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Module Catalogue

For the Master Degree Programme in

Geodesy and Geoinformation Science

Faculty VI

Department of Geodesy and Geoinformation Science

The module catalogue completes the examination regulations and conditions of study alternatively the study guide for the
Master Degree Programme in “Geodesy and Geoinformation Science”.

Imprint / Editor

Institute for Geodesy and Geoinformation Science

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Version: April 2nd, 2009 (amendments and errors may occur)

Nomenclature

SPW: Semester Periods per Week (Number of lecturing hours per week)
Credits: Credit Points (ECTS-Credit Points; CP)

General Information

The study course structure is modular, i.e. thematically connected courses are combined to one module. A module is passed, if the assigned test achievements were passed successfully. The achieved credits of a module get assigned when the entire module is passed successfully.

The credits are calculated on a basis of the average necessary study outlay for the successful completion of the module.

The study outlay covers:

- Course attendance (based on of **number of hours per week: SPW)**
- Preparation and post processing
- Task processing
- Production of presentations, journals, drafts, project results
- Test preparation

A full time study consists of 45 weeks a year with 40 working hours each. That results in a maximum of 1800 hours per academic year or 900 hours per term. **One credit is equivalent to 30 hours studying** therefore the student can get 30 credits per term alternatively 60 credits per academic year.

The **Masters Degree programme consists of** modules leading to a total of **at least 120 credits**.

During the course, modules with a total value of **90 credits** must be selected as follows:

a) **Foundation modules** with a total amount of **30 credits**;
b) Modules selected from **one of the four specialised subjects (major subject)** with a value of **21 credits**. The project seminar for this specialised subject must be included, with a value of at least 6 credits;
c) Modules with a value of **9 credits from the other specialised subjects (minor subject)**;
d) Modules with a value of **12 credits from the whole range of courses offered by the Technical University of Berlin or by other universities**, equivalent higher education institutions subject to the German Higher Education Framework Act or foreign higher education institutions and universities recognised to be equivalent. A Language Module is recommended.

The amount of work required for the **Master's dissertation** is equivalent to **30 credits**. Work for the dissertation is carried out during the final semester.
It is recommended to select the modules according to the course schedule.

Programme Structure

1st semester

Foundation Section (30 CP)

Modules equivalent to 30 CP must be selected from the foundation section.

FOU Geoinformation Technology	(6 CP)
FOU Adjustment Calculation I	(6 CP)
FOU Geo Databases	(6 CP)
FOU Introduction to Satellite Geodesy	(6 CP)
FOU CV1 Photogrammetric Computer Vision	(6 CP)
FOU Geophysical Investigation in Geo Technologies	(6 CP)

2nd / 3rd semester

Specialised Subjects (48 CP)

Out of the following thematic blocks, a major subject (main specialisation) has to be chosen (21 CP). Within this major subject, the project seminar with an amount of 6 CP has to be taken. From each remaining thematic block (minor subjects), modules with an amount of 9 CP have to be taken.

A	B	C	D
Geo Information Science (GIS)	Space Geodesy and Navigation (SGN)	Engineering Surveying and Estimation Theory (EGA)	Computer Vision and Remote Sensing (CV)

Elective Section (12 CP)

Modules from the course catalogue of the Berlin University of Technology or other universities. The choice of a language module as well as courses from the special catalogue of interdisciplinary courses (FÜS) is recommended.

4th semester

Master’s Dissertation (30 CP)

Module Overview

Foundation Section (FOU)

FOU Geoinformation Technology	1st term	4 SPW	6 CP
FOU Adjustment Calculation I	1st term	4 SPW	6 CP
FOU Introduction to Satellite Geodesy	1st term	4 SPW	6 CP
FOU Geo-Databases	1st term	4 SPW	6 CP
FOU CV1 Photogrammetric Computer Vision	1st term	6 SPW	6 CP
FOU Geophysical Investigation (Geophysics I - Geotech) (offered by the Department of Applied Geosciences)	1st term	4 SPW	6 CP

Tutorials (TUT)

Offer on a voluntary basis in order to refresh the student's knowledge and to improve their operational skills.

TUT Basics in Engineering Surveys	1st term	2 SPW	0 CP
TUT Java Programming for GIS and Geodesy	1st term	2 SPW	0 CP

Geoinformation Science (GIS)

GIS Collection of Geo Base Data	2nd term	3 SPW	9 CP
	3rd term	3 SPW	
GIS Administration	2nd term	2 SPW	6 CP
	3rd term	2 SPW	
GIS Analytical Methods	2nd term	2 SPW	9 CP
	3rd term	4 SPW	
GIS Visualisation	2nd term	3 SPW	9 CP
	3rd term	3 SPW	
GIS Research	2nd term	2 SPW	3 CP
GIS Project Seminar Geoinformation Technology	2nd term	2 SPW	6 CP
	3rd term	2 SPW	

GIS Selected Sections of Geoinformation Technology	3rd term	2 SPW	3 CP
GIS Geoinformation Science I	2nd term	3 SPW	9 CP
	3rd term	2 SPW	
GIS Geoinformation Science II	2nd term	6 SPW	9 CP

Space Geodesy and Navigation (SGN)

SGN Physical Geodesy	2nd term	2 SPW	3 CP
SGN Geodetic Space Procedures in Earth System Research	3rd term	4 SPW	6 CP
SGN Planetary Geodesy	2nd term	2 SPW	6 CP
	3rd term	2 SPW	
SGN Global Navigation Satellite Systems (GNSS)	2nd term	2 SPW	9 CP
	3rd term	4 SPW	
SGN Calculation of Satellite Orbits	3rd term	2 SPW	3 CP
SGN Current and Future Methods of Navigation and Positioning	2nd term	4 SPW	6 CP
SGN Data Communication and Signal Processing in GNSS	3rd term	2 SPW	3 CP
SGN Geoscientific Aspects of Geodesy	2nd term	2 SPW	3 CP
SGN Planetary and Space Science Seminar	2nd term	2 SPW	6 CP
	3rd term	2 SPW	
SGN Space Geodesy and Navigation I	2nd term	6 SPW	9 CP
SGN Space Geodesy and Navigation II	2nd term	4 SPW	9 CP
	3rd term	2 SPW	
SGN Space Geodesy and Navigation III	3rd term	8 SPW	9 CP
SGN Theoretical Basics of Geophysical Investigations (offered by the Department of Applied Geosciences)	2nd term	2 SPW	3-12 CP
	2nd term	2 SPW	
	2nd term	2 SPW	
	2nd term	2 SPW	

SGN Inversion and Filter of Applied Geophysics (offered by the Department of Applied Geosciences)	3rd term	2 SPW	3-6 CP
	3rd term	2 SPW	

Engineering Surveying and Estimation Theory (EGA)

EGA Adjustment Calculation II	2nd term	4 SPW	9 CP
	3rd term	2 SPW	
EGA Methods of Engineering Geodesy	2nd term	3 SPW	9 CP
	3rd term	3 SPW	
EGA Geodetic Sensors and 3D Measurement	2nd term	2SPW	6 CP
	3rd term	2SPW	
EGA Analysis of Deformation Processes	3rd term	2 SPW	3 CP
EGA Transformation of Geodetic Networks	3rd term	2 SPW	3 CP
EGA Current Methods of Measurement Data Analysis in Geodesy	3rd term	2 SPW	3 CP
EGA Project Seminar Engineering Surveying and Estimation Theory	2nd term	2 SPW	6 CP
	3rd term	2 SPW	

Computer Vision and Remote Sensing (CV)

CV2 Digital Image Processing	2nd term	4 SPW	6 CP
CV3 Automatic Image Analysis	3rd term	4 SPW	6 CP
CV4 Optical Remote Sensing	3rd term	4 SPW	6 CP
CV5 Microwave and Radar Remote Sensing	2nd term	4 SPW	6 CP
CV6 Seminar Hot Topics in Computer Vision	2nd or 3rd term	2 SPW	3 CP
CV7 Project Hot Topics in Computer Vision	2nd or 3rd term	4 SPW	6 CP
CV8 Seminar Hot Topics in Image Analysis	2nd or 3rd term	2 SPW	3 CP
CV9 Project Hot Topics in Image Analysis	2nd or 3rd term	4 SPW	6 CP

Additional Elective Courses (AEC)

AEC Remote Sensing Applications	3rd term	2 SPW	3 CP

Master’s Dissertation (MSC)

MSC Master’s Thesis	4th term		30 CP

Foundation Section (FOU)

FOU Geoinformation Technology (6 CP)

Geoinformation Technology **IV 3633 L 200**

Semester: winter term **(1st semester)**
Attendance: 4 semester periods per week

Module type:	Compulsory elective
Person in charge:	Prof. Kolbe, Secretariat H12, GIS@igg.tu-berlin.de
Entry requirements:	Computer literacy
Duration:	1 semester
Examination:	Study effort equivalent to the examination: • Presentation and written report (80%) • Exercises and oral contribution (20%)
Workload:	Overall attendance: 15 x 4 h = 60 h Preparation and post processing: 15 x 8 h = 120 h

Objectives:

This module provides and deepens knowledge of modelling and analysis of geospatial data and geo-algorithms. The students learn about different methods of geometric and topological modelling. This is followed by a discussion of various data structures with different degrees of geometric and topological information – maps, winged-edge data, graphs, TINs, and Voronoi diagrams among them. In the seminar part, the students learn how to deal with implementations of geoinformation methods and algorithms in a standard GIS software environment.

Module elements:

Geoinformation Technology **IV 3633 L 200**

Content

- Object oriented and relational modelling
- Models of space
- Modelling of geometry and topology
- Common geo data structures
- Practical work with a standard GIS software environment

Didactic concept

- Lecture (50%)
- Hands-on exercises (10%)
- Student presentations and discussions (40%)

Literature:

- Longley, Goodchild, Maguire (2005): *Geographical information systems and science.* Wiley & Sons; 2nd ed. ISBN: 978-0470870006.

- Worboys (2004): *GIS: a computing perspective.* Routledge Chapman & Hall; 2nd ed. ISBN: 978-0415283755.
- Ormsby (2001): *Getting to know ArcGIS desktop: basics of ArcView, ArcEditor, and ArcInfo.* ESRI Press; Pap/Cdr edition. ISBN: 978-1879102897.

FOU Adjustment Calculation I (6 CP)

Adjustment Calculation I **IV 3633 L 201**

Semester: winter term **(1st semester)**
Attendance: 4 semester periods per week

Module type:	Compulsory elective				
Person in charge:	Prof. Gründig, Secretariat H20, EGA@igg.tu-berlin.de				
Entry requirements:	Basic knowledge in surveying techniques is desirable				
Duration:	1 semester				
Examination:	Written exam				
Workload:	Overall attendance:	15 x	4 h	=	60 h
	Homework:	4 x	15 h	=	60 h
	Preparation and planning:	15 x	2 h	=	30 h
	Examination preparation:				30 h

Objectives:

Students will gain a profound theoretic and methodical knowledge in variance-covariance propagation, parameter estimation and statistical testing. They are able to design functional and stochastic models and apply these on geodetic and general engineering tasks.

Module elements:

Adjustment Calculation I IV 3633 L 201

Content

- Binomial and normal distribution
- Confidence intervals
- Evaluation of the mathematical model via statistical tests
- Evaluation of measured normally distributed quantities
- Theory of standard deviations
- Variance analysis
- Inner and outer reliability
- Parametric linear adjustment
- Solving nonlinear adjustment problems
- Accuracy, reliability, stochastic processes,

Didactic concept

- Lecture 50%
- Recitation 50%

Literature:

- Mikhail, E., & Ackerman, F. (1976). *Observations and Least Squares*. New York: University Press of America.´
- Allan, L (2008) *Principles of Geospatial Surveying*, Whittles Publishing
- Allan, L (2004*) Math for Map Makers*, London, Whittles Publishing
- Ghilani C. & Wolf P.(2006), *Adjustment Computations*, New Jersey, John Wiley
- Harvey b.R. (2006), *Practical Least Squares and Statistics for Surveyors*, The University of new South Wales, Australia

FOU Introduction to Satellite Geodesy (6 CP)

Introduction to Satellite Geodesy **IV 3633 L 202**

Semester: Winter term **(1st semester)**
Attendance: 4 semester periods per week (2 h Introduction to Satellite Geodesy, 2 h Geodetic Reference Systems)

Module type:	Compulsory elective				
Person in charge:	Prof. Oberst, Dr. Stary Secretariat H12, SGN@igg.tu-berlin.de				
Entry requirements:	Specialised knowledge of maths and physics as well as computer literacy is desirable.				
Duration:	1 semester				
Examination:	Oral Exam				
Workload:	Overall attendance:	15 x	4 h	=	60 h
	Homework and post processing:	15 x	4 h	=	60 h
	Examination preparation:				60 h

Objectives:

Familiarize students with fundamentals in space and satellite geodesy. Communicate an understanding of the inertial and various global and local reference and coordinate systems.

Module elements:

Introduction to Satellite Geodesy **IV 3633 L 202**

Content

- Definition of stellar/inertial, global/geographic, and local reference systems
- Transformations between the systems
- Basics of solid earth physics, gravity, tides
- Mechanics of earth rotation: precession, nutation, and their kinematic description
- Time definition: Atomic time, UT and UTC, sidereal and synodic time
- Basic concepts in solar system science, space technology and remote sensing
- Fundamentals of satellite dynamics and geodetic methods
- Structure of modern geodetic reference stations
- GPS-supported procedures of point determination
- Realisation of the reference systems for surveying

Didactic concept

- Lectures (80%)
- Discussion (20%)

Literature:

- Torge, W.: *Geodesy*; de Gruyter; ISBN 978-3-11-017072-6
- Seeber, G.: *Satellite Geodesy*; Walter de Gruyter, 2nd revised edition (September 2003); 589 p.
- Gill, Montenbruck, *Satellite Orbits: Models, Methods, and Applications*, Springer

FOU Geo-Databases (6 CP)

Geo-Databases **VL 3633 L 203**
UE 3633 L 204

Semester: winter term **(1st semester)**
Attendance: 4 semester periods per week (2 h lecture and 2 h exercise)

Module type:	Compulsory elective				
Person in charge:	Prof. Kolbe, Secretariat H12, GIS@igg.tu-berlin.de				
Entry requirements:	Computer literacy				
Duration:	1 semester				
Examination:	oral exam				
Workload:	Overall attendance:	15 x	4 h	=	60 h
	Preparation and post processing:	15 x	4 h	=	60 h
	Examination preparation:				60 h

Objectives:

Students will learn methods for object-oriented spatial data modeling in the field of geoinformation sciences and how to map the models to a relational database schema. They gain experience in both data modeling and database querying languages such as UML and SQL. They understand advanced theoretic concepts and operations of spatial database systems and are able to apply methods for data integrity and geometric-topological relations. During hands-on-exercises the students set up and manage a real world spatial database environment. They apply the acquired knowledge, e.g. on spatial index structures and performance optimised queries, in order to guarantee efficient data retrieval.

Module elements:

Geo-Databases **VL 3633 L 203**
UE 3633 L 204

Content

- Database management systems
- Relational data model
- Normalisation
- Queries in SQL
- Data integrity
- Data base design, modelling with UML
- Mapping the model onto a relational schema
- Management of spatial data using spatial database management systems (e.g. Oracle)
- Use of reference systems in spatial database systems
- Geometric and topologic relations with geo-databases
- Spatial index structures
- Query strategies for performance enhancement (spatial filter etc.)

Didactic concept

- Lecture (50%)
- Hands-on exercises (50%)

Literature:

- *Ramez Elmasri, Shamkant B. Navathe*, Fundamentals of Database Systems, 5th Ed., Addison Wesley, 2006
- *Hector Garcia-Molina, Jeffrey D. Ullman*, Database Systems: The Complete Book, 2nd Ed., Pearson International, 2008
- *Ravikanth V. Kothuri, Albert Godfrind , Euro Beinat*: Pro Oracle Spatial: From Professional to Expert, Apress, 2004 (based on Oracle 10g)
- *Thomas Brinkhoff*: Geodatenbanksysteme in Theorie und Praxis: Einführung in objektrelationale Geodatenbanken unter besonderer Berücksichtigung von Oracle Spatial, Wichmann; Auflage: 2nd ed., 2008)

FOU CV1 Photogrammetric Computer Vision (6 CP)

Photogrammetric Computer Vision (CV1) **VL 0433 L 120**
UE 0433 L 121

Semester: winter term **(1st semester)**
Attendance: 6 semester periods per week (4 h lecture and 2 h exercise)

Module type:	Compulsory elective	
Person in charge:	Prof. Hellwich, Secretariat FR 3-1, hellwich@cs.tu-berlin.de	
Entry requirements:	None	
Duration:	1 semester	
Examination:	Written exam	
Workload:	Contact times:	90 h
	Private study:	90 h

Objectives:

The mathematic-physical modelling of a sensor is treated using the photographic camera as example. The modelling is completely expressed by algebraic projective geometry. Not only studying object reconstruction using image data of a multifaceted sensor, but and first of all the complete modelling of technically relevant issues in a homogeneous mathematical framework is important in this course. This framework is also used for 3D-computer graphics.

The course is principally designed to impart technical skills 30 % method skills 50 % system skills 10 % social skills 10 %.

The mathematical basics are conveyed in the context of a lecture. What has been learned is applied in parallel held lab exercises.

Module elements:

Photogrammetric Computer Vision (CV1) **VL 0433 L 120**
UE 0433 L 121

Content

Geometric basics of sensor orientation and object reconstruction: homogeneous coordinates, projectivity and perspective, modelling of image formation, inner and outer orientation, orientation of uncalibrated and calibrated cameras, spatial resection, least-squares adjustment, orientation of the image pair, relative and absolute orientation, spatial triangulation, multi-view geometry, bundle block adjustment, image digitalisation, radiometric basics.

Didactic concept

- lectures (33%)
- exercises (67%)

Literature:

- O. Faugeras, Q.T. Luong: The Geometry of Multiple Images. MIT Press 2004.
- R. Hartley, A. Zisserman: Multiple View Geometry in Computer Vision. 2nd ed. Cambridge University Press 2004.
- Y. Ma, S. Soatto, J. Kosecka, S. Sastry: An Invitation to 3D-Vision - From Images to Geometric Models. 2nd ed. Springer Verlag 2004.

FOU Geophysical Investigation (6 CP)

(offered by the Department of Applied Geosciences)

Geophysical Investigation Methods **IV 0632 L 401**

Semester: winter term **(1st semester)**
Attendance: 2 semester periods per week (1 h lecture and 1 h exercise)

Geophysical Investigation in Practice **IV 0632 L 402**

Semester: winter term **(1st semester)**
Attendance: 2 semester periods per week (1 h lecture and 1 h exercise)

Module type:	Compulsory elective			
Person in charge:	N.N., Secretariat ACK 2, SGN@igg.tu-berlin.de			
Entry requirements:	Extensive mathematical, physical and chemical basics are desirable			
Duration:	1 semester			
Examination:	Written exam			
Workload:	Overall attendance:	15 x 4 h	=	60 h
	Homework:	15 x 4 h	=	60 h
	Preparation and post processing:			30 h
	Examination preparation:			30 h

Objectives:

To have the ability to analyse geo technological problems alternatively projects regarding the application of geophysical investigation and monitoring methods; the ability to select, combine and evaluate the methods, to the correct handling of results of the used methods and transformation of the results to geo technological statements.

Module elements:

Geophysical Investigations Methods **IV 0632 L 401**
Geophysical Investigations in Practice **IV 0632 L 402**

Content

- Analysis of geo technological tasks (integrated geo technology)
- Geophysical investigation methods
- Rock-physical basics
- Criteria for the selection, combination and optimisation of the geophysical methods
- Case examples (for applications in investigation for oil, natural gas, ore, groundwater, building ground, subsurface investigation, geo technique etc)

Didactic concept

- Lectures (70%)
- Exercises (30%)

Literature:

- Telford, W. M., Geldart, L. P., Sheriff, R. E., 1990*, Applied Geophysics* (2. ed), Cambridge University Press
- Bender, F., (Hrsg.), 1985*, Angewandte Geowissenschaften Band II, Angewandte Geophysik*, Enke Verlag

Tutorials (TUT)

TUT Basics in Engineering Surveys (0 CP)

Basics in Engineering Surveys **IV 3633 L 228**

Semester: winter term **(1st semester)**
Attendance: 2 semester periods per week

Module type:	Elective				
Person in charge:	PD Dr. Gielsdorf, Secretariat H20, EGA@igg.tu-berlin.de				
Entry requirements:	None				
Duration:	1 semester				
Examination:	Oral exam				
Workload:	Overall attendance:	15 x	2 h	=	30 h
	Homework and post processing:	15 x	1 h	=	15 h

Objectives:

This optional tutorial is intended for students who have no previous training in surveying. It provides the main features of surveying techniques. This includes the introduction of measuring units, coordinate systems as well as construction and function of the most important measurement instruments. Basic measurement procedures are introduced. In practical exercises basic methods of geodetic calculations are imparted.

Module elements:

Basics in Engineering Surveys **IV 3633 L 228**

Content

- Local Coordinates
- Global Coordinates
- Direction Measurement
- Theodolit
- Distance Measurement
- GNSS
- Measurement of Heights
- Handling of Deviations
- Coordinates Conversion
- Datum Transformation
- Traverse
- Point Determinations
- Helmert- and Affin-Transformation
- Polar Survey

Didactic concept

- Lectures (75%)
- Exercises (25%)

Literature:

- Bannister, A.; Raymond, A.; Baker, R.: *Surveying*; Prentice Hall; 7th ed. (1998); 512 p.

TUT Java Programming for GIS and Geodesy (0 CP)

Java Programming for GIS and Geodesy **IV 3633 L 242**

Semester: winter term **(1st semester)**
Attendance: 2 semester periods per week

Module type:	Elective				
Person in charge:	Prof. Kolbe, Secretariat H12, GIS@igg.tu-berlin.de				
Entry requirements:	None				
Duration:	1 semester				
Examination:	No examination				
Workload:	Overall attendance:	15 x	2 h	=	30 h
	Preparation and post processing:	15 x	2 h	=	30 h

Objectives:

This optional tutorial gives an introduction to the principles of object-oriented programming using the Java programming language. The students learn about fundamental concepts and methods for how to come from a well-defined problem description to a Java computer program. In practical exercises the students develop and implement basic data structures and geo algorithms in the field of GIS and get familiar with the storage and exchange of spatial data using geo databases and JDBC techniques.

Module elements:

Java Programming for GIS and Geodesy **IV 3633 L 242**

Content

- Core concepts of Java
- Software development using an Integrated Development Environment
- Principles of object-oriented software design (OOD)
- Fundamentals of object-oriented programming (OOP)
- Data structures and algorithms in the field of GIS based on object-oriented design patterns
- Java and geo databases

Didactic concept

- Lecture (70%)
- Exercises (20%)

Literature:

- Niemeyer, P., Knudsen, J. (2005): *Learning Java*. O'Reilly Media, 3rd ed.; ISBN: 978-0596008734.
- Liang, Y. D. (2006): *Introduction to Java Programming – Comprehensive Version*. Prentice Hall, 6th ed.; ISBN: 978-0132221580.
- Mensah, K. (2006): *Oracle Database Programming using Java and Web Services*. Digital Press; ISBN: 978-1555583293.
- Herter, M., Koos, B. (2006): *Java und GIS: Programmierung – Beispiele – Lösungen* (German only). Wichmann, ISBN: 978-3879073795.

Specialised Subjects

Out of the following thematic blocks, a major block (main specialisation) has to be chosen (21 CP). Within this major block, the project seminar with an amount of 6 CP has to be taken. From each remaining thematic block, modules with an amount of 9 CP have to be taken.

Geoinformation Science (GIS)

GIS Collection of Geo Base Data (9 CP)

Measuring Systems and Methods **IV 3633 L 211**

Semester: summer term **(2nd semester)**
Attendance: 3 semester periods per week

Integration of Redundant Geo Data **IV 3633 L 212**

Semester: winter term **(3rd semester)**
Attendance: 3 semester periods per week

Module type:	Compulsory elective
Person in charge:	Dr. Stary, Secretariat H12, GIS@igg.tu-berlin.de
Entry requirements:	The modules *FOU Adjustment Calculation I*, *FOU Geoinformation Technology*, *FOU Introduction to Satellite Geodesy* with *Geodetic Reference Systems* or previous knowledge are mandatory; knowledge of a programming language is desirable
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Theoretical and practical exercises (70%) • Measurements and practical work (30%)
Workload:	Overall attendance: 15 x 6 h = 90 h Preparation and post processing: 15 x 12 h = 180 h

Objectives:

The students learn to control high-end methods and scientific concepts for situation moderate and height moderate collection of geo base data. They have the ability to plan and manage surveying campaigns of geometrical-physical measurements and other data collection techniques independently. The students can judge the quality of geo base data with methods of the mathematical statistics and adjustment calculation. They control techniques of the measurement and combination of hybrid data and can model redundant heterogeneous observations functionally and stochastically. They are ready to prepare them for the subsequent treatment in a geo information system.

Module elements:

Measuring Systems and Methods **IV 3633 L 211**

Content

- Primary data entry (modern terrestrial surveying procedures, laser scanning, astronomical positioning, gravity field parameter)
- Measuring systems (Theodolite, Gravimeter, Laser Scanner, etc.)
- Valuation of measuring methods
- Valuation of differences, similarities and combination of measuring procedures
- Data quality and estimation of costs

Didactic concept

- Lecture (40%)
- Practical exercises in surveying and other measuring techniques (60%)

Integration of Redundant Geo Data **IV 3633 L 212**

Content

- Possibilities of parameterisation of geometry information
- Modelling of the stochastic characteristics of geometry data
- Compensating algorithms for the generation of clear geometry parameters
- Integration of redundant heterogeneous observation data
- Procedures for the fusion, reduction and consistent combination of complex heterogeneous geo information

Didactic concept

- Lecture (25%)
- Hands-on software and project work (50%)
- Groupwise exercises (25%)

Literature:

- Alan, A.L. (2007): *Geospatial Surveying*. Whittles Publishing; 2nd ed. ISBN: 978-1420073461.
- Gielsdorf, F., Gründig, L., Aschoff, B. (May 2004). *Positional Accuracy Improvement - A necessary tool for updating and integration of GIS data*, FIG Working Week Athens,
- Hope, S., Gielsdorf, F. (May 2007), *Quality considerations for optimal positioning when integrating spatial data.* Spatial Sciences Institute International Biennial Conference 2007, Hobart Australia

GIS Administration (6 CP)

Geo Database Management **IV 3633 L 215**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Structure and Operation of Distributed Geo Data Infrastructures **IV 3633 L 235**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective
Person in charge:	Prof. Kolbe, Secretariat H12, GIS@igg.tu-berlin.de
Entry requirements:	The modules *FOU Geoinformation Technology* and *FOU Geo-Databases* resp. equivalent previous knowledge is mandatory, programming skills are desirable.
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Exercises (10%) • Presentation in reading groups and oral contribution (15%) • Oral examination (75%)
Workload:	Overall attendance: 15 x 4 h = 60 h Preparation and post processing: 15 x 8 h = 120 h

Objectives:

This module qualifies the students to evolve and manage complex GIS data and application models. A main focus lies in the systematic discussion and methodical application of the most important international standards for geographic information. The students are familiar with principles and technologies for interoperable storage, exchange and processing of geo data in heterogeneous and distributed environments. They are able to classify and evaluate the concepts and methods of geo data infrastructures and acquire fundamental knowledge about the "open" and standardised interfaces and systems in the GIS world.

Module elements:

Geo Database Management **IV 3633 L 215**

Content

- Advanced UML concepts for geo data modelling
- GIS standards for geographic information
- Interoperable data storage and exchange using XML
- XML Schema Definition Language (XSD)
- Geography Markup Language (GML)
- Examples of GML application schemas
- Processing of XML/GML using Java
- Architectures for geo databases and GIS

Didactic concept

- Lecture (70%)
- Exercises (20%)
- Oral contribution (10%)

Structure and Operation of Distributed Geo Data Infrastructures **IV 3633 L 235**

Content

- Standardisation in the field of GIS
- Service Oriented Architecture (SOA)
- Principles and technology of Web Services
- Geo data infrastructures
- OpenGIS Web Service specifications
- Meta data, data catalogues, repositories
- Interoperability, Security / Digital Rights Management
- Web Service orchestration

Didactic concept

- Lecture (70%)
- Presentations, reading groups (20%)
- Oral contribution (10%)

Literature:

- Herring, J. (2001): *The OpenGIS Abstract Specification, Topic 1: Feature Geometry (ISO 19107 Spatial Schema).* OGC Document Number 01-101.
- ISO 19109 (2005): *Geographic information — Rules for application schema*.
- Cox, S., Daisy, P., Lake, R., Portele, C., Whiteside, A. (2004): *OpenGIS Geography Markup Language (GML3),* Implementation Specification, Version 3.1.1. OGC Doc. No. 03-105r1.
- Papazoglou, M. P. (2008): *Web Services: Principles and Technology.* Prentice Hall; ISBN: 978-0321155559.
- Groot, R., McLaughlin J. (2000): *Geospatial Data Infrastructure,* Oxford University Press, ISBN 978-0198233817.
- Booch, Rumbaugh, Jacobsen (2005): *The Unified Modeling Language User Guide,* 2nd ed., Addison Wesley, ISBN0-321-26797-4
- Bray, T. et al. (2008): *Extensible Markup Language (XML) 1.0*. W3C Recommendation; 5th ed., online accessible at http://www.w3.org/TR/2008/REC-xml-20081126.
- Bray, T. et al. (2006): *Extensible Markup Language (XML) 1.1*. W3C Recommendation; 2nd ed., online accessible at http://www.w3.org/TR/2006/REC-xml11-20060816.
- Ray, E. (2003): *Learning XML*. O'Reilly; 2nd ed. ISBN: 978-0596004200.

GIS Analytical Methods (9 CP)

Geostatistics **IV 3633 L 213**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Conception and Implementation of Spatial Analysis Methods **IV 3633 L 236**

Semester: winter term **(3rd semester)**
Attendance: 4 semester periods per week

Module type:	Compulsory elective
Person in charge:	Prof. Kolbe, Secretariat H12, GIS@igg.tu-berlin.de
Entry requirements:	The modules *FOU Adjustment Calculation I, FOU Geoinformation Technology* or previous knowledge in these fields; object-oriented programming skills are required
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Exercises and paper review (75%) • Oral contribution (25%)
Workload:	Overall attendance: 15 x 6 h = 90 h Homework and post processing: 15 x 12 h = 180 h

Objectives:

The students know mathematical and information-technical concepts of spatial analytical methods. They have knowledge of the prediction and simulation of conditions (e.g. danger situations), which can be derived from geo data. The students can model statistical concepts of geospatial phenomena and implement them in an object-oriented programming environment.

Module elements:

Geostatistics **IV 3633 L 213**

Content

- Non-statistical interpolation methods
- Spatial interpolation methods
- Variogram, Semivariogram
- Kriging (Simple Kriging, Ordinary Kriging, Universal Kriging)
- Geostatistic Simulation

Didactic concept

- Lecture (70%)
- Hands-on exercises (30%)

Conception and Implementation of Spatial Analysis Methods **IV 3633 L 236**

Content

- Methods of the object-oriented modelling of data and algorithms
- Memory, searching and selecting of geo data
- Blending, modelling of fuzziness
- Classification
- Matching Algorithms

Didactic concept

- Lecture (50%)
- Hands-on exercises (50%)

Literature:

- Olea (1999): *Geostatistics for Engineers and Earth Scientists.* Springer; 1st ed. ISBN: 978-0792385233.
- Houlding (2000): *Practical Geostatistics.* Springer; ISBN: 978-3540668206.
- de Berg, van Krefeld, Overmars, Schwarzkopf (2000): *Computational Geometry - Algorithms and Applications,* 2nd edition, Springer, ISBN 3-540-65620-0
- Samet (2006): *Foundations of Multidimensional and Metric Data Structures,* Morgan Kaufmann, ISBN 0-12-369-446-9
- Duda, Hart, Stork (2001): *Pattern Classification,* 2nd edition, Wiley&Sons, ISBN 0-471-05669-3

GIS Visualisation (9 CP)

Visualisation Techniques of Spatial Data **IV 3633 L 214**

Semester: summer term **(2nd semester)**
Attendance: 3 semester periods per week

Web Cartography **IV 3633 L 237**

Semester: winter term **(3rd semester)**
Attendance: 3 semester periods per week

Module type:	Compulsory elective
Person in charge:	Prof. Kolbe, Secretariat H12, GIS@igg.tu-berlin.de
Entry requirements:	Programming skills
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Exercises (75%) • Reports, presentations and oral contribution (25%)
Workload:	Overall attendance: 15 x 6 h = 90 h Homework and post processing: 15 x 12 h = 180 h

Objectives:

The students understand the main concepts of cartography and their technical implementation for geo-visualisation. They learn to distinguish different forms of data and choose appropriate visualisation methods. This includes various forms of cartographic representation from topographic and thematic maps to advanced representations including multimedia and interactivity, also suitable for web publishing. The students work with standard software and technologies to generate classical paper maps, digital maps, and web applications in 2D and 3D.

Module elements:

Visualisation Techniques of Spatial Data **IV 3633 L 214**

Content

- Reference systems
- Elements and principles of cartographic visualisation
- Topographic & thematic maps
- Cartographic generalisation
- Cartographic information systems (e.g., ATKIS)
- Multimedia cartography
- Interaction in cartography
- Software demos: Adobe Illustrator, Macromedia Flash

Didactic concept

- Lecture (70%)
- Hands-on software training (20%)
- Supporting practical work (10%)

Web Cartography **IV 3633 L 237**

Content

- Advanced web technologies
- Expressing geometric information in web pages
- Accessing thematic content from database using internet technologies
- 1-2 of the following additional topics:
  - Modelling of 3D geo information using Autodesk 3dsMax
  - Using Google maps API
  - Web services and map servers

Didactic concept

- Lecture (10%)
- Hands-on software and programming training (70%)
- Exercise preparation and discussion (20%)

Literature:

- Kraak, Ormeling (2002): *Cartography. Visualization of Geospatial Data.* Prentice Hall; 2nd ed. ISBN: 978-0130888907.
- Morrison, Robinson, Muehrcke (1995): *Elements of cartography.* John Wiley & Sons; 6th ed. ISBN: 978-0471555797.
- Cartwright, Peterson, Gartner (2006): *Multimedia Cartography.* Springer, Berlin; 2 nd ed. ISBN: 978-3540366508.
- Kraak, Brown (2000): *Web Cartography.* Taylor & Francis Ltd; illustrated edition. ISBN: 978-0748408689.

GIS Research (3 CP)

GIS - Current and Future Research Fields **IV 3633 L 232**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective
Person in charge:	Prof. Kolbe, Secretariat H12, GIS@igg.tu-berlin.de
Entry requirements:	The modules *FOU Geoinformation Technology, FOU Geo-Databases* or previous knowledge are mandatory
Duration:	1 semester
Examination:	Study effort equivalent to the examination: • Presentation and report (85%) • Oral contribution (15%)
Workload:	Overall attendance: 15 x 2 h = 30 h Homework and post processing: 15 x 4 h = 60 h

Objectives:

The students get an insight into current research work in the field of geoinformation sciences and learn to classify already learned skills in a research context. The seminar shall motivate the students for the development of own research work for the master thesis.

Module elements:

GIS - Current and Future Research Fields **IV 3633 L 232**

Content

Topics of this seminar are based upon current or future research fields. Following thematic blocks are given as an example:

- Modeling of geospatial data
- Navigation
- Disaster management
- 3D-/4D-GIS
- Distributed Computing Environments
- GIS data interpretation

Didactic concept

- Introduction and advice (10%)
- Student presentations (70%)
- Open questions and discussions (20%)

Literature:

- depends on the actual topics and will be selected accordingly

GIS Project Seminar Geoinformation Technology (6 CP)

GIS Seminar **SE 3633 L 216**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

GIS Project **PJ 3633 L 239**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective, Compulsory for major subject
Person in charge:	Prof. Kolbe, Secretariat H12, GIS@igg.tu-berlin.de
Entry requirements:	The modules *FOU Geoinformation Technology* and *GIS Administration* resp. equivalent previous knowledge is mandatory, programming skills are required.
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Presentations, reports (50%) • Exercises (30%) • Oral contribution (20%)
Workload:	Overall attendance: 15 x 4 h = 60 h Preparation and post processing: 15 x 6 h = 90 h Project processing: 30 h

Objectives:

This module is designed to impart an advanced level of knowledge and competence to students that is specific to scientific work. The students are confronted with current research topics in the field of GIS which have to be evaluated and worked out by the students autonomously using the theoretical concepts and scientific methods acquired in the previous modules. In the GIS Project, a single, complex research task has to be dealt with by the students in project work applying project management methods and strategies. As a project deliverable, GIS software components have to be developed. By this means, the students learn how to review the theoretical concepts from a developer's perspective and are familiar with team-oriented development strategies in the geoinformation technology field. The project work and collaboration promotes social competence.

Module elements:

GIS Seminar **SE 3633 L 216**

Content

The contents of the seminar depend on the current research at the department for geodesy and geoinformation science. The following thematic blocks serve as examples.

- 3D Modeling
- 3D Object interpretation and reconstruction
- 3D Geo-databases

Didactic concept

- Introduction and assignment of topics (10%)
- Autonomous working and preparation of the topic (50%)
- Presentations and reports (40%)

GIS Project **PJ 3633 L 239**

Content

The contents of the seminar depend on the current research at the department for geodesy and geoinformation science. The following thematic blocks serve as examples.

- 3D Modeling
- 3D Object interpretation and reconstruction
- 3D Geo-databases

Didactic concept

- Lecture (comprising introduction to the project's topic and goals) (10%)
- Autonomous working within project teams (50%)
- Exercises, presentations and reports (40%)

Literature:

Literature recommendations depend on the actual contents of the module elements and are therefore provided in the corresponding courses.

GIS Selected Sections of Geoinformation Technology (3 CP)

Selected Sections of Geoinformation Technology **IV 3633 L 240**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective
Person in charge:	PD Dr. Scheu, Secretariat H12, GIS@igg.tu-berlin.de
Entry requirements:	The module *FOU Geoinformation Technology* or previous knowledge is mandatory; knowledge of geodetic reference systems and data base knowledge is desirable.
Duration:	1 semester
Examination:	Study effort equivalent to the examination: • Oral presentation and oral contribution (75%) • Homework (25%)
Workload:	Overall attendance: 15 x 2 h = 30 h Homework and post processing: 15 x 2 h = 30 h Excursion: 30 h

Objectives:

The students get a view of current operational areas of geographical information systems (e.g. local GIS). The excursions support further work on non-university projects.

Module elements:

Selected Sections of Geoinformation Technology **IV 3633 L 240**

Content

- Network information systems (public transportation, raw material companies and energy supply companies)
- Current GIS projects in offices for land surveying or local authorities
- Homogenisation of large geo data stocks
- Business models of GIS companies

Didactic concept

- Lectures (60%)
- Discussion (20%)
- Excursion (20%)

Literature:

- Shekhar, Shashi; Xiong, Hui (Eds.) : *Encyclopedia of GIS*, Springer, 2008
- Michael F. Goodchild: *Geographic Information Sxstem and Science,* Wiley & Sons, 2005
- Peter van Oosterom, Siyka Zlatanova, Elfriede M. Fendel: *Geo-information for Disaster Management,* Springer, 2005

additional literature dependent on the topics discussed

GIS Geoinformation Science I (9 CP)

Visualisation Techniques of Spatial Data **IV 3633 L 214**

Semester: summer term **(2nd semester)**
Attendance: 3 semester periods per week

Structures and Operation of Distributed Geo Data Infrastructures **IV 3633 L 235**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective (only for minor subject)
Person in charge:	Prof. Kolbe, Secretariat H12, GIS@igg.tu-berlin.de
Entry requirements:	The modules *FOU Geoinformation Technology and FOU Geo-Databases* resp. equivalent previous knowledge is mandatory, programming skills are desirable.
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Exercises (50%) • Reports, presentations and oral contribution (50%)
Workload:	Overall attendance: 15 x 5 h = 75 h Homework and post processing: 15 x 13 h = 195 h

Objectives:

Please refer to the objectives of the modules GIS Visualisation and GIS Administration.

Module elements:

Visualisation Techniques of Spatial Data **IV 3633 L 214**

Content and Didactic Concept

- Reference systems
- Elements and principles of cartographic visualisation
- Topographic & thematic maps
- Cartographic generalisation
- Cartographic information systems (e.g., ATKIS)
- Multimedia cartography
- Interaction in cartography
- Software demos: Adobe Illustrator, Macromedia Flash

Didactic concept

- Lecture (70%)
- Hands-on software training (20%)
- Supporting practical work (10%)

Structures and Operation of Distributed Geo Data Infrastructures

IV 3633 L 235

Content

- Standardisation in the field of GIS
- Service Oriented Architecture (SOA)
- Principles and technology of Web Services
- Geo data infrastructures
- OpenGIS Web Service specifications
- Meta data, data catalogues, repositories
- Interoperability, Security / Digital Rights Management
- Web Service orchestration

Didactic concept

- Lecture (70%)
- Presentations, reading groups (20%)
- Oral contribution (10%)

Literature:

- Kraak, Ormeling (2002): *Cartography. Visualization of Geospatial Data.* Prentice Hall; 2nd ed. ISBN: 978-0130888907.
- Morrison, Robinson, Muehrcke (1995): *Elements of cartography.* John Wiley & Sons; 6th ed. ISBN: 978-0471555797.
- Cartwright, Peterson, Gartner (2006): *Multimedia Cartography.* Springer, Berlin; 2 nd ed. ISBN: 978-3540366508.
- Herring, J. (2001): *The OpenGIS Abstract Specification, Topic 1: Feature Geometry (ISO 19107 Spatial Schema).* OGC Document Number 01-101.
- ISO 19109 (2005): *Geographic information — Rules for application schema*.
- Cox, S., Daisy, P., Lake, R., Portele, C., Whiteside, A. (2004): *OpenGIS Geography Markup Language (GML3),* Implementation Specification, Version 3.1.1. OGC Doc. No. 03-105r1.
- Papazoglou, M. P. (2008): *Web Services: Principles and Technology.* Prentice Hall; ISBN: 978-0321155559.
- Groot, R., McLaughlin J. (2000): *Geospatial Data Infrastructure,* Oxford University Press, ISBN 978-0198233817.

GIS Geoinformation Science II (9 CP)

Visualisation Techniques of Spatial Data **IV 3633 L 214**

Semester: summer term **(2nd semester)**
Attendance: 3 semester periods per week

Measuring Systems and Methods **IV 3633 L 211**

Semester: summer term **(2nd semester)**
Attendance: 3 semester periods per week

Module type:	Compulsory elective (only for minor subject)
Person in charge:	Prof. Kolbe, Secretariat H12, GIS@igg.tu-berlin.de
Entry requirements:	The modules *FOU Adjustment Calculation I, FOU Geoinformation Technology, FOU Introduction to Satellite Geodesy* with Geodetic Reference Systems or previous knowledge are mandatory; knowledge of a programming language is desirable
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Exercises, practical work, measurements (75%) • Reports, presentations and oral contribution (25%)
Workload:	Overall attendance: 15 x 6 h = 90 h Homework and post processing: 15 x 12 h = 180 h

Objectives:

Please refer to the objectives of the modules GIS Visualisation and GIS Collection of Geo Base Data.

Module elements:

Visualisation Techniques of Spatial Data **IV 3633 L 214**

Content

- Reference systems
- Elements and principles of cartographic visualisation
- Topographic & thematic maps
- Cartographic generalisation
- Cartographic information systems (e.g., ATKIS)
- Multimedia cartography
- Interaction in cartography
- Software demos: Adobe Illustrator, Macromedia Flash

Didactic concept

- Lecture (70%)
- Hands-on software training (20%)
- Supporting practical work (10%)

Measuring Systems and Methods **IV 3633 L 211**

Content

- Primary data entry (modern terrestrial surveying procedures, laser scanning, astronomical positioning, gravity field parameter)
- Measuring systems (Theodolite, Gravimeter, Laser Scanner, etc.)
- Valuation of measuring methods
- Valuation of differences, similarities and combination of measuring procedures
- Data quality and estimation of costs

Didactic concept

- Lecture (40%)
- Practical exercises in surveying and other measuring techniques (60%)

Literature:

- Kraak, Ormeling (2002): *Cartography. Visualization of Geospatial Data.* Prentice Hall; 2nd ed. ISBN: 978-0130888907.
- Morrison, Robinson, Muehrcke (1995): *Elements of cartography.* John Wiley & Sons; 6th ed. ISBN: 978-0471555797.
- Cartwright, Peterson, Gartner (2006): *Multimedia Cartography.* Springer, Berlin; 2 nd ed. ISBN: 978-3540366508.
- Alan, A.L. (2007): *Geospatial Surveying*. Whittles Publishing; 2nd ed. ISBN: 978-1420073461.

Space Geodesy and Navigation (SGN)

SGN Physical Geodesy (3 CP)

Physical Geodesy **IV 3633 L 217**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective
Person in charge:	Dr. Stary, Secretariat H12, SGN@igg.tu-berlin.de
Entry requirements:	*FOU Introduction to Satellite Geodesy* with Geodetic Reference Systems; Scientific programming language (Matlab, Fortran, C)
Duration:	1 semester
Examination:	Oral exam
Workload:	Overall attendance: 15 x 2 h = 30 h Homework and post processing: 15 x 2 h = 30 h Examination preparation: 30 h

Objectives:

This module teaches how to describe the gravity field of the Earth and its timely variations. The inner density structure of the Earth, as the causal property of the Earth' gravity field, is derived from gravity observations by satellites (f.e. GOCE, GRACE) or terrestrial measurements. Scientific methods and mathematical concepts for the functional description of gravity related parameters are introduced. Global Reference Systems based on the gravity potential are defined and used as a basis for the fixation of different (local or global) height systems.

Module elements:

Physical Geodesy **IV 3633 L 217**

Content

- Potential Theory
- Fundamental integral formulas (body, surface, line integral)
- Geodetic boundary value tasks
- Gravity potential by spherical harmonic functions
- Spherical potential coefficients of the gravity field of the Earth
- Theoretical and practical determination of the spherical potential coefficients
- Geodetic normal potential
- Geoid as a reference surface
- Determination of the density structure of the Earth
- Hydrostatic-isostatic density distributions
- Spectral Analysis of the gravity field of the Earth
- Interpretation of gravity anomalies and other gravity parameters

Didactic concept

- Lectures (75%)
- Exercises (25%)

Literature:

- Hofmann-Wellenhof, B., Moritz, H.: *Physical Geodesy;* Springer Verlag; ISBN 978-3-211-33544-4
- Torge, W.: *Geodesy*; de Gruyter; ISBN 978-3-11-017072-6
- Moritz, H.: *The Figure of the Earth*; ISBN 978-3-87907-220-0

SGN Geodetic Space Procedures in Earth System Research (6 CP)

Geodetic Space Procedures in the Earth System Research **IV 3633 L 241**

Semester: winter term **(3rd semester)**
Attendance: 4 semester periods per week

Module type:	Compulsory elective
Person in charge:	Prof. Galas, Secretariat H12, SGN@igg.tu-berlin.de
Entry requirements:	*FOU Introduction to Satellite Geodesy*, knowledge of GNSS technology is desirable
Duration:	1 semester
Examination:	Oral exam

Workload:

Overall attendance:	15 x	4 h	=	60 h
Preparation and post processing:	15 x	2 h	=	30 h
Homework:	15 x	3 h	=	45 h
Examination preparation:				45 h

Objectives:

After this module the students are familiar with the most important observation methods in space geodesy and how the data is analysed. They know the strengths and weaknesses of the individual techniques, how they contribute to measure the three pillars of geodesy (Earth shape, Earth rotation and Earth gravity field) and what type of phenomena and processes in the Earth system they can observe and monitor. They understand that only the integrated analysis of a variety of complementary sensors allows the separation of different processes of global change in the Earth system.

Module elements:

Geodetic Space Procedures in the Earth System Research **IV 3633 L 241**

Content

Measurement principles of the most important space- and ground-based geodetic observation techniques, namely Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser Ranging (SLR/LLR), Global Navigation Satellite Systems (GNSS, including GPS, GLONASS, GALILEO, ...), Doppler Orbitography and Radio positioning Integrated by Satellite (DORIS), ocean and ice altimetry, InSAR and gravity field satellite missions and innovative future concepts. The application of these techniques to determine the three pillars of space geodesy: the Earth's geometry and deformation (including sea surfaces), the Earth orientation and rotation, and the Earth gravity field and its temporal variations (mass transport). Methods to solve huge parameter estimation problems and for time series analyses are explained and applied. Estimation/monitoring of station motion and surface deformation. Models of the processes deforming the Earth's surface like plate tectonics, post-glacial rebound, solid Earth tides, surface loads (ocean, atmosphere, ice, ...). Importance of deformation measurements for natural hazards and early warning systems (deformation by earthquakes, GNSS seismology, land slides, sea level change, volcano monitoring, subsidence).

Methods to determine the global gravity field of the Earth and its temporal variability including satellite to satellite tracking (SST; high-low, low-low), satellite gravity gradiometry (SGG) and altimetry. Orbit determination methods. Static gravity field as reference surface (Geoid) and information about the structures and processes in the Earth‘s interior; the temporal variations to monitor mass transport phenomena (global hydrology, sea level change, melting of ice sheets, post-glacial rebound, ...).

Geodetic and geophysical models of the Earth orientation and rotation including effects of

Sun, Moon and planets, and of the different components of the Earth system like ocean, atmosphere, hydrosphere, ...). Comparisons with observed Earth orientation parameters series.

GNSS remote sensing comprising atmospheric sounding from ground and space (radio occultations), determination of water vapor in the troposphere and the electron density in the ionosphere. GNSS reflectometry and scatterometry. Importance for meteorology, weather forecasts and climatology.

Didactic concept

- Lectures (70%)
- Exercises (20%)
- Discussions (10%)

Literature:

- G. Seeber (2003). *Satellite Geodesy.* de Gruyter. Berlin.
- R. Rummel, H. Drewes, W. Bosch, H. Hornik (Eds.) (1998). *Towards an Integrated Global Geodetic Observing System* (IGGOS).

SGN Planetary Geodesy (6 CP)

Geodetic Methods in Planetary Research **IV 3633 L 218**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Selected Topics in Planetary Science **IV 3633 L 230**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective				
Person in charge:	Prof. Oberst, Secretariat H12, SGN@igg.tu-berlin.de				
Entry requirements:	Module *SGN Physical Geodesy* or equivalent (mandatory), good knowledge in mathematics and physics are desirable				
Duration:	2 semesters				
Examination:	Oral exam				
Workload:	Overall attendance:	15 x	4 h	=	60 h
	Preparation and post processing:	15 x	1 h	=	15 h
	Homework:	15 x	4 h	=	60 h
	Examination preparation:				45 h

Objectives:

The goal of this module is to give students good working knowledge on the architecture and dynamics of the Solar System and to familiarize them with science goals, methods, and current results of planetary research. In particular, the students are to obtain insights in the current state and acting processes of the planets, moons, asteroids, and comets. The course is strongly focused, but not limited to planetary geodesy and planetary geophysics.

Module elements:

Geodetic Methods in Planetary Research **IV 3633 L 218**

Content

This course will begin to give a thorough overview of the architecture of the Solar System and to will continue to discuss the various methods that are being used to determine orbit, size, shape, and rotation of planetary bodies and to map their surface topography and gravity fields. We shall discuss in some depth the basic tools used in planetary geodesy such as cameras, laser altimeters, and radar. One focus is on photogrammetric procedures for construction of local or global topographic models from stereo data. We shall discuss methods for analysis of data obtained from orbit or from the ground using cameras on landed spacecraft or on rovers roaming the surface. We shall also deal with the development and use of planetary information systems and visualisation techniques.

Didactic concept

- Course Material (60%)
- Reading (20%)
- Home Work (20%)

Selected Topics in Planetary Science **IV 3633 L 230**

Content

This course will deal with the developing knowledge of origin, evolution, and current state of Solar System planets, moons, asteroids, and comets. We shall closely follow any progress that is being made in ongoing planetary missions (e.g. Mars Express, Cassini, MESSENGER, Rosetta, DAWN), and we will discuss science goals and design issues of future planetary missions (Lunar Reconnaissance Orbiter, Marco Polo, ExoMars, BepiColombo). While we shall focus on results in the context of planetary geodesy, the course work may include other selected topics from planetary geophysics and geology. Emphasis will be placed on the understanding of current publications in planetary science and in the development of (English) reading, presentation, and writing skills.

Didactic concept

- Course Material (60%)
- Reading and Seminars (20%)
- Practical Programming Exercise (20%)

Literature:

- Holger Heuseler, Ralf Jaumann, und Gerhard Neukum: *Zwischen Sonne und Pluto,* BLV Verlagsgesellschaft mbH, 2000
- Frank Stacey und Paul Davis: *Physics of the Earth,* Cambridge Univ Press, 2008

SGN Global Navigation Satellite Systems (GNSS) (9 CP)

Mathematical Geodesy **IV 3633 L 219**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Methodology of the Positioning and Navigation with GNSS **VL 3633 L 243**
UE 3633 L 244

Semester: winter term **(3rd semester)**
Attendance: 4 semester periods per week (2h lecture and 2h exercise)

Module type:	Compulsory elective
Person in charge:	Prof. Galas, Secretariat H12, SGN@igg.tu-berlin.de
Entry requirements:	*FOU Adjustment Calculation I, FOU Introduction to Satellite Geodesy*with Geodetic Reference Systems
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Exercises (50%) • Oral consultation (50%)
Workload:	Overall attendance: 15 x 6 h = 90 h Homework and post processing: 15 x 12 h = 180 h

Objectives:

After this module the students have a detailed knowledge of the Global Navigation Satellite Systems (GNSS) that are operational today and planned for the future: The mathematical and scientific strategies for positioning and navigation and the effects important for the error budget in navigation and positioning solutions are understood and can be applied to new scenarios.

Regarding Mathematical Geodesy, the students will learn about different aspects of Differential Geometry and the Theory of Functions.

Module elements:

Mathematical Geodesy **IV 3633 L 219**

Content

- Differential Geometry: Space Curves (Representation, Curvature, Torsion, Moving Trihedron), Curved Surfaces (Surface Theory, Normal Sections and Geodesics on Ellipsoids of Revolution), Space Geometry
- Geodesy: Earth Dimensions, Main Geodetic Problems, Coordinate Systems (Gauß, Soldner and other) and its Transformations, Mappings (conformal, equidistant) and its Kinematic Interpretation
- Theory of Functions: Complex Approach, Cauchy-Riemann Differential Equations, Transformations of the Element of Arc and the Metric Tensor

Didactic Concept

- Lecture (80%)
- Discussions (20%)

Methodology of the Positioning and Navigation with GNSS **VL 3633 L 243**
UE 3633 L 244

Content

Motivation: why Global Navigation Satellite Systems (GNSS: GPS, GLONASS, Galileo, BEIDOU, ...)? The space- and ground-based components of GNSS. Signal structures of the GNSS and the differences between them. Time- and reference systems for GNSS and their realizations. Principles of code and phase measurements. Observation equations for phase and code and the basic algorithms for positioning. Differencing and linear combinations of observations. Satellite orbits and their representation. Impact of atmospheric refraction (ionosphere and troposphere). Site specific effects (antenna phase centre variations, multipath, etc.). Positioning and navigation methods and approaches (PPP, differential positioning, kinematic/static, …); pre-processing algorithms. Ambiguity resolution methods. Reference networks and positioning services. SAPOS. Wide- and Local Augmentation Systems.

Didactic concept

- Lecture (70%)
- Tutorials (20%)
- Projects (10%)

Literature:

- David Wells (1996). *Guide to GPS Positioning.* Canadian GPS Associates
- P.J.G. Teunissen, A. Kleusberg (Eds.) (1998). *GPS for Geodesy.* Springer.
- B. Hofmann-Wellenhof, H. Lichtenegger, J. Collins. (1994). *Global Positioning System.* Springer Verlag Wien New York
- A. Leick (1995). *GPS Satellite Surveying. (Second edition).* Willey-Interscience
- G. Strang, K. Borre (1997). *Linear Algebra, Geodesy and GPS.* Wellesley-Cambridge Press.
- E.D. Kaplan, C.J. Hegarty (2006). *Understanding GPS. Principles and Applications.* Artech House.
- A. Leick (2004). *GPS Satellite Surveying*. 3rd Edition. Wiley.
- Dirk. J. Struik (1988). *Lectures on Classical Differential Geometry*. Dover.
- A. Gray (2006). *Modern Differential Geometry of Curves and Surfaces with Mathematica.* CRC Press.

SGN Calculation of Satellite Orbits (3 CP)

Calculation of Satellite Orbits **IV 3633 L 245**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective
Person in charge:	Dr. Mai, Secretariat H12, SGN@igg.tu-berlin.de
Entry requirements:	The module *SGN Physical Geodesy* is strongly recommended; previous knowledge of general analytical and numerical integration techniques is mandatory; knowledge of a programming language is desirable.
Duration:	1 semester
Examination:	Oral exam
Workload:	Overall attendance: 15 x 2 h = 30 h Post processing: 15 x 2 h = 30 h Examination preparation: 30 h

Objectives:

The goal of this module is to familiarize the students with the basic concepts of celestial mechanics and how to apply these to calculate satellite orbits. Integration methods for the computation of satellite orbits provide the basis for the evaluation of time series of highly exact measuring data, in the time domain as well as in the spectral domain, for the positioning as well as for the collection of the geodynamic changes of the Earth's surface.

Module elements:

Calculation of Satellite Orbits **IV 3633 L 245**

Content

- Fundamentals of Celestial Mechanics (Kepler's laws, Newton's laws)
- 1-body Problem, Conic Sections, 2-body Problem, Kepler's Equation
- Orbital Elements; Properties and Transformations
- Perturbing Forces (conservative and dissipative) and its Modelling
- Perturbation Techniques (special vs. general approaches)
- Integration of the Equations of Motion (numerical, analytical)
- Specialized Mission Orbits (sun-synchronous, repeat-groundtrack, frozen)
- Orbital Maneuvers (transfers, rendezvous, relative motion)

Didactic concept

- Lecture (80%)
- Discussions, Q&A (20%)

Literature:

- Kaula, W.M. (1966): *Theory of Satellite Geodesy*. (reprint) Blaisdell Publishing Company; ISBN 0486414655
- Vallado, D.A. (2004): *Fundamentals of Astrodynamics and Applications*. (2nd ed.) Microcosm Press & Kluwer Academic Publishers; ISBN 0792369033
- Montenbruck, O., Gill, E. (2005): *Satellite Orbits*. (3rd printing) Springer; ISBN 354067280X

SGN Current and Future Methods of Navigation and Positioning (6 CP)

Selected Sections of Navigation and Positioning **IV 3633 L 220**

Semester: summer term **(2nd semester)**
Attendance: 4 semester periods per week

Module type:	Compulsory elective
Person in charge:	Prof. Galas, Secretariat H12, SGN@igg.tu-berlin.de
Entry requirements:	Module *FOU Adjustment Calculation I*, Knowledge of Satellite Orbit Calculation is desirable
Duration:	1 semester
Examination:	Oral exam
Workload:	Overall attendance: 15 x 4 h = 60 h Preparation and post processing: 15 x 6 h = 90 h Examination preparation: 30 h

Objectives:

After this module the students control scientific methods of different navigation and positioning systems, e.g. celestial navigation, inertial navigation systems, satellite navigation systems, navigation with radio waves, WiFi positioning. The students learn from current examples of research and industry the applications and potential of precision of different sensor types. Current fields of research and future developments of navigation and positioning are pointed out

Module elements:

Selected Sections of Navigation and Positioning **IV 3633 L 220**

Content

Optical celestial navigation: Formulas of spherical trigonometry. Terrestrial latitude and longitude. Celestial co-ordinate systems: right ascension system, hour angle system, ecliptic system, horizon system. Sideral and solar time. Conversion between time scales. Navigation triangle. Determination of geographical latitude and time.

Satellite based navigation techniques: General methodology of navigation with radio waves. Principles of satellite based positioning. Pseudo-random codes and their measurements. Generation of the GPS signals. Navigation messages. Measurements of the code and carrier phases. GNSS receivers. GNSS biases and error sources. Signal propagation errors. Data processing errors. Simplified range model. Single-, double- and triple differences of observations. Constrain of simultaneity. Influence of non-synchronous clocks. Non-linear observation equations. Range formulation of the carrier beat phase model. Linear combination of observations. GPS data pre-processing. Data quality monitoring. Main segments of the GPS. International GNSS service (IGS). GNSS single point positioning algorithms. Relative positioning. Carrier phase ambiguity fixing. GPS wide- and local area augmentation services. Theory and various approaches for differential GNSS. DGPS services. SAPOS. Post Processing Kinematic (PPK)- and Real Time Kinematic (RTK) techniques. Positioning in large GNSS networks. Other past, current and future satellite based navigation systems (PRARE, DORIS, GLONASS, Galileo, ...). Regional satellite navigation systems.

Inertial navigation: Sensor types (accelerometers, gyroscopes) and observables. Navigation equations.

Integrated navigation: Basics of Kalman filter. Sensor fusion. Examples of multi-sensor systems (Integrated GPS/INS, ocean buoys equipped with GPS, etc.). Multi-sensor systems for machine guidance and control. Integrated GPS/WiFi real-time positioning.

Radio astrometry methods of navigation: Connected interferometry. Very long baseline interferometry (VLBI). Differential VLBI for spacecraft navigation.

Didactic concept

- Lectures (70%)
- Tutorials (20%)
- Discussions (10%)

Literature:

- Mueller (1977). Spherical and Practical Astronomy as Applied to Geodesy. Frederic Ungar Publishing. New York.
- Leick (1995). *GPS Satellite Surveying.* (Second edition). Willey-Interscience
- Hofmann-Wellenhof, K. Legat, M. Wieser. (2003). *Navigation. Principles of Positioning and Guidance.* Springer Verlag Wien.
- Hofmann-Wellenhof, K. Legat, E. Wasle. (2003). *Navigation. Principles of Positioning and Guidance (2008)*. GNSS - Global Navigation Satellite Systems. Springer Wien New York.
- Leick (2004). *GPS Satellite Surveying* (3rd edition). Wiley.
- P. D. Groves (2008). Principles of GNSS, Inertial and Multisensor Integrated Navigation Systems. Artech House
- Jekeli (2001). Inertial Navigation Systems with Geodetic Applications. Walter de Gruyter, Berlin

SGN Data Communication and Signal Processing in GNSS (3 CP)

GNSS Signal Processing and Real Time Positioning **IV 3633 L 246**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective				
Person in charge:	Prof. Galas, Secretariat H12, SGN@igg.tu-berlin.de				
Entry requirements:	Knowledge of maths and computing skills are desirable.				
Duration:	1 semester				
Examination:	Oral exam				
Workload:	Overall attendance:	15 x	2 h	=	30 h
	Preparation and post processing:	15 x	2 h	=	30 h
	Examination preparation:				30 h

Objectives:

After this module the students control scientific methods of data communication and signal evaluation in global navigation satellite systems. Current fields of research and future developments of data communication and evaluation of GNSS data are pointed out.

Module elements:

GNSS Signal Processing and Real Time Positioning **IV 3633 L 246**

Content

Digital data communication: Requirements. Twisted/coaxial cables. Optical fibres. Radio transmission and packet radio. Public telephone network and GSM. Satellite communication technologies: Inmarsat services (for example Inmarsat A, B, BGAN), VSAT systems. Public Internet. Data transmission bandwidth of the above data links and protocols. Synchronous and asynchronous transmission. Serial interfaces. Communication networks. Ad-hock sensor networks.

GNSS navigation signals in space (SIS): Electromagnetic wave propagation. Atmospheric and environmental influences on propagation of radio waves. Generation of navigation signals. Code generation techniques. Carrier generation. Representation of bandpass signals. Digital data transmission. Modulation techniques. Spread-spectrum communication. Mulitplexing. Signal structures of GPS, GLONASS and GALILEO. Pseudolits. Doppler effect on SIS. Simple simulations of GNSS signals. Primary GNSS measurements.

GNSS antennas and RF front ends: Antenna types. Antenna phase centre variations. Calibrations. Amplifiers and analogue/digital (A/D) converters. RF front ends.

Relative real time positioning: System components. Communication between processing units and sensors (real time data loggers, serial interfaces, protocols, binary data streams). Generation of GNSS differential corrections. Real time dissemination of observations, corrections and orbits. Numerical algorithms. advanced ambiguity fixing strategies. Constrained solutions. Virtual reference stations approach. Network RTK. Practical examples.

Didactic concept

- Lectures (75%)
- Exercises (20%)
- Demonstrations, discussions (5%)

Literature:

- Ray Horal (2007). *Telecommunication and data communications handbook*. Wiley-Interscience.
- E. Del Re, M. Ruggieri (Eds.) (2008). *Satellite Communications and Navigation Systems.* Springer.
- Raja Jurdak (2007*). Wireless Ad Hoc and Sensor Networks*. Springer.
- Kai Borre, Dennis M. Akos, Nicolaj Bertelsen, Peter Rinder, Soren Holdt Jensen, (2007). *A Software-Defined GPS and Galileo Receiver. A Single-Frequency Approach.*
- James Bao-Yen Tsui (2008). *Fundamentals of Global Positioning System Receivers*. A Software Approach. Wiley-Interscience.

SGN Geoscientific Aspects of Geodesy (3 CP)

Geoscientific Aspects of Geodesy **IV 3633 L 299**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective				
Person in charge:	PD Dr. Klotz, Secretariat H12, SGN@igg.tu-berlin.de				
Entry requirements:	The allocation of other modules from specialised subject space geodesy and navigation is desirable				
Duration:	1 semester				
Examination:	Oral exam				
Workload:	Overall attendance:	15 x	2 h	=	30 h
	Homework and post processing:	15 x	2 h	=	30 h
	Examination preparation:				30 h

Objectives:

The participants will learn the current geoscientific research project with special emphasis on geodetic methods.

Module elements:

Geoscientific Aspects of Geodesy **IV 3633 L 299**

Content

Basics of geodynamic:

- plate tectonics, deformation zones of the Earth, geological and geophysical methods
- Geodetic deformation measurement:
- Overview, challenges, methods, current projects

GPS networks for geodynamic investigation:

- Reconnaissance, network setup, monumentation, observations, Definition of geodetic reference systems

Interpretation of observed deformation:

- short-term deformation, Earthquake processes, models, seismic risk
- long-term deformation, mountain building processes, models, estimation of rheological parameters

Didactic concept

- Lectures (70%)
- Attendance (30%)

Literature:

- To be announced

SGN Planetary and Space Science Seminar (6 CP)

Planetary and Space Science Seminar **SE 3633 L 222**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Planetary and Space Science Project **PJ 3633 L 247**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective, Compulsory for major subject
Person in charge:	Dr. Oberst, Secretariat H12, SGN@igg.tu-berlin.de
Entry requirements:	The module *SGN Physical Geodesy* or previous knowledge is mandatory; other modules from the specialised subject space geodesy and navigation are desirable.
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Oral presentation (70%) • Written report (30%)
Workload:	Overall attendance: 15 x 4 h = 60 h Preparation and post processing: 15 x 8 h = 120 h

Objectives:

This module enables the students to carry out scientific research, and it supports the social work competence within a team. The students are confronted with the full complexity of current research issues in the wider context of "space geodesy and navigation" and will receive an overview of current research projects as well as currently used geodetic methods in Earth system- and planetary research by the international science community. Here, an important goal is to familiarize the students with current literature and publications in planetary and space geodesy. This module encourages students to identify small and confined research projects and carry out structured work under tight schedule – which shall lead to highly qualified master thesis work later in the curriculum.

Content:

The students will focus on specific problems from current research at the department for geodesy and geoinformation technology and will work independently or in small groups. Written reports shall be delivered and oral presentations to the entire group shall be made. Also, during the semester, guest lecturers will be invited to contribute with presentations from the various fields of space geodesy and navigation and from topics beyond.

The content of the module comes from basically three different areas:

1. Planetary Science: Data from ESA's Mars Express mission has given planetary scientists new insights into the history and current state of the Red Planet. Other spacecraft on their way or to be launched in the near future include Rosetta and DAWN (which will be visiting comets and asteroids), MESSENGER and BepiColombo (which will explore Mercury) and several orbiter missions to the Moon. The seminar will introduce students to the status of ongoing missions and hot topics in planetary science and exploration. Concepts for the acquisition and evaluation of sensor data will be discussed as well as methods for modelling of spacecraft or planetary satellite motion. Possible other seminar contributions from a wide

range of topics include the current search for extrasolar Earth-like planets, the exploration and hability of our Moon and other planets, the risk and environmental consequences of asteroid impacts on Earth, as well as the role of space travel for society and future generations.

2. Navigation and Locating: At present the focus is on the announced modifications of the American GPS system as well as the European navigation system GALILEO which is in preparation. Procedures of precision navigation for engineering tasks (automated construction machines, city and land surveying for geo information purposes, navigation of measuring airplanes) are worldwide in development. At present a current development is the combination of highly exact gyroscope systems (laser gyroscope, helium gyroscope) with Accelerometer to inertial navigation systems and their linkage with satellite navigation systems. Furthermore current developments are discussed on the area of vehicle navigation and the "location based services".

3. Earth System Research: At present the focus of Earth system research is on the gravity field missions GRACE and GOCE, as well as on altimeter missions, such as Envisat, Ice Sat, and others, which collect information on the condition of the physical system earth and the atmosphere. However, topics of the seminar may also include unusual science issues of great social significance, such as ocean monitoring for Tsunami detection, studies of global warming and pollution, as well as traffic surveillance and observations for military security. Unusual science issues may require alternative sensor systems and measurement techniques, some of which are in fact currently under discussion or development. The students will obtain an overview of the present science objectives and methods used in Earth system research by space agencies and science communities worldwide which constitutes a basis for successful master work.

Module elements:

Planetary and Space Science Seminar	**SE 3633 L 222**

Didactic concept

- Oral Presentation (50%)
- Discussion in Groups (25%)
- Report (25%)

Planetary and Space Science Project	**PJ 3633 L 247**

Didactic concept

- Project Work (70%)
- Written report (30%)

Literature:

- To be defined according to the chosen topic

SGN Space Geodesy and Navigation I (9 CP)

Physical Geodesy **IV 3633 L 217**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Selected Sections of Navigation and Positioning **IV 3633 L 220**

Semester: summer term **(2nd semester)**
Attendance: 4 semester periods per week

Module type:	Compulsory elective (only for minor subject)				
Person in charge:	Prof. Galas, Dr. Stary Secretariat H12, SGN@igg.tu-berlin.de				
Entry requirements:	Programming skills				
Duration:	1 semester				
Examination:	Oral exam				
Workload:	Overall attendance: Homework and post processing:	15 x 6 h 15 x 12 h	=	90 h 180 h	

Objectives:

This module teaches how to describe the gravity field of the Earth and its timely variations. Scientific methods and mathematical concepts for the functional description of gravity related parameters are introduced. After this module the students control scientific methods of different navigation and positioning systems, e.g. celestial navigation, inertial navigation systems, satellite navigation systems, navigation with radio waves, WiFi positioning. Current fields of research and future developments of navigation and positioning are pointed out.

Module elements:

Physical Geodesy **IV 3633 L 217**

Content

- Potential Theory
- Fundamental integral formulas (body, surface, line integral)
- Geodetic boundary value tasks
- Gravity potential by spherical harmonic functions
- Spherical potential coefficients of the gravity field of the Earth
- Theoretical and practical determination of the spherical potential coefficients
- Geodetic normal potential
- Geoid as a reference surface
- Determination of the density structure of the Earth
- Hydrostatic-isostatic density distributions
- Spectral Analysis of the gravity field of the Earth
- Interpretation of gravity anomalies and other gravity parameters

Didactic concept

- Lectures (75%)
- Exercises (25%)

Selected Sections of Navigation and Positioning **IV 3633 L 220**

Content

Optical celestial navigation: Formulas of spherical trigonometry. Terrestrial latitude and longitude. Celestial co-ordinate systems: right ascension system, hour angle system, ecliptic system, horizon system. Sideral and solar time. Conversion between time scales. Navigation triangle. Determination of geographical latitude and time.

Satellite based navigation techniques: General methodology of navigation with radio waves. Principles of satellite based positioning. Pseudo-random codes and their measurements. Generation of the GPS signals. Navigation messages. Measurements of the code and carrier phases. GNSS receivers. GNSS biases and error sources. Signal propagation errors. Data processing errors. Simplified range model. Single-, double- and triple differences of observations. Constrain of simultaneity. Influence of non-synchronous clocks. Non-linear observation equations. Range formulation of the carrier beat phase model. Linear combination of observations. GPS data pre-processing. Data quality monitoring. Main segments of the GPS. International GNSS service (IGS). GNSS single point positioning algorithms. Relative positioning. Carrier phase ambiguity fixing. GPS wide- and local area augmentation services. Theory and various approaches for differential GNSS. DGPS services. SAPOS. Post Processing Kinematic (PPK)- and Real Time Kinematic (RTK) techniques. Positioning in large GNSS networks. Other past, current and future satellite based navigation systems (PRARE, DORIS, GLONASS, Galileo, ...). Regional satellite navigation systems.

Inertial navigation: Sensor types (accelerometers, gyroscopes) and observables. Navigation equations.

Integrated navigation: Basics of Kalman filter. Sensor fusion. Examples of multi-sensor systems (Integrated GPS/INS, ocean buoys equipped with GPS, etc.). Multi-sensor systems for machine guidance and control. Integrated GPS/WiFi real-time positioning.

Radio astrometry methods of navigation: Connected interferometry. Very long baseline interferometry (VLBI). Differential VLBI for spacecraft navigation.

Didactic Concept

- Lectures (70%)
- Tutorials (20%)
- Discussions (10%)

Literature:

- Hofmann-Wellenhof, B., Moritz, H.: *Physical Geodesy;* Springer Verlag; ISBN 978-3-211-33544-4
- Torge, W.: *Geodesy*; de Gruyter; ISBN 978-3-11-017072-6
- Moritz, H.: *The Figure of the Earth*; ISBN 978-3-87907-220-0
- Mueller (1977). Spherical and Practical Astronomy as Applied to Geodesy. Frederic Ungar Publishing. New York.
- Leick (1995). *GPS Satellite Surveying.* (Second edition). Willey-Interscience
- Hofmann-Wellenhof, K. Legat, E. Wasle. (2003). Navigation. Principles of Positioning and Guidance (2008). GNSS - Global Navigation Satellite Systems. Springer Wien New York.
- Leick (2004). *GPS Satellite Surveying* (3rd edition). Wiley.
- P. D. Groves (2008). Principles of GNSS, Inertial and Multisensor Integrated Navigation Systems. Artech House
- Jekeli (2001). Inertial Navigation Systems with Geodetic Applications. Walter de Gruyter, Berlin

SGN Space Geodesy and Navigation II (9 CP)

Geodetic Methods in Planetary Research **IV 3633 L 218**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Selected Topics in Planetary Science **IV 3633 L 230**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Geoscientific Aspects of Geodesy **IV 3633 L 299**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective (only for minor subject)			
Person in charge:	Prof. Oberst, PD Dr. Klotz, Secretariat H12, SGN@igg.tu-berlin.de			
Entry requirements:	Good knowledge in mathematics and physics are desirable			
Duration:	2 semesters			
Examination:	Oral exam			
Workload:	Overall attendance:	15 x 6 h	=	90 h
	Preparation, post processing and homework:	15 x 6 h	=	90 h
	Examination preparation:			90 h

Objectives:

The goal of this module is to give students good working knowledge on the architecture and dynamics of the Solar System and to familiarize them with science goals, methods, and current results of planetary research. In particular, the students are to obtain insights in the current state and acting processes of the planets, moons, asteroids, and comets. The course is strongly focused, but not limited to planetary geodesy and planetary geophysics. The participants will learn the current geoscientific research project with special emphasis on geodetic methods.

Module elements:

Geodetic Methods in Planetary Research **IV 3633 L 218**

Content

This course will begin to give a thorough overview of the architecture of the Solar System and to will continue to discuss the various methods that are being used to determine orbit, size, shape, and rotation of planetary bodies and to map their surface topography and gravity fields. We shall discuss in some depth the basic tools used in planetary geodesy such as cameras, laser altimeters, and radar. One focus is on photogrammetric procedures for construction of local or global topographic models from stereo data. We shall discuss methods for analysis of data obtained from orbit or from the ground using cameras on landed spacecraft or on rovers roaming the surface. We shall also deal with the development and use of planetary information systems and visualisation techniques.

Selected Topics in Planetary Science **IV 3633 L 230**

Content

This course will deal with the developing knowledge of origin, evolution, and current state of Solar System planets, moons, asteroids, and comets. We shall closely follow any progress that is being made in ongoing planetary missions (e.g. Mars Express, Cassini, MESSENGER, Rosetta, DAWN), and we will discuss science goals and design issues of future planetary missions (Lunar Reconnaissance Orbiter, Marco Polo, ExoMars, BepiColombo). While we shall focus on results in the context of planetary geodesy, the course work may include other selected topics from planetary geophysics and geology. Emphasis will be placed on the understanding of current publications in planetary science and in the development of (English) reading, presentation, and writing skills.

Geoscientific Aspects of Geodesy **IV 3633 L 299**

Content

Basics of geodynamic:

- plate tectonics, deformation zones of the Earth, geological and geophysical methods
- Geodetic deformation measurement:
- Overview, challenges, methods, current projects

GPS networks for geodynamic investigation:

- Reconnaissance, network setup, monumentation, observations, Definition of geodetic reference systems

Interpretation of observed deformation:

- short-term deformation, Earthquake processes, models, seismic risk
- long-term deformation, mountain building processes, models, estimation of rheological parameters

Didactic concept for all courses

- Course Material (60%)
- Reading (20%)
- Home Work (20%)

Literature:

- Holger Heuseler, Ralf Jaumann, und Gerhard Neukum: *Zwischen Sonne und Pluto,* BLV Verlagsgesellschaft mbH, 2000
- Frank Stacey und Paul Davis: *Physics of the Earth,* Cambridge Univ Press, 2008

SGN Space Geodesy and Navigation III (9 CP)

Methodology of the Positioning and Navigation with GNSS **VL 3633 L 243**
UE 3633 L 244

Semester: winter term **(3rd semester)**
Attendance: 4 semester periods per week (2h lecture and 2h exercise)

Geodetic Space Procedures in the Earth System Research **IV 3633 L 241**

Semester: winter term **(3rd semester)**
Attendance: 4 semester periods per week

Module type:	Compulsory elective (only for minor subject)
Person in charge:	Prof. Galas, Secretariat H12, SGN@igg.tu-berlin.de
Entry requirements:	*FOU Adjustment Calculation I, FOU Introduction to Satellite Geodesy,* Programming skills
Duration:	1 semester
Examination:	Oral exam
Workload:	Overall attendance: 15 x 8 h = 120 h Homework and post processing: 15 x 10 h = 150 h

Objectives:

After this module the students have a detailed knowledge of the Global Navigation Satellite Systems (GNSS) that are operational today and planned for the future: The mathematical and scientific strategies for positioning and navigation and the effects important for the error budget in navigation and positioning solutions are understood and can be applied to new scenarios.

Regarding Mathematical Geodesy, the students will learn about different aspects of Differential Geometry and the Theory of Functions.

Module elements:

Methodology of the Positioning and Navigation with GNSS **VL 3633 L 243**
UE 3633 L 244

Content

Motivation: why Global Navigation Satellite Systems (GNSS: GPS, GLONASS, Galileo, BEIDOU, ...)? The space- and ground-based components of GNSS. Signal structures of the GNSS and the differences between them. Time- and reference systems for GNSS and their realizations. Principles of code and phase measurements. Observation equations for phase and code and the basic algorithms for positioning. Differencing and linear combinations of observations. Satellite orbits and their representation. Impact of atmospheric refraction (ionosphere and troposphere). Site specific effects (antenna phase centre variations, multipath, etc.). Positioning and navigation methods and approaches (PPP, differential positioning, kinematic/static, ...); pre-processing algorithms. Ambiguity resolution methods. Reference networks and positioning services. SAPOS. Wide- and Local Augmentation Systems.

Didactic concept

- Lecture (70%)
- Tutorials (20%)
- Projects (10%)

Geodetic Space Procedures in the Earth System Research **IV 3633 L 241**

Content

Measurement principles of the most important space- and ground-based geodetic observation techniques, namely Very Long Baseline Interferometry (VLBI), Satellite and Lunar Laser Ranging (SLR/LLR), Global Navigation Satellite Systems (GNSS, including GPS, GLONASS, GALILEO, …), Doppler Orbitography and Radio positioning Integrated by Satellite (DORIS), ocean and ice altimetry, InSAR and gravity field satellite missions and innovative future concepts. The application of these techniques to determine the three pillars of space geodesy: the Earth's geometry and deformation (including sea surfaces), the Earth orientation and rotation, and the Earth gravity field and its temporal variations (mass transport). Methods to solve huge parameter estimation problems and for time series analyses are explained and applied. Estimation/monitoring of station motion and surface deformation. Models of the processes deforming the Earth's surface like plate tectonics, post-glacial rebound, solid Earth tides, surface loads (ocean, atmosphere, ice, ...). Importance of deformation measurements for natural hazards and early warning systems (deformation by earthquakes, GNSS seismology, land slides, sea level change, volcano monitoring, subsidence).

Methods to determine the global gravity field of the Earth and its temporal variability including satellite to satellite tracking (SST; high-low, low-low), satellite gravity gradiometry (SGG) and altimetry. Orbit determination methods. Static gravity field as reference surface (geoid) and information about the structures and processes in the Earth's interior; the temporal variations to monitor mass transport phenomena (global hydrology, sea level change, melting of ice sheets, post-glacial rebound, ...).

Geodetic and geophysical models of the Earth orientation and rotation including effects of

Sun, Moon and planets, and of the different components of the Earth system like ocean, atmosphere, hydrosphere, ...). Comparisons with observed Earth orientation parameters series.

GNSS remote sensing comprising atmospheric sounding from ground and space (radio occultations), determination of water vapor in the troposphere and the electron density in the ionosphere. GNSS reflectometry and scatterometry. Importance for meteorology, weather forecasts and climatology.

Didactic Concept

- Lectures (70%)
- Exercises (20%)
- Discussions (10%)

Literature:

- David Wells (1996). *Guide to GPS Positioning.* Canadian GPS Associates
- P.J.G. Teunissen, A. Kleusberg (Eds.) (1998). *GPS for Geodesy.* Springer.
- B. Hofmann-Wellenhof, H. Lichtenegger, J. Collins. (1994). *Global Positioning System.* Springer Verlag Wien New York
- A. Leick (1995). *GPS Satellite Surveying. (Second edition).* Willey-Interscience
- G. Strang, K. Borre (1997). *Linear Algebra, Geodesy and GPS.* Wellesley-Cambridge Press.
- E.D. Kaplan, C.J. Hegarty (2006). *Understanding GPS. Principles and Applications.* Artech House.
- A. Leick (2004). *GPS Satellite Surveying*. 3rd Edition. Wiley.
- G. Seeber (2003). *Satellite Geodesy*. de Gruyter. Berlin.
- R. Rummel, H. Drewes, W. Bosch, H. Hornik (Eds.) (1998). *Towards an Integrated Global Geodetic Observing System (IGGOS)*.

SGN Theoretical Basics of Geophysical Investigations (3 CP - 12 CP)

(offered by the Department of Applied Geosciences)

Mathematical Methods of Geophysics **IV 0632 L407**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week (1 h lecture and 1 h exercise)

Theory of Seismics **IV 0632 L408**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week (1 h lecture and 1 h exercise)

Theory of Geo Electricity and Electro-Magnetic **IV 0632 L409**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week (1 h lecture and 1 h exercise)

Theory of Gravimetry, Magnetic and Geothermal Power **IV 0632 L410**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week (1 h lecture and 1 h exercise)

Module type:	Compulsory elective (3 ECTS-Credits each course)
Person in charge:	N.N., Secretariat ACK 2, SGN@igg.tu-berlin.de
Entry requirements:	The module *FOU Geophysical Investigations of Geo Technologies* is mandatory; extensive knowledge of mathematical and physical basics is desirable
Duration:	1 semester
Examination:	Oral exam

Workload each course:

Overall attendance:	15 x	2 h	= 30 h
Homework:	15 x	2 h	= 30 h
Preparation and post processing:			15 h
Examination preparation:			15 h

Objectives:

Understanding of theoretical basics of geophysical methods; The ability to evaluate possibilities and limits of methods due to the theory; The ability to utilise potencials and advanced methods.

Module elements:

Content

- Mathematical methods of geophysics
- Theory of seismics
- Theory of geo electricity and electro - magnetic
- Theory of gravimetry, magnetic and geothermal power

Didactic concept

- Lectures (50%)
- Exercises (50%)

Literature:

- Telford, W. M., Geldart, L. P., Sheriff, R. E., 1990, *Applied Geophysics* (2. ed), Cambridge University Press
- Militzer, H., Weber, F., (Hrsg), 1985, *Angewandte Geophysik, Band 1, Gravimetrie und Magnetik*, Springer Verlag
- Militzer, H., Weber, F., (Hrsg), 1985*, Angewandte Geophysik, Band 2, Geoelektrik, Geothermik, Radiometrie, Aerogeophysik*, Springer Verlag
- Militzer, H., Weber, F., (Hrsg), 1985*, Angewandte Geophysik, Band 3, Seismik*, Springer Verlag

SGN Inversion and Filter of Applied Geophysics (3 CP - 6 CP)

(offered by the Department of Applied Geosciences)

Data Processing and Filter in Geophysics

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week (1 h lecture and 1 h exercise)

Inversion and Modelling in Geophysics

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week (1 h lecture and 1 h exercise)

Module type: Compulsory elective (3 ECTS-Credits each course)

Person in charge: N.N., Secretariat ACK 2, SGN@igg.tu-berlin.de

Entry requirements: The module *FOU Geophysical investigations in Geo Technologies* is mandatory; extensive knowledge of mathematical and physical basics as well as programming skills are desirable.

Duration: 1 semester

Examination: Oral exam

Workload each course:

Overall attendance:	15 x	2 h	=	30 h
Homework and post processing:	15 x	3 h	=	45 h
Examination preparation:				15 h

Objectives:

To have the ability to advanced development, analysis and inversion of geophysical measuring data, to physical modelling and conversion to computing codes.

Module elements:

Data Processing and Filter in Geophysics

Content

- Spectrographic analysis
- Digital data in geophysics
- Filters and linear systems
- Data models and ideal filter

Didactic concept

- Lectures (50%)
- Exercises (50%)

Inversion and Modelling in Geophysics

Content

- Physical and numeric modelling
- Basics and procedures of the inversion
- Numerics for inversion
- Quality of the inversion

Didactic concept

- Lectures (50%)
- Exercises (50%)

Literature:

- Buttkus, B., 1991*, Spektralanalyse und Filtertheorie in der Angewandten Geophysik*, Verlag
- Meju, M. A., 1994, *Geophysical Data Analysis: Understanding Inverse Problem*, Theory Practice, Society os Exploration Geophysicists
- Menke, W., 1989, *Geophysical Data Analysis: Discrete Inverse Theory*, International Series Vol. 45, Academic Press Inc
- Yilmaz, Ö., 1987, Seismic Data Processing, Society os Exploration Geophysicists

Engineering Surveying and Estimation Theory (EGA)

EGA Adjustment Calculation II (9 CP)

Selected Sections of Adjustment Calculation **VL 3633 L 223**
UE 3633 L 224

Semester: summer term **(2nd semester)**
Attendance: 4 semester periods per week (2 h lecture and 2 h exercise)

Statistic Test Procedures and Analysis of Stochastic Processes **IV 3633 L 231**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective, Compulsory for minor subject
Person in charge:	Prof. Gründig, Secretariat H20, EGA@igg.tu-berlin.de
Entry requirements:	The modules *FOU Adjustment Calculation I*, *FOU Geoinformation Technology*, *FOU Introduction to Satellite Geodesy* with Geodetic Reference Systems or previous knowledge are mandatory; knowledge of MatLab is desirable
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Exercises (50%) • Oral presentation (25%) • Practical work; Measurement (25%)
Workload:	Overall attendance: 15 x 6 h = 90 h Preparation and post processing: 15 x 7 h = 105 h Project processing: 15 x 5 h = 75 h

Objectives:

After this module the students have a good command of the methods of the multivariate measuring data analysis for the evaluation of large data sets also with respect to the search for and treatment of incorrect observations. In addition the students manage the assessment of quality of measuring data including time series analysis and filtering techniques. They know the basices in detecting static and dynamic deformations and have the knowledge to solve tasks in engineering surveying.

Module elements:

Selected Sections of Adjustment Calculation **VL 3633 L 223**
UE 3633 L 224

Content

- Planning and doing spatial measurements
- conditional and parametric adjustment
- treatment of singular adjustment models
- datum problems
- variance component estimation

- Planning and doing spatial measurements
- conditional and parametric adjustment
- treatment of singular adjustment models
- datum problems
- variance component estimation

Didactic concept

- Lecture (50%)
- Practical exercises in surveying (30%)
- Adjustment calculation of the given tasks (20%)

Statistic Test Procedures and Analysis of Stochastic Processes **IV 3633 L 231**

Content

- Deformation analysis methods
- Kalman filtering
- theory of time series analysis and filtering
- regression and collocation
- transformations and proximity smoothening of adjusted data
- overview of the main tasks and solutions in engineering surveying
- precept of sensors and measurements with inertial measurement units (IMU), gyroscopes, hydrostatic devices

Didactic concept

- Lecture (50%)
- Oral presentation (20%)
- Exercises in adjustment calculations (30%)

Literature:

- J. Anderson and E. Mikhail (October 1, 1997): *Surveying: Theory and Practice*; McGraw-Hill Science/Engineering/Math; 7 edition,
- Charles D. Ghilani Ph.D. and Paul R. Wolf Ph.D. (June 12, 2006*): Adjustment Computations*: Spatial Data Analysis; Wiley; 4 edition
- W. Schofield and Mark Breach (April 27, 2007): *Engineering Surveying*; Butterworth-Heinemann; 6 edition

EGA Methods of Engineering Geodesy (9 CP)

Methods of Engineering Geodesy and Industrial Measuring Techniques **IV 3633 L 225**

Semester: summer term **(2nd semester)**
Attendance: 3 semester periods per week

Geodetic Basics and Monitoring Measurements **PJ 3633 L 250**

Semester: winter term **(3rd semester)**
Attendance: 3 semester periods per week

Module type:	Compulsory elective
Person in charge:	Prof. Gründig, Secretariat H20, EGA@igg.tu-berlin.de
Entry requirements:	The module *EGA Adjustment Calculation II* or previous knowledge is mandatory, extensive knowledge of maths as well as programming skills is desirable
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Exercises (60%) • Oral presentations (40%)
Workload:	Overall attendance: 15 x 6 h = 90 h Project processing: 15 x 12 h = 180 h

Objectives:

The students possess extensive scientific knowledge of the technology of engineering geodesy, in particular the technology of the properties and the applications of innovative sensor systems including the analysis and processing of relevant information.

Module elements:

Methods of Engineering Geodesy and Industrial Measuring Techniques **IV 3633 L 225**

Content

- Application and use of geodetic and non-geodetic sensor systems
- extended parameter estimation
- network optimisations
- generalised estimation theories
- S-transformation
- prediction, collocation,
- principles of the application and analysis of series of continuous measurements
- application of time series analysis and filtering
- application of concepts for the data filtering of geodetic and non-geodetic series of measurements

Didactic concept

- Lecture (50%)
- Oral presentation (10%)
- Exercises (40%)

Geodetic Basics and Monitoring Measurements **PJ 3633 L 250**

Content

- Project in the area of the electronic precision measuring procedures
- combination of terrestrial and satellite-based measuring procedures
- Monitoring of engineering structures
- planning, realisation and analysis of monitoring measurements on engineering structures (e.g. dams) with respect of time dependent influences

Didactic concept

- Lecture (50%)
- Oral presentation (10%)
- Exercises (40%)

Literature:

- J. Anderson and E. Mikhail (October 1, 1997): *Surveying: Theory and Practice*; McGraw-Hill Science/Engineering/Math; 7 edition,
- Charles D. Ghilani Ph.D. and Paul R. Wolf Ph.D. (June 12, 2006): *Adjustment Computations*: Spatial Data Analysis; Wiley; 4 edition
- W. Schofield and Mark Breach (April 27, 2007): *Engineering Surveying*; Butterworth-Heinemann; 6 edition
- Additional literature will be announced

EGA Geodetic Sensors and 3D Measurement (6 CP)

Geodetic Sensors **IV 3633 L 226**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Laser Scanning and 3D – Measurement Techniques **IV 3633 L 251**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective
Person in charge:	Prof. Gründig, Secretariat H20, EGA@igg.tu-berlin.de
Entry requirements:	The modules *FOU Adjustment Calculation I, FOU Geoinformation Technology*, *FOU Introduction to Satellite Geodesy* with Geodetic Reference Systems or previous knowledge are mandatory; knowledge of a programming language is desirable
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Oral presentation (40%) • Written report (60%)
Workload:	Overall attendance: 15 x 4 h = 60 h Homework and post processing: 15 x 8 h = 120 h

Objectives:

The students possess extensive scientific knowledge of the geodetic sensor technology, in particular the technology of use and calibration of geodetic sensor systems, the technology of innovative sensor systems and the analysis and processing of observational data.

Module elements:

Geodetic Sensors **IV 3633 L 226**

Content

- Structure, functionality and handling of electronic tachymeter
- Basic principle of the electro-optical distance measuring
- Investigation and calibration of electro-optical distance measurers, external influences on the measuring system
- Structure, functionality and handling of analogue and digital leveling instruments
- Modeling systematic effects of the measuring process (systematic errors with respect to inclination and to the focusing lens, vertical misalignments etc.)
- Modeling systematic effects of the environment, i.e. the influence of the gravity field of the Earth, vertical refraction, design of measuring methods, structure,
- Functionality and handling of GPS receivers, antenna calibration

Didactic concept

- Lecture (50%)
- Oral presentation (10%)
- Project work (40%)

Laser Scanning and 3D – Measurement Techniques **IV 3633 L 251**

Content

- Structure, measurement principles and sample applications of the sensors of the optical measuring technique without reflectors (laser scanner, laser tracker)
- Calibration strategies of polar measuring systems
- Use of close range photogrammetry for the solution of complex problems, registration and analysis of 3D-point clouds resulting from laser scanners, including data fusion for medium range applications i.e. building information systems and other documentation purposes
- Interdisciplinary applications.

Didactic concept

- Lecture (50%)
- Oral presentation (10%)
- Project work (40%)

Literature:

- J. Anderson and E. Mikhail (1997): *Surveying: Theory and Practice*; McGraw-Hill Science/Engineering/Math; 7 edition
- Jon Wilson (2004): *Sensor Technology Handbook*; Newnes
- Additional literature will be announced

EGA Analysis of Deformation Processes (3 CP)

Analysis of Deformation Processes **IV 3633 L 252**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective
Person in charge:	Prof. Gründig, Secretariat H20, EGA@igg.tu-berlin.de
Entry requirements:	The modules *FOU Adjustment Calculation I, FOU Geoinformation Technology*, *FOU Introduction to Satellite Geodesy* with Geodetic Reference Systems or previous knowledge are mandatory; knowledge of a programming language is desirable
Duration:	1 semester
Examination:	Study effort equivalent to the examination: • Written report (50%) • Oral presentation (25%) • Practical work (25%)
Workload:	Overall attendance: 15 x 2 h = 30 h Project processing: 15 x 4 h = 60 h

Objectives:

The students possess extensive scientific knowledge of the analysis of geodetic deformation measurements including modelling of deformation processes

Module elements:

Analysis of Deformation Processes **IV 3633 L 252**

Content

- Two- and multi-epoch comparison
- Spectrographic analysis of a monitoring network and the deformation vectors
- Generalisation of the deformation field and geometrical interpretation (polynomial approach, rigid body movement, procedures of strain and stress analysis)
- Kalman filtering, prediction, collocation, mechanical and statistical basics (stress and strain analysis, Hook`s law)
- Analysis of the deformation of static systems (differential equation of the bending line)
- Finite element approach and application
- Neuronal data processing
- Interdisciplinary applications

Didactic concept

- Lecture (50%)
- Oral presentation (10%)
- Project work (40%)

Literature:

- Proceedings of the Symposia of FIG Commission 6.1

EGA Transformation of Geodetic Networks (3 CP)

Transformation of Geodetic Network **IV 3633 L 253**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective
Person in charge:	Prof. Gründig, Secretariat H12 EGA@igg.tu-berlin.de
Entry requirements:	The module *EGA Adjustment Calculation II* or previous knowledge is mandatory; extensive knowledge of maths is desirable
Duration:	1 semester
Examination:	Study effort equivalent to the examination: • Exercise (70%) • Oral presentation (30%)
Workload:	Overall attendance: 15 x 2 h = 30 h Homework and post processing: 15 x 4 h = 60 h

Objectives:

After this module the students control the general methodology of the one, two and three-dimensional transformation of geodetic networks.

Module elements:

Transformation of Geodetic Network **IV 3633 L 253**

Content

- Cartesian and ellipsoidal coordinates tangential
- Geodetic, geocentric and projected systems
- Ellipsoidal heights and standard heights
- Geodetic datum
- One, two and three-dimensional datum transformation
- Network building and compensation from GPS base vectors
- One, two, three-dimensional transformation of GPS nets into a national system
- Combined compensation of terrestrial and GPS measurements
- Treatment of selected case examples

Didactic concept

- Lecture (50%)
- Oral presentation (10%)
- Exercises (40%)

Literature:

- Wolfgang Torge (April 2001): *Geodesy*; Walter de Gruyter; 3rd edition
- Christian Manthe (Mai 2009): *How to Define a Regional Arbitrary Geodetic Datum in Oracle Spatial*; FIG Working Week 2009
- Kothuri ,R. & Godfrind, A. & Beinat, E. (2007): *Pro Oracle Spatial for Oracle Database* 11g. Apress.
- Ghilani, C.D. & Wolf, P. R. (1998): *Surveying Theory and Practice*. Boston: McGraw-Hill.

EGA Current Methods of Measurement Data Analysis in Geodesy (3 CP)

Current Methods of Measurement Data Analysis in Geodesy **IV 3633 L 256**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective
Person in charge:	PD Dr. Petrovic, Secretariat H20, EGA@igg.tu-berlin.de
Entry requirements:	The module *FOU Adjustment Calculation I* are mandatory
Duration:	1 semester
Examination:	Oral exam
Workload:	Overall attendance: 15 x 2 h = 30 h Preparation and post processing: 15 x 2 h = 30 h Examination preparation: 30 h

Objectives:

After this module the students are able to see the use of the method of the smallest squares in the current measuring data analysis criti-cally and compile alternative evaluation strategies. A further objective consists of suggesting topics for the master work. The Control of alter-native solution strategies of the parameter estimation on selected case examples.

Module elements:

Current Methods of Measurement Data Analysis in Geodesy **IV 3633 L 256**

Content

- Functionality and problems of the method of the smallest squares
- Alternative solution methods
- Range of the L2-norm-estimation and alternative estimation theories (e.g. compensation after maximum correlation)
- Problem of the realistic modeling
- Instabilities and regularization
- Interval mathematics
- Use of global optimization procedures (e.g. heuristic)

Didactic concept

- Lecture (70%)
- Exercise (30%)

Literature:

- To be announced

EGA Project Seminar Engineering Surveying and Estimation Theory (6 CP)

Engineering Geodesy Seminar **SE 3633 L 227**

Semester: summer term **(2nd semester)**
Attendance: 2 semester periods per week

Engineering Geodesy and Adjustment Calculation Project **PJ 3633 L 255**

Semester: winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective, Compulsory for major subject
Person in charge:	Prof. Gründig, Secretariat H20, EGA@igg.tu-berlin.de
Entry requirements:	The module *EGA Adjustment Calculation II* or previous knowledge is mandatory; other modules from the specialised subject Engineering Geodesy and Estimation Theory are desirable.
Duration:	2 semesters
Examination:	Study effort equivalent to the examination: • Written report (60%) • Practical measurements (20%) • Oral presentation (20%)
Workload:	Overall attendance: 15 x 4 h = 60 h Homework and post processing: 15 x 8 h = 120 h

Objectives:

This module is designed for strengthening the capability for scientific work and social competence (team work). In this module the students are challenged with the full complexity of a current research topic in the area of engineering geodesy and adjustment calculation. Thus the students acquire knowledge with respect to the concepts of the measuring system to be applied, the processing strategy, the data analysis and preparation of the results with respect to interdisciplinary needs. In the course the students get introduced to the tasks to be solved, in the project they work together in small groups on relevant topics. They get insight to solution methods and to open problems, which provides the start for new research activities. This module is designed to introduce the students to current scientific questions, which can lead to high qualified master works.

Module elements:

Engineering Geodesy Seminar **SE 3633 L 227**

Content

Contents of the module depend on the current research activities at the department for geodesy and geoinformation technology and can originate from the following areas.

Measuring systems and modelling:

- Engineering surveying measuring systems for application in building processes and in industrial manufacturing processes
- Real time measuring systems for buildings and land slides monitoring
- Applying neuronal data processing

- integration of geotechnical measuring and conceptional methods for the interpretation of deformations
- Investigations with respect to geodetic sensor systems (e.g. laser scanners).

Analysis of measuring data:

- Functionality and problems of the method of least squares, alternative solution methods
- L2-Norm-estimation and alternative processes of estimation
- problems of proper realistic modeling
- Instabilities and regularization
- innovative blunder theories
- interval mathematics
- fuzzy logic
- Use of global optimization procedures (e.g. heuristics)
- filtering techniques
- analysis of stochastic processes

A special application of least squares adjustment:

- Computation of cable nets and structural membranes
- optimisation tasks
- transformation of geodetic networks

Didactic concept

- Lecture (35%)
- Oral presentation (10%)
- Project work (55%)

Engineering Geodesy and Adjustment Calculation Project **PJ 3633 L 255**

Content

See content of the *Engineering Geodesy Seminar*

Didactic concept

- Lecture (50%)
- Oral presentation (10%)
- Project work (40%)

Literature:

- To be announced

Computer Vision and Remote Sensing (CV)

CV2 Digital Image Processing (6 CP)

Digital Image Processing **VL 0433 L 110**
UE 0433 L 110

Semester: summer term **(2nd semester)**
Attendance: 4 semester periods per week (2 h lecture and 2 h exercise)

Module type:	Compulsory elective	
Person in charge:	Prof. Hellwich, Secretariat FR 3-1, hellwich@cs.tu-berlin.de	
Entry requirements:	None	
Duration:	1 semester	
Examination:	Written exam	
Workload:	Contact times:	60 h
	Private study:	120 h

Objectives:

Based on the fact that images represent a signal, methods for image enhancement, feature extraction and grouping are developed.The module clarifies that the learned skills can be used within multifaceted application areas for automatic image understanding.

The course is principally designed to impart technical skills 30% method skills 30% system skills 20% social skills 20%

Underlying philosophy, methods and algorithms are explicated in the lectures. In the lab exercises which take place in parallel, methods and algorithms are implemented and applied exemplarily.

Module elements:

Digital Image Processing **VL 0433 L 110**
UE 0433 L 110

Content

Image representation in frequency domain, Fourier transform, sampling theorem, Filtering, Wiener Filter, image enhancement, edge detection, Hough transform, segmentation, interest operators, mathematical morphology, vectorisation, texture, skeletonization, medical axis transform, contour / line tracing and -smoothing, Gestalt psychology, grouping

Didactic concept

- lectures (33%)
- exercises (67%)

Literature:

- E. Oran Brigham: *The Fast Fourier Transform and its Applications*. Prentice-Hall 1988.
- B. Jähne: *Digital Image Processing*. 5th ed. Springer Verlag 2002.
- R. C. Gonzalez, R. E. Woods: *Digital Image Processing*. 2nd ed. Prentice Hall International 2001.

CV3 Automatic Image Analysis (6 CP)

Automatic Image Analysis **VL 0433 L 130**
UE 0433 L 131

Semester: winter term **(3rd semester)**
Attendance: 4 semester periods per week (2 h lecture and 2 h exercise)

Module type:	Compulsory elective	
Person in charge:	Prof. Hellwich, Secretariat FR 3-1, hellwich@cs.tu-berlin.de	
Entry requirements:	*CV2 Digital Image Processing* or equivalent knowledge	
Duration:	1 semester	
Examination:	Written exam	
Workload:	Contact times:	60 h
	Private study:	120 h

Objectives:

The students acquire stepwise competence for the development of image understanding methods. According to computer vision paradigm knowledge-based image analysis methods are developed based on feature extraction. The learned skills can be used within multifaceted application areas of automatic image understanding and pattern recognition.

The course is principally designed to impart technical skills 30% method skills 30% system skills 20% social skills 20%

Underlying philosophy, methods and algorithms are explicated in the lectures. In the lab exercises which take place in parallel, methods and algorithms are implemented and applied exemplarily.

Module elements:

Automatic Image Analysis **VL 0433 L 130**
UE 0433 L 131

Content

Visual cognition, grouping, shape descriptors, computer vision paradigm, knowledge-based image analysis, models of the real world, formal representation of the models, modelling of uncertainty, invariant pattern recognition, Bayesian decision theorem, Markoff random field models, Bayesian networks, object categorisation, automatic interpretation of maps, application to close range- and air photographs

Didactic Concepts

- lectures (33%)
- exercises (67%)

Literature:

- Duda, Hart, Stork: *Pattern Classification*. 2nd ed. Springer Verlag 2001.

CV4 Optical Remote Sensing (6 CP)

Optical Remote Sensing **VL 0433 L 140**
UE 0433 L 141

Semester: winter term **(3rd semester)**
Attendance: 4 semester periods per week (2 h lecture and 2 h exercise)

Module type:	Compulsory elective	
Person in charge:	Prof. Hellwich, Secretariat FR 3-1, hellwich@cs.tu-berlin.de	
Entry requirements:	None	
Duration:	1 semester	
Examination:	Oral exam	
Workload:	Contact times:	60 h
	Private study:	120 h

Objectives:

The module imparts primarily professional and methodological expertise in analyzing remote sensing data. The exploration of the context between physical reality of the environment and data collected with imaging sensors are in the foreground. Mathematical modells are used for description. Data analysis, e.g. object extraction, is conducted with methods of the automatic image analysis. Remote sensing is conceived as an electronical-physically motivated area of computer vision.

The course is principally designed to impart technical skills 40% method skills 40% system skills 10% social skills 10%

Underlying sensor components, methods and algorithms are explained in a way allowing transmission of the handled sensor- and system aspects to other cases. Methods and algorithms are implemented and applied exemplarily in the lab exercises taking part in parallel. Field work is part of the course.

Module elements:

Optical Remote Sensing **VL 0433 L 140**
UE 0433 L 141

Content

Physical basics, optical sensors, multi- and hyper spectral-sensors, functionality of optical sensors, geometrical and radiometrical image calibration, pre-processing of satellite images, arithmetic image operations, principal axis transform, Tasseled Cap Transform, supervised and unsupervised classification processes, BRDF, spectral demixing, image textures, microwave systems, radar with synthetic aperture (SAR)

Didactic concept

- lectures (33%)
- exercises (67%)

Literature:

- J. A. Richards, X. Jia: *Remote Sensing Digital Image Analysis – An Introduction*. Springer Verlag 2006.

CV5 Microwave and Radar Remote Sensing (6 CP)

Microwave and Radar Remote Sensing **VL 0433 L 112**
UE 0433 L 112

Semester: summer term **(2nd semester)**
Attendance: 4 semester periods per week (2 h lecture and 2 h exercise)

Module type:	Compulsory elective	
Person in charge:	Prof. Hellwich, Secretariat FR 3-1, hellwich@cs.tu-berlin.de	
Entry requirements:	Preferable: *CV4 Optical Remote Sensing*	
Duration:	1 semester	
Examination:	Oral exam	
Workload:	Contact times:	60 h
	Private study:	120 h

Objectives:

The module imparts primarily professional and methodological expertise in analyzing remote sensing data. The exploration of the relations between physical reality of the environment and data collected with imaging sensors are emphasized. Mathematical modells are used for description.

The course is principally designed to impart technical skills 40% method skills 40% system skills 10% social skills 10%

Underlying sensor components, methods and algorithms are explained in a way allowing the transmission of the handled sensor- and system aspects to other cases. Methods and algorithms are implemented and applied exemplarily in the lab exercises taking place in parallel.

Module elements:

Microwave and Radar Remote Sensing **VL 0433 L 112**
UE 0433 L 112

Content

Physical basics, microwave systems, radar with synthetic aperture (SAR): application process, SAR-image generation, SAR-interferometry, coherence, differential SAR-interferometry, permanent scatterer analysis, SAR-polarimetry, scattering matrix, partial scatterer, decomposition theorems, entropy/alpha-classification, polarimetric SAR-interferometry, object extraction from SAR-data, sensor / data fusion

Didactic concept

- lectures (33%)
- exercises (67%)

Literature:

- D. Massonnet, J.-C. Souyris: *Synthetic Aperture Radar Imaging*. EFPL Press 2008.
- C. Oliver, S. Quegan: *Understanding Synthetic Aperture Radar Images*. SciTech Publishing 2004.

CV6 Seminar Hot Topics in Computer Vision (3 CP)

Hot Topics in Computer Vision **SE 0433 L 160**

Semester: summer term **(2nd semester)** and winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective, Compulsory for major subject
Person in charge:	Prof. Hellwich, Secretariat FR 3-1, hellwich@cs.tu-berlin.de
Entry requirements:	Preferable: depends on topic; e.g. *CV1 Photogrammetric Computer Vision, CV2 Digital Image Processing*
Duration:	1 semester
Examination:	Study effort equivalent to the examination: • Presentation (60%) • Participation (40%)
Workload:	Contact times: 30 h Private study: 60 h

Objectives:

The participants will be led to a research and industrially relevant subject. It is not aspired to explore a specific area completely. The aim of the course is to confrontate the participants with the whole complexibility of one issue and to challenge their own initiative. We provide an insight in the research and development projects of the field.

The course is principally designed to impart technical skills 20% method skills 30% system skills 20% social skills 30%

The participants explore basics and advanced issues of the field. Differences in the preparatory training of the participants can be balanced.

Module elements:

Hot Topics in Computer Vision **SE 0433 L 160**

Content

Example: Advanced topics of the real-time processing and –image analysis will be explored.

Didactic concept

- introductory lectures (15%)
- seminar (85%)

Literature:

- various

CV7 Project Hot Topics in Computer Vision (6 CP)

Hot Topics in Computer Vision **PJ 0433 L 161**

Semester: summer term **(2nd semester)** and winter term **(3rd semester)**
Attendance: 4 semester periods per week

Module type:	Compulsory elective, Compulsory for major subject
Person in charge:	Prof. Hellwich, Secretariat FR 3-1, hellwich@cs.tu-berlin.de
Entry requirements:	Preferable: depends on topic; e.g. *CV1 Photogrammetric Computer Vision, CV2 Digital Image Processing*
Duration:	1 semester
Examination:	Study effort equivalent to the examination: • Project Report (50%) • Demonstration (50%)
Workload:	Presence: 10 h Meetings: 10 h Project Work: 120 h Elaboration: 15 h Written Project Report: 25 h

Objectives:

The capacity for teamwork of the participants shall be strenghten through the module. They will be led to a research and industrially relevant subject. It is not aspired to explore a specific area completely. The aim of the course is to confrontate the participants with the whole complexibility of one issue and to challenge their own initiative. Therefore we do not provide a pedagogically gentle introduction of the learners to the scientific area, but we allow an insight and participation in research and development of the field.

The course is principally designed to impart technical skills 20% method skills 30% system skills 20% social skills 30%

The participants explore basics and advanced issues. Differences in the preparatory training of the participants can be balanced.

Module elements:

Hot Topics in Computer Vision **PJ 0433 L 161**

Content

Example: Basics of real-time processing and –image analysis. The participants shall develop a software system in the course enabling to calculate the orientation parameters of a digital camera with respect to an object plane - a two-dimensional object room – to transform the position of a movable agent, whose coordinates are given in image space, into object space.
The software system can be made up of the modules camera calibration, detection of object markers, tracing of object markers, precise localization of object markers, calculation of camera orientation and transformation of the agent position into object space.

Didactic concept

- introduction (10%)
- self study and implementation (80%)
- supervision (10%)

Literature:

- various

CV8 Seminar Hot Topics in Image Analysis (3 CP)

Hot Topics in Image Analysis **SE 0433 L 162**

Semester: summer term **(2nd semester)** and winter term **(3rd semester)**
Attendance: 2 semester periods per week

Module type:	Compulsory elective	
Person in charge:	Prof. Hellwich, Secretariat FR 3-1, hellwich@cs.tu-berlin.de	
Entry requirements:	Preferable*: CV3 Automatic Image Analysis*	
Duration:	1 semester	
Examination:	Study effort equivalent to the examination: • Presentation (60%) • Participation (40%)	
Workload:	Contact times: Private study:	30 h 60 h

Objectives:

The participants will be led to a research and industrially relevant subject. It is not aspired to explore a specific area in the whole bandwith. The aim of the course is to confrontate the participants with the whole complexibility of one issue and to challenge their own initiative. We provide an insight in the research and development projects of the field.

The course is principally designed to impart technical skills 20% method skills 30% system skills 20% social skills 30%

The participants explore basics and advanced issues of the field. Differences in the preparatory training of the participants can be balanced.

Module elements:

Hot Topics in Image Analysis **SE 0433 L 162**

Content

Example: Basics of pattern recognition and modelling of insecurity in image analysis.

Didactic concept

- introductory lectures (15%)
- seminar (85%)

Literature:

- various

CV9 Project Hot Topics in Image Analysis (6 CP)

Hot Topics in Image Analysis **PJ 0433 L 163**

Semester: summer term **(2nd semester)** and winter term **(3rd semester)**
Attendance: 4 semester periods per week

Module type:	Compulsory elective	
Person in charge:	Prof. Hellwich, Secretariat FR 3-1, hellwich@cs.tu-berlin.de	
Entry requirements:	Preferable: *CV3 Automatic Image Analysis*	
Duration:	1 semester	
Examination:	Study effort equivalent to the examination: • Project Report (50%) • Demonstration (50%)	
Workload:	Presence:	10 h
	Meetings:	10 h
	Project Work:	120 h
	Elaboration:	15 h
	Written Project Report:	25 h

Objectives:

The capacity for teamwork of the participants shall be strenghten through the module. They will be led to a research and industrially relevant subject. It is not aspired to explore a specific area completely. The aim of the course is to confrontate the participants with the whole complexibility of one issue and to challenge their own initiative. Therefore we do not provide pedagogically gentle introduction of the learners to the scientific area, but we allow an insight and participation in research and development of the field.

The course is principally designed to impart technical skills 20% method skills 30% system skills 20% social skills 30%

The participants explore basics and advanced issues of the field. Differences in the preparatory training of the participants can be balanced.

Module elements:

Hot Topics in Image Analysis **PJ 0433 L 163**

Content

Example: Advanced topics of pattern recognition and modelling of uncertainty in image analysis. The participants shall develop a software system which enables to automatically recognize objects under the specified condition, e.g. real-time requirements.

Didactic concept

- introduction (10%)
- self study and implementation (80%)
- supervision (10%)

Literature:

- various

Additional Elective Courses (AEC)

AEC Remote Sensing Applications (3 CP)

Remote Sensing Applications **IV 0433 L 229**

Semester: winter term **(3rd semester)**
Attendance: see duration (60% lecture and 40% exercise)

Module type:	Elective	
Person in charge:	PD Dr. Werner, Secretariat H12, GIS@igg.tu-berlin.de	
Entry requirements:	Computer basics (Windows, Microsoft Office package)	
Duration:	Compact Seminar 5 days à 8 hours	
Examination:	Study effort equivalent to the examination: • Exercises (75%) • Practical work (25%)	
Workload:	Overall attendance: Post processing	40 h 50 h

Objectives:

The students are able to organize and to realise remote sensing projects. The students know the characteristics of different remote sensing systems and the properties of the image data. They can judge the applicability of remote sensing for environmental analysis. They know modern techniques of image interpretation which includes visual analysis as well as working with the digital image program ERDAS Imagine. Quantitative field research will be performed for data classification and for verification of the remote sensing analysis results.

Module elements:

Remote Sensing Applications **IV 0433 L 229**

Content

- **Remote Sensing Procedures** (properties of remote sensing data and their applicability for different purposes)
- **Interpretation of Remote Sensing Data** (Exercises of thematic interpretation of remote sensing data, e. g. land use, vegetation damages)
- **Application of Remote Sensing in Practice** (biotope mapping, change detection, landscape planning, security and crisis management, modelling)

Didactic concept

- Lecture (50%)
- Exercises and practical work (50%)

Literature:

- Avery, T.E. and Berlin, G.L., 2001: *Fundamentals of Remote Sensing and Airphoto Interpretation. - 6th Ed.*, MacMillan Publ. Co., 472 pp.
- Campbell, J.B., 2002: Introduction to Remote Sensing. - 3rd Ed., The Guilford Press.

- Lillesand, T.M. Kiefer, R.W., & Chipman, J.W., 2004: *Remote Sensing and Image Interpretation. - 5th Ed.*, J. Wiley & Sons, 720 pp.
- Richards, J.A. and Jia, X, 1999: *Remote Sensing Digital Image Analysis: an Introduction*. - Springer-Verlag.
- Sabins, Jr., F.F., 1996: Remote *Sensing: Principles and Interpretation. 3rd Ed.*, W.H. Freeman & Co., 496 pp.

Journals

- International Journal of Remote Sensing
- Photogrammetric Engineering and Remote Sensing
- Remote Sensing of the Environment

Internet

- http://www.dfd.dlr.de/
- http://rst.gsfc.nasa.gov/
- http://landsathandbook.gsfc.nasa.gov/handbook/handbook_htmls/

Master’s Dissertation (MSC)

MSC Master’s Thesis (30 CP)

Master’s Thesis

Semester: summer term **(4th semester)**

Module type:	Compulsory
Person in charge:	To be defined according to the thesis topic
Entry requirements:	At least 45 ECTS of mandatory and elective modules must be completed, including the corresponding examinations.
Duration:	6 months
Examination:	Study effort equivalent to the examination: • Master Thesis (85%) • Oral Presentation (15%)
Workload:	Maximum: 120 days à 8 hours h

Objectives:

With the Master’s Thesis the candidates are to demonstrate their ability to complete and document a well defined research project within a given time frame.

Module elements:

Master’s Thesis

Content

To be defined according to the thesis topic

Didactic concept

- Written Thesis (50%)
- Conceptual and practical work (50%)

Literature:

- To be selected according to the thesis topic