Artificial Intelligence and Operations Research

Transnational University Limburg

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This report was finalized on 10 November 2013

Report on the master's programmes Artificial Intelligence and Operations Research of the School of Information Technology, Transnational University Limburg

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

Administrative data regarding the programmes

Master's programme Artificial Intelligence

Name of the programme:	Artificial Intelligence
CROHO number:	66981
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specializations or tracks:	-
Location(s):	Maastricht
Mode(s) of study:	full-time
Expiration of accreditation:	December 2014

Master's programme Operations Research

Name of the programme:	Operations Research
CROHO number:	60125
Level of the programme:	master's
Orientation of the programme:	academic
Number of credits:	120 EC
Specializations or tracks:	-
Location(s):	Maastricht
Mode(s) of study:	full-time
Expiration of accreditation:	December 2014

The visit of the assessment committee Artificial Intelligence to the School of Information Technology of the Transnational University Limburg took place on May 28 and 29, 2013.

Administrative data regarding the institution

Name of the institution:	transnational University Limburg
Status of the institution:	publicly funded institution
Result institutional quality assurance assessment:	not applied

Quantitative data regarding the programme

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

Composition of the assessment committee

The assessment of the master's programmes Artificial Intelligence and Operations Research 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 eight members:

- Prof. drs. dr. L.J.M. (Leon) Rothkrantz (chairman), Associate Professor at Delft University of Technology and Professor of Intelligent Sensor-Systems at the Netherlands Defense Academy;
- Prof. 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 Laboratory for Declarative Languages and Artificial Intelligence, Department of Computer Science at 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, Ghent, Belgium, and Head of the CODes research group, coordinator of the interdisciplinary research team itec at K.U. Leuven, Kortrijk Campus;
- R.H.M. (Rik) Claessens, BSc, student of the master's programme Artificial Intelligence at Maastricht University;
- Y. (Yfke) Dulek, student of the bachelor's programme Artificial Intelligence at Utrecht University.

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

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

The committee that assessed the master's programmes Artificial Intelligence and Operations Research 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, Ghent, 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 Transnational University Limburg board and the Accreditation Organisation of the Netherlands and Flanders (NVAO) approved the composition of the assessment committee. Appendix 1 contains the CVs of the committee members.

Working method of the assessment committee

Preparation
To prepare the contents of the site visits, the coordinator first checked the quality and completeness of the self-evaluation reports prepared by the programmes and forwarded them to the participating committee members. They read the reports and formulated questions on the 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, but attention was paid to incorporating 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 set (see appendix 3).

Site visit
Prior to the visit, the coordinator prepared timetables for the visit in consultation with the committee chair and the participating institutions. The timetable for the visit for the master's programmes of Transnational University Limburg is included as appendix 2.

Prior to the visit, the committee asked the programmes to select interview partners on the basis of representativity. 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, the committee spoke in turn to representative 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 of the committee.

Decision rules
In accordance with the NVAO's Assessment framework for extensive 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 School to check for factual irregularities. Any comments of the School were discussed with the chair of the assessment committee and, if necessary, with the other committee members. After that, the report was finalised.

Summary judgement regarding the quality of the master's programmes Artificial Intelligence and Operations Research

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

Master's programme Artificial Intelligence

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 master's programme AI are, in general, in line with the framework. The master's programme AI focuses on games and agents and knowledge discovery and learning. The committee values the international and academic level and orientation of the programme. The committee also concludes that the intended learning outcomes are cross-matched to the different components of the programme. It recommends making the relation between courses and intended learning outcomes more explicit in the course descriptions.

The committee concludes that academic and professional skills are adequately addressed. The projects and the master's thesis play an important role in the realisation of these skills. The committee is however also of the opinion that reflective skills could be addressed more. Students learn to analyse and solve complex problems very well but learn less on how to reflect on the scientific relevance of their work or the relation with the broader field of artificial intelligence.

The committee feels that students are adequately prepared for the professional field. The projects and the optional internship play an important role in this.

The committee is of the opinion that the PCL concept is unique and differentiates the programmes from others in the field. The projects offer ample room for students to apply their acquired knowledge. The PCL concept is very well implemented in the programme. The number of contact hours is adequate.

The programme applies adequate admission criteria; also the number of students entering the programme is sufficient. The committee is positive about the increasing number of female students and the amount of international students in the programme.

The programme is feasible and adequate guidance is available (also for students with physical or psychological study impairments). The programme meets the formal requirements relating to the scope and duration of the curriculum. The committee is of the opinion that the programme offers sufficient facilities. It shares the department's concern that an increase in the number of students can put pressure on the current facilities.

An adequate staff policy is in place and the staff is qualified for the realisation of the curriculum in terms of content, didactical and organizational aspects. The committee also

concludes that the staff:student ratio is acceptable. In addition to that, lecturers are accessible and approachable.
The committee concludes that the programme has an adequate quality assurance system in place, in which all stakeholders are involved. The committee appreciates that the curriculum is evaluated on a yearly basis. The committee realises that the small scale of the programme makes contact easy and encourages discussions between the director, lecturers, students and programme committee. This creates an informal atmosphere, which students and lecturers can benefit from. It can also lead however to a more internal perspective on the programme. The committee supports the resolution of the programme committee to write an annual report.

The committee concludes that even though this is not formalised, the programme has an adequate, more informal assessment system in place. The committee is of the opinion that the assessments are adequate in terms of level and content. To formalise the assessment system, the committee advises the department to develop and implement an assessment policy. It also recommends that the department instruct lecturers to complete consistently all parts of the thesis assessment forms. In addition, it advises the Board of Examiners to assess a selection of theses regularly and to actively monitor the relationship between the theses from both master's programmes 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 the overall quality and level of the theses are high. Therefore, the committee concludes that graduates achieve the required level.

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

Intended learning outcomes

Standard 1:	satisfactory

Curriculum

Standard 2:	satisfactory
Standard 3:	satisfactory
Standard 4:	good
Standard 5:	satisfactory
Standard 6:	satisfactory
Standard 7:	satisfactory

Staff

Standard 8:	satisfactory
Standard 9:	satisfactory
Standard 10:	satisfactory

Facilities

Standard 11:	satisfactory
Standard 12:	satisfactory

Quality assurance

Standard 13:	satisfactory
Standard 14:	satisfactory
Standard 15:	satisfactory

Assessment and intended learning outcomes
Standard 16: satisfactory

General conclusion
Master's programme of Artificial Intelligence **satisfactory**

Master's programme Operations Research

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 master's programme OR reflect the KION qualifications. The master's programme OR addresses classical operations research and systems and control theory. The committee values the international and academic level and orientation of the programme. It notes, however, that the master's programme OR operates on the crossroads of knowledge engineering, applied mathematics, operations research and artificial intelligence. Therefore, its relationship to the field of AI is less clear. The committee also concludes that the intended learning outcomes are cross-matched to the different components of the programme. It recommends making the relation between courses and intended learning outcomes more explicit in the course descriptions.

The committee concludes that academic and professional skills are adequately addressed. The projects and the master's thesis play an important role in the realisation of these skills. The committee is however also of the opinion that reflective skills could be addressed more. Students learn to analyse and solve complex problems very well but learn less on how to reflect on the scientific relevance of their work or the relation with the broader field of operations research.

The committee feels that students are adequately prepared for the professional field. The projects and the optional internship play an important role in this.

The committee is of the opinion that the PCL concept is unique and differentiates the programmes from others in the field. The projects offer ample room for students to apply their acquired knowledge. The PCL concept is very well implemented in the programme. The number of contact hours is adequate.

The programme applies adequate admission criteria; also the number of students entering the programme is sufficient. The committee is positive about the increasing number of female students and the amount of international students in the programme.

The programme is feasible and adequate guidance is available (also for students with physical or psychological study impairments). The programme meets the formal requirements relating to the scope and duration of the curriculum. The committee is of the opinion that the programme offers sufficient facilities. It shares the department's concern that an increase in the number of students can put pressure on the current facilities.

An adequate staff policy is in place and the staff is qualified for the realisation of the curriculum in terms of content, didactical and organizational aspects. The committee also concludes that the staff:student ratio is acceptable. In addition to that, lecturers are accessible and approachable.

The committee concludes that the programme has an adequate quality assurance system in place, in which all stakeholders are involved. The committee appreciates that the curriculum is evaluated on a yearly basis. The committee realises that the small scale of the programme makes contact easy and encourages discussions between the director, lecturers, students and programme committee. This creates an informal atmosphere, which students and lecturers can benefit from. It can also lead however to a more internal perspective on the programme. The committee supports the resolution of the programme committee to write an annual report.

The committee concludes that even though this is not formalised, the programme has an adequate, more informal assessment system in place. The committee is of the opinion that the assessments are adequate in terms of level and content. To formalise the assessment system, the committee advises the department to develop and implement an assessment policy. It also recommends that the department instruct lecturers to complete consistently all parts of the thesis assessment forms. In addition, it advises the Board of Examiners to assess a selection of theses regularly and to actively monitor the relationship between the theses from both master's programmes 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 the overall quality and level of the theses are high. Therefore, the committee concludes that graduates achieve the required level.

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

Intended learning outcomes

Standard 1:	satisfactory

Curriculum

Standard 2:	satisfactory
Standard 3:	satisfactory
Standard 4:	good
Standard 5:	satisfactory
Standard 6:	satisfactory
Standard 7:	satisfactory

Staff

Standard 8:	satisfactory
Standard 9:	satisfactory
Standard 10:	satisfactory

Facilities

Standard 11:	satisfactory
Standard 12:	satisfactory

Quality assurance

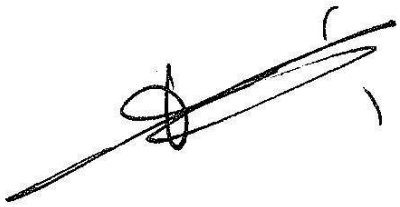
Standard 13:	satisfactory
Standard 14:	satisfactory
Standard 15:	satisfactory

Assessment and intended learning outcomes
Standard 16: satisfactory

General conclusion
Master's programme of Operations Research **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 extensive programme assessments

The Transnational University Limburg started in 2001 as a joint venture between Maastricht University (the Netherlands) and Hasselt University (Belgium). The master's programmes Artificial Intelligence and Operations Research are embedded in this transnational structure. The programmes are conducted by the Department of Knowledge Engineering of Maastricht University (at the campus). In 2009, both programmes changed from a one-year into a two-year programme. This change was used to restructure the programmes. For example, the courses increased from 5 EC to 6 EC, and a second project was introduced in the first year of both programmes. The master's theses were also enlarged to 30 EC. Students were offered the option of switching to the two-year programme. A few students took advantage of this and were offered an individual programme, approved by the Board of Examiners.

