Module ‘Coordinate Systems’

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>MGE-01</td>
<td>90 h</td>
<td>3.0 LP</td>
<td>Winter semester</td>
<td>1 semester</td>
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</table>

**Module coordinator**
Prof. Dr. C. Stachniss

**Module lecturers**
Prof. Dr. C. Stachniss, Prof. Dr. H. Kuhlmann, PD Dr. A. Nothnagel, Prof. Dr. J. Kusche, Prof. Dr. J.-H. Haunert

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

### Course program usability

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>mandatory module</td>
<td>1st regular semester</td>
</tr>
</tbody>
</table>

### Learning objectives

Acquisition of advanced knowledge and use of different 3D coordinate systems as well as different parameterizations for typical geodetic applications on local and global scales

### Key competences

Realization of small codes that perform common coordinate transformations and projections; Problem-solving abilities; Ability to transfer knowledge and methods to similar scientific challenges

### Learning content

- Euler angles; Quaternions; Homogeneous coordinates; Typical transformations (similarity, affine, projective);
- Local 3D Systems; Registration and georeferencing; Number of parameters depending on conditions; Concatenation of transformations; Transformation from GNSS to local systems; Global and local systems; UTM and Gauß-Krüger; Ellipsoids;
- International Terrestrial Reference Frame (definition, scale, datum, no-net-translation, no-net-rotation, velocity field, no-net-translation-rate, no-net-rotation-rate);
- Earth’s motion in space; Earth-fixed and celestial coordinate systems; Global and local coordinate systems; Reference systems and reference frames;
- Projected coordinate systems in cartography and GIS; Map distortions and consequences for GIS-based computations

### Prerequisites for admission to the module

none

### Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>1L+1Es</td>
<td>Coordinate Systems</td>
<td>18</td>
<td>30 h</td>
<td>90 h</td>
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</tbody>
</table>

### Academic performance

- Type of academic performance: un/marked
- Oral and/or written coursework: unmarked

### Examination

- Type of examination (Duration in minutes): un/marked
- Written examination (120 min): marked
- Weight: 100 %

### Further information

References:

### Date of issue

15 May 2017
Module 'Global Navigation Satellite Systems'

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
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<td>90 h</td>
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</table>

**Module coordinator**
Prof. Dr.-Ing. H. Kuhlmann

**Module lecturers**
Prof. Dr.-Ing. H. Kuhlmann, Dr.rer.nat. L. Klingbeil

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

**Course program usability**

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
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<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>mandatory module</td>
<td>1st regular semester</td>
</tr>
</tbody>
</table>

**Learning objectives**
Acquisition of advanced knowledge of the physical, functional, and stochastical characteristics of satellite-based positioning procedures and systems; In-depth knowledge of the structure and processing of GNSS signals; Skills in positioning with GNSS and performing absolute and relative GNSS measurements for static and kinematic applications; Understanding and interpretation of GNSS results and systematic deviations

**Key competences**
Working in groups; Self-organization of experiments; Problem-solving abilities; Ability to transfer knowledge and methods to similar scientific challenges

**Learning content**
Basic principle of Global Navigation Satellite Systems; Coordinate systems, time systems, and satellite orbit representations; GNSS signals and receiver technology; Observables, atmospheric effects, and multipath; Positioning procedures: Single point positioning, relative GNSS with carrier phases, precise point positioning; RTK GNSS; Network GNSS; Kinematic GNSS; GNSS attitude determination; GPS, GLONASS, Galileo, and BeiDou; GNSS applications

**Prerequisites for admission to the module**
none

**Courses**

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>1L+1Ep</td>
<td>Global Navigation Satellite Systems</td>
<td>18</td>
<td>30 h</td>
<td>90 h</td>
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**Academic performance**

Type of academic performance: un/marked
Oral and/or written coursework: unmarked

**Examination**

Type of examination (Duration in minutes): un/marked
Written examination (120 min): marked
Weight: 100 %

**Further information**

References:

**Date of issue**
15 May 2017
Module description
Course of study: Master program ‘Geodetic Engineering’
Faculty of Agriculture - University of Bonn

<table>
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<td>90 h</td>
<td>3.0 LP</td>
<td>Winter semester</td>
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**Module coordinator**
Prof. Dr.techn. W.-D. Schuh

**Module lecturers**
Prof. Dr. techn. W.-D. Schuh; Dr.-Ing. J.M. Brockmann; MSc Ch. Esch; MSc J. Köhler

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

**Course program usability**

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>mandatory module</td>
<td>1st regular semester</td>
</tr>
</tbody>
</table>

**Learning objectives**
Acquisition of advanced knowledge about concepts in parameter estimation and hypothesis testing

**Key competences**
Problem-solving abilities in order to independently solve practical adjustment problems; Ability to independently interpret the quality and reliability of adjustment results

**Learning content**
Least Squares Estimation; Regression analysis; Probability theory (Random variables, probability distribution, statistic moments and their propagation); Best linear unbiased estimator (BLUE, Gauss-Markov-model); Confidence regions; Hypothesis testing

**Prerequisites for admission to the module**
none

**Courses**

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
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</thead>
<tbody>
<tr>
<td>Pathway: Statistics and Adjustment Theory</td>
<td>1L+1Es</td>
<td>Statistics and Adjustment Theory</td>
<td>18</td>
<td>30 h</td>
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**Academic performance**
Type of academic performance | unmarked
Oral and/or written coursework | unmarked

**Examination**
Type of examination (Duration in minutes) | unmarked | Weight |
Written examination (120 min) | marked | 100 % |

**Further information**
Basic knowledge on applied mathematics (analysis, linear algebra, numerics) and computing are recommended.
References:

**Date of issue**
15 May 2017
Module ‘Geoinformation Systems’

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
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<th>Turnus</th>
<th>Duration</th>
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<tbody>
<tr>
<td>MGE-04</td>
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<td>Winter semester</td>
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</table>

**Module coordinator**
Prof. Dr.-Ing. J.-H. Haunert

**Module lecturers**
Prof. Dr.-Ing. J.-H. Haunert

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

**Course program usability**

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
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<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>mandatory module</td>
<td>1st regular semester</td>
</tr>
</tbody>
</table>

**Learning objectives**

Acquisition of advanced competences in developing and using geoinformation systems for problems of spatial analysis. Successful candidates are able to handle different data formats, to design spatial databases, and to query databases to answer questions about non-spatial and spatial relations between objects.

**Key competences**

Spatial reasoning; Use of geo-data as well as free and commercial geoinformation systems; Problem-solving abilities; Ability to transfer knowledge and methods to similar scientific challenges

**Learning content**

Foundations of geoinformation systems; Vector and raster models; Spatial referencing of objects in geoinformation systems; Metric spaces; Topological spaces and topological relations; Object-oriented modeling of geoinformation; Spatial databases; Spatial queries; Geometric algorithms for spatial analysis

**Prerequisites for admission to the module**

none

**Courses**

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>1L+1Es</td>
<td>Geoinformation Systems</td>
<td>18</td>
<td>30 h</td>
<td>90 h</td>
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</table>

**Academic performance**

Type of academic performance: un/marked
Oral and/or written coursework: unmarked

**Examination**

Type of examination (Duration in minutes): un/marked
Oral examination (25 min): marked
Weight: 100%

**Further information**

References:

**Date of issue**
15 May 2017
# Module 'Geodetic Earth Observation'

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
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</thead>
<tbody>
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<td>MGE-05</td>
<td>90 h</td>
<td>3.0 LP</td>
<td>Winter semester</td>
<td>1 semester</td>
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</table>

**Module coordinator**
Prof. Dr.-Ing. J. Kusche

**Module lecturers**
Prof. Dr.-Ing. J. Kusche, PD. Dr.-Ing. A. Nothnagel, Dr.-Ing. Roelof Rietbroek

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

## Course program usability

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
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<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>mandatory module</td>
<td>1st regular semester</td>
</tr>
</tbody>
</table>

## Learning objectives

- Advanced comprehension of fundamental concepts in global geodesy and geodetic Earth observation.

## Key competences

- Recognition and application of complex topological relationships; Ability to transfer knowledge and methods to similar scientific challenges

## Learning content

- Concepts of global reference systems and reference frames; Representation of Earth rotation and Earth orientation parameters (EOPs);
- Concepts of reference ellipsoid, geoid, and gravity field; Satellite orbits for geodesy and remote sensing (Kepler and J2 effects);
- Basics of space-geodetic observing techniques; Propagation of electromagnetic waves; Atmosphere; Principles of timing systems; Space environment

## Prerequisites for admission to the module

None

## Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
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</thead>
<tbody>
<tr>
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<td>Geodetic Earth Observation</td>
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<td>30 h</td>
<td>90 h</td>
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</table>

## Academic performance

- Type of academic performance: un/marked
- Oral and/or written coursework: unmarked

## Examination

- Type of examination (Duration in minutes): un/marked
- Oral examination (25 min): marked

## Further information

- Optional excursion to geodetic observatory.
- References:

## Date of issue

17 May 2017
Module description
Course of study: **Master program ‘Geodetic Engineering’**
Faculty of Agriculture - University of Bonn

### Module ‘Profile Fundamentals’

<table>
<thead>
<tr>
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<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
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<td>MGE-06</td>
<td>90 h</td>
<td>3.0 LP</td>
<td>Winter semester</td>
<td>1 semester</td>
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</table>

**Module coordinator**
PD Dr.-Ing. A. Nothnagel

**Module lecturers**
all lecturers of ‘Geodetic Engineering (MSc)’

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

### Course program usability

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>mandatory module</td>
<td>1st regular semester</td>
</tr>
</tbody>
</table>

### Learning objectives

Additional learning objectives regarding the chosen profile, according to the students competences

### Key competences

Ability of self-instruction in order to independently acquire new skills and knowledge

### Learning content

Additional learning objectives regarding the chosen profile, according to the students’ competences.

Topics are chosen from a predefined list of required competences regarding the main profile:

* **Profile Mobile Sensing and Robotics:**
  Random and systematic measurement error; Variance propagation; Probability basics (conditioning, marginalization, independence, Bayes’ rule); Bayes filter basics; Traverses; Total stations (angular measurements, electro-optical distance measurements, relevant uncertainties, propagation of light in atmosphere); Reference system of height; Camera basics (Pinhole modes, mapping points); Relative orientation of the image pair and fundamental matrix; Feature extraction & matching

* **Profile Geodetic Earth System Science and Data Analysis:**
  Fundamental spaces of matrices; Vector space and orthogonal projectors; Generalized solution of rank deficient systems; Generalized inverses; Spectral analysis of linear systems (eigenvectors and singular values); Matrix algebra and decomposition techniques (Schur-Form, Sherman-Morrison-Formula); Sequential Adjustment; Kalman-Filter; Deterministic vs. Stochastic approximation; Interpolation with polynomials, splines, and finite elements in 1D and 2D; Array-Algebra; Numerics of linear equations; Multivariate probability distributions (marginal and conditional distributions); Characteristics of the electro-magnetic spectrum in the neutral and charged atmosphere; Conversions of frequencies and wavelengths; Relationships between frequency, cycle frequency, phase, and arc length; Background of Doppler-effect; Universal law of gravitation, mass, density, and gravity; Kepler’s laws, planetary and satellite motion; Motion w.r.t. inertial and non-inertial reference systems; Rotation of rigid bodies; Tides

* **Profile Geoinformation and Spatial Development**
  Principles and framework of regional and urban planning; Strategies of rural development; Framework of land management and land tenure; Mechanism of land markets, interrelation of planning and property value; Design and analysis of algorithms (e.g., incremental algorithms, divide and conquer, dynamic programming, greedy algorithms, geometric algorithms, graph-theoretic algorithms); Fundamental data structures (e.g., arrays, lists, binary search trees, heaps, hash tables); Object oriented modeling and programming, profound knowledge of at least one programming language; Relational databases and object-relational spatial databases; Foundations of geo-information systems (GIS), including GIS standards (e.g., the OGC simple feature specification) and data formats (e.g., GML); Cartographic visualization

### Prerequisites for admission to the module

none

### Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
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<td>IgS</td>
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### Academic performance

Type of academic performance un/marked
passed exercises unmarked
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<th>Examination</th>
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<td>Further information</td>
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<tr>
<td>Date of issue</td>
<td>16 May 2017</td>
<td></td>
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</table>
### Module 'Satellite Geodesy and Earth System'

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGE-GES-01</td>
<td>180 h</td>
<td>6.0 LP</td>
<td>Winter semester</td>
<td>1 semester</td>
</tr>
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</table>

#### Module coordinator
Prof. Dr.-Ing. J. Kusche

#### Module lecturers
Prof. Dr.-Ing. J. Kusche, PD. Dr.-Ing. A. Nothnagel, PD Dr.-Ing. Luciana Fenoglio-Marc

#### Providing teaching unit(s)
Institute of Geodesy and Geoinformation

#### Course program usability
<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
</tr>
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<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>mandatory module (profile GES)</td>
<td>1st regular semester</td>
</tr>
</tbody>
</table>

#### Learning objectives
Detailed comprehensive knowledge of state-of-the-art in satellite and space geodesy. Specialized conceptual skills to be able to apply the most relevant satellite techniques for specific fields of Earth system research.

#### Key competences
Recognition and application of complex topological relationships; Ability to transfer knowledge and methods to similar scientific challenges.

#### Learning content
Introduction to geometric space-geodetic techniques (SLR, GNSS, VLBI, DORIS, radar altimetry, intersatellite ranging); Earth in space; Dynamical satellite geodesy; Spherical harmonics and spherical harmonic computations; Force model; Gravity field representation; Space gravimetry; Effects of mass transports on geodetic observables (solid Earth, atmosphere, ocean, hydrosphere)

#### Prerequisites for admission to the module
none

#### Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
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<tbody>
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<td>12</td>
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<td>180 h</td>
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#### Academic performance
- Type of academic performance: un/marked
- Oral and/or written coursework: unmarked

#### Examination
- Type of examination (Duration in minutes): un/marked
- Oral examination (25 min): marked, Weight 100 %

#### Further information
Optional excursion to geodetic observatory.
References:

#### Date of issue
17 May 2017
## Module 'Advanced Data Analysis'

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
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<tbody>
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<td>180 h</td>
<td>6.0 LP</td>
<td>Summer semester</td>
<td>1 semester</td>
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</table>

### Module coordinator
Prof. Dr. techn. W.-D. Schuh

### Module lecturers
Prof. Dr. techn. W.-D. Schuh; Prof. Dr.-Ing. J. Kusche; MSc J. Köhler

### Providing teaching unit(s)
Institute of Geodesy and Geoinformation

### Course program usability

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>mandatory module (major profile GES)</td>
<td>2nd regular semester</td>
</tr>
</tbody>
</table>

### Learning objectives
Acquisition of detailed comprehensive knowledge of state-of-the-art in physical geodesy and geostatistics with a special focus on a variety of deterministic and stochastic approaches; Specialized conceptual skills to be able to apply the most relevant data analysis methods to problems of physical geodesy.

### Key competences
After successful completion of the course, the students have acquired basic skills to approximate spatial data and are able to assess the pros and cons of the different strategies. They are able to apply geostatistical concepts to practical applications.

### Learning content
Fundamental of potential theory, boundary value problems, physical geodesy, geoid determination; Basic concepts of geostatistics, deterministic approximation (polynoms, finite elements, splines), stochastic approximation (stochastic processes, stationary, covariance functions, Wiener-Kolmogorov-filtering, kriging, collocation)

### Prerequisites for admission to the module
none

### Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
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<td>75 h</td>
<td>180 h</td>
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### Academic performance

<table>
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<th>Type of academic performance</th>
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<td>Oral and/or written coursework</td>
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### Examination

<table>
<thead>
<tr>
<th>Type of examination (Duration in minutes)</th>
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<td>Oral examination (25 min)</td>
<td>marked</td>
<td>100 %</td>
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</table>

### Further information

- References:

### Date of issue
07 February 2018
### Module description

**Course of study:** Master program ‘Geodetic Engineering’  
Faculty of Agriculture - University of Bonn

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#### Module ‘Mass Transport Modelling and Monitoring’

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
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<td>MGE-GES-03</td>
<td>180 h</td>
<td>6.0 LP</td>
<td>Summer semester</td>
<td>1 semester</td>
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</table>

**Module coordinator**  
Prof. Dr.-Ing. J. Kusche

**Module lecturers**  
Prof. Dr.-Ing. J. Kusche

**Providing teaching unit(s)**  
Institute of Geodesy and Geoinformation

**Course program usability**

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
</tr>
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<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>elective module (profile GES)</td>
<td>2nd regular semester</td>
</tr>
<tr>
<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
<td>2nd regular semester</td>
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</tbody>
</table>

**Learning objectives**

Expert knowledge in the application of satellite-geodetic data for Earth system research; Properties and design of satellite missions for Earth system research

**Key competences**

Understanding advanced scientific publications; Discussion of scientific methods; Compiling and presenting scientific results; Ability to transfer knowledge and methods to similar scientific challenges.

**Learning content**

Introduction to physical oceanography, Navier-Stokes and geostrophic equations, ocean currents, boundary layer; Introduction to Earth’s climate and radiation budget; Introduction to hydrology, hydrological cycle, hydrological observation and modelling, glacial cycles, loading, and viscoelastic Earth models, sea level, sea-level equation; Interpretation of time-variable gravity and of sea level changes; Analysis of data products, data assimilation, sampling properties of satellite orbits; Design of satellite missions

**Prerequisites for admission to the module**

none

**Courses**

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
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<tbody>
<tr>
<td>1L+2Ep+1S</td>
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<td>6</td>
<td>60 h</td>
<td>180 h</td>
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</table>

**Academic performance**

Type of academic performance: un/marked  
Oral and/or written coursework: unmarked

**Examination**

Type of examination (Duration in minutes): un/marked  
Oral examination (25 min): marked 100 %

**Further information**

References:  
Www.iapg.bgu.tum.de/mediadb/21768/21769/programmschrift-Ed2.pdf

**Date of issue**

07 February 2018
Module description
Course of study: Master program ‘Geodetic Engineering’
Faculty of Agriculture - University of Bonn

Module ‘Numerics in C++’

<table>
<thead>
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<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
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<tr>
<td>MGE-GES-04</td>
<td>180 h</td>
<td>6.0 LP</td>
<td>Summer semester</td>
<td>1 semester</td>
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Module coordinator
Prof. Dr. techn. W.-D. Schuh

Module lecturers
Prof. Dr. techn. W.-D. Schuh, Dr.-Ing. J.M. Brockmann

Providing teaching unit(s)
Institute of Geodesy and Geoinformation

Course program usability

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
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<tr>
<td>Geodetic Engineering (MSc)</td>
<td>elective module (profile GES)</td>
<td>2nd regular semester</td>
</tr>
<tr>
<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
<td>2nd regular semester</td>
</tr>
</tbody>
</table>

Learning objectives
Specialized conceptual skills for scientific programming in C++, mapping of numerical algorithms to the object oriented C++ programming language, and the use of scientific standard libraries for linear algebra (BLAS, LAPACK); Expert knowledge in parallel programming and software development for the implementation of massive parallel numerical software with applications to adjustment problems

Key competences
Scientific programming skills, software development, efficient object oriented software development for numerical problems, working on massive parallel high-performance architectures, parallel computing and development

Learning content
Working in a LINUX environment; C++ basics (data types, loops, conditional statements, integral and floating point numbers, arrays and pointer, memory management, functions); Templates and standard template library; Object orientated programming, classes in C++ (operators); I/O; Compiling and linking programs (libraries, preprocessor, compiler and linker, make/cmake); Program optimization; Standard libraries for linear algebra (Basic Linear Algebra Subprograms and Linear Algebra Package); Introduction to parallel computing, concepts of parallel architectures, introduction to the message passing interface (basic idea and features, point to point and collective communication, parallel adjustment procedure)

Prerequisites for admission to the module
Cannot be selected simultaneously with ‘MGE-MSR-03 Modern C++ for Computer Vision’

Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
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<th>Workload</th>
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<tr>
<td>3L+1Ep</td>
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<td>180 h</td>
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Academic performance
Type of academic performance
un/marked

Oral and/or written coursework
unmarked

Examination
Type of examination (Duration in minutes)
un/marked

Oral examination (25 min)
marked 100%

Further information

References:
MPI Forum. MPI: A Message-Passing Interface Standard

Date of issue
08 February 2018
Module ‘VLBI for Geodetic and Geodynamical Applications’

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
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**Module coordinator**
PD Dr.-Ing. A. Nothnagel

**Module lecturers**
PD Dr.-Ing. A. Nothnagel

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

### Course program usability

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<td>elective module</td>
<td>3nd regular semester</td>
</tr>
</tbody>
</table>

### Learning objectives

Acquisition of expert knowledge on Very Long Baseline Interferometry for precise determination of positions of extragalactic radio sources, Earth orientation parameters, and terrestrial point positions and their kinematics; Competences in technical details of VLBI scheduling, correlations, fringe fitting, and data analysis

### Key competences

Ability to collect, describe, evaluate, and to interpret scientific information and to draw scientifically founded conclusions. Ability of recognition and application of complex topical relationships, competences in transfer of knowledge to other techniques

### Learning content

Planning, observations, and analysis of geodetic VLBI sessions; Operational aspects of radio telescopes; Theory of interferometry; Time systems; Relativistic effects; Technical realization of VLBI observations and correlation, bandwidth synthesis, mathematical issues of correlation und extraction of observables, parameter estimation, data interpretation; Geodynamic interpretation of results

### Prerequisites for admission to the module

none

### Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
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<td>1L+3S</td>
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<td>6</td>
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### Academic performance

- Type of academic performance: un/marked
- Oral and/or written coursework: unmarked

### Examination

- Type of examination (Duration in minutes):
  - Written term paper: marked, 75 %
  - Oral presentation (20 min): marked, 25 %

### Further information

Optional excursion to geodetic observatory.

References:
Ojars Sovers, John Fanselow, & Christopher Jacobs (1998): Astrometry and geodesy with radio interferometry: experiments, models, results; Reviews of Modern Physics, Vol. 70, No. 4, pp. 1393 - 1454

**Date of issue**
07 February 2018
## Module 'Satellite Gravimetry and Altimetry'

<table>
<thead>
<tr>
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<th>Workload</th>
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<tr>
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<td>6.0 LP</td>
<td>Winter semester</td>
<td>1 semester</td>
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### Module coordinator
Prof. Dr.-Ing. J. Kusche

### Module lecturers
Prof. Dr.-Ing. J. Kusche, PD Dr.-Ing. Luciana Fenoglio-Marc, PD Dr.-Ing. K. Börger

### Providing teaching unit(s)
Institute of Geodesy and Geoinformation

### Course program usability
<table>
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<th>Program of study</th>
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<tr>
<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
<td>3rd regular semester</td>
</tr>
</tbody>
</table>

### Learning objectives
Detailed comprehensive knowledge of state-of-the-art in satellite-geodetic modelling and data processing

### Key competences
- Ability to collect, describe, evaluate, and to interpret scientific information and to draw scientifically founded conclusions;
- Ability of recognition and application of complex topical relationships, competences in transfer of knowledge to other techniques

### Learning content
- Special methods in satellite geodesy (tracking, ranging, gradiometry);
- Principles and data processing of pulse-limited and delay-Doppler radar altimetry;
- Special methods of orbit integration, complete force model for near-Earth satellites, non-conservative force modelling, precise orbit determination;
- Fundamental of relativistic modelling, relativistic effects in satellite geodesy

### Prerequisites for admission to the module
none

### Courses
<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
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<tbody>
<tr>
<td>1L+2Ep+1S</td>
<td>Geodetic processing of satellite data</td>
<td>6</td>
<td>60 h</td>
<td>105 h</td>
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<tr>
<td>1L+1S</td>
<td>Relativistic modelling in satellite geodesy</td>
<td>6</td>
<td>30 h</td>
<td>75 h</td>
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### Academic performance
- Type of academic performance: un/marked
- Oral and/or written coursework: unmarked

### Examination
- Type of examination (Duration in minutes): un/marked
- Oral examination (25 min): marked

### Further information
- References:

### Date of issue
07 February 2018
# Module 'Stochastic Processes'

<table>
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**Module coordinator**
Prof. Dr. techn. W.-D. Schuh

**Module lecturers**
Prof. Dr. techn. W.-D. Schuh; Dr.-Ing. J.M. Brockmann

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

## Course program usability

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<tr>
<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
<td>3rd regular semester</td>
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## Learning objectives

Acquisition of expert knowledge on data analysis of deterministic and stochastic signals processing; Ability to apply the most relevant techniques to analyze and transform deterministic and stochastic signals

## Key competences

Ability to collect, describe, evaluate, and to interpret scientific information and to draw scientifically founded conclusions; Ability of recognition and application of complex topical relationships; Competences in transfer of knowledge to other techniques

## Learning content

Deterministic signal processing for periodic and non periodic, continuous time series (amplitude and phase spectrum, Parseval theorem, Fourier transform, convolution) Transition from continuous to discrete time series (Dirac Delta distribution, sampling theorem, window-function, discrete Fourier transform, discrete cyclic and linear convolution); discrete digital filters (design in time domain and frequency domain).

## Prerequisites for admission to the module

none

## Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
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<th>Workload</th>
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<td>6</td>
<td>75 h</td>
<td>180 h</td>
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## Academic performance

Type of academic performance : un/marked
Oral and/or written coursework : unmarked

## Examination

Type of examination (Duration in minutes) : un/marked
Oral examination (25 min) : marked

## Further information

References:

**Date of issue**
07 February 2018
Module ‘Understanding and modeling ocean dynamics’

<table>
<thead>
<tr>
<th>Code</th>
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<th>Credits</th>
<th>Turnus</th>
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<td>MGE-GES-08</td>
<td>180 h</td>
<td>6.0 LP</td>
<td>Summer semester</td>
<td>1 semester</td>
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**Module coordinator**
Prof. Dr. M. Schindelegger

**Module lecturers**
Prof. Dr. M. Schindelegger

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

**Course program usability**

<table>
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</tr>
<tr>
<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
<td>2rd regular semester</td>
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</table>

**Learning objectives**
Comprehensive knowledge of dynamical processes in the ocean and their representation through numerical means; Competence in applying forward modeling techniques for Earth system research

**Key competences**
Scientific programming skills; Conducting own numerical experiments and presenting the results; Ability to transfer knowledge of physical oceanography to similar scientific challenges, such as the analysis and interpretation of satellite-geodetic data

**Learning content**
Dynamics of the ocean being influenced by Earth rotation, density stratification, and atmospheric forces; Introduction to the conservation principles obeyed by fluids in motion and their finite-difference formulation; Substantiating theory with computer programs; Gradual construction of modular FORTRAN codes to illustrate and explore various dynamical phenomena (e.g., buoyancy-driven oscillations, inertial oscillations, surface gravity waves, 2D shallow-water waves, geostrophic currents, subtropical gyres, western boundary currents, formation of eddies due to baroclinic instability); Outlook on full 3D level modeling, tidal modeling, and other types of ocean models; Meridional overturning circulation and open science questions

**Prerequisites for admission to the module**
none

**Courses**

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
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</thead>
<tbody>
<tr>
<td>1L+2Es+1Ep</td>
<td>Understanding and modeling ocean dynamics</td>
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<td>180 h</td>
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**Academic performance**

<table>
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<th>Type of academic performance</th>
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**Examination**

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<td>100 %</td>
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**Further information**
FORTRAN skills are not required at the start of the course but will be gradually developed

**References:**

**Date of issue**
08 February 2018
# Module ‘Project Geodetic Earth System Science and Data Analysis - Part I’

<table>
<thead>
<tr>
<th>Code</th>
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<th>Credits</th>
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<td>MGE-GES-P-S</td>
<td>360 h</td>
<td>12.0 LP</td>
<td>Summer semester</td>
<td>1 semester</td>
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**Module coordinator**  
Prof. Dr.-Ing. J. Kusche

**Module lecturers**  
Prof. Dr.-Ing. J. Kusche, PD. Dr.-Ing. A. Nothnagel, Prof. Dr. techn. W.-D. Schuh, Prof. Dr.-Ing. R. Roscher

**Providing teaching unit(s)**  
Institute of Geodesy and Geoinformation

## Course program usability

<table>
<thead>
<tr>
<th>Program of study</th>
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<tr>
<td>Geodetic Engineering (MSc)</td>
<td>mandatory module (major profile GES)</td>
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</table>

## Learning objectives

Ability to work in a team on a complex and demanding scientific challenge in the field of space geodesy applying contemporary research methods; Capability to document and present the work and results in a concise manner to the scientific community

## Key competences

Project management; Team work; Leading and communication capabilities; Project presentation and documentation; Understanding scientific literature; Understanding and exploration of interdisciplinary contents

## Learning content

Extension of the existing MATLAB toolbox "Space Geodesy Simulator Bonn" including simulations of measurement processes in space-geodetic observing techniques such as SLR, VLBI, GPS, altimetry, and gravity missions; Simulation of perturbing effects, Earth rotation and transformations; Methods of processing satellite data, observing models, simulations of data analysis processes, and planning of new satellite missions or observing stations; Extension of the toolbox's module handbook

## Prerequisites for admission to the module

4 out of the mandatory modules, obligatory MGE-06

## Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
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<th>Workload</th>
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<td>6</td>
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<td>360 h</td>
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## Academic performance

Type of academic performance  
un/marked

Oral and/or written coursework  
unmarked

## Examination

Type of examination (Duration in minutes)  
un/marked

Projectwork  
marked  
Weight 100 %

## Further information

none

## Date of issue

15 May 2017
Module 'Project Geodetic Earth System Science and Data Analysis - Part II'

<table>
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<td>12.0 LP</td>
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</table>

**Module coordinator**
Prof. Dr. techn. W.-D. Schuh

**Module lecturers**
Prof. Dr.-Ing. J. Kusche, PD. Dr.-Ing. A. Nothnagel, Prof. Dr. techn. W.-D. Schuh, Prof. Dr.-Ing. R. Roscher

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

**Course program usability**

<table>
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<td>Geodetic Engineering (MSc)</td>
<td>mandatory module (major profile GES)</td>
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**Learning objectives**
Ability to work in a team on a complex and demanding scientific challenge in the field of space geodesy applying contemporary research methods; Capability to document and present the work and results in a concise manner to the scientific community

**Key competences**
Project management; Team work; Leading and communication capabilities; Project presentation and documentation; Understanding scientific literature; Understanding and exploration of interdisciplinary contents

**Learning content**
Extension of the existing MATLAB toolbox "Space Geodesy Simulator Bonn" including simulations of measurement processes in space-geodetic observing techniques such as SLR, VLBI, GPS, altimetry, and gravity missions; Simulation of perturbing effects, Earth rotation and transformations; Methods of processing satellite data, observing models, simulations of data analysis processes, and planning of new satellite missions or observing stations; Extension of the toolbox's module handbook

**Prerequisites for admission to the module**
Project Geodetic Earth System Science and Data Analysis - Part I (MGE-GES-P-S)

**Courses**

<table>
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<th>Workload</th>
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<td>Geodetic Earth System Science and Data Analysis</td>
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<td>120 h</td>
<td>360 h</td>
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**Academic performance**

<table>
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**Examination**

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**Further information**

none

**Date of issue**
15 May 2017
Module description
Course of study: Master program ‘Geodetic Engineering’
Faculty of Agriculture - University of Bonn

<table>
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<td>180 h</td>
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**Module coordinator**
Prof. Dr.-Ing. T. Kötter

**Module lecturers**
Prof. Dr.-Ing. T. Kötter

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

### Course program usability

<table>
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<tr>
<th>Program of study</th>
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<td>Geodetic Engineering (MSc)</td>
<td>mandatory module (profile GSD)</td>
<td>1st regular semester</td>
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</table>

### Learning objectives
Detailed comprehensive knowledge of state-of-the-art in urban development; Specialized conceptual skills to to solve strategic problems in urban development

### Key competences
Ability to collect, describe, evaluate, and to interpret scientific information and to draw scientifically founded conclusions; Ability of recognition and application of complex topical relationships

### Learning content
Current determinants and trends in urban development: reurbanization, suburbanization, urban sprawl, demographic change, climate change, energy demand; Models and principles for sustainable urban development and a resiliency city; Quantitative and qualitative methods of planning (MCA, UVP); Strategies and instruments of sustainable and resilient urban development: cost, land and resource efficiency, climate adaptation; Social housing, participation models; Planning and land management approaches to internal development: gap between buildings, redensification, brownfield redevelopment; Cooperative and sovereign action; Strategies and legal instruments of city renewal: urban regeneration, social urban renewal and urban reconstruction, urban design and urban preservation; Urban monument protection

### Prerequisites for admission to the module
none

### Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
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<tr>
<td>3L+2Es</td>
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### Academic performance

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### Examination

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### Further information

References:

### Date of issue
17 May 2017
Module description

Course of study: Master program ‘Geodetic Engineering’
Faculty of Agriculture - University of Bonn

Module 'Spatial Decision Support Systems'

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
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**Module coordinator**
Prof. Dr.-Ing. J.-H. Haunert

**Module lecturers**
Prof. Dr.-Ing. T. Kötter; Prof. Dr.-Ing. J.-H. Haunert

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

**Course program usability**

<table>
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<tr>
<th>Program of study</th>
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<th>Semester</th>
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**Learning objectives**
Detailed comprehensive competences in abstracting problems of spatial planning in mathematical terms; Specialized conceptual skills to solve problems with optimization software

**Key competences**
Scientific writing with terminology of spatial decision support systems; Team work; Use of geo-data as well as free and commercial software

**Learning content**
Methods of operations research in spatial planning; Dynamic urban calculation; Multi criteria assessment methods; Spatial unit allocation; Districting; Facility location; Mathematical modelling; Mathematical programming; Linear and integer linear programming; Neighborhood analysis; Applications of neighborhood graphs, Voronoi diagrams, and triangulations in planning

**Prerequisites for admission to the module**
none

**Courses**

<table>
<thead>
<tr>
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<th>Topic</th>
<th>Group size</th>
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<th>Workload</th>
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**Academic performance**

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**Further information**

References:


**Date of issue**
07 February 2018
Module ‘Land Management’

<table>
<thead>
<tr>
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**Module coordinator**
Prof. Dr.-Ing. T. Kötter

**Module lecturers**
Prof. Dr.-Ing. T. Kötter, Dipl.-Geogr. S. Müller-Grunau

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

**Course program usability**

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
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<tr>
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</tr>
<tr>
<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
<td>2nd regular semester</td>
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**Learning objectives**
Detailed comprehensive knowledge of state-of-the-art in land management; Specialized conceptual skills to solve strategic problems in land management

**Key competences**
Ability to collect, describe, evaluate, and to interpret scientific information and to draw scientifically founded conclusions; Ability of recognition and application of complex topical relationships; Competence in transfer of knowledge to other challenges

**Learning content**
Land policy; Land administration, land cadastre, and land register; Land law and land tax, rights and burdens on land, public and private stakeholders; Instruments of private and public law for building land development and provision: land use planning, planning security, urban development; Urban contracts, land acquisition, voluntary, and sovereign land management procedures; Expropriation, infrastructure provision, urban development measures; Land management in urban regeneration and urban redevelopment; Processes, actors, and funding urban development projects

**Prerequisites for admission to the module**
none

**Courses**

<table>
<thead>
<tr>
<th>Teaching method</th>
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**Further information**

References:

**Date of issue**
07 February 2018
### Module 'Location-Based Services'

<table>
<thead>
<tr>
<th>Code</th>
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**Module coordinator**
Prof. Dr.-Ing. J.-H. Haunert

**Module lecturers**
Prof. Dr.-Ing. J.-H. Haunert, J. Oehrlein

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

### Course program usability

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<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
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### Learning objectives
Detailed comprehensive knowledge of state-of-the-art in location-based services; Specialized conceptual skills to be able to develop methods and computer programs (apps) that help people accomplish complex navigations tasks.

### Key competences
Team work; App programming; Presentation of developed methods and systems

### Learning content
- Navigation systems and their components;
- Sensors for location-based services;
- Graph-theoretical concepts and algorithms for location-based services;
- Network analysis and visualization;
- Centrality and connectivity measures for the analysis of networks;
- Algorithms for routing problems;
- Route choice models;
- Landmark-based navigation;
- Cartographic visualization for navigation systems;
- Automatic generation of schematic network maps;
- Implementation of navigation apps for small mobile devices

### Prerequisites for admission to the module
none

### Courses

<table>
<thead>
<tr>
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<th>Topic</th>
<th>Group size</th>
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<th>Workload</th>
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### Academic performance

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### Further information
The lecture is based on scientific conference papers and articles, for example:

### Date of issue
07 February 2018
## Module 'Rural Development'

<table>
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<tr>
<th>Code</th>
<th>Workload</th>
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### Module coordinator
Prof. Dr.-Ing. T. Kötter

### Module lecturers
Prof. Dr.-Ing. T. Kötter, M.Sc. A.-M. Bolte

### Providing teaching unit(s)
Institute of Geodesy and Geoinformation

### Course program usability
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<td>Geodesy and Geoinformation (MSc)</td>
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### Learning objectives
Detailed comprehensive knowledge of state-of-the-art in rural development; Specialized conceptual skills to be able to solve strategic problems in rural development

### Key competences
Ability to collect, describe, evaluate, and to interpret scientific information and to draw scientifically founded conclusions; Ability of recognition and application of complex topical relationships; Competence in transfer of knowledge to other challenges

### Learning content
Structures, types, and trends of rural regions; Demographic and economic changes, problems of peripheral rural regions, urban-rural-cooperation, public and private stakeholders; Rural infrastructure and land consolidation: legal background, targets, and procedures; International approaches of rural development; Theory of regional and endogenous development; LEADER approach, change management, village renewal

### Prerequisites for admission to the module
none

### Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
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### Academic performance
Type of academic performance: un/marked
Oral and/or written coursework: unmarked

### Examination

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### Further information

References:

### Date of issue
07 February 2018
## Module description

**Course of study:** Master program ‘Geodetic Engineering’  
Faculty of Agriculture - University of Bonn

### Module 'Advanced Algorithms for Geo-Information Systems'

<table>
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**Module coordinator**  
Prof. Dr.-Ing. J.-H. Haunert

**Module lecturers**  
Prof. Dr.-Ing. J.-H. Haunert

**Providing teaching unit(s)**  
Institute of Geodesy and Geoinformation

### Course program usability

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<tr>
<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
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### Learning objectives

Detailed comprehensive knowledge of state-of-the-art in designing, analyzing, implementing, and testing new efficient algorithms for problems related to the analysis and visualization of spatial information.

### Key competences

Scientific writing with algorithmic terminology and mathematical rigor; Team work; Implementing software and experimenting with it

### Learning content

Design, analysis, and implementation of algorithms for problems of spatial analysis and the visualization of spatial information; Geometric integration of spatial data; Analysis of trajectories; Map matching; Automatic generalization; Line simplification; Aggregation of spatial information; Automatic map labelling; Automation in geoinformation science and cartography based on combinatorial optimization, including efficient algorithms, exact algorithms, and heuristics

### Prerequisites for admission to the module

none

### Courses

<table>
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<th>Group size</th>
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### Academic performance

Type of academic performance: un/marked
Oral and/or written coursework: unmarked

### Examination

Type of examination (Duration in minutes): un/marked  
Oral examination (25 min): marked  
Weight: 100 %

### Further information

References:  

### Date of issue

07 February 2018
### Module ‘Land Markets and Valuation’

<table>
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<th>Code</th>
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<th>Credits</th>
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#### Module coordinator
Prof. Dr.-Ing. T. Kötter

#### Module lecturers
Prof. Dr.-Ing. T. Kötter, Dr. D. Weiß

#### Providing teaching unit(s)
Institute of Geodesy and Geoinformation

#### Course program usability

<table>
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<td>elective module</td>
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#### Learning objectives
Detailed comprehensive knowledge of state-of-the-art in land markets and real estate valuation; Specialized conceptual skills to solve strategic problems in land valuation

#### Key competences
Ability to collect, describe, evaluate, and to interpret scientific information and to draw scientifically founded conclusions; Ability of recognition and application of complex topical relationships; Competence in transfer of knowledge to other challenges

#### Learning content
Structures, elements, and trends of land and real estate markets, public and private stakeholders; Interrelations between urban development and land markets; Economic, legal, and financial mathematical principles of real estate valuation; Determinants of land and real estate values; Methods of land and real estate valuation; Instruments for creating transparency on the property market; National standards of valuation methods: income approach, cost approach, sales comparison approach; International standards of valuation methods; Residual method, special tasks of valuation; Actors and institutions of land valuation

#### Prerequisites for admission to the module
none

#### Courses

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<th>Group size</th>
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<th>Workload</th>
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#### Academic performance

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#### Further information

References:

#### Date of issue
07 February 2018
# Module ‘Project Geoinformation and Spatial Development - Part I’

<table>
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## Module coordinator
Prof. Dr.-Ing. J.-H. Haunert

## Module lecturers
Prof. Dr.-Ing. T. Kötter; Prof. Dr.-Ing. J.-H. Haunert; Prof. Dr. S. Lautenbach; Prof. Dr.-Ing. R. Roscher

## Providing teaching unit(s)
Institute of Geodesy and Geoinformation

## Course program usability
<table>
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## Learning objectives
Successful students are able to work in a group on an open research problem related to geoinformation and spatial development. They are able to define realistic project goals, to choose and apply appropriate methods and tools for accomplishing these goals, and to assess their results critically.

## Key competences
- Project management
- Definition of project goals
- Working in a group
- Accomplishing project goals with individual contributions by group members
- Presentation, documentation, and discussion of project results
- Self-evaluation and reflection

## Learning content
Current topics of geoinformation and spatial development

## Prerequisites for admission to the module
4 out of the mandatory modules, obligatory MGE-06

## Courses
<table>
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<th>Topic</th>
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## Academic performance
- Type of academic performance: un/marked
- Oral and/or written coursework: unmarked

## Examination
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## Further information
none

## Date of issue
16 May 2017
Module description
Course of study: Master program ‘Geodetic Engineering’
Faculty of Agriculture - University of Bonn

<table>
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**Module coordinator**
Prof. Dr.-Ing. T. Kötter

**Module lecturers**
Prof. Dr.-Ing. T. Kötter; Prof. Dr.-Ing. J.-H. Haunert; Prof. Dr. S. Lautenbach; Prof. Dr.-Ing. R. Roscher

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

**Course program usability**
Program of study: Geodetic Engineering (MSc) Mode: mandatory module (major profile GSD) Semester: 3rd regular semester

**Learning objectives**
Successful students are able to work in a group on an open research problem related to geoinformation and spatial development. They are able to define realistic project goals, to choose, and apply appropriate methods and tools for accomplishing these goals, and to assess their results critically.

**Key competences**
Project management; Definition of project goals; Working in a group; Accomplishing project goals with individual contributions by group members; Presentation, documentation, and discussion of project results; Self-evaluation and reflection

**Learning content**
Current topics of geoinformation and spatial development

**Prerequisites for admission to the module**
Project Geoinformation and Spatial Development - Part I (MGE-GSD-P-S)

**Courses**

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**Academic performance**
Type of academic performance: un/marked
Oral and/or written coursework: unmarked

**Examination**
Type of examination (Duration in minutes): un/marked
Projectwork: marked Weight 50 %
Written report: marked Weight 50 %

**Further information**
none

**Date of issue**
16 May 2017
Module 'Sensors and State Estimation'

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**Module coordinator**

Prof. Dr. C. Stachniss

**Module lecturers**

Prof. Dr. C. Stachniss, Prof. Dr.-Ing. H. Kuhlmann

**Providing teaching unit(s)**

Institute of Geodesy and Geoinformation

**Course program usability**

<table>
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<th>Program of study</th>
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<tr>
<td>Geodetic Engineering (MSc)</td>
<td>mandatory module (profile MSR)</td>
<td>1st regular semester</td>
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</table>

**Learning objectives**

Detailed comprehensive knowledge of state-of-the-art in state estimation, smoothing, and filtering with a key focus on trajectory as well as pose estimation; Specialized conceptual skills to be able to solve strategic problems in the field of mobile sensing and robotics.

**Key competences**

Understanding of scientific papers; Presentation of own results; Team work; Programming skills that enable the implementation of basic techniques discussed in the lecture

**Learning content**

- Sensors (inertial sensors, accelerometer, gyroscope, IMU, magnetometer, laser scanner, GPS, RTK GPS); Odometry; Geometric and probabilistic motion models; Inertial navigation; Basic probabilistic models of range sensors; Environment models; Recursive Bayes filter, Kalman filter, and extended Kalman filter; Particle filter, Monte-Carlo localization; Smoothing

**Prerequisites for admission to the module**

none

**Courses**

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
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**Academic performance**

- Type of academic performance: un/marked
- Oral and/or written coursework: unmarked

**Examination**

- Type of examination (Duration in minutes): un/marked
- Oral examination (25 min): marked

**Weight**

Weight: 100 %

**Further information**

- Thrun, Burgard, Fox: Probabilistic Robotics, MIT Press, 2005

**Date of issue**

07 February 2018
Module 'Advanced Techniques for Mobile Sensing and Robotics'

<table>
<thead>
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<th>Turnus</th>
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<tr>
<td>MGE-MSR-02</td>
<td>180 h</td>
<td>6.0 LP</td>
<td>Summer semester</td>
<td>1 semester</td>
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</table>

**Module coordinator**
Prof. Dr. C. Stachniss

**Module lecturers**
Prof. Dr. C. Stachniss, Prof. Dr.-Ing. H. Kuhlmann, Dr.rer.nat. Lasse Klingbeil

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

**Course program usability**
Program of study: Geodetic Engineering (MSc) Mode: mandatory module (major profile MSR) Semester: 2nd regular semester

**Learning objectives**
Detailed comprehensive knowledge of state-of-the-art in key methods for state estimation, smoothing, and filtering with a key focus on trajectory estimation and mapping as well as motion planning; Specialized conceptual skills to solve problems in mobile sensing and robotics

**Key competences**
Understanding of scientific papers; Presentation of own results; Team work; Programming skills that enable the implementation of the techniques discussed in the lecture

**Learning content**
Camera models; Sensor calibration; System calibration; Relative orientation; Simultaneous localization and mapping; Bundle adjustment; Advanced sensor modeling; Time series analysis; Correlation; Shaping filter; Advanced Kalman filters; 3D environment models; Point clouds; Visual features; Feature matching; RANSAC; Path planning

**Prerequisites for admission to the module**
none

**Courses**

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>3L+2Ep</td>
<td>Advanced Techniques for Mobile Sensing and Robotics</td>
<td>12</td>
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**Academic performance**
Type of academic performance: un/marked
Oral and/or written coursework: unmarked

**Examination**
Type of examination (Duration in minutes): un/marked
Oral examination (25 min): marked 100 %

**Further information**
Thrun, Burgard, Fox: Probabilistic Robotics, MIT Press, 2005

**Date of issue**
07 February 2018
Module description
Course of study: **Master program ‘Geodetic Engineering’**
Faculty of Agriculture - University of Bonn

### Module ‘Modern C++ for Computer Vision’

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
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<td>Summer semester</td>
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</table>

**Module coordinator**
Prof. Dr. C. Stachniss

**Module lecturers**
I. Bogoslavskyi, Prof. Dr. C. Stachniss

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

### Course program usability

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
</tr>
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<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>elective module (profile MSR)</td>
<td>2nd regular semester</td>
</tr>
<tr>
<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
<td>2nd regular semester</td>
</tr>
</tbody>
</table>

### Learning objectives
Detailed comprehensive knowledge in programming in C++ with focus on image processing; Specialized conceptual skills to solve typical image processing tasks using C++ and OpenCV such as feature extraction, clustering, segmentation, and matching; Use of revision control systems such as git

### Key competences
Presentation of own software developments; Project planning

### Learning content
Programming in C++: Revision control using git; Solving typical image processing task using C++ and OpenCV; Feature extraction; Clustering; Segmentation; Matching;

### Prerequisites for admission to the module
Cannot be selected simultaneously with 'MGE-GES-04 Numerics in C++'

### Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>1L+2Ep+1S</td>
<td>Modern C++ for Computer Vision</td>
<td>6</td>
<td>60 h</td>
<td>180 h</td>
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</tbody>
</table>

**Academic performance**

Type of academic performance: un/marked
Oral and/or written coursework: unmarked

**Examination**

Type of examination (Duration in minutes): un/marked
Oral examination (25 min): marked
Weight: 100 %

### Further information
References:
http://docs.opencv.org/2.4/doc/tutorials/tutorials.html
https://www.atlassian.com/git/tutorials

**Date of issue**
07 February 2018
### Module 'GNSS: methods for quality assurance'

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGE-MSR-04</td>
<td>180 h</td>
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<td>1 semester</td>
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</table>

**Module coordinator**  
Prof. Dr.-Ing. H. Kuhlmann

**Module lecturers**  
Prof. Dr.-Ing. H. Kuhlmann, F. Zimmermann

**Providing teaching unit(s)**  
Institute of Geodesy and Geoinformation

**Course program usability**

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
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<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>elective module (profile MSR)</td>
<td>2nd regular semester</td>
</tr>
<tr>
<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
<td>2nd regular semester</td>
</tr>
</tbody>
</table>

**Learning objectives**

Knowledge in performing and processing GNSS-observations; In-depth knowledge of systematic observation errors in GNSS; Implementation of algorithms for the detection, quantification and minimization of systematic observation errors.

**Key competences**

Academic writing, planning, realization and analysis of test measurements; Understanding of scientific and technical papers; Documentation of experiments and software; Presentation of results and experiments

**Learning content**

Literature research and knowledge of common and state-of-the-art techniques to minimize systematic observation errors; Handling of GNSS equipment and post-processing software packages; Conception and realization of suitable field test; Interpretation of GNSS data and processing results.

**Prerequisites for admission to the module**

none

**Courses**

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>2Ep+1S</td>
<td>GNSS: methods for quality assurance</td>
<td>6</td>
<td>45 h</td>
<td>180 h</td>
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**Academic performance**

Type of academic performance: un/marked  
Oral and/or written coursework: unmarked

**Examination**

<table>
<thead>
<tr>
<th>Type of examination (Duration in minutes)</th>
<th>Weight</th>
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</thead>
<tbody>
<tr>
<td>Written term paper</td>
<td>75 %</td>
</tr>
<tr>
<td>Oral presentation (20 min)</td>
<td>25 %</td>
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</table>

**Further information**

none

**Date of issue**  
07 February 2018
## Module ‘Accuracy evaluation of geodetic 3D metrology’

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGE-MSR-05</td>
<td>180 h</td>
<td>6.0 LP</td>
<td>Winter semester</td>
<td>1 semester</td>
</tr>
</tbody>
</table>

### Module coordinator
Prof. Dr.-Ing. H. Kuhlmann

### Module lecturers
Prof. Dr.-Ing. H. Kuhlmann, Dr.-Ing. Ch. Holst

### Providing teaching unit(s)
Institute of Geodesy and Geoinformation

### Course program usability

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>elective module (profile MSR)</td>
<td>3rd regular semester</td>
</tr>
<tr>
<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
<td>3rd regular semester</td>
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</table>

### Learning objectives
Knowledge in performing and processing laser scanner measurements; In-depth knowledge of systematic observation errors at laser scanning; Implementation of algorithms for the detection, quantification and minimization of systematic observation errors

### Key competences
Academic writing, planning, realization and analysis of test measurements; Understanding of scientific and technical papers; Documentation of experiments and software; Presentation of results and experiments

### Learning content
Literature research and knowledge of common and state-of-the-art techniques to minimize systematic observation errors; Handling of laser scanners and corresponding equipment; Conception and realization of suitable field tests; Interpretation of laser scans and processing of results

### Prerequisites for admission to the module
none

### Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>2Ep+1S</td>
<td>Accuracy evaluation of geodetic 3D metrology</td>
<td>6</td>
<td>45 h</td>
<td>180 h</td>
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### Academic performance

<table>
<thead>
<tr>
<th>Type of academic performance</th>
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</thead>
<tbody>
<tr>
<td>Oral and/or written coursework</td>
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### Examination

<table>
<thead>
<tr>
<th>Type of examination (Duration in minutes)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written term paper</td>
<td>marked 75 %</td>
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<tr>
<td>Oral presentation (20 min)</td>
<td>marked 25 %</td>
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### Further information
none

### Date of issue
07 February 2018
# Module 'Advanced Perception for Mobile Robotics'

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
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<td>MGE-MSR-06</td>
<td>180 h</td>
<td>6.0 LP</td>
<td>Winter semester</td>
<td>1 semester</td>
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</table>

**Module coordinator**
Prof. Dr. C. Stachniss

**Module lecturers**
Prof. Dr. C. Stachniss

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

## Course program usability

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>elective module (profile MSR)</td>
<td>3rd regular semester</td>
</tr>
<tr>
<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
<td>3rd regular semester</td>
</tr>
</tbody>
</table>

## Learning objectives
Detailed comprehensive knowledge of key methods for robot perception and navigation including the development of robot modules using C++

## Key competences
Understanding of scientific papers; Presentation of own results; Team work; Programming skills in C++ that enable the implementation of the techniques discussed in the course; Use of revision control systems such as git

## Learning content
The Robot Operating System ROS; Developing ROS modules; Classification and machine learning for robot navigation; Advanced perception; Robot navigation systems

## Prerequisites for admission to the module
Programming experience in C++, for example obtained through the course 'MGE-MSR-03 Modern C++ for Computer Vision'

## Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>1L+2Ep+1S</td>
<td>Advanced Perception for Mobile Robotics</td>
<td>6</td>
<td>60 h</td>
<td>180 h</td>
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## Academic performance

<table>
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<td>Oral and/or written coursework</td>
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## Examination

<table>
<thead>
<tr>
<th>Type of examination (Duration in minutes)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral examination (25 min)</td>
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</table>

## Further information

References:
http://wiki.ros.org/ROS/Tutorials

## Date of issue
07 February 2018
Module 'Stochastic of Inertial Navigation Systems'

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGE-MSR-07</td>
<td>180 h</td>
<td>6.0 LP</td>
<td>Winter semester</td>
<td>1 semester</td>
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</table>

**Module coordinator**
Prof. Dr.-Ing. H. Kuhlmann

**Module lecturers**
Prof. Dr.-Ing. H. Kuhlmann, Dr. rer. Nat. L. Klingbeil

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

**Course program usability**
<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>elective module (profile MSR)</td>
<td>3rd regular semester</td>
</tr>
<tr>
<td>Geodesy and Geoinformation (MSc)</td>
<td>elective module</td>
<td>3rd regular semester</td>
</tr>
</tbody>
</table>

**Learning objectives**
Specialized conceptual skills and practical experience in using inertial sensors; Validation of the stochastic behavior of inertial sensors; Determination and interpretation of the Allan-variance; Integration of inertial sensors in a strapdown-algorithm; Calibration of sensors; Assessment of the accuracy of measurement results

**Key competences**
Realization of measurements; Academic writing; Working in groups; Group or team coordination; Understanding of scientific and technical papers; Coordination of software developments; Preparation of software documentations

**Learning content**
Development of methods for the assessment and calibration of inertial sensors; Planning and realization of static long-term experiments under stable conditions and kinematic experiments; Comparison of the behavior and the results of different grades of inertial sensors, such as automotive, tactical-grade and navigation-grade inertial sensors

**Prerequisites for admission to the module**
none

**Courses**

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>1L+2Ep+1S</td>
<td>Stochastic of Inertial Navigation Systems</td>
<td>6</td>
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<td>180 h</td>
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**Academic performance**
Type of academic performance: un/marked
Oral and/or written coursework: unmarked

**Examination**
Type of examination (Duration in minutes)
Written term paper: marked, Weight: 75 %
Oral presentation (20 min): marked, Weight: 25 %

**Further information**
References:

**Date of issue**
07 February 2018
# Module ‘Project Mobile Sensing and Robotics - Part I’

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
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<tbody>
<tr>
<td>MGE-MSR-P-S</td>
<td>360 h</td>
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<td>Summer semester</td>
<td>1 semester</td>
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**Module coordinator**
Prof. Dr.-Ing. H. Kuhlmann

**Module lecturers**
Prof. Dr.-Ing. H. Kuhlmann; Prof. Dr. C. Stachniss

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

## Course program usability

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
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<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>mandatory module (major profile MSR)</td>
<td>2nd regular semester</td>
</tr>
</tbody>
</table>

## Learning objectives

Ability to systematically solve relevant problems in the context of mobile sensing and robotics, document the progress and present results in a scientific way.

## Key competences

Understanding of scientific papers; Programming skills; Developing state-of-the-art methods in robotics and mobile sensing; Documentation and presentation of own results; Team work; Use of revision control systems such as git

## Learning content

Moving objects; Pose estimation and localization; Trajectory estimation; Simultaneous localization and mapping; Sensor calibration; Sensor fusion; Advanced sensor data interpretation; Pointcloud processing; Machine learning for perception; AI techniques for robot navigation

## Prerequisites for admission to the module

4 out of the mandatory modules, obligatory MGE-06

## Courses

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
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<th>Workload</th>
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<td>1Es+5Ep+2S</td>
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## Academic performance

<table>
<thead>
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<tr>
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## Examination

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<tbody>
<tr>
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## Further information

none

## Date of issue

15 May 2017
Module ‘Project Mobile Sensing and Robotics - Part II’

<table>
<thead>
<tr>
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<tbody>
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<td>MGE-MSR-P-W</td>
<td>360 h</td>
<td>12.0 LP</td>
<td>Winter semester</td>
<td>1 semester</td>
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</table>

**Module coordinator**
Prof. Dr. C. Stachniss

**Module lecturers**
Prof. Dr.-Ing. H. Kuhlmann; Prof. Dr. C. Stachniss

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

**Course program usability**

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
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<tr>
<td>Geodetic Engineering (MSc)</td>
<td>mandatory module (major profile MSR)</td>
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</table>

**Learning objectives**
Ability to systematically solve relevant problems in the context of mobile sensing and robotics, document the progress and present results in a scientific way.

**Key competences**
Understanding of scientific papers; Programming skills; Developing state-of-the-art methods in robotics and mobile sensing; Documentation and presentation of own results; Team work; Use of revision control systems such as git

**Learning content**
Moving objects; Pose estimation and localization; Trajectory estimation; Simultaneous localization and mapping; Sensor calibration; Sensor fusion; Advanced sensor data interpretation; Pointcloud processing; Machine learning for perception; AI techniques for robot navigation

**Prerequisites for admission to the module**
Project Mobile Sensing and Robotics - Part I (MGE-MSR-P-S)

**Courses**

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
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<th>Workload</th>
</tr>
</thead>
<tbody>
<tr>
<td>1Es+5Ep+2S</td>
<td>Mobile Sensing and Robotics</td>
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<td>120 h</td>
<td>360 h</td>
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**Academic performance**

<table>
<thead>
<tr>
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</thead>
<tbody>
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**Examination**

<table>
<thead>
<tr>
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<th>Weight</th>
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<tbody>
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<tr>
<td>Written report</td>
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<td>50 %</td>
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**Further information**
none

**Date of issue**
15 May 2017
### Module ‘Master’s Thesis’

<table>
<thead>
<tr>
<th>Code</th>
<th>Workload</th>
<th>Credits</th>
<th>Turnus</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>MGE-MT</td>
<td>900 h</td>
<td>30.0 LP</td>
<td>Summer semester</td>
<td>1 semester</td>
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**Module coordinator**
PD Dr.-Ing. A. Nothnagel

**Module lecturers**
all lecturers of “Geodetic Engineering (MSc)”

**Providing teaching unit(s)**
Institute of Geodesy and Geoinformation

<table>
<thead>
<tr>
<th>Program of study</th>
<th>Mode</th>
<th>Semester</th>
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</thead>
<tbody>
<tr>
<td>Geodetic Engineering (MSc)</td>
<td>Master’s thesis</td>
<td>4th regular semester</td>
</tr>
</tbody>
</table>

**Learning objectives**
Independent and extensive analysis and interpretation of a research task; Ability to independently cope with a scientific problem in the relevant subject area on the basis of scientific methods within a set period of time; Specialized professional and conceptual skills to assess and present the research results

**Key competences**
Project management; Systematic search of information and literature; Understanding and using scientific texts; Writing scientific text in a concise way; Oral presentation of scientific results

**Learning content**
According to the Master’s thesis task.

**Prerequisites for admission to the module**
All mandatory modules (MGE-01 to MGE-06) and at least 60 LP

**Courses**

<table>
<thead>
<tr>
<th>Teaching method</th>
<th>Topic</th>
<th>Group size</th>
<th>Time of contact</th>
<th>Workload</th>
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</thead>
<tbody>
<tr>
<td>...</td>
<td>Master’s Thesis</td>
<td>1</td>
<td>0 h</td>
<td>900 h</td>
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</table>

**Academic performance**
Type of academic performance: un/marked, none

**Examination**
Type of examination (Duration in minutes): un/marked
Master’s thesis: marked, 100 %

**Further information**
The Master’s thesis is issued at the beginning of the fourth semester. The Master’s thesis task is given by the examination board. According to the examination regulations the working time of the Master’s thesis is at least four but not more than six months. Upon motivated request, the examination board, in agreement with the supervisor, may grant an extension of time of up to six weeks. The printed version of the Master’s thesis has to be handed over to the examination board in triplicate. In addition, the thesis has to be submitted electronically in an appropriate format suited for digital inspection, such as MS Word or pdf format. The result of the evaluation of the Master’s thesis shall be brought to the attention of the student eight weeks after submission at the latest.

**Date of issue**
16 May 2017