Technische Universität Nürnberg

M.Sc. Artificial Intelligence and Robotics

Module Handbook

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Contents

Learning outcomes

Goal 1: To provide students theory-grounded and science-based content and methods for the innovative, effective and sustainable design or development of technologies for AI and robotics systems.

Objective 1.1: Students are able to understand advanced fundamental approaches in Artificial intelligence and Robotics including Machine Learning, Computer Vision, and Data Science.

Objective 1.2: Students are able to articulate and differentiate their knowledge from different domains regarding innovative ideas.

Objective 1.3: Students are able to critically reflect on limitations of state-of-the-art approaches.

Goal 2: To provide students with scientifically-based experience (content, methods, assignments) to develop and apply skills in data collection, analysis and evaluation for AI and robotics systems.

Objective 2.1: Students are able to apply state-of-the-art methods to given problems and existing datasets.

Objective 2.2: Students are able to scientifically analyze AI approaches.

Objective 2.3: Students are able to combine their knowledge from different domains to identify innovative solutions.

Goal 3: To provide students with scientific experiences to create novel solutions of AI/robotics technologies in response to current and future challenges of emerging technologies.

Objective 3.1: Students are able to create novel AI or robotic systems that extend the state of the art.

Objective 3.2: Students are able to evaluate the consequences of the application of AI and robotics approaches on spheres outside their own core expertise and adapt their approaches appropriately.

Goal 4: To provide students theory-grounded and science-based content and methods from complementary academic fields in order to critically reflect AI and robotic approaches and their consequences.

Objective 4.1: Students are able to understand fundamental approaches in selected fields of social sciences or humanities.

Objective 4.2: Students are able to combine knowledge from different academic fields to evaluate AI and robotics approaches.

Goal 5:

- To provide students with techniques to act effectively also in diverse teams and continuously develop their own expertise and learning.
- To provide students with the capability to demonstrate awareness for sustainability and democratic citizenship.
- To enable students to reflect and relate their own actions to social and ethical contexts.

Objective 5.1: Students are able to appropriately coordinate, cooperate and communicate with the target group.

Objective 5.2: Demonstrate effective problem solving and critical thinking skills in resolving job-related issues.

Objective 5.3: Students are able to utilize adaptive expertise and pursue creativity and lifelong learning.

Objective 5.4: Students are able to demonstrate values of a democratic society as well as sustainable environment and act accordingly.

Objective 5.5: Students are able to reflect on technology leadership and knowledge of ethics and relate them to current and future socio-technical contexts.

Study program outline

	Module	ECTS	Associated courses
mandatory	Artificial Intelligence Basic Module	6	Course Artificial Intelligence
	Mobile Robot Navigation Basic Module	6	Course Mobile Robot Navigation
	Machine Learning Basic Module	6	Course Machine Learning
	Deep Learning Basic Module	6	Course Deep Learning
	Computer Vision Basic Module	6	Course Computer Vision
	Data Engineering Basic Module	6	Course Data Engineering
elective	Advanced Module 1	6	All advanced AIR courses Choice of one course per module It is recommended to finish the basic module before starting the advanced module. examples for advanced course include: ● Cloud Databases ● Large Language Models ● Multimodal Foundation Models ● 3D Vision and Geometry
	Advanced Module 2	6	
	Advanced Module 3	6	
mandatory	Learning in Transformation Project	12	Learning in Transformation Project
	Key Competencies Basic Module	6	Courses Good Scientific Practice, Project Management, Communication All three courses have to be taken
elective	Key Competencies Module 1	6	All KC courses For each module course totaling 6 ECTS-Points have to be taken (usually two to three courses)
	Key Competencies Module 2	6	
	Interdisciplinary Module 1	6	All ID courses Choice of one course per module
	Interdisciplinary Module 2	6	
	Master Thesis	24	Master Thesis and Colloquium

Recommended Study Plan

Semester					
1	Artificial Intelligence (req.)	Mobile Robot Navigation (req.)	Machine Learning (req.)	Data Engineering (req.)	Key Competencies Basic Module
2	Deep Learning (req.)	Computer Vision (req.)	Interdisciplinary Module 1	Key Competencies Module 1	Learning in Transformation (Project)
3	Advanced Module 1 e.g. Cloud Databases	Advanced Module 2 e.g. Large Language Models	Advanced Module 3 e.g. Multimodal Foundation Models	Interdisciplinary Module 2	
4	Master Thesis (Colloquium + Thesis)				Key Competencies Module 2

List of Modules

Artificial Intelligence Basic Module			**6 ECTS**
Recommended Semester	**1st semester**	**Total Workload**	**180 hours**

Module No.	1-M-AIR-AIB-1
Duration	one semester
Course Frequency	winter semester
Module language	English
Admission requirements	None
Associated courses	Artificial Intelligence
Instructor	Prof. Dr. Wolfram Burgard
Examination	Learning-oriented assignments
Grading	graded
Learning outcomes	Students are able to ● describe different approaches to define artificial intelligence ● classify different types of problems, environments and intelligent agents ● formulate problems as search and apply different algorithms to solve them ● explain basic concepts of first-order and predicate logic ● apply basic approaches to probabilistic reasoning and decision making under uncertainty ● identify advanced concepts of artificial intelligence ● assess ethical consequences of artificial intelligence and its application and discuss interdisciplinary aspects of artificial intelligence
Contents	The contents of this module are mainly based on the contents of the textbook: Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach, Chapter 1-4. The book is available in the library.
Teaching and learning formats	See syllabus
Related Programs	M. Sc. AI & Robotics

Mobile Robot Navigation Basic Module			**6 ECTS**
Recommended Semester	**1st semester**	**Total Workload**	**180 hours**

Module No.	1-M-AIR-MRB-1
Duration	one semester
Course Frequency	winter semester
Module language	English
Admission requirements	None
Associated courses	Mobile Robot Navigation
Instructor	Prof. Dr. Wolfram Burgard
Examination	Learning-oriented assignments
Grading	graded
Learning outcomes	Students are able to ● explain basic approaches to probabilistic sensor and motion models as well as state estimation ● compare basic approaches to robot localization, robot mapping, simultaneous localization and mapping, motion and path planning, and exploration ● design basic architectures for vehicles that navigate autonomously in complex environments ● identify advanced concepts of mobile robotics ● assess ethical consequences of robotics and its application and discuss interdisciplinary aspects
Contents	● probabilistic sensor and motion models ● robot localization ● robot mapping ● simultaneous localization and mapping ● motion and path planning, and exploration
Teaching and learning formats	See syllabus
Related Programs	M. Sc. AI & Robotics

Machine Learning Basic Module			**6 ECTS**
Recommended Semester	**1st semester**	**Total Workload**	**180 hours**
Module No.	1-M-AIR-MLB-1		
Duration	one semester		
Course Frequency	winter semester		
Module language	English		
Admission requirements	None		
Associated courses	Machine Learning		
Instructor	NN		
Examination	Learning-oriented assignments		
Grading	graded		
Learning outcomes	Students are able to ● explain basic approaches to supervised, unsupervised, weakly-supervised learning, reinforcement learning, gradient descent and optimization ● compare basic approaches to regression, classification, clustering, and principle component analysis ● implement techniques for model selection and regularization ● develop strategies to solve problems using machine learning approaches ● identify advanced concepts of machine learning ● assess ethical consequences of machine learning and its application and discuss interdisciplinary aspects		
Contents	● supervised Learning (Regression and Classification) ● unsupervised Learning (Clustering, PCA) ● weakly-supervised learning ● model selection and Regularization		
Teaching and learning formats	See syllabus		
Related Programs	M. Sc. AI & Robotics		

Data Engineering Basic Module			**6 ECTS**
Recommended Semester	**1st semester**	**Total Workload**	**180 hours**

Module No.	1-M-AIR-DEB-1
Duration	one semester
Course Frequency	winter semester
Module language	English
Admission requirements	None
Associated courses	Data Engineering
Instructor	Prof. Dr. Andreas Kipf
Examination	Learning-oriented assignments
Grading	graded
Learning outcomes	Students are able to ● explain basic approaches to data engineering and visualization ● compare basic approaches to data cleaning and integration ● design basic architectures for data processing systems and data pipelines ● identify advanced concepts of data engineering ● assess ethical consequences of large data and its application and discuss interdisciplinary aspects
Contents	● Data Engineering Foundations ● Data Cleaning ● Data Integration ● Data Processing Systems ● Data Pipelines ● Visualization
Teaching and learning formats	See syllabus
Related Programs	M. Sc. AI & Robotics

Computer Vision Basic Module			**6 ECTS**
Recommended Semester	**2nd semester**	**Total Workload**	**180 hours**

Module No.	1-M-AIR-CVB-1
Duration	one semester
Course Frequency	summer semester
Module language	English
Admission requirements	Deep Learning Basic Module should be attended in the same semester (highly recommended!)
Associated courses	Computer Vision
Instructor	Prof. Dr. Eddy Ilg
Examination	Learning-oriented assignments
Grading	graded
Learning outcomes	Students are able to ● explain different sensor types and the image formation process; ● describe the main disciplines in 2D computer vision ● discuss the strengths and weaknesses of the main disciplines in 2D computer vision ● implement basic deep learning architectures that work on images ● identify advanced concepts of computer vision; and ● design, analyze and evaluate their own approach for an object detection task ● assess ethical consequences of computer vision and its application and discuss interdisciplinary aspects
Contents	● Image Formation ● 2D Semantic Understanding ● Motion and Depth Estimation ● Generative Models
Teaching and learning formats	See syllabus
Related Programs	M. Sc. AI & Robotics

Deep Learning Basic Module			**6 ECTS**
Recommended Semester	**2nd semester**	**Total Workload**	**180 hours**

Module No.	1-M-AIR-RLB-1
Duration	one semester
Course Frequency	summer semester
Module language	English
Admission requirements	None
Associated courses	Deep Learning
Instructor	Prof. Dr. Josif Grabocka
Examination	Learning-oriented assignments
Grading	graded
Learning outcomes	Students are able to ● understand basic foundations of deep feedforward networks, regularization for deep learning, and convolutional networks ● explain recurrent recursive networks, practical aspects of deep learning ● analyze deep learning approaches in the context of practical applications from computer vision, robotics and related fields ● implement techniques for model selection and regularization for deep learning ● identify advanced concepts of deep learning ● assess ethical consequences of deep learning and its application and discuss interdisciplinary aspects
Contents	● deep feedforward networks ● regularization for deep learning ● convolutional networks ● recurrent recursive networks ● practical aspects of deep learning ● model selection and regularization for deep learning
Teaching and learning formats	See syllabus
Related Programs	M. Sc. AI & Robotics

Advanced Module 1			**6 ECTS**
Recommended Semester	**3rd semester**	**Total Workload**	**180 hours**
Module No.	1-M-AIR-AM1-1		
Duration	one semester		
Course Frequency	winter semester		
Module language	English		
Admission requirements	None		
Associated courses	All advanced AIR courses One course has to be taken		
Instructor	Depending on course		
Examination	See syllabus		
Grading	See syllabus		
Learning outcomes	Students are able to ● develop in-depth knowledge in selected fields of AI and robotics ● demonstrate an advanced and comprehensive understanding of the fundamental concepts, principles, and theories in AI and robotics, such as machine learning, data engineering, deep learning, robotics, natural language processing, computer vision, reinforcement learning, and control systems ● analyze and find solutions to a given problem ● generate novel solutions and approaches to problems based on a concept or a combination of concepts presented in this course ● develop proficiency in using state-of-the-art AI and robotics tools and platforms. ● effectively reflect upon their knowledge and experiences in an interdisciplinary context, as well as identify connections between different disciplines and apply them in a meaningful way		
Contents	In the advanced module, students deepen their knowledge in up to three of the six fields artificial intelligence, robot navigation, deep learning, data engineering, machine learning, and computer vision. Students select one course from the advanced course offerings. The syllabus specifies the course content.		
Teaching and learning formats	See syllabus		
Related Programs	M. Sc. AI & Robotics		

Advanced Module 2			**6 ECTS**
Recommended Semester	**3rd semester**	**Total Workload**	**180 hours**
Module No.	1-M-AIR-AM2-1		
Duration	one semester		
Course Frequency	winter semester		
Module language	English		
Admission requirements	None		
Associated courses	All advanced AIR courses One course has to be taken		
Instructor	Depending on course		
Examination	See syllabus		
Grading	See syllabus		
Learning outcomes	Students are able to ● develop in-depth knowledge in selected fields of AI and robotics ● demonstrate an advanced and comprehensive understanding of the fundamental concepts, principles, and theories in AI and robotics, such as machine learning, data engineering, deep learning, robotics, natural language processing, computer vision, reinforcement learning, and control systems ● analyze and find solutions to a given problem ● generate novel solutions and approaches to problems based on a concept or a combination of concepts presented in this course ● develop proficiency in using state-of-the-art AI and robotics tools and platforms. ● effectively reflect upon their knowledge and experiences in an interdisciplinary context, as well as identify connections between different disciplines and apply them in a meaningful way		
Contents	In the advanced module, students deepen their knowledge in up to three of the six fields artificial intelligence, robot navigation, deep learning, data engineering, machine learning, and computer vision. Students select one course from the advanced course offerings. The syllabus specifies the course content.		
Teaching and learning formats	See syllabus		
Related Programs	M. Sc. AI & Robotics		

Advanced Module 3			**6 ECTS**
Recommended Semester	**3rd semester**	**Total Workload**	**180 hours**

Module No.	1-M-AIR-AM3-1
Duration	one semester
Course Frequency	winter semester
Module language	English
Admission requirements	None
Associated courses	All advanced AIR courses One course has to be taken
Instructor	Depending on course
Examination	See syllabus
Grading	See syllabus
Learning outcomes	Students are able to ● develop in-depth knowledge in selected fields of AI and robotics ● demonstrate an advanced and comprehensive understanding of the fundamental concepts, principles, and theories in AI and robotics, such as machine learning, data engineering, deep learning, robotics, natural language processing, computer vision, reinforcement learning, and control systems ● analyze and find solutions to a given problem ● generate novel solutions and approaches to problems based on a concept or a combination of concepts presented in this course ● develop proficiency in using state-of-the-art AI and robotics tools and platforms. ● effectively reflect upon their knowledge and experiences in an interdisciplinary context, as well as identify connections between different disciplines and apply them in a meaningful way
Contents	In the advanced module, students deepen their knowledge in up to three of the six fields artificial intelligence, robot navigation, deep learning, data engineering, machine learning, and computer vision. Students select one course from the advanced course offerings. The syllabus specifies the course content.
Teaching and learning formats	See syllabus
Related Programs	M. Sc. AI & Robotics

Learning in Transformation Project			**12 ECTS**
Recommended Semester	**2nd and 3rd semester**	**Total Workload**	**360 hours**
Module No.	1-M-AIR-LTP-1		
Duration	two semesters		
Course Frequency	summer semester		
Module language	English		
Admission requirements	None		
Associated courses	Transformative Learning Project		
Instructor	1-2 professor(s) from any department who can supervise the projects + Coaches/Teaching Assistants		
Examination	Project or scientific paper or presentation		
Grading	Pass/fail (with 70% of points for passing)		
Learning outcomes	Students are able to ● identify steps to solving a real-world research problem and design an action plan to implement these steps. ● develop and test a working prototype. ● critically evaluate and provide feedback on solution approaches of other student groups. ● explain and present the solution approach to the stakeholder(s) and peers. ● assess/evaluate the outcome of the project and defend the development steps.		
Contents	The Learning in Transformation project is an interdisciplinary scientific research project that focuses on practical learning experiences. The project aims to provide students with a scientific-based approach to solving real-world industrial, societal, or political problems faced by non-university stakeholders. The project encourages students to creatively apply their prior knowledge to solve these problems in groups. For further information see syllabus.		
Teaching and learning formats	The module is set up as a mixture of learning units, discussion and supervision sessions, field trips and a high proportion of independent work within student groups. Over the course of the two semesters, milestones help to structure the project planning and assure that the group is on track and on time. They are further used to document the project and learning progress. For further information see syllabus.		
Related Programs	See module description		

Interdisciplinary Module 1			**6 ECTS**
Recommended Semester	**2nd semester**	**Total Workload**	**180 hours**

Module No.	2-M-IND-IM1-1
Duration	one semester
Course Frequency	summer semester
Module language	English
Admission requirements	None
Associated courses	All interdisciplinary courses One course has to be taken
Instructor	Depending on course
Examination	See syllabus
Grading	graded
Learning outcomes	Students are able to ● understand selected scientific approaches and methods in the social sciences and humanities. ● develop critical thinking and problem-solving skills and apply them to real-world problems. ● apply knowledge of social science and liberal arts theories to analyze and evaluate the impact of technology on society. ● analyze the social, ethical, legal, and cultural implications of technology using social science and liberal arts methodologies. ● combine technological, social science, and liberal arts knowledge and methods to create novel technological solutions.
Contents	In the interdisciplinary module, students develop an interdisciplinary perspective that complements their scientific core courses. Students select one course from the interdisciplinary course offerings. Courses are offered in the area of design, social sciences, ethics/philosophy, law, and economics/business studies. The syllabus specifies the course content.
Teaching and learning formats	See syllabus
Related Programs	M. Sc. AI & Robotics

Interdisciplinary Module 2			**6 ECTS**
Recommended Semester	**3rd semester**	**Total Workload**	**180 hours**

Module No.	2-M-IND-IM2-1
Duration	one semester
Course Frequency	winter semester
Module language	English
Admission requirements	None
Associated courses	All interdisciplinary courses One course has to be taken
Instructor	Depending on course
Examination	See syllabus
Grading	graded
Learning outcomes	Students are able to ● understand selected scientific approaches and methods in the social sciences and humanities. ● develop and apply critical thinking and problem-solving skills and apply them to real-world problems. ● apply knowledge of social science and liberal arts theories to analyze and evaluate the impact of technology on society. ● analyze the social, ethical, legal, and cultural implications of technology using social science and liberal arts methodologies. ● combine technological, social science, and liberal arts knowledge and methods to create novel technological solutions.
Contents	In the interdisciplinary module, students acquire an interdisciplinary perspective that complements their scientific core courses. Students select one course from the interdisciplinary course offerings. Courses are offered in the area of design, social sciences, ethics/philosophy, law, and economics/business studies. The syllabus specifies the course content.
Teaching and learning formats	See syllabus
Related Programs	M. Sc. AI & Robotics

Key Competencies Basic Module			**6 ECTS**
Recommended Semester	**1st semester**	**Total Workload**	**180 hours**