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 programmes (1.2) and the intended learning outcomes of the programmes (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 with 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 (hereafter: the framework) which presented the content and learning outcomes of bachelor's and master's programmes in artificial intelligence. The framework forms the common basis for all programmes in artificial intelligence and helps specify the intended learning outcomes of the different programmes in this cluster visitation. The committee in general noticed that all of the assessed programmes meet the intended learning outcomes described in the framework to a greater or lesser degree. For example, all programmes pay sufficient attention to the basic knowledge and skills of artificial intelligence. However, there are variations in the extent to which the different programmes offer students deepening or broadening of the field. In addition, almost all programmes highlight certain topics and add parts of new disciplines. The committee notes 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 between the intended learning outcomes at the bachelor's and master's level is not always clear in the framework. The gradual/incremental aspect of knowledge and skills could be elaborated on more. This could also prevent divergence of the AI programmes on this matter.

Master's programme Artificial Intelligence
All the qualifications from the KION framework are reflected in the intended learning outcomes of the master's programme Artificial Intelligence. For example the topics addressed in the master's programme, intelligent techniques, situated agents, multi agent systems, formal reasoning techniques, datamining, text mining and relational learning are also part of the KION Framework. In addition to that, academic skills such as formulating a project plan, choosing, applying, formulating and validating models, theories and hypotheses is also addressed in the KION framework. The committee concludes that the programme matches the KION framework.

Master's programme Operations Research
The self-evaluation report states that for the knowledge engineering and artificial intelligence parts of the programme, the KION framework was used as a reference. For the parts concerning applied mathematics and operations research, the KION definitions and qualifications have been adapted to the specific discipline.

The committee concludes that the KION framework gives an adequate picture of the AI domain and the basic knowledge and skills that graduates need to acquire. The intended learning outcomes of the master's programme AI are in line with the framework. The master's programme AI focuses on games and agents and knowledge discovery and learning. The intended learning outcomes of the master's programme OR reflect the majority of the KION qualifications. The programme addresses classical operations research and systems and control theory.

1.2 Profile and orientation
The self-evaluation reports state that both programmes provide students with the following:

1) a university education within the framework of Project-Centred Learning (PCL) and the universities' teaching philosophy;
2) added depth to the student's knowledge in the chosen academic field;
3) the opportunity to broaden his/her education into other disciplines;
4) specialised knowledge, skills and understanding in the specific field;
5) a preparation for the research programmes in the specific fields.

The programmes also support independent academic thinking and conduct, academic communication in English, and application of the knowledge gained in the discipline in a broader social context.

According to the self-evaluation reports, the programmes differ from comparable programmes at other universities in two aspects. First, students can select courses from the other master's programmes in Maastricht. They can thus give their programme a more mathematical or AI orientation and can specialise in their own area of interest. Second, the programmes use the educational concept of Maastricht University, in which group-wise collaboration and problem-based education (PBL) are emphasised (see also Standard 2).

Master's programme Artificial Intelligence
The self-evaluation report states that the master's programme Artificial Intelligence (AI) focuses on two themes: games and agents, and knowledge discovery and learning. The first theme, games and agents, discusses intelligent search and games, autonomous systems, foundation of agents and multi-agent systems. The second theme, knowledge discovery and learning, addresses relational learning, data and text mining, and ontology and the semantic web.

The programme wants to offer students with a bachelor's degree in knowledge engineering a solid continuation in the academic field of artificial intelligence. It gives students a thorough knowledge of algorithms, methods, and techniques from the fields of artificial intelligence, agent technology, search techniques, machine learning, data and text mining, and computer games to model, analyse and implement intelligent software in a variety of contexts. The programme prepares students for an academic as well as a professional career.

During the site visit, the committee discussed the profile of the programme with several representatives. Alumni from the master's programme AI revealed that their interest in computing determined their choice for the programme. Lecturers indicated that the goal of the programme is to familiarize students with advanced methods of artificial intelligence, such as agents, multi-agent systems, search and autonomous systems, symbolic and non-symbolic artificial intelligence. The lecturers remarked that quite a lot of alumni obtain mathematical and management functions in the professional field.

The committee also discussed with lecturers the focus on game theory and game playing. This was what the programme was known for, and the committee noted that this focus was not explicitly mentioned in the self-evaluation report. Lecturers revealed that there is still quite a strong research group focused on games. Due to changes in the programme and the staffing, game theory and game playing are more integrated in the programme.

The committee concludes that the interdisciplinary profile and academic orientation of the programme are appropriate for a master's programme in the field of AI. It appreciates the focus of the programme.

Master's programme Operations Research
According to the self-evaluation report, the master's programme Operations Research (OR) focuses on two themes: classical operations research, and systems and control theory. The first theme, classical operations research, addresses topics such as optimisation, simulation, business intelligence, decision theory under uncertainty, and game theory. The second theme, systems and control theory, addresses signal and image processing, model identification, control system design, and symbolic and exact computation. The self-evaluation report states that to show new scientific developments and to demonstrate the broad applicability of the learned techniques, modern application areas such as evolutionary game theory, biomedical engineering and bioinformatics are included in the programme.

The programme builds upon the bachelor's programme Knowledge Engineering and continues the focus on the mathematics of the discipline, regarding both the practical application and the research on mathematical aspects. The self-evaluation report states that the programme wants to offer students a solid continuation in the academic field, at the crossroads of knowledge engineering, applied mathematics, operations research and artificial intelligence. The self-evaluation report remarks that the programme does not intend to cover all aspects of applied mathematics, however. The programme focuses on decision-making and strategic optimisation in a broad sense and data analysis and various methods of mathematical modelling. Students are meant to develop mathematical skills as well as software and computing skills.

The self-evaluation report remarks that the programme differs in several aspects from other master's programmes in this field in its focus on other application areas than economics (which is more traditional for master's programmes in operations research).

During the site visit, the committee discussed the profile of the programme with several representatives. Alumni indicated that the main reason for choosing the master's programme OR was the emphasis on the mathematical aspects. Students also revealed that an interest in computational and mathematical aspects was the reason for choosing this programme. The management of the programme indicated that the historical context plays an important role in the current profile of the programme.

The committee concludes that the programme has an academic orientation and that the orientation and profile are fitting for a master's programme AI. It is of the opinion that the relationship with the field of AI forms a topic for discussion, but it also recognizes the rather unique profile of the programme. Regarding the historical context and the profile of the department as a whole (focusing on artificial intelligence, operations research and knowledge engineering), the committee is however of the opinion that the profile is fitting.

1.3 Intended learning outcomes

Master's programme Artificial Intelligence
The self-evaluation report lists the 18 intended learning outcomes that have been formulated for the master's programme AI. The committee is of the opinion that they reflect the academic nature of the programme. Graduates should have the ability, for example, to formulate a project plan for an open problem in the field of AI. Also, they are expected to be able to determine the feasibility of a proposal, to develop a scientifically sound, problem-solving attitude, to formulate an opinion and to make judgments that include social and ethical aspects.

Master's programme Operations Research
The intended learning outcomes described in the self-evaluation report reflect the vast majority of the qualifications of the KION framework. The more mathematical profile of the programme is visible in the intended learning outcomes. For example, graduates are expected to have gained knowledge of optimisation, stochastic decision-making, and mathematical modelling and parameter estimation from data. They acquire the ability to translate academic knowledge and expertise into social, professional, economic and ethical contexts. The academic nature of the programme is also reflected in the intended learning outcomes. Graduates are able to choose, apply, formulate and validate models, theories, hypotheses and ideas from the domains of applied mathematics and operations research.

The committee concludes that the intended learning outcomes of both programmes are of an academic nature and level. It is also of the opinion that the intended learning outcomes of the master's programme AI reflect the KION framework. The committee concludes that even though the intended learning outcomes of the master's programme OR reflect the qualifications mentioned in the KION framework, not all knowledge areas of the framework are covered.

For both programmes, 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 master's programme. The self-evaluation reports show the match between the intended learning outcomes and the Dublin descriptors. The committee concludes that in both programmes, all Dublin descriptors are reflected in the intended learning outcomes.

Considerations

The committee compared both programmes to the domain-specific reference framework. It concludes that the framework gives an adequate picture of the AI domain and the basic knowledge and skills that graduates need to acquire. The intended learning outcomes of the master's programme AI are, in general, in line with the framework. The master's programme AI focuses on games and agents and knowledge discovery and learning. The intended learning outcomes of the master's programme OR also reflect the KION qualifications. The

master's programme OR addresses classical operations research and systems and control theory.

The committee values the international and academic level and orientation of both programmes. It notes, however, that the master's programme OR operates on the crossroads of knowledge engineering, applied mathematics, operations research and artificial intelligence. Therefore, its relationship to the field of AI is less clear.

The committee considers the intended learning outcomes of both programmes to be adequately defined. It finds the intended learning outcomes suited to the objectives and appropriate for the level and orientation of an international master's programme. In both programmes the relation with the Dublin descriptors is visible in the intended learning outcomes.

1.3 Conclusion

Master's programme of Artificial Intelligence.: the committee assesses Standard 1 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 1 as **satisfactory**.

Standard 2: Orientation
The orientation of the curriculum assures the development of skills in the field of scientific research and/or the professional practice.

Explanation:
The curriculum has demonstrable links with current developments in the professional field and the discipline.

Descriptions of the programmes

Both are two-year programmes, comprising 120 EC. The first year 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 second year students compose their own programme. The last semester consists of the master's thesis.

