M.Sc. Electrical Engineering and Information Technology (PO 2014)

Automation Systems
Date: 01.09.2021

TECHNISCHE
UNIVERSITÄT
DARMSTADT

Department of Electrical Engineering and Information Technology

Module manual: M.Sc. Electrical Engineering and Information Technology (PO 2014)
Automation Systems
Date: 01.09.2021

Department of Electrical Engineering and Information Technology
Email: servicezentrum@etit.tu-darmstadt.de

Contents

1 Fundamentals

Module name System Dynamics and Automatic Control Systems III					
Module Nr. 18-ad-2010	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Jürgen Adamy		

1	**Content** Topics covered are: • basic properties of non-linear systems, • limit cycles and stability criteria, • non-linear control of linear systems, • non-linear control of non-linear systems, • observer design for non-linear systems
2	**Learning objectives / Learning Outcomes** After attending the lecture, a student is capable of: • explaining the fundamental differences between linear and non-linear systems, • testing non-linear systems for limit cycles, • stating different definitions of stability and testing the stability of equilibria, • recalling the pros and cons of non-linear controllers for linear systems, • recalling and applying different techniques for controller design for non-linear systems, • designing observers for non-linear systems
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 180 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC, MSc iST, MSc WI-ETiT, MSc iCE, MSc EPE, MSc CE, MSc Informatik
7	**Grade bonus compliant to §25 (2)**
8	**References** Adamy: Systemdynamik und Regelungstechnik III (available for purchase at the FG office)

Courses

Course Nr. 18-ad-2010-vl	**Course name** System Dynamics and Automatic Control Systems III		
Instructor Prof. Dr.-Ing. Jürgen Adamy		**Type** Lecture	**SWS** 2

<table>
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18-ad-2010-ue</td><td colspan="3">Course name
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<tr><td colspan="2">Instructor
Prof. Dr.-Ing. Jürgen Adamy</td><td>Type
Practice</td><td>SWS
1</td></tr>
</table>

Module name Digital Control Systems I					
Module Nr. 18-ko-2020	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** SoSe
Language German			**Module owner** Prof. Dr.-Ing. Ulrich Konigorski		

1	**Content** Theoretical fundamentals of sampled control systems: Discrete-time functions, sample/hold element, z-transform, convolution sum, z-transfer function, stability of sampled systems, design of digital controllers, discrete PI-, PD-, and PID-controllers, compensation and dead-beat controller, anti-windup methods
2	**Learning objectives / Learning Outcomes** The students know the fundamental analysis and design methods for digital feed-forward and feed-back control systems. They know the fundamental differences between continuous-time and discrete-time control systems and can design and analyze discrete-time control systems using different methods.
3	**Recommended prerequisite for participation** Helpful is knowledge of the Laplace- and Fourier-transforms as well as continuous-time control systems. These fundamentals are taught in the lecture "System Dynamics and Control Systems I"
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** BSc/MSc Wi-ETiT, MSc ETiT, BSc/MSc CE, MSc MEC, BSc/MSc iST, MSc iCE, MSc Informatik
7	**Grade bonus compliant to §25 (2)**
8	**References** Lecture notes Konigorski: "Digitale Regelungssysteme" Ackermann: "Abtastregelung" Aström, Wittenmark: "Computer-controlled Systems" Föllinger: "Lineare Abtastsysteme" Phillips, Nagle: "Digital control systems analysis and design" Unbehauen: "Regelungstechnik 2: Zustandsregelungen, digitale und nichtlineare Regelsysteme"

Courses

Course Nr.	Course name	Instructor	Type	SWS
18-ko-2020-vl	Digital Control Systems I	Prof. Dr.-Ing. Ulrich Konigorski	Lecture	2
18-ko-2020-ue	Digital Control Systems I	Prof. Dr.-Ing. Ulrich Konigorski	Practice	1

Module name Identification of Dynamic Systems					
Module Nr. 18-ko-2040	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Ulrich Konigorski		

