MODULHANDBUCH

für den Studiengang der
Fakultät Mobilität und Technik

Automotive Systems (Master) – SPO 2.0

Fassung 1.2
Stand 06.02.2024

Gültig ab Sommersemester 2024

Änderungsverzeichnis

Datum	Version	Beschreibung der Änderung	Bearbeiter
30.11.2022	1.0	Modulbeschreibungen	Oberhauser
12.12.2023	1.1	Aktualisierung Modulbeschreibungen	Oberhauser / Schuler
06.02.2024	1.2	Änderungen in Modulbeschreibungen	Schuler

Hinweis zur Gültigkeit

Dieses Modulhandbuch gilt für Studierende, die das Studium im Studiengang

- Automotive Systems SPO 2.0

der Studien- und Prüfungsordnung der Hochschule Esslingen ab dem WS23/24 aufgenommen haben.

Sonstige Anmerkungen

Der Workload pro Creditpoint beträgt in diesen Studiengängen (§8 (1) MRVO):

Credits	Workload in Stunden
1	30

Freigabe

Dieses Dokument ist freigegeben.

gez. Prof. Mathias Oberhauser

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Inhaltsverzeichnis

Studiengangstrukturen und Modulübersichten

Studiengangstruktur

1	2		3	4			5	6	7
Modul-nummer ASM	Modulname	Teil-Creditpunkte	Teilgebiet	Lehrumfang SWS je Semester 1	2	3	Studien-Leistung	Prüfungs-Leistung	Credits
13570	Mathematical Methods in Engineering			8				KL 120	8
13571	System Design			8				KL 120	8
13572	Simulation and Control			8				KL 120	8
Ergänzungsmodule. Zu studieren ist Modul 13573 **oder** 13574 je nach Vorkenntnissen;									
13573	Vehicle Systems Fundamentals							KL 120	6
13574	IT Fundamentals			6				KL 120	6
Summen 1. Semester				**30**					**30**
13575	Autonomous Systems				8			KL 120	8
13576	Team Project		Project Seminar		1			PA	8
Zwei Spezialisierungs-Module je Studienschwerpunkt									
Nur Studierende mit dem Schwerpunkt **Automotive IT**									
13580	Automotive Communications				7			KL 120	7
13582	Usability and Dependability				7			KL 120	7
Nur Studierende mit dem Schwerpunkt **Vehicle Systems**									
13583	Ride and Handling				8			KL 120	8
13585	Propulsion Systems				6			KL 120	6
Summen 2. Semester					**23**				**30**
13577	Softskills	2	Global Engineering			2		KL 120	7
		2	Project Management			2			
		3	International Negotiations			3			
13578	Master Thesis	21	Master Thesis Project					BE (7)	23
		2	Presentation and Defence					MP 30 (1)	
Summen gesamtes Studium									**90**

Überblick Änderungen Modulhandbuch ASM Stupo 2.0 zu 1.0

Nr.	Modul	Credits	Anmerkungen
13570	Mathematical Methods	8 (+1)	Bereich Stochastik als theoretische Grundlage des autonomen Fahrens neu. Stoff im Teilgebiet Numerical Differential Equations reduziert.
13571	System Design	8	unverändert
13572	Simulation and Control	8	Teilgebiet Microcontroller aus 3809 übernommen, Fuzzy Logik gestrichen da technisch nicht mehr relevant.
13573	Vehicle System Fundamentals	6 (-1)	Modulname geändert (früher Vehicle Technology) Weniger Grundlagen Verbrennungs-motoren zugunsten Grundlagen alternative Antriebe (Batterie-fahrzeug, Brennstoffzelle).
13574	IT Fundamentals	6(-1)	Ersetzt das Modul Electronics, Sensors, and Measurement Techniques da künftig stärkere Ausrichtung in Richtung Software und Algorithmen.
13575	Autonomous Systems	8 (+1)	Ersetzt Simulation and Control 2 Kenntnisse in autonomen Fahren werden für Absolventen sehr wichtig.
13576	Team Project	7(+1)	Inhalt gleichgeblieben. Etwas mehr Zeit für Projektarbeit
13580	Automotive Communications	7 (-1)	Teilgebiete Safety and Security und MMI zwischen 3908 und 3909 getauscht.
13582	Usability and Dependability	7 (-1)	Modulname geändert (früher Reliable Embedded Systems) Teilgebiet Reliable Embedded Systems teils in 3903 verlagert Teilgebiete Safety and Security und MMI zwischen 3908 und 3909 getauscht. Teilgebiet Safety and Security etwas reduziert da z.T. in 3906 verlagert
13583	Ride and Handling	8	unverändert
13585	Propulsion Systems	6 (-2)	Synergie mit dem Modul Antriebsentwicklung (6h) im Masterstudiengang Fahrzeugtechnik (Unterricht auf Englisch). Stärkere Ausrichtung auf Betriebsstrategie hybrider Antriebe. Weniger konventioneller Antrieb (Verbrennungsmotor, Vielganggetriebe). Gemeinsames Lernen internationaler und deutscher Masterstudenten soll gefördert werden.
3912	*Electric and Electronic Architecture*		Modul entfällt (siehe Begründung Stuporeform)
3913	*Packaging and Integration*		Modul entfällt (siehe Begründung Stuporeform)
13577	Softskills	7	Zahl der Prüfungen verringert
13578	Master Thesis	23	unverändert

Module erstes Semester

Mathematical Methods

1	**Module Number**	**Study Program**	**Semester**	**Offered in**	**Duration**	**Module Type**	**Workload (h)**	**ECTS Points**
	13570	ASM	1	XWS ☐SS	1 Semester	compulsory	240	8

2	**Courses**	**Teaching and Learning Forms**	**Contact Time**		**Self-Study Time**	**Language**
			(SWS)	**(h)**	**(h)**	
	a) Numerical Analysis	Lecture	3	45	120	English
	b) Numerical Differential Equations	Lecture	2	30		
	c) Statistics and Kalman Filter	Lecture	3	45		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... explain the basic ideas of numerical analysis and understand the relation to the applications
- ... understand the algorithms and their constraints
- ... understand the limitations of the algorithms

Use, Application and Generation of Knowledge

Use and Transfer

- ... apply the algorithms in MATLAB.
- ... analyze the solutions concerning plausibility.
- … recognize and classify connections.
- ... analyze technical problems and derive or develop solutions.
- ... familiarize themselves with new ideas and topics based on their basic knowledge.