The first year of both programmes consists of 48 EC of mandatory courses and two research projects (6 EC each). The second year has electives (30 EC) in the first semester and the master's thesis (30 EC) in the second semester. In the first semester of the second year students can also opt for an internship, attend courses from the other master's programme in the department or other relevant master's programmes. Student can also participate in a research project (a research-oriented internship within the department) or study abroad during this period. All study curricula for the first semester of the second year have to be approved by the Board of Examiners.

During the first semester of the second year, students from the master's programme OR can also opt for courses from the Dutch Network on the Mathematics of Operations Research (LNMB), the Dutch Institute of Systems and Control (DISC) or the MasterMath programme (the Dutch master's degree programme in Mathematics).

Master's programme Artificial Intelligence
The first year of the master's programme AI consists of eight courses. It starts with the *Autonomous Systems* course. This course introduces the basics of situated autonomous robots. The question of how to effectively control a mobile robot is addressed from a probabilistic perspective and from an evolutionary perspective. In the *Intelligent Search & Games* course, students learn to apply advanced techniques in the framework of game-playing programmes. The last mandatory course, the *Information Retrieval and Text Mining course*, focuses on understanding and applying the techniques of information retrieval and text mining.

Master's programme Operations Research
During the first year, students follow eight courses, including the *Optimization* course, the *Business Intelligence* course and the *Identification* course. In the first course (*Optimization*), they learn about combinatorial optimization and linear and non-linear optimization. They also learn several techniques that can be used to tackle optimization problems. Computer assignments are given in the course. The *Identification* course focuses on the practical and theoretical aspects involved in producing a mathematical model within a given model class. During this course students learn to create models from measurement data.

Findings

Academic and professional skills
The self-evaluation reports state that in both programmes, students learn three types of skills: 1) the course-dependent, content-related skills, i.e., applying AI techniques learned during the courses, 2) the course-dependent learning skills, like reflecting on course-related problems

and being able to interpret the literature independently, and 3) academic and professional skills. In the two research projects, skills such as writing, presenting, demonstrating leadership, cooperation, critically appraising and arguing, and showing initiative are addressed. 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. The relation to relevant other courses is also highlighted. To acquire all relevant skills, students take different roles in the projects. They receive feedback from their tutor and two examiners. The academic and professional skills are also trained in the master's thesis and internships. In the latter case, the students' skills are also discussed with the external supervisor.

Students of the master's programme AI revealed during the site visit that they value the academic character of the programme. They feel the academic and research skills taught are also useful in the professional field.

The committee is of the opinion that academic and professional skills are adequately addressed within the two programmes. The projects and the master's thesis play an important role in the realisation of these skills. The committee is however also of the opinion that reflective skills could be addressed more. Students learn to analyse and solve complex problems very well but learn less on how to reflect on the scientific relevance of their work or the relation with the broader field of artificial intelligence or operations research, respectively.

Labour market
According to the self-evaluation reports, the projects and the optional internship in both programmes play an important role in preparing students for the professional field. During the projects students apply the learned knowledge, and skills from different disciplines are integrated, they work and reason on an academic level and acquire professional skills. Part of the first project includes master classes and workshops in which presentation skills, academic writing skills, leadership skills, teambuilding, and creativity skills are taught. Students also attend workshops from the Universities Career Service, during which their competences are highlighted and clarified.

The committee feels that students are adequately prepared for the professional field. The option of internships is also highly appreciated by the committee.

Internationalisation
The committee examined to what extent internationalisation is part of the programmes. Like all programmes of Maastricht University, they are both taught in English. As mentioned before, the programmes are part of the Transnational University of Limburg, a joint venture between Maastricht University and Hasselt University. The first semester of the second year can also be used for study or an internship abroad. In 2011 seven students went abroad. The department cooperates with several international universities such as UESTC China, Reykjavik University, Aarhus University, Université de Montreal, Hasselt University and Aachen University.

The self-evaluation report reveals that most students enrolling in the master's programme AI come from Maastricht's bachelor's programme and from Aachen University. Some 80% of the students are non-Dutch. The ambition to increase the diversity of the student population is mentioned in the self-evaluation report, to create a truly international classroom.

Students enrolling in the master's programme OR mainly come from Germany and the Netherlands. The self-evaluation report states that 63% of the students are non-Dutch. For

this programme also the department wants to increase the diversity of the international student population.

The relationship with Hasselt University was a topic of conversation during the site visit. It became clear that the differences in educational concepts and the travelling distance stand in the way of increased cooperation. For example, it is easier for Dutch students to travel to Aachen than to Hasselt. Maastricht University and Hasselt University also use different schedules/timetables.

The committee is very positive about the international character of both programmes and the opportunities for studying abroad. It supports the ambition of the programmes to attract international students from a wider range of countries.

Considerations

The committee feels that the development of academic research skills and professional skills are adequately addressed within the two programmes. The projects and the master's thesis play an important role in this aspect. The committee is also of the opinion that reflective skills could be addressed more. Students learn to analyse and solve complex problems very well but less attention is paid to reflect on the scientific relevance of their work or the relation with the broader field of artificial intelligence or operations research, respectively.

The committee feels that students are sufficiently prepared for the professional field. It applauds the option of internships. In addition to that, it values the international character of both programmes and the opportunities this gives students to study abroad. It supports the ambition of the programmes to attract international students from a wider range of countries.

Conclusion

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

Standard 3: Content
The contents of the curriculum enable students to achieve the intended learning outcomes.

Explanation:
The learning outcomes have been adequately translated into attainment targets for (components of) the curriculum. Students follow a study curriculum, which is coherent in terms of content.

Findings

The committee evaluated whether and how the intended learning outcomes formulated by the programmes have been translated in the curriculum. It studied the correspondence between the learning outcomes and the curriculum, as presented by the programmes in the self-evaluation reports. It gained further insight by examining the study guides, course books and the literature. In the course descriptions, the content of the courses 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 (such as applying specific techniques or reasoning about representational issues in the field of machine learning argument) are defined per course.

The committee noted that the course descriptions do not specify the learning goals of the courses. Also, the relation with the intended learning outcomes is not explicated. Lecturers of the master's programme AI revealed during the site visit that the focus, goals and organisation of the current programme were discussed with them. It is also made clear to students what is expected of them regarding the literature to be studied, assignments to be completed and presentations to be held. The committee recommends the programmes to make the relation between courses and intended learning outcomes more explicit in the course descriptions by, for example, formulating learning goals for each course.

The matrices in the self-evaluation reports show which intended learning outcomes are addressed in the projects. The committee notes that in both programmes, the vast majority of the intended learning outcomes are part of all projects. During the site visit, the management of the programmes explained that not all intended learning outcomes are realised in all projects. The projects do get more complex as the programmes progress, and there is differentiation in the related intended learning outcomes. The committee is of the opinion that not all intended learning outcomes can be realised in the projects. It advises the department to make the matrices more balanced so that the increased complexity of the projects is reflected in the intended learning outcomes addressed.

Considerations

The committee concludes that the intended learning outcomes of both programmes are cross-matched to the different components of the programmes. It recommends the programmes making the relation between courses and intended learning outcomes more explicit in the course descriptions.

Conclusion

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

Standard 4: Structure
The structure of the curriculum encourages study and enables students to achieve the intended learning outcomes.

Explanation:
The teaching concept is in line with the intended learning outcomes and the teaching formats tie in with the teaching concept.

Findings

Both master's programmes use the Project-Centred Learning (PCL) concept. According to the self-evaluation reports, through this concept, students learn to apply the acquired knowledge in realistic and challenging projects. During each project students work in small groups (maximum of six students), execute all tasks of the project, including finding the relevant literature and data, producing results (often by implementing a computer programme), discussion of the results, and reflection on whether the set goals have been achieved. Students also write a report and present the results of each project for the tutor, the examiners and fellow students. The committee noted that even though the PCL concept is a very important part of both programmes, it is not elaborated on in the self-evaluation reports.

During the site visit the alumni revealed that they were satisfied with the PCL concept. Especially the experience with group work and the presentation skills acquired are useful in their current work. Regarding the high frequency of presentations, the alumni remarked that all group members had to present a part of the project. Students from the master's programme Operations Research are also satisfied with the PCL concept. They appreciate the focus on connecting theory and practice.

Students from the master's programme AI indicated during the site visit that even though the topics of the projects are fixed, the projects in the master's programme are more complex than those in the bachelor's programme. Also, the projects are broader and tend to have an open end. In addition, they confirmed that the projects are related to the courses in the programme.

The committee also discussed the work in project groups with the students. Students from the master's programme AI remarked that groups usually consist of a mix of nationalities, which works quite well. Also, there are no fixed roles. The distribution of roles depends on the skills and goals of the involved students.

The committee concludes that the PCL concept suits both programmes and is more than adequately implemented in both programmes. The PCL concept is unique and differentiates the programmes from others in the field. The projects offer ample room for students to apply their acquired knowledge.

Contact hours
The programmes use lectures, practicals and skills training as the other main teaching methods. Both programmes encompass 13 contact hours per week on average. Students are also expected to participate in project groups for 3 hours per week. During the master's thesis students receive individual guidance, on average 1 hour per week. For both programmes, the committee finds the number of contact hours sufficient.

The Board of Examiners is directly involved in the quality assurance of the individual study programmes. Students who wish to replace courses of the regular programmes with other courses must submit a motivated request to the Board. Students also have to submit their plans

for the first semester of the second year to the Board. Electives, internships and study abroad have to be approved by the Board. During the site visit, students from the master's programme AI indicated that they are satisfied with the flexible first semester of the second year. They confirmed that an individual study plan is drawn up that has to be approved by the Board of Examiners. During a preliminary meeting students are informed by the study advisor about the options for the coming semester.

Considerations

The committee is of the opinion that the chosen educational format suits both programmes and is more than adequately implemented in both programmes. The PCL concept is unique and differentiates the programmes from others in the field. The projects offer ample room for students to apply their acquired knowledge. The committee also concludes that the number of contact hours is adequate for both programmes. The committee is positive about the opportunities students have to follow their own interests in the first semester of the second year.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 4 as **good**.
Master's programme of Operations Research: the committee assesses Standard 4 as **good**.

Standard 5: Qualifications incoming students
The curriculum ties in with the qualifications of the incoming students.