1 Content

- Introduction into the determination of mathematical process models based on measured data
- Theoretical and experimental modeling of dynamic systems
- System identification using continuous time signals:
  - Aperiodic signals
    - Fourier analysis
    - Evaluation of characteristic values (stepresponses)
  - Periodic signals
    - Frequency response analysis
    - Correlation analysis
- System identification using discrete time signals:
  - Deterministic and stochastic signals
  - Basics in estimation theory
  - Correlation analysis
- Parameter estimation techniques:
  - Least-squares estimation
  - Model structure determination
  - Recursive estimation algorithms
- Kalman Filter and Extended Kalman Filter
- Numerical Methods
- Implementation under MatLab Numerous examples with real experimental data

2 Learning objectives / Learning Outcomes

The students are taught the fundamental methods in signal and system analysis. Furthermore, the students master methods such as Fourier analysis, correlation analysis and parameter estimation methods. Based on this foundation, the students are able to assess and to apply the individual methods and can derive non-parametric as well as parametric models from measured data.

3 Recommended prerequisite for participation

MSc ETiT, MSc MEC

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Optional, Weighting: 100 %)

6 Usability of this module

All disciplines of Electrical Engineering and Information Technology and similar disciplines (Mechatronics, Mechanical and Process Engineering, . . .), Master of Science

7 Grade bonus compliant to §25 (2)

8 References

	Pintelon, R.; Schoukens, J.: System Identification: A Frequency Domain Approach. IEEE Press, New York, 2001. Ljung, L.: System Identification: Theory for the user. Prentice Hall information and systems sciences series. Prentice Hall PTR, Upper Saddle River NJ, 2. edition, 1999.

Courses

Course Nr.	Course name		
18-ko-2040-vl	Identification of Dynamic Systems		
Instructor		**Type**	**SWS**
Dr. Ing. Eric Lenz		Lecture	2
Course Nr.	**Course name**		
18-ko-2040-ue	Identification of Dynamic Systems		
Instructor		**Type**	**SWS**
Dr. Ing. Eric Lenz		Practice	1

Module name					
Modeling and Simulation					
Module Nr. 18-ko-2010	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** SoSe
Language German			**Module owner** Prof. Dr.-Ing. Ulrich Konigorski		

1	**Content** aim of modeling, theoretical modeling by application of fundamental physical laws, generalized network analysis, modeling of distributed parameter systems, model reduction, linearization, order reduction, digital simulation of linear systems, numerical integration methods
2	**Learning objectives / Learning Outcomes** The students will know different techniques for the mathematical modeling of dynamic systems from various domains. They will acquire the ability to digitally simulate the dynamic behavior of the modeled systems and to systematically apply the available numerical integration methods.
3	**Recommended prerequisite for participation** Basic knowledge of continuous- and discrete-time control theory. Supplementary lectures are "System Dynamics and Control Systems I and II" as well as "Digital Control Systems I and II".
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC
7	**Grade bonus compliant to §25 (2)**
8	**References** Lecture notes Konigorski: "Modellbildung und Simulation", Lunze: „Regelungstechnik 1 und 2", Föllinger: „Regelungstechnik: Einführung in die Methoden und ihre Anwendung"

Courses

Course Nr.	Course name	Instructor	Type	SWS
18-ko-2010-vl	Modeling and Simulation	Prof. Dr.-Ing. Ulrich Konigorski	Lecture	2
18-ko-2010-ue	Modeling and Simulation	Prof. Dr.-Ing. Ulrich Konigorski	Practice	1

Module name					
Laboratory Control Engineering II					
Module Nr. 18-ad-2060	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 90 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Jürgen Adamy		

1	**Content** During the laboratory course the following experiments will be conducted: Coupling control of a helicopter, Non-linear control of a gyroscope, Nonlinear multivariable control of an aircraft, Servo control systems, Control of an overhead crane system, Programmable logic control of a stirring process
2	**Learning objectives / Learning Outcomes** After attending this laboratory course, a student is capable of: • recalling the basics of the conducted experiments, • organize and comprehend background information for experiments, • assemble experimental set-ups based on manuals, • judge the relevance of experimental results by comparing them with theoretically predicted outcomes, • present the results of the experiments
3	**Recommended prerequisite for participation** System Dynamics and Control Systems II, the attendance of the additional lecture "System Dynamics and Control Systems III" is recommended
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Written Examination, Duration: 180 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Written Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC, MSc iST, MSc Wi-ETiT, Biotechnik
7	**Grade bonus compliant to §25 (2)**
8	**References** Adamy: Instruction manuals for the experiments (available during the kick-off meeting)