Scientific Innovation

- … use methods and tools to gain new insights in the field of numerical analysis.
- ... create new models.
- ... optimize systems.
- ... independently develop approaches for new concepts and assess their suitability.
- ... develop concepts for the optimization of technical applications.

Communication and Cooperation

- ... interpret the results of numerical analysis and draw admissible conclusions.
- ... use the learned knowledge, skills and competences to evaluate the field and interpret them according to other aspects.
- ... communicate and cooperate within the group in order to find adequate solutions for the task at hand.

Scientific Self-Conception/ Professionalism

- ... justify the solution theoretically and methodically.

4	**Contents** Lecture a) • Linear systems • Regression • Numerical differentiation and integration • Nonlinear equations and nonlinear systems Lecture b) • Ordinary differential equations (Runge-Kutta methods, stability and stiffness, shooting methods, applications) • Partial differential equations (finite difference methods, finite element methods, applications) Lecture c) • Descriptive and inferential statistics • Probability theory • Kalman filter Programming in MATLAB as part of the lecture.
5	**Participation Requirements** compulsory: - recommended: Good knowledge of further mathematics
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination, 120 minutes
7	**Further Use of Module** Applying mathematical methods in other lectures and major fields of automotive engineering
8	**Module Manager and *Full-Time Lecturer*** Prof. Dr. rer. nat. J. Gaukel, *Prof. Dr. rer. nat. M. Stämpfle, Prof. Dr. rer. nat. G. Schaaf*
9	**Literature** • Gander W., Gander M.J., Kwok, F., Scientific Computing • Stanoyevitch, Introduction to Numerical Ordinary and Partial Differential Equations Using MATLAB, Wiley • Marchthaler, Dingler: Kalman-Filter: Einführung in die Zustandsschätzung und ihre Anwendung für eingebettete Systeme • Chui, Chen: Kalman Filtering, Springer
10	**Last Updated** 06.12.2023

System Design

1	Module Number	Study Program	Semester	Offered in	Duration	Module Type	Workload (h)	ECTS Points
	13571	ASM	1	☒WS ☐SS	1 Semester	compulsory	240	8

2	Courses	Teaching and Learning Forms	Contact Time (SWS)	Contact Time (h)	Self-Study Time (h)	Language
	a) Automotive Systems Engineering	Lecture	4	60	120	English
	b) Software Engineering	Lecture	4	60		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

- … analyze automotive systems bottom-up …
- … design automotive systems top-down or middle-out …

Knowledge and Understanding

- ... know vehicle domains and their specific properties …
- … know mechatronic vehicle systems and their components …
- … know e/e architectures, bus systems and related terms …
- ... know relevant terms and fundamental principles related to automotive systems engineering …
- … know the system engineering process with relevant intermediate steps and artifacts …

Use, Application and Generation of Knowledge

Use and Transfer

- … be able to classify systems engineering within the process landscape
- … be able to describe the system in the problem and solution space and to apply procedures and methods to generate system engineering artifacts …
- … be able to create models for automotive systems and analyze them with respect to structure, performance and behavior …

Scientific Innovation

- … formalize systems engineering and system engineering artifacts …
- … enhance traceability, consistency and interoperability of system engineering artifacts …

Communication and Cooperation

- ... use formal models to communicate within development projects …
- … increase reusability and automated generation of artifacts …

Scientific Self-Conception/ Professionalism

- … be able to contribute to professional engineering of automotive systems from a methodological and a technical point of view …

4	**Contents**
	Lecture a): Automotive Systems Engineering
	• Introduction to Systems Engineering
	• Quick reference to Automotive Systems including:
	  ○ application domains powertrain, chassis, body, advanced driver assistance, infotainment
	  ○ mechatronic vehicle systems and their components
	  ○ E/E architecture, automotive bus systems, communication protocols
	• Systems Engineering in the Process Landscape
	• System Theory and Formalization
	• Methodologies
	• Examples
	
	Lecture b): Software Engineering
	• Introduction to Software Lifecycle Models
	• Agile Software Engineering
	• Requirements Engineering
	• Model-based Software Engineering with UML
	• Software Quality Assurance
	• Versioning Control and Configuration Management
	• Software Architecture
	• Software Design
	• Clean Code
	• Continuous Integration and Delivery

5	**Participation Requirements** compulsory: - recommended: a) Simulink, Simscape and Stateflow Onramp Courses offered from Mathworks. b) Familiarity with one of the major programming languages, C/C++ preferred.
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination, 120 min
7	**Further Use of Module** Autonomous Systems, Propulsion Systems , Team Project, Master Thesis
8	**Module Manager and *Full-Time Lecturer*** Prof. Dr.-Ing. R. Schuler, *Prof. Dr.-Ing. M. Röhricht*
9	**Literature** • J. Schäuffele, T. Zurawka: Automotive Software Engineering. Springer, 2016 • R. Isermann, Mechatronic Systems - Fundamentals, Springer, 2005 • R. Isermann, Automotive Control, Springer, 2022 • I. Sommerville, Software Engineering, Pearson, 2015
10	**Last Updated** 06.12.2023

Simulation and Control

1	Module Number	Study Program	Semester	Offered in	Duration	Module Type	Workload (h)	ECTS Points
	13572	ASM	1	☒WS ☐SS	1 Semester	compulsory	240	8