Explanation:
The admission requirements are realistic with a view to the intended learning outcomes.

Findings

Students can enroll in both programmes twice a year, in September and in February. Each programme aims at 30 students enrolling each year. To realise this, the department appointed a new PR officer in 2010. For both programmes the number of female students has increased since then. In the master's programme AI, the number of female students entering the programme has increased from 10% to 15%. For the master's programme OR, this has increased from 7% to an average of 33% over the last four years. The committee is positive about this increase. Students can enter both programmes with a bachelor's degree in Knowledge Engineering or a related field. They must also submit proof of English language proficiency. The programme's Board of Admissions discusses all applications. This Board is the same as the Board of Examiners. If necessary, additional information is requested from the students. For students who do not match the criteria, an individual pre-master's programme is prepared, consisting of 30 EC. A scholarship is available for excellent international students. The committee is of the opinion that both programmes apply adequate admission criteria.

The self-evaluation report states that it is challenging to guarantee an adequate match between international students and the master's programmes. To make sure international students can bridge possible gaps and integrate in the programmes, specific skill modules regarding competences and learning were introduced in the 2012/2013 academic year. During these first-semester modules, students learn to work in teams, to understand the PCL concept and start developing skills in writing and presenting. Also, attention is paid to career planning. The committee is positive about the introduction of the skill modules for international students.

The self-evaluation report shows that the number of enrolling students in the Master's programme Artificial Intelligence varied over the last four years. In the 2011/2012 academic year, 13 students enrolled in the first year, in the 2012/2013 academic year, 25 students enrolled (see also appendix 6). The number of enrolling students in the Master's programme Operations Research has increased over the last four years. In 2010/2011 academic year, 25 students enrolled in the first year, in the 2012/2013 academic year, 32 students enrolled (see also appendix 6). The committee is of the opinion that enough students enter the programmes.

During the site visit, the committee discussed with the lecturers the inflow of national and international students. It became clear that the programme wants to attract more local students from the region. Lecturers indicated that regional secondary schools are not aware that Maastricht University offers programmes in AI.

Considerations

The committee concludes that both programmes apply adequate admission criteria. The number of students entering the programmes is sufficient. The committee appreciates that the number of female students entering the programmes has increased in the last few years. In addition, both programmes attract quite a lot of international students. The committee values the fact that for students who have not followed the bachelor's programme at Maastricht University, extra skills classes have been introduced.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 5 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 5 as **satisfactory**.

Standard 6: Feasibility
The curriculum is feasible.

Explanation:
Factors pertaining to the curriculum and hindering students' progress are removed as far as possible. In addition, students with functional disabilities receive additional career tutoring.

Findings

The lecturers of both programmes have office hours scheduled on the same two days every week, to support students who work part-time and to facilitate students who follow courses of the other master's programme. Students are expected to study 25 hours per week, in addition to the contact hours. The self-evaluation reports state that the study load can differ, depending on the choices students make in the first semester of the second year. Reference is also made to student evaluations. They indicate that students of the master's programme AI study 35 hours per week on average. Students of the master's programme OR study 33 hours per week on average. The committee concludes that both programmes are feasible. The committee is however also of the opinion that the scheduling of the courses on two days leaves students almost no time to absorb the learned knowledge and to prepare classes.

For students with physical, psychological or sensory study impairments, the study advisor or the Student Service Centre offer individual guidance. If necessary, an individual plan is drawn up and approved by the Board of Examiners (for example, regarding extended exam time, adapted schedules and course materials, etc.). For outstanding master's students, an honours programme is available.

Completion rates
Since both programmes started in 2009, success rates are only available for two cohorts of students. The self-evaluation report states that for 2011 – 2012 academic year, the success rate for the master's programme AI is 65%. For the master's programme OR, the success rate in the same period is 58%. The committee is of the opinion that the completion rates of both programmes are sufficient.

Considerations

The committee confirms that, based on the information provided and the interviews it conducted with students, lecturers and alumni, both programmes are feasible. In addition, it noted that measures are taken when parts of the programmes are discovered to be impeding the students' study progress. It is also satisfied with the completion rates. For students with physical or psychological study impairments, adequate guidance is available, and individual study plans are drawn up.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 6 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 6 as **satisfactory**.

Standard 7: Scope and duration
The programme meets statutory requirements regarding the scope and duration of the curriculum.

Explanation:
Scope and duration: master's programmes (academic orientation): in principle, a minimum of 60 credits, depending on the programme.

Both master's programmes are full-time two-year programmes, comprising 120 EC. Both programmes therefore meet the formal requirements relating to the scope and duration of the curriculum.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 7 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 7 as **satisfactory**.

Standard 8: Staff policy
The programme has an effective staff policy in place.

Explanation:
The staff policy provides for the qualifications, training, assessment and size of the staff required for the realisation of the curriculum.

Findings

In the department two full, two associate and five assistant professors are involved in coordinating the courses and the projects of both programmes. In addition, external lecturers, PhD students and post-docs assist with practicals, projects and the supervision of theses. The self-evaluation reports state that it is the department's policy that all assistant, associate and full professors should have a PhD. Also, all professors have educational and research duties: assistant professors spend 50% on education, associate and full professors 45%. PhD students and post-docs spend 15% and 10% of their time on education. The department wants to ensure that the programmes are taught by lecturers who are active in research and that the programme is related to the research done by the lecturers.

Teaching performance is discussed with the lecturers during annual assessment reviews. The student evaluations held at the end of each block form the input for these interviews. According to the self-evaluation reports the quality of teaching is a factor considered when extending contracts and offering promotions. The committee is of the opinion that an adequate staff policy is in place. Both programmes are taught by lecturers who are active in research.

Considerations

The committee concludes that for both programmes an adequate staff policy is in place. Both programmes are taught by lecturers who are active in research.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 8 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 8 as **satisfactory**.

Standard 9: Staff quality
The staff is qualified for the realisation of the curriculum in terms of content, educational expertise and organisation.

Explanation:
The factual expertise available among the staff ties in with the requirements set for professional or academic higher education programmes.

Findings

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. All staff members of the department have a PhD degree and hold positions as an assistant, associate or full professor. PhD students and post-docs assist with the labs and during projects. Lecturers whose courses fall in the same period as the research projects are involved in the projects.

The self-evaluation report mentions that 80% of the department should have their BKO certificate (Basic University Teaching Qualification) by 2016. The committee supports this, since it is of the opinion that the number of BKO registrations is quite low. Currently, 63% of the lecturers involved in the master's programme AI had acquired their BKO. And 75% of the lecturers involved in the master's programme OR also had their BKO. The university offers master classes in didactical skills, supervision and examination. The international character of the programmes is also reflected in the staff of the department, with twelve different nationalities.

The site visit revealed that students from both programmes are, in general, satisfied with their lecturers. Alumni were also very positive about the quality of and support from their lecturers.

According to the self-evaluation report, new lecturers are informed about the PCL concept and the role of lecturers in this concept. During the site visit, the committee talked with lecturers from the master's programme OR about the Project-Centred Learning concept. To its surprise, the committee realised that new lecturers do not receive any formal training regarding this didactical concept. Instead, new lecturers always team up with a more experienced lecturer and receive training on the job. The committee realises that this can work in such a small-scale and informal programme. However, it advises the programme to elaborate on the didactical concept in a manual, so lecturers can use this as a reference book.

Considerations

The committee is of the opinion that the staff of both programmes is qualified for the realisation of the curriculum in terms of content, didactical and organizational aspects.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 9 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 9 as **satisfactory**.

Standard 10: Staff quantity
The size of the staff is sufficient for the realisation of the curriculum.

Findings

There are nine lecturers involved in the master's programme AI, with a total amount of 3.0 FTE in the 2011–2012 academic year. The master's programme AI currently has a staff:student ratio of 1:20. In the master's programme OR nine lecturers are involved, with a total amount of 2.2 FTE. The master's programme OR has a staff:student ratio of 1:15 .

Considerations

The committee is of the opinion that both staff:student ratios are acceptable. In addition, it concludes that lecturers from both programmes are accessible and approachable.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 10 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 10 as **satisfactory**.

Standard 11: Services and facilities
The accommodation and the facilities (infrastructure) are sufficient for the realisation of the curriculum.

Findings

Master's programme Artificial Intelligence
Along with the regular lecture rooms, computer facilities, project rooms and rooms for individual study, etc., the programme has at its disposal a Kecs cluster, a robot lab and a swarm lab. The Kecs cluster consists of 12 nodes and is available 24x7. The robot lab includes four humanoid robots (NAO). In the master's programme AI these NAOs are used for thesis projects and the first research project in the first year. 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 swarm lab consists of an experimentation room and a robot hall where experiments with flying robots can be held. The swarm lab is used in the master's programme AI during the first research project and in the *Autonomous Systems* course. The lab is also used for internships and thesis research. In addition, the swarm lab participates in the Robocup@work competition. The programmes also have a common room available for students that serves as a meeting and relaxation space. The committee concludes that the programme offers students adequate facilities, as was confirmed during the tour of the facilities during the site visit.

Master's programme Operations Research
For these students the regular lecture rooms, computer facilities, project rooms, rooms for individual study, and common room are available. In addition, the computers in the computer rooms and the Kecs cluster have been loaded with specific software such as Matlab, Mathematica and Java. The self-evaluation report states that the robot lab and the swarm lab are mostly used by students of the master's programme OR who follow optional AI courses. The committee is of the opinion that also the master's programme OR offers the students adequate facilities.

Both programmes use Blackboard to inform students about the teaching material, the schedules, the examinations, etc. Lecturers also place presentations, additional information and links to websites on Blackboard. Students can register for electives and view their study results. Blackboard is also available for students on a smartphone.

The self-evaluation reports remark that the accommodations and facilities will become too small when the number of students increases. It is also mentioned that there are no specific project rooms or individual workspaces for students working on their master's thesis.

Considerations

The committee is of the opinion that the programmes offer sufficient facilities. It shares the department's concern that an increase in the number of students can put pressure on the current facilities.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 11 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 11 as **satisfactory**.

Standard 12: Tutoring and guidance
Tutoring and student information provision bolster students' progress and tie in with the needs of students.