Module No.	8-M-KCO-KCB-1
Duration	one semester
Course Frequency	winter semester
Module language	English
Admission requirements	None
Associated courses	Good Scientific Practice Project Management Communication All three courses have to be completed
Instructor	Depending on course
Examination	Learning-oriented assignments
Grading	pass/fail
Learning outcomes	Students are able to ● understand basic principles of good scientific practice. ● identify different forms and situations of scientific misconduct and apply strategies to avoid them. ● discuss various project management techniques and tools. ● identify potential problems within teams and respond appropriately. ● understand communication forms and techniques and apply them appropriately to different situations. ● apply principles of intercultural communication. ● communicate effectively in groups with different scientific or professional backgrounds.
Contents	Good Scientific Practice Students learn the rules and values of responsible and ethical research. This includes handling data, sources, and ideas of others, citation rules, forms of scientific misconduct and how to avoid them, and research ethics. Project Management Students learn basic project management tools and techniques and how to apply them correctly. This includes project planning, risk management, roles and associated tasks, team management, project monitoring and evaluation. The course specifically prepares students for the Learning in Transformation Project. Communication

	Students acquire communication techniques to communicate effectively in intercultural and interprofessional teams. The course specifically prepares students for the Learning in Transformation Project.
Teaching and learning formats	Courses are offered in weekly sessions or as block courses during the course-free period. The syllabus specifies the course content.
Related Programs	M. Sc. AI & Robotics

Key Competencies Module 1			**6 ECTS**
Recommended Semester	**2nd semester**	**Total Workload**	**180 hours**

Module No.	8-M-KCO-KC1-1
Duration	one semester
Course Frequency	summer semester
Module language	English
Admission requirements	None
Associated courses	All KC courses Courses totaling 6 ECTS have to be taken
Instructor	Depending on course
Examination	See syllabus
Grading	pass/fail
Learning outcomes	Students are able to ● apply key techniques and methodologies needed to work in an academic and professional environment. ● communicate effectively in foreign languages. ● reflect on and extend their knowledge independently.
Contents	In the Key Competencies Module, students acquire academic and professional key competencies. Students select two to three courses from the key competencies course offerings. The syllabus specifies the course content.
Teaching and learning formats	Courses are offered in weekly sessions or as block courses during the course-free period. The syllabus specifies the course content.
Related Programs	M. Sc. AI & Robotics

Key Competencies Module 2			**6 ECTS**
Recommended Semester	**4th semester**	**Total Workload**	**180 hours**
Module No.	8-M-KCO-KC2-1		
Duration	one semester		
Course Frequency	summer semester		
Module language	English		
Admission requirements	None		
Associated courses	All KC courses Courses totaling 6 ECTS have to be taken		
Instructor	Depending on course		
Examination	See syllabus		
Grading	pass/fail		
Learning outcomes	Students are able to ● apply key techniques and methodologies needed to work in an academic and professional environment. ● communicate effectively in foreign languages. ● reflect on and extend their knowledge independently.		
Contents	In the Key Competencies Module, students acquire academic and professional key competencies. Students select two to three courses from the key competencies course offerings. The syllabus specifies the course content.		
Teaching and learning formats	Courses are offered in weekly sessions or as block courses during the course-free period. The syllabus specifies the course content.		
Related Programs	M. Sc. AI & Robotics		

Master Thesis			**24 ECTS**
Recommended Semester	**4th semester**	**Total Workload**	**720 hours**
Module No.	1-M-AIR-THE-1		
Duration	one semester		
Course Frequency	winter semester		
Module language	English		
Admission requirements	None		
Associated courses	Master colloquium		
Instructor	XX		
Examination	Thesis and oral exam		
Grading	graded		
Learning outcomes	Students are able to ● formulate a research question in artificial intelligence and robotics, select the appropriate methodology and literature, and design an evaluation strategy ● use scientific methods to propose an innovative solution to a complex problem ● critically analyze and evaluate theories and approaches and reflect on their assumptions and limitations also in an interdisciplinary context ● integrate knowledge from different domains in order to create novel solutions to the research problem ● independently plan a research project within a given time frame ● apply the rules of good scientific practice to all parts of the research project ● structure and communicate research results in accordance with academic standards		
Contents	The students select their research topics in coordination with their advisor. The students present their work during a research colloquium, a separate course that takes place during the term.		
Teaching and learning formats	Independent research and colloquium (see syllabus)		
Related Programs	M. Sc. AI & Robotics		