2	Courses	Teaching and Learning Forms	Contact Time (SWS)	Contact Time (h)	Self-Study Time (h)	Language
	a) Microcontroller, Modelling and Simulation	Lecture + Lab	2+1	45	120	English
	b) Basic Control	Lecture	2	30		
	c) Advanced Control	Lecture	3	45		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... understand and know the basic methods of modelling, system simulation and control engineering
- … know how and where to use these methods in the development of automotive systems
- … build up basic control loops using a small Microcontroller (e.g. Arduino)

Use, Application and Generation of Knowledge

Use and Transfer

- ... apply physical laws to derive mathematical system models in different domains (mechanical, electrical, thermal)
- ... apply methods of system simulation and control engineering in automotive applications
- ... analyze and evaluate the behavior of automotive systems and subsystems by use of simulation results
- … develop small circuits with sensors and actuators and develop programs for Microcontroller, build up, test and calibrate control functions

Scientific Innovation

- … use simulation and control engineering methods and tools to gain new insights into automotive systems or subsystems.
- ... create and optimize the behavior of automotive systems based on system models
- … get acquainted with practical realization of the simulated problem in a microcontroller environment

Communication and Cooperation

- ... create, communicate and discuss technical information’s in the area of the course subject
- ... communicate actively within an organization and obtain information.

Scientific Self-Conception/ Professionalism

- ... justify the solution theoretically and methodically to improve development methods.
- ... reflect and assess one's own abilities in a group comparison.

4	**Contents** **1. Microcontroller, Modelling and Simulation (2h)** • Systematic System Modelling and Identification in different domains (mechanical, electrical, thermal) • Adding sensors and actuators to the modelled system to get the complete transfer function • Integration of Control loops to manage system control and dynamics • Linearization of sensors / actuators or models (practical example) • Do Simulations using Simulink and Simscape and evaluate results • Build up small control system examples in Hardware and transfer control algorithm to a Real-Time Environment and do AutoCoding (Simulink to Arduino) • Compare pure Simulink/Simscape Simulation with the System realized in Hardware with Microcontroller **2. Basic Control** (2h) • System Representation of SISO Systems (e.g. LDE, Transfer functions, Block diagrams) • Basic principles of open loop and closed loop feedback control • Elements of control loops • Linearization of nonlinear differential equations • Laplace transformation (definition, rules, examples) • Basic Controllers (PID) • Bode diagram • Stability, Nyquist criteria, amplitude margin, phase edge • Root locus **3. Advanced Control I** (3h) • Linear and non-linear State Space Representation • State Space Controller Design (Pole Placement) • Observer Design and Separation Theorem • Digital Control / Discrete State Space Design • LQR-Controller Design • Discretization, Matrix exponential function **4. Computer Lab (1h)** • System Representations using Matlab/Simulink, Numerical Simulation • Modelling/Identification and Controller Design of an Electric Drive System • Controller Design of an Electric Drive System
5	**Participation Requirements** compulsory: Mathematics, Physics, Mechanics , Control Engineering Basics recommended: Basics in Matlab/Simulink
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination, 120 minutes
7	**Further Use of Module** Autonomous Systems, Propulsion Systems, Team project, Master Thesis
8	**Module Manager and *Full-Time Lecturer*** Prof. Dr.-Ing. Walter Lindermeir , *Prof. Mathias Oberhauser, Prof. Georg Mallebrein*
9	**Literature** • Lecture Notes and Scripts • Ogata, K.: Modern Control Engineering, Pearson Verlag • Liu, Xiangjie: Systems Control Theory, Science Press Beijing • Palm, W. J.: MATLAB for Engineering Applications, McGraw-Hill • Hanselman D.C., Littlefield B.: Mastering Matlab, Pearson Verlag • Dabney, J.B.; Harman, T.L.: Mastering Simulink • Mohthari: Engineering Applications in Process Control, Fuzzy Control
10	**Last Updated** 06.12.2023

Vehicle System Fundamentals

1	Module Number	Study Program	Semester	Offered in	Duration	Module Type	Workload (h)	ECTS Points
	13573	ASM	1	XWS ☐SS	1 Semester	compulsory	180	6

2	Courses	Teaching and Learning Forms	Contact Time (SWS)	Contact Time (h)	Self-Study Time (h)	Language
	a) Motor Vehicles	Lecture	3	45	90	English
	b) Introduction to Vehicle Propulsion	Lecture	2	30		
	c) Lab Motor Vehicles	Lab	1	15		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... explain the basic terms in vehicle technology and internal combustion engine technology as well as in components of electric and hybrid vehicles
- ….describe the different powertrain topologies like conventional, hybrid and battery- as well as fuel cell electric
- ... describe the different vehicle drivetrain configurations like front wheel, rear wheel and 4-wheel-drive
- … explain basic component parts of the chassis and the drive train
- … understand and calculate rolling resistance, aerodynamic drag, climbing and acceleration resistance and their impact on energy consumption
- … gain a first knowledge of transversal vehicle system simulation including torques, powers and energy flows

Use, Application and Generation of Knowledge

Use and Transfer

- … choose the best engine and driveline combination for different types of vehicles.
- ... create testing reports and present test results.
- ... analyze the state of the art wheel suspension systems
- ... understand the physical behavior of forces between road and tire for vehicle dynamics simulation
- … familiarize themselves with new ideas and topics in the field of automotive powertrains and suspensions
- … compare different powertrain topologies and their performance and efficiency

Scientific Innovation

- … find new technologies to lower energy consumption .
- ... optimize powertrains for high driving performance
- ... set up new driving test procedures and experience energy flows and driving performance with the help of simulation
- … calibrate tire models to measurements
- ... independently develop approaches for new suspension and driveline concepts and assess their suitability.

Communication and Cooperation

- ... communicate actively within a research or development team and obtain information.
- ... interpret the results of vehicle testing and draw admissible conclusions.
- ... communicate with powertrain and chassis designers about new solutions

Scientific Self-Conception/ Professionalism

- … derive recommendations for decisions from an environmental and safety perspective on the basis of the analyses and evaluations made.
- ... justify the solution theoretically and methodically

4	**Contents** a) Lecture: Motor Vehicles The course gives a basic knowledge in vehicle technology and their components The power train is mainly focused The aim is to learn the ability to calculate driving resistance and to design the power train with respect to driving performance and fuel consumption b) Introduction to Vehicle Propulsion Internal Combustion Engine (Ice) and Engine Control Fundamentals, including trends of the Ice. Alternative Powertrains: Ice-Hybrid, Battery-Electric Vehicle, Fuel-Cell Electric Vehicle and their specific components (Battery, Fuel-Cell, Electric Motor) Longitudinal vehicle Simulation (Simulink), consumption and performance (torque, power, energy flows) c) Lab: Motor Vehicles Determination of full-load torque and power pattern by using the car test bench Detection of fuel consumption map Determination of a tire map by using the tire test bench EUREPA. Analysis of vehicle road tests
5	**Participation Requirements** compulsory: no recommended: Fundamentals of Engineering Mechanics
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination 120 Minutes
7	**Further Use of Module** Propulsion Systems, Team Project
8	**Module Manager and *Full-Time Lecturer*** Prof. Dr.-Ing. Jens Holtschulze, *Prof. Georg Mallebrein, Dr.-Ing. Jens Neubeck*
9	**Literature** Heywood, J.B. Internal Combustion Engine Fundamentals McGraw-Hill BOSCH Automotive Handbook Distribution SAE
10	**Last Updated** 06.12.2023

IT Fundamentals

1	**Module Number** 13574	**Study Program** ASM	**Semester** 1	**Offered in** ☒WS ☐SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 180	**ECTS Points** 6
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	c) Data Structures and Algorithms		Lecture		3	45	90	English
	d) Programmable Systems and Networks		Lecture		3	45		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can ...

Knowledge and Understanding

- … explain the architecture and workings of a modern computer
- … understand the representation of items as data in computers
- … explain the working of an operation system
- … explain the challenges and solutions for communication between computers

Use, Application and Generation of Knowledge

Use and Transfer

- … design an algorithm for a specific task
- … implement an algorithm efficiently in an imperative programming language (C, Python)
- … analyse the complexity of an algorithm
- … choose a data structure suitable for a specific task
- … analyse network communication
- … choose types of network communication for a specific task
- … consider the architecture of the computer and the operating system to implement a distributed system

Scientific Innovation

- … use methods and tools to gain new insights in the field
- ... create software solutions to task at hand

Communication and Cooperation

- ... communicate actively within the lectures and obtain information.
- ... present technical contents and simulation results and discuss them with the class and the lecturer.
- ... communicate and cooperate within the group in order to find adequate solutions for the task at hand.

Scientific Self-Conception/ Professionalism

- ... present and justify the solution to given tasks theoretically and methodically
- … take ideas and suggestions from other source into consideration

4	**Contents** a) Lecture: Data Structures and Algorithms • Number theory • Graph theory • Notation, design and classification of algorithms • Data structures: arrays, lists, sets • Complexity, efficiency, computability, O-notation • Search and sort algorithms • Programming in C • Programming in Python b) Lecture: Programmable Systems and Networks • Number and character encoding (range, resolution, overflows) • Architecture of computers • Architecture of CPU, memory and inputs/outputs • Overview of structure and tasks of an operation system • Types of operation systems • Processes and threads • Memory management • Inter-process communication and synchronization • File systems • Program execution • Network fundamentals and architectures • Addressing, media access (Ethernet, WLAN) • Local networks (IP) • Routing in networks • Transport protocols (TCP, UDP) • Application protocols
5	**Participation Requirements** **Compulsory:** • none **Recommended:** • Discrete mathematics • Basics of some programming language • Computer handling
6	**Examination Forms and Prerequisites for awarding ECTS Points** Written Examination 120 Minutes
7	**Further Use of Module** Automotive Communication Usability and Dependability
8	**Module Manager and Full-Time Lecturer** Prof. Dr. Dominik Schoop
9	**Literature** • Brian W. Kernighan and Dennis M. Ritchie: The C Programming language, Prentice Hall, 2000 • Randal E. Bryant, David R. O'Hallaron: Computer Systems A Programmer's Perspective, Pearson, 2015 • Andrew S. Tanenbaum and Herbert Bos: Modern Operating Systems, Pearson, 2014 • James Kurose and Keith Ross: Computer Networking, Pearson, 2021
10	**Last Updated** 06.12.2023

Pflichtmodule zweites Semester

Autonomous Systems

1	**Module Number** 13575	**Study Program** ASM	**Semester** 2	**Offered in** ☐WS ☒SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 240	**ECTS Points** 8
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	a) Computer Vision and Deep Learning		Lecture		4	60	120	English
	b) Motion Planning		Lecture		1	15		
	c) Simultaneous Localization and Mapping		Lecture		3	45		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students will be able to design, implement and evaluate autonomous systems, especially in the fields of mobile robotics and self-driving vehicles.

Knowledge and Understanding

The students

- understand the challenges in analyzing and interpreting image data
- understand principles of machine learning and apply them to the interpretation of images
- understand sensor principles and sensor signal processing
- understand how to retrieve situation understanding from sensor data
- understand the motivation and approaches for Simultaneous Localization and Mapping

Use, Application and Generation of Knowledge

Use and Transfer

- … select, implement, and evaluate elementary algorithms from the field of computer vision
- … define and train neural networks on large datasets
- … select and implement motion planning and decision making methods for autonomous robots
- … apply fundamental techniques and algorithms for data fusion and localization and mapping
- … analyze and develop solutions to real-world problems

Scientific Innovation

- … develop novel approaches using state of the art statistics and filtering methods
- … develop novel approaches using state of the art computer vision and deep learning methods
- … develop novel approaches using state of the art motion planning methods

Communication and Cooperation

- ... communicate actively within a development team with engineers from other disciplines
- ... present technical contents and discuss them