Findings

Both self-evaluation reports state the following description of student guidance: student guidance is aimed at preventing, identifying and solving study problems for students, and is required to offer students assistance in preparing for their future social position and the related choices in their study career. The study advisor is available for students of both master's programmes. S/he monitors the progress and the grades of all students. S/he also offers guidance relating to individual study planning, future study programmes and careers. Students can also address the study advisor about more personal issues that may cause study delay. While students need to take the initiative to contact the study advisor, students with possible study delay are invited for a meeting with the study advisor.

The Educational Office is available for students with questions regarding administrative matters, such as schedules, grades, exams, booking of courses, etc. The Admissions Office supports new students with their admission, eligibility tests for courses and languages, etc.

The site visit revealed that students are in general positive about the guidance they receive. Also the small scale of the programme is appreciated by the students. It creates an informal atmosphere. The committee is of the opinion that both programmes offer adequate guidance to students. Also the student's progress is actively followed by the study advisor.

Considerations

The committee concludes that the programmes offer sufficient guidance to students.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 12 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 12 as **satisfactory**.

Standard 13: Quality assurance system
The programme is evaluated on a regular basis, partly on the basis of assessable targets.

Explanation:
The programme ensures the quality of the intended learning outcomes, the curriculum, the staff, the services and facilities, the assessments and the learning outcomes achieved through regular evaluations. The programme also collects management information regarding the success rates and the staff-student ratio.

Findings

According to the self-evaluation reports, the programme committee (see also standard 15) and the directors of studies safeguard the quality of the programmes. This is done by measuring the development of research and professional skills, the achievement of the learning outcomes and by evaluating the programme. The programmes use questionnaires for the evaluation of courses, projects and the thesis. If deemed necessary, the programme committee adds extra questions to a questionnaire. Lecturers are asked to reflect on the course or project by email. A report is drawn up for each course or project, consisting of the evaluation results, the comments made by students and lecturers, and the grades and the number of students who passed and failed. The self-evaluation reports state that the first part of this report is public and emailed to all students and lecturers. Lecturers also receive the comments that students made. The reports are discussed by the programme committee. Both programmes yearly perform a curriculum evaluation. The committee concludes that the programmes are evaluated on a regular basis. It however also concludes that that their small and informal scale result in close contact between lecturers, students and director. It is of the opinion that this could be more formalised, for example by creating more structural management information.

The self-evaluation reports remark that informal quality assurance also takes place. Due to the small scale of the programmes, lecturers and students have quite a lot of contact. For example, during the weekly meetings of the project groups, the courses and the organisation of the programmes are also discussed.

Considerations

The committee concludes that both programmes have an adequate quality assurance system in place. The courses are evaluated on a structural basis. The committee appreciates that both curricula are also evaluated on a yearly basis.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 13 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 13 as **satisfactory**.

Standard 14: Measures for improvement
The outcomes of these evaluations constitute the basis for demonstrable measures for improvement that contribute to the realisation of the targets.

Findings

The self-evaluation reports mention that the directors of studies are responsible for implementing the changes in the programmes arising from the aforementioned evaluations. When a course receives a poor evaluation score, the director of studies meets with the lecturer involved and discusses measures for improvement. During the last few years changes have been made to the content of courses, related to changes in the field, to avoid overlap between courses, and to ensure the relationship between projects and courses. More concretely, in the last five years both programmes have moved from a one-year to a two-year programme, a second research project and skill classes were introduced and the master's thesis project lengthened.

The self-evaluation report also remarks that the programme committee is currently developing a standard for grading master's theses. This is expected to reduce the differences in grading that sometimes occur. The committee is of the opinion that the programmes adequately act on the outcomes of evaluations and strives to improve the curricula.

Considerations

The committee concludes that both programmes pay sufficient attention to measures for improvement as a result of evaluations or suggestions by the previous visitation committee. It ascertained that both programmes properly monitor and check the quality of the courses.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 14 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 14 as **satisfactory**.

Standard 15: Involvement of stakeholders
Programme committees, examining boards, staff, students, alumni and the relevant professional field of the programme are actively involved in the programme's internal quality assurance.

Findings

Programme Committee
Both master's programmes share the programme committee with the bachelor's programme in Knowledge Engineering. The programme committee consists of four members (two students and two lecturers) and three advisory members (the director, the quality officer and the study advisor). It meets once a month. The self-evaluation report states that it is responsible for safeguarding the quality of the programme, monitoring the study load and study progress of students, and advising relevant representatives of the programmes (for example, Director of Studies, Board of Examiners, Faculty Council) regarding educational issues. Starting September 2013, the programme committee will consist of three students and three lecturers.

The committee spoke during the site visit to members of the programme committee. It became clear that the programme committee reviews the evaluations and also gives students feedback regarding the comments they make 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). In addition, the programme committee will start to write annual reports. The committee seconds this initiative. It believes this will provide relevant information for the management of the programmes.

Staff and students
Students and lecturers are not only involved in the programme committee, they are also involved in the Faculty Council. Currently, one staff member from the DKE Department is a member of the Faculty Council. The study association MSV Incognito also discusses educational or organisational issues from time to time with the supervisor, director or the managing director of the programmes. Staff members meet regularly during monthly staff meetings. The committee concludes that staff and students are actively involved in the (quality assurance of the) programmes.

Professional field and alumni
The self-evaluation report states that the professional field is involved in the assessment of internship and thesis research, if applicable. This feedback is documented on an assessment form. A few lecturers also hold positions in the professional field. Alumni are mainly involved through surveys, such as the National Student Survey, the annual business day and alumni day. The results of these surveys are discussed in the programme committee. The committee is of the opinion that the professional field and alumni are sufficiently involved in the programmes. To further improve this, the programmes want to install a committee consisting of alumni and members of the professional field, which will critically reflect on the curriculum on an annual basis. The committee supports this.

Considerations

The committee concludes that all stakeholders are actively involved in the quality assurance of both programmes. The committee realises that the small scale of the programmes makes contact easy and encourages discussions between the director, lecturers, students and programme committee. This creates an informal atmosphere, which students and lecturers

can benefit from. It can also lead to a more internal perspective on the programme. The committee supports the resolution of the programme committee to write an annual report. This will provide structural information for the programme management.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 15 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 15 as **satisfactory**.

Standard 16: Assessment system 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 subsequent programmes. The tests and assessments are valid, reliable and transparent to the students.

Findings

Master's programme Artificial Intelligence
The self-evaluation report states that the assessment form used depends on the structure of the course. All courses include a written assessment with open questions. Some courses also assess the students' practical skills. This is done during the practicals by means of assignments. In the *Relational Learning* course students have to select, review and discuss a paper. The *Intelligent Search & Games* course is assessed by a small project in which students design and implement a game-playing computer programme. For some courses students can acquire one bonus point by, for example, competing in a competition for game-playing programmes. The committee noted that when assignments are used, the weighting attached to the assignments is not always specified in the course descriptions. Students are informed about the assessments and criteria in the course descriptions and the study guide. The committee recommends the programmes to include the information about the weighting of the different forms of assessment in the course descriptions.

According to the self-evaluation report, exams are discussed between lecturers when more than one lecturer is involved in the course. The grading of the exams is also discussed between lecturers. The committee advices the programmes to introduce peer review for exams of courses with one lecturer involved.

Master's programme Operations Research
According to the self-evaluation report, most courses of the first year are assessed with a written exam, with open questions, which require motivation, explanation or calculation. Some of the courses (*Optimization*, *Stochastic Decision Making*, *Dynamic Game Theory* and *Identification*) are assessed only by a written exam. Other courses use other assessment forms as well. The *Signal and Image Processing* course is examined by writing a computer programme or solving exercises by computer. The *Topics in Computation and Control* and *Advanced Concepts in Bio-Informatics* courses are assessed with computer exams. The *Business Intelligence* course is assessed by means of case studies. For some courses bonus points can be obtained for mini-exams and practicals.

Projects (both programmes)
The projects are assessed 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 before the examiners and the tutor, who provide students with feedback. The final presentations are given before 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 motivation 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 from the master's programme

Operations Research during the site visit. Students also remarked that during the weekly meetings with the project coordinator, the individual contribution of each group member is evident. At the end of the project, a peer review is held.

Internships are graded by a small committee of at least two staff members, using a grading form. As mentioned earlier, all internships and therefore all internship proposals have to be approved by the Board of Examiners.

The self-evaluation report states that students are informed about the results of the exams within 15 working days. Students can also 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 revealed that students from both programmes are satisfied, in general, with the level and the form of the assessments used. They appreciate the fact that not only written exams are used and that practicals are used to test their ability to apply the acquired knowledge. During the site visit and in preparation for it, the committee also looked at the different forms of assessment. It confirmed that the assessments from both programmes seem adequate in terms of level and content.

Board of examiners
The self-evaluation report states that the Board of Examiners monitors formal compliance of the assessments with the rules and regulations for examination. According to the self-evaluation report, the Board of Examiners also plays a crucial role in the thesis process. The thesis plan that students draw up before the thesis research starts has to be approved by the Board. It also has to be approved by the hosting company or institution (if applicable) and a qualified supervisor. The Board appoints the supervisors. 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 their courses.

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 that lecturers do not always fill out all aspects of the form. Also, the grade given does not always reflect the information provided on the form. During the site the committee discussed this 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 forms. This was confirmed during the interviews with the management. Lecturers revealed that currently a grading scale for the master's theses is being developed. For example, if the thesis can be published as an article, the grade is a 9.5.

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. The committee noted that even though the projects are graded and evaluated, supervisors do not systematically measure whether the learning goals and intended learning outcomes related to the projects are realised. 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.

Thesis procedure (both programmes)
The committee examined the procedure for the thesis of both programmes and is of the opinion that the procedures are adequate. The thesis is individual and encompasses a short scientific research project, which can be either empirical or theoretical. The topic is open but has to match the field of the master's programme. Relevant appendices and software can be added to the thesis.

