Hochschule Karlsruhe
Technik und Wirtschaft
UNIVERSITY OF APPLIED SCIENCES

IMM Fakultät für Informations-
management und Medien

# Module descriptions
# Master of Science (M.Sc.)
# **Geomatics**

## Faculty of Information Management & Media

January 2019

# Content

Module summary

# GMCM110 GIS & Databases

**Module coordinator:** Prof. Dr. Gertrud Schaab, Prof. Dr. Heinz Saler
**Credits (ECTS):** 5
**Semester:** 1

**Pre-requisites with regard to content:**
Basic knowledge in GIS and databases

**Pre-requisites according to the examination regulations:**
None

**Competencies:**
The students are able to apply GIS for complex spatial analysis. In addition, an understanding for Internet-GIS and the programming within GI-systems for applications from diverse fields is created. The students have practical experience in the handling, analysis and visualization of geospatial data in a GIS environment.

The students are able so set up of spatial models with confidence based on wide-ranging knowledge in non-spatial and spatial databases. The students have the ability to setup data models either based on given representative data by applying normalization processes or by given information about part of the real world to be modeled in a database.

**Assessment:**
Joint written examination (120 min)

**Usability:**
GIS and databases are key technologies of the geomatics field. Quite a number of the modules of the 2nd and 3rd semester students require to apply knowledge in regard to GIS and databases while adding new/other skills.

Course

## GMCM112 GIS

**Lecturer:** Prof. Dr. Gertrud Schaab
**Contact hours (SWS):** 3 SWS
**Semester of delivery:** Annually

**Type / mode**: Lecture and exercises / Mandatory course

**Language of instruction:** English

**Content:**
The lecture starts with a summary of those basics of GIS which are deemed to be most important when handling vector and raster data for complex analyses. The focus is on spatial analysis, including overlay (vector-based), raster computations (weighted overlay, drainage, cost surface), also integrating DEM data, as well as network analyses. Further, a wide-ranging overview on Internet-GIS and the programming within GI-systems for applications from diverse fields is provided. The students work individually on different practical tasks applying ArcGIS Pro. This way they deepen their understanding regarding the theoretical content of the course.

**Recommended reading:**

Bernhardsen, N., Geographic information systems. New York 1999.

Burrough, P. & R. McDonnell, Principles of geographical information systems. Oxford 1998.

Chrisman, N., Exploring geographic information systems. New York 2002.

DeMers, M.N., Fundamentals of geographic information systems. New York 1999.

Fu, P. & J. Sun, Web GIS. Principles and applications. Redlands (CA) 2011.

Longley, P.A., M.F. Goodchild, D.J. Maguire & D.W. Rhind, Geographic information systems and science. New York 2005.

Zeiler, M., Modeling our world. Redlands 1999.

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| GIS | 3 | 25 h | 20 h | 45 h | 90 h | assignments | written exam 60 min |

Course

## GMCM113 Databases

| | |
|---|---|
| **Lecturer:** | Prof. Dr. Heinz Saler |
| **Contact hours (SWS):** | 2 SWS |
| **Semester of delivery:** | Annually |
| **Type / mode**: | Lecture and exercises / Mandatory course |
| **Language of instruction:** | English |

**Content:**
The course covers entity relation diagrams, multiplicity, modeling of geodata under consideration of national and international standards (OGC, ISO, INSPIRE, GDI-DE, WKT, SRID/EPSG), UML, normalization process, spatial data base models, spatial indexing of geodata with B/B+, Quadtrees and R/R+ trees, relational and object-relational databases, and spatial queries with SQL. Exercises employ MS-ACCESS and PostgreSQL/PostGIS with QGIS. This way, the students learn to setup data models and understand the difference between non-spatial and spatial DB.

**Recommended reading:**

Arctur D. & M. Zeiler, Designing geodatabases – Case studies in GIS data modelling. Redlands (CA) 2004.

Brinkhoff, T., Geodatenbanksysteme in Theorie und Praxis. Berlin 2013.

Levenne M. & G. Loizou, A guided tour of relational database and beyond. London 1999.

Mata-Toledo R. & P. Cushman**,** Fundamentals of relational databases. Schaum´s Outline, New York 2000.

Rigaux, P., M. Scholl, A. Voisard, Spatial databases: With application to GIS. Morgan Kaufmann Series in Data Management Systems, San Francisco 2001.

Schneider, M., Spatial data types for database systems. Finite resolution geometry for geographic information systems. Berlin, Heidelberg 1997.

Silberschatz. A, H.F. Korth & S. Susarshan, Database system concepts. New York 2010.

**Comments:**
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**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Databases | 2 | 20 h | 10 h | 30 h | 60 h | assignments | written exam 60 min |

Module summary

# GMCM120 Object-Oriented & Web Programming

**Module coordinator:** Prof. Dr. Bernhard Bürg, N.N.
**Credits (ECTS):** 5
**Semester:** 1

**Pre-requisites with regard to content:**
Basic knowledge in all areas of computer science

**Pre-requisites according to the examination regulations:**
None

**Competencies:**
The students understand the concepts of a modern object-oriented programming language. They are able to solve simple programming problems and to independently develop and implement these. | Students are able to create dynamic content on both server and client side. They have fundamental understanding of Web technologies, Web software development and markup languages. They are capable of making decisions which Web technology and technique to apply for a given problem.

**Assessment:**
Written examination (120 min)

**Usability:**
Project works in programming and other modules building on computer science. | A base for all Web-based modules in consecutive semesters.

Course

## GMCM122 Object-Oriented Programming

**Lecturer:** Prof. Dr. Bernhard Bürg
**Contact hours (SWS):** 3 SWS
**Semester of delivery:** Annually

**Type / mode**: Lecture and exercises / Mandatory course

**Language of instruction:** English

**Content:**
The lecture introduces the Java programming language and hence object-oriented programming. Contents covered are the structured formulating of algorithms, structure of programs, data types, expressions, statements, loops, classes, instances and inheritance. Therefore, the students learn the concepts of a modern object-oriented programming language.

**Recommended reading:**
Flanagan, D., Java in a nutshell, Sebastopol (CA) 2014.

Mycroft, A. & M. Fusco, Java 8 in action: Lambdas, streams, and functional-style programming. New York 2014.

**Comments:**
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**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Object-Oriented Programming | 3 | 30 h | 15 h | 45 h | 90 h | assignments | written exam 60 min |

Course

## GMCM123 Web Programming

**Lecturer:** M.Sc. Sabrina Kuhn
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually

**Type / mode**: Lecture and exercises / Mandatory course

**Language of instruction:** English

**Content:**
Web Programming encompasses in particular HTML5, CSS3, JavaScript and libraries like Leaflet.js, Bootstrap and jQuery. In addition, DOM, JSON and PHP play a role, too. This provides the basis for applying script languages to create and design dynamic and responsive Web pages. The students learn also to develop and prepare interactive maps with GIS functionality for the Internet, which bind in database information. Building on exercises, students receive hands-on in using a variety of different software development tools in an efficient manner by teaching development techniques and also debugging tools.

**Recommended reading:**

Duckett, J., JavaScript and JQuery: Interactive front-end Web development, Hoboken (NJ) 2014.

Nixon, R., Learning PHP, MySQL & JavaScript: with jQuery, CSS & HTML5. Sebastopol (CA) 2014.

http://www.w3c.org (W3C)

http://www.webreference.com/programming/javascript/ (JavaScript)

http://www.htmlgoodies.com/ (HTML)

**Comments:**
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**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Web Programming | 2 | 15 h | 15 h | 30 h | 60 h | assignments | written exam 60 min |

Module summary

# GMCM130 Language & Academic Writing

**Module coordinator:** Prof. Dr. Gertrud Schaab, Course director Geomatics Master
**Credits (ECTS):** 5
**Semester:** 1

**Pre-requisites with regard to content:**
Language courses according to existing skills | Familiarity with academic writing (e.g. a Bachelor Thesis) are an advantage

**Pre-requisites according to the examination regulations:**
None

**Competencies:**
In this module students acquire general language skills (for international students - German) as well as for writing an academic paper or thesis in English. For the latter, skills are learnt by studying and practically applying the theoretical foundations of literature-based academic research to a chosen research topic of interest.

**Assessment:**
See IFS programme | Marked academic paper

**Usability:**
Language skills for in Germany or abroad | Preparation for Master Thesis in 4th sem. as well as other written academic assignments during Master studies. Applicable to all study courses at HsKA where the language of instruction is English.

Course

## GMCM133 Language

**Lecturer:** Institute of Foreign Languages (IFS)
**Contact hours (SWS):** 4 SWS
**Semester of delivery:** Every semester

**Type / mode**: Exercises in small groups / Mandatory course

**Language of instruction:** English or German

**Content:**
Courses as offered by the Institute for Foreign Languages (IFS). All courses have 4ECTS. For international students 'German as Foreign Language' is compulsory. The minimum level required is A2 (B1 is recommended). The appropriate course is decided by a placement test. For German students the minimum requirement is English B1 and the IFS C1 level course Technical English is recommended. The emphasis of the IFS language courses is on communicative competence. Prerequisite for participation is either completion of the preceding course or the IFS placement test. All language skills (listening, reading, speaking and writing) are practiced systematically, with an emphasis on professionally-oriented communicative ability. Module descriptions for the IFS language courses can be found at https://www.hs-karlsruhe.de/ifs/.

**Recommended reading:**
See IFS

**Comments:**
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**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Language | 4 | | | | 90 h | see IFS | see IFS |

Course

## GMCM132 Academic Writing

**Lecturer:** Institute of Foreign Languages (IFS)
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually

**Type / mode**: Lecture and exercises / Mandatory course

**Language of instruction:** English

**Content:**
The course guides students through the process of writing an academic paper and includes the foundations of literature-based academic research as well as formatting and submission recommendations. The lectures consist of a theoretical input as well as in-class exercises. During the semester, students write an academic paper (e.g. Literature Review). Students are also encouraged to critically reflect on their peer's practical application of the topics studied.

**Recommended reading:**
Bailey, S., Academic writing: a handbook for international students. London 2015.

Goodson, P., Becoming an academic writer: 50 exercises for paced, productive, and powerful writing. Los Angeles 2013.

Macgilchrist, F., Academic writing. Paderborn 2014.

**Comments:**
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**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Academic Writing | 2 | 20 h | 10 h | 30 h | 60 h | assignments | academic paper |

Module summary

# GMCE140 Pre-required electives

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|---|---|
| **Module coordinator:** | Prof. Dr. Gertrud Schaab, Course director Geomatics Master |
| **Credits (ECTS):** | 15 |
| **Semester:** | 1 |

**Pre-requisites with regard to content:**
Basic knowledge of geomatics-related topics in general

**Pre-requisites according to the examination regulations:**
None.

**Competencies:**
By going through the most important aspects of the various subjects, students are able to judge where additional self-study is required to make up for existing knowledge gaps. The modules of the 1st sem. serve also the purpose to familiarize the students with teaching system and style in Germany and at universities of applied sciences.

**Assessment:**
Each pre-required elective concludes with a written exam (60 min). Student have to elect five out or eight elective courses offered.

**Usability:**
The pre-required electives serve the purpose to harmonize the existing knowledge among the students and to prepare them for specific elective modules in the 2nd and 3rd semester. In all courses relevant state-of-the-art knowledge is imparted covering both theory and practical aspects of benefit for the full geomatics range of topics.

Course

## GMCE151 Remote Sensing and Digital Image Processing

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|---|---|
| **Lecturer:** | Prof. Luis Ángel Ruiz Fernández |
| **Contact hours (SWS):** | 2 SWS |
| **Semester of delivery:** | Annually |
| **Type / mode**: | Lecture and exercises / Elective course |
| **Language of instruction:** | English |

**Content:**
The course treats a wide range of topics from physical fundamentals on remote sensing, spectral properties of the Earth's surface, set-up, geometry and radiometry of passive and active sensor systems, digital image processing, and image classification. After having completed the course, the students are acquainted with the basics physics of remote sensing and its data acquisition systems, and the use of satellite imagery for various applications. They have gained first experiences in supervised image analysis.

**Recommended reading:**

Campbell, J.B., Introduction to remote sensing. New York 1987.

Colwell, R.N. (ed.), Manual of remote sensing. American Society of Photogrammetry, Sheridan (WY) 1983.

Gose, E., R. Jonhsonbaugh & S. Jost. Pattern recognition and image analysis. Upper Saddle River (NJ) 1996.

Henderson, F.M. & A.J. Lewis, Principles and applications of imaging radar. Manual of Remote Sensing. American Society for Photogrammetric and Remote Sensing. Hoboken (NJ) 1998.

Jähne, B., Digital image processing. Concepts, algorithms and scientific applications. Berlin, Heidelberg 1997.

Jensen, J., Introductory digital image processing. A remote sensing perspective. Upper Saddle River (NJ) 1996.

Lillesand, T.M. & R.W. Kiefer, Remote sensing and image interpretation. New York 2000.

Lunetta, R.S. & C.D. Elvidge, Remote sensing change detection. Environmental monitoring methods and applications. London 1999.

Richards, J.A., Remote sensing digital image analysis. An introduction. Berlin, Heidelberg 1993.

Sabins, F.F., Remote sensing principles and interpretation. 3rd ed., New York 1996.

Schowengerdt, R.A., Remote sensing, models and methods for image processing. Burlington (MA) 1997.


**Comments:**
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**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Remote Sensing and DIP | 2 | 20 h | 10 h | 60 h | 90 h | assignments | written exam 60 min |

Course

## GMCE152 Photogrammetry and Computer Vision

**Lecturer:** Prof. José Luis Lerma García
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually
**Type / mode**: Lecture / Elective course
**Language of instruction:** English

**Content:**
Photogrammetry content focuses on fundamentals of photogrammetry: projective geometry, transformations, camera parameters (intrinsic, extrinsic), DLT, central projection, homography. Furthermore, the basics of photogrammetric processing such as single-image processing, standard stereo (double-image) and convergent multi-image cases, and collinearity equation are taught. The photographic and measurement campaign basics as well as state-of-the art processing procedures to yield photorealistic 3D models form also a significant part of the lectures. Computer Vision content focuses on basics of computer vision, image types, image analysis, histograms, statistical image analysis and image matching algorithms. Student use state-of-the-art scriptable image processing tool-boxes to get hands on practical problems and to solve them during exercises and labs.

**Recommended reading:**
Gonzalez, R.C. & R.E. Woods, Digital image processing. 3rd ed., Upper Saddle River (NJ) 2006.

Hartley, R.I. & A. Zisserman, Multiple view geometry in computer vision. 2nd ed., Cambridge 2004.

Kraus, K., Photogrammetry: Geometry from images and laser scans. Berlin 2007.

Linder, W., Digital photogrammetry. Berlin 2006.

Luhmann, T., Close-range photogrammetry and 3D imaging. 2nd ed., Berlin, 2014.

Szeliski, R., Computer vision algorithms and applications. London, New York 2011.

**Comments:**
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**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Photogrammetry and Computer Vision | 2 | 20 h | 10 h | 60 h | 90 h | assignments | written exam 60 min |

Course

## GMCE153 Thematic Cartography

**Lecturer:** Prof. Dr. Detlef Günther-Diringer
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually
**Type / mode**: Lecture and exercises / Elective course
**Language of instruction:** English

**Content:**
Students learn the basics of cartography in order to ensure a solid background for any visualization of geospatial data in thematic maps. Topics covered are basics of cartography (scale, projection, cartographic generalisation, base map, map design & layout, lettering, symbols, patterns, colour, graphic variables), transformation of statistical data into map symbols, the resulting map types and their usage, compilation and production of thematic maps by means of different software tools. Exercises exemplify the theoretical aspects covered and make use of univariate as well as multivariate data.

**Recommended reading:**
Bertin, J., Semiology of graphics. Diagrams, networks, maps. Redlands (CA) 1983/2011.

Dent, B.B., Cartography. Thematic Map Design. Boston 1999.

Kraak, M.-J. & F. Ormeling, Cartography: Visualization of geospatial data. Harlow 2003.

Robinson, A.H., J.L. Morrison, P.C. Muerhcke, A.J. Kimerling & S. Guptill, Elements of cartography. New York 1995.

Slocum, T.A., R.B. McMaster, F.C. Kessler & H.H. Howard, Thematic cartography and geovisualization. 3rd ed., Upper Saddle River (NJ) 2010.

Tyner, J.A., Principles of map design. New York (NY) 2010.

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Thematic Cartography | 2 | 20 h | 10 h | 60 h | 90 h | assignments | written exam 60 min |

Course

## GMCE154 3D Visualization

**Lecturer:** Prof. Dr. Detlef Günther-Diringer
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually
**Type / mode**: Lecture and exercises / Elective course
**Language of instruction:** English

**Content:**
Students are enabled to import geospatial 2D data together with further 3D data into a georeferenced 3D model. Input data for the 3D model-building can be e.g. point clouds acquired by means of 3D laser scanning, structured light techniques or 3D photogrammetry, computed digital elevation models, or image data from remote sensing sensor platforms like satellites, drones, etc. The students set up and edit 3D data structures with different 3D construction programs. For the visualization they learn different scale-based methods and dissemination techniques. The fields of application can differ from indoor-applications to 3D city models or 3D landscape models. Next to 3D construction they learn to import the generated 3D data into a game engine environment to generate basic applications, which can be used for Virtual Reality (VR) and/or Augmented Realty (AR) applications. All the practical work is based on lectures for a theoretical grounding.

**Recommended reading:**
Kent, B.R., 3D scientific visualization with Blender (IOP Concise Physics). Williston (VT) 2016.

Parisi, T., Programming 3D applications with HTML5 and WebGL: 3D animation and visualization for Web pages. Sebastopol (CA) 2014.

Tal, D., SketchUp for site design. Hoboken (NJ) 2016.

https://www.sketchup.com/learn/videos (SketchUp)

https://unity3d.com (Unity3Dp)

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| 3D Visualization | 2 | 10 h | 20 h | 60 h | 90 h | assignments | written exam 60 min |

Course

## GMCE155 Statistics and Adjustments

**Lecturer:** Prof. Dr. Heinz Saler
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually
**Type / mode**: Lecture and exercises / Elective course
**Language of instruction:** English

**Content:**
The course aims at students understanding the application of statistical approaches on geodata. They are enabled to determine confidence intervals and to test parameters regarding significance. Furthermore, they can do data snooping and testing of stochastic and mathematical model. The students have the ability to apply LSM onto all over-determined problems of geomatics (geodetic problems, regression). The course covers random error theory, standard normal, student, chi-square and Fisher distribution, confidence Intervals, parameter testing, error propagation, weight of observations, as well as linear and non-linear problems solved by the least squares method (LSM). For a better understanding, tasks will be solved with a computer algebra system (MAPLE) or MS EXCEL.

**Recommended reading:**

Ghiliani, C., Adjustment computations: Spatial data analysis. Hoboken (NJ) 2017.

Jäger, R., T. Müller & H. Saler: Klassische und robuste Ausgleichungsverfahren. 2nd ed., Berlin 2019.

Keller, G., Statistics for management and economics. Boston (MA) 2017.

www.statsoft.com/textbook/ (distributions, tests, linear algebra)

www.tech.plym.ac.uk/maths/resources/PDFLaTeX/mathaid.html (basis maths)

www.itl.nist.gov/div898/handbook/eda/section3/eda35.htm (tests)

http://bit.ly/spatialstats (Esri Geostats)


**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Statistics and Adjustments | 2 | 20 h | 10 h | 60 h | 90 h | assignments | written exam 60 min |

Course

## GMCE156 Advanced Parameter Estimation

**Lecturer:** Prof. Dr. Reiner Jäger
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually
**Type / mode**: Lecture and exercises / Elective course
**Language of instruction:** English

**Content:**
The course treats sequential adjustment procedures, (quasi)integrated geodesy, Gauß-Markov parameter estimation model, generalized M-Estimation and Kalman filtering, generalized Bayesian estimation, adjustment of free engineering networks, as well as measures to quantify and describe distortions of parameters and geodetic networks due to deterministic and stochastic errors in coordinate space. Specific tasks allow for training on software tools and programming.

**Recommended reading:**

Jäger, R., T. Müller, & H. Saler: Klassische und robuste Ausgleichungsverfahren. 2nd ed., Berlin 2019.

Teunissen, P.J.G., Adjustment theory: an introduction (Mathematical geodesy and positioning), Delft 2000.

Krumm, F., Geodetic network adjustment examples. Geodätisches Institut. Universität Stuttgart 2018. http://web.gis.uni-stuttgart.de/res/study/addons/adjustment_examples.pdf.

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Advanced Parameter Estimation | 2 | 20 h | 10 h | 60 h | 90 h | assignments | written exam 60 min |

Course

## GMCE157 Satellite Geodesy

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|---|---|
| **Lecturer:** | Prof. Dr. Reiner Jäger |
| **Contact hours (SWS):** | 2 SWS |
| **Semester of delivery:** | Annually |
| **Type / mode**: | Lecture and exercises / Elective course |
| **Language of instruction:** | English |

**Content:**

The students get a deep insight in the mathematical and physical foundations, algorithms and concepts of satellite geodesy. As concerns GNSS-based positioning (geometrical satellite geodesy) the topics of reference frames, GNSS data acquisition, algorithms and data processing, software and RTCM-corrections are treated. The other focus is on satellite-based gravity field determination (dynamical satellite geodesy), satellite interferometry (SAR/INSAR data processing) and altimetry. A small seminar work comprises individual reports on up-to-date satellite geodesy topics. Exercises cover RTK measurements and transformation using SAPOS, and GNSS data processing using Bernese GNSS, GPSLab, etc.

**Recommended reading:**

Borre, K., D.M. Akos, N. Bertelsen, P. Rinder & S.H. Jensen, A software defined GPS and GALILEO receiver. A single-frequency approach. Basel 2007.

Ferretti, A., Satellite inSAR Data – Reservoir monitoring from space (EAGE Education Tour Series, vol. 9). Houten 2014.

Hofmann-Wellenhof, B., H. Lichtenegger & E. Wasle, GNSS. Global navigation satellite systems. GPS, GALIELO & more. Wien 2007.

Kaula, W.M., Determination of the Earth's gravitational field. In: Reviews of Geophysics, 1(4), 507–551, 1963.

Xu, G., GPS. Theory, algorithms and applications. Berlin, Heidelberg 2007.

Xu, G., Sciences of geodesy II. Berlin, Heidelberg 2013.

http://www.copernicus.eu/ (global monitoring)

www.rtklib.org (RTKLIP)

https://www.aviso.altimetry.fr/en/techniques/altimetry.html (altimetry)

https://link.springer.com/journal/190 (Journal of Geodesy)

**Comments:**

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**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Satellite Geodesy | 2 | 20 h | 10 h | 60 h | 90 h | assignments | written exam 60 min |

Course

## GMCE158 Economics and Marketing

**Lecturer:** Dipl.-Ing. Dipl.-Wi.-Ing. Rüdiger Kleinknecht
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually
**Type / mode**: Lecture and exercises / Elective course
**Language of instruction:** English

**Content:**
The course covers topics like communication and management, organisation, corporate culture, product and brands, marketing activities, consumer behaviour and international trade. Therefore, students get an overview of the most important aspects in economics and marketing. Case studies and practical examples from the management point of view will help the students to understand economic processes and help them to understand the competitive market economy as well as the structure of companies. Students apply their knowledge in small projects.

**Recommended reading:**
Cateora, G., International marketing. New York 2016.

Cavusgil S.T., G. Knight & J.R. Riesenberger, International business. Upper Saddle River (NJ) 2013.

Hill, C.W.L., International business - Competing in the global marketplace. New York 2016.

Hollendsen, S., Global marketing. Upper Saddle River (NJ) 2013.

Kavoura, A., D.P. Sakas & P. Tomaras, Strategic innovative marketing. Heidelberg 2016.

Kotabe, M. & K. Helsen, Global marketing management. Indianapolis (IN) 2014.

Krugman, P. & M. Obstfeld, International economics: Theory and policy. Boston (MA), 2012.

Mankiw, N.G. & M.P. Taylor, Economics. Andover 2015.

Obstfeld, M. & K. Rogoff, Foundations of international macroeconomics. Cambridge (MA) 2011.

Quelch, J.A. & C.A. Bartlett, Global marketing management. Upper Saddle River (NJ) 1998.

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Economics and Marketing | 2 | 20 h | 10 h | 60 h | 90 h | assignments | written exam 60 min |

Module summary

# GMCM210 Software Engineering

**Module coordinator:** Prof. Dr. Bernhard Bürg, Prof. Dr. Klaus Dürrschnabel
**Credits (ECTS):** 6
**Semester:** 2

**Pre-requisites with regard to content:**
Solid knowledge in programming and databases

**Pre-requisites according to the examination regulations:**
None

**Competencies:**
The students have gained knowledge regarding the principles of software development, especially the SADT-method, as well as the object-orientated methods (spiral model, UML), the principles of software examination, and the method of software project management (especially Scrum). They know a software tool for computer aided software engineering.
Furthermore, the students are enabled to independently develop problem-solutions with an average degree of difficulty and to implement these. Through independent practical work the students have learned how to solve difficult problems in a team and how to develop a software package.

**Assessment:**
Joint oral examination (30 min)

**Usability:**
Any project works in programming and other modules based on computer science methods

Course

## GMCM212 Software Engineering

**Lecturer:** Prof. Dr. Bernhard Bürg
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually
**Type / mode**: Lecture and exercises / Mandatory course
**Language of instruction:** English

**Content:**
The students learn the methods of information technology and are capable of high quality software development. The students learn both the classic and the modern object-oriented development methods. As such, the lecture treats problems in software development, the software development process, structured analysis and design techniques (e.g. flow charts, Jackson-diagram), object-oriented modeling, UML, software testing, and project management. More detailed, the module covers: basics, software development process, software requirements, structured analysis and structured design technique, object-oriented analysis and object-oriented design technique, UML, software validation, project management, agile software development and Scrum. Concrete tasks and exercises ensure experience in usage and handling of tools from software engineering.

**Recommended reading:**

Balzert, H., Lehrbuch der Softwaretechnik. 2 vol., Wiesbaden, 2008.

Booch, G., I. Jacobson & J. Rumbough, The unified software development process. Boston (MA), 1999.

Dumke, R., Software Engineering. Eine Einführung für Informatiker und Ingenieure: Systeme, Erfahrungen, Methoden, Tools. Wiesbaden 2003.

Grechenig, T., M. Bernhart, R. Breiteneder & K. Kappel, Softwaretechnik. Mit Fallbeispielen aus realen Entwicklungsprojekten. München, 2010.

Oestereich, B., Developing software with UML. Object-oriented analysis and design in practice (Addison-Wesley Object Technology Series). Boston (MA) 2002.

Pressman, R. & P. Maxim, Software engineering. A practitioner's approach. New York 2014.

Schwaber, K. & M. Beedle, Agile software development with Scrum. Upper Saddle River (NJ) 2001.

Sommerville, I., Software engineering. 10$^{th}$ ed., London 2016.


**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Software Engineering | 2 | 15 h | 15 h | 60 h | 90 h | assignments | oral exam 15 min |

Course

## GMCM213 Object-Oriented Programming 2

**Lecturer:** Prof. Dr. Bernhard Bürg
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually
**Type / mode**: Lecture and exercises / Mandatory course
**Language of instruction:** English

**Content:**
Based on the lecture 'Object-Oriented Programming' of the 1st sem., the following themes are treated: methods, graphical output with AWT and Swing, threads, exceptions, applets, events, animations, and use of class libraries. On the one hand, the students receive in-depth knowledge in software development with Java, on the other hand they learn how software is developed in a team. They learn to independently develop problem-solutions with an average degree of difficulty and implement these as software package.

**Recommended reading:**
Flanagan, D., Java in a nutshell. 5th ed., Sebastopol (CA) 2009.

Martin, R., Clean code – A handbook of agile software craftsmanship. London 2009.

Bloch, J., Effective Java. 3rd ed., London 2018.

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Object-Oriented Programming 2 | 2 | 15 h | 15 h | 60 h | 90 h | assignments | oral exam 15 min |

Module summary

# GMCM220 Web Services & Monitoring

**Module coordinator:** Prof. Dr. Gertrud Schaab, Prof. Dr. Reiner Jäger
**Credits (ECTS):** 6
**Semester:** 2

**Pre-requisites with regard to content:**
Knowledge of parameter estimation, statistics and object-oriented programming | Knowledge of GIS and scripting

**Pre-requisites according to the examination regulations:**
None

**Competencies:**
The students know how to set up different parametric approaches of an integrated geo-monitoring in 3D geometry and gravity space. This includes competencies in IT technologies for local and global object geo-monitoring, and software implementation for time-series analysis, change detection and visualization based on real data.

The students learn the setting-up and programming of a Web processing service (WPS) following OGC standards and including own scripting parts.

**Assessment:**
Two written examinations (2 x 60 min)

**Usability:**
Prepares for the implementation of different kinds of geo-monitoring systems | Enables to integrate WPS into mobile map applications (see e.g. module Mobile Map Apps in Nature Conservation)

Course

## GMCM222 Programming for Geomonitoring

**Lecturer:** Prof. Dr. Reiner Jäger
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually

**Type / mode**: Lecture exercises / Mandatory course

**Language of instruction:** English

**Content:**

The students learn about the present profile, the hardware, software and communication design and intensively about the mathematical models of scalable multi-sensor geodetic monitoring systems. The application domain is manifold and covers different estimation concepts in deformation networks, observation and coordinate related adjustment approaches, as well as quality control and statistically based concepts for forecasting and alert setting in real time (e.g. displacement estimation, Kalman filter). Programming exercises make use of the systems GOCA and MONIKA in real-data environment. For time series analysis in geomonitoring, Python and the programming environment Jupiter are used. Here the methods for modeling, removing and forecasting of the non-stationary parts by different trend models and FFT are treated. As stationary parts Random Walk, ARP, MA(q), ARMA(p,q) and ARIMA (p,d1) modeling, estimation and forecasting are treated based on real data.

**Recommended reading:**

Eichhorn, A., Ein Beitrag zur Identifikation von dynamischen Strukturmodellen mit Methoden der adaptiven Kalman-Filterung. DGK-C Nr. 585, Deutsche Geodätische Kommission, München 2005.

Johansson, R., Numerical Python. A practical techniques approach for industry. New York 2015.

Kühne, H., H. Einstein, E. Krauter, H. Klapperich & R. Pöttler (eds), Proceedings international conference on landslides causes, impacts and countermeasures. Davos, Switzerland, June 17-21, 2002. Cloppenburg 2002.

Markert, M. et al., Das Python3.3-Tutorial auf Deutsch. Release 3.3. 2017. https://media.readthedocs.org/pdf/py-tutorial-de/python-3.3/py-tutorial-de.pdf.

Marschallinger, R. (ed.), Geomonitoring, FE-Modellierung, Sturzprozesse und Massenbewegungen: Beiträge zur COG-Fachtagung Salzburg 2008.

Nittel, S., A. Labrinidis & A. Stefanidis (eds.): GeoSensor Networks: Second International Conference, GSN 2006, Boston, MA, USA, October 1-3, 2006, Revised selected and invited Papers. Berlin, Heidelberg 2008.

Plag, H.-P. & M. Pearlman (eds.), Global geodetic observing system. Meeting the Requirements of a global society on a changing planet in 2020. Berlin, Heidelberg 2009.

http://www.copernicus.eu/ (Copernicus)

www.goca.info (GOCA)

https://en.wikipedia.org/wiki/Structural_health_monitoring (structural health monitoring)

**Comments:**

-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Programming for Geomonitoring | 2 | 20 h | 10 h | 60 h | 90 h | assignments | written exam 60 min |

Course

## GMCM224 Web Processing Services

| | |
|---|---|
| **Lecturer:** | Dipl.-Ing. (FH) Christian Stern |
| **Contact hours (SWS):** | 2 SWS |
| **Semester of delivery:** | Annually |
| **Type / mode**: | Lecture and exercises / Mandatory course |
| **Language of instruction:** | English |

**Content:**
The course starts with an introduction to programming with Python. Building up on that, the students learn how to use Python/ArcPy in the ArcGIS environment, keeping the focus on geoprocessing by calling ArcGIS tools first and then in a second step by using advanced concepts like cursors and methods to manipulate features and geometries directly. In the second part of the lecture, an introduction to the OGC specification for WPS is given, the setting-up of such a service is discussed and introduced by means of a simple task and then finally an example of a complex process programmed by the students using the previously gained knowledge in Python/ArcPy. Here, the students learn how to combine Esri's ModelBuilder for configuring and/or customizing scripts with own scripting in order to be most flexible. In addition, service chaining is also covered including so-called 'zip & ship'.

**Recommended reading:**

Lutz, M., Learning Python. 5th ed., Beijing, Köln 2013.

Pimpler, E., Programming ArcGIS Pro with Python. North Charleston (SC) 2017.

Schut, P. (ed.), OGC Document 05-007r7, OpenGIS Web Processing Service, http://portal.opengeospatial.org/files/?artifact_id=24151.

Silas, T. & D. O'Beirne, ArcPy and ArcGIS. 2nd ed., Birmingham 2017.

Whiteside A. & J. Greenwood (eds.), OGC Document 06-121r9, OGC Web Services Common Standard, http://portal.opengeospatial.org/files/?artifact_id=38867.

Zandbergen, P.A., Python scripting for ArcGIS. Redlands 2015.

Zhao, P., F. Lu & T. Foerster (eds.), Towards a geoprocessing web. Computers & Geosciences, 47, 2012.


**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Web Processing Services | 2 | 20 h | 10 h | 60 h | 90 h | assignments | written exam 60 min |

Module summary

# GMCM 230 Virtual Reality

**Module coordinator:** Prof. Dr. Detlef Günther-Diringer, Prof. Dr. Heinz Saler
**Credits (ECTS):** 6
**Semester:** 2

**Pre-requisites with regard to content:**
Solid knowledge of 3D visualization

**Pre-requisites according to the examination regulations:**
GMCE230 3D Visualization

**Competencies:**
Competencies acquired cover theoretical knowledge and practical experience on the set up of augmented reality (AR) and virtual reality (VR) applications using appropriate software environments and their publishing on different output devices.

**Assessment:**
Marked project work

**Usability:**
Virtual reality projects are not limited to geospatial data, but used also in e.g. architecture, technical engineering and technical documentation applications.

**Course**

## GMCE235 Virtual Reality

**Lecturer:** Prof. Dr. Detlef Günther-Diringer
**Contact hours (SWS):** 4 SWS
**Semester of delivery:** Annually
**Type / mode**: Project / Elective module
**Language of instruction:** English

**Content:**

Based on the students' knowledge of setting up georeferenced 3D models, the programming of interactive activities into the constructed 3D environment is taught for a further enhancement of 3D models towards augmented and virtual reality applications (e.g. virtual sights, flight-overs and movements in the 3D environment). The students learn how to make 3D visualisations run on different output devices like head-mounted-displays, mobile devices, virtual walls, etc. Also here, the fields of application can differ from indoor-applications to 3D city models or 3D landscape models.

Portions of lecture and project work: 30% / 70%. In the lecture students gain knowledge on the theoretical background and the practical framework of AR and VR applications. The project work includes the setting-up of an AR/VR application together with a documentation describing the practical work. The results are tested by the other students, too.

**Recommended reading:**

Kent, B.R., 3D scientific visualization with Blender (IOP Concise Physics). Williston (VT) 2016.

Linowes, J., Unity virtual reality projects. Birmingham 2015.

Parisi, T., Programming 3D applications with HTML5 and WebGL: 3D animation and visualization for Web pages. Sebastopol (CA) 2014.

https://unity3d.com (Unity3D)

**Comments:**

-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Virtual Reality | 4 | 18 h | 42 h | 120 h | 180 h | - | project |

Module summary

# GMCE240 Combining Space and Marketing

**Module coordinator:** Prof. Dr. Peter Freckmann, N.N.
**Credits (ECTS):** 6
**Semester:** 2

**Pre-requisites with regard to content:**
Solid knowledge in economics and marketing

**Pre-requisites according to the examination regulations:**
GMCE158 Economics and Marketing

**Competencies:**
Students are familiar with all parts of a company in which business geographic methods play an important role. They have extensive knowledge in using business geographics methods and tools in a company's internal processes. They can also operate business geographic tools within the framework of an existing IT-environment.

**Assessment:**
Marked project work

**Usability:**
Working with real business data leads to a better knowledge how to handle the requirements of a companie's customers. That gives an impression of the operational procedures within a company and in relationship to the customers. The module provides hands-on for wherever benefit is to be gained from using the spatial reference in combination with economic data. Therefore, it could be of interest to students from other faculties if with a background in economics as well as in GIS.

Course

## GMCE245 Combining Space and Marketing

| | |
|---|---|
| **Lecturer:** | Prof. Dr. Peter Freckmann |
| **Contact hours (SWS):** | 4 SWS |
| **Semester of delivery:** | Annually |
| **Type / mode**: | Project / Elective module |
| **Language of instruction:** | English |

**Content:**
Students are working on a strategic planning problem in business geographics with real geodata. The project is done in cooperation with a company. Students work in teams and they use standard geographical information systems (ArcGIS Pro, MapInfo), OpenSource GIS and special tools for tasks in business geographics (RegioGraph, MarktAnalyst, Map&Market). Every team works on its own project.

Portions of lecture and project work: 30% / 70%. In the lecture students gain knowledge in the theoretical and practical framework of business geographics. To finalise the project, students present how they solved the given task and they discuss the results with the students from the other project teams. In addition they prepare a document which describes the complete workflow of the project and contains all information to make their work understandable.

**Recommended reading:**
Crampton, J.W., M. Graham, A. Poorthuis, T. Shelton, M.W. Wilson & M. Zook, Beyond the geotag: situating 'big data' and leveraging the potential of the geoweb. In: Cartography and Geographic Information Science, 40(2), 130-139, 2013.

Douglas, B., Achieving business success with GIS. Chichester 2008.

Pick, J.B., Geographical information systems in Business, London 2005.

Warf, B. & D. Sui, D., From GIS to neogeography: ontological implications and theories of truth. In: Annals of GIS, 16(4), 197-209, 2010.

Wilken, R., Locative media: From specialized preoccupation to mainstream fascination. In: Convergence: The International Journal of Research into New Media Technologies, 18(3), 243-247, 2012.

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Combining Space and Marketing | 4 | 18 h | 42 h | 120 h | 180 h | - | project |

Module summary

# GMCE250 Mobile Map Apps in Nature Conservation

| | |
|---|---|
| **Module coordinator:** | Prof. Dr. Gertrud Schaab, Prof. Dr. Detlef Günther-Diringer |
| **Credits (ECTS):** | 6 |
| **Semester:** | 2 |

**Pre-requisites with regard to content:**
Solid knowledge in geographical information systems (Web GIS), databases, and JavaScript programming

**Pre-requisites according to the examination regulations:**
None

**Competencies:**
The students learn to conceptualize native mobile map apps being of value in nature conservation. They learn how to program such mobile map apps based on Qt / QML and JavaScript. By working in groups, the students have gained experience and skills in project management and software development within a team.

**Assessment:**
Marked project work including an individual assessment of the project group members

**Usability:**
Any app development in the growing mobile app development field, this ideally independent of an operating system and considering responsive design.

Course

## GMCE255 Mobile Map Apps in Nature Conservation

**Lecturer:** Prof. Dr. Gertrud Schaab
**Contact hours (SWS):** 4 SWS
**Semester of delivery:** Annually
**Type / mode**: Project / Elective module
**Language of instruction:** English

**Content:**
The project work covers the development of a mobile map app of use in nature conservation. Applications are sought for supporting research or participatory activities in development cooperation. After an introduction to participatory sensing and the particular app task, students in groups of four or five need to make themselves familiar with similar mobile mapping applications via examples described in the Internet or in scientific papers. This allows them to conceptualize the app. Besides, the students are prepared for their development task by introductory lectures on Qt / QML. Programming hands-on are offered first via the configuration of ‘play apps’ based on out-of-the-box templates in the cloud version of AppStudio for ArcGIS. Next the desktop version of AppStudio and programming QML in the Integrated Development Environment (IDE) Qt Creator is introduced by developing a ‘mock-up app’.

For the actual app development, students have to concentrate on app design (prototyping, GUI design), database entry via forms, the use of map services, and the implementation of specific functionality depending on the app task. As AppStudio for ArcGIS is supporting cross-platform app development, responsive design matters. The students per group have to organize themselves for working as a team following project management methods. For sharing and integrating the source code developed by different members of the group, the students are also introduced to a version control system. Regular meetings with the lecturer will provide opportunity to the students to discuss their progress, to ask questions and to ensure their route to success. The students will thus gain experience in software development within a team and in the growing mobile app development field.

Portions of lectures / programming hands-on and project work: 40% / 60%. The project work handed in consists of the developed app and its source code as well as a written documentation of background/setting and the development process, which follows standards of scientific publications. Additionally a presentation in front of class per group and an individual assessment is envisaged.

**Recommended reading:**
Brovelli, M.A., M. Minghini & G. Zamboni, Public participation in GIS via mobile applications. In : ISPRS Journal of Photogrammetry and Remote Sensing 114, 306-315, 2015.

Hennig, S. (ed.), Online-Karten im Fokus: Praxisorientierte Entwicklung und Umsetzung. Berlin, 2006.

McKinley, et al., Citizen science can improve conservation science, natural resource management, and environmental protection. In: Biological Conservation, 208, 15-28, 2017.

Mousa, H., S. Ben Mokhtar, O. Hasan, O. Younes, M. Hadhoud & L. Brunie, Trust management and reputation systems in mobile participatory sensing applications: A survey. In: Computer Networks 90, 49-73, 2015.

Reichenbacher, T., Kartographie in der mobilen digitalen Welt. In: D. Beineke, O. Heunecke, T. Horst & U.G.F. Kleim (eds.): Festschrift für Univ.-Prof. Dr.-Ing. Kurt Brunner anlässlich des Ausscheidens aus dem aktiven Dienst. Schriftenreihe des Instituts für Geodäsie der Universität der Bundeswehr München 87, 179-188, 2012.

Rice, R.M., Ensuring the quality of volunteered geographic information: A social approach. Kartographische Nachrichten. In: Journal of Cartography and Geographic Information 3/2015, 123-130, 2015.

Rischpater, R., Application development with Qt Creator. Design and build dazzling cross-platform applications using Qt and Qt Quick. Birmingham, Mumbai, 2014.

Salz, P. & J. Moranz, The everything guide to mobile apps. A practical guide to affordable mobile app development for your business. Avon (MA), 2013.

Sheth, A., Citizen sensing, social signals, and enriching human experience. In: IEEE Internet Computing 13 (4), 80-85, 2009.

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Mobil Map Apps in Nature Conservation | 4 | 24 h | 36 h | 120 h | 180 h | - | project |

Module summary

# GMCE260 Intelligent Systems and Engineering Geodesy

**Module coordinator:** Prof. Dr. Reiner Jäger, N.N.
**Credits (ECTS):** 6
**Semester:** 2

**Pre-requisites with regard to content:**
Solid knowledge in software development, parameter estimation, satellite geodesy

**Pre-requisites according to the examination regulations:**
None

**Competencies:**
Course attendees obtain knowledge necessary to design the mathematical models, software- and hardware of intelligent systems, and to realize and evaluate intelligent systems in engineering geodesy (in- and outdoor; airborne, ground, water; stationary or mobile multi-sensor robot systems). The students are able to evaluate off-the-shelf systems and have acquired skills in rapid prototyping of in-telligent systems. Students have obtained also capabilities of active participation in industrial-level product development by tackling product development paradigms.

**Assessment:**
Marked project work

**Usability:**
The module provides algorithms and parameter estimation for intelligent multi-sensor GNSS/MEMS/optics robotic systems being of relevance in mapping, moni-toring and change detection in BIM. It could be integrated in other study programmes such as Sensor Systems Technology (Master) or Micro-Mechatronic Systems (Master).

Course

## GMCE265 Intelligent Systems and Engineering Geodesy

| | |
|---|---|
| **Lecturer:** | Prof. Dr. Reiner Jäger |
| **Contact hours (SWS):** | 4 SWS |
| **Semester of delivery:** | Annually |
| **Type / mode**: | Project / Elective module |
| **Language of instruction:** | English |

**Content:**
The module comprises recursive parameter estimation, machine control, computer vision, machine learning and photogrammetry in order to provide students with an understanding of intelligent systems. Based on that knowledge, attendees build a sample robot using available robotic kit and equip the systems with off-the-shelf sensors for navigation, obstacle detection and data acquisition. For this purpose, a training ground is provided where emulated or real GNSS system provides a global positioning service. Localization of robotic system will be performed by the system itself (redundancy, sensor fusion). The modular design of the robotic system allows attendees to modify, extend or simplify the system and in order to grasp the complexity and extend of general-purpose systems. The course attendees are also encouraged to modify and improve existing algorithms, taught during the lectures or obtained from third party.

By means of the project work students, in small teams of four, learn rapid prototyping and active participation in industrial-level product development, which requires comprehensive knowledge on sensor physics, and the mathematical models, Bayes estimation, algorithmic concepts, software-development (e.g. based on OpenSource) and operating systems (e.g. ROS for robotic systems) of a sensor-fusion (GNSS, MEMS, Optics), SLAM and system integration expertise. The attendants will work with the Volksbot RT3-2 as a remote controlled or autonomously driving intelligent robotic and the implemented system MSM (ROS as operational system) provided by the Laboratory on GNSS & Navigation.

Portions of lecture and project work: 50% / 50%. The course ends with marked presentation and benchmarking between teams on predefined tasks.

**Recommended reading:**
Bishop, C.M., Pattern recognition and machine learning. Berlin, Heidelberg 2006.

Dewhurst, S.C., C++ common knowledge: Essential intermediate programming. Boston (MA) 2005.

Douglass, B.P., Real-time design patterns: Robust scalable architecture for real-time systems. Boston (MA) 2003.

Hartley, R. & A. Zisserman, Multiple view geometry in computer vision. 2nd ed., New York 2003.

Koch, K.-R., Introduction to Bayesian Statistics. Berlin, Heidelberg 2007.

Luhmann, T., S. Robson, S. Kyle & J. Boehm, Close range photogrammetry and 3D imaging. 2nd ed., Berlin 2014.

Metzger, J., Optimierung des Akquisitions- und Trackingverhaltens zentraler und modularer Terrainnavigationssysteme. Dissertation Universität Karlsruhe 2006.

Siegwart, R., I.R. Nourbakhsh & D. Scaramuzza, Introduction to autonomous mobile robots. 2nd ed. Cambridge (MA) 2011.

Thrun, S., W. Burgard & D. Fox, Probabilistic robots. Cambridg (MA), London 2006.

Wendel, J., Integrierte Navigationssysteme. München, Wien 2007.

http://www.navka.de/index.php/de/ (NAVKA)

www.ros.org (ROS)

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Intelligent Systems and Engineering Geodesy | 4 | 30 h | 30 h | 120 h | 180 h | - | project |

Module summary

# GMCE270 Building Information Modelling

**Module coordinator:** Prof. Dr. Heinz Saler, N.N.
**Credits (ECTS):** 6
**Semester:** 2

**Pre-requisites with regard to content:**
Solid knowledge in 3D visualization, photogrammetry and statistics

**Pre-requisites according to the examination regulations:**
GMCE270 Statistics and Adjustments

**Competencies:**
The students are able to use terrestrial laser scanner (TLS) for acquiring geometry data of constructions and buildings along with image data, to process TLS data and to archive information for building models. Students understand the benefit of BIM and how to integrate data into BIM.

**Assessment:**
Marked project work

**Usability:**
No usability in other module of the Geomatics Master

Course

## GMCE270 Building Information Modelling

| | |
|---|---|
| **Lecturer:** | Prof. Dr. Heinz Saler |
| **Contact hours (SWS):** | 4 SWS |
| **Semester of delivery:** | Annually |
| **Type / mode**: | Lecture and project work / Elective module |
| **Language of instruction:** | English |

**Content:**

The students are enabled to capture building geometries with terrestrial laser scanner (TLS) technique and to prepare the data for BIM. After an introduction to BIM and the BIM data model, information acquisition is performed with the newest generation of surveying instruments and software. Here, current state-of-the-art methods for post-processing information extraction methods are presented to the attendees. The acquired data is transferred into a BIM structure using Autodesk Revit and AutoCAD Architecture. Teaching makes use of tutorials made available via ILIAS.

Portions of lecture and project work: 30% / 70%. In the lecture students are prepared for the practical project work by means of presentations on the theoretical background of BIM, its setting within various disciplines, and introductory practical exercises. The actual project work, which is performed in groups of 2-3 students, includes the solving of a given task together with a documentation of the project work. Results are to be presented regularly.

**Recommended reading:**

Borrmann, A., M. König, C. Koch & J. Beetz (eds.), Building information modeling. Wiesbaden 2015.

Building SMART, National building information – Standard, Part 1. 2007. http://www.1stpricing.com/pdf/NBIMSv1_ConsolidatedBody_Mar07.pdf.

Hausknecht, K. & T. Liebich, BIM-Kompendium. Fraunhofer IRB, Stuttgart 2016.

Liebich T & K. Hausknecht, Praxisnahe Workflows für die durchgängige Nutzung von IFC Gebäudemodellen. 10. buildingSMART Anwendertag, Hamburg, 18.06.2013. https://www.buildingsmart.de/kos/WNetz?art=File.download&id=1458&name=10_BIM_AT_Ref_B3_Liebich.pdf

http://au.autodesk.com/au-online/classes-on-demand/class-catalog/2016/revit-architecture/ar20299#chapter=0 (Autodesk: creating Revit families)

https://www.autodesk.com/shortcuts/revit (Autodesk: Revit shortcuts)

https://github.com/enocholumide/Laserscan-to-dxf (Laserscan to dxf)

**Comments:**

-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Building Information Modelling | 4 | 18 h | 42 h | 120 h | 180 h | - | project |

Module summary

# GMCM310 Geostatistics

**Module coordinator:** Prof. Dr. Heinz Saler, Prof. Dr. Klaus Dürrschnabel
**Credits (ECTS):** 6
**Semester:** 3

**Pre-requisites with regard to content:**
Solid knowledge in statistics, linear algebra, and experiences in working with spatial data and GIS

**Pre-requisites according to the examination regulations:**
None

**Competencies:**
The students are able to derive spatially distributed information from point data. Students get competences in answering questions about the spatial behavior of data in geo-sciences. They know how to prepare the data, what method of multivariate statistics and geostatistics to apply, and to interpret the results.

**Assessment:**
Written examination (120 min)

**Usability:**
Knowledge in geostatistics can be applied in the modules on Space-Time Visualization of Statistical Data and on Physical and Mathematical Geodesy.

Course

## GMCM315 Theory in Geostatistics

| | |
|---|---|
| **Lecturer:** | Prof. Dr. Heinz Saler |
| **Contact hours (SWS):** | 2 SWS |
| **Semester of delivery:** | Annually |
| **Type / mode:** | Lecture / Mandatory course |
| **Language of instruction:** | English |

**Content:**

The students get an overview on spatial variability, the modelling of spatial characteristics for variables as well as interpolation methods including Kriging (simple, ordinary, universal, co-kriging). It enables the students to derive area-related information from point data. The content is structured as follows: statistical hypotheses, multiple correlations and regression analysis, interpolation methods, Kriging, kernel density method.

**Recommended reading:**

Armstrong, M., Basic linear geostatistics. Berlin, Heidelberg 1998.

Besch, S., Geostatistik. Lecture notes. n.d. http://forum.diegeodaeten.de/?fid=252.

Chiles, J.-P. & P. Delfiner, Geostatistics: Modeling spatial uncertainty. 2nd ed., New York, 2012.

Clark, I. & W.V. Harper, Practical geostatistics 2000. 2007. http://geoecosse.hypermart.net/PG2000ForWeb.pdf.

Cressie, N., Statistics for spatial data. Rev. ed., New York 1993.

Davis, J.C., Statistics and data analysis in geology. 3rd ed., New York 2002.

Dutter, R., Geostatistik. Eine Einführung mit Anwendungen. Wiesbaden 1985.

Isaaks, E.H. & M.R.Srivastava 1992, An introduction to applied geostatistics. Oxford 1992.

Olea, R.A., Geostatistics for engineers and earth scientists. Heidelberg, New York 1999.

Olea, R.A., A practical primer on geostatistics. USGS Open-File Report 2009–1103, 2018. https://pubs.usgs.gov/of/2009/1103/ofr20091103.pdf.

Oliver M.A. & R. Webster, A tutorial guide to geostatistics: Computing and modelling variograms and Kriging. In: Catena, 113, 56-69, 2014.

Stein, M.L., Interpolation of spatial data. Some theory for Kriging. Berlin, Heidelberg 1999.

Wackernagel, H., Multivariate Geostatistics. Berlin, Heidelberg 2003.

**Comments:**

-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Theory in Geostatistics | 2 | 30 h | 0 h | 60 h | 90 h | - | written exam 120min |

Course

## GMCM312 Applications of Geostatistical Methods

**Lecturer:** Prof. Dr. Heinz Saler
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually
**Type / mode**: Exercises / Mandatory course
**Language of instruction:** English

**Content:**
Students apply methods of multivariate statistics and geostatistics. Processing of geostatistical data is done using geographic information systems. This way, the students understand the functionality of GIS for the analysis of geostatistical data, i.e. they learn to prepare data related to the geostatistical methods, to apply the geostatistical method and to present and discuss the results in a competent way. Students program tasks like IDW and Kriging with MatLab or MS Excel.

**Recommended reading:**
See Theory in Geostatistics

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Application of Geostatistical Methods | 2 | 0 h | 30 h | 60 h | 90 h | assignments | - |

Module summary

# GMCM320 OpenSource GIS

**Module coordinator:** Prof. Dr. Gertrud Schaab, Prof. Dr. Detlef Günther-Diringer
**Credits (ECTS):** 6
**Semester:** 3

**Pre-requisites with regard to content:**
Solid knowledge in the field of geographic information systems, software handling, and programming

**Pre-requisites according to the examination regulations:**
None

**Competencies:**
Students know how to develop software tools based on OGC standards and/or the knowledge of the community. They are able to set-up a new WebGIS by combining various tools depending on the aims and functionalities required.

**Assessment:**
Written examination (120 min)

**Usability:**
This module provides the basis for any software development based on standards and/or the knowledge of the community. Knowing how to use and develop tools based on free OpenSource technology is indispensable when low-cost approaches are required, as this is often the case in less developed countries.

Course

## GMCM325 Introduction to OpenSource GIS

| | |
|---|---|
| **Lecturer:** | Dr. Marco Lechner |
| **Contact hours (SWS):** | 4 |
| **Semester of delivery:** | Annually |
| **Type / mode**: | Lecture / Mandatory course |
| **Language of instruction:** | English |

**Content:**
Students learn about the current range of software tools available in OpenSource GIS. Further, the concepts of OpenSource software, licensing and community structures are taught. The theory of OGC standards like WMS, WFS is presented, enabling the students to solve problems with the related methods. Linux and the OpenSource WebGIS tools UMN-Mapserver, PostgreSQL/PostGIS, GeoServer, QGIS, OpenLayers/GeoEXT and several tiny Open Source GIS tools are introduced.

**Recommended reading:**
Adams, T. & M. Jansen, OpenLayers, Webentwicklung mit dynamischen Karten und Geodaten. München 2010.

Mitchell, T., Web mapping illustrated. Sebastopol (CA) 2005.

Mitchell, T., A. Christl & A. Emde, Web-Mapping mit Open Source-GIS-Tools. Köln 2008.

Obe, R. & L. Hsu, PostGIS in action. 2nd ed., New York 2014.

Ramm, T, J. Topf & S. Chilton. OpenStreetMap: Using and enhancing the free map of the world. Cambridge 2017.

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Introduction to OpenSource GIS | 2 | 30 h | 0 h | 60 h | 90 h | assignments | written exam 120 min |

Course

## GMCM322 Application of OpenSource GIS

**Lecturer:** Dr. Marco Lechner
**Contact hours (SWS):** 2 SWS
**Semester of delivery:** Annually
**Type / mode**: Exercises / Mandatory course
**Language of instruction:** English

**Content:**
Students receive hands-on in OpenSource GIS programming for solving space-related questions and for preparing the relating technical documentations. By applying various OpenSource WebGIS software, they learn how to interact with the developer community. In the end, the students are familiar with UMN-Mapserver, GeoServer, PostgreSQL/ PostGIS and OpenLayers/GeoEXT for developing and using OpenSource WebGIS tools. In addition to that, students gain an overview on the existing colourful bouquet of tiny Open Source GIS tools.

**Recommended reading:**
See course Introduction to OpenSource GIS

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Application of OpenSource GIS | 2 | 0 h | 30 h | 60 h | 90 h | assignments | - |

Module summary

# GMCE330 Space-Time Visualization of Statistical Data

**Module coordinator:** Prof. Dr. Gertrud Schaab, Prof. Dr. Peter Freckmann
**Credits (ECTS):** 6
**Semester:** 3

**Pre-requisites with regard to content:**
Solid knowledge in thematic cartography, HTML5, JavaScript, and statistics.

**Pre-requisites according to the examination regulations:**
GMCE153 Thematic Cartography

**Competencies:**
The students learn the distinct considerations when visualizing statistical data in a printed and thus static map versus the display of multivariate data in a dynamic, interactive visualization tool. They are highly aware of cartographically correct depictions as well as of good UI/UX design. Their extended JavaScript programming knowledge lets them visualize data in versatile complex maps or develop visualization tools, this from the very scratch.

**Assessment:**
Marked project work.

**Usability:**
It is of benefit to any work where flexible and appealing thematic maps are required. As map compilation is achieved without the need of proprietary software, the module is useful for any later work where spatial patterns and correlations needs to be visualized.

Course

## GMCE335 Space-Time Visualization of Statistical Data

**Lecturer:** Prof. Dr. Gertrud Schaab
**Contact hours (SWS):** 4 SWS
**Semester of delivery:** Annually
**Type / mode**: Project / Elective module
**Language of instruction:** English

**Content:**
For project work the students are asked to individually look for time-dependent multivariate statistical data that can be used to reveal a geographical pattern and thus to tell a narrative of space and time. By first analyzing the data, the students need to come up with a concept each for a static and a dynamic interactive map depiction. The map for printout is limited in regard to space available and teaches them to skillfully apply proven cartographic visualization methods, while the dynamic visualization tool requires a well-thought graphical user interface around the legend. Here, the students have to decide on where to place the emphasis on, either more towards cartographic communication or more towards geographic visualization. For the static map, the participants are asked to apply Illustrator or Inkscape to assure understanding of principles in thematic cartography. In regard to the dynamic tool, the students should work with HTML5, JavaScript and the relevant libraries (e.g. leaflet, D3).

In order to provide knowledge on visualizing time-dependent spatially referenced data, accompanying lecturers cover the topics geographical visualization (GVIS), time in analogy to space on maps, state-of-the-art capabilities in advanced thematic cartography, the dynamic cartographic environment, dynamic variables, interactive vs. animation graphics, the time-space cube, and usability considerations. This way, the students will gain the ability of presenting space and time dependent processes through the analysis of time series data and their effective representation in high-quality static and animated thematic maps.

Portions of lecturers and project work: 40% / 60%. The project work to be handed in encompasses besides the static map and the dynamic interactive map also a textual description recapitulating the lecture materials covered. The results are to be presented in front of class.

**Recommended reading:**
Aigner, W., S. Miksch, H. Schumann & C. Tominski, Visualization of time-oriented data. London, Dordrecht 2011.

Andrienko, N. & G. Andrienko, Exploratory analysis of spatial and temporal data: A systematic approach. Berlin, Heidelberg 2005.

Andrienko, G., A. Andrienko, P. Bak, D. Keim & S. Wrobel, Visual analytics of movement. Heidelberg, New York 2013.

Dodge, M., M. McDerby & M. Turner (eds.), Geographic visualization: Concepts, tools and applications. Chichester 2008.

Dykes, J., A.M. MacEachren & M.J. Kraak (eds.), Exploring geovisualization. Oxford 2005.

Kraak, M.-J., Mapping time. Illustrated by Minard’s map of Napoleon’s Russian campaign of 1812. Redlands (CA), 2014.

Kraak, M.-J. & F. Ormeling, Cartography: Visualization of spatial data. Harlow 2010.

MacEachren, A.M., How maps work. Representation, visualization, and design. New York, London 1995.

Monmonier, M., Strategies for the visualization of geographic time-series data. In: Cartographica, 27(1), 30-45, 1990.

Tufte, E.R., Envisioning information. Cheshire (CT) 1990.

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Space-Time Visualization of Statistical Data | 4 | 24 h | 36 h | 90 h | 180 h | - | project |

Module summary

# GMCE340 LBS for Business

**Module coordinator:** Prof. Dr. Peter Freckmann, N.N.
**Credits (ECTS):** 6
**Semester:** 3

**Pre-requisites with regard to content:**
Solid knowledge in economics and marketing

**Pre-requisites according to the examination regulations:**
GMCE158 Economics and Marketing

**Competencies:**
The students have profound knowledge about CRM and the available data sources for location based services (LBS), the requirements on the data and the general methods to prepare data for LBS applications, the hard- and software requirements and user interfaces. They are also competent in evaluating geodata referring to their usability for LBS.

**Assessment:**
Marked project work.

**Usability:**
CRM systems on mobile devices today are essential tools for the customer friendliness of a company. The module provides an understanding of several factors, which are important to support the company staff working with customer data. These factors are e.g. simplicity, speed and consistency over time.

Course

## GMCE345 LBS for Business

**Lecturer:** Prof. Dr. Peter Freckmann, N.N.
**Contact hours (SWS):** 4 SWS
**Semester of delivery:** Annually
**Type / mode**: Project / Elective module
**Language of instruction:** English

**Content:**
Students get an introduction into customer relationship management (CRM), especially the combination of geographical information systems and geobusiness tools with CRM-systems will be the main focus.

On this basis student teams develop in various projects location-based services applications (ArcGIS field apps, apps based on Android or iOS). The focus lies on the visualization of LBS use-cases on mobile devices connected with CRM-systems. The following functions should be created: viewer for several maps, data and tables, geocoding and address verification, catchment areas for POIs, as well as routing.

Portions of lecture and project work: 30% / 70%. To finalise the project students present how they solved the given task and they discuss the results with the students from the other project teams. In addition they prepare a document, which describes the complete workflow of the project and contains all information to make their work understandable.

**Recommended reading:**
Ding, Y. & R. Malaka, An agent-based architecture for resource-aware mobile computing. In: A. Heuer & T. Kirste (eds.): Intelligent interactive assistance and mobile multimedia computing. Proceedings of the Workshop IMC2000, Rostock, November 9-10, 2000, Rostock 2001. 60-66

De Souza e Silva, A., Location-aware mobile technologies: Historical, social and spatial approaches. In: Mobile Media & Communication, 1(1), 116-121, 2013.

Wilson, W.M., Location-based services, conspicuous mobility and the location-aware future. In: Geoforum, 43(6), 1266–1275, 2012.

Zipf, A. & R. Malaka, Developing “location based services” (LBS) for tourism – the service provider’s view. In: P. Sheldon, K. Wöber & D. Fesenmaier (eds.), Information and communication technologies in tourism 2001. Proceedings of ENTER 2001, 8th International Conference, Montreal, 83-92. Wien, 2001.

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| LBS for Business | 4 | 18 h | 42 h | 90 h | 180 h | - | project |

Module summary

# GMCE350 Satellite Image Change Detection

**Module coordinator:** Prof. Dr. Gertrud Schaab, Prof. Dr. Detlef Günther-Diringer
**Credits (ECTS):** 6
**Semester:** 3

**Pre-requisites with regard to content:**
Solid knowledge in digital image processing and remote sensing

**Pre-requisites according to the examination regulations:**
GMCE151 Remote Sensing and Digital Image Processing

**Competencies:**
Via the project work, students gain confidence regarding the ability to perform satellite image analyses, which help to observe landscape changes (e.g. land use/cover change). By letting the students develop literature-based concepts they are trained to look for appropriate imagery and methods depending on the envisaged task.

**Assessment:**
Marked project work

**Usability:**
This module prepares for independent, scientific working during the Master thesis. Due to more and more satellite imagery becoming available without costs, applications will be more wide-spread in the future.

Course

## GMCE355 Satellite Image Change Detection

**Lecturer:** Prof. Dr. Gertrud Schaab
**Contact hours (SWS):** 4 SWS
**Semester of delivery:** Annually
**Type / mode**: Project / Elective module
**Language of instruction:** English

**Content:**
For project work students in groups of three are asked to develop a concept for a change detection study. Due to the lecturer's research activities in Eastern Africa, the geomonitoring tasks are likely to be located in that region. Dependent on a particular topic chosen or provided, the task is to find an appropriate workflow by reviewing literature as published in scientific papers. The workflow has to cover pre-processing, classification and analysis of multispectral satellite image data. Here, satellite image analysis can follow pixel-based or object-based approaches and is mainly performed by means of Erdas Imagine. Students with experience can also explore possibilities with ArcGIS, eCognition or R. The working on the processing tasks are to be equally divided among the group members and processed subsequently within a rigid time schedule. Regular meetings of the group members with the lecturer will assure timely and quality work. The students will thus obtain the qualification to determine and apply a suitable processing chain, this dependent on the available satellite image data and the concrete task.

In order to provide a knowledge basis for performing the project task, a summary on the following satellite image analysis topics is covered in lecturers at the start of the semester: radiometric corrections (atmosphere, terrain), sensor fusion (pansharpening), image transformations (ratioing, PCA, TCT, etc.), pixel-based classification algorithms of multispectral image data, object-based image analysis (segmentation, NN and rule-based classification), change detection methods, trajectories.

Portions of lecturers and project work: 30% / 70%. The project work handed in requires providing a full picture of the conceptual as well as practical work, allowing a judgement on the results achieved, and following standards of scientific publications. In addition, a presentation in front of class is required.

**Recommended reading:**
Blaschke, T., S. Lang & G.J. Hay (eds.), Object-based image analysis. Spatial concepts for knowledge-driven remote sensing applications (with DVD ROM). Berlin, Heidelberg, 2008.

Jensen, J.R., Introductory digital image processing. A remote sensing perspective. Upper Saddle River (NJ), 2005.

Lillesand, T.M., R.W. Kiefer & J.W. Chipman, Remote sensing and image interpretation. New York, 2008.

Richards, J.A. & X. Jia, Remote sensing digital image processing: An introduction. Berlin, Heidelberg, 2006.

Schowengerdt, R.A., Remote sensing: Models and methods for image processing. Burlington (MA), 2007.

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Satellite Image Change Detection | 4 | 18 h | 42 h | 90 h | 180 h | - | project |

**Module summary**

# GMCE360 Physical and Mathematical Geodesy

**Module coordinator:** Prof. Dr. Tilman Müller, Prof. Dr. Reiner Jäger
**Credits (ECTS):** 6
**Semester:** 3

**Pre-requisites with regard to content:**
Solid knowledge in mathematics, physics, statistics and adjustment, as well as satellite geodesy

**Pre-requisites according to the examination regulations:**
GMCE157 Satellite Geodesy

**Competencies:**
The students have internalized the fundamentals of mathematical and physical geodesy. Therefore, they are able to make themselves familiar with complex problems of mathematical geodesy and physical problems and to find solutions. They are acquainted with the main methods of gravity field determination and of geoid computation, and they are able to apply them.

**Assessment:**
Written examination (120 min) and marked project work

**Usability:**
Physical and mathematical geodesy supplies the gravity field related fundamental theories for satellite geodesy, modern height systems and global as well as regional geodetic computations. So it gives theoretical background information for all areas dealing with satellite data and navigation.

Course

## GMCE365 Physical Geodesy

**Lecturer:** Prof. Dr. Tilman Müller
**Contact hours (SWS):** 4 SWS
**Semester of delivery:** Annually
**Type / mode**: Lecture and project work / Elective course
**Language of instruction:** English

**Content:**
Lectures cover the history of physical geodesy, gravitation and gravitational potential, gravity potential and level surfaces, spherical harmonics, level ellipsoid and normal field, geodetic boundary value problems (Stokes, Molodensky, …), temporal variations in the gravity field, absolute and relative gravimetry, geoid determination with satellite methods, as well as regional and high accuracy geoid determination. Portions of lecture and project work: 70% / 30%. Project work is combined with Mathematical Geodesy. Practical experience is gained by solving fundamentals and complex problems of gravity field determination with different methods.

**Recommended reading:**
Hofmann-Wellenhof, B., Physical geodesy. Wien 2006.

Torge, W., Geodesy. Berlin 2003.

Torge, W., Gravimetry. Berlin 1989.

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Physical Geodesy | 2 | 20 h | 10 h | 60 h | 90 h | - | written exam 60 min and project |

Course

## GMCE362 Mathematical Geodesy

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|---|---|
| **Lecturer:** | Prof. Dr. Reiner Jäger |
| **Contact hours (SWS):** | 2 SWS |
| **Semester of delivery:** | Annually |
| **Type / mode**: | Lecture / Elective course |
| **Language of instruction:** | English |

**Content:**
Mathematical Geodesy starts with interpolation and prediction (Kernel-based Methods, Kriging, Collocation) of reference surfaces. Problems of datum transformations, estimation of surface parameters and height reference systems are also covered. A further topic is advanced mapping. Exercises encompass diverse methods in the field of geoid computations and make use of the DFHBF, WTRANS and COPAG software.

Portions of lecture and project work: 70% / 30%. The joint project with Physical Geodesy is related to theory evaluation followed by computations on gravity field and quasi-geoid-computations. The integrated geodesy method maps a global geopotential model to regional spherical cap harmonic models by integrating gravity measurement and fitting points. The computation of a regional quasi-geoid model is done in terms of a geometric surface (continuous polynomials) as carrier function, integrating fitting-points and deflections from the vertical.

**Recommended reading:**
International Association of Geodesy (ed.). The geodesist‘s handbook. In: Journal of Geodesy, 90(10), 2016. https://iag.dgfi.tum.de/fileadmin/handbook/handbook_2016/Handbook_2016.pdf.

Jäger, R., Geodätische Infrastrukturen für GNSS-Dienste (GIPS). In: K. Zippelt (ed.), Vernetzt und ausgeglichen. Festschrift zur Verabschiedung von Prof. Dr.-Ing. habil. Dr.-Ing. E.h. Günter Schmitt. Karlsruhe 2010.

Snyder, J.P., Map projections – A working manual. U. S. Geological Survey Professional Paper 1395, Washington DC 1987.

Younis, G., Regional gravity field modeling with adjusted spherical cap harmonics in an integrated approach. PhD thesis TU Darmstadt, 2014.

Younis, G., R. Jäger & M. Becker, Transformation of global spherical harmonic models of the gravity field to a local adjusted spherical cap harmonic model. In: Arabian Journal of Geosciences, 6(2), 375-381, 2013.

http://dfhbf.de/ (DFHBF)

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Mathematical Geodesy | 2 | 20 h | 10 h | 60 h | 90 h | - | written exam 60 min |

Module summary

# GMCE370 Navigation Technologies and Mobile GIS

**Module coordinator:** Prof. Dr. Reiner Jäger
**Credits (ECTS):** 6
**Semester:** 3

**Pre-requisites with regard to content:**
Solid knowledge in mathematics, physics, reference frames, positioning, object-oriented programming

**Pre-requisites according to the examination regulations:**
None

**Competencies:**
The students acquire a deep understanding of the theoretical and algorithmic background of navigation and georeferencing technologies. They have gathered knowledge for designing multi-sensor multi-platform systems for different outdoor/indoor-technologies and applications. This covers the development of algorithms and software for the realization of state-of-the-art multi-sensor systems, including mobile GIS.

**Assessment:**
Marked project work

**Usability:**
Any technical solutions supporting mobility activities of humans, vehicles or robots are heavily based on navigation and georeferencing technologies and therefore benefit from real-time use of GNSS rawdata on iOS and Android devices.

Course

## GMCE375 Navigation Technologies and Mobile GIS

| | |
|---|---|
| **Lecturer:** | Prof. Dr. Reiner Jäger |
| **Contact hours (SWS):** | 4 SWS |
| **Semester of delivery:** | Annually |
| **Type / mode**: | Lecture and project work / Elective module |
| **Language of instruction:** | English |

**Content:**

Students learn about the various mathematical models and algorithms for designing multi-sensor multi-platform systems for different outdoor/indoor-technologies and applications in navigation and geo-referencing. These include deep and tight coupling of GNSS, MEMS and camera sensor data, modelling, and self-calibration of distributed sensors and platform navigation. It is also related to mobile computing and mobile GIS. Therefore, the students can use partly their own hardware for the project tasks of complex software and algorithmic developments. Software development is based on Java (typically under Eclipse), and the use of OpenSource (e.g. RTKLIB, KITTI) and non-open software.

The students learn to apply the mathematical models for developing algorithms and software for the realization of multi-sensor systems. Portions of lecture and project work: 50% / 50%. Design and development of navigation systems use smartphones/tablets as sensor- and computation platform, based on Java programming (e.g. under eclipse) and embedding open source software, communication and ICT-technologies. By using GNSS for positioning, MEMS-sensors for altitudinal heights, and smartphone camera for positioning and orientation, integrated GNSS/MEMS/optics systems can be developed for positioning, navigation, georeferencing and mobile GIS applications.

**Recommended reading:**

Bauer, M., Vermessung und Ortung mit Satelliten - Globales Navigationssatellitensystem (GNSS) und andere satellitengestützte Navigationssysteme. 7th ed., Berlin, Offenbach 2018.

Becker, M. & K. Hehl, Geodäsie. Darmstadt 2012.

Blankenbach, J., Handbuch der mobilen Geoinformation: Architektur und Umsetzung mobiler standort-bezogener Anwendungen und Dienste unter Berücksichtigung von Interoperabilität. Berlin, Offenbach 2010.

Böser, W., K. Dürrschnabel, U. Girndt, R. Hanauer, G. Hell, R. Jäger, U. Klein, T. Müller, H. Saler, R. Schwäble & G. Schweinfurth (eds.), Geomatik aktuell 2012. Präzise Navigation und Mobile Geodaten-erfassung Out- und Indoor. Karlsruher Geowissenschaftliche Schriften, B7, 2012.

Hofmann-Wellenhof, B., K. Legat & M. Wieser, Navigation: Principles of positioning and guidance. Wien, 2011.

Hofmann-Wellenhof, B., H. Lichtenegger & E. Wasle, GNSS – Global navigation satellite systems: GPS, GLONASS, Galileo, and more. Wien, 2008.

Jäger, R., T. Müller, & H. Saler: Klassische und robuste Ausgleichungsverfahren. 2nd ed., Berlin 2019.

Ruizhi, C. & R. Guiness, Geospatial computing in mobile devices. Boston (MA), London 2014.

Runder Tisch GIS e.V. (ed.), Leitfaden - Mobiles GIS und standortbezogene Dienste. München 2013.

www.navka.de (NAVKA)

http://wiki.openstreetmap.org/wiki/RTKLIB (RTKLIB)

http://rts.igs.org/ (RTS)

http://www.galileo-masters-bw.de/start.oscms/0/3860/25046/Baden-Wuerttemberg.html (Galileo Masters)

http://www.eclipse.org/ (Eclipse)

http://developer.android.com/index.html (Android)

**Comments:**
-/-

**Overview:**

| Course | SWS | Lecture Time | Supported Indiv. Learning (Exercises, Lab Work, Project Work) | Indepen-dent Learning | Total | Pre-Examination | Examination |
|---|---|---|---|---|---|---|---|
| Navigation Technologies and Mobile GIS | 4 | 30 h | 30 h | 120 h | 180 h | - | project |

Module summary

# GMCM410 Seminar for Master Thesis

**Module coordinator:** Prof. Dr. Gertrud Schaab, Course director Geomatics Master
**Credits (ECTS):** 5
**Semester:** 4

**Pre-requisites with regard to content:**
Deepened knowledge within the range of the topic of the Master thesis

**Pre-requisites according to the examination regulations:**
None. Successful conclusion of all modules is recommended (max two modules can be completed after beginning of the thesis)

**Competencies:**
The student is given a month time to familiarize him/herself with the topic by means of scientific publications, to phrase objectives for the thesis and to plan the work. The result has to be delivered to the referees as a report, i.e. the seminar work (about 3000 words, in English) and also includes the elaboration of the task description. With this work the candidate demonstrates his/her knowledge of scientific rules and standards. It ensures that the candidate is aware of what the Master thesis has to cover and what the supervisors expect.

**Assessment:**
Marked seminar work

**Usability:**
Seminar work and task description provide the basis for elaborating the Master thesis.

Module summary

# GMCM420 Master Thesis

**Module coordinator:** Prof. Dr. Gertrud Schaab, Course director Geomatics Master
**Credits (ECTS):** 22
**Semester:** 4

**Pre-requisites with regard to content:**
Deepened knowledge within the range of the topic of the Master thesis and knowledge of scientific rules and standards

**Pre-requisites according to the examination regulations:**
None. Advised is the successful conclusion of the seminar work

**Competencies:**
With the Master thesis the student shows his/her ability to independently work on a scientific topic and to finalize it within a limited time frame (5 months). Purpose of the thesis is to develop a research topic, to convert it methodically, to analyze it critically and to evaluate the results. The work is to make a contribution for knowledge extension to the selected scientific topic. It usually investigates a research problem in a theoretical and in a practical part. The Master thesis has to be written in English.

**Assessment:**
Marked Master thesis

**Usability:**
The Master thesis is based on the seminar work and profoundly deepens knowledge gained within modules of the previous semesters.

Module summary

# GMCM430 Colloquium for Master Thesis

**Module coordinator:** Prof. Dr. Gertrud Schaab, Course director Geomatics Master
**Credits (ECTS):** 3
**Semester:** 4

**Pre-requisites with regard to content:**
See Master thesis

**Pre-requisites according to the examination regulations:**
None. The handed-in of the Master thesis is expected

**Competencies:**
In the colloquium, the candidate demonstrates that he/she is able to present his/her thesis in a talk of 30 min and to sufficiently answer questions in the discussion afterwards.

**Assessment:**
Marked oral presentation

**Usability:**
The colloquium concludes the Master thesis phase.