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

September 2021

Content

Module summary

GMCM110 Software Engineering

Module coordinator:	Prof. Dr. Klaus Dürrschnabel, Prof. Dr.-Ing. Ulrike Klein
Credits (ECTS):	6
Semester:	1

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

GMCM111 Software Engineering

Lecturer: N.N.
Contact hours (SWS): 3 SWS
Semester of delivery: annually

Type / mode: Lecture and project / 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 project teamwork ensures 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. 10th ed., London 2016.

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
Software Engineering	3	20 h	25 h	135 h	180 h	assignments	oral exam 15 min

Module summary

GMCM120 Soft Skills

Module coordinator: Prof. Dr.-Ing. Heinz Saler
Credits (ECTS): 6
Semester: 1

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

Pre-requisites according to the examination regulations:
None

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

Assessment:
See IFS programme | Marked academic paper (literature review)

Usability:
Language skills for in Germany or abroad | Preparation for Master Thesis in 3rd 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

GMCM121 Language Courses from IFS

Lecturer: of IFS
Contact hours (SWS): 4 SWS
Semester of delivery: each semester

Type / mode: Exercises in small groups / Mandatory course

Language of instruction: English

Content:
Courses as offered by the Institute for Foreign Languages (IFS). For international students 'German as Foreign Language' (each course 4 ECTS; target is A2 minimum, B1 is recommended) is a must. The appropriate course is decided by a placement test. For German students Advanced English or 'Business / Technical English' (each 4 ECTS; target is C1 TE, min B2 required) is recommended. The goal of this course is to develop the students' language skills. In the German courses, grammar and vocabulary are taught using the course book Netzwerk. The courses emphasis is on speaking and understanding, although there will also be practice in reading and writing skills. Prerequisite for participation is either completion of the preceding course or advanced placement in the placement test. In the English courses the goal is to develop the students' general language skills (supplementary grammatical structures and vocabulary building) and to introduce topics from applied business language. All language skills (listening, reading, speaking and writing) are practiced systematically, with an emphasis on professionally-oriented communicative ability. Descriptions for the various courses offered can be found on 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	30 h	30 h	30 h	90 h	see IFS	see IFS

Course

GMCM122 Academic Writing

Lecturer: Lynn Beechey-Volz B.SocSci
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 starting from the foundations of literature-based academic research and ending with formatting and submission recommendations. The lectures consist of a theoretical input session by the lecturer on the different subjects during the course, followed by in-class exercises. Over the run of the semester, students write their own academic paper (a literature review) step-by-step, assess each other's progress in a peer review process and are guided by the supervisor in regard to academic writing in English. This way, students not only learn how to write a well-structured academic paper following the formal rules, but also have to take the role as examiner and 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	60 h	90 h	assignments	review paper

Module summary

GMCM130 BIM and AR/VR

Module coordinator: Prof. Dr. Heinz Saler, Prof. Dr. Detlef Günter-Diringer

Credits (ECTS): 6

Semester: 1

Pre-requisites with regard to content:

Solid knowledge in 3D visualization and CAD construction

Pre-requisites according to the examination regulations:

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Competencies:

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

In AR/VR 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

GMCM131 Building Information Modelling Project

Lecturer: Prof. Dr. Heinz Saler

Contact hours (SWS): 2 SWS

Semester of delivery: Annually

Type / mode: Project work / mandatory course

Language of instruction: English

Content:

The students are enabled to capture building geometries to prepare the data for BIM based on TLS data. After an introduction to BIM and the BIM data model, information acquisition is demonstrated with the newest generation of surveying instruments and software. Here post-processing information extraction methods are presented to the attendees. The acquired data is transferred into a BIM structure. Teaching makes use of tutorials made available via ILIAS. Portions of lecture and project work: 15% / 85%. 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 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., König, M., Koch, C. & Beetz, J. (2018). Building Information Modeling: Technology Foundations and Industry Practice. Cham: Springer.

BMVI 2017. Umsetzung des Stufenplans Digitales Planen und Bauen. Erster Fortschrittsbericht

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

buildingSMART. What is openBIM? https://www.buildingsmart.org/about/openbim/openbim-definition/

buildingSMART. Standards, https://technical.buildingsmart.org/standards

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

ISO (2018). ISO 16739:2018: Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries — Part 1: Data schema. International Organization for Standardization. Geneva, Switzerland.

ISO (2016). ISO 10303-21:2016: Industrial automation systems and integration – Product data representation and exchange — Part 21: Implementation methods: Clear text encoding of the exchange structure. International Organization for Standardization. Geneva, Switzerland.

ISO (2007). ISO 10303-28:2007: Industrial automation systems and integration – Product data representation and exchange — Part 28: Implementation methods: XML representations of EXPRESS schema and data, using XML schemas. International Organization for Standardization. Geneva, Switzerland.

ISO (2020). ISO 16739-1:2018. http://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/07/03/70303.html

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

Poljansek, Martin. (2018). Building Information Modelling (BIM) standardization

Tchouanguem Djuedja J.F., Karray M.H., Foguem B.K., Magniont C., Abanda F.H. (2019). Interoperability Challenges in Building Information Modelling (BIM). In: Popplewell K., Thoben KD., Knothe T., Poler R. (eds) Enterprise Interoperability VIII. Proceedings of the I-ESA Conferences, vol 9. Springer, Cham.

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
Building Information Modelling	2	5 h	25 h	60 h	90 h	-	project

Course

GMCM132 Virtual Reality

Lecturer: Prof. Dr. Detlef Günther-Diringer

Contact hours (SWS): 2 SWS

Semester of delivery: annually

Type / mode: Project / Mandatory Course

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 workincludes the setting-up of a AR/VR applications 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.

Comments:

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Overview:

Course	SWS	Lecture Time	Supported Indiv. Learning (Exercises, Lab, Proj.Work)	Indepen-dent Learning	Total	Pre-Examination	Examination
Virtual Reality	2	9 h	21 h	60 h	90 h	-	Project

Module summary

GMCE140 Big Data

Module coordinator: Prof. Dr. Klaus Dürrschnabel, Prof. Dr. Reiner Jäger

Credits (ECTS): 6

Semester: 1

Pre-requisites with regard to content:

Solid knowledge in mathematics and computer science

Pre-requisites according to the examination regulations:

None

Competencies:

The amount of Big Data to be processed is too large, too complex, too fast-moving or too weakly structured to be evaluated using manual and conventional methods of data processing. The students have gained knowledge regarding the principles of handling Big Data and to solve special problems in a realistic time and with economical use of computer memory. There are two alternative courses, Big Data Analytics (Mathematical Modeling) or Big Data in Photogrammetry and Remote Sensing.

The students are enabled to find correct models and effective algorithms for special problems with Big Data.

Assessment:

Written exam (90 min.)

Usability:

The use of Big Data is used in a lot of applications, e.g. databases, cloud computing, statistics, economics and geographic data.

Course

GMCE141 Big Data Analytics

Lecturer: Prof. Dr. Klaus Dürrschnabel

Contact hours (SWS): 3 SWS

Semester of delivery: annually

Type / mode: Lecture and project / Elective course

Language of instruction: English or German

Content:

In this module basic mathematical models in the field of Big Data Analytics are presented, e.g. methods of Graph Theory and Matrices (esp. Adjacency Matrices and Thin Matrices), Numerical Linear Algebra (esp. Matrix Factorization, Conditioning of a problem), Statistics and Optimization Theory (esp. Stochastic Mixed-Integer Programming). All Algorithms are implemented and tested by the students in MATLAB. A self-developed program for a more complex task with the associated test completes the course.

Recommended reading:

Bornemann, V., Numerische lineare Algebra. Springer Spektrum 2018

Briskorn, D., Operations Research. Springer Gabler 2020

Diestel, R., Graph Theory. Springer 2017

Klein Haneveld, W., van der Vlerk, M., Romeijnders, W., Stochastic Programming. Springer 2020

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
Big Data Analytics	3	10 h	35 h	135 h	180 h	Laboratory work	Written exam 90 min

Course

GMCE142 Big Data in Photogrammetry and Remote Sensing

Lecturer: Prof. Dr. Reiner Jäger
Contact hours (SWS): 3 SWS
Semester of delivery: annually

Type / mode: Lecture and project / Mandatory course

Language of instruction: English or German

Content:
The Big Data era situations in Photogrammetry and Remote Sensing come up in terms of the volume, the variety, the velocity and the veracity, in which data sets and streams become available and challenge current management and processing capabilities. While big data can be situated here in the disciplinary area of traditional geospatial data handling theory and methods, the increasing volume and varying format of collected geospatial Big Data itself leads to news new challenges in storing, managing, processing, analyzing, visualizing and verifying the quality of data in Photogrammetry and Remote Sensing. This has caused a paradigm shift to a data-driven research concerning all steps along the whole chain of data acquisition and processing. The lecture accordingly starts with new spatial indexing and algorithms to handle real-time, streaming Big Data and the support of topology for real-time analytics. It is followed by Big Data method for quality assessment, data structuring and modeling, and data base problems for Big Data streams. Then by chapters on methods for Big Data functional programming on artificial intelligence (AI) and machine learning, Further chapters are on Big Data geospatial analytics, visualization and visual analytics, data mining and knowledge discovery, up to fractals emerged from Big Data. As concerns sensor data to be treated in the frame of the lecture and the project, as being submitted to the above Big Data processing chain, are in Photogrammetry Big Data concerning classical multispectral images, laser scanner point-clouds, time of flight (ToF) and recent plenoptic cameras. In Remote Sensing for earth observation (EO) three types of Big Data occur and are regarded, namely synthetic aperture radar (SAR), such as free available from European ESA Sentinel satellites, optical imaging and atmospheric spectrometry data from satellites. Common topics of Photogrammetry and Remote Sensing Big Data are on the fusion of SAR and optical images, the fusion of InSAR and optical 3D point clouds, and the fusion of polarimetric SAR, multi-/hyper-spectral image and lidar, e.g. for classification tasks. In respect to the project the final chapters are open source software packages for Big Data working along the above processing chains in Photogrammetry (e.g. Hadoop, **Cassandra,** OpenGL, Meshroom, OpenDroneMap) and Remote Sensing (e.g. ESA Sentinel Toolboxes).

Recommended reading:
Lecture related

Acar, U. A., & Chen, Y. (2013). Streaming Big Data with Self-Adjusting Computation. Proceedings of the 2013 Workshop on Data Driven Functional Programming -DDFP ’13, 15-18.

Luhrmann, T. (2018): Nahbereichsphotogrammetrie. 4. Auflage. Wichmann.

Ma, Y., Wu, H., Wang, L., Huang, B., Ranjan, R., Zomaya, A., & Jie, W. (2014). Remote Sensing Big Data Computing: Challenges and Opportunities. Future Generation Computer Systems.

Lu, Y., Zhang, M., Witherspoon, S., Yesha, Y., Yesha, Y., & Rishe, N. (2013). sksOpen: Efficient Indexing, Querying, and Visualization of Geo-spatial Big Data. Proceedings of the 2013 12th International Conference on Machine Learning and Applications (ICMLA), 2, 495-500.

Pettit, C., Stimson, R., Nino-Ruiz, M., Moradini, L., Widjaja, I., Delaney, P. Kvan, T. (2014). Supporting Urban Informatics through a Big Data Analytics Online Workbench. NSF Workshop on Big Data and Urban Informatics.

http://dgk.badw.de/fileadmin/docs/c-766.pdf

http://dgk.badw.de/fileadmin/docs/c-747.pdf

Project related

Bernasocchi, M., Çöltekin, A., & Gruber, S. (2012). An Open Source Geovisual Analytics Toolbox for Multivariate Spatio-Temporal Data for Environmental Change Modeling. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 1-2(2), 123-128.

https://gisgeography.com/open-source-remote-sensing-software-packages/

http://www.esa.int/esapub/tm/tm19/TM-19_ptA.pdf

http://www.esa.int/esapub/tm/tm19/TM-19_ptB.pdf

http://www.esa.int/esapub/tm/tm19/TM-19_ptC.pdf

Comments:

-/-

Overview:

Course	SWS	Lecture Time	Supported Indiv. Learning (Exercises, Lab Work, Project Work)	Independent Learning	Total	Pre-Examination	Examination
Big Data in Photogrammetry and Remote Sensing	3	30 h	15 h	135 h	180 h		Module written exam 90 min and project work

Module summary

GMCE150 Geovisual Analytics

Module coordinator: Prof. Dr. Gertrud Schaab
Credits (ECTS): 6
Semester: 1

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

Pre-requisites according to the examination regulations:
none

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

GMCE151 Space-Time Visualization of Statistical Data

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

Type / mode: Project / Elective module

Language of instruction: English or german

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	3	18 h	27 h	135 h	180 h	-	Project (La/1S)

Module summary

GMCE160 Navigation

Module coordinator: Prof. Dr.-Ing. Reiner Jäger

Credits (ECTS): 6

Semester: 1

Pre-requisites with regard to content:

Knowledge on mathematics, physics, object-oriented programming

Pre-requisites according to the examination regulations:

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Competencies:

By the course Navigation Technologies and Mobile GIS, the students will know the theoretical and algorithmic background, the full spectrum of algorithms for out- und indoor-navigation and programming of multisensor navigation, geo-referencing and Mobile GIS technologies and systems. By the course Satellite Geodesy, the students know the theoretical background of reference systems for a global georeferencing and positioning using GNSS space systems and other space technologies (VLBI, Altimetry) in the context of modelling the dynamics of satellite orbits and a dynamic earth frame. Further the theoretical background and algorithms for the methods of satellite based gravity field determination are known. The students will be able to work in the full spectrum of navigation technologies and mobile GIS. So they can work as consulting experts, in industrial and technological developments, design navigation systems and mobile GIS, as well as in research institutions on other satellite geodes topics.

Assessment:

Written examination (120 min.) and marked project work.

Usability:

Navigation supplies based on Markov-chains and a Bayes background the full spectrum for the develop¬ment of multisensor navigation, georeferencing and mobile GIS systems using GNSS, MEMS and optical sensor data, state transition information and different navigation state estimation concepts.
Sa¬tellite Geodesy supplies spatial reference frames, earth dynamics, and GNSS positioning. Further, sa¬telli¬te-based gravity field determination, satellite altimetry, VLBI and SAR/INSAR are teached in order to complete the spectrum of satellite geodetic methods.

Course

GMCE161 Navigation Technologies and Mobile GIS

Lecturer: Prof. Dr.-Ing. Reiner Jäger
Contact hours (SWS): 2 SWS
Semester of delivery: annually

Type / mode: Lecture and project work / Elective Module

Language of instruction: English or German

Content:

Navigation parameters, navigation frames and transition between different frames

- Overview on out-and indoor navigation of air/land/sea vehicles system design.
- Markov-chain and Bayes background for the common use sensor data and state transition information for navigation state estimation
- Kalman filter and particle filter based on Chapman-Kolmogorov equation solution
- GNSS, MEMS and optical sensor observations in a general multi-sensor multi-platform design
- SLAM algorithms
- Time synchronization algorithms
- GNSS, MEMS and optical sensor algorithms and state estimation concepts, equations and state inequations for navigation, geo-referencing- and mobile GIS system design
- UAV out and indoor navigation and control
- Software design and developments on GNSS-positioning and internet-based data communication components using smartphones
- Software design and developments for the integration of GNSS raw-data by opensource software (RTKLIB, NTRIP), MEMS-sensors, maps and internet communication on smartphones

Recommended reading:

Literature:

Jäger, R. (2019): Multisensorische 3D-Mappingsysteme für BIM – SLAM basierte Navigation und Steuerung, Systemrealisierung MSM und Profil künftiger Entwicklungen. Buchbeitrag zur Internationalen Geodätischen Woche 2019, Obergurgl, Österreich. Klaus Hanke / Thomas Weinold (Eds.) ISBN 978-3-87907-659-8. Wichmann-Verlag. S. 286-293.

Runder Tisch GIS e.V. (2020): Leitfaden Mobile GIS – Von der GNSS-basierten Datenerfassung bis zu Mobile Mapping, Version 4.0 (erschienen 10/2020), 7., vollständig aktualisierte und erweiterte Auflage

Jäger, R. (2018): Multisensornavigation auf Bayes'scher Grundlage – Stand, Anwendungen und Entwicklungen. In: A. Heck, K. Seitz, T. Grombein, M. Mayer, J.-M. Stövhase, H. Sumaya, M. Wampach, M. Westerhaus, L. Dalheimer, P. Senger (ed.): (Schw)Ehre, wem (Schw)Ehre gebührt - Festschrift zur Verabschiedung von Prof. Dr.-Ing. Dr. h.c. Bernhard Heck. Schriftenreihe des Studiengangs Geodäsie und Geoinformatik, vol. 2018–1, Karlsruhe (KIT Scientific Publishing). S. 123-130.

Thrun, S., Burgard, W. und D. Fox (2006): Probabilistic Robotics. The MIT Press. Massachusetts, USA.

Internet / Multimedia:

- www.navka.de
- http://developer.android.com/index.html
- http://rtklib.com
- https://www.gsa.europa.eu/gnss-applications/gnss-raw-measurements

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 Theory	1	15 h	0 h	30 h	45 h	-	Module written exam (90 min.) and Development Project
Navigation Technologies and Mobile GIS Implementation	1	15 h	0 h	30 h	45 h		

Course

GMCE162 Satellite Geodesy and Spatial Reference Systems

Lecturer:	Prof. Dr.-Ing. Reiner Jäger
Contact hours (SWS):	2 SWS
Semester of delivery:	annually
Type / mode:	Lecture / Elective Module
Language of instruction:	English or German

Content:

- Spatial reference frames (Inertial system (ECIS/F), Earth fixed system (ECES/F) and transition). Modelling of Earth dynamics (datum, datum-drift, plate movements). Regional classical and modern reference frames related to frozen plates. Transition algorithms between spatial reference systems.
- GNSS satellite orbits equation and orbit representations
- Atmospheric models (ionosphere and troposphere) and delays in GNSS-positioning
- Satellite signals (Code, Phase, Doppler)
- Modelling of GNSS satellite signals in PPP and DGNSS positioning
- RTCM OSR, SSR and transformation messages data
- Commercial and Open Source GNSS processing software
- Classical and advanced ambiguity resolution and cycle-slip detection methods in static GNSS and RTK positioning
- Computations with the open-source software RTKLIB and NTRIP
- Satellite based gravity field determination (gravity field and orbit pertubations, Lagrange perturbation calculation, orbit perturbation and disturbance potential. Theory of Kaula and Müller. Observation equations for gravity field determination, satellite-to-satellite-tracking, gradiometry. Gravity missions on global monitoring, future gravity missions, data fusion for gravity field determination
- Earth tides modelling in satellite geodesy
- VLBI (principle, observation equations, parameter estimation)
- Satellite altimetry (Satellites, sea-surface topography definition and monitoring)

The seminar work comprises individual marked reports on present topics on spatial reference frames and GNSS

Recommended reading:

Becker, M. und K. Hehl (2012): Geodäsie. WBG Edition. Darmstadt. ISBN: 978-3-534-23156-0

Kaula W.M. (1963) Determination of the Earth's gravitational field. Reviews of Geophysics Volume 1, Issue 4. November 1963. Pages 507–551. The American Geophysical Union.

Satellite Altimetry Website (2018): https://www.aviso.altimetry.fr/en/techniques/altimetry.html

Journal of Geodesy (2018): https://link.springer.com/journal/190

Xu, G. (2016): GPS. Theory, Algorithms and Applications. Springer.

Xu, G. (2016): Sciences of Geodesy II. Springer.

Bauer, M. (2018). Vermessung und Ortung mit Satelliten. Globale Navigationssatellitensysteme (GNSS) und anders satellitengestützte Navigationssysteme. 7., neu bearbeitete und erweitere Auflage.

Borre, K., Akos, D.M., Bertelsen, N., Rinder, P., Jensen, S.H. (2007): A software defined GPS and GALILEO receiver. Springer.

RTKLIB-Website (2018): RTKLIB - An Open Source Program Package for GNSS Positioning. www.rtklib.org.

Overview:

Course	SWS	Lecture Time	Supported indiv. learning (exercises, lab work, project work)	Indepen-dent Learning	Total	Pre-Examination	Examination
Satellite Geodesy and Spatial Reference Systems	2	20 h	10 h	60 h	90 h	-	written exam (90 min.) and Project

Module summary

GMCM210 OpenSource GIS

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

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

GMCM211 Introduction to OpenSource GIS

Lecturer: Dr. Marco Lechner
Contact hours (SWS): 1
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 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 PHP 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.

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	1	15 h	0 h	15 h	30 h	assignments	written exam 120 min

Course

GMCM212 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.

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	120 h	150 h	assignments	-

Module summary

GMCM220 Web Services & Geomonitoring

Module coordinator: Prof. Dr.-Ing. Reiner Jäger

Credits (ECTS): 6

Semester: 2

Pre-requisites with regard to content:

Knowledge of mathematics, physics, parameter estimation, statistics, object oriented programming.

Pre-requisites according to the examination regulations:

- / -

Competencies:

In the lecture Geomonitoring with Programming Application the students will get to know the sensor equations (GNSS, SAR/INSAR and gravity satellites, terrestrial geodetic & optical sensors, and physical sensors), the mathematical models and the algorithms, in order to be able to set up different parametric approaches of an integrated geo-monitoring in 3D geometry and gravity space. The programming part gives competencies on IT technologies for setting up different kinds of local and global object geo-monitoring, and on the software implementation of different algorithms on time-series analysis, the monitoring of change detections and visualization algorithms in object oriented programming languages. As programming language Python will be used. The geo-monitoring system GOCA, its installation on the Stuttgart television tower, and in the Laboratory on GNSS & Navigation are giving competences on working with real data, local and Interned related communication and IT technologies.

In the modules Web Services the students learn the setting-up and programming of a Web processing service (WPS) following OGC standards and including own scripting parts and App Developments to access, and for the analysis and control geomonitoring data and projects

Assessment:

Written examination (2 x 60 min.) and marked project work in each lecture part

Usability:

Web Services & Monitoring supplies the full spectrum of global and local geomonitoring. It covers the space and terrestrial sensor equations, the mathematical models and algorithms for sensordata fusion,and the IT and programming technologies for the implementation of different kind of geo-monitoring systems. The programming is done on Python based timer series analys, script language for Web Services and Android Apps.

Course

GMCM221 Geomonitoring with Programming Applications

Lecturer: Prof. Dr.-Ing. Reiner Jäger
Contact hours (SWS): 2 SWS
Semester of delivery: annually

Type / mode: Lecture and project work / Mandatory Module

Language of instruction: English

Content:
General standards and profile of geo-monitoring, change detection and early warning in geodynamics, natural objects, man-made structures, geotechnics. Geo-Monitoring, environmental-monitoring. Geo-monitoring chain. Coordinate systems, global and local reference frames.

Satellite (GNSS, SAR/INSAR, Gravity), terrestrial geodetic, optical and physical geo-monitoring sensors. Sensor-equations and -parametrization in geometry and gravity space. Mathematical models and parameter estimation for sensor fusion in geo-monitoring. Classification of parametric deformation models (observation and coordinate related approaches and network types (absolute, relative deformation network). Special problems related to local, and ITRF embedded free and on-defect deformation networks (global geodynamics modelling, datum, datum-drift, plate tectonics handling). Statistical control of the reference frame.

Change detection (black-, grey- and white box) approaches. Selected change detection models (basic deformation state vector, virtual sensors, surface and volume changes, system analysis, state space and spectral domain, structural health monitoring) on the above sensors. Estimation concepts for change detection (geometric deformation analysis, system analysis, Kalman filtering, spectral analysis, prediction and early-warning. Types of geo-sensor networks and IT-Structures.

Project work combined with Geo-Monitoring and Programming: Software implementations along the IT-structure, data processing, data interfaces of the geo-monitoring system GOCA. As installation the Television Tower Stuttgart with internet-based data communication, and local installations in the Laboratory GNSS & Navigation are used for programming of static and dynamic displacement estimations. Further App-programming on visualization of state-space and spectral characteristics.

For time series analysis in geomonitoring, the programming language Python and programming environment Jupiter (Pandas, NumPy and SciPy libraires) will be used in the lecture room. Additive and multiplicative time series modeling and analysis and stationary and non-stationary are treated. The methods and Python poramming for modeling, removing and forecsting 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 of processing from real data are treaetd theoretically and in programing applications.

Recommended reading:

Copernicus-Website (2018): Global Monitoring. http://www.copernicus.eu/

Kühne, Einstein, Krauter, Klapperich, Pöttler (2002): Proceedings International Conference on Landslides Causes, Impacts and Countermeasures. Davos, Switzerland, June 17-21, ISBN 3-7739-5969-9 Runge, GmbH, Cloppenburg. S. 261 – 275

Eichhorn, A. (2005): Ein Beitrag zur Identifikation von dynamischen Strukturmodellen mit Methoden der adaptiven Kalman-Filterung. DGK-C Nr. 585. Deutsche Geodäische Kommisssion, München.

Plag, H.-P., Pearlman, M. (2009): Global Geodetic Observing System. Meeting the Requirements of a Global Society on a Changing Planet in 2020. Springer

Silvia Nittel (2006): GeoSensor Networks: Second International Conference, GSN 2006, Boston, MA, USA, October 1-3, 2006, Revised selected and invited Papers. Springer Edittion.

Wikipedia (2018): Structural Health Monitoring, https://en.wikipedia.org/wiki/Structural_health_monitoring

Jäger, R. and F. Gonzalez (2005): GNSS/GPS/LPS based Online Control and Alarm System (GOCA) - Mathematical Models and Technical Realisation of a System for Natural and Geotechnical Deformation Monitoring and Hazard Prevention. ISGDM IAG-Symposium 2005, April 2003, University of Escuela Politécnica Superior de Jaén. Spain. (F. Sanso, A. J. Gil (Eds.): Geodetic Deformation Monitoring: From Geophysical to Engineering Roles. IAG Series on Geodesy Symposia. Springer Heidelberg and New York. ISBN 3-540-38595-9. 293 – 304.

Jäger, R., Kälber, S., Oswald, M. and M. Bertges (2006): GNSS/LPS/LS based Online Control and Alarm System (GOCA) – Mathematical Models and Technical Realisation of a System for Natural and Geotechnical Deformation Monitoring and Analysis. Proceedings of 3rd IAG Symposium on Geodesy for Geotechnical and Structural Engineering and 12th FIG Symposium on Deformation Measurements / 22.-24. May 2006, Baden/Austria, CD-Rom. IAG and FIG, Vienna.

Jäger, R., Gorokhova, L. und E. Messmer (2017): Modell- und Sensorintegration zum integrierten 3D Geomonitoring in moderner Datenkommunikationsstruktur mit Anwendung auf den Stuttgarter Fernsehturm. Ingenieurvermessung 17: Beiträge zum 18. Internationalen Ingenieurvermessungskurs Graz, 2017. Wichmann-Verlag. ISBN: 978-3-87907-630-7. S.23-251.

GOCA Web-Site (1998-2018): GNSS/LPS-based Online Control and Alarm System (GOCA). www.goca.info

Kaiser, R. (2017): C++ mit Visual Studio 2017. Ein Fach- und Lehrbuch für Standard-C++. Springer.

Hagos, T. (2018): Learn Android Studio 3. Efficient Android App Development. Springer.

Marschallinger und Wanker (Hrsg.): Geomonitoring, FE-Modellierung, Sturzprozesse und Massenbewegungen: Beiträge zur COG-Fachtagung. Salzburg 2008. Wichmann-Verlag.

Johansson R. (2015): Numerical Python. Springer.

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

Wes McKinney & PyData Development Team (2018): Pandas - Powerful Python Data Analysis Toolkit. Release 0.22.0. https://pandas.pydata.org/pandas-docs/stable .

Comments:

-/-

Overview:

Course	SWS	Lecture Time	Supported Indiv. Learning (Exercises, Lab Work, Project Work)	Indepen-dent Learning	Total	Pre-Examination	Examination
Geomonitoring with programming applications	2	20 h	10 h	60 h	90 h	assignments	Module written exam 120 min

Course

GMCM222 Web Services

Lecturer: N.N.
Contact hours (SWS): 2 SWS
Semester of delivery: annually

Type / mode: Lecture / Mandatory

Language of instruction: English

Content: The course starts with an introduction to the OGC specification for WPS as well as to programming with Python. Further, the setting-up of a WPS is discussed and an example of a complex process programmed by the students. 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'. Further Android based App Developments are done, with application to the data of the project Structural Health Monitoring (SHM) of Fernsehturm Stuttgart project.

Recommended reading: ./.

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 Services	2	20 h	10 h	60 h	90 h	assignments	Module written exam 120 min

Module summary

GMCM230 Satellite Image Analysis

Module coordinator: Prof. Dr. Gertrud Schaab
Credits (ECTS): 6
Semester: 2

Pre-requisites with regard to content:
Basic knowledge in Digital Image Processing; in existing acquisition sensor systems (multispectral and RADAR) as well as in the geometry and physics background influencing data acquisition; practical experience in DIP (including multi-band imagery and georeferencing) and in visual interpretation of aerial photography.

Pre-requisites according to the examination regulations:
none

Competencies:
The students gain confidence in pre-processing, classification and analysis of multispectral-, hyperspectral-and radar-satellite image data. Therefore they get the opportunity to learn about theory and practical applications of pixel-based and object-based segmentation and classification. The students should obtain the qualification to determine and apply a suitable processing chain, this dependent on the available satellite image data and the concrete 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

GMCM231 Satellite Image Analysis

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

Type / mode: Lecture and Laboaratory Exercises / Mandatory course

Language of instruction: English

Content:
Algorithms for classification of multispectral and hyperspectral image data;Methods for RADAR-data processing; Image transformations (IHS, PCA) and sensor fusion (pansharpening); Atmospheric corrections; Fuzzy approaches in image analysis; Object-based segmentation and classification.

Recommended reading:
Albertz, J., Einführung in die Fernerkundung. Grundlagen der Interpretation von Luft-und Satellitenbildern: Eine Einführung in die Fernerkundung. Darmstadt 2007.

Hildebrandt, G., Fernerkundung und Luftbildmessung. für Forstwirtschaft, Vegetationskartierung und Landschaftsökologie. Heidelberg 1996.

Jensen, J.R., Introductory digital image processing. A remote sensing perspective, Upper Saddle River (New Jersey) 1995.

Lillesand, T.M. & R.W. Kiefer, Remote sensing and image interpretation. Cichester 2

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 Image Analysis	3	10 h	35 h	135 h	180 h		Project (La/1S)

Module summary

GMCE240 Statistics for Big Data

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

Pre-requisites with regard to content:
Solid knowledge in mathematics and fundamental statistical methods, experiences in working with spatial data and GIS

Pre-requisites according to the examination regulations:
None

Competencies:
Students have the capacity for analyzing spatial distributions, patterns, processes, and relationships on the basis of big data sets using explorative statistical methods. Students are able to incorporate space (proximity, area, connectivity, and/or other spatial relationships) directly into their mathematical framework. In general students get skills in answering questions about the spatial behavior of big data in geo-sciences.

Assessment:
Marked project work

Usability:
In particular knowledge in complex statistical methods can be applied in the modules Geovisual Analytics, Navigation, Geodesy and Satellite Image Analysis. In general this module provides the basis for any analysis exploring big data sets. Knowing how to use complex statistical methods is essential when making unknown spatial patterns und distributions understandable.

Course

GMCE241 Statistics for Big Data

Lecturer:	Prof. Dr. Peter Freckmann
Contact hours (SWS):	3 SWS
Semester of delivery:	annually
Type / mode:	Lecture and project work / Elective module
Language of instruction:	English or german

Content:

Students learn also how to identify characteristics of a spatial distribution and statistically significant spatial clusters or spatial outliers, assess overall patterns of clustering or dispersion, group features based on attribute similarities, identify an appropriate scale of analysis, and explore spatial relationships. There for they learn to apply explorative statistical methods like factor and cluster analysis, spatial auto correlation measurements and hot and cold spots analysis.

Recommended reading:

Armstrong, M.P., Xiao, N. & Bennett, D.A., 2003: Using Genetic Algorithms to Create Multicriteria Class Intervals for Choropleth Maps. Annals of the Association of American Geographers, **93**(3), 595-623.

Bahrenberg, G., Giese, E. & Nipper, J.: Statistische Methoden in der Geographie. Band 2 - Multivariate Statistik. Springer.

Bennett, L., D’Acosta, J. & Vale, F., 2010: Spatial Data Mining: A Deep Dive into Cluster Analysis. https://blogs.esri.com/esri/arcgis/2010/07/13/spatial-statistics-resources/, letzter Zugriff 25.09.2017.

Burt, J. E. u. G. M. Barber, Elementary Statistics for Geographers, New York 1996

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

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

Duque, J.C., Ramos, R. & Surinach, J., 2007: Supervised Regionalization Methods: A Survey. Research Institute of Applied Economics 2006, Working Papers 2006/**8**, 1-31.

Getis, A. & Ord J.K., 1992: The Analysis of Spatial Association by Use of Distance Statistics. Geographical Analysis **24**(3), 189-206.

Getis, A. & Ord J.K., 1995: Local Spatial Autocorrelation Statistics: Distributional Issues and an Application. Geographical Analysis **27**(4), 286-306.

Goodchild, M.F., 1986: Spatial Autocorrelation. Catmog 47, Geo Books.

Sachs, L., Angewandte Statistik, Heidelberg 1999

Comments:

-/-

Overview:

Course	SWS	Lecture Time	Supported Indiv. Learning (Exercises, Lab Work, Project Work)	Indepen-dent Learning	Total	Pre-Examination	Examination
Statistics for Big Data	3	15 h	30 h	135 h	180 h	-	project

Module summary

GMCE250 Mobile Apps & GIS

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 how to conceptualize native mobile map apps based on Qt / QML programming. The students have gained experience in 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

GMCE251 Mobile Map Apps in Nature Conservation

Lecturer: Prof. Dr. Gertrud Schaab
Contact hours (SWS): 3 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 way students learn 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 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 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 use a version control system. Regular meetings with the lecturer provides opportunity to the students to discuss their progress, to ask questions and to ensure their route to success. The students are thus able to perform software development within a team for 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 back-ground/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. 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. 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. Computer Networks 90, 49-73, 2015.

Reichenbacher, T., Kartographie in der mobilen digitalen Welt. 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. 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. IEEE Internet Computing 13 (4), 80-85, 2009.

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
Mobil Map Apps in Nature Conservation	3	18 h	27 h	135 h	180 h	-	Project (La/1S)

Module summary

GMCE260 Geodesy

Module coordinator: Prof. Dr. Reiner Jäger
Credits (ECTS): 6
Semester: 1

Pre-requisites with regard to content:
Knowledge of mathematics, physics, software development, parameter estimation, satellite geodesy

Pre-requisites according to the examination regulations:
. /

Competencies:
Course Intelligent systems in Engineering Geodesy: Attendees obtain knowledge necessary to design the mathematical models, software- and hardware of intelligent systems, to realize and to evaluate intelligent systems in engineering geodesy. Typical systems are autonomous in- and outdoor vehicles (airborne, ground, water) and stationary or mobile multi-sensor robot systems, etc. The students are able to apply suitable development evaluation methods on off-the-shelf systems in order to provide digested information to decision-makers or make qualified, fact-based decision themselves. Attendees are also skilled in rapid prototyping of intelligent systems, which requires comprehensive knowledge on sensor physics, and the mathematical models, Bayes Estimation, algorithmic concepts, software-development (e.g. based on Open Source) and operating systems (e.g. ROS for robotic systems) of a sensor-fusion (GNSS, MEMS, Optics). SLAM and system-integration expertise. Tackling product development paradigms students obtain also capabilities of active participation in industrial-level product development.

Course Physical and Integrated Geodesy: The students have internalized the fundamentals of mathematical and physical geodesy. Therefore, they are able to make themselves familiar with complex problems of the mathematical models, estimation and prediction on different problems on integrated 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 exam 90 Min/120 Min and marked project work

Usability:
The module is self-consistent in its contents both from theory and project work. In respect to other modules of the Geomatics program it is dealing with algorithms and parameter estimation for multi-

sensor GNSS/MEMS/Optics robotic systems. As concerns other university programs it could be integrated in study programs such as Sensor Systems Technology (Master) or Micro-Mechatronic Systems (Master). Physical and integrated geodesy supplies the geometry and gravity field related fundamental theories for fields like advanced parameter estimation concepts, satellite geodesy, modern height systems and global as well as regional geodetic computations, estimation and prediction concepts. The module gives theoretical background information for many areas of Geodesy and Geoinformatics.

Course

GMCE261 Intelligent Systems in Engineering Geodesy

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

Type / mode: Elective Module

Language of instruction: English or german

Content:

This course is integration/unification of several engineering subjects within the field of geometrics with strong practical emphasis. It comprises, among others, recursive parameter estimation, machine control, computer vision, machine learning and photogrammetry in order to provide students comprehensive one-semester theory-supported-project walk-through and explain to build and understand intelligent systems basics. The students obtain in strongly focused and in-depth theoretical lectures necessary fundamentals on sensor fusion, computer vision, machine learning basics, robotic control, etc. Based on that knowledge, attendees will build a sample robot using available robotic kit and equip the systems with off-the-shelf sensors, SBC's, etc. The systems must be realized to operate in unknown environment and "behave intelligent": they are able to observe and judge surroundings and fulfill tasks autonomously. 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. The course ends with marked presentation and benchmark between teams on predefined tasks.
The course consists of two parts: Theoretical primer and practical application. In the first Part following themes are elaborated.
<u>Theoretical Part:</u>
The course starts with "Intelligent Systems and Challenges on Navigation State Estimation and Control" and proceeds then with algorithmic fundamentals: Markov Chains and Bayes Representation of Sensor Measurements and Controls, Navigation and Control of Systems in Markov Chain based Bayes Presentation. Transition from Markov Chains to conditioned Densities and Bayes Formulations, Integration of additional State Information via Chapman-Kolmogorov Equation, First Order Markov Chain Assumption on the Navigation and Control of Systems, Integration of State Transition and Control Equations and Examples, Final Bayes A-posterior-Density Relation.
Transition from Bayes Formulation to Classical and Extended Kalman Filtering by Maximum Posterior Density Estimation, Transition from Bayes Formulation to Particle Filtering. Bayes-based SLAM formulation: Multi-Sensor-Multiplatform Sensor System Design, Modelling of a Leverarm-Design for all

sensors. Sensor-observation equations (GNSS, MEMS, Optics) examples, State Transition and Control Equations, Systems without control actions, controlled Systems.
Trajectory based planning of intelligent autonomous vehicles, obstacle detection, intelligence concepts and algorithms for a dynamically modified course planning. Navigation and PID Control of UAS. This includes flight physics and the derivation of UAS PID regulation at the example NAVKA Flight Control.
Projects Part:
The project part will of the course will gather students in small teams of four students, which will implement different kind of intelligent systems (mathematical models, algorithms, software and hardware-design). These are practical exercises on GNSS-based and navigation positioning using Open Source Software. Further the use of GNSS/MEMS/Camera/Laserscanner ground robots intelligent system for environmental mapping or BIM based on SLAM (Simultaneous Localization and Mapping). 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.

Recommended reading:

Herzberg, J., Lingemann, K. und A. Nüchter (2012): Mobile Roboter: Springer Vieweg, Heidelberg.

Jäger, R. (2019): Multisensorische 3D-Mappingsysteme für BIM – SLAM basierte Navigation und Steuerung, Systemrealisierung MSM und Profil künftiger Entwicklungen. Buchbeitrag zur Internationalen Geodätischen Woche 2019, Obergurgl, Österreich. Klaus Hanke / Thomas Weinold (Eds.) ISBN 978-3-87907-659-8. Wichmann-Verlag. S. 286-293.

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Luhmann, T. (2014). Close Range Photogrammetry (2rd ed.). Wichmann Verlag.

NAVA-Webseite (2012-2021): www.navka.de.

ROS (2018): Robot Operation System (ROS). Web-Site: www.ros.org/-

Russell, S., & Norvig, P. (2009). Artificial Intelligence: A Modern Approach (3rd Edition). Prentice Hall.

Szeliski, R. (2010). Computer Vision: Algorithms and Applications (1st ed.). New York, NY, USA: Springer-Verlag New York, Inc.

Thrun, S., Burgard, W. und D. Fox (2006): Probabilistic Robots: The MIT Press. Cambridge, Massachusetts. London.

Zwiener, J. (2019): Robuste Zustandsschätzung zur Navigation und Regelung autonomer und bemannter Multikopter mit verteilten Sensoren. *Darmstadt, Technische Universität, ISBN 978-3-935631-43-3. Dissertation.*

Comments:

Overview:

Course	SWS	Lecture Time	Supported Indiv. Learning (Exercises, Lab Work, Project Work)	Indepen-dent Learning	Total	Pre-Examination	Examination
Intelligent Systems in Engineering Geodesy	2 (Theory)	25 h	5 h	15 h	45 h	-	Written examination based on theory and project work (90 min)
	0 (Projects)	0 h	0 h	45 h	45 h		

Course

GMCE262 Physical and Integrated Geodesy

Lecturer: Prof. Dr. Tilman Müller, Prof. Dr. Reiner Jäger
Contact hours (SWS): 2 SWS
Semester of delivery: annually

Type / mode: Lecture / Elective course

Language of instruction: English or German

Content:

Physical Geodesy: Lectures cover 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. **Integrated Geodesy** is dealing with parametric and stochastic mathematical models, estimation and prediction questions on geometrical and gravity field space problems in Geodesy, Bayesian theory is used as a foundation to derive the basic estimation methods and their branches to integrate all mathematical models down to interpolation and prediction (Kernel-based Methods, Kriging, Collocation). The further treatment of mathematical models is concerned with classical 3D integrated geodetic network adjustment and its extension to modern sensor types and parametrizations. roblems of datum transformations, estimation of surface parameters and height reference systems are also covered. Selected problems are on integrated conformal mapping and numerical integration to solve geodetic major tasks. 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:

Hofmann-Wellenhof, B., Physical geodesy. Wien 2006.

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.

Torge, W., Geodesy. Berlin 2003.

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/

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
Physical Geodesy	1	15 h	-/-	30 h	45 h	-	written exam 120 min
Integrated Geodesy	1	10 h	5 h	30 h	45 h	-	

Module summary

GMCM310 Seminar for Master Thesis

Module coordinator:	Course director Geomatics Master
Credits (ECTS):	5
Semester:	3

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:
Successful conclusion of all modules (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

GMCM320 Master Thesis

Module coordinator: Prof. Dr. Gertrud Schaab, Course director Geomatics Master
Credits (ECTS): 22
Semester: 3

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:
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

GMCM330 Colloquium for Master Thesis

Module coordinator: Course director Geomatics Master
Credits (ECTS): 3
Semester: 3

Pre-requisites with regard to content:
See Master thesis

Pre-requisites according to the examination regulations:
Handed in Master thesis

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.