Both programmes distinguish six phases in the thesis procedure. First, students select a topic and select a supervisor. To guide students in this process, they are informed about the main directions of research within the department. Students can acquire additional information about topics in individual discussions with lecturers. During the site visit, students from the master's programme Operations Research remarked that they are free to choose a thesis topic. Lecturers suggest topics, and during the first year a presentation of thesis topics is given. Once students select their topic, it is relatively easy to find a supervisor, since students are aware of the lecturers' specialisations.

The second phase consists of writing a thesis research plan (including research question). The thesis plan is signed by the student and supervisor and is submitted to the Board of Examiners for approval. Students present their research topic to staff members and fellow students. During the third phase, the thesis research is executed. During this phase students are guided by their supervisor. Part of this phase is also a presentation of the initial results to staff members and fellow students. The fourth phase encompasses the writing of the master's thesis. During the fifth and sixth phases, the final presentation is prepared and held.

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.

Achievement of the learning outcomes
The committee assessed the achieved learning outcomes by inspecting a selection of 15 theses from each programme (see Appendix 7). 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 of both programmes are of good quality, and graduates of both master's programmes achieve the required level. The theses it examined discussed quite complex topics and were very well written in general. They had a logical structure, a clear and relevant problem definition and showed adequate use of research methods. Also, the theses showed that the students were very aware of the developments and relevant literature relating to the thesis topic.

Even though the level of the theses of both master's programmes was quite high, the committee noted that they did not always have a clear relationship with the field of AI. This was not only the case for theses from the master's programme OR but also for some theses from the master's programme AI. The committee discussed this during the site visit with several representatives of the programmes. The Board of Examiners confirmed that all thesis proposals are reviewed by the board. During this review the relationship between the proposal and the programme is assessed. The management of the programmes remarked that the field of AI is looked at from different perspectives in the department: formal, psychological, symbolic and mathematical. This broad perspective is also reflected in the theses.

The committee realises that there will always be tension about the chosen topic of a thesis in a broad discipline such as AI. Nevertheless, it believes that the AI character of the theses should be evident, especially in theses of the master's programme in AI. It recommends that the Board of Examiners more actively monitor this relationship.

Considerations

The committee concludes that even though this is not formalised, the programmes have an adequate, more informal assessment system in place. The committee is of the opinion that the assessments are adequate in terms of level and content. Students are also satisfied about the assessment system in general. To formalise the assessment system, the committee advises the department to develop and implement an assessment policy. It also recommends that the department instruct lecturers to complete consistently all parts of the thesis assessment forms. In addition, it advises the Board of Examiners to assess a selection of theses regularly and to actively monitor the relationship between the theses from both master's programmes 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 the overall quality and level of the theses are high. Therefore, the committee concludes that graduates of both master's programmes achieve the required level.

Conclusion

Master's programme of Artificial Intelligence: the committee assesses Standard 16 as **satisfactory**.
Master's programme of Operations Research: the committee assesses Standard 16 as **satisfactory**.

General conclusion

The committee assesses the *master's programme of Artificial Intelligence* as **satisfactory**.
The committee assesses the *master's programme of Operations Research* 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).

[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

[5] In Dutch: Kunstmatige Intelligentie

programme. Because the core is defined as minimal, it does not, by itself, constitute a complete undergraduate curriculum. Every undergraduate programme must include additional elective courses from the body of knowledge. This report does not define what those courses should be, but does enumerate options in terms of modules.

2.3 Assessing the time required to cover a course

To give readers a sense of the time required to cover a particular course, a metric must be defined that establishes a standard of measurement. No standard measure is recognized throughout the world, but within the European Community agreement has been reached upon a uniform European Credit Transfer System[6] (ECTS) in which study load is measured in European Credits (ECs). One EC stands for 28 hours of study time and a full year of study is standardized at 60 EC. In this document, we shall use the EC metric as the standard of measurement for study load.

2.4 Coping with change

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

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

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

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

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

intelligence so that they are more effective, more reliable, more efficient, safer, and often require less natural resources. This role, in combination with the interdisciplinary nature of the field, requires the Artificial Intelligence alumnus to be able to contribute to interdisciplinary teams and, in many cases function as an intermediate who facilitates the interaction of (other) domain specialists.

3.2 Common requirements

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

1. Essential and foundational underpinnings of the core aspects of intelligence. These must be founded on empirical efforts and based on a formal theory, and they may address professional values and principles. Regardless of their form or focus, the underpinnings must highlight those essential aspects of the discipline that remain unaltered in the face of technological change. The discipline's foundation provides a touchstone that transcends time and circumstances, giving a sense of permanence and stability to its educational mission. Students must have a thorough grounding in that foundation.
2. A foundation in the core concepts of modelling and algorithms for implementing intelligence. The construction and use of models (simplified, abstracted and dynamic representations of some phenomenon in reality) is common to many sciences. In Artificial Intelligence, however, model building is central: the field of Artificial Intelligence may actually be defined as trying to model aspects of (formal or natural) intelligence and knowledge. Moreover, models within Artificial Intelligence have specific characteristic: they are computational and therefore necessarily formal. Artificial Intelligence-graduates must therefore be able to work with (computational) models at different levels of abstraction and understand the recursive nature of models in Artificial Intelligence. This foundation has a number of layers:
    a. An understanding of, and appreciation for, many of the diverse aspects of intelligence, models of intelligent phenomena, and of algorithms that describe intelligent processes.
    b. Skills to model intelligent phenomena and appreciate the abilities and limitation of these models, if appropriate in comparison with a natural example.
    c. Skills to model and implement intelligent phenomena on a computer, in particular skills to work with algorithms and data-structures in software.
    d. Skills to design and build systems that are robust, reliable, and appropriate for their intended audience.
3. An understanding of the possibilities and limitations of what intelligent systems can and cannot do. This foundation has a number of levels:
    a. An understanding of what current state-of-the-art can and cannot accomplish, if appropriate in combination with the accomplishment of the natural system that inspired it;
    b. An understanding of the limitations of intelligent systems, including the difference between what they are inherently incapable of doing versus what may be accomplished via future science and technology;
    c. The impact of deploying technological solutions and interventions on individuals, organizations, and society.
4. The identification and acquisition of non-technical skills, including interpersonal communication skills, team skills, and management skills as appropriate to the discipline.

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

3.3 Shared background for bachelor programmes

Similar to alumni of programmes such as Physics, Computer Science, and Psychology, all Artificial Intelligence bachelors are expected to share a certain amount of support knowledge, domain specific knowledge, specialized domain knowledge, and a set of skills. The content mentioned below ensures a firm common basis that enables AI bachelors of any Dutch university admission to any Dutch Master programme in AI. At the same time, it allows for a wide range of individual and/or institute specific specialisation. The list is an update (extension) of the shared programme agreed upon by the KION platform in 2006.

3.3.1 Common core between AI bachelor degree programmes

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

Artificial Intelligence modules

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

Support modules

- Computer science
  - Programming
  - Data structures and algorithms
- Logic
- Mathematics
  - Calculus
  - Probability theory
  - Linear algebra
  - Statistics

Academic skills

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

- Analytic skills
- Empirical methods
- Modelling
- Teamwork
- Written and oral communication, argumentation and presentation

3.3.2 Artificial Intelligence elective courses
The following list of modules is considered as representative of the AI field at this moment. Given that the different AI programs have different priorities in selecting topics, and assigning topics to either the Bachelor or Master, each Bachelor should offer a substantial subset of the following list as part of their Bachelor programme, either as specific course, or as a substantial part of a broader course.

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

4. Bachelor programme Artificial Intelligence

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

4.1 Objectives

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

4.1.1 Access to master programmes
The bachelor provides the student with the specific knowledge and abilities, exemplified in the form of a bachelor diploma that allows the bachelor access to a master programme in Artificial Intelligence or other national or international masters, particularly in related disciplines.

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

- Supervised work on a national and international academic level;

- Positions in the modern high-tech society, such as functions in knowledge-intensive companies and knowledge intensive parts of the non-profit sector.

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

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

4.2 Final qualifications

The objectives of the bachelor can be specified into final qualifications. To comply with international standards these qualifications are presented below in terms of the Dublin descriptors for the bachelor's profile[7]. Together these final qualifications must lead to alumni that exemplify the shared identity defined in section 3.

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

Qualifications:
1. Basic understanding of key areas in Artificial Intelligence in accordance with the shared identity.
2. Advanced knowledge of at least one of the key areas in Artificial Intelligence, up to a level that without further requirements grants access to a master programme in this area.
3. Knowledge of the symbolic approach to Artificial Intelligence.
4. Knowledge of the numerical, non-symbolic, approach to Artificial Intelligence.
5. Knowledge of the most important philosophical theories regarding the fundamental questions of AI as well as its ethical, legal and societal implications.
6. Knowledge of the most important theories developed in the area of empirical sciences, particularly psychology.
7. Expertise in constructing and evaluating computational models of cognitive processes and intelligent systems.

4.2.2 Applying knowledge and understanding
Bachelors can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation, and have competences typically demonstrated through devising and sustaining arguments and solving problems and/or designing systems within their field of study. They are able to analyse and model *prototypical* Artificial Intelligence problems by using *known* Artificial Intelligence methods and techniques.

Qualifications:
1. The ability to understand, apply, formulate, and validate models from the domains of Artificial Intelligence.
2. The ability to apply the symbolic approach to Artificial Intelligence.

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

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

4.2.3. Making judgements

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

Qualifications:

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

4.2.4.Communication

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

Qualifications:

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

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

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

5. Master programme Artificial Intelligence

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

5.1 Objectives

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

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

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

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

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

5.1.4. Place in society
The programme provides the master with the knowledge and tools needed to formulate an informed opinion about the meaning and impact of Artificial Intelligence in society. Masters are able to enrich society with results from contemporary research and oversee the consequences of proposed measures to society and are aware of their responsibility towards society.

5.2 Final qualifications

The objectives of the master can be specified into final qualifications. To comply with international standards these qualifications are presented below in terms of the Dublin descriptors for the master's profile[8]. Together these final qualifications must lead to alumni that exemplify the shared identity defined in section 3.

5.2.1. Knowledge and understanding

The master demonstrates knowledge and understanding in a field of study that builds upon and supersedes their bachelor degree. Knowledge, understanding, and abilities are typically at a level at which the master is able to formulate a feasible research plan in one's own specialisation.

Qualifications:

1. Advanced understanding of key areas in Artificial Intelligence.
2. Specialist knowledge of at least one of the key areas in Artificial Intelligence, up to a level that the master can appreciate the forefront of research in that field.
3. The master is able to judge the quality of his of her work or the work of others from scientific literature.

5.2.2. Applying knowledge and understanding

Masters can apply their knowledge and understanding in a manner that indicates a scientific approach to their work or vocation. They are able to handle complex and ill-defined problems for which it is not a priori known if there is an appropriate solution, how to acquire the necessary information to solve the sub-problems involved, and for which there is no standard or reliable route to the solution.

Qualifications:

1. The ability to formulate a project plan for an open problem in a field related to Artificial Intelligence in general and the own specialisation in particular.
2. The ability to determine the feasibility of a proposal to lead to a solution or design as specified.
3. The ability to contribute autonomously and with minimal supervision to an interdisciplinary project team and to profit from the abilities, the knowledge, and the contributions of other team members.
4. The ability to choose, apply, formulate, and validate models, theories, hypotheses, and ideas from the domains of Artificial Intelligence.
5. The ability to submit an argument in the exact sciences (or humanities) to critical appraisal and to incorporate its essence in the solution of Artificial Intelligence problems.
6. The ability to translate academic knowledge and expertise into social, professional, economic, and ethical contexts;
7. Awareness of, and responsibility concerning, the ethical, normative and social consequences of developments in science and technology, particularly resulting from original contributions.

5.2.3. Making judgements

The master is able to formulate an opinion or course of action on the basis of incomplete, limited and in part unreliable information.

Qualifications:

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

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

5.2.4. Communication

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

Qualifications:

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

5.2.5. Learning skills

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

Qualifications:

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

6. International perspective

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

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

Cognitive Science. Furthermore, we will compare the Dutch bachelor qualifications with the requirements for enrolment in Artificial Intelligence master programmes in other countries.

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

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

6.1 Comparison of bachelor programmes

6.1.1. The Artificial Intelligence bachelors in Edinburgh

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

6.1.2. Comparison with the Dutch frame of reference

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

6.1.3. The Cognitive Science bachelors in Osnabrück and Linköping

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

6.1.4. Comparison with the Dutch frame of reference

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

each individual study programme has a specific profile in addition to the communal areas appears to hold for both inspected study programmes outside the Netherlands as well.

6.2 Comparison of master programmes

6.2.1. Edinburgh

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

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

6.2.2. Comparison with the Dutch frame of reference

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

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

6.2.3. Stanford

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

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

6.2.4. Comparison with the Dutch frame of reference

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

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

7. Concluding remarks

Artificial Intelligence is a developing field. Due to its relatively recent start as a coherent field of research, the term Artificial Intelligence does not have the stature of Physics, Psychology, or even Computer Science. Internationally, the study of natural and artificial intelligence with computational means is firmly, but usually not very visibly, embedded in the fabric of modern Universities.

Modern topics such as gaming, ambient intelligence, ambient awareness, and believable-agent systems are fashionable manifestations of Artificial Intelligence and these and future fashionable spin-offs of Artificial Intelligence will increasingly affect humans. Future challenges will force products, services, and even societies to react faster but remain reliable, to be both flexible and effective, be both efficient and versatile, and to utilize natural resources with maximal benefit. Making the most of this combination of conflicting demands, which is very much at the core of in the concept of *intelligence*.

The Dutch situation is special because of the existence of Artificial Intelligence bachelor and master programs on most of the general universities. This offers the Netherlands a competitive advantage, consistent with its main economic strategy to remain one of the leading "knowledge intensive" economies. This frame of reference explicates how the bachelor and master programmes in Artificial Intelligence of Dutch universities contribute to educate alumni that will take a leading role in meeting these future challenges.

Appendix 3: Intended learning outcomes

Master's programme Artificial Intelligence

Knowledge and understanding
Q1: The Master programme Artificial Intelligence covers a range of subjects emphasizing the following eight research topics:

1. intelligent techniques for playing and solving abstract games and controlling virtual characters in video games,
2. situated agents to study the control and coordination of embodied agents, i.e. robots (e.g. e-puck and telepresence robots),
3. multi-agent systems of collaborating autonomous intelligent systems,
4. formal techniques for reasoning in agents,
5. techniques for representing knowledge,
6. data mining to extract useful patterns and knowledge from large data repositories,
7. text mining to extract interesting non-trivial information and knowledge from unstructured text,
8. relational learning to extend machine learning techniques to deal with expressive logical or relational representations.

Q2: Through their research work for the Master's thesis students come into contact with the forefront of research in a sub-field of Artificial Intelligence of their choice. During the research projects and the Master thesis research, as well as during internships and practical work at various courses, students experience the versatility of the research process and learn to handle it in a proper way.
Q3: During thesis meetings, research projects, and several courses students present and discuss recent AI publications. They also relate their own work to the state of the art.

Applying knowledge and understanding
Q4: Through PCL students develop the ability to formulate a project plan for an open problem in in a field related to Artificial Intelligence in general and to their own specialisation in particular.
Q5: Through PCL students develop the ability to determine the feasibility of a proposal to achieve a solution or design as specified.
Q6: Through PCL students develop 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.
Q7: Through PCL, practical work in courses, and thesis research students develop the ability to choose, apply, formulate, and validate models, theories, hypotheses, and ideas from the domains of Artificial Intelligence.
Q8: Through courses, research projects and thesis research students develop the ability to submit an argument in the exact sciences to critical appraisal and to incorporate its essence in the solution of Artificial Intelligence problems.
Q9: Through research projects, internships, thesis research students develop the ability to translate academic knowledge and expertise into social, professional, economic, and ethical contexts.
Q10: Through research projects, internships, and thesis research students develop awareness of, and responsibility concerning, the ethical, normative and social consequences of developments in science and technology, particularly resulting from original contributions.

Making judgements
Q11: Through PCL and thesis research, Master students develop a scientifically sound problem-solving attitude. They are able to find autonomously relevant literature and software applications through libraries or the Internet, and to assess their applicability.
Q12: Through PCL and internships students develop the ability to demonstrate a professional attitude conform the international scientific conduct in Artificial Intelligence.
Q13: Through PCL and thesis meetings students develop the ability to provide and receive academic criticism conform the standards in one specialism of Artificial Intelligence-research.
Q14: Through PCL and thesis meetings students develop 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.

Communication
Q15: During the Master education students give several presentations: while working on projects, at thesis meetings and during some courses, where they discuss and comment on each other's work. Students have to finish their projects and internship with a report. The Master programme is concluded with a research assignment culminating in a thesis and, ideally, publishable results. The thesis is presented individually.

Learning skills
Q16: In PCL students reflect upon one's competences and knowledge. If necessary, students have to take the appropriate corrective action.
Q17: In PCL assignments are set up in such a way that students have to investigate the current state of the art in AI (either academic or professional).
Q18: Project assignments are generally so challenging that a considerable appeal is made to the creativity and learning skills of the students.

Master's programme Operations Research

Knowledge and understanding
The Master demonstrates knowledge and understanding in a field of study that builds upon and supersedes the 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 specialization.

Qualifications:
Q1. Advanced understanding of key areas in Applied Mathematics and Knowledge Engineering, in particular in the subfields Operations Research and Mathematical Systems and Control Theory, and possibly of Artificial Intelligence.
Q2. Specialist knowledge of at least one of the key areas in Applied Mathematics and Knowledge Engineering, up to a level that the Master can appreciate the forefront of research in that field.
Q3. The Master is able to judge the quality of his or her work, or the work of others from the scientific literature.

Applying knowledge and understanding
Masters can apply their knowledge and understanding in a manner that shows 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, they know how to acquire the necessary information to solve the sub-problems involved, and they know how to proceed with problems for which there is no standard or reliable route to the solution.

Qualifications:
Q4. The ability to formulate a project plan for an open problem in a field related to Applied Mathematics (Operations Research, Mathematical Systems Theory, Signal Processing and Data Analysis, Modelling, Optimisation, and Decision Making) in general, and to one's own specialization in particular.
Q5. The ability to judge the feasibility of a proposal to lead to a solution or design as specified.
Q6. 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.
Q7. The ability to choose, apply, formulate, and validate models, theories, hypotheses, and ideas from the domains of Applied Mathematics and Knowledge Engineering (c.q. Artificial Intelligence).
Q8. The ability to submit an argument in the Exact Sciences (or Humanities) to critical appraisal and to incorporate its essence in the solution of problems in Applied Mathematics and Knowledge Engineering.
Q9. The ability to translate academic knowledge and expertise into social, professional, economic, and ethical contexts.
Q10. Awareness of, and responsibility concerning, the ethical, normative and social consequences of developments in science and technology, particularly resulting from original contributions.

Making judgements
The Master is able to formulate an opinion or course of action on the basis of incomplete, limited and in part unreliable information.

Qualifications:
Q11. Competence in the search and critical processing of all sources of information that helps to solve an open and ill-defined problem.
Q12. The ability to demonstrate a professional attitude conform the (international) scientific conduct in Applied Mathematics and Knowledge Engineering.
Q13. The ability to provide and receive academic criticism conform the standards in one's own specialism of Applied Mathematical research.
Q14. 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.

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

Qualifications:
Q15. 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.

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:
Q16. Being able to reflect upon one's competences and knowledge and, if necessary, being able to take the appropriate corrective action.
Q17. The ability to follow current (scientific) developments related to the professional environment.
Q18. Showing an active attitude towards continued learning throughout a professional career.

Appendix 4: Programme

Master's programme Artificial Intelligence

Programme Master AI	**EC**
Year 1	
Period 1	
Autonomous Systems (KEN4114)	6
Foundations of Agents (KEN4115)	6
Research Project 1 (**)	
Period 2	
Multi-Agent Systems (KEN4111)	6
Intelligent Search & Games (KEN4123)	6
Research Project 1 (**)	
Period 3	
Research project 1 (KEN4130)	6
Period 4	
Data Mining (KEN4113)	6
Ontology Engineering & Semantic Web (KEN4144)	6
Research Project 2 (**)	
Period 5	
Relational Learning (KEN4143)	6
Information Retrieval & Text Mining (KEN4153)	6
Research Project 2 (**)	
Period 6	
Research Project 2 (KEN4131)	6
Year 2	
Period 1, 2, 3	
Electives *	30
Period 4, 5, 6	
Master Thesis AI (KEN4160)	30

** Note, during the elective semester (first semester of year 2) of the master programme it is possible to take electives from our other master programme or relevant master programmes at Maastricht University (maximum of 2 courses outside DKE) or to participate in a research project, a company internship or a study abroad semester at one of our partner universities (Aarhus University in Denmark, Université de Montreal in Canada, University of Electronic Science and Technology of China and Reykjavik University in Iceland). Please contact the board of examiners for more information.*

*** The Research Project 1 will start in Period 1.1 and Period 1.2 with weekly meetings. The credits for the project will become available at the end of Period 1.3. The Research Project 2 will start in Period 1.4 and Period 1.5 with weekly meetings. The credits for the project will become available at the end of Period 1.6.*

Part of the Research project is a Project skill programme (all elements are mandatory):

Period 1.1:

- Session 1 (1 hour): Introduction to Project centred Learning and LateX
- Session 2 (3 hours): Team Building afternoon
- Session 3 (2 hours): Discover your Competences Part 1 (Career Services)
- Session 4 (2 hours): Discover your Competences Part 2 (Career Services)
- Session 5 (2 hours): Presentation skills
- Session 6 (2 hours): Presentation skills

Period 1.2:

- Session 1 (3 hours): Master class Leadership
- Session 2 (3 hours): Academic Writing Skills
- Session 3 (3 hours): Master class Creativity
- Session 4 (3 hours): A workshop of choice at Career Services

Master's programme Operations Research

Period 1	**EC**
Optimization (KEN4211)	6
Signal- and Image Processing (KEN4222)	6
Research Project 1(**)	
Period 2	
Stochastic Decision Making (KEN4221)	6
Business Intelligence (KEN4212)	6
Research Project 1 (**)	
Period 3	
Research project 1 (KEN4230)	6
Period 4	
Dynamic Game Theory (KEN4251)	6
Identification (KEN4242)	6
Research Project 2 (**)	
Period 5	
Advanced Concepts in Bio-Informatics (KEN4241)	6
Topics in Computation and Control (KEN4252)	6
Research Project 2 (**)	
Period 6	
Research Project (KEN4231)	6
Year 2	
Period 1, 2, 3	
Electives (*)	30
Period 4, 5, 6	
Master Thesis OR (KEN4260)	30

** Note, during the elective semester (first semester of year 2) of the master programme it is possible to take electives from our other master programme or relevant master programmes at Maastricht University (maximum of 2 courses outside DKE) or to participate in a research project, a company internship or a study abroad semester at one of our partner universities (Aarhus University in*

Denmark, Université de Montreal in Canada, University of Electronic Science and Technology of China and Reykjavik University in Iceland). Please contact the board of examiners for more information.

*** The Research Project 1 will start in Period 1.1 and Period 1.2 with weekly meetings. The credits for the project will become available at the end of Period 1.3. The Research Project 2 will start in Period 1.4 and Period 1.5 with weekly meetings. The credits for the project will become available at the end of Period 1.6.*

Part of the Research project is a Project skill programme (all elements are mandatory):
Period 1.1:

- Session 1 (1 hour): Introduction to Project centred Learning and LateX
- Session 2 (3 hours): Team Building afternoon
- Session 3 (2 hours): Discover your Competences Part 1 (Career Services)
- Session 4 (2 hours): Discover your Competences Part 2 (Career Services)
- Session 5 (2 hours): Presentation skills
- Session 6 (2 hours): Presentation skills

Period 1.2:

- Session 1 (3 hours): Master class Leadership
- Session 2 (3 hours): Academic Writing Skills
- Session 3 (3 hours): Master class Creativity
- Session 4 (3 hours): A workshop of choice at Career Services

Appendix 5: Quantitative data regarding the programme

Data on intake, transfers and graduates

Master's programme Artificial Intelligence

Two-year Master programme

Number of AI students	09/10	10/11	11/12	12/13*
Total number of students	11	48	54	51
New students (1st year)	11	37	13	25
Of which originating from BA KE	7	10	1	10
Premaster	1	0	2	0
Re-registered students (2nd year)	0	11	41	26
Graduates	0	6	19	4**

*Only the September inflow included **Up till 1-2-2013

One-year Master programme

Number of AI students	**07/08**	**08/09**	**09/10**	**10/11**	**11/12**	**12/13**
Total number of students	41	49	32	10	6	1
New students	24	22	3	0	0	0
Of which originating from BA KE	19	5	2	0	0	0
Premaster	0	1	1	0	0	0
Re-registered students	17	27	29	10	6	1
Graduates	11	13	19	3	4	1

Success Rates Master AI 2-year programme

2009-2010	**September 2010**	**September 2011**	**September 2012**
64%	[65%-89%]*	-	-

*65% up till now, 9 students are expected to graduate by the end of the academic year which could rise to a maximum success rate 89%

Success Rates Master AI 1-year programme

2007-2008	**2008-2009**	**2009-2010**
46%	73%	33%*

* Only 3 1-year Master AI students registered: 1 drop-out, 1 graduate in time, 1 later.

Master's programme Operations Research

Two-year MSc programme

Number of OR students	**09/10**	**10/11**	**11/12**	**12/13**
Total number of students	13	25	32	32*
New students (1st year)	13	12	16	12
Of which originating from BA KE	7	3	5	3
Premaster	0	0	0	0
Re-registered students (2nd year)	0	13	16	20
Graduates	0	5	8	1**

* Total number of students includes September inflow only ** Graduates 2012-2013 until 1 February 2013

One-year MSc programme

Number of OR students	07/08	08/09	09/10	10/11	11/12	12/13
Total number of students	14	16	9*	3	1	1
New students	5	8	2	0	0	0
Of which originating from BA KE	3	5	1	0	0	0
Premaster	1	0	0	0	0	0
Re-registered students	9	8	7	3	1	1
Graduates	7	4	3	2	0	0

*1 student re-registered in the Master AI (neutral switch)

Success Rate Master OR (2 year)

2007-2008	2008-2009	2009-2010	September 2010
-	-	54%	[58%-67%]*

*58% up till now, 1 student is expected to graduate by the end of the academic year which could rise to a maximum success rate 67%

Success Rate Master OR (1 year)

2007-2008	2008-2009	2009-2010	2010-2011
80%	75%	0%*	-

*2 new OR students 2009-2010: 1 drop-out, 1 neutral switch to the Master AI.

Teacher-student ratio achieved

Master's programme Artificial Intelligence

Given that the number of Master students in 2011-2012 was 60 and the deployed teaching FTE was 3.0, a teacher-student ratio was achieved of 1: 20

Master's programme Operations Research

Given that the number of Master students in 2011-2012 was 33 and the deployed teaching FTE was 2.2, a teacher-student ratio of 1:14.9 was achieved

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

Master's programme Artificial Intelligence & Master's programme Operations Research

Type	Contact hours per week
Regular courses (group)	13
Project (group)	3
Graduation Period (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**

- 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 master's programme Artificial Intelligence

6025792	471879	6025214	424013	6024430
529044	582360	6025541	6011215	6025035
471828	5009138	408662	6018854	6033010

Theses master's programme Operations Research

399701	489883	431133	314366	355410
6017683	6005460	481408	399736	103144
473421	6028763	362077	5008131	5006864

Appendix 8: Declarations of independence

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ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: León Rothkrantz

PRIVÉ ADRES: Ld. 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/UvT/UvA/VU

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

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nederlands-vlaamse accreditatieorganisatie

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

PLAATS: Utrecht DATUM: 14 maart 2013

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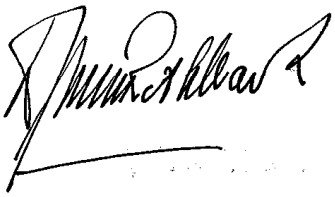

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ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: Dirk Herfen

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:

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

PLAATS: Utrecht

DATUM: 14/3/2013

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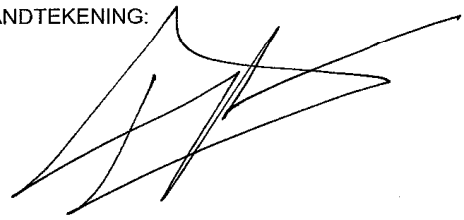

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ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

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:

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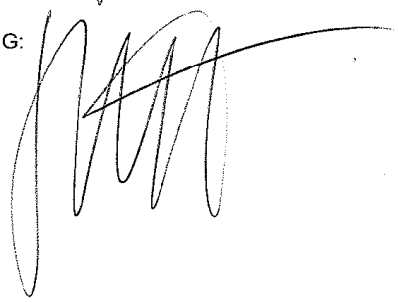
PLAATS: Delft DATUM: 14/3/2013

HANDTEKENING:



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ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: DE CAUSMAECKER PATRICK

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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PLAATS: UTRECHT DATUM: 14/8/2013

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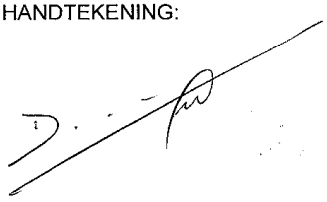

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ONAFHANKELIJKHEIDS- EN GEHEIMHOUDINGSVERKLARING

INDIENEN VOORAFGAAND AAN DE OPLEIDINGSBEOORDELING

ONDERGETEKENDE

NAAM: Yfke Marie Dulek

PRIVÉ ADRES: Cambridgelaan 617

3584 DM

Utrecht

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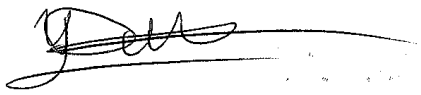
PLAATS: Utrecht DATUM: 14-03-2013

HANDTEKENING:



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ONDERGETEKENDE

NAAM: T. Bueving

PRIVÉ ADRES: De Onde Klaverbeek 20
7359 GZ Ugchelen

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PLAATS: Utrecht

DATUM: 14-3-2013

HANDTEKENING: