CvB stukken voor agenda Universiteitsraad

Overlegvergadering d.d. : 11 november 2015
Commissievergadering : **OOS, 21 oktober 2015**
Agendapunt : Spatial Engineering
Bijgevoegde stukken : Spatial Engineering – designing a sustainable future

Betrokken dienst: S&B paraaf:

Secretaris: Van Keulen paraaf:

Portefeuillehouder: Brinksma paraaf:

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1. Status agendapunt:

Rol URaad:

- Ter informatie
- Ter advisering
- **Ter instemming**
- Anders:

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2. Eerder behandeld in:

Naam gremium:
Datum behandeling:
Naam agendapunt:
Conclusie toen:

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3. Toelichting/samenvatting:

Als uitvoering van de ITC- faculteitsplannen en Vision2020 heeft het ITC het bijgevoegde voorstel voor de Masteropleiding "Spatial Engineering" ontwikkeld. Het CvB vindt het voorstel veelbelovend en heeft het ITC gevraagd om een macrodoelmatigheidstoets en een "Toets Nieuwe Opleiding" inclusief het bijzonder kenmerk internationalisering voor te bereiden[1].
Het bijgevoegde document bevat de inhoudelijke basis van de nieuw te starten opleiding. Kern van het voorstel is een combinatie tussen de ruimtelijk expertise en kennis van het ITC in een civiel technische en ruimtelijke planning context.
Omdat de beoogde startdatum 1 september 2016 is en het CvB een zorgvuldige behandeling van de Uraad waardeert, wordt het plan vroegtijdig aan de Uraad voorgelegd. Na (de beoogde) instemming zal het CvB regelmatig over de voortgang informeren.

English summary:
The ITC wants to start a new educational programme, the MSc "Spatial Engineering, as a result of faculty plans and Vision2020. The CvB finds the proposal promising and asked the ITC to prepare a "Macrodoelmatigheidstoets[2]" and a "Toets Nieuwe Opleiding[3]" including the distinctive feature "internalization".
Because of the desired start of 1 September 2016 the planning is ambitious. To guarantee a careful consultation of the Uraad, the CvB asked already in this stage for approval. Of course, after the approval, the Uraad will be informed regularly about the progress.

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[1] Voor meer informatie over de macrodoelmatigheidstoets zie www.cdho.nl en voor meer informatie over de Toets Nieuwe Opleiding zie https://www.nvao.net/beoordelingsproceduresnederland/toets-nieuwe-opleiding-nederland
[2] A check commissioned by the Minister of the proposed educational program is effective; is there a necessity? And need for the proposed program? And room within the national offer of MSc curricula? Does it fit within the vision of the UT?
[3] Toets nieuwe opleiding = initial accreditation, more information http://nvao.com/initial_accreditation

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4. (Voorgenomen) besluit CvB:

Gezien
Gehoord
Overwegende
Neemt het CvB: neemt het voorgenomen besluit de MSc Spatial Engineering per 1 september 2016 te starten en legt dit ter instemming voor aan de UR omdat het een wijziging van het BBR betreft.

GRIFFIE URaad: **(door griffie UR in te vullen)**
Eerder in URaad aan de orde geweest?

- Nee.
- Ja, op
  Conclusie toen:

Nadere toelichting: (Voor als presidium/griffier vindt dat één van bovengenoemde punten nadere toelichting behoeft)
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SPATIAL ENGINEERING
Designing a sustainable future

Proposal for a new MSc for the University of Twente

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Draft 3.5 – Sep 29, 2015

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SPATIAL ENGINEERING

DESIGNING A SUSTAINABLE FUTURE

THE NEED FOR A SPATIAL ENGINEERING PROGRAM

Major problems in today's world, like distribution of limited natural resources, water, energy or food security, catastrophic consequences of natural and man-made disasters, or the unplanned development of mega cities, require multidisciplinary solutions and systems thinking. These "wicked" problems do not have single causes, and thus cannot be solved by single interventions. Moreover, designing interventions without a thorough and deep understanding of the full complexity of the situation, has often lead to the opposite of what was wished for.

Experts who designs solutions for multilevel spatial problems have to be aware of the societal context, and be able to cooperate and communicate with other disciplines on a common solution. A common denominator in these problems is *spatial information science*. Any technical engineering design or solution will have wider spatial implications in terms of environmental impact, economy and society. This information is crucial not only for the design of the solution. In most, if not all, cases we see an ongoing emancipation of stakeholders. Both in developed and developing countries, citizen groups are claiming positions in which they can demand a thorough assessment of the consequences of interventions. A modern engineer has to be aware and adapt to this context.

We see this type of thinking in many strategies and policies: the Europe 2020 agenda, UN and FAO strategies, World Bank and Asian Development Bank policies, and the Dutch national top sectors approach to innovation. Large engineering and consultancy firms think and present themselves along these lines as well: divisions like "integrated water management, sustainable living environment" etc. are commonplace. Engineering companies, industry, service centers, and local and national government institutions ask for two types of engineers: the technical specialist, who can design and build a solution (a structure, a means of transport, a medical instrument, a smart algorithm), and the engineer that has a broad and multidisciplinary view; who can design analysis scenarios with input from multiple knowledge fields, and work with a range of software platforms that combine data of various sources. His or her goal is to present stakeholders with a range of scenarios to counteract problems rapidly and accurately, in order to select sustainable solutions.

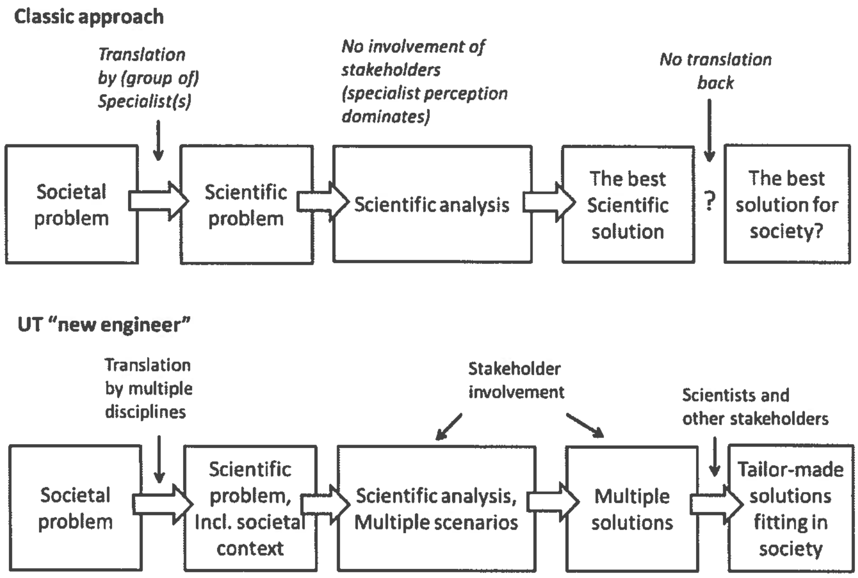
To meet this need, we have developed a MSc-program to train this type of professional; an engineering professional who feels at home in the international arena, is trained in assessing and dealing with complex multidisciplinary spatial systems problems in different socio-economic, cultural and political settings.

This MSc is intended for students who are motivated by solving these large scale problems and understand that we need to invest all our academic creativity if we want to design a sustainable society. To achieve this the curriculum uses as a learning environment a series of current real life national and international projects, with the full representation of multilevel problems, of imperfect datasets, a complex societal context.

The most important feature of our program is that instead of teaching already known methods and tools we focus on teaching students to learn to identify, select and master the most appropriate technologies, data sources and software solutions. This is especially important if we want to prepare students for the fast pace of technological and scientific development and the quickly changing job market. In most cases by the time students graduate there will be new and advanced methods, which they will have to learn themselves to be able to solve the kinds of transdisciplinary problems described above.

EMBEDDED IN THE UNIVERSITY OF TWENTE

The mission of the University of Twente is to train people who can make a difference in society and can contribute to solutions for the world's big problems. The motto of the University - "High Tech, Human Touch" - reflects the ambition to be a research and training institute with a strong emphasis on problem solving through innovation and entrepreneurship. The diagram below tries to show this (in an exaggerated way!). All too often the classic approach is a specialist translating a societal problem in narrowly defined discipline with stakeholder involvement only in the beginning. There is little involvement of stakeholders afterwards and the solution is a solution to the translation, and presented as the best possibility. The University of Twente is moving away from this: it wants its students to embed their science and academic thinking in society, to work in close relation to stakeholders throughout the process. You find this in the applied mathematics, medical sciences, civil engineering, creative technology, management and governance and many other disciplines. The UT embraces the idea of the "new engineer".



The Faculty of Geo-Information Science and Earth Observation (ITC) joined the University of Twente in 2010. It has a 60-year tradition in international teaching and capacity development and merges excellence in spatial information science and technology with a solid understanding of developing world issues around the globe. The ITC has a mission that fits well in the High Tech Human Touch vision of the UT: its dedication to science and education for capacity building has resulted in decades of experience in working with stakeholders, from government bodies to citizen all around the globe. The HTHT motto comes naturally to the ITC.

The strengths of ITC and the other UT faculties come together in this new MSc-program. ITC is coordinator of the program. It draws on the expertise of other faculties of the University of Twente such as civil engineering, computer science and public administration.

TWENTE TEACHING MODEL AND 3O'S

The teaching model of the University Twente has a number of distinctive features. Project-based learning is central to its educational philosophy. Students work together on real-life problems, which they derive questions to guide their learning. This learning model is proven to be very effective, especially in multi-disciplinary contexts. Integrating different perspectives is the default activity in project-groups. Added advantages to the model are that students train project-management and (intercultural) communication skills and develop an active, entrepreneurial learning attitude.

A second feature of the Twente teaching model is that, within each program, we train students in three aspects of their professional role. They are called the 3 O's, for the first letters of their respective names in Dutch: research (*Onderzoeken*), design (*Ontwerpen*) and manage (*Organiseren*). This MSc touches on all of these aspects. Students are trained in the three roles central to the work of an academic engineering professional: doing research, designing and managing.

"Research" – the critical assessment of existing scientific knowledge and contributing to the development of new scientific knowledge.

The MSc closely integrates research and education. Students learn to critically assess concepts, derive research questions from a general hypothesis framework and design research methodologies. They are trained in finding and combining data from different sources, in critically appraising data analyses and literature, and comparing methods for the analysis of problem situations. The projects in the first year are so complex that they need scientific thinking to move towards solutions. In the second year of the program, students do an individual MSc research and furthermore can opt for a research track that prepares him/her for a PhD-position. The Twente Graduate School framework can help to find a PhD position in the university, but many students will find places in other national or international higher education institutes. We envisage courses in proposal writing and scientific writing and where possible the results of the MSc thesis can be rewritten to a ISI paper.

"Design" - Integrating scientific knowledge in the systematic development of new solutions for complex problems.

Designing new solutions for complex problems, using software tools, is part of the program. Often, stakeholders will want ready-made tools to analyze their problems This can for example be a web-based decision support system or a "big data" database that combines crowd sourced data with objects derived from high resolution satellite imagery. Moreover, Geographical Information Systems are not only database systems, they are excellent tools to translate scientific results to useful information and communicate these to stakeholders.

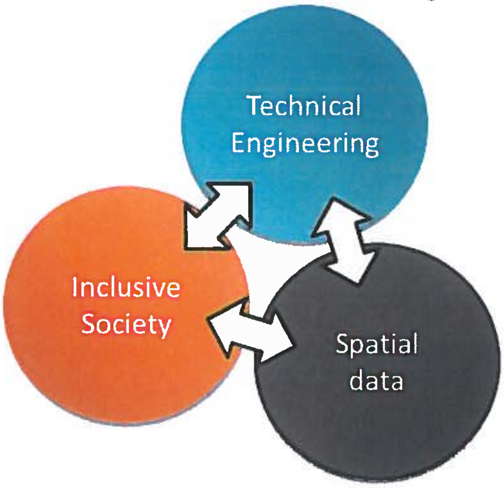
"Organisation" - Combining knowledge from different scientific disciplines to implement new solutions in a complex societal context.

The multidisciplinary approach and integration of the societal context in this program is exactly this "O". Project management as such is not part of the curriculum to make a clear distinction with the MSc programmes offered by the faculty CTW. Nevertheless we students take on responsibilities in different roles in the projects, and have ample opportunity to train their organizing and communication skills.

RATIONAL

The MSc-program Spatial Engineering focuses on large scale spatial problems, that need a combination of engineering and spatial planning to find solutions, based on smart data analysis.

Central to this MSc are three knowledge fields of the spatial engineer. We envisage a programme that gives equal weight to these three fields. "Technical engineering" symbolizing the knowledge of the physical processes causing societal and environmental problems described above, the "inclusive society", characterized by knowledge fields such as spatial planning and governance and stakeholder analysis, and "smart data" represented by Geographic Information and Earth Observation sciences.



The white arrows between the circles represent the multidisciplinary mixes of these fields: society is linked to engineering because stakeholders pose boundary conditions on solutions offered, while engineering poses boundaries on society, society and data are linked because stakeholders are valuable sources of data (crowd sourcing, open data sources) while spatial data is an excellent tool to communicate technical solutions to society, and the link between engineering and spatial data is not only a simple one way direction (data used to analyze), but new spatial data sources that generate new ideas. The notion that there are "data poor" areas on earth is slowly fading as literally dozens of data types are available for each m^2 of the globe, and engineers should know how to work with them.

TARGET GROUPS

This MSc is for students who want to use their scientific knowledge and skills to solve some of the world's bigger problems. They are inspired by large scale complexity, by the creativity needed to go beyond obvious solutions, and who are willing to discuss and if needed adapt their solutions to the societal context. They should have affinity with technology and systems thinking, and also with processes on the earth' surface.

In the table below the knowledge fields that are part of the Bachelors of Dutch Universities are compared to the knowledge fields in Spatial Engineering (as specified in the learning goal matrix in annex 1). This table is based on the information available on the university websites including study guides, and general information sites (http://universitairebachelors.nl/).

These bachelors have sufficient overlap to form students that should be capable to successfully continue in Spatial Engineering. None of them have a complete set of knowledge and skills to make a one on one match, but this is not problematic. Two ways are envisaged to deal with this.

First, students can take a role in the group in a project that fits closer to their knowledge and skill set. This is part of multidisciplinary approach, where students learn about their strength and weaknesses, and how to work together towards a common goal. While certain bachelors (such as ATLAS) already train students extensively in tin this, other follow a more classical approach.

Second, the curriculum has to enable all students to reach the end-terms in 120 EC and so each student can make a choice subjects in the first project of the first year. Five modules are offered of which the student has to select three. The modules have a content that enables students to "repair" a topic of which they do not have sufficient knowledge. For instance, many studies either have a more human centered content, emphasizing the role of humans on the earth surface (planning, urban development), these students may not have sufficient background in hydrological processes and climatic drivers. Vice versa exists as well: many of the BSc's in the table are specialized in processes on the earth surface, but lack basics in spatial planning and governance. Also technologies such as GIS are generally part of the skill and knowledge set of the students of these BSc's, but earth observation techniques are less well known, or this is less clear from the information offered.

This does not mean the subjects offered in the first project are all on a bachelor level. There will be a steep learning curve and considerable effort required from the students. Furthermore, personal specialization (15 EC) is offered in between the second and third project.

The university colleges, such as ATLAS at the UT and BETA-GAMMA at the UvA, have a more general approach, teaching "liberal arts and sciences" with a broad number of choices. The emphasis is as much on forming the student on a personal level, as it is to impart a certain knowledge set. In principle these students are welcome to Spatial Engineering, depending on the personal choices they made in their bachelor education.

Bachelor programmes addressing knowledge fields (columns) that are used in Spatial Engineering.

Institute	Bachelors	Hydrology and climate	Geo-Engin. Physical Geography	Civil Engineering	Spatial planning & governanxe	Strong Societal context	Spatial data sciences
UT	Civiele Techniek	x		x	x	x	x
TUD	Applied Earth Sciences		x				
TUD	Civiele Techniek	x	x	x			
TU/e	Architecture, Urbanism and Building Sciences			x	x	x	?
UU	Aardwetenschappen	x	x		x		x
UU	Global Sustainability Science	x	x		x	x	x
UU	Sociale Geografie en Planologie				x	x	x
RUG	Technische Planologie	x		x	x		x
UvA	Future Planet studies	x				x	x
VU	Aarde en Economie	x			x	x	x
VU	Aardwetenschaappen	x	x				x
WUR	Landschapsarchitectuur en Ruimtelijke Planning	x	x		x	x	x
WUR	Milieuwetenschappen	x			x		
WUR	Bodem-Water-Atmosfeer	x	x				x
WUR	Internationaal Land en Waterbeheer	x	x			x	x
WUR	Landschapsarchitectuur en Ruimtelijke Planning	x			x	x	x
Universityy Colleges and general bachelors							
UT	ATLAS	Liberal Arts and Sciences, Depends on personal choices					
UU	University College Utrecht	Liberal Arts and Sciences, Depends on personal choices					
UU	University College Roosevelt	Liberal Arts and Sciences, Depends on personal choices					
RUG	University college Groningen	Liberal Arts and Sciences, Depends on personal choices					
UvA	Beta-Gamma	Liberal Arts and Sciences, Depends on personal choices					

THE CURRICULUM

YEAR 1 - PROJECTS

The word project here has a double meaning in this MSc. First of all in terms of content, the first year is based on three existing real life consultancy projects, with a rich societal context, imperfect data, a range of possible methodologies and solutions. These solutions are not pre-cooked, students teams are triggered to use their creativity, for instance in discussions with experts from the field (engineering companies, government officials etc.), and even a site visit to one of the project areas. In the course of these projects comparisons will be made to other places on earth with similar or related problems, including the Netherlands. The aim is to promote an understanding that local solutions are needed and international comparison stimulates creativity.

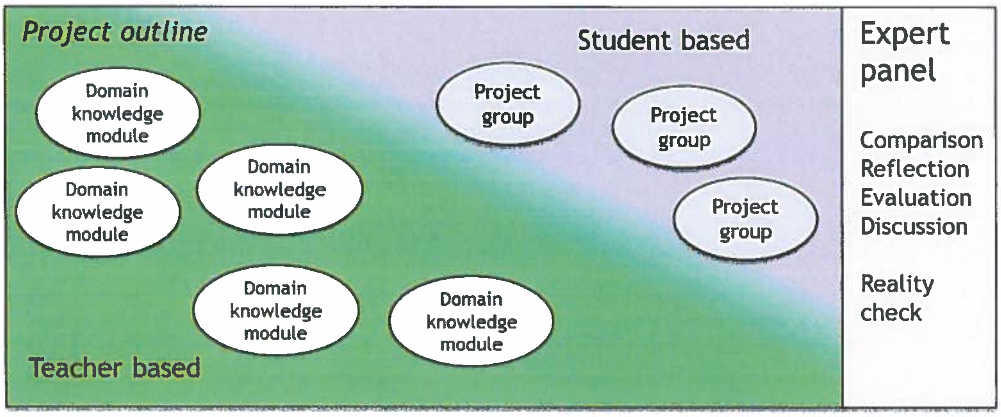
In a different sense, project means "project based education". In the first year of this MSc we aim to mix specialist in-depth teaching with project learning activities and group work. The aim is to achieve the best possible understanding and stimulation, while at the same time offering sufficient possibilities for personal specialization. Therefore both in the projects and in a 15EC specialization phase, room is created the pursuit of for personal interests, within a broad range of subjects offered at the UT at that moment.

Students work together on real-life problems, from which they derive questions to guide their learning process. This learning model has proven to be very effective, especially in multi-disciplinary contexts. Integrating different perspectives is the default activity in project-groups. Added advantages to the model are that students train project-management and (intercultural) communication skills and develop an active, entrepreneurial learning attitude.

FLIPPED CLASSROOM

Each 15EC project has a minimum set of core knowledge and skills that the student needs to have for a successful result. A "flipped classroom" approach is followed: the core knowledge is offered in various ways through multimedia, literature, guest lectures etc., and the classroom time is used to discuss the content and answer questions, engage in further discussion which includes further analysis using a variety of tools, individual or in groups. Practical skills, such as data analysis techniques, various forms spatial modelling etc., will be learned in the context of the project.

Ideally, a project group consists of 4-6 persons from different backgrounds. Students bring their specific background knowledge to the table and take turns leading group sessions. While this creates a challenging context, there has to be sufficient common ground and knowledge and students may experience certain deficiencies. Some not have had any courses in the basics of civil engineering design, while others lack geo-information science and earth observation data and related technical skills. Therefore, a choice in domain knowledge modules is offered, where a student can choose at least 3 out of 5 domain modules. In later project this may change to 40/60. These modules will be about 2-3 EC each, and will be tested on an individual basis. The total time in the first project is approximately 6 weeks for domain knowledge, 4 weeks for group work. In principle therefore the 120Ec curriculum will enable every student to achieve the end terms, but specializations are offered based on personal backgrounds.



In the project groups, tasks can be divided among students in a group, offering further possibility of specialization and taking the responsibility for a part of the analysis that is closest to the individual experience and liking, as long as a coherent group result is being created. At the end of a project the group results will be discussed with the help of experts in the field, from for instance engineering companies, government, NGO's etc.

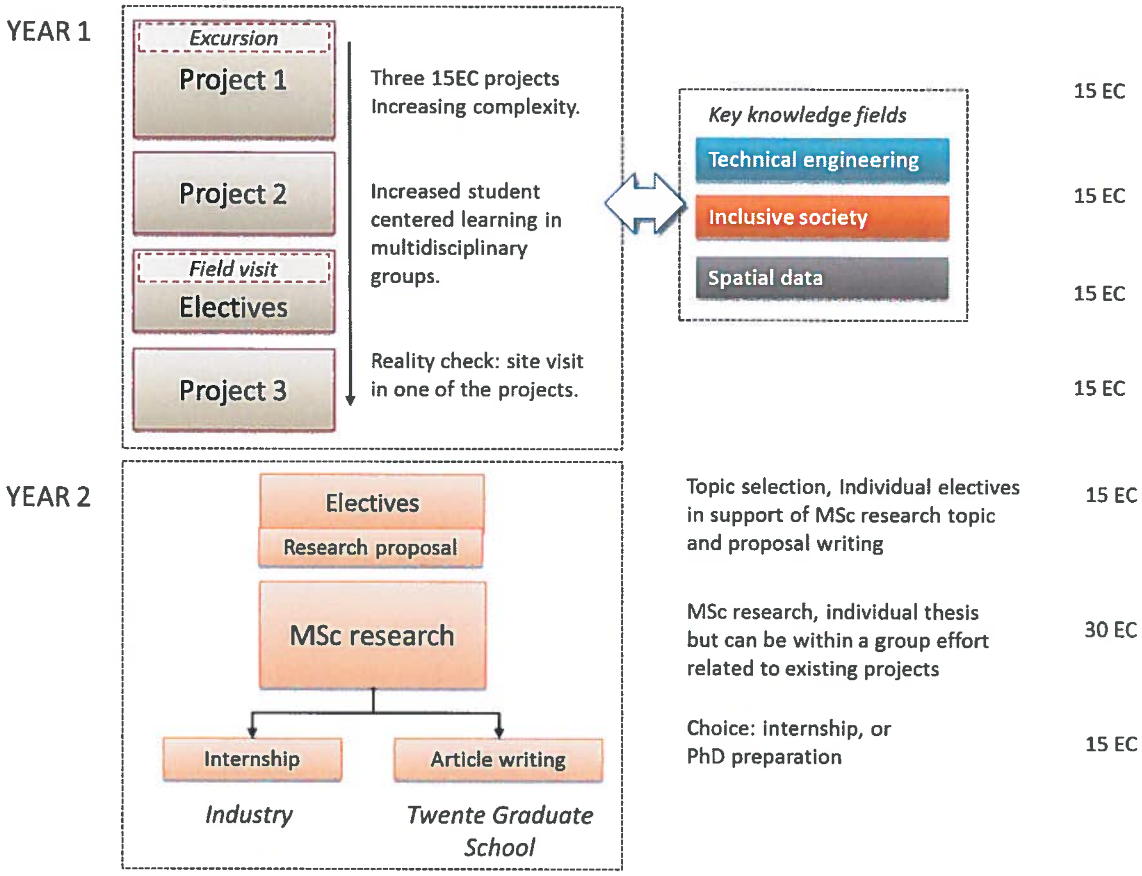
PROJECT THEMES

Three projects have been currently selected, whereby the complexity of both the technical and data analysis, as well as the societal context increases. These are: 1) disaster proof cities, 2) food and water security, 3) man-induced earthquakes and 3D damage assessment.

These three broadly defined projects offer enough width and depth for students of several subsequent years to tackle a problem form different angles and/or in a different context. Switching in focus areas, target stakeholders, governance context from year to year will make these topics viable for several years.

It is expected that these projects have a "life span" of three years. After that the content and context will likely change, to link them to the research and capacity development activities of the contributing faculties. One can think of a medical and health context, urban infrastructure or sustainable energy, or a combination of these topics. The learning goals and learning strategy (increasing complexity, three knowledge fields) will remain the same.

In annex 1 a provisional overview is given of knowledge fields and learning goals of the projects in the first year, to give a more detailed idea of the current content.



Excursion

This first year starts off with a 1 week excursion which has a dual purpose: for the students to get to know each other, and cooperate in a series of daily assignments, while the context is disaster management for flooding in the Netherlands which serves as an introduction for the first project.

PROJECT 1 - DISASTER PROOF CITIES

Many fast growing cities around the world suffer from floods, caused by excessive rainfall, or extremes such as hurricanes/typhoons. Population pressure and immigration causes people to settle in locations less suitable for habitation (former wetlands, coastal zones, river floodplains). In developing countries, these areas are highly dynamic in terms of human activities, and develop in an unplanned fashion. Resilience levels are low: there is little understanding of the situation, and general poverty prevents personal or community action. City authorities however, want to reduce the effects of disasters or prevent them all together.

Solutions can be found in integrated flood management: a mix of better spatial planning, engineering of a mix of protection measures and upstream water harvesting, and improved resilience in various levels. Creativity lies in dealing with future population increase, with added long term effects of climate change, while still coming up with sustainable scenarios. The project offers a wide range of interesting problems: what determines the differences in flooding of New York, Kampala, Bandung, Amsterdam?

When is a city flood proof and what is acceptable risk? What data and methodologies do you need to investigate this? What is the influence of different levels of planning, governance and resilience? Group work can focus on finding answers to these and other problems.

Learning goals

Students who want to become experts in flood management, need to understand this mix of factors and how they are related. They will gain in depth understanding of hydrology and meteorology. They will learn how to combine high resolution airborne imagery and laser scanning data for elevation information, housing and infrastructure with physical data for surface hydrology and hydraulics. In this first project, they will learn the basics of spatial planning and discuss different levels of planning in the Northern cities (e.g. Toronto, Amsterdam, New York), and cities Africa and Asia. Students will do a stakeholder analysis based on available data, and analyze which stakeholder groups are present, how they deal disasters, their resilience and network of influence, using for instance multi-criteria and trade-off analysis. They will learn concepts such as vulnerability, how to quantify this with for instance spatial multi-criteria analysis and how to combine flood hazard and vulnerability data in a risk assessment.

(project context: UN-HABITAT Kampala project, WB projects Caribbean, PhD projects on city growth and climate change)

PROJECT 2 - FOOD AND WATER SECURITY IN THE MARA RIVER BASIN

To meet a growing need for food and at the same time offer food and water security, integrated catchment management is needed in many parts of the world. Dutch consultancies, NGO's and government have a long since recognized this. Nevertheless, solutions are complex because of competing claims, shortage of resources, the political and economic context. Earth observation data can give us a wealth of information on land cover change, climate variability, drought warning, but how can this help people on the ground? What else is needed in the short and long term?

This second project deals with integrated management of the Mara River Basin (Kenya) where water resources are important for different user groups who suffer from drought spells. The goals of sustainable basin management are high: improve water safety and security to support structural poverty reduction, sustainable economic growth for the inhabitants as well as conservation of the basin's key forest and savannah ecosystems. Stakeholders are farmers, river basin authorities, NGOs, wildlife conservation agencies. Ultimately, these interconnected public, private, and environmental elements of the basin serve as a model of sustainability for surrounding basins, with transferrable tools and approaches.

An important part of sustainability is to understand and quantify the capacity of an area for various forms of land use must be quantified. Equally important is to understand how stakeholders behave and use water, what their needs are, how they change over time. Moreover people have coping strategies when faced with drought situations, such as alternative sources of livelihood, or for instance being able to migrate cattle to greener areas.

Learning goals

Students start this project by learning how to do a drought assessment with water balance modelling and analysis of long term meteorological fluctuations. The next step is to estimate biomass production for rangelands (carrying capacity) and agriculture with growth models. This is confronted with the reality of vegetation development assessed with hyper-temporal (e.g. 10-day series) satellite imagery. Using spectral information biomass variability is analysed and anomalies related to drought identified. Again a stakeholder analysis is done, but less focused on individuals and more on groups/communities. The second project is more large-scale in space and time, and needs a more advanced understanding of the processes, and analysis of datasets.

In terms of spatial data analysis, the complexity increases with respect to the first project, because of change analysis and time-series analysis, and up and downscaling issues. Also the stakeholder context is more complex, with cultural differences between stakeholders, and competition for resources.

(project context: MaMaSe project, Lake Naivasha project, PhD projects on rice production in Mekong delta and West Java)

ELECTIVES

Field visit

The electives period can start with a field visit to the countries of projects 1 and 2, in east Africa to get first-hand experience on the international social and cultural context of the projects, and to confront the results for the projects and the reality. Government agencies, NGO's and other specialists will receive the students for discussions about the background of the project themes. Students will reflect on how they would adjust certain project results, given what they know at this stage and have learned from the site visits.

Personal specialisation

Between the second and third project, students have time to pursue individual education in the form of electives at ITC or other faculties, also outside the University of Twente. Having done the first two projects, that are broad in scope students may want to specialize in certain topics. These can be analytical and skills oriented, or enabling the acquisition of knowledge in supporting fields. The size of this block (15EC) allows the student to follow 2 or 3 subjects. Examples of modules from the UT are:

- Computer programming and construction of spatial models
- Advanced statistics
- Mathematical optimization
- Governance and policy
- Infrastructure planning and transport modelling
- Collaborative design and engineering
- Sustainable energy
- Decision support systems
- Environmental impact assessment
- Spatial data management

It is possible that not all of these modules are available in the third quarter of the programme. If the interest is large enough certain courses might be scheduled. Following courses in other universities will be made possible.

PROJECT 3 - MAN INDUCED EARTH QUAKES AND 3D DAMAGE ASSESSMENT

Extraction of groundwater, salt, natural gas and other resources, or fragging of shale, often may result in subsidence of the earth surface or earth quakes. It is an increasing problem both in the Netherlands (Groningen) and in many mega-cities in the world (Jakarta, Bangkok, Beijing). Solutions are not readily available, but studying these phenomena and quantifying their effects on our living environment needs complex 3D analysis of large datasets. For instance earth quake wave propagation can be modelled using seismic data and knowledge of the 3D composition of the material through which the waves travel. In the Netherlands we have such knowledge, compiled in databases such as DINO.

Above ground, the resulting movement of the surface, causes damage to housing and infrastructure. The use of UAV's, crowd sourcing and other tools to characterize for instance damage is a rapidly evolving science which we want our students to know and understand. Besides 3D information below the surface also detailed three-dimensional as-is-documentation of the above-ground infrastructure is needed. For this purpose, state-of-the-art data acquisition techniques based on mobile mapping, or aerial surveys are used. It helps to estimate possible losses in case of earthquakes (demanded by local government, insurances). After the event very high resolution images, like acquired from unmanned aerial vehicles, and derived 3D information will help to assess damage to buildings.

Learning goals

Students have to deal with one spatial dimension more in this project compared to the first two. This means 3D analysis and reconstruction, using appropriate spatial statistics techniques. They will acquire the basics of geophysics, and learn about geophysical data acquisition (seismic data, GPR, resistivity) and how to use this to model wave propagation. They will be confronted with uncertainty about the location of the earth quake epicentre, while they still have to create what-if scenarios. They will learn how to deal with the values and uncertainty of data form DINO, and how this affects damage patterns at the surface. Students will also know how to acquire 3D point cloud data with drones and from other platforms, and how to reconstruct building information from that. Subsequently, this data will be interpreted for signs of damage for which structural building information is needed. They will not become expert building engineers, but will understand basic terminology. Also here the stakeholder context is extremely important, with little (political) room for mistakes. The political context is very strong which adds a dimension, comparable to the first project. A mistake may cost people's lives, similar to flood disasters.

(project context, cooperation with KNMI, EU FP7 Projects Reconass and Inachus)

THE LOGIC BEHIND THE PROJECT ORDER: INREASING COMPLEXITY

The projects increase in required knowledge and skills. The urban context in the first project is complex but we have an intuitive understanding of the context and datasets. The datasets and modelling are relatively straightforward, although the generation and interpretation of results in a stakeholder context is not. The scale and resolution is a "human" scale, a high level of detail. Field measurements, GIS and remote sensing data can be used with standard image interpretation and classification. Urban development in time offers a good way of learning how to deal with change detection and quantifying spatial change. The climate context less straightforward: how do we define the weather of the future?

The second project is more complex: the effects of drought can be analysed by looking at the meteorological data, by modelling the area water balance in combination with biomass production, and by looking directly at effect of drought on the vegetation and biomass in time. The latter depends on a hyper-temporal analysis, which analyses datasets based on *temporal changes* instead of on a single moment in time. This allows us to analyse anomalies related to drought. The level of data analysis and interpretation is higher and needs more skill and understanding, and the data layers have very different scales and resolution which have to be brought together. Also the stakeholder context is more complex than in the first project: cultural backgrounds are important and resilience levels depend on access to different sources of income/livelihood.

YEAR 2- RESEARCH AND (INTERNATIONAL) WORK EXPERIENCE

The second year starts with a 15EC module in which the student selects a research topic and can follow one or possibly two additional specialization electives in support of the MSc research topic. This module ends with a research proposal for an individual MSc research. The proposal is based on a summary of state of the art literature on the subject, a hypothesis and research objectives, likely data sources (existing or to be acquired in the field or laboratory) and a proposed analysis methodology. The MSc research proposal follows the logic of an NWO proposal. At the end of this module the student defends the proposal before a panel of staff and peers.

If the proposal is accepted, the he or she can enter into the 30 EC MSc research phase. In principle this is an individual research, however if more students are involved in a running project in which they do their research, cooperation may take place. The purpose of this MSc research is to do an in depth analysis, including literature review, design of a methodology, and data acquisition and analysis.

Research topics can be more applied in nature, closely related to the type of work in a professional career, or more fundamental in nature with a possible academic career as PhD researcher in mind (provided an academic quality level is met).

Following the research project, i.e. upon successful completion and thesis defense, two tracks are offered. The student can opt for an internship in a Dutch or international company, to increase work experience. Alternatively, students can opt for a research track, with time to write a PhD proposal and a course in scientific writing which could lead to a first ISI paper based on the results of the MSc study. This is part of the Twente Graduate School framework and may lead to a PhD position, thus offering an efficient transition into a PhD study.

AN INTERNATIONAL STUDY

Not only is the curriculum content international, the students learn during their study how to deal with stakeholders and their different cultural realities and backgrounds, how you have to translate their knowledge so that is has a place in the scientific analysis, and how the results should be translated in terms that they understand and find useful. The Dutch are known for their relatively honest but rather unsubtle behaviour abroad, let's see what we can do about that!

The Students will be tested : we will invite professionals from the ITC network, that have a long standing expertise in various countries around the world, while working for consultancies, in government positions, NGO's, international organisations. Together with the students they will reflect on the international context of the project results and identify possibilities and impossibilities. When possible, the student can find an MSc research topics in a context of the many international projects at ITC.

END TERMS

BECOMING AN EXPERT SPATIAL ENGINEER

None of the core knowledge fields mentioned are unique in the Netherlands. Their combination in one study, with equal emphasis both to the technical sciences and a social context however, is uniquely given form in a project context. It is the combination of knowledge and skills in a problem context that can generate expertise.

Hydrology is one of the core knowledge fields, in combination with various expressions of climate change. The student will learn how to predict the consequences of extreme rainfall, leading to floods, and with prolonged absence or erratic rainfall leading to drought. Different spatial models and datasets are needed for this analysis with different analysis techniques, but also with different consequences. Flooding often leads to direct damages to infrastructure and loss of lives, drought leads to loss of livelihood and, adaptation of behaviour, competition for water and food. In our view, it is not possible to become an expert hydrologist and design solutions based on spatial modelling, without a deeper understanding of the societal context. Also here the expert level is gained because of the integration with other knowledge fields.

Other core knowledge fields is spatial data analysis in nits widest sense, but again the expertise is reached precisely because of the context of hydrology, engineering, stakeholder data, planning and governance. The different forms in which this data is available, the expertise needed to combine these layers into new information, while knowing the quality aspects of each information layer, is what creates the added value above a data manager. The student will gain the self-confidence to use whatever software is necessary to solve a problem.

Given this approach, and matching it to the current higher education teaching philosophy we have defined the following qualifications for a successful graduate:

1. Is able to create scientifically sound spatial and temporal models and scenarios that show the future effects of driving factors and can help to design policies to anticipate on them.
2. Can find, generate and analyze data to provide the best spatial analysis for a given problem and is acutely aware of the scientific quality issues.
3. Can analyze stakeholders involved: decision makers, industry and grass root level stakeholders, and is able to understand, structure and translate societal problems into scientific problems.
4. Is able to synthesize scientific results and translate these to socially acceptable and beneficial results that can be implemented.
5. Can generate solutions as part of a multidisciplinary team.
6. Has learned how to work in a multidisciplinary team and can communicated clearly both to peers and to stakeholders.
7. Can operate in large international projects (and has gained experience during the study in such projects)

THE JOB MARKET

The idea of Spatial Engineering was presented to and discussed with a committee ("werkveld commissie") consisting of the following persons: Basja Jantowski (Aidenvironment), Gerard v/d Steenhoven (KNMI), Arthur de Groof (Grondmij), Fons Nelen (Nelen-Schuurmans), Wil Bekkering (Vilentum Hogeschool), Helmus v/d Langemheen (Min. Verkeer en Waterstaat), Maarten van Aalst (Red Cross/Red Crescent Climate Center). The following remarks are based on a meeting on 06/07/2015 and written contact. This group is asked to reflect on the idea and contents of Spatial Engineering, and indicate if students that have successfully finished this MSc would easily find a job in the Dutch job market.

The committee emphasizes that the combination of a technically oriented engineer who has good insight in a societal context and knows how to communicate with various stakeholders is a strong, and even unique combination that is needed in their line of work. Some of them mention that they often have to provide in-house training for new personnel in the stakeholder and communication context, and welcome the idea of providing this practical context within the study.

The committee emphasizes that the strength should be in dealing spatial data and spatial modelling, that water is still an important aspect for Dutch consultancy and NWO work, both national and international, but that the skill set demanded is changing from hardcore engineering to an IT and modelling context. Dutch excellence is more and more achieved in spatial data and modelling, Big Data related to climate and water, and using earth observation data. However it is emphasized that to operate successfully in the various companies and institutions, an engineer has to be able to deal with a variety of stakeholders and is able to communicate results well.

The international context is seen as a must, almost all bigger companies have projects abroad. However, this is not necessarily only in developing countries, and the committee advises to offer sufficient examples of in "western" countries as well, and to give examples of successful solutions to problems, not only difficulties/failures.

The committee advises to make a cross check between professional knowledge and skills needed, and those offered by Spatial Engineering, in the phase when the actual content of the curriculum is created, and offer their continued assistance in this.

ANNEX 1. SPATIAL ENGINEERING AND OTHER MASTERS AT THE UT

At the University of Twente several master programmes with specializations exist that bare resemblance to, or have elements in overlap with Spatial Engineering.

FACULTY OF GEOINFORMATION SCIENCE AND EARTH OBSERVATION (ITC)

First, there is overlap with the MSc degree in Geoinformation Science and Earth Observation, which is a post initial MSc available to students from developing countries and emerging economies. This programme there are a number of course domains, which are more or less mono-disciplinary specializations. These are in alphabetical order: Applied Earth Sciences, Geoinformatics, Land Administration, Natural Resources Management, Urban Planning and Management and Water Resources Management. The programme is set up in a way that all students start courses in GIS and Earth Observation, followed by domain specific modules, followed electives and an MSc research phase. The starting point for each domain is the use of geoinformation and earth observation as important sources of information for the home countries of the students, and the emphasis is on advanced technological skills. The overall learning objectives are more general and academic, and there is less emphasis on a multi-disciplinary project based teaching environment. The programme has received the official qualification of international study with the last accreditation. Annually about 120-130 students graduate from this programme, of which about 45% are mid-career professionals (mostly outside Europe).

ITC participates in, and is now taking the lead of GIMA, a joint degree in Geographical Information Management and Application, with the universities of Utrecht, Delft and Wageningen. GIMA specializes in the use and management of geo-information data. The GIMA program offers advanced use of GIS for a variety of applications. It emphasizes the also the management of geo-information and spatial data infrastructures in organizations and management styles. The programme can be followed as a part time study over 4 years, and has a number of blended learning (distance education based) elements, which enables professionals to follow the study as well. GIMA draws between 30 and 40 students per year.

Within other faculties at the University of Twente:

FACULTY OF ENGINEERING TECHNOLOGY (CTW)

Five master programs are offered: Civil Engineering and Management, Construction Management and Engineering, Industrial Design Engineering, Mechanical Engineering and Sustainable Energy Technology. Civil Engineering and Management offers a specialization in Water Engineering and Management which focuses on the behavior and management of water systems (e.g. rivers, coastal zones and seas) and on the physical and socio-economic aspects of water management, and analyzing long-term behavior of water systems and for evaluating the impact of human interventions on these systems. In addition, the role of models and uncertainty in decision-making processes and sustainable aspects of water management are important topics. As of this year (2015), tailor made profiles can be chosen, of which "Mega Cities", " Integrated Water Management", "Sustainability" and "Modelling and forecasting" that are made of combinations of modules around these thematic themes. For example Smart Cities is a combination of transport related modules, building and water management, combined with legal and governance aspects.

The overlap with spatial engineering is in the technological knowledge fields (such as hydrology and modelling), while the difference is that where Spatial Engineering adds Spatial Data sciences as distinct knowledge fields, CTW profiles focusses on project management. In knowledge fields such as spatial planning and governance and stakeholder analysis, there is some overlap, although Spatial Engineering seems to treat these subjects more explicitly (in learning objectives) than the programmes offered by CTW. The envisaged teaching method in Spatial Engineering is also different, being much more project lead and project based.

ANNEX 2. PRELIMINARY OVERVIEW OF KNOWLEDGE FIELDS AND LEARNING GOALS.

	Technical engineering		Inclusive society		Spatial data		
Knowledge field / **Project**	Hydrology and climate	Civil and Geo Engineering	Stakeholder analysis	Spatial planning and governance	Spatial data analysis	Visualisation and communication	**Development of understanding, integration level**
Urban disasters (Africa - Asia)	Urban hydrology, river hydraulics, Flood forecasting. Extreme rainfall, climate change. flood hazard assessment.	Water retention and harvesting, protection structures, infra-structure, sustainable urban drainage. Structure design principles.	knowledge, Influence, policies. Resilience, health, vulnerability. Individual versus community operation. Spatial Multi-criteria analysis.	Flood risk analysis. Strong versus weak spatial planning. Stakeholder strategies and responsibilities. urban growth modelling.	High res imagery analysis (buildings and infrastructure), open street data, ground truth, environmental data. stakeholder data. Visualising risk scenarios.	Create (interactive) maps that explain the spatial context and inform about specific data (stake-holders, risk, planning etc.). Communicate uncertainty, vagueness of data.	Single scale, 2D data analysis. Strong cause-effect links. Quantitative analysis, principles of modelling. Basic (geo) environment data. Complexity in stakeholder context.
Water and food security (Africa)	Land surface hydrology Spatial water balance modelling, crop/biomass growth, drought, climate change.	Water retention and harvesting, Hydro-power. Irrigation schemes	Farmers livelihood, tourism, wildlife protection, resilience. Sustainable land management, cultural aspects. Participatory GIS.	Sustainable land management. Multiple competing land use. agriculture versus urbanization, nature reserves, tourism	Land use and land cover analysis, soils, , change detection, time series analysis. Environmental data. Satellite observed hydro-meteorological data. Stakeholder data.	Time series and dynamic visualization. Decision support systems. Gain understanding by visualizing alternative scenarios.	Multiple scales in space and time. Change analysis. Short and long term effects. Geo and biosphere. Complexity in stakeholder issues and strong cultural motivations. Competition for resources.
Man-induced earthquakes (Netherlands)		Earthquake wave propagation, Subsoil materials and geotechnical analysis, building damage assessment and building codes.	Inhabitants, industry, government, research institutes. Policy and politics. Physical vulnerability.	Environmental impact assessment. Spatial planning and zonation. Physical risk assessment.	Seismic and geophysical data, DINO, 3D point clouds (drones) of buildings, Object oriented analysis, Spatial statistics. Stakeholder data. Spatial planning scenarios.	3D visualisation. Visualization as a form of data mining. Make sense of big data and gain insight.	3D data analysis, big data. High level of data interpretation and modelling. Geo and manmade environment. Importance of precision, margin of error.
End level	Expert: evaluate, create new knowledge. Deep understanding and design of scenarios is reached in hydrology because of the context of the other knowledge fields. Can create and carry out multiple solutions and is aware of the strengths and weaknesses of each solution.	Application: analyse conditions to advise on and contribute to the design of structural engineering works. Can analyse and advise on boundary conditions based on hydraulics and geotechnical analysis.	Application: analyse and conceptualise, evaluate consequences. Can interpret and analyse stakeholder information. Can communicate with stakeholders within the context of the problem and explain solutions.	Application: analyse and conceptualise, can assist planners in designing spatial plans that take into account solutions to the problems at hand.	Expert: can combine and convert data from multiple sources (ground, remote sensing, 3D point clouds) and scales into one dataset for quantitative analysis. Has data driven modelling skills. Is acutely aware of data quality and advises on improvements.	Application: Uses visualisation of spatial data to communicate with stakeholders, both in defining problems and in communicating solutions. Uses visualisation skills as a way to gain insight and generate understanding in complex datasets (data mining).	Spatial Engineer

ANNEX 3. DUTCH UNIVERSITY BACHELORS

Institute	Bachelors
UT	Civiele Techniek
TUD	Applied Earth Sciences
TUD	Civiele Techniek
TU/e	Architecture, Urbanism and Building Sciences
UU	Aardwetenschappen
UU	Global Sustainability Science
UU	Sociale Geografie en Planologie
RUG	Technische Planologie
UvA	Future Planet studies
VU	Aarde en Economie
VU	Aardwetenschaappen
WUR	Landschapsarchitectuur en Ruimtelijke Planning
WUR	Milieuwetenschappen
WUR	Bodem-Water-Atmosfeer
WUR	Internationaal Land en Waterbeheer
WUR	Landschapsarchitectuur en Ruimtelijke Planning
Universityy Colleges and general bachelors	
UT	ATLAS
UU	University College Utrecht
UU	University College Roosevelt
RUG	University college Groningen
UvA	Beta-Gamma

ANNEX 4. DUTCH MSC'S, THAT HAVE ELEMENTS OVERLAPPING WITH SPATIAL ENGINEERING

http://universitairemasters.nl/universiteiten/Universiteit-Utrecht/research-master/Sustainable-Development/
http://universitairemasters.nl/universiteiten/Universiteit-Utrecht/master/Water-Science-and-Management/
http://universitairemasters.nl/universiteiten/Wageningen-University/master/Agris-Mundus/
http://universitairemasters.nl/universiteiten/Wageningen-University/master/Earth-and-Environment/
http://universitairemasters.nl/universiteiten/Universiteit-Utrecht/research-master/Earth-Surface-and-Water/
http://universitairemasters.nl/universiteiten/Rijksuniversiteit-Groningen/master/Environmental-and-Infrastructure-Planning/
http://universitairemasters.nl/universiteiten/Wageningen-University/master/International-Land-and-Water-Management/
http://universitairemasters.nl/universiteiten/Radboud-Universiteit-Nijmegen/master/Transnational-Ecosystem-based-Water-Management/
http://universitairemasters.nl/universiteiten/Wageningen-University/master/Urban-Environmental-Management/
http://universitairemasters.nl/universiteiten/Universiteit-Utrecht/master/Water-Science-and-Management/
http://universitairemasters.nl/universiteiten/Rijksuniversiteit-Groningen/master/Water-Technology-joint-degree/
http://universitairemasters.nl/universiteiten/Technische-Universiteit-Delft/master/Applied-Earth-Sciences/
http://universitairemasters.nl/universiteiten/Technische-Universiteit-Delft/master/Civil-Engineering/