Courses

Course Nr.	Course name		
18-ad-2060-pr	Laboratory Control Engineering II		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Jürgen Adamy, M.Sc. Jan Christian Zimmermann		Internship	4

2 Optional Modules

2.1 AUT I: Automatic Control Systems

Module name Digital Control Systems II						
Module Nr. 18-ko-2030	**Credit Points** 3 CP		**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** SoSe
Language German				**Module owner** Prof. Dr.-Ing. Ulrich Konigorski		
1	**Content** State space description of discrete-time systems, controllability, observability, state feedback controller, pole assignment, PI-state feedback controller, discrete state observers, modified Luenberger observer					
2	**Learning objectives / Learning Outcomes** The students know the state spacel description of sampled control systems and the corresponding analysis and design methods. They can design deadbeat controllers, state feedback controllers by pole assignment and PI- state feedback controllers for single input systems and know how to implement state feedback controllers together with a discrete- time observer.					
3	**Recommended prerequisite for participation** Knowledge of the z-transform as well as the fundamentals of discrete-time control systems. These fundamentals are taught in the lecture “Digital Control systems I”.					
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)					
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)					
6	**Usability of this module** MSc ETiT, MSc Wi-ETiT, BSc/MSc iST, MSc MEC, MSc iCE					
7	**Grade bonus compliant to §25 (2)**					
8	**References** Lecture notes Konigorski: “Digitale Regelungssysteme” Ackermann: "Abtastregelung" Aström, Wittenmark: "Computer-controlled Systems" Föllinger: "Lineare Abtastsysteme" Phillips, Nagle: "Digital control systems analysis and design" Unbehauen: "Regelungstechnik 2: Zustandsregelungen, digitale und nichtlineare Regelsysteme"					
Courses						
	Course Nr. 18-ko-2030-vl	**Course name** Digital Control Systems II				
	Instructor Prof. Dr.-Ing. Ulrich Konigorski				**Type** Lecture	**SWS** 1

	Course Nr.	Course name		
	18-ko-2030-ue	Digital Control Systems II		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Ulrich Konigorski		Practice	1

Module name Fuzzy Logic, Neural Networks and Evolutionary Algorithms					
Module Nr. 18-ad-2020	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Jürgen Adamy		

1 Content

Fuzzy systems: basics, rule based fuzzy logic, design methods, decision making, fuzzy control, pattern recognition, diagnosis; Neural networks: basics, multilayer perceptrons, radial basis functions, pattern recognition, identification, control, interpolation and approximation, Neuro-fuzzy: optimization of fuzzy systems, data driven rule generation; Evolutionary algorithms: optimization problems, evolutionary strategies and their applications, genetic programming and its applications

2 Learning objectives / Learning Outcomes

After attending the lecture, a student is capable of:

- recalling the elements and set-up of standardized fuzzy-logic, neural networks and evolutionary algorithms,
- discussing the pros and cons of certain set- ups of systems from computational intelligence for solving a given problem,
- recognizing situations in which tools taken from computational intelligence can be applied for problem solving,
- creating programs from algorithms taught in the lecture, and
- extending the learned standard procedures in order to solve new problems.

3 Recommended prerequisite for participation

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

BSc iST, MSc ETiT, MSc MEC, MSc WI-ETiT, MSc iCE, MSc EPE, MSc CE, MSc Informatik

7 Grade bonus compliant to §25 (2)

8 References

Adamy: Fuzzy Logik, Neuronale Netze und Evolutionäre Algorithmen, Shaker Verlag (available for purchase at the FG office)
www.rtr.tu-darmstadt.de (optionales Material)

Courses

Course Nr.	**Course name**		
18-ad-2020-vl	Fuzzy Logic, Neuronal Networks and Evolutionary Algorithms		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Jürgen Adamy		Lecture	2

Course Nr.	**Course name**		
18-ad-2020-ue	Fuzzy Logic, Neuronal Networks and Evolutionary Algorithms		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Jürgen Adamy		Practice	1

Module name					
Controller Design for Multivariable Systems in State Space					
Module Nr. 18-ko-2050	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 90 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Ulrich Konigorski		

1	**Content** Pole assignment, Coupling and decoupling of linear multivarible systems, Optimal control, Design of state observers, Dynamic state feedback control, Structurally constrained state feedback
2	**Learning objectives / Learning Outcomes** The students will be able to analyse and design linear time-invariant multivariable systems by means of different state space design methods.
3	**Recommended prerequisite for participation** Basic knowledge of linear control theory ("System Dynamics and Control Systems I and II”)
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC
7	**Grade bonus compliant to §25 (2)**
8	**References** Skript Konigorski: “Mehrgrößenregler im Zustandsraum”, Anderson, Moore: "Optimal Control: Linear Quadratic Methods", Föllinger:"Regelungstechnik: Einführung in die Methoden und ihre Anwendung", Föllinger: "Optimale Regelung und Steuerung: Eine Einführung für Ingenieure", Roppenecker: "Zeitbereichsentwurf linearer Regelungen: Grundlegende Strukturen und eine Allgemeine Methodik ihrer Parametrierung", Unbehauen: "Regelungstechnik II:Zustandsregelungen, digitale und nichtlineare Regelungssysteme", Zurmühl: "Matrizen und ihre Anwendung: Für Angewandte Mathematiker, Physiker und Ingenieure. Teil 1: Grundlagen"

Courses

Course Nr.	Course name		
18-ko-2050-vl	Controller Design for Multivariable Systems in State Space		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Ulrich Konigorski, M.Sc. Viktor Kisner		Lecture	2
Course Nr.	**Course name**		
18-ko-2050-ue	Controller Design for Multivariable Systems in State Space		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Ulrich Konigorski, M.Sc. Viktor Kisner		Practice	2

Module name Industrial Electronics					
Module Nr. 18-ho-2210	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language German and English			**Module owner** Prof. Dr.-Ing. Klaus Hofmann		

1	**Content** Typical Struture of Industrial Electronics Components. Characteristics of Typical Building Blocks (Digital Core, Sensor Frontend, Actuator Frontend, Supply and Reference Level), Functioning of Relevant Field Bus Systems, Knowledge of Relevant Standards and Technical Regulations.
2	**Learning objectives / Learning Outcomes** After successfull completion of the module, students are able to: 1. understand the use of electronic components in typical industrial environments, 2. understand the function of the building blocks of typical IE comonents, 3. deeply understand the functioning of analog bulding blocks, 4. understand relevant field bus systemes, 5. understand the regulatory and technical standards of industrial electronics components.
3	**Recommended prerequisite for participation** Lecture "Elektronik" and "Analog IC Design"
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, M.Sc. iCE, M.Sc. MEC
7	**Grade bonus compliant to §25 (2)**
8	**References** • Dietmar Schmid, Gregor Häberle, Bernd Schiemann, Werner Philipp, Bernhard Grimm, Günther Buchholz, Jörg Oestreich, Oliver Gomber, Albrecht Schilling: „Fachkunde Industrieelektronik und Informationstechnik"; Verlag Europa-Lehrmittel, 11 th Ed. 2013. • Gunter Wellenreuther, Dieter Zastrow; „Automatisieren mit SPS – Theorie und Praxis"; Springer Verlag, 6 th Ed. 2015. • Ulrich Tietze, Christoph Schenk, Eberhard Gamm: „Halbleiter-Schaltungstechnik"; Springer Verlag, 15 th Ed. 2016.

Courses

Course Nr.	**Course name**		
18-ho-2210-vl			
Instructor Dr.-Ing. Roland Steck		**Type** Lecture	**SWS** 2
Course Nr. 18-ho-2210-ue	**Course name**		
Instructor Dr.-Ing. Roland Steck		**Type** Practice	**SWS** 1

Module name Optimal and Predictive Control					
Module Nr. 18-fi-2010	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Rolf Findeisen		

1 Content

Optimal control approaches, like model predictive control, are one of the most versatile, flexible and most often used modern control approaches by now. Fields of applications span from robotics, autonomous driving, aerospace systems, energy systems, chemical processes, biotechnology, up to biomedicine. The lecture provides an introduction to fundamentals of optimal control, focusing on the method and theoretical base. It furthermore provides an outreach towards efficient numerical solution strategies and model predictive control.

The following topics are covered during the lecture:

- Application examples from various fields such mechatronics, robotics, electrical systems, chemical processes, economics, as well as aeronautics
- Review of nonlinear programming
- Dynamic programming, the principle of optimality, Hamilton-Jacobi-Bