Module Manual
Master's Program

Mobile Robotics
(M.Sc.)

Faculty of Agricultural, Nutritional and Engineering Sciences

in cooperation with the

Faculty of Mathematics and Natural Sciences

Content

Module Manual
Master's Program

Mobile Robotics
(M.Sc.)

General mandatory modules

Code: **MA-MORO-M01**
Title: **Introduction to Mobile Robotics**

1 Content and intended learning outcomes

Content:

Part 'Introduction to Mobile Robotics':

Bayes filter, environment models, occupancy mapping, motion modeling, probabilistic motion models, probabilistic sensor models, state estimation, Kalman filter, extended Kalman filter, localization, particle filter, sensor odometry, basics of simultaneous localization and mapping (SLAM); SLAM with kalman and particle filters.

Part 'Robot Planning and Control':

Theory of dynamic systems; Basics of control theory; kinematic structures and models for wheeled robots; digital control systems; P/PD/PID Controller; Model predictive control; Trajectory control; Planning; Motion planning; Roadmap planning; Markov decision processes.

Qualification goals:

Students are able to

- explain the methods discussed in the lecture precisely, including the underlying equations;
- assess which estimation methods are suitable for different application scenarios and which are not;
- explain how the above-mentioned estimation methods are adapted and used for specific sensors;
- establish the connection between the mathematical description of state estimation methods and their implementation;
- explain and derive the basic equations;
- implement the basic solution methods;
- assess the complexity of methods and algorithms.

2 Teaching and learning methods

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	Introduction to Mobile Robotics	EN	30	2	90	W
2	Exercise, scientific	Introduction to Mobile Robotics	EN	15	2	90	W
3	Lecture	Robot Planning and Control	EN	30	1	45	W
4	Exercise, scientific	Robot Planning and Control	EN	15	1	45	W

3 Prerequisites to take part the module

obligatory:

none

recommended:

Basic programming skills in Python for completing homework assignments

4 Study program allocation

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-M01	General mandatory selection	1st

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Written examination	Successful completion of the exercises (minimum 50% of the points)	120 min.	graded	EN	67%
2	Written examination	Successful completion of the exercises (minimum 50% of the points)	60 min.	graded	EN	33%

6 **Credits according ECTS**

9 LP

7 **Workload**

270 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Winter

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Cyrill Stachniss	Institut für Geodäsie und Geoinformation	2,5	1,3	1,2,3,4
2	Prof. Dr. Maren Bennewitz	Institut für Informatik	0,5	1	---
3	Team Prof. Stachniss	Institut für Geodäsie und Geoinformation	3,0	1,2,3,4	---

Module coordinator / Organization:
Prof. Dr. Cyrill Stachniss, Institut für Geodäsie und Geoinformation

12 **Further information**

- Thrun, Burgard, Fox: Probabilistic Robotics, MIT Press, 2005
- Corke: Robotics, Vision and Control, Springer, 2017
- LaValle: Planning Algorithms, Cambridge University Press, 2006, http://lavalle.pl/planning/
- Siciliano, Khatib (Eds): Springer Handbook of Robotics, 2nd edition

13 **Date of version**

17.02.2026

Code: **MA-MORO-M02**
Title: **Trajectory Estimation**

1 Content and intended learning outcomes

Content:

Basic principle of Global Navigation Satellite Systems; Coordinate systems, 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; Trajectory estimation for mobile platforms; Sensors (inertial sensors, accelerometer, gyroscope, IMU, magnetometer, GNSS); Odometry; Inertial navigation; State Estimation algorithms; Kalman filter, Extended Kalman filter; Smoothing

Qualification goals:

Students are able to

Part 'Global Navigation Satellite Systems':

- describe and explain the basics of satellite-based global positioning (GNSS) and its physical, functional, and stochastical characteristics
- apply different GNSS based processing methods to raw dats sets
- interpret and evaluate processing results and discuss deviations and rerrors

Part 'Inertial Navigation Systems':

- explain the trajectory estimation methods discussed in the lecture precisely, including the underlying equations;
- assess which estimation methods are suitable for different application scenarios and which are not;
- explain how the above-mentioned estimation methods are adapted and used for specific sensors;
- establish the connection between the mathematical description of state estimation methods and their implementation;
- explain and derive the basic equations;
- implement the basic solution methods;
- assess the complexity of methods and algorithms.

2 Teaching and learning methods

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	Global Navigation Satellite Systems	EN	30	1	45	W
2	Exercise, scientific	Global Navigation Satellite Systems	EN	15	1	45	W
3	Lecture	Inertial Navigation Systems	EN	30	1	45	W
4	Exercise, scientific	Inertial Navigation Systems	EN	15	1	45	W

3 Prerequisites to take part the module

obligatory:

none

recommended:

none

4 Study program allocation

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-M02	General mandatory selection	1st

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Written examination	Successful completion of the exercises (minimum 50% of the points)	60 min.	graded	EN	50%
2	Written examination	Successful completion of the exercises (minimum 50% of the points)	60 min.	graded	EN	50%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Winter

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Lasse Klingbeil	Institut für Geodäsie und Geoinformation	2,0	1,3	1,2,3,4
2	Team Prof. Klingbeil	Institut für Geodäsie und Geoinformation	2,0	2,4	···

Module coordinator / Organization:
Prof. Dr. Lasse Klingbeil, Institut für Geodäsie und Geoinformation

12 **Further information**

none

13 **Date of version**

17.02.2026

Code: **MA-MORO-M03**
Title: **Python for Robotics and Computer Vision**

1 Content and intended learning outcomes

Content:

In this course students will be introduced several of the basic ideas of programming and learn how to use it practically by using Python as the programming language. In the first half of the course, the students will become familiar with basic concepts such as variables, control statements, functions, modules (libraries), and object-oriented programming (classes). In the second half, the students will gain a deeper understanding of classes and also be introduced into scientific computing including data structures, manipulation of images (multi-dimensional arrays), advanced operators and insights into performing efficient operations in Python. The students are expected to be programming throughout the course so that they can practically demonstrate their knowledge by developing their own solutions and code.

Qualification goals:

Ability to convert problems into code (Python), principles of objects-oriented programming, and able to perform operations on multi-dimensional data. Problem solving and abstract thinking.

2 Teaching and learning methods

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	Python for Robotics & Computer Vision	EN	30	2	90	W
2	Exercise, scientific/practical	Python for Robotics & Computer Vision	EN	30	2	90	W

3 Prerequisites to take part the module

obligatory:

none

recommended:

Prior programming experience is considered a plus.

4 Study program allocation

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-M03	General mandatory selection	1st

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Tasks accompanying the semester	none	90 min.	graded	EN	40%
2	Written examination	completed exercises	120 min.	graded	EN	60%

6 Credits according ECTS

6 LP

7 Workload

180 h

8 Duration

1 Semester

9 Frequency

Start in Winter

10 Maximum number of students

no limitation

11	**Module coordination**
	Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Dr. Patrick Zimmer	Institut für Landtechnik	4,0	1,2	1,2

Module coordinator / Organization:
Dr. Patrick Zimmer, Institut für Landtechnik

12	**Further information**
	Examination must be passed. Students are expected to have access to their own computer/laptop
13	**Date of version**
	20.02.2026

Code: **MA-MORO-M04**
Title: **Computer Vision**

1 **Content and intended learning outcomes**

Content:

The class will cover a number of mathematical methods and their applications in computer vision. For example, linear filters, edges, derivatives, Hough transform, segmentation, graph cuts, mean shift, active contours, level sets,

MRFs, expectation maximization, background subtraction, temporal filtering, active appearance models, shapes, optical flow, 2d tracking, cameras, 2d/3d features, stereo, 3d reconstruction, 3d pose estimation, articulated pose

estimation, deformable meshes, RGBD vision.

Qualification goals:

Learning goals technical skills: Students will be able to understand and explain mathematical descriptions of methods in publications from Computer Vision. Students will be able to implement the discussed Computer Vision algorithms, apply them, and choose the right approach and hyper-parameters for a given problem.

Learning goals soft skills: Productive work in small teams, development and realization of individual approaches and solutions, critical reflection of competing methods, discussion in groups.

2 **Teaching and learning methods**

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	Computer Vision	EN	30	4	165	W
2	Exercise, scientific/practical	Computer Visino	EN	30	2	105	W

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

Basic knowledge of linear algebra, analysis, probability theory, Python programmin

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-M04	Elective selection	1st
2	Computer Science (M.Sc.)	MA-INF 2201	Optional selection	1st,2nd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Written examination	The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved.	120 min.	graded	EN	100%

6 **Credits according ECTS**

9 LP

7 **Workload**

270 h

8 **Duration**

1 Semester

9	**Frequency**
	Start in Winter
10	**Maximum number of students**
	no limitation
11	**Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Jürgen Gall	Institut für Informatik	6,0	1,2	1,2

Module coordinator / Organization:
Prof. Dr. Jürgen Gall, Institut für Informatik

12	**Further information**
	Literature: R. Hartley, A. Zisserman: Multiple View Geometry in Computer Vision R. Szeliski: Computer Vision: Algorithms and Applications S. Prince: Computer Vision: Models, Learning, and Inference
13	**Date of version**
	20.02.2026

Code: **MA-MORO-M05**
Title: **Robot Mapping**

1 Content and intended learning outcomes

Content:

Point cloud registration and iterative closet point algorithm; graph-based simultaneous localization and mapping; robust least squares; hierarchical optimization approaches; camera parameters and calibration; stereo and relative orientation; triangulation; bundle adjustment; 3D sensors, laser scanners, kinematic laser scanning, mobile mapping, system calibration, sensor synchronization, mapping with UAVs, uncertainties of mapping products, basics of point cloud processing.

Qualification goals:

Students are able to

- explain the methods discussed in the lecture precisely, including the underlying equations;
- assess which estimation methods are suitable for different application scenarios and which are not;
- explain how the above-mentioned estimation methods are adapted and used for specific sensors;
- establish the connection between the mathematical description of state estimation methods and their implementation;
- explain and derive the basic equations;
- implement the basic solution methods;
- assess the complexity of methods and algorithms.

2 Teaching and learning methods

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	Graph-based SLAM	EN	30	2	60	S
2	Exercise, scientific/practical	Graph-based SLAM	EN	15	1	45	S
3	Lecture	3D Mapping	EN	30	1	30	S
4	Exercise, scientific/practical	3D Mapping	EN	14	1	45	S

3 Prerequisites to take part the module

obligatory:

none

recommended:

Mobile Robotics: MA-MoRo-M01, MA-MoRo-M01
Geodetic Engineering: MGE-MSR-01, MGE-01, MGE-02, MGE-06

4 Study program allocation

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-M05	General mandatory selection	2nd
2	Geodetic Engineering (M.Sc.)	MA-GE-MSR-02	Profile-related mandatory selection	2nd

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Written examination	Successful completion of the exercises (minimum of 50% of the points)	60 min.	graded	EN	50%
2	Written examination	Successful completion of the exercises (minimum of 50% of the points)	60 min.	graded	EN	50%

6	**Credits according ECTS**
	6 LP
7	**Workload**
	180 h
8	**Duration**
	1 Semester
9	**Frequency**
	Start in Summer
10	**Maximum number of students**
	no limitation
11	**Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Cyrill Stachniss	Institut für Geodäsie und Geoinformation	2,0	1	1,2
2	Prof. Dr. Heiner Kuhlmann	Institut für Geodäsie und Geoinformation	0,3	3	3
3	PD Dr. Lasse Klingbeil	Institut für Geodäsie und Geoinformation	0,8	3	3,4
4	Team Prof. Stachniss	Institut für Geodäsie und Geoinformation	1,0	2	---
5	Team Prof. Kling-beil/Kuhlmann	Institut für Geodäsie und Geoinformation	1,0	4	---

Module coordinator / Organization:

Prof. Dr. Cyrill Stachniss, Institut für Geodäsie und Geoinformation; Prof. Dr. Lasse Klingbeil, Institut für Geodäsie und Geoinformation

12	**Further information**
	none
13	**Date of version**
	20.02.2026

Code: **MA-MORO-M06**

Title: **Machine Learning for Robotics and Computer Vision**

1 Content and intended learning outcomes

Content:

Introduction to machine learning covering supervised and unsupervised techniques in the context of robotics and computer vision; basic concepts of machine learning: classification, regression, clustering; Ensemble methods and boosting; Machine learning applications for computer vision and robotics; Deep learning with a focus on convolutional neural networks (CNN) and Vision Transformers; Learning and techniques for training deep models; Common approaches for different perception tasks (classification, detection, semantic/panoptic segmentation); Current research topics: Applications of Vision Transformers, Representation Learning, Self-supervised Learning, Vision Language Models (VLMs)

Qualification goals:

Students are able to

- explain the methods discussed in the lecture precisely, including the underlying equations and assumptions;
- assess which learning approaches are suitable for different application scenarios and which are not;
- explain how the above-mentioned approaches are adapted and used for specific datasets;
- establish the connection between the mathematical description of learning approaches and their implementation;
- explain and derive the basic equations;
- implement the basic solution methods in Python;
- assess the complexity of methods and algorithms.

2 Teaching and learning methods

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	Machine Learning for Robotics and Computer Vision	EN	30	2	90	S
2	Exercise, scientific/practical	Machine Learning for Robotics and Computer Vision	EN	30	2	90	S

3 Prerequisites to take part the module

obligatory:

Geodetic Engineering (M.Sc.): MA-GE-MSR-01

Geodäsie und Geoinformation (M.Sc.): MA-GuG-M23

recommended:

Python programming capabilities

Mobile Robotics (M.Sc.): MA-MoRo-M01

4 Study program allocation

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-M06	General mandatory selection	2nd
2	Geodetic Engineering (M.Sc.)	MA-GE-MSR-03	Elective selection	2nd
3	Geodäsie und Geoinformation (M.Sc.)	MA-GuG-M26	Fachgebundener Wahlpflichtbereich: Wahlpflichtmodul "groß"	2.

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Written examination	successful competion of the exercises (minimum 50% of the points)	120 min.	graded	EN	100%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Summer

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Jens Behley	Institut für Geodäsie und Geoinformation	2,0	1	1,2
2	Team Stachniss	Institut für Geodäsie und Geoinformation	2,0	2	---

Module coordinator / Organization:

PD Jens Behley, Institut für Geodäsie und Geoinformation

12 **Further information**

none

13 **Date of version**

20.02.2026

Module Manual
Master's Program

Mobile Robotics
(M.Sc.)

Project-related mandatory modules

Code: **MA-MORO-PS**
Title: **Mobile Robotics Research Part 1**

1 **Content and intended learning outcomes**

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; Semantic sensor data interpretation; AI techniques for robot navigation

Qualification goals:

Students are able to
- acquire advanced knowledge about a given research topic/problem;
- develop a project plan toward a solution to a given problem;
- organize and distribute the work within their team;
- systematically solve the research problems;
- document the progress and present results in a scientific way.

2 **Teaching and learning methods**

#	Type	Topic	Lan-guage	Group-size	SWS	Work-load	Term
1	Small Group Project	Mobile Robotics Research - Part 1	EN	5	4	180	S

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

MA-MoRo-M01, MA-MoRo-M02, MA-MoRo-M03

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-PS	General mandatory selection	2nd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
1	Projectwork	successful presentation and dis-cussion of intermediate results at two project meetings within the semester	cours e ac-com-pany-ing	graded	EN	100%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Summer

10 **Maximum number of students**

no limitation

11	**Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Cyrill Stachniss	Institut für Geodäsie und Geoinformation	1,0	1	1
2	Prof. Dr. Lasse Klingbeil	Institut für Geodäsie und Geoinformation	1,0	1	1
3	Prof. Dr. Ribana Roscher	Institut für Geodäsie und Geoinformation	1,0	1	1
4	Prof. Dr. Heiner Kuhlmann	Institut für Geodäsie und Geoinformation	1,0	1	1
5	Group Stachniss	Institut für Geodäsie und Geoinformation	3,0	1	---
6	Group Klingbeil	Institut für Geodäsie und Geoinformation	3,0	1	---
7	Group Roscher	Institut für Geodäsie und Geoinformation	3,0	1	---
8	Group Kuhlmann	Institut für Geodäsie und Geoinformation	3,0	1	---

Module coordinator / Organization:

Prof. Dr. Cyrill Stachniss, Institut für Geodäsie und Geoinformation; Prof. Dr. Lasse Klingbeil, Institut für Geodäsie und Geoinformation

12	**Further information**
	none
13	**Date of version**
	20.02.2026

Code: **MA-MORO-PW**
Title: **Mobile Robotics Research Part 2**

1 **Content and intended learning outcomes**

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; Semantic sensor data interpretation; AI techniques for robot navigation

Qualification goals:

Students are able to
- acquire advanced knowledge about a given research topic/problem;
- develop a project plan toward a solution to a given problem;
- organize and distribute the work within their team;
- systematically solve the research problems;
- document the progress and present results in a scientific way.

2 **Teaching and learning methods**

#	Type	Topic	Lan-guage	Group-size	SWS	Work-load	Term
1	Small Group Project	Mobile Robotics Research - Part 2	EN	5	4	180	W

3 **Prerequisites to take part the module**

obligatory:

MA-MoRo-PS

recommended:

MA-MoRo-M01, MA-MoRo-M02, MA-MoRo-M03

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-PW	General mandatory selection	3rd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
1	Projectwork	successful presentation and dis-cussion of intermediate results at two project meetings within the semester.	cours e ac-com-pany-ing	graded	EN	66%
2	Written report	successful presentation and dis-cussion of intermediate results at two project meetings within the semester.	6 pg.	graded	EN	33%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Winter

10	**Maximum number of students**
	no limitation
11	**Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Cyrill Stachniss	Institut für Geodäsie und Geoinformation	1,0	1	1
2	Prof. Dr. Lasse Klingbeil	Institut für Geodäsie und Geoinformation	1,0	1	1
3	Prof. Dr. Ribana Roscher	Institut für Geodäsie und Geoinformation	1,0	1	1
4	Prof. Dr. Heiner Kuhlmann	Institut für Geodäsie und Geoinformation	1,0	1	1
5	Group Stachniss	Institut für Geodäsie und Geoinformation	3,0	1	---
6	Group Klingbeil	Institut für Geodäsie und Geoinformation	3,0	1	---
7	Group Roscher	Institut für Geodäsie und Geoinformation	3,0	1	---
8	Group Kuhlmann	Institut für Geodäsie und Geoinformation	3,0	1	---

Module coordinator / Organization:

Prof. Dr. Cyrill Stachniss, Institut für Geodäsie und Geoinformation; Prof. Dr. Lasse Klingbeil, Institut für Geodäsie und Geoinformation

12	**Further information**
	none
13	**Date of version**
	20.02.2026

Module Manual
Master's Program

Mobile Robotics
(M.Sc.)

Master's Thesis

Code: **MA-MORO-MT**
Title: **Master's Thesis**

1 **Content and intended learning outcomes**

Content:

according to the Master's Thesis task

Qualification goals:

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; System-atic search of information and literature; Understanding and using scientific texts; Writing scientific text in a concise way; Presentation of findings and results.

2 **Teaching and learning methods**

#	Type	Topic	Lan-guage	Group-size	SWS	Work-load	Term
1	Thesis	Master's Thesis	EN	1	-1	900	S

3 **Prerequisites to take part the module**

obligatory:

all mandatory modules (54 ECTS-CP)

recommended:

none

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-MT	General mandatory selection	4th

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
1	Master's Thesis	none	cours e ac-com-pany-ing	graded	EN	100%

6 **Credits according ECTS**

30 LP

7 **Workload**

900 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Summer

10 **Maximum number of students**

no limitation

11	**Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	All lecturers of the study program	---	---	1	1

Module coordinator / Organization:

Prof. Dr. Cyrill Stachniss, Institut für Geodäsie und Geoinformation

12	**Further information**

The Master's thesis is issued at the beginning of the fourth semester. The Master thesis task is given by the thesis supervisor over the examination board. According to the examination regulations the working time of the Master thesis is six months; the Master's thesis may be submitted after 4 months at the earliest. Upon motivated request, the examination board, in agreement with the supervisor, may grant an extension of time of up to six weeks. The Master thesis has to be submitted to the examination board. The result of the evalua-tion of the Master thesis shall be brought to the attention of the student eight weeks after submission at the latest.

Parts of the thesis:

· Written part of the Master Thesis

· Appendix 1: Paper-style summary of four to six pages (recommended: IEEE paper style)

· Appendix 2: Poster ("eye-catching presentation", concise presentation with figures and a few words: relevance, procedure, results)

· Bibliography

· Colloquium

13	**Date of version**

25.02.2026

Module Manual
Master's Program

Mobile Robotics
(M.Sc.)

Subject-related elective modules

Code: **MA-MORO-E01**
Title: **Agricultural Robotics and Phenotyping**

1 **Content and intended learning outcomes**

Content:

In this course the students will take existing systems (robots, UAVs, etc.) and use them in practical agricultural environments. The students will learn how to deploy and operate robotic systems for data collection, handling, and analysis in real-world agricultural settings. As part of this, the students will learn how to measure important phenotypic traits and the practical implications of deploying these systems.

Qualification goals:

Deployment of robots in real world settings, data collection, handling and analysis. Abstract thinking, presentation skills, teamwork, critical discussion of methods/algorithms

2 **Teaching and learning methods**

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	Agricultural Robotics and Phenotyping	EN	30	1	30	S
2	Exercise, practical	Agricultural Robotics and Phenotyping	EN	15	2	90	S
3	Seminar	Agricultural Robotics and Phenotyping	EN	30	1	60	S

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

MA-MoRo-M01; MA-MoRo-M06 or comparable experience

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E01	Elective selection	2nd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Projectwork	completed exercises	course accompanying	not graded	EN	100%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Summer

10 **Maximum number of students**

no limitation

11	**Module coordination**					
	Lecturer:					
	#	Name	Organization	SWS	exe.	res.
	1	Tem Agricultural Robotics	Institut für Landtechnik	4,0	1,2,3	1,2,3
	Module coordinator / Organization: Professur für Agricultural Robotics (derzeit unbesetzt), Institut für Landtechnik					
12	**Further information**					
	none					
13	**Date of version**					
	20.02.2026					

Code: **MA-MORO-E02**
Title: **Humanoid Robotics**

1 **Content and intended learning outcomes**

Content:

Sensing and perception, environment representations, active perception, inverse kinematics, motion planning, grasping, balance control, walking, and footstep planning.

Qualification goals:

This lecture covers techniques for humanoid robots such as perception, navigation, and motion planning. After the lecture, the students will be able to understand and implement techniques that enable humanoid robots to

autonomously navigate in human environments as well as perceive, represent, and manipulate objects. Communicative skills (oral and written presentation of solutions, discussions in small teams), ability to analyze problems.

2 **Teaching and learning methods**

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	Humanoid Robotics	EN	30	2	75	S
2	Exercise, scientific/practical	Humanoid Robotics	EN	15	2	105	S

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

MA-MoRo-M01

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E02	Elective selection	2nd
2	Computer Science (M.Sc.)	MA-INF 4215	Optional selection	2nd,3rd
3	Cyber Security (M.Sc.)	MA-INF 4215	Optional selection	2nd,3rd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Oral examination	The completion of regularly provided exercise sheets. The work can be done in groups of up to three students. A total of 50% of the points must be achieved.	20 min.	graded	EN	100%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Summer

10 **Maximum number of students**

	no limitation
11	**Module coordination**
	Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Maren Bennewitz	Institut für Informatik	4,0	1,2	1,2

	Module coordinator / Organization: Prof. Dr. Maren Bennewitz, Institut für Informatik
12	**Further information**
	Literature: · S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005. · B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics · K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer · Selected research papers. (in course)
13	**Date of version**
	20.02.2026

Code: **MA-MORO-E03**
Title: **Modern C++ for Robotics and Computer Vision**

1 Content and intended learning outcomes

Content:

C++ Language Basics; Programming in C++; Build System using Modern CMake; Memory Management; STL Containers; STL Algorithms; Generic Programming; Object Oriented Programming; LiDAR Mapping; 3D Point Cloud processing

Qualification goals:

Students are able to

- write code in C++ demonstrating comprehensive knowledge in basic concepts of the programming language;
- demonstrate conceptual as well as practical understanding of Modern C++ STL container library, data structures, and algorithms;
- transfer C++ programming skills to efficiently solve typical mobile robotics tasks such as 3D point cloud processing, LiDAR odometry and 3D mapping;
- understand Modern CMake tools and develop a basic build system for a moderately complex C++ library;
- use version control systems such as Git for maintaining software projects as well as for working in team projects.

2 Teaching and learning methods

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	Modern C++ for Robotics and Computer Vision	EN	40	1,5	46	S
2	Exercise, scientific	Modern C++ for Robotics and Computer Vision	EN	20	1,5	69	S
3	Project	Modern C++ for Robotics and Computer Vision	EN	20	1	65	S

3 Prerequisites to take part the module

obligatory:

none

recommended:

Basic programming skills, for example, obtained in the course "Python for Robotics and Computer Vision" (MoRo) or "GE Profile Fundamentals" on Python Programming as well as "Introduction to Mobile Robotics" (MoRo) or "Mobile Sensing and Robotics MSR-01" (GE) or "Photogrammetry and Remote Sensing (M23)" (GuG)

4 Study program allocation

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E03	Elective selection	2nd
2	Geodetic Engineering (M.Sc.)	MA-GE-MSR-07	Elective selection	2nd
3	Geodäsie und Geoinformation (M.Sc.)	MA-GuG-M26	Fachgebundener Wahlpflichtbereich: Wahlpflichtmodul "groß"	2.

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
1	Oral examination	(Successful completion of the homework assignments during the in-semester, which includes one presentation and discussion of the assignment in class) AND (Completed and working pro-ject, implemented in C++)	25 min.	graded	EN	100%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Summer

10 **Maximum number of students**

Yes, limitation of 40 students

11 **Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Cyrill Stachniss	Institut für Geodäsie und Geoinformation	0,3	1	1,2,3
2	Saurabh Gupta	Institut für Geodäsie und Geoinformation	2,0	1,2,3	---
3	Meher Malladi	Institut für Geodäsie und Geoinformation	1,8	1, 2, 3	---

Module coordinator / Organization:

Prof. Dr. Cyrill Stachniss, Institut für Geodäsie und Geoinformation

12 **Further information**

References:

· https://en.cppreference.com/w/

· https://www.atlassian.com/git/tutorials

Note for MA-GuG and MA-GE students:

The course cannot be taken in parallel to the elective course "Numerics in C++" due to the overlap in topics.

13 **Date of version**

20.02.2026

Code: **MA-MORO-E04**
Title: **Robot Learning**

1 **Content and intended learning outcomes**

Content:

Reinforcement learning, Markov decision processes, dynamic programming, Monte Carlo methods, temporal-difference methods, function approximation, liear quadratic regulation, differential dynamic programming, partially observable MDPs, policy gradient methods, inverse reinforcement learning, imitation learning, learning kinematic models, perceiving and handling of objects.

Qualification goals:

This lecture is one of two introductory lectures on Robotics of the intelligent systems track. Creating autonomous robots that can learn to assist humans in situations of daily life is a fascinating challenge for machine learning. The

lecture covers key ingredients for a general robot learning approach to get closer towards human-like performance in robotics, such as reinforcement learning, learning models for control, learning motor primitives, learning from

demonstrations and imitation learning, and interactive learning. This module complements MA-INF 4113 and can be taken before or after that module. Communicative skills (oral and written presentation of solutions, discussions in small teams), self competences (ability to accept and formulate criticism, ability to analyze problems

2 **Teaching and learning methods**

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	Robot Learning	EN	30	2	65	S
2	Exercise, scientific/practical	Robot Learning	EN	15	2	105	S

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

none

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E04	Elective selection	2nd
2	Computer Science (M.Sc.)	MA-INF 4114	Optional selection	1st,2nd
3	Cyber Security (M.Sc.)	MA-INF 4114	Optional selection	1st,2nd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Written examination	The completion of regularly provided exercise sheets. The work can be done in groups of up to two students. A total of 50% of the points must be achieved.	120 min.	graded	EN	100%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8	**Duration**
	1 Semester
9	**Frequency**
	Start in Summer
10	**Maximum number of students**
	no limitation
11	**Module coordination**
	Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Sven Behnke	Institut für Informatik	2,0	1,2	1,2
2	Dr. Nils Goerke	Institut für Informatik	2,0	1,2	---

Module coordinator / Organization:
Prof. Dr. Sven Behnke, Institut für Informatik

12	**Further information**
	Literature: · R. Sutton and A. Barto: Reinforcement Learning, MIT-Press, 1998. · O. Sigaud and J. Peters (Eds.): From Motor Learning to Interaction Learning in Robots. Springer, 2010
13	**Date of version**
	20.02.2026

Code: **MA-MORO-E05**
Title: **Lab Cognitive Robotics**

1 Content and intended learning outcomes

Content:

Robot middleware (ROS), simultaneous localization and mapping (SLAM), 3D representations of objects and environments, object detection and recognition, person detection and tracking, action recognition, action planning and control, mobile manipulation, human-robot interaction.

Qualification goals:

Participants acquire practical experience and in-depth knowledge in the design and implementation of perception and control algorithms for complex robotic systems. In a small group, they analyze a problem, realize a state-of-the-art solution, and evaluate its performance. Self-competences (time management, goal-oriented work, ability to analyze problems and to find practical solutions), communication skills (Work together in small teams, oral and written presentation of solutions, critical examination of implementations)

2 Teaching and learning methods

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lab	Lab Cognitive Robotics	EN	8	4	280	S

3 Prerequisites to take part the module

obligatory:

none

recommended:

MA-MoRo-E04

4 Study program allocation

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E05	Elective selection	2nd
2	Computer Science (M.Sc.)	MA-INF 4304	Optional selection	2nd,3rd
3	Cyber Security (M.Sc.)	MA-INF 4304	Optional selection	2nd,3rd

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Projectwork	none	course accompanying	graded	EN	100%

6 Credits according ECTS

9 LP

7 Workload

270 h

8 Duration

1 Semester

9 Frequency

Start in Summer

10 Maximum number of students

no limitation

11	**Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Sven Behnke	Institut für Informatik	2,0	1	1
2	Dr. Raphael Memmesheimer	Institut für Informatik	2,0	1	---

Module coordinator / Organization:
Prof. Dr. Sven Behnke, Institut für Informatik

12	**Further information**

none

13	**Date of version**

20.02.2026

Code: **MA-MORO-E06**
Title: **Lab Humanoid Robots**

1 **Content and intended learning outcomes**

Content:

Robot middleware, perception, state estimation, navigation, manipulation, and motion planning for humanoid robots.

Qualification goals:

Design and implementation of perception, state estimation, navigation, manipulation, and motion planning techniques for humanoid robots. Ability to analyze problems theoretically and to find creative and practical solutions; to examine one's solutions and results critically; to prepare readable documentation of software and research results; to present, defend and discuss design decisions and results in the team/group and to other students clearly and in accordance with academic standards; to collaborate constructively with others in small teams over a longer period of time;

2 **Teaching and learning methods**

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lab	Lab Humanoid Robots	EN	8	4	270	S

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

At least 1 of the following:

- MA-INF 4215 – Humanoid Robotics
- MA-INF 4113 – Cognitive Robotic

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E06	Elective selection	2nd
2	Computer Science (M.Sc.)	MA-INF 4214	Optional selection	2nd,3rd
3	Cyber Security (M.Sc.)	MA-INF 4214	Optional selection	2nd,3rd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Projectwork	none	course accompanying	graded	EN	100%

6 **Credits according ECTS**

9 LP

7 **Workload**

270 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Summer

10 **Maximum number of students**

no limitation

11	**Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Maren Bennewitz	Institut für Informatik	4,0	1	1

Module coordinator / Organization:
Prof. Dr. Maren Bennewitz, Institut für Informatik

12	**Further information**

Literature:
- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics
- K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer
- Selected papers (in course)

13	**Date of version**

20.02.2026

Code: **MA-MORO-E07**
Title: **Lab Vision**

1 **Content and intended learning outcomes**

Content:

Computer Vision: research topics and applications

Qualification goals:

The students will carry out a practical computer vision task (project). Ability to properly present and defend design decisions, to prepare readable documentation of software; skills in constructively collaborating with others in small teams over a longer period of time; ability to classify ones own results into the state-of-the-art of the resp. area.

2 **Teaching and learning methods**

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lab	Lab Vision	EN	8	4	270	W

3 **Prerequisites to take part the module**

obligatory:

MA-MoRoB-M04

recommended:

good C++ or Python programming skills

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E07	Elective selection	3rd
2	Computer Science (M.Sc.)	MA-INF 2307	Optional selection	2nd,3rd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Projectwork	none	course accompanying	graded	EN	100%

6 **Credits according ECTS**

9 LP

7 **Workload**

270 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Winter

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Jürgen Gall	Institut für Informatik	4,0	1	1

Module coordinator / Organization:
Prof. Dr. Jürgen Gall, Institut für Informatik

12 **Further information**

none

13 **Date of version**

20.02.2026

Code: **MA-MORO-E08**
Title: **Seminar Cognitive Robotics**

1 **Content and intended learning outcomes**

Content:

Current research papers from conferences and journals in the field of cognitive robotics covering fundamental techniques and applications.

Qualification goals:

Knowledge in advanced topics in the area of cognitive robotics, such as robot perception, action planning, and robot learning. Ability to understand new research results presented in original scientific papers and to present them in a research talk as well as in a seminar report. Self-competences (time management, literature search, self-study), communication skills (preparation and clear didactic presentation of research talk, scientific discussion, structured writing of seminar report), social skills (ability to formulate and accept criticism, critical examination of research results).

2 **Teaching and learning methods**

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Seminar	Seminar Cognitive Robotics	EN	10	2	120	W

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

MA-MoRo-E04

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E08	Elective selection	3rd
2	Computer Science (M.Sc.)	MA-INF 4211	Optional selection	2nd,3rd
3	Cyber Security (M.Sc.)	MA-INF 4211	Optional selection	2nd,3rd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Written report	none	6-8 pg.	graded	EN	40%
2	Seminartalk	none	45 min.	graded	EN	60%

6 **Credits according ECTS**

4 LP

7 **Workload**

120 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Winter

10 **Maximum number of students**

no limitation

11	**Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Sven Behnke	Institut für Informatik	1,0	1	1
2	Dr. Raphael Memmesheimer	Institut für Informatik	1,0	1	---

Module coordinator / Organization:
Prof. Dr. Sven Behnke, Institut für Informatik

12	**Further information**

Literature:
- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.
- selected papers.

13	**Date of version**

20.02.2026

Code: **MA-MORO-E09**
Title: **Seminar Humanoid Robots**

1 **Content and intended learning outcomes**

Content:

Current research papers from conferences and journals in the field of humanoid robotics covering fundamental techniques and applications.

Qualification goals:

Enhanced and in-depth knowledge in specialized topics in the area of humanoid robotics, such as perception, state estimation, navigation, manipulation, and motion planning. Self-competences (time management, literature search, self-study), communication skills (preparation of the talk, clear didactic presentation of techniques and experimental results, scientific discussion, structured writing of summary), social skills (ability to formulate and accept criticism, critical examination of algorithms and experimental results).

2 **Teaching and learning methods**

#	Type	Topic	Language	Group-size	SWS	Workload	Term
1	Seminar	Seminar Humanoid Robots	EN	10	2	120	W/S

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

MA-MoRo-E02

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E09	Elective selection	2nd,3rd
2	Computer Science (M.Sc.)	MA-INF 4213	Optional selection	2nd,3rd
3	Cyber Security (M.Sc.)	MA-INF 4213	Optional selection	2nd,3rd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Written report	none	6-8 pg.	graded	EN	30%
2	Seminartalk	none	45 min.	graded	EN	70%

6 **Credits according ECTS**

4 LP

7 **Workload**

120 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Winter and Summer

10 **Maximum number of students**

no limitation

11	**Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Maren Bennewitz	Institut für Informatik	2,0	1	1

Module coordinator / Organization:
Prof. Dr. Maren Bennewitz, Institut für Informatik

12	**Further information**

Literature:
- S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press
- B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics
- K. Harada, E. Yoshida, K. Yokoi (Eds.), Motion Planning for Humanoid Robots, Springer
-selected papers (in course)

13	**Date of version**

20.02.2026

Code: **MA-MORO-E10**
Title: **Seminar Vision**

1 **Content and intended learning outcomes**

Content:
Current conference and journal papers.

Qualification goals:
Ability to understand new research results presented in original scientific papers. Ability to present and to critically discuss these results in the framework of the corresponding area

2 **Teaching and learning methods**

#	Type	Topic	Lan-guage	Group-size	SWS	Work-load	Term
1	Seminar	Seminar Vision	EN	10	2	120	W

3 **Prerequisites to take part the module**

obligatory:
MA-MoRo-M04

recommended:
none

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E10	Elective selection	3rd
2	Computer Science (M.Sc.)	MA-INF 2206	Optional selection	2nd,3rd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
1	Written report	none	6-8 pg.	graded	EN	20%
2	Seminartalk	none	45 min.	graded	EN	80%

6 **Credits according ECTS**

4 LP

7 **Workload**

120 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Winter

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Jürgen Gall	Institut für Informatik	2,0	1	1

Module coordinator / Organization:
Prof. Dr. Jürgen Gall, Institut für Informatik

12 **Further information**

	none
13	**Date of version**
	20.02.2026

Code: **MA-MORO-E11**
Title: **Seminar Mobile Robotics**

1 **Content and intended learning outcomes**

Content:
Original research papers in the context of robot perception

Qualification goals:
Ability to understand new research results presented in original scientific papers. Ability to present and to critically discuss these results in the framework of the corresponding area.

2 **Teaching and learning methods**

#	Type	Topic	Lan-guage	Group-size	SWS	Work-load	Term
1	Seminar	Seminar Mobile Robotics	EN	12	2	90	W

3 **Prerequisites to take part the module**

obligatory:
none

recommended:
MA-MoRo-M01, MA-MoRo-M05, MA-MoRo-06

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E11	Elective selection	3rd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
1	Colloquium	none	30 min.	graded	EN	1%

6 **Credits according ECTS**

3 LP

7 **Workload**

90 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Winter

10 **Maximum number of students**

Yes, limitation of 12 students

11 **Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Team Stachniss	Institut für Geodäsie und Geoinformation	1,0	1	---
2	Prof. Dr. Cyrill Stachniss	Institut für Geodäsie und Geoinformation	1,0	1	1

Module coordinator / Organization:
Prof. Dr. Cyrill Stachniss, Institut für Geodäsie und Geoinformation

12 **Further information**

none

13 **Date of version**

Code: **MA-MORO-E12**
Title: **Advanced Deep Learning**

1 **Content and intended learning outcomes**

Content:

This course explores advanced concepts in deep learning. Throughout the course the students will be given lectures to provide background material on selected topics in the area of deep learning. To make this learning concrete, the students will then read, discuss and present related papers on these topics in the form of a short presentation (seminar). Additionally, during the course code will be developed for some of these techniques (in Python).

Qualification goals:

Deeper insights into selected deep learning techniques. Abstract thinking, presentation skills, team work, critical discussion of methods/algorithms

2 **Teaching and learning methods**

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	Advanced Deep Learning	EN	30	2	60	W
2	Exercise, scientific/practical	Advanced Deep Learning	EN	30	2	120	W

3 **Prerequisites to take part the module**

obligatory:

MA-MoRo-M03

recommended:

none

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E12	Elective selection	3rd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Oral examination	completed exercises	25 min.	not graded	EN	70%
2	Projectwork	none	course accompanying	not graded	EN	30%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Winter

10 **Maximum number of students**

no limitation

11	**Module coordination**
	Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr.-Ing. Ribana Roscher	Institut für Geodäsie und Geoinformation	4,0	1,2	1,2

Module coordinator / Organization:
Prof. Dr.-Ing. Ribana Roscher, Institut für Geodäsie und Geoinformation

12	**Further information**
	none
13	**Date of version**
	20.02.2026

Code: **MA-MORO-E13**
Title: **Technique for Self-Driving-Cars**

1 Content and intended learning outcomes

Content:

The lecture aims at covering various aspects and techniques used for enabling vehicles to drive autonomously. To this end, we will look at different paradigms to realize autonomous vehicles, where we cover the following topics: Introduction to self-driving cars and current challenges; perception stack of self-driving cars, including RGB cameras, LiDAR, and Radar; vehicle localization and state estimation/pose estimation; PD and model-predictive control for steering autonomous vehicles; Approaches for path planning, obstacle avoidance, and behavior planning and estimation; Techniques for detection & segmentation of driving-related entities using RGB cameras, LiDAR or Radar; Self-driving car simulation; software infrastructure of self-driving vehicles

Qualification goals:

Students are able to

- explain and discuss different paradigms for realizing self-driving cars;
- understanding central building blocks and underlying methods for perception, planning, and control of self-driving cars;
- explain what specific challenges occur and must be handled in the context of autonomy for urban environments;
- establish connection between the above-mentioned challenges and their implementation in the software stack of self-driving cars;
- implement basic solutions and building blocks in Python;
- assess the complexity of methods and algorithms.

2 Teaching and learning methods

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	Technique for Self-Driving-Cars	EN	40	2	90	W
2	Exercise, practical	Technique for Self-Driving-Cars	EN	20	2	90	W

3 Prerequisites to take part the module

obligatory:

MA-MoRo-M01; MGE-MSR-01, MA-GuG-M23

recommended:

- Python programming capabilities
- MA-MoRo-M06 / MA-GE-MSR-03 / MA-GuG-M26: Machine Learning for Robotics and Computer Vision

4 Study program allocation

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E13	Elective selection	3rd
2	Geodetic Engineering (M.Sc.)	MA-GE-MSR-06	Elective selection	3rd
3	Geodäsie und Geoinformation (M.Sc.)	MA-GuG-M26	Fachgebundener Wahlpflichtbereich: Wahlpflichtmodul "groß"	3.

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Written examination	Successful completion of the exercises (minimum 50% of the points)	120 min.	graded	EN	100%

6	**Credits according ECTS**
	6 LP
7	**Workload**
	180 h
8	**Duration**
	1 Semester
9	**Frequency**
	Start in Winter
10	**Maximum number of students**
	Yes, limitation of 40 students
11	**Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	PD Jens Behley	Institut für Landtechnik	2,0	1	1, 2
2	Team Stachniss	Institut für Landtechnik	2,0	2	---

Module coordinator / Organization:

PD Jens Behley , Institut für Geodäsie und Geoinformation; Prof. Dr. Cyrill Stachniss, Institut für Geodäsie und Geoinformation

12	**Further information**
	none
13	**Date of version**
	24.02.2026

Code: **MA-MORO-E14**
Title: **High Precision Sensing**

1 Content and intended learning outcomes

Content:

High precision kinematic and static laser scanning, aspects of system calibration, accuracy analysis and influencing factors

Qualification goals:

Perform high precision measurements, data processing and analysis, understand potential applications and accuracy requirements. Abstract thinking, project planning, presentation skills, teamwork, critical discussion of methods and results

2 Teaching and learning methods

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lecture	High Precision Sensing	EN	30	2	89	W
2	Exercise, practical	High Precision Sensing	EN	15	2	91	W

3 Prerequisites to take part the module

obligatory:

none

recommended:

MMoRo-M02, MMoRo-M05

4 Study program allocation

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E14	Elective selection	2nd

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Projectwork	written and/or verbal academic performance	course accompanying	graded	EN	1%

6 Credits according ECTS

6 LP

7 Workload

180 h

8 Duration

1 Semester

9 Frequency

Start in Summer

10 Maximum number of students

no limitation

11	**Module coordination**					
	Lecturer:					
	#	Name	Organization	SWS	exe.	res.
	1	Prof. Dr. Heiner Kuhlmann	Institut für Geodäsie und Geoinformation	2,0	1	1,2
	2	Group Kuhlmann	Institut für Geodäsie und Geoinformation	2,0	2	---
	Module coordinator / Organization: Prof. Dr. Heiner Kuhlmann, Institut für Geodäsie und Geoinformation					
12	**Further information**					
	none					
13	**Date of version**					
	20.02.2026					

Code: **MA-MORO-E15**
Title: **Multi-Agent Learning System**

1 **Content and intended learning outcomes**

Content:

In this course, the students will learn how to model the collective dynamics emerging from multiple independent learning agents. We explore different individual learning processes (e.g., reinforcement learning), the basics of non-cooperative game theory (e.g., social dilemmas), and different settings regarding the observation and policy spaces of these agents (e.g., partial observability). By taking a complex systems science perspective, we will develop a unified approach to these topics. Students learn how to use concepts from non-linear dynamics to distill qualitative insight into the collective behavior of individual learning agents coevolving with dynamic environments and apply these in practical projects.

Qualification goals:

Students are able to model multi-agent learning systems in Python

2 **Teaching and learning methods**

#	Type	Topic	Language	Group-size	SWS	Workload	Term
1	Lecture	Multi-agent Learning Systems	EN	20	2	90	W
2	Exercise, scientific/practical	Multi-agent Learning Systems	EN	20	2	90	W

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

previous programming experience in Python and basic mathematical literacy is a plus.

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E15	Elective selection	3rd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Oral presentation	recognized report	15 min.	graded	EN	50%
2	Oral examination	recognized report	15 min.	graded	EN	50%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Winter

10 **Maximum number of students**

no limitation

11	**Module coordination**
	Lecturer:

#	Name	Organization	SWS	exe.	res.
1	JProf. Dr. Wolfram Barfuss	Center for Development Research (ZEF)	4,0	1,2	1,2

Module coordinator / Organization:
JProf. Dr. Wolfram Barfuss, Center for Development Research (ZEF)

12	**Further information**
	none
13	**Date of version**
	20.02.2026

Code: **MA-MORO-E16**
Title: **Robot Operating Systems**

1 **Content and intended learning outcomes**

Content:

Robot Operating System 2 basic software architecture (Nodes, Topics, Services, and Actions); Colcon build system for ROS2 packages; Standard modules in ROS2; 2D navigation stack using Nav2; Gazebo simulation and RVIZ2 visualization

Qualification goals:

Students are able to

- demonstrate basic understanding of software design in ROS2;
- develop custom nodes and packages in ROS2 and write a build system for the same;
- understand and setup a complete 2D navigation stack in Gazebo simulation using Nav2.

2 **Teaching and learning methods**

#	Type	Topic	Lan-guage	Group-size	SWS	Work-load	Term
1	Exercise, practi-cal	Robot Operating System	EN	24	2	90	W

3 **Prerequisites to take part the module**

obligatory:

Course "Modern C++ for Robotics". Alternatively, "Numerics in C++"

recommended:

Familiarity with basic terminal commands in Linux (Ubuntu)

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E16	Elective selection	3rd
2	Geodäsie und Geoinformation (M.Sc.)	MA-GuG-M25	Fachgebundener Wahlpflichtbereich: Wahlpflichtmodul "Block"	3.

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
1	Oral examination	active participation in the block	25 min.	graded	EN	100%

6 **Credits according ECTS**

3 LP

7 **Workload**

90 h

8 **Duration**

1 Semester

9 **Frequency**

Start in Winter

10 **Maximum number of students**

Yes, limitation of 24 students

11	**Module coordination**
	Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Saruabh Gupta	Institut für Geodäsie und Geoinformation	1,0	1	---
2	Meher Mallado	Institut für Geodäsie und Geoinformation	1,0	1	---

	Module coordinator / Organization: Prof. Dr. Cyrill Stachniss, Institut für Geodäsie und Geoinformation
12	**Further information**
	A computer with Ubuntu Linux and ROS2 installed is required · computer lab space (limited!) can be provided
13	**Date of version**
	24.02.2026

Code: **MA-MORO-E17**
Title: **Explainable Machine Learning**

1 Content and intended learning outcomes

Content:

Advanced methods in Machine Learning with a focus on Explainable Machine Learning. The module covers post-hoc and intrinsic explainability methods, model- and data-driven explanation approaches, as well as application examples from diverse domains.

Qualification goals:

After successful completion of the module, students are able to:

- explain and classify core concepts, objectives, and methodological approaches of Explainable Machine Learning.
- select and apply appropriate explainability methods for given machine learning models and data sets.
- implement and adapt explainability techniques to concrete analysis tasks.
- analyse and critically assess explanations with respect to plausibility, stability, and limitations.
- identify potential risks such as bias, artefacts, or spurious correlations in model explanations.
- present explainability concepts and results in a structured and comprehensible manner and discuss them critically.

2 Teaching and learning methods

#	Type	Topic	Lan-guage	Group-size	SWS	Work-load	Term
1	Vorlesung	Explainable Machine Learning	EN	15	1	30	W
2	Seminar	Explainable Machine Learning	EN	15	1	60	W

3 Prerequisites to take part the module

obligatory:

none

recommended:

Basic knowledge of machine learning concepts (e.g. supervised learning, model training and evaluation) and basic programming skills in Python, including experience with common machine learning libraries.

4 Study program allocation

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E17	Elective selection	3rd
2	Geodäsie und Geoinformation (M.Sc.)	MA-GuG-M27	Fachgebundener Wahlpflichtbereich: Wahlpflichtmodul "klein"	3.

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

#	Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
1	Oral presentation	Successful completion of the ex-ercises (min 50% of the points)	20 min.	graded	EN	100%

6 Credits according ECTS

3 LP

7 Workload

90 h

8 Duration

1 Semester

9 Frequency

Start in Winter

10	**Maximum number of students**
	no limitation
11	**Module coordination**
	Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr.-Ing Rbana Roscher	Institut für Geodäsie und Geoinformation	1,0	1	1,2
2	Group Roscher	Institut für Geodäsie und Geoinformation	1,0	2	---

Module coordinator / Organization:
Prof. Dr.-Ing. Rbana Roscher, Institut für Geodäsie und Geoinformation

12	**Further information**
	none
13	**Date of version**
	24.02.2026

Code: **MA-MORO-E18**
Title: **Point Cloud Processing**

1 Content and intended learning outcomes

Content:

Point cloud generation, proprocessing steps (outlier removal, subsampling), surface reconstruction and modelling, features, keypoints, segmentation, clustering, registration

Qualification goals:

After successful completion of the module, students are able to:

- explain necessary steps of 3D data processing discussed in the lecture
- understand standard procedures used in point cloud processing
- implement basic methods and apply them to simple problems using state of the art software products and libraries
- present and discuss current research topics in the context of the lecture content

2 Teaching and learning methods

#	Type	Topic	Lan-guage	Group-size	SWS	Work-load	Term
1	Lecture	Point Cloud Processing	EN	20	1	45	W
2	Exercise, practi-cal	Point Cloud Processing	EN	10	2	75	W
3	Seminar	Point Cloud Processing	EN	20	1	60	W

3 Prerequisites to take part the module

obligatory:

none

recommended:

none

4 Study program allocation

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E18	Elective selection	3rd
2	Geodetic Engineering (M.Sc.)	MA-GE-MSR-05	Elective selection	3rd

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

#	Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
1	Oral examination	Successful completion of the ex-ercises (minimum 50% of the points) AND successful partici-pation in the seminar	25 min.	graded	EN	100%

6 Credits according ECTS

6 LP

7 Workload

180 h

8 Duration

1 Semester

9 Frequency

Start in Winter

10 Maximum number of students

no limitation

11	**Module coordination**

Lecturer:

#	Name	Organization	SWS	exe.	res.
1	Prof. Dr. Lasse Klingbeil	Institut für Geodäsie und Geoinformation	2,0	1,3	1,2,3
2	Group Klingbeil/Kuhlmann	Institut für Geodäsie und Geoinformation	2,0	2,3	---

Module coordinator / Organization:
Prof. Dr. Lasse Klingbeil, Institut für Geodäsie und Geoinformation

12	**Further information**
	none
13	**Date of version**
	24.02.2026

Code: **MA-MORO-E19**
Title: **Lab Perception and Learning for Robotics**

1 **Content and intended learning outcomes**

Content:

In small groups, students apply their knowledge of robot perception, deep learning, and computer vision to a novel problem. They analyze the problem, read into relevant literature, propose and implement a solution, and empirically test it. They then refine their approach based on an analysis of the experimental outcomes. The course projects are related to one of multiple of the following topics: Robot localization, planning, navigation, manipulation; Practical aspects of Deep Learning; Sensor models, calibration, capture, processing. Software deployment.

Qualification goals:

Participants learn how to practically approach a robot perception problem. They learn how to critically read a research paper, how to conduct experiments in the context of robot perception, and how to report and present scientific findings. Ability to analyze problems theoretically and to find creative and practical solutions; to examine one's solutions and results critically; to classify one's own results into the state-of-the-art of the respective area; to prepare readable documentation of software and research results; to present, defend and discuss design decisions and results in the team/group and to other students clearly and in accordance with academic standards; to collaborate constructively with others in small teams over a longer period of time; to aim at long-range goals under limited resources; to work under pressure.

2 **Teaching and learning methods**

#	Type	Topic	Language	Group-size	SWS	Work-load	Term
1	Lab	Lab Perception and Learning for Robotics	EN	8	4	270	W/S

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

Students are expected to have general programming skills and prior experience with python. Students will need to operate linux terminal systems such as the university's GPU cluster.

It is recommended to first take two of the following modules: MA-INF 2201 Computer Vision, MA-INF 2213 Advanced Computer Vision, MA-INF 2218 Video Analytics, MA-INF 4113 Cognitive Robotics

4 **Study program allocation**

#	Study program	(alternative) module code	mandatory / elective module	recommended semester
1	Mobile Robotics (M.Sc.)	MA-MoRo-E19	Elective selection	3rd
2	Computer Science (M.Sc.)	MA-INF 4331	Optional selection	2nd,3rd
3	Artificial Intelligence (M.Sc.)	MA-INF 4331	Optional selection	2nd,3rd

5 **Requirements for the rewarding of credits (ECTS)**

Examination(s):

#	Type	Prerequisites	Duration	graded/ not graded	Language	Weight
1	Projectwork	none	course accompanying	graded	EN	100%

6 **Credits according ECTS**

9 LP

7 **Workload**

270 h

8	**Duration**
	1 Semester
9	**Frequency**
	Start in Winter
10	**Maximum number of students**
	no limitation
11	**Module coordination**
	Lecturer:

#	Name	Organization	SWS	exe.	res.
1	JProf. Dr. Hermann Blum	Institut für Informatik	4,0	1	1

Module coordinator / Organization:
JProf. Dr. Hermann Blum, Institut für Informatik

12	**Further information**
	Literature: · S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005 · I. Goodfellow, Y. Bengio and A. Courville: Deep Learning. MIT Press, 2016 · per-project assigned literature (in course)
13	**Date of version**
	24.02.2026