose 6 out of 8 optional courses during Period 1 and 2 (i.e., Semantic Web, Game theory, Prolog, Chaos and Fractals, Data Analysis Logic for AI, Parallel Programming, Robotics).*
*** Project 3-1 will start in Period 3.1 and Period 3.2 with weekly meetings. The credits for the project will become available at the end of Period 3.3.*

Appendix 5: Quantitative data regarding the programme

Data on intake, transfers and graduates

Number of Bachelor students	07/08	08/09	09/10	10/11	11/12	12/13
Total number of students	110	105	100	110	117	127
New students (1st year)	39	35	39	42	50	51
Of which originating from VWO	15	11	18	13	18	13
Other pre-education	24	24	21	29	32	38
Re-registered students	71	70	61	68	67	76
Graduates	18	21	14	13	19	3*

* Graduates 2012-2013 up till 1-2-2013

Dropout after 1, 2, and 3 years (VWO inflow)

Cohort	2006	2007	2008	2009	2010	2011
Size	17	15	11	18	13	18
Dropout after 1yr	18% (n=3)	13% (n=2)	27% (n=3)	28% (n=5)	46% (n=6)	33% (n=6)
Dropout after 2yr	0% (n=0)	0% (n=0)	9% (n=1)	6% (n=1)	8% (n=1)	
Dropout after 3yr	6% (n=1)	33% (n=5)	0% (n=0)	0% (n=0)		

Dropout after 1, 2, and 3 years (total inflow)

Cohort	2006	2007	2008	2009	2010	2011
Size	35	39	35	39	42	50
Dropout after 1yr	31% (n=11)	36% (n=14)	43% (n=15)	38% (n=15)	55% (n=23)	28% (n=14)
Dropout after 2yr	0% (n=0)	0% (n=0)	6% (n=2)	13% (n=5)	7% (n=3)	
Dropout after 3yr	9% (n=3)	21% (n=8)	0% (n=0)	0% (n=0)		

Success rate (VWO inflow)

Cohort	2006	2007	2008	2009
Cohort Size*	14	13	8	13
Success rate after 3 years	43% (n=6)	31% (n=4)	38% (n=3)	46% (n=6)
Success rate after 4 years	64% (n=9)	31% (n=4)	75% (n=6)	
Success rate after 5 years	71% (n=10)	38% (n=5)		
Success rate after 6(+) years	79% (n=11)			

*Number of students re-registered after 1st year

Success rate (total inflow)

Cohort	2006	2007	2008	2009
Cohort Size*	24	25	20	24
Success rate after 3 years	38% (n=9)	32% (n=8)	30% (n=6)	42% (n=10)
Success rate after 4 years	63% (n=15)	44% (n=11)	50% (n=10)	
Success rate after 5 years	67% (n=16)	52% (n=13)		
Success rate after 6(+) years	71% (n=17)			

*Number of students re-registered after 1st year

Teacher-student ratio achieved

Given that the number of Bachelor students in 2011-2012 was 117 and the deployed teaching FTE was 7.0, a teacher-student ratio was achieved of 1: 16.7

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

Type	Contact hours per week
Regular (group)	18
Project (group)	3
Bachelor thesis (individual)	1

Appendix 6: Programme of site visit

Tuesday May 28

9:00-11:30	**Welcome + Internal meeting panel** Brief presentation about the education at DKE (10 minutes)
11:30-12:30	**Session 1: Management on BA & MA** - Prof. dr. Marc Gyssens (Dean School of Information Technology) - Prof. dr. Gerhard Weiss (Chair of DKE) - Prof. dr. ir. Ralf Peeters (Vice-Chair of DKE) - Dr. Mark Winands (Director of Studies) - Drs. Pascal Breuls (Managing Director)
12:30-13:00	**Lunch**
13:00-13:45	**Session 2: BA Students** - Lena Martens (Ba Student Y1) - Lars Mennen (Ba Student Y1) - Tagi Aliyev (Ba Student Y2) - Cindy Hubinon (Ba Student Y2) - Dina Zverinski (Ba Student Y2) - Nadine Barth (Ba Student Y3) - Christopher Wittlinger (Ba Student Y3)
13:45-14:30	**Session 3: Teaching staff BA** - Dr. Frank Thuijsman (Associate professor) - Dr. ir. Kurt Driessens (Assistant professor) - Dr. Joel Karel (Assistant professor) - Dr. Katerina Stankova (Assistant professor) - Drs. Jan Paredis (Project coordinator)
14:30-15:15	**Session 3: Students MA AI** - Tim van Cann B.Sc. - Lukas Kang B.Sc. - Tom Pepels B.Sc. - Benjamin Schnieders B.Sc. - Yannick Thimister B.Sc.
15:15-16:00	**Session 4: Teaching staff MA AI** - Prof. dr. Gerhard Weiss (Professor) - Dr. ir. Jos Uiterwijk (Associate Professor) - Dr. Karl Tuyls (Associate Professor) - Dr. ir. ing. Nico Roos (Assistant Professor) - Dr. Evgueni Smirnov (Assistant Professor)
16:00-16:15	***Break***

16:15-17:00	**Session 5: Students MA OR**	

16:15-17:00 **Session 5: Students MA OR**
- Enno Ruijters B.Sc.
- Stefan van der Horst B.Sc.
- Martin Hendges B.Sc.
- Leoni Haagmans B.Sc.
- Tim Cooijmans B.Sc.

17:00-17:45 **Session 6: Teaching staff MA OR**
- Prof. dr. ir. Stan van Hoesel (Professor at SBE)
- Dr. Ronald Westra (Associate Professor)
- Dr. Gijs Schoenmakers (Assistant Professor)
- Dr. Pieter Collins (Assistant Professor)
- Dr. Pietro Bonizzi (Assistant Professor)

17:45-18:30 **Session 7: Alumni**
- Michael Gras M.Sc. (Graduate MA AI)
- Bastian Küppers M.Sc. (Graduate MA AI)
- Michiel Moonen M.Sc. (Graduate BA KE & MA AI)
- Solmaz Karami M.Sc. (Graduate BA KE & MA OR)
- Lian Nouwen M.Sc. (Graduate BA KE & MA OR)
- Philippe Uyttendaele M.Sc. Graduate BA KE & MA OR)
- Ruud Wetzels M.Sc. (Graduate BA KE & MA OR)
- Esther Verhoef B.Sc. (Graduate BA KE)

Wednesday May 29

9:00-9:45 **Session 8: Programme Committee**
- Dr. ir. Jos Uiterwijk (Chair)
- Dr. Gijs Schoenmakers (Scientific staff member)
- Rik Claessens B.Sc (Student member)
- Irme Groothuis (Student member)
- Drs. Jan Paredis (Quality Officer)

9:45-10:30 **Session 9: Board of Examiners and Study Adviser**
- Prof. dr. ir. Ralf Peeters (Chair)
- Dr. ir. Kurt Driessens (Member)
- Dr. Evgueni Smirnov (Member)
- Drs. Gonny Willems (Study adviser)

10:30-11:00 **Break**

11:00-11:45 **Guided Tour**

11:15-13:30 **Lunch + Preparation Final Talk**

13:30-14:30 **Session 10: Final talk**
- Prof. dr. Harm Hospers (Dean of Faculty of Humanities of Sciences)

- Prof. dr. Marc Gyssens (Dean of School of Information Technology)
- Prof. dr. Gerhard Weiss (Chair of DKE)
- Prof. dr. ir. Ralf Peeters (Vice-Chair of DKE)
- Dr. Mark Winands (Director of Studies)
- Dr. Karl Tuyls (Director of Research)
- Drs. Pascal Breuls (Managing Director)

14:30-17:00	**Deliberation**
17:00-17:15	**Findings & Closure**
17:15-18:00	Drinks

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:

298700	599565	6001816	6003734	381691
6022923	399698	6001974	6004092	313688
549339	520608	6002674	6004858	556378

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ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: Léon Rothkrantz

PRIVÉ ADRES: W. 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/UM/UA/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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VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Utrecht DATUM: 14 maart 2013

HANDTEKENING:

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INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: Dirk Heylen

PRIVÉ ADRES: Oude Hontensepad 32
3582 CX UTRECHT

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

KUNSTMATIGE INTELLIGENTIE

AANGEVRAAGD DOOR DE INSTELLING:

KUB / RU / UM

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

PLAATS: Utrecht

DATUM: 14/3/2013

HANDTEKENING:

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INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: J.M. TROOST

PRIVÉ ADRES: Molenweg 7
6862 HM Oosterbeek

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

Kunstmatige Intelligentie

AANGEVRAAGD DOOR DE INSTELLING:

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

PLAATS: Delft DATUM: 14/3/2013

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ONDERGETEKENDE

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PRIVÉ ADRES: REIBROEKSTRAAT 128
BE 9940 EVERGEM
BELGIE

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

Kunstmatige Intelligentie

AANGEVRAAGD DOOR DE INSTELLING:

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

PLAATS: UTRECHT DATUM: 14/3/2013

HANDTEKENING:

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Ypke Marie Dulek

PRIVÉ ADRES:
Cambridgelaan 617
3584 DM
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VERKLAART HIERBIJ OP DE HOOGTE TE ZIJN VAN DE NVAO GEDRAGSCODE.

PLAATS: Utrecht DATUM: 14-03-2013

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ONDERGETEKENDE

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PRIVÉ ADRES: De Oude Klarenbeek 20
7339 EL Ugchelen

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

Kunstmatige Intelligentie

AANGEVRAAGD DOOR DE INSTELLING:

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PLAATS: Utrecht

DATUM: 14-3-2013

HANDTEKENING:

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