Scientific Self-Conception/ Professionalism

- … design and implement software algorithms as part of a project team
- … evaluate different sensor configurations and autonomous driving system architectures

4	**Contents** Lecture: Computer Vision and Deep Learning • Image formation • Convolution, filters and features • Fundamentals of machine learning • Loss-based optimization • Deep learning models (e.g., multi-layer perceptrons, convolutional neural networks) for image classification/object detection/semantic segmentation • Application examples in autonomous driving Lecture: Motion Planning • Overview motion planning and behavior generation for autonomous robots • Fundamentals of robot motion planning (configuration and action space, collision checking) • Search based planning (A*) • Monte-Carlo-planning methods (RRT) • Planning using optimal control • Learning based planning methods • Motion forecasting Lecture: Simultaneous Localization and Mapping • Motivation & Taxonomies • Bayes-Filter • Motion and senor models • SLAM and Kalman Filter (z.B. EKF SLAM, UKF SLAM) • SLAM and Particle Filter (z.B. FastSLAM) • Monte Carlo Localization • Occupancy Grid Mapping
5	**Participation Requirements** compulsory: no recommended: undergraduate course in physics undergraduate course in computer science, programming in C/C++ or Python module ASM 3901 (Mathematical Methods in Engineering) module ASM 3902 (Simulation and Control)
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination 120 Min
7	**Further Use of Module** Master Thesis
8	**Module Manager and *Full-Time Lecturer*** Prof. Dr. R. Schuler, *Prof. Dr.-Ing. Thao Dang, Prof. Dr. rer. nat. Markus Enzweiler, Prof. Dr.-Ing. Frank Niewels*
9	**Literature** Sebastian Thrun et al.: Probabilistic Robotics. MIT Press, 2005. Richard Szeliski.: Computer Vision: Algorithms and Applications, 2022. RaJ, A. (Jun 28, 2002). Euclidean Clustering for Lidar point cloud data. RaJ, A. (Jun 6, 2002). 3D RANSAC Algorithm for Lidar PCD Segmentation. Maybeck, P.S. (1979). Chapter 1, "Introduction" from STOCHASTIC MODELS, ESTIMATION, AND CONTROL, Volume 1. Academic Press, 1979.
10	**Last Updated** 06.02.2024

Team Project

1	**Module Number** 13576	**Study Program** ASM	**Semester** 2	**Offered in** ☐WS ☒SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 240	**ECTS Points** 8
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
	Team Project		Project work		**(SWS)** 1	**(h)** 15	**(h)** 225	English

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... develop a project plan
- ... split complex tasks into subtasks.
- ... apply the knowledge from lectures and labs on a real application.
- ... understand the limitations of project time and human resources.

Use, Application and Generation of Knowledge

Use and Transfer

- ... use methods and tools of project management.
- ... understand the principles of systems engineering.
- … work with state of the art engineering software and measurement equipment.

Scientific Innovation

- ... describe interfaces of complex systems.
- ... apply scientific methods to solve industrial problems.
- … discuss pros and cons of new solutions in a group.
- … interpret measurement data and simulation results.

Communication and Cooperation

- ... work together according to a project plan
- ... take into account cultural differences in working style, leadership and communication.
- ... cooperate within the group in order to find adequate solutions for the project task.

Scientific Self-Conception/ Professionalism

- ...work successfully in international development groups in industry.

4 **Contents**

- application of project management
- constitution of hierarchy (project-manager, teams members)
- constitution of project structure (time schedule, work packages)
- realization of given task
- documentation and evaluation of results
- presentation of results
- project feedback

5 **Participation Requirements**

compulsory: -

recommended: Lectures and labs of first semester

6	**Examination Forms and Prerequisites for Awarding ECTS Points** Presentation in a group , 20 minutes Group report
7	**Further Use of Module** Preparation for Master thesis
8	**Module Manager and Full-Time Lecturer** Prof. M. Oberhauser
9	**Literature** • -
10	**Last Updated** 06.12.2023

Wahlmodule Vertiefung Automotive IT

Automotive Communications

1	**Module Number** 13580	**Study Program** ASM	**Semester** 2	**Offered in** ☐WS ☒SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 210	**ECTS Points** 7
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	a) Automotive Communication Networks		Lecture		3	45	105	English
	b) Vehicle-to-X (V2X)		Lecture		4	60		

3 **Learning Outcomes and Competences**
Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... know network architectures used in vehicles for onboard and off board communication.
- … understand wired and wireless technologies, protocols, and standards relevant for vehicular networks.
- … comprehend use cases and applications of automotive communication.

Use, Application and Generation of Knowledge

Use and Transfer
- … design and implement automotive communication technologies.
- ... setup and configure networked devices in a vehicle.

Scientific Innovation
- … evaluate the suitability of different technical solutions.
- … use measurements and/or simulation tools to analyze automotive communication.

Communication and Cooperation
- ... communicate actively within an organization and obtain information.
- ... present technical contents and discuss them.
- ... communicate and cooperate within the group to find adequate solutions for the task at hand.

Scientific Self-Conception/ Professionalism
- … derive recommendations for decisions from a social and ethical perspective based on analysis and evaluation.

4	**Contents** Lecture a): **Communication systems** • Fundamentals of communication networks • Ethernet and TCP/IP basics • On-board communication systems in vehicles • Automotive Ethernet technology • Selected applications (e.g., SOME/IP) Lecture b): **Vehicle-to-X (V2X)** • Fundamentals of radio communication • Radio communication technologies (e.g., 5G, IEEE 802.11p) • Fundamentals of safety • Message encoding (e.g., ASN.1) • Vehicle-to-X (V2X) motivation and use cases • V2X messages • Geo-networking (e.g., addressing, routing) • V2X applications • Simulation tools • Privacy and security for V2X
	Participation Requirements compulsory: - recommended: • Basics of communication systems and computer networks, • Knowledge of a programming language, preferably C/C++ and/or Java
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination, 120 min
7	**Further Use of Module** Master Thesis
8	**Module Manager and *Full-Time Lecturer*** Prof. Dr.-Ing. Michael Scharf, *Prof. Dr. Dominik Schoop, Prof. Dr.-Ing. Harald Melcher*
9	**Literature** • Andrew S. Tanenbaum, Nick Feamster, David Wetherall, “Computer Networks”, 6th Edition, Pearson, 2021 • James F. Kurose, Keith W. Ross, “Computer Networking: A Top-Down Approach”, 7th edition, Pearson, 2016 • Kirsten Matheus, Thomas Königseder, “Automotive Ethernet”, Cambridge University Press, 2015 • Christoph Sommer, Falko Dressler, “Vehicular Networking”, Cambridge University Press, 2014 • Standards of the European Telecommunications Standards Institute (ETSI), Intelligent Transport Systems (ITS)
10	**Last Updated** 06.12.2023

Usability and Dependability

1	**Module Number** 13582	**Study Program** ASM	**Semester** 2	**Offered in** ☐WS ☒SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 210	**ECTS Points** 7
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	a) Safety and Security		Lecture		3	45	105	English
	b) Automotive Man Machine Interaction (MMI)		Lecture		4	60		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- … understand usability, user experience (UX), and users'/drivers' requirements and project management issues in the development of automotive applications
- ... understand safety and security issues in the development of automotive applications

Use, Application and Generation of Knowledge

Use and Transfer

- … understand and apply requirements analysis, test and documentation
- … understand and evaluate existing navigation systems
- … implement and test a prototype navigation system
- … understand usability and UX management according to ISO 9241
- … give presentations of project results

- ... understand the main concepts: safety, functional safety, security, information security.
- … understand the main concepts in security
- ... be aware of security threats in the automotive domain
- ... understand security risk management
- … understand the main concepts in safety
- … understand safety management according to ISO 26262

Scientific Innovation

- … use methods and tools to gain new insights in the field of usable and dependable automotive systems

Communication and Cooperation

- ... communicate actively within an organization and obtain information
- ... present technical contents and discuss them regularly
- ... communicate and cooperate within the group to find adequate solutions for the task at hand

Scientific Self-Conception/ Professionalism

- … derive recommendations for decisions from a social and ethical perspective based on the analyses and evaluations made

4	**Contents**
	Lecture a): **Safety and Security**
	• Main concepts: safety, functional safety, security, information security
	• Main concepts in security
	• Security threats in the automotive domain, e.g.
	  ○ Insecure bus systems
	  ○ Chip manipulation
	  ○ Component theft
	  ○ Evading access controls
	• Counter measures based on cryptography
	• Security risk management
	• Safety and Security in vehicular ad hoc networks (VANETs)
	• Main concepts in safety
	• Safety management according to ISO 26262
	Lecture b): **Automotive Man Machine Interaction (MMI)**
	Basics terms and concepts of man machine interaction, requirements of graphical user interfaces, design requirements (software ergonomics, usability, dialog principles). On-board Pattern Recognition Systems.
	• machine vision systems (e.g. in traffic monitoring and automatic congestion detection, in driver assistance systems, for gesture recognition)
	• speech communication: speech recognition and understanding systems, speech dialogs: speech synthesis and language generation (Human-Machine Interface).
	• usability engineering, testing and evaluation of recognition systems
	Driver Assistance Systems
	• concepts for programming of driver assistance systems in automobiles: environment models, interpretation and fusion of sensor data, piloting functions, cooperative concepts.
	• implementation of important concepts in laboratory – user-centered design
	Human Factors Engineering
	• human factors, such as vision, cognition
	• driver attention and distraction
	• usability, user-centered design, UX
	• multimodal Interfaces Lab (programming exercises and presentations, simulation)
	Project
	• selected tasks and semester project (group work)

	Participation Requirements compulsory: - recommended: • C/C++ programming • computer networks basics • object oriented modelling (UML) • software engineering
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination, 120 min
7	**Further Use of Module** Master Thesis
8	**Module Manager and *Full-Time Lecturer*** Prof. Astrid Beck, *Prof. Dr. Dominik Schoop*

9	**Literature** • Shiho Kim, Rakesh Shrestha, Automotive Cyber Security Introduction, Challenges, and Standardization, Springer, 2020 • Christof Paar, Embedded Security in Cars, 2005 • Hans-Leo Ross, Safety for Future Transport and Mobility, Springer, 2021 • ISO 26262 („Road vehicles – Functional safety“) • DIN EN ISO 9241 („Ergonomics of human-system interaction”)
10	**Last Updated** 16 Oct 2022

Wahlmodule Vertiefung Vehicle Systems

Ride and Handling

1	**Module Number** 13583	**Study Program** ASM	**Semester** 2	**Offered in** ☐WS ☒SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 240	**ECTS Points** 8
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	a) Handling		Lecture		4	60	120	English
	b) Suspension Modelling		Lecture		4	60		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... develop an understanding of theory and methods in vehicle dynamics, with the focus on ride and handling properties
- ... estimate the effect of changing model parameters on ride and handling criteria

Use, Application and Generation of Knowledge

Use and Transfer

- ... analyze the performance characteristics for ride and handling

Scientific Innovation

- … apply scientific tools to the development of computer simulation models

Communication and Cooperation

- ... work together with electronic and software experts in the field of chassis control
- ... discuss new solutions for suspension systems with design engineers
- ... present technical contents in the field of suspension and handling technology and discuss them.

Scientific Self-Conception/ Professionalism

- *... justify the solution theoretically and methodically.*

4	**Contents** a) Lecture Handling terminology of vehicle handling, control loop ”driver-vehicle-environment”, demands on vehicle handling, planar kinematics of vehicle motion, linear (bicycle) model, under- and oversteer, steady state and transient test procedures, handling characteristics under normal driving conditions, analysis and discussion of vehicle dynamics and vehicle handling including a description of the tire, nonlinear model, yaw velocity damping characteristics, effects of design parameters and the road/tire friction coefficient on handling performance b) Lecture Suspension Modeling terminology in multibody dynamics, kinematics of free bodies, force and tor- que elements, play and friction, Newton-Euler equations, constraint functions, joints and linkages, flexible bodies, structure and functionality of multi- body codes, types of analysis, introduction into MSC.ADAMS, application in suspension modeling and simulation for ride, handling on uneven roads, and load case generation for durability Lab projects: development of a simple multibody simulation blockset in Simulink, modeling and analysis of double wishbone and McPherson suspensions in MSC.ADAMS, full vehicle simulations in MSC.ADSAMS/Car
5	**Participation Requirements** compulsory: no recommended: undergraduate course in mechanics (especially planar kinematics and kinetics of rigid bodies) fundamentals of automotive engineering including principles of chassis de- sign linear algebra including fundamental matrix calculus and eigenvalues Modul Simulation and Control
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination 120 Minutes
7	**Further Use of Module** Master Thesis
8	**Module Manager and *Full-Time Lecturer*** Prof. Dr.-Ing. Thomas. Schirle, *Prof. Dr.-Ing. Jens Holtschulze*
9	**Literature** Schindler, E.: Fahrdynamik – Grundlagen des Lenkverhaltens und ihre Anwendung für Fahrzeugregelsysteme. expert verlag, 2007 Gillespie, T.D.: Fundamentals of Vehicle Dynamics. SAE Wong: Theory of Ground Vehicles. SAE Nikravesh, P. E.: Computer-Aided Analysis of Mechanical Systems. Prentice Hall 1988 MSC: ADAMS Documentaion and Tutorials
10	**Last Updated** 06.12.2023

Propulsion Systems

1	Module Number	Study Program	Semester	Offered in	Duration	Module Type	Workload	ECTS
	13585	ASM	2	☐WS ☒SS	1 Semester	compulsory	180 h	6

2	Courses	Teaching and Learning Forms	Contact Time		Self-Study Time	Language
			(SWS)	(h)	(h)	
	a) Control of electrical and electrified Powertrains (Comb. Eng./EM/Hybrid)	Lecture / Exercise	3	45	90	English
	b) Operating Strategies of electrical and electrified Powertrains	Lecture / Exercise	2	30		
	c) Seminar Powertrain Simulation	Seminar	1	15		

3 **Learning Outcomes and Competences**

Once the module has been successfully completed, the students can...

Knowledge and Understanding

a) Control of electrical and electrified powertrains
- …understand the function and construction of modern combustion engine control systems
- …know about torque based system structure, air-, fuel- and ignition paths
- …know and understand the possibilities of distribution of torque/power in hybrid powertrains
- …understand and explain the scope of functions for recuperation in electrified powertrains
- …understand the functionality of power electronic actuators

b) Operating strategies of electrical and electrified powertrains
- …identify and explain operating modes of hybrid vehicles
- …know and present operating modes of various powertrains
- …understand and evaluate operating strategies of electric- and hybrid vehicles in detail
- …understand the interaction of components in the powertrain system to optimize consumption and emissions

c) Seminar powertrain simulation
- …understand structure and functionality of powertrain simulation models

Use, Application and Generation of Knowledge

Use and Transfer

a) Control of electrical and electrified powertrains
- … design control of e-drives for electric and hybrid vehicles
- … evaluate concepts of electric drives
- … compare fuel consumption with different loads, speeds, ignition timings
- … calculate resulting speeds, torques, and powers for different powertrain types
- … based on the basic knowledge of common drive components, evaluate new drive structures in terms of evaluate essential properties such as performance, smoothness, package or costs

b) Operating strategies of electrical and electrified powertrains
- …design and optimize operating strategies for different hybrid structures
- …recognize concept-related restrictions and evaluate operating quality
- …compare different operating strategies and evaluate them with regard to consumption, emissions, efficiency and range

c) Seminar powertrain simulation
- … make use of simulation tools to represent and evaluate interactions in drive systems

	Scientific Innovation a) Control of electrical and electrified powertrains • … create some software, functions for drives and discuss how they work
4	**Contents** a) Control of electrical and electrified powertrains • Structure and function of motor controls; components of motor controls: Sensors, actuators and control unit, structure and function of software, control strategies used. Structure of electrical control loops, functions and software. Torque and power paths in hybrid drives, functions, software. b) Operating strategies of electrical and electrified powertrains • Operating strategies, efficiency increase, emission avoidance, range increase, energy management in the vehicle c) Seminar powertrain simulation • Powertrain simulation
5	**Participation Requirements** compulsory: none recommended: Prior knowledge of propulsion systems from lecture “Vehicle System Fundamentals”
6	**Examination Forms and Prerequisites for Awarding ECTS Points** Written Examination 100 Minutes, midterm
7	**Further Use of Module** Master Thesis
8	**Module Manager and *Full-Time Lecturer*** Prof. Dr.-Ing. Michael Auerbach, *Prof. Dr.-Ing. Gregor Rottenkolber, Prof. Georg Mallebrein*
9	**Literature** • Reif, Konrad: Grundlagen Fahrzeug- und Motorentechnik im Überblick: Konventioneller Antrieb, Hybridantriebe, Bremsen, Elektrik und Elektronik; Bosch Fachinformation Automobil • Robert Bosch GmbH (Hrsg.): Ottomotor-Management, Vieweg Verlag, 2006 • Robert Bosch GmbH (Hrsg.): Dieselmotor-Management, Vieweg Verlag, 2006 • U. Nuss: Hochdynamische Regelung von Drehstrommaschinen • O. Zirn.: Elektrifizierung in der Fahrzeugtechnik - Grundlagen und Anwendungen, Hanser-Verlag Leipzig 2017 • R. Fischer: Elektrische Maschinen. Hanser Verlag, München Wien 2011 • Peter Hofmann, Hybridfahrzeuge: Ein alternatives Antriebssystem für die Zukunft, Springer 2014
10	**Last Updated** 6.12.2023

Pflichtmodule drittes Semester

Softskills

1	**Module Number** 13577	**Study Program** ASM	**Semester** 2	**Offered in** ☒WS ☐SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload** 210 h	**ECTS** 6
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
	a) Global Engineering b) Project Management c) International Negotiations		Lecture Lecture Lecture		**(SWS)** 2 2 3	**(h)** 30 30 45	**(h)** 105	English

Learning Outcomes and Competences

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... understand sales & marketing aspects of global engineering projects.
- … understand different approaches towards global engineering projects (waterfall, agile, hybrid project management).
- … develop a project plan, split complex tasks into subtasks.
- ... apply the knowledge from lectures and labs on a real application.
- ... understand the limitations of project time and human resources.
- … know about Intellectual properties and patent topics in engineering
- … know cultural differences.
- … improve language and mimic as a tool of successful interaction
- … understand mechanisms of multilateral business and trade formals

Use, Application and Generation of Knowledge

Use and Transfer

- ... be able to choose the right engineering approach in relation to the market needs
- … use methods and tools of project management.
- ... understand the principles of Global Engineering.
- … interpret Gant-charts, calculate the time and financial aspects of projects.
- … include and consult IP and patent experts in a professional manner – and know when appropriate
- … use state-of –the-art software support for projects
- … apply the gained knowledge to case-studies.
- … improve cooperation within your own unit / company
- … improve company - customer relationships
- … come to better results with international partners
- … being able to estimate the economic impact of IPR
- … transfer engineering results to production
- …

Scientific Innovation

- ... describe the dependency of R&D, production, sales & finance of projects.
- ... apply scientific methods to solve engineering tasks.
- … discuss pros and cons of different project management approaches.

Communication and Cooperation

- ... work together according to a project plan
- ... take into account cultural differences in working style, leadership and communication.
- ... cooperate within diverse international groups in order to find adequate solutions for the project task.
- … lead project teams
- … achieve more satisfying business output of international negotiations
- … use the right negotiation options according to the specific (cultural) counterparts
- … handle difficult situations and settle conflicts peacefully

Scientific Self-Conception/ Professionalism

- ...work successfully in international development groups in industry.

4	**Contents** **a) and b) (Global Engineering & Project Management)** • Sales & Marketing Aspects of Engineering Projects - Project lifecycle and analysis - Branding - Key Account Management - Customer Management - Bid management • Intellectual Property and Patents - Basics of Intellectual Property Rights (IPR) - Global Corporate Patent Strategy and Management - Company examples • Classical Project Management - Project Management Processes - Functions and responsibilities of a project manager - Scope, Time, Quality & Risk Management - Communications, HR & Integration Management - Documentation, reporting, presentation, decision making • Agile and Hybrid Project Management - Overview of different agile methods - Scrum - Integration of classical and agile methods • Critical Chain Project Management (CCPM) - Gamification with theoretical inputs - application of project management to a case study • Supporting IT structures - IT Network and Infrastructure - IT Organization - IT Security - Managing Product Data - From Engineering to Production **c) International Negotiations** • Background teaching of cultural differences • Interactive / international role plays • Exchanging of experiences of business and other cross-cultural transactions and achievements / failures. • Discourse and examples aimed at improving individual skills / arguments. • Win-win situations – learning different methods of negotiations
	Participation Requirements • compulsory: - • recommended: Negotiation English Some basic business experience Basic multicultural skills
6	**Examination Forms and Prerequisites for Awarding ECTS Points** 120 min written exam
7	**Further Use of Module** Module Team Project, Preparation for Master thesis, Preparation for negotiations in job situations
8	**Module Manager and Full-Time Lecturer** Prof. Dr. rer. nat. S. Zürn
9	**Literature** • Script and case studies will be provided in electronic format • PMBOK Guide 8th edition, PMI Institute • Larson, E.W.; C.F. Gray (2016): Project Management – The Managerial Process, McGraw-Hill • Mühlen, Alexander (2010): International negotiations, Münster Verlag,2010
10	**Last Updated** 06.12.2023

Master Thesis

1	**Module Number** 13578	**Study Program** ASM	**Semester** 3	**Offered in** X WS SS	**Duration** 1 Semester	**Module Type** compulsory	**Workload (h)** 690	**ECTS Points** 23
2	**Courses**		**Teaching and Learning Forms**		**Contact Time**		**Self-Study Time**	**Language**
					(SWS)	**(h)**	**(h)**	
	Master Thesis		Thesis		2	30	600	English
	Master Thesis Presentation and Defense		Presentation		1	15	45	

3 Learning Outcomes and Competences

Once the module has been successfully completed, the students can...

Knowledge and Understanding

- ... handle and solve a problem with scientific methods on their own

..**Use, Application and Generation of Knowledge**

Use and Transfer

- ... do scientific literature research .
- … write a scientific report.
- … give a presentation about thesis results.
- … organize themselves.

...

Scientific Innovation

- ... understand the theories and their limitations in there engineering discipline.
- ... find new solutions.

...

Communication and Cooperation

- ... give comprehensive intermediate reports to supervisors.
- ... work together with technical staff in industrial labs.
- ... cooperate within their own department and other departments and suppliers.

Scientific Self-Conception/ Professionalism

- ...work in R&D departments in industry
- … join a PhD program

4 Contents

- constitution of project structure (time schedule, work packages)
- realization of given task with scientific methods and within a given timeframe
- documentation and evaluation of results
- presentation and defense of results

5 Participation Requirements

compulsory: -

recommended: Lectures and labs of first and second semester, team project

6 Examination Forms and Prerequisites for Awarding ECTS Points

Presentation and oral examination , 30 minutes

Thesis report

7	**Further Use of Module** Preparation for Master thesis
8	**Module Manager and Full-Time Lecturer** Prof. M. Oberhauser
9	**Literature** •
10	**Last Updated** 06.12.2023