Curriculum MSc Geomatics

for the Built Environment

Website

1 MSc Geomatics – *for the built environment*

1.1 What will you learn

Over the last decades world population has doubled to nearly seven billion people, resulting in constant migration to cities; since 2008, worldwide, more people are living in urban conglomerates than in rural areas. Furthermore impacts of disasters, mobility and many other phenomena have shown massive expansion. Monitoring and managing these developments require detailed descriptions of earth-related phenomena and processes often in their full spatial (3D) dimensions. They often also require time series measurements (fourth dimension) and representation at multiple scales (fifth dimension). As the demand for accurate, detailed and up-to-date geo-data in all five dimensions is steadily increasing, the importance of geomatics as a scientific discipline, which provides the technologies and methods to solve planning, management and disaster issues in the built environment raises exponentially.

However, all the gigantic number of terabytes of geo-data in the world is of no help in solving these issues, so long as these terabytes fail to reach the hands of a knowledgeable and skilled professional who has thorough understanding of all the facets of the technologies involved and, by far most vital, who knows how to focus all available resources: human, technological, monetary and so on.

No geo-data can be successfully used without at the very centre a smart person who understands the whole and the TU Delft MSc Geomatics programme aims at making you such a smart professional.

Along what chain does a typical planning, monitoring or geo-management task proceeds? First of all the geo-management objective, that is the application, has to be defined: without a predefined objective nothing can be done. Once the application is known, you have to determine which geo-datasets have to be used. After collection/measurement and storage on a computer you will process and analyse the data by using a Geographical Information System (GIS). The analysis will provide you with the information to solve the real-world problem. For communication with others the information needs to be visualized and disseminated. Since the amount of data will be abundant, proper management of the data is a prerequisite. Often the data will stem from various organisations, involving legal and billing issues.

The aim of the TU Delft Geomatics programme is to give you a thorough understanding of the theories and technologies involved in all aspects of this geo-information chain applied to the built environment.

1.2 MSc Geomatics programme objectives

The programme objective is to offer high quality education covering the complete geo-information chain, by:

a. Emphasising the role of geo-information in decision making applied to the built environment.
b. An information system's approach to store, process, manage, disseminate and visualise geodata and geo-information, acting at the forefront of data analysis methodology and spatio-temporal database management systems technology, and also paying attention to legal and organisational aspects of geo-information.
c. A technology and application driven approach to geo-data acquisition and geo-information extraction.

Graduates will be able to deliver valuable technological and methodological contributions to industry and the public sector and to society as a whole, in all domains involving production, management, dissemination and application of geo-information.

These contributions include the design and development of systems and methodologies in support of the geo-information chain. Having affection with geo-information issues in several application fields, graduates will appreciate similarities as well as differences amongst Geomatics related issues in those fields, and be able to judge possibilities and limitations of expanding the application of methods, techniques and practices across applications.

1.3 Programme overview

1rst Quarter	2nd Quarter	3rd Quarter	4th Quarter
60 EC – First Year			
GM.1 (5 EC)	**GM.4 (5 EC)**	**GM.6 (5 EC)**	**GM.7 (5 EC)**
GM.2 (5 EC)	**GM.5 (5 EC)**	**GM.8 (5 EC)**	**GM.9 (5 EC)**
GM.3 (5 EC)	**Electives**	**Electives**	**Electives**
60 EC – Second Year			
10 EC – Synthesis Project	**45 EC – Graduation Project**		
Electives			

1.4 Coreprogramma MSc Geomatics – 45 EC

- GM.1 Sensing Technologies for the Built Environment
- GM.2 Geographical Information Systems (GIS) and Cartography
- GM.3 Positioning and Location Awareness
- GM.4 3D Modelling of the Built Environment
- GM.5 Spatial Decision Support for Planning and Crisis Management
- GM.6 Geo Database Management Systems
- GM.7 Geo Web, Sensor Networks and 3D-GeoVisualisation Technology
- GM.8 Geo Datasets and Quality
- GM.9 Geo-information Organisation and Legislation

1.4.1 GM.1 Sensing Technologies for the Built Environment

Study load: 5 EC

Course Contents

The aim of the course is to obtain basic insight in the sensing technologies and methodologies used in the Geomatics discipline and how these technologies support the diverse application domains related to the built environment. The course consists of:

- introduction to the major types of sensing technologies (laser, imaging)
- basics of physical aspects involved when applying sensing technologies
- methods for preparing geo-data for use in a GIS environment
- an overview of application domains related to the built environment

Study Goals

After the course the student is able to describe:

- the basics of geomatics sensing technologies
- the basics of physical principles of sensing technologies
- the basics of the methods used to prepare geo-data for use in a geographical information system
- the concepts of least squares adjustment and blunder detection
- how the diverse sensing technologies can be applied to support planning, decision making and other activities in the built environment

Education Method

Lectures 28 hours; practicals 28 hours; self-study 84 hours

Prior Knowledge

Mathematics and statistics at BSc introductory level.

Literature/Materials

Lemmens, M., Geo-information: Technologies, Applications and the Environment, 2011, Springer Dordrecht Heidelberg London New York, ISBN 978-94-007-1666-7; e-ISBN 978-94-007-1667-4, selected capita.

Assessment

Written exam and practicals. The result of the written exam determines 80% of the final score and the practicals (20%).

1.4.2 GM.2 Geographical Information Systems (GIS) and Cartography

Study load: 5 EC

Course Contents

An important software tool used in geomatics is a Geographical Information System (GIS). A GIS enables to store, analyse, visualize and disseminate geo-information. In this course the student will learn the theory underpinning GIS software modules and data types. The student will also learn how to use GIS packages to solve real-world problems. The course has both a theoretical part and a practical part, where open-source GIS packages are used (QGIS and GRASS). In addition the course provides an introduction to visualisation of geo-information (cartography). The course has 3 parts:

1. Introduction to GIS

Topics covered include: spatial data modelling (vector and raster spatial models), geo-data manipulation (editing, digitizing, importing, converting, etc.), overview of spatial analysis operations, and the production of interpretable output (e.g. maps).

2. Algorithms and data structures for GIS

What is happening when you click on a button in a GIS? This is what will be covered. Topics include: data structures for vector and raster data (including topological data structures), basic algorithms for vector (point-in-polygon, Boolean operations, intersection, area, etc.), basic algorithms for raster (encoding, quad trees, map algebra), networks and related algorithms such as shortest-path

3. Applications of GIS to real-world problems

Real-world problems related to the built environment, such as determination of the most suited track for constructing a new railway, will be solved with the help of GIS packages. In a practical part students do exercises to get hands-on experience with GIS packages (open-source software and scripting with GIS libraries).

Study Goals

After the course the student is able to:

- describe and compare the two conceptualisations of space (field versus objects) and how these are modelled in a GIS
- use a GIS to visualise, convert and analyse geo-datasets coming from different sources
- identify, classify and evaluate the various internal running processes and algorithms used when clicking a button in a GIS package
- given a specific geographical problem, analyse and identify which data structure and algorithms are the most suitable, and justify why
- generalise their knowledge of GIS to solve complex problems related to the built environment

Education Method

Lectures 28 hours; supervised practicals 14 hours; group project 28 hours; self-study and practicals 70 hours

Prior knowledge

Scripting/programming in at least one language (e.g. Matlab, Java or Python).

Literature / Materials

Reader

Assessment

Written exams (1 mid-term quiz + 1 final exam), assignments (practicals with a GIS package and scripting in Python), and one group project. The mid-term quiz will determine 5% and the exam result 50% of the final score, the assignment 25% and the group project 20%.

1.4.3 GM.3 Positioning and Location Awareness

Study load: 5 EC

Course Contents

This course addresses Global Navigation Satellite Systems (GNSS) and other indoor positioning methods for sensing people, devices, and assets in the built environment with the focus on location-aware applications. The course covers the requirements and context for these location-aware applications: global and local reference and coordinate systems, (indoor) positioning methods and techniques, and the social and technical push and legislative pull factors that empower the development of location-based services. The students will demonstrate the knowledge acquired by writing a theoretical paper or by defining, designing, and building a location-aware application.

The course consists of three parts:

1. Analyses of location aware applications: Concepts of location awareness, location sensitivity to context awareness; use cases of location-based applications; technical and legislation factors, privacy issues, standards;
2. Global and local reference and coordinate systems; coordinate systems and coordinate conversions; geodetic datum and datum parameters, relative measures and dynamic segmentation along a linear element for example a milestone along a road; basic types of map projections, map distortions; 3D coordinate reference frames; concept of gravity-related heights;
3. Positioning methods and techniques: Global Navigation Satellite Systems; terrestrial radio-based positioning by using Loran-C; Bluetooth, UWB, RFID, WiFi and other short range technologies; Inertial Navigation Systems (INS); technologies with dead reckoning and map-matching methods; fingerprinting (templates) for indoor positioning.

Study goals

After the course the student is able to

- discuss aspects of locational awareness; evaluate technology and standards; analyse the needed positioning accuracy
- describe (3D) coordinate systems, perform transformations between them and express the location of a point in these systems
- discuss the different chart datums, how they are defined and how they can be linked to each another
- compare and evaluate positioning methods and technologies to support location awareness
- analyse the availability, accuracy, and integrity of positioning methods and techniques

Education method

Lectures: 28 hours; Design/Paper: 72 hours; self-study: 40 hours

Assignment

Design of LBS-application or theoretical paper; exam

Prior Knowledge

N.A.

Literature/Materials

Reader

1.4.4 GM.4 3D Modelling of the Built Environment

Study load: 5 EC

Course Content

In this course students will learn how to model the built environment into computer based, well-structured abstractions in 3D. The module covers the entire process of deciding what kind of phenomena should be measured, selecting the appropriate data collection technology, applying suitable data processing algorithms and data structuring for the purpose of extracting further information by analysis/modifications/explorations needed in different applications. The course deals with 3D data structures for representation, briefly presents different data collection technologies, discusses fundamental processing algorithms and gives examples of well-established or prototype manual, semi-automatic and automatic approaches for 3D reconstruction of man-made and natural phenomena. The course consists of three parts:

1. Overview of 3D models: B-reps, Topology, Voxels, Constructive Solid Geometry (CSG), freeform curves and surfaces (Bézier, B-spline, NURBS). Transformations, Design vs. Real-world models: BIM/CAD, CityGML, Semantics;
2. Collecting and processing 3D data. Short overview of sensing techniques used for 3D reconstruction of built environment. Processing algorithms such as co-registration, geo-referencing, filtering, feature extraction, classification, segmentation, object recognition;
3. 3D reconstruction methods: manual, semi-automatic and automatic methods for reconstruction of terrain (including filtering of vegetation), man-made objects (buildings, tunnels, bridges in different levels of detail) and trees. Integration of different dataset to reconstruct 3D models.

Study goals

After the course the student is able to:

- analyse advantages and disadvantages of different 3D models (design and real-world) and advise on representations, levels of detail and data structures
- evaluate approaches and tools for conversions between different representations (data formats)
- describe, evaluate and apply processing algorithms on one or multiple data products
- analyse datasets and advise on algorithms and tools for 3D reconstruction considering given application
- estimate benefits of different 3D reconstruction approaches with respect of richness of the final model in terms of objects, attributes, relationships, semantics

Education method

Lectures: 28 hours; 11 regular lectures (22 hours) and 3 invited lectures (6 hours)

Practicals: 70 hours; 3 exercises (18 hours) and 1 group assignment (52 hours)

Self-study: 42 hours

Prior Knowledge

N.A.

Literature / Materials

Selected scientific and professional articles

Kinect (at least 2), commercial software

Assessment

Written exam and practicals. The exam result will determine 50% of the final score, the practicals

50%.

1.4.5 GM.5 Spatial Decision Support for Planning and Crisis Management

Study load: 5 EC

Course Content

Spatial Decision Support Systems (SDSS) provide computerized assistance to decision-makers in development, evaluation and selection of alternatives for policies, plans, scenarios, projects or interventions where the problems have a geographic or spatial component. This refers to both long-term decision-making (e.g. planning for sustainable places, mitigating hazards, infrastructure management, and strategic business planning) and short-term time critical decisions such as emergency response and resource logistics. This course provides a basic knowledge on theoretical aspects of SDSS and concentrates on SDSS for two representative domains: urban planning and crisis management. While urban planning time span is months and years have as a goal sustainable development, crisis management requires information and decisions in hours and the goal is saving human lives and limiting damages on property.

The course consists of three parts:

1. General introduction to SDSS. Components, functionalities, including geographic analysis, simulations (what-if scenarios), and interaction; spatial (and often spatio-temporal) character of SDSS and the difference with GIS, integration of heterogeneous spatial information, technologies for developing of SDSS.
2. SDSS in urban planning: background information of the urban planning processes and the needed geo-information, analyses and visualisation through the entire process of spatial planning and modelling. SDSS for spatial processes within the built environment such as urban renewal, mobility, travel-behaviour, commuting, and public transportation
3. SDSS in crisis response: short introduction on the characteristics (processes and tasks) of rescuers and the needed/used geographical information and spatial analysis. SDSS systems for collecting and analysing information with emphasis on command and control systems, supporting spatial-temporal models, volunteer geographical information, crowdsouring and specific spatial analysis (such as navigation for rescue and evacuation)

Study goals

After the course the student is able to:

- describe basic terms, concepts and technologies underlying SDSS
- analyse the geo-component needed for SDSS
- describe, develop, analyse and present SDSS models for various urban applications
- compare and evaluate approaches, technologies and solutions to support decision support in crisis management
- compare SDSS for long-term and short-term decision-making and evaluate the needed geo-information and spatial functionality

Educational method

Lectures 28 hours, practicals 42 hours; self-study 70 hours.

Prior Knowledge

GM.2

Literature / Materials

Selected scientific and professional articles

Assessment

Exam

1.4.6 GM.6 Geo Database Management Systems

Study load: 5 EC

Course content

This course is about managing geo-information in a database management system (DBMS). The geo-DBMS is the central component of the geo-information chain. All information observed and interpreted should be managed in a manner that supports further use, so the Geo-DBMS is the end-point of data collected. Analysis, visualizing and (web-) dissemination of the geo-information start from the geo-DBMS. It is crucial that the content of the geo-DBMS is clear (the information model and its associated semantics) to the users, but also that it is high performant, as the geo-data volumes are often very high and especially in a web-based environment there may be many uses. The course consists of three parts; the first two concern introductions. The main part is devoted to spatial modelling and geo-DBMS. More specifically the three parts cover:

1. Introduction object-oriented information modelling: UML and more specifically class diagram to create conceptual models. Mastering (and applying in design) the key notions such as: Class, Abstract Class, Identifiers, Instances, Attribute, Operation, Association, Generalization, Aggregation, Composition, Multiplicity, Note, Constraint, Package, Stereotype, etc.
2. Introduction relational database management systems: the relational model, SQL DDL (schema definition) and DML (queries). Relational algebra. Some implementation issues (clustering and indexing techniques, such as the b-tree, primary and foreign key constructions supporting referential integrity).
3. Spatial databases: theoretical aspects of spatial modelling (object and field models), DBMS-GIS architectures (dual, layered, integrated), spatial-temporal data model, Abstract Data Types (ADTs) for geometric primitives, topology model (ISO 19107), temporal aspects, spatial indexing (quad tree, r-tree, field-tree), spatial data clustering (Hilbert, Morton, Cantor, row, row prime, etc.), geo-DBMSs (data modelling, structures, queries, visualisation), (non-)commercial systems (Oracle Spatial, PostGIS, etc.). One or more advanced topics: 3D, Raster, Point cloud data, Simplicial complexes, Geo-OCL, Vario-scale, 5D modelling (deeply integrated 3D space, time and scale).

Study goals

After the course the student is able to:

- read and understand UML class diagrams and design conceptual models for information systems
- understand relational databases and read DBMS schema, translate a conceptual model into an implementation of a standard relational database, retrieve (select) and update information from the database using SQL (including joins) and optimize the implementation based on standard database techniques (primary/foreign key, indexing and clustering)
- understand the differences of spatial data and design a conceptual model for a spatial information system, translate the spatial conceptual model in a relational database with spatial extension, optimize the implementation of spatial databases (spatial clustering indexing, spatial constraints,...) and retrieve and update spatial data using spatial operations (both geometric and topological) in the selection in combination with non-spatial predicates
- understand some advanced topics: spatial-temporal modelling, 3D modelling, vario- or multiscale modelling, Spatial OCL (Object Constraint Language) formalization, routing, TIN, point clouds, efficient raster data management, and 5D modelling.

Educational method

Lectures: 2 hours theory and 1 hour assignment feedback (per week). The assignments require the use of software: Enterprise Architect, PostgreSQL/PostGIS and Quantum GIS.

Prior knowledge

Basic programming skills (object-oriented programming) and BSc Engineering level mathematical skills

Literature/Materials

Textbook (Elmasri & Navathe, Fundamentals of Database systems, 5th. Int. Edition, Addison-Wesley, ISBN: 0-321-41506-X), scientific publications & slides published on blackboard.

Assessment

Written exam (3 hours) and assignments. The exam result will determine 80% of the final score and the assignments 20%.

1.4.7 GM.7 Geo Web, Sensor Networks and 3D-GeoVisualisation Technology

Study load: 5 EC

Course content

Today professionals and laymen alike have access to geo-data through the internet. Using a smart phone or tablet connected to broadband internet one can virtually fly-through a city and view buildings, underground constructions and proposed designs from any viewing angle, even augmented reality. The internet also strengthens the communication between government and citizens, who can comment on the designs, fill in questionnaires and vote, and in this way (local) government may increase public participation in city planning and other public affairs. Access to geo web services should be fast and based on open standards such as OGC (Open Geospatial Consortium), ISO (International Organization for Standardization) and INSPIRE (European Spatial Data Infrastructure). The map interfaces should be user friendly while sufficient functionality should be available for carrying out analyses on the diverse datasets. A key tool when building geo web services is Geography Markup Language (GML) an exchange language for geo-data based on XML (eXtensible Markup Language), the standard language of the internet.

The course consists of three parts:

1. Principles, application, evaluation and integration of geo web services and the importance of using standards when building them. The standards involved start with general ICT standards like HTTP, XML and SOAP (Simple Object Access Protocol. Based on these general standards, geo standards and protocols can be build. Combining the geo standards and protocols results in a set of geo web services that more and more replace the traditional GIS tools. In addition to the international ISO TC211/OGC web services and protocols the European INSPIRE network services will be discussed and used. Increasingly the semantics of data in the framework of web services, and linked data, plays an important role.
2. Principles and applications of (real-time) Sensor Web. The components of Sensor Web will be explained and (some of them) used: Observations & Measurements, Transducer Markup Language, Sensor Observation Service, Sensor Planning Service, Sensor Alert Service and the Web Notification Service.
3. Applying software tools for the visualization of 3D geo-data. Normally the first, and in many cases the most important, thing to do with (3D) geo-data is to visualize it. Nowadays data is delivered over the internet by means of web services. The standards, architecture and services for 3D geo-visualization, and the practical aspects of available (web) tools and how to use them will be explored.

Study goals

After the course the student is able to:

- understand formal geo standards and derived implementation specifications / describe the existing geo web services and their application domains
- integrate several geo web services for supporting spatial decision making;
- evaluate existing geo web services in terms of specified applications and give motivated suggestions for improvement
- understand the Sensor Web Enablement Common Data Framework (common data models and schema) and the SensorML (models and schema for sensor systems and processes surrounding measurements) and use them in web services;
- describe the available (visualization) standards like X3D, 3D-pdf, WebGL, CityGML, KML, and other industry standards / apply software tools for the visualization of 3D geo-data.

Education methods

Lectures: 28 hours

Individual assignments (20 hours): on the various standards, protocols, web services and tools to prepare the student for the design assignment

Design assignment (50 hours): students build a prototype in which one of the 3 main topics (geo web, sensor web, 3D geo-visualization) plays a central role to show that student can apply acquired knowledge in practice

Self-study: 32 hours

Prior Knowledge: GM.2; GM.5; programming: principles and practical experiences

Literature:

Selected scientific and professional articles

Assessment:

written exam (3 hours), exercises and design assignment. The exam result will determine 50% of the final score, the individual assignments 25% and the design assignment 25%

1.4.8 GM.8 Geo Datasets and Quality

Study load: 5 EC

Course content

The availability, interoperability and quality of geo datasets is a core factor in the success of projects where geo-information is used. In this course students will learn how to find, access, assess and when needed harmonise geographic datasets. Datasets of different data producers are very often heterogeneous as far as file format, conceptual model, level-of-detail, and semantic content is concerned. Several aspects of data harmonisation are discussed, using real-world examples from national and international projects. Another important condition for effective use of geographic datasets is their data quality. In the course the main methods to assess and describe geodata quality are presented, including the main error propagation methods. In case of data about natural (or otherwise continuous) phenomena (e.g. noise, temperature, rainfall) the inherent fuzziness of this kind of data asks for other methods than in the case of 'discrete' objects, such as buildings.

The course consists of three parts:

1. Overview of available spatial datasets and data sources, data content (specification), accessibility (use conditions), main applications, etc. for the most important existing spatial datasets (base registrations) at international and national (i.e. Dutch) level.
2. Methods for quality description of spatial data; assessing quality of spatial analysis results given both the quality of the input data and how well the applied processes model real world phenomena; methods to describe and cope with the inherent fuzziness of spatial data representing natural phenomena.
3. Techniques for combining spatial data from heterogeneous sources; semantic translations between different datasets; practical examples such as (semantic) transformation of Dutch spatial data to spatial data according to European specifications (e.g. INSPIRE Directive).

Study goals

After the course the student is able to:

- describe the characteristics (data content, multi-scale, spatiotemporal aspects) of the main available geo datasets at (inter)national level, and demonstrate how to find and assess them using available metadata and catalogue services, data models (expressed in UML) and object catalogues
- apply the main error propagation methods to determine the quality of results of spatial analysis, given both the quality of the input data and how well the applied model represents reality
- describe and cope with the inherent fuzziness of geo datasets representing natural phenomena
- understand the various aspects of spatial data harmonisation and have knowledge about the process steps needed to integrate spatial data from heterogeneous sources
- compare data models of different datasets and create transformation rules between them as step in the integration process

Education method

Lectures 20 hours; Practical 40 hours to gain experience in collecting and integration spatial datasets, to use them in spatial analysis and to assess the quality of the outcomes; Exercises 20 hours ; Self-study 60 hours

Literature/Materials

Selected scientific and professional articles

Lemmens, M., Geo-information: Technologies, Applications and the Environment, 2011, Springer Dordrecht Heidelberg London New York, ISBN 978-94-007-1666-7; e-ISBN 978-94-007-1667-4, selected capita.

Assessment

Written exam (3 hours); practical and exercises. The exam result will determine 50% of the final score, the practical and exercises 50%.

1.4.9 GM.9 Geo-information Organisation and Legislation

Study load: 5 EC

Course Contents

In this course students will learn about the organisational and legal aspects relevant for developing a strategy for a geographic information infrastructure.

Many organisations, and increasingly also citizens, collect, process and disseminate geo-information (e.g., Google, TomTom, mapping agencies and cadastres). Some information serves a specific purpose, while other information acts as multipurpose or base information, which is the fundament of an information infrastructure. An adequate information infrastructure allows for information to be collected efficiently (collect it once, use it many times) and provides reliable information for effective use in decision-making processes at all levels in government, private sector, academia and among citizens. Legislation is a critical component that needs to be considered to determine whether information can be used for a certain purpose and shared with others.

The course consists of three parts:

1. Theoretical basis for the introduction, organisation and management of (geo-) information infrastructures. Aspects that will be addressed are stakeholders, co-ordination mechanisms and components of an information infrastructure, the affiliation with policy lines like electronic and efficient government.
2. Overview of legislation pivotal to developing geographic information infrastructures. Legal aspects applying to geo-information, such as intellectual property rights, privacy and access to government information legislation, constitute a major part of this course.
3. Practical application of the theory. Students are tasked to experience for themselves how well an infrastructure functions: how easy is it to find, assess, access and obtain geographic information for a predefined purpose/ data from a predefined organisation? Progress will be monitored through a monitoring framework designed by the students.

Study goals

After this course the student is able to:

- recognize and anticipate upon relevant legal (especially privacy, copyright, database rights, freedom of information law, and data sharing legislation), and organisational issues evolving around the acquisition, processing, dissemination and use of (geographic) information
- understand the needs of potential users of geographic information and their requirements within organisations
- apply the concepts, processes and main components of (geographic) information infrastructures (Data, People (human resources), Policies, Access networks and standards) to support geographic information sharing between organisations
- critically assess geographic information management strategies for organisations
- assess the performance of an (geographic) information infrastructure from a user perspective

Education method

Interactive lectures: 28 hours; Individual assignment: 42 hours; self-study and excursion: 70 hours.

Literature

Scientific and professional articles

Assessment

Written exam (3 hours); individual assignment (report and presentation). The exam will determine 50% of the final score and the individual assignment 50%.

1.5 Electives – 20 EC

This not exhaustive list with electives gives a direction of possible application domains.

1.5.1 Domain Application: Informatics (convergence)

- Matlab / Programming (AES1011) 2 EC
- Other courses (to be approved by the examination commission)

1.5.2 Domain Application: Urban Design

- Beyond 3D Computer Visualization (AR0771) 6 EC
- Workshop High Rise Buildings (AR2RP111) 12 EC
- XXL Workshop (AR0025) 12 EC

1.5.3 Domain Application: Urban Analysis

- Urbanism on Track (AR0068) 12 EC
- People, Movement & Public Space (AR0551) 3EC

1.5.4 Domain Application: Landscape Architecture

- Landscape Architecture II: The Fine Dutch Tradition (AR1LA060) 3 EC
- Reflecting Ideas on Landscape: Paradigms and Positions (AR1LA070) 3 EC
- Landscape Components: Green and Blue (AR1LA080) 3 EC

1.5.5 Domain Application: Built Environment – TU Delft

- Use of Underground Space (CT3300) 9EC
- Real Estate Management (AR1R025) 7EC
- Urban Planning and Transport Networks (CIE4751) 4EC
- Infrastructure Projects: Assessment and Planning (CIE4760) 6EC
- Game Design Project (SPM9235) 4EC

1.5.6 Domain Application: Informatics

- Data Visualization (IN4086) 6 EC
- Web and Semantic Web Engineering (IN4324) 5EC
- Artificial Intelligence Techniques (IN4010) 6EC

1.5.7 Geomatics Specialisation (based on curriculum 2011-2012)

- Climate Change: Science & Ethics (CIE4510) 4EC
- Microwave Remote Sensing (CIE4520) 4EC
- Multivariate Data Analysis (CIE4521) 4EC
- Satellite Navigation (CIE4522) 4EC
- Scientific Applications of GPS (CIE4523) 4EC