UNIVERSITÄT BONN

Module Manual
Master's Program

Mobile Robotics
(M.Sc.)

Agricultural Faculty

in cooperation with the

Faculty of Mathematics and Natural Sciences

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Module Manual
Master's Program

Mobile Robotics
(M.Sc.)

General mandatory modules

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

1 **Content and intended learning outcomes**

Content:

Robotic sensors; Odometry; Geometric and probabilistic motion models; Basic probabilistic models of range sensors; Environment models; Recursive Bayes filter, Kalman filter, and extended Kalman filter; Particle filter, Monte-Carlo localization; Simultaneous localization and mapping (SLAM); Main paradigms to solve SLAM (Kalman Filter, Particle Filters, Graph-based); P/PD/PID Controller; Model predictive control; Trajectory control; Planning; Motion planning; Roadmap planning; Markov decision processes.

Qualification goals:

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 robotics.

2 **Teaching and learning methods**

Type	Topic	Language	Group-size	SWS	Work-load	Term
Lecture	Introduction to Mobile Robotics	en	30	2	90	W
Exercise, scientific	Introduction to Mobile Robotics	en	15	2	90	W
Lecture	Robot Planning and Control	en	30	1	45	W
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
Mobile Robotics (M.Sc.)	MA-MOROB-M01	General mandatory selection	1st semester

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Written examination	written and/or verbal academic performance	120	graded	en	67%
Written examination	written and/or verbal academic performance	60	graded	en	33%

6 **Credits according ECTS**

9 LP

7 **Workload**

270 h

8 **Duration**

1 semester

9 **Frequency**

winter term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Cyrill Stachniss	Institut für Geodäsie und Geoinformation	2	X	X
Prof. Dr. Maren Bennewitz	Institut für Informatik	1	X	
Team Prof. Stachniss	Institut für Geodäsie und Geoinformation	3	X	

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

12 **Further information**

References:
* 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**

26.03.2024 (20252)

Code: **MA-MOROB-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:

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; 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

2 **Teaching and learning methods**

Type	Topic	Language	Group-size	SWS	Work-load	Term
Lecture	Global Navigation Satellite Systems	en	30	1	45	W
Exercise, scientific	Global Navigation Satellite Systems	en	15	1	45	W
Lecture	Inertial Navigation Systems	en	30	1	45	W
Exercise, practical	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
Mobile Robotics (M.Sc.)	MA-MOROB-M02	General mandatory selection	1st semester

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Written examination	written and/or verbal academic performance	60	graded	en	50%
Written examination	written and/or verbal academic performance	60	graded	en	50%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 semester

9 **Frequency**

winter term

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

Name	Organization	SWS	exe.	res.
PD Dr. Lasse Klingbeil	Institut für Geodäsie und Geoinformation	2	X	X
Team Prof. Kuhlmann	Institut für Geodäsie und Geoinformation	2	X	

Module coordinator / Organization:
Prof. Dr. Heiner Kuhlmann (Institut für Geodäsie und Geoinformation)

12	**Further information**
	References: * Paul D. Groves (2007): Principles of GNSS, Inertial and Multisensor Navigation Systems; Artech House Publishers, ISBN 1580532551, ISBN 13: 9781580532556
13	**Date of version**
	26.03.2024 (20252)

Code: **MA-MOROB-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
Lecture	Python for Robotics & Computer Vision	en	30	2	90	W
Exercise, 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
Mobile Robotics (M.Sc.)	MA-MOROB-M03	General mandatory selection	1st semester

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Tasks accompanying the semester	written and/or verbal academic performance	-	graded	en	40%
Written examination	written and/or verbal academic performance	120	graded	en	60%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 semester

9 **Frequency**

winter term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Chris McCool	Institut für Landtechnik	3	X	X
Dr. Michael Halstead	Institut für Landtechnik	1	X	

Module coordinator / Organization:
Prof. Dr. Chris McCool

12 **Further information**

none

13 **Date of version**

26.03.2024 (20252)

Code: **MA-MOROB-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:

Students will learn about various mathematical methods and their applications to computer vision problems. 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	Workload	Term
Lecture	Computer Vision	en	30	4	165	W/S
Exercise, scientific	Computer Vision	en	30	2	105	W/S

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

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

4 **Study program allocation**

Study program	(alternative) module code	mandatory / elective module	recommended semester
Mobile Robotics (M.Sc.)	MA-MOROB-M04	General mandatory selection	1st semester
Cyber Security (M.Sc.)	MA-INF 2201	Elective selection	1st or 2nd semester
Computer Science (M.Sc.)	MA-INF 2201	Elective selection	1st or 2nd semester

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Written examination	written and/or verbal academic performance	-	graded	en	100%

6 **Credits according ECTS**

9 LP

7 **Workload**

270 h

8 **Duration**

1 semester

9 **Frequency**

every term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Jürgen Gall	Institut für Informatik	6	X	X

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

12 **Further information**

References:
* 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**

26.03.2024 (20261)

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

1 **Content and intended learning outcomes**

Content:

Point cloud registration; ICP; Graph-based simultaneous localization and mapping; robust least squares; Hierarchical optimization approaches; Visual features; Feature matching; RANSAC; Camera calibration; Relative orientation; 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:

Obtain advanced knowledge about the topics above, including the ability to implement a basic mapping system in Python, including effective processing of 3D point cloud data as well as realizing basic photogrammetric problem solutions.

2 **Teaching and learning methods**

Type	Topic	Language	Group-size	SWS	Workload	Term
Lecture	Graph SLAM	en	30	2	60	S
Exercise, scientific/practical	Graph SLAM	en	15	1	45	S
Lecture	3D Mapping	en	30	1	30	S
Exercise, scientific	3D Mapping	en	15	1	45	S

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

MA-MOROB-M01; MA-MOROB-M02

4 **Study program allocation**

Study program	(alternative) module code	mandatory / elective module	recommended semester
Mobile Robotics (M.Sc.)	MA-MOROB-M05	General mandatory selection	2nd semester

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Written examination	written and/or verbal academic performance	120	graded	en	100%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 semester

9 **Frequency**

summer term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Cyrill Stachniss	Institut für Geodäsie und Geoinformation	2	X	X
PD Dr. Lasse Klingbeil	Institut für Geodäsie und Geoinformation	0,5	X	
Prof. Dr. Heiner Kuhlmann	Institut für Geodäsie und Geoinformation	0,5	X	X
Team Prof. Kuhlmann	Institut für Geodäsie und Geoinformation	1	X	
Team Prof. Stachniss	Institut für Geodäsie und Geoinformation	1	X	

Module coordinator / Organization:
Prof. Dr. Cyrill Stachniss, Prof. Dr.-Ing. Heiner Kuhlmann (Institut für Geodäsie und Geoinformation)

12 **Further information**

References:

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

* Grisetti, Kümmerle, Stachniss, Burgard: A Tutorial on Graph-based SLAM, IEEE Transactions on Intelligent Transportation Systems Magazine, vol. 2, p. 31-43, 2010.

* Paul D. Groves (2007): Principles of GNSS, Inertial and multisensor navigation systems. Artech House Publishers, ISBN 1580532551, ISBN 13: 9781580532556

13 **Date of version**

26.03.2024 (20261)

Code: **MA-MOROB-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); Learning and techniques for training deep models; Common approaches for different perception tasks (classification, detection, semantic/panoptic segmentation); Current research topics: attention & transformer models for vision, contrastive learning for pre-training of visual representations

Qualification goals:

Ability to apply and implement machine learning algorithms for real tasks using Python & Pytorch

2 **Teaching and learning methods**

Type	Topic	Language	Group-size	SWS	Workload	Term
Lecture	Machine Learning for Robotics and Computer Vision	en	30	2	90	S
Exercise, scientific	Machine Learning for Robotics and Computer Vision	en	30	2	90	S

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

MA-MOROB-M03; MA-MOROB-M04

4 **Study program allocation**

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

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Oral examination	written and/or verbal academic performance	25	graded	en	100%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 semester

9 **Frequency**

summer term

10 **Maximum number of students**

	no limitation
11	**Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
PD Dr. Jens Behley	Institut für Geodäsie und Geoinformation	2	X	X
Team Prof. Stachniss	Institut für Geodäsie und Geoinformation	2	X	

Module coordinator / Organization:
PD Dr. Jens Behley (Institut für Geodäsie und Geoinformation)

12	**Further information**
	Lectures and tutorials will take place in person. Video recordings of lectures from past year(s) are available
13	**Date of version**
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Module Manual
Master's Program

Mobile Robotics
(M.Sc.)

Project-related mandatory modules

Code: **MA-MOROB-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:

Acquire basic knowledge in the development of a project work and work out a solution to a problem from the above-mentioned topics. Ability to systematically solve relevant problems in the context of mobile sensing and robotics, document the progress and present results in a scientific way; Team work; Project presentations;

2 **Teaching and learning methods**

Type	Topic	Language	Group-size	SWS	Work-load	Term
Lab	Mobile Robotics Research - Part 1	en	30	4	180	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
Mobile Robotics (M.Sc.)	MA-MOROB-PS	General mandatory selection	2nd semester

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Project work	written and/or verbal academic performance	-	graded	en	100%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 semester

9 **Frequency**

summer term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Cyrill Stachniss	Institut für Geodäsie und Geoinformation	2	X	X
PD Dr. Lasse Klingbeil	Institut für Geodäsie und Geoinformation	1	X	X
Prof. Dr. Heiner Kuhlmann	Institut für Geodäsie und Geoinformation	1	X	

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

12 **Further information**

none

13 **Date of version**

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Code: **MA-MOROB-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:

Acquire advanced knowledge in the development of a project work and work out a solution to a problem from the above-mentioned topics. Ability to systematically solve relevant problems in the context of mobile sensing and robotics, document the progress and present results in a scientific way; Team work;

2 **Teaching and learning methods**

Type	Topic	Lan-guage	Group-size	SWS	Work-load	Term
Lab	Mobile Robotics Research - Part 2	en	30	4	180	W

3 **Prerequisites to take part the module**

obligatory:

MA-MOROB-PS

recommended:

none

4 **Study program allocation**

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

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

Examination(s):

Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
Project work	written and/or verbal academic performance	-	graded	en	67%
Written report	written and/or verbal academic performance	-	graded	en	33%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 semester

9 **Frequency**

winter term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
PD Dr. Lasse Klingbeil	Institut für Geodäsie und Geoinformation	2	X	X
Prof. Dr. Cyrill Stachniss	Institut für Geodäsie und Geoinformation	1	X	X
Prof. Dr. Heiner Kuhlmann	Institut für Geodäsie und Geoinformation	1	X	

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

12 **Further information**

none

13 **Date of version**

25.01.2024 (20252)

Module Manual
Master's Program

Mobile Robotics
(M.Sc.)

Subject-related elective modules

Code: **MA-MOROB-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:

Advanced knowledge of robot deployment 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
Exercise, practical	Agricultural Robotics and Phenotyping	en	15	3	120	S
Seminar	Agricultural Robotics and Phenotyping	en	20	1	60	S

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

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

4 **Study program allocation**

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

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Project work	written and/or verbal academic performance	-	graded	en	100%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 semester

9 **Frequency**

summer term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Chris McCool	Institut für Landtechnik	2	X	X
PD Dr. Lasse Klingbeil	Institut für Geodäsie und Geoinformation	2	X	X

Module coordinator / Organization:

PD Dr. Lasse Klingbeil (Institut für Geodäsie und Geoinformation)

12	**Further information**
	none
13	**Date of version**
	26.03.2024 (20261)

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

1 **Content and intended learning outcomes**

Content:

Self-calibration with least squares, 3D environment representations, self-localization with particle filters, footstep planning, inverse kinematics, whole-body motion planning with rapidly exploring random trees, statistical testing.

Qualification goals:

This lecture covers advanced techniques for humanoid robots such as perception, navigation, and motion planning. 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
Lecture	Humanoid Robotics	en	30	2	75	S/W
Exercise, scientific	Humanoid Robotics	en	15	2	105	S/W

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

MA-MOROB-M01

4 **Study program allocation**

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

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Oral examination	written and/or verbal academic performance (successful exercise participation)	20	graded	en	100%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 semester

9 **Frequency**

every term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Maren Bennewitz	Institut für Informatik	4	X	X

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

12 **Further information**

References:
* 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.

13 **Date of version**

26.03.2024 (20261)

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

1 Content and intended learning outcomes

Content:

Programming in C++; Revision control using git; Solving typical robotics tasks using C++, examples tasks include

Qualification goals:

Detailed comprehensive knowledge in programming in C++ with focus on robotics applications; Specialized conceptual skills to solve typical robotics tasks using C++ such as point cloud registration, odometry, and mapping; Use of revision control systems such as git. Work in small teams (typically teams of 2 students) realizing small software projects, also using distributed version control (git)

2 Teaching and learning methods

Type	Topic	Language	Group-size	SWS	Work-load	Term
Lecture	Modern C++ for Robotics and Computer Vision	en	30	1	45	S
Exercise, scientific/practical	Modern C++ for Robotics and Computer Vision	en	15	2	75	S
Project	Modern C++ for Robotics and Computer Vision	en	20	1	60	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
Mobile Robotics (M.Sc.)	MA-MOROB-E03	Elective selection	2nd semester
Geodetic Engineering (M.Sc.)	MGE-MSR-03	Elective selection	2nd semester
Geodäsie und Geoinformation (M.Sc.)	M26	Fachgebundener Wahlpflichtbereich: Wahlpflichtmodul "groß"	2. Fachsemester

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Oral examination	written and/or verbal academic performance	25	graded	en	100%

6 Credits according ECTS

6 LP

7 Workload

180 h

8 Duration

1 semester

9 Frequency

summer term

10 Maximum number of students

	no limitation
11	**Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Cyrill Stachniss	Institut für Geodäsie und Geoinformation	1	X	X
Dr. Tiziano Guadagnino	Institut für Geodäsie und Geoinformation	2	X	
Team Prof. Stachniss	Institut für Geodäsie und Geoinformation	1	X	

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

13	**Date of version**

26.03.2024 (20261)

Code: **MA-MOROB-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, linear 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:

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. 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
Lecture	Robot Learning	en	30	2	75	W/S
Exercise, scientific	Robot Learning	en	15	2	105	W/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
Mobile Robotics (M.Sc.)	MA-MOROB-E04	Elective selection	2nd semester
Computer Science (M.Sc.)	MA-INF 4114	Elective selection	1st or 2nd semester
Cyber Security (M.Sc.)	MA-INF 4114	Elective selection	1st or 2nd semester

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Written examination	written and/or verbal academic performance (successful exercise participation)	90	graded	en	100%

6 **Credits according ECTS**

6 LP

7 **Workload**

180 h

8 **Duration**

1 semester

9 **Frequency**

every term

10 **Maximum number of students**

no limitation

11	**Module coordination**
	Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Sven Behnke	Institut für Informatik	4	X	X

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

12	**Further information**
	References: * 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**
	29.04.2024 (20261)

Code: **MA-MOROB-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
Lab	Lab Cognitive Robotics	en	8	4	270	S/W

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

MA-MOROB-E04

4 **Study program allocation**

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

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Project work	none	-	graded	en	100%

6 **Credits according ECTS**

9 LP

7 **Workload**

270 h

8 **Duration**

1 semester

9 **Frequency**

every term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Sven Behnke	Institut für Informatik	4	X	X

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

12 **Further information**

References:
* S. Thrun, W. Burgard and D. Fox: Probabilistic Robotics. MIT Press, 2005.
* B. Siciliano, O. Khatib (Eds.): Springer Handbook of Robotics, 2008.
* Selected research papers.

13 **Date of version**

26.03.2024 (20252)

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

1 **Content and intended learning outcomes**

Content:

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

Qualification goals:

Practical experience in the design and implementation of perception, state estimation, environment representation, navigation, and motion planning techniques for humanoid robots. In small groups, the participants analyze a problem, realize a solution, and perform an experimental evaluation. Self-competences (time management, goal-oriented work, ability to analyze problems theoretically and to find practical solutions), communication skills (collaboration in small teams, oral and written presentation of solutions, critical examination of implementations).

2 **Teaching and learning methods**

Type	Topic	Language	Group-size	SWS	Workload	Term
Lab	Lab Humanoid Robots	en	8	4	270	S/W

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

MA-MOROB-E02

4 **Study program allocation**

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

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Oral presentation	written and/or verbal academic performance (successful lab participation, written report)	20	graded	en	100%

6 **Credits according ECTS**

9 LP

7 **Workload**

270 h

8 **Duration**

1 semester

9 **Frequency**

every term

10 **Maximum number of students**

Yes, limitation of 8 students

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Maren Bennewitz	Institut für Informatik	4	X	X

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

12 **Further information**

References:
* 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.

13 **Date of version**

09.04.2024 (20261)

Code: **MA-MOROB-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 one's own results into the state-of-the-art of the resp. Area

2 **Teaching and learning methods**

Type	Topic	Lan-guage	Group-size	SWS	Work-load	Term
Lab	Lab Vision	en	8	4	270	S/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
Mobile Robotics (M.Sc.)	MA-MOROB-E07	Elective selection	3rd semester
Computer Science (M.Sc.)	MA-INF 2307	Elective selection	2nd or 3rd se-mester

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

Examination(s):

Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
Project work	none	-	graded	en	100%

6 **Credits according ECTS**

9 LP

7 **Workload**

270 h

8 **Duration**

1 semester

9 **Frequency**

winter term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Jürgen Gall	Institut für Informatik	4	X	X

Module coordinator / Organization:

Prof. Dr. Jürgen Gall (Institut für Informatik)

12 **Further information**

none

13	**Date of version**
	26.03.2024 (20261)

Code: **MA-MOROB-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 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	Workload	Term
Seminar	Seminar Cognitive Robotics	en	10	2	120	S/W

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

MA-MOROB-E04

4 **Study program allocation**

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

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Seminartalk	none	45	graded	en	60%
Written report	none	-	graded	en	40%

6 **Credits according ECTS**

4 LP

7 **Workload**

120 h

8 **Duration**

1 semester

9 **Frequency**

every term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Sven Behnke	Institut für Informatik	2	X	X

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

12 **Further information**

References:
* 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**

26.03.2024 (20261)

Code: **MA-MOROB-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:

Knowledge in topics in the area of humanoid robotics, such as environment perception, state estimation, navigation, or motion planning. Ability to understand new research results of scientific papers and to present them in a talk as well as in a self-written summary. 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
Seminar	Seminar Humanoid Robots	en	10	2	120	S/W

3 **Prerequisites to take part the module**

obligatory:

none

recommended:

MA-MOROB-E02

4 **Study program allocation**

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

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Seminartalk	written and/or verbal academic performance (successful seminar participation)	25	graded	en	70%
Written report	written and/or verbal academic performance (successful seminar participation)	-	graded	en	30%

6 **Credits according ECTS**

4 LP

7 **Workload**

120 h

8 **Duration**

1 semester

9 **Frequency**

every term

10 **Maximum number of students**

	Yes, limitation of 10 students
11	**Module coordination**
	Lecturer: Name | Organization | SWS | exe. | res. Prof. Dr. Maren Bennewitz | Institut für Informatik | 2 | X | X Module coordinator / Organization: Prof. Dr. Maren Bennewitz (Institut für Informatik)
12	**Further information**
	References: * 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.
13	**Date of version**
	27.03.2024 (20261)

Code: **MA-MOROB-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
Seminar	Seminar Vision	en	10	2	120	S/W

3 Prerequisites to take part the module

obligatory:
MA-MOROB-M04

recommended:
none

4 Study program allocation

Study program	(alternative) module code	mandatory / elective module	recommended semester
Mobile Robotics (M.Sc.)	MA-MOROB-E10	Elective selection	3rd semester
Computer Science (M.Sc.)	MA-INF 2206	Elective selection	2nd or 3rd se-mester

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
Seminartalk	none	45	graded	en	80%
Written report	none	-	graded	en	20%

6 Credits according ECTS

4 LP

7 Workload

120 h

8 Duration

1 semester

9 Frequency

every term

10 Maximum number of students

no limitation

11 Module coordination

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Jürgen Gall	Institut für Informatik	2	X	X

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

12 Further information

none

13	**Date of version**
	26.03.2024 (20261)

Code: **MA-MOROB-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
Seminar	Mobile Robotics	en	10	2	90	W

3 Prerequisites to take part the module

obligatory:
none

recommended:
MA-MOROB-M01; MA-MOROB-M04

4 Study program allocation

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

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
Colloquium	none	30	graded	en	100%

6 Credits according ECTS

3 LP

7 Workload

90 h

8 Duration

1 semester

9 Frequency

winter term

10 Maximum number of students

no limitation

11 Module coordination

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Cyrill Stachniss	Institut für Geodäsie und Geoinformation	2	X	X

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

12 Further information

none

13 Date of version

26.03.2024 (20261)

Code: **MA-MOROB-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
Lecture	Advanced Deep Learning	en	30	1	60	W
Exercise, scientific/practical	Advanced Deep Learning	en	30	3	120	W

3 Prerequisites to take part the module

obligatory:

MA-MOROB-M03

recommended:

none

4 Study program allocation

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

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Project work	written and/or verbal academic performance	-	graded	en	30%
Oral examination	written and/or verbal academic performance	25	graded	en	70%

6 Credits according ECTS

6 LP

7 Workload

180 h

8 Duration

1 semester

9 Frequency

winter term

10 Maximum number of students

no limitation

11 Module coordination

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Chris McCool	Institut für Landtechnik	2	X	X
Dr. Michael Halstead	Institut für Landtechnik	2	X	

Module coordinator / Organization:
Prof. Dr. Chris McCool

12 **Further information**

none

13 **Date of version**

26.03.2024 (20262)

Code: **MA-MOROB-E13**
Title: **Techniques for Self-Driving Cars**

1 Content and intended learning outcomes

Content:

Introduction to self-driving cars and current challenges; vehicle localization and state estimation; detection of driving-related entities; PD and model-predictive control for steering autonomous vehicles; path planning and obstacle avoidance; self-driving car simulation; software infrastructure in self-driving vehicles

Qualification goals:

Advanced knowledge in implementation of basic techniques for control, planning, and perception in Python and testing in simulation environment CARLA. Understanding and writing of a summary of a scientific paper

2 Teaching and learning methods

Type	Topic	Lan-guage	Group-size	SWS	Work-load	Term
Lecture	Techniques for Self-Driving Cars	en	30	2	90	W
Exercise, scien-tific/practical	Techniques for Self-Driving Cars	en	15	2	90	W

3 Prerequisites to take part the module

obligatory:

MA-MOROB-M01

recommended:

MA-MOROB-M06

4 Study program allocation

Study program	(alternative) module code	mandatory / elective module	recommended semester
Mobile Robotics (M.Sc.)	MA-MOROB-E13	Elective selection	3rd semester
Geodetic Engineering (M.Sc.)	MGE-MSR-06	Elective selection	3rd semester
Geodäsie und Geoinformation (M.Sc.)	M26	Fachgebundener Wahlpflichtbereich: Wahlpflichtmodul "groß"	3. Fachsemes-ter

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
Oral examination	written and/or verbal academic performance	25	graded	en	100%

6 Credits according ECTS

6 LP

7 Workload

180 h

8 Duration

1 semester

9 Frequency

winter term

10 Maximum number of students

no limitation

11 Module coordination

Lecturer:

Name	Organization	SWS	exe.	res.
PD Dr. Jens Behley	Institut für Geodäsie und Geoinformation	2	X	X
Team Prof. Stachniss	Institut für Geodäsie und Geoinformation	2	X	

Module coordinator / Organization:
PD Dr. Jens Behley, Prof. Dr. Cyrill Stachniss (Institut für Geodäsie und Geoinformation)

12 **Further information**

Lectures and tutorials will take place in person. Video recordings of lectures from past year(s) are available

13 **Date of version**

26.03.2024 (20262)

Code: **MA-MOROB-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. Advanced knowledge, 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
Exercise, practical	High Precision Sensing	en	15	3	105	W
Seminar	High Precision Sensing	en	20	1	75	W

3 Prerequisites to take part the module

obligatory:

none

recommended:

MA-MOROB-M02; MA-MOROB-M05

4 Study program allocation

Study program	(alternative) module code	mandatory / elective module	recommended semester
Mobile Robotics (M.Sc.)	MA-MOROB-E14	Elective selection	3rd semester

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Project work	written and/or verbal academic performance	-	graded	en	100%

6 Credits according ECTS

6 LP

7 Workload

180 h

8 Duration

1 semester

9 Frequency

winter term

10 Maximum number of students

no limitation

11 Module coordination

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Heiner Kuhlmann	Institut für Geodäsie und Geoinformation	1	X	X
PD Dr. Lasse Klingbeil	Institut für Geodäsie und Geoinformation	1	X	
Team Prof. Kuhlmann	Institut für Geodäsie und Geoinformation	2	X	

Module coordinator / Organization:

Prof. Dr. Heiner Kuhlmann (Institut für Geodäsie und Geoinformation)

12	**Further information**
	none
13	**Date of version**
	26.03.2024 (20262)

Code: **MA-MOROB-E15**
Title: **Multi-Agent Learning Systems**

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:

Ability to model multi-agent learning systems in Python. Advanced knowledge, abstract thinking, presentation skills, teamwork, critical discussion of methods, interdisciplinary competence

2 Teaching and learning methods

Type	Topic	Language	Group-size	SWS	Workload	Term
Lecture	Multi-agent Learning Systems	en	20	2	90	W
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
Mobile Robotics (M.Sc.)	MA-MOROB-E15	Elective selection	3rd semester

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Oral presentation	written and/or verbal academic performance (written report)	15	graded	en	50%
Oral examination	written and/or verbal academic performance (written report)	15	graded	en	50%

6 Credits according ECTS

6 LP

7 Workload

180 h

8 Duration

1 semester

9 Frequency

winter term

10 Maximum number of students

no limitation

11 Module coordination

Lecturer:

Name	Organization	SWS	exe.	res.
Jun.-Prof. Dr. Wolfram Barfuss	Center for Development Research (ZEF)	4	X	X

Module coordinator / Organization:
Jun.-Prof. Dr. Wolfram Barfuss

12 **Further information**

none

13 **Date of version**

09.04.2024 (20262)

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

1 **Content and intended learning outcomes**

Content:

Develop a complete robot navigation stack in ROS2, including mapping, localization, path planning, obstacle avoidance, and control. A focus will be on message exchange, message handling, logging, and the use of ROS2 modules.

Qualification goals:

Knowledge about the ROS2 ecosystem, focusing on the build system, communication protocols, and sensor data processing. Work in small teams realizing a software project in ROS2 in a self-organized manner within a short time horizon.

2 **Teaching and learning methods**

Type	Topic	Language	Group-size	SWS	Work-load	Term
Lecture	Robot Operating Systems	en	30	1	30	W
Exercise, practical	Robot Operating Systems	en	15	1	60	W

3 **Prerequisites to take part the module**

obligatory:

MA-MOROB-E03 or comparable C++ programming experience in theoretical and practical form

recommended:

none

4 **Study program allocation**

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

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

Examination(s):

Type	Prerequisites	Duration	graded/ not graded	Language	Weight
Project work	written and/or verbal academic performance	-	graded	en	100%

6 **Credits according ECTS**

3 LP

7 **Workload**

90 h

8 **Duration**

1 semester

9 **Frequency**

winter term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

Name	Organization	SWS	exe.	res.
Dr. Tiziano Guadagnino	Institut für Geodäsie und Geoinformation	1	X	X
Team Prof. Stachniss	Institut für Geodäsie und Geoinformation	1	X	

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

12 **Further information**

The course will be executed as a block module
* https://docs.ros.org/en/rolling/Releases/Release-Humble-Hawksbill.html

13 **Date of version**

26.03.2024 (20262)

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

1 Content and intended learning outcomes

Content:

Advanced methods of machine learning, explainable machine learning

Qualification goals:

Technical skills: Knowledge of machine learning methods for data analysis and data interpretation with a focus on methods of explainable machine learning; ability to design and implement a method from the field of explainable machine learning

2 Teaching and learning methods

Type	Topic	Lan-guage	Group-size	SWS	Work-load	Term
Lecture	Explainable Machine Learning	en	30	1	30	W
Exercise, practical	Explainable Machine Learning	en	15	1	60	W

3 Prerequisites to take part the module

obligatory:

none

recommended:

Basic knowledge in deep machine learning

4 Study program allocation

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

5 Requirements for the rewarding of credits (ECTS)

Examination(s):

Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
Project work	written and/or verbal academic performance	20	graded	en	100%

6 Credits according ECTS

3 LP

7 Workload

90 h

8 Duration

1 semester

9 Frequency

winter term

10 Maximum number of students

no limitation

11 Module coordination

Lecturer:

Name	Organization	SWS	exe.	res.
Prof. Dr. Ribana Roscher	Institut für Geodäsie und Geoinformation	1	X	X
M.Sc. Ahmed Emam	Institut für Geodäsie und Geoinformation	1	X	

Module coordinator / Organization:
Prof. Dr. Ribana Roscher (Institut für Geodäsie und Geoinformation)

12 **Further information**

none

13 **Date of version**

17.04.2024 (20262)

Module Manual
Master’s Program

Mobile Robotics
(M.Sc.)

Master's Thesis

Code: **MA-MOROB-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; Systematic 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
Thesis	Master's Thesis	en	1	0	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
Mobile Robotics (M.Sc.)	MA-MOROB-MT	General mandatory selection	4th semester

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

Examination(s):

Type	Prerequisites	Dura-tion	graded/ not graded	Lan-guage	Weight
Master's Thesis	none	-	graded	en	100%

6 **Credits according ECTS**

30 LP

7 **Workload**

900 h

8 **Duration**

1 semester

9 **Frequency**

summer term

10 **Maximum number of students**

no limitation

11 **Module coordination**

Lecturer:

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

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 evaluation 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**
	26.03.2024 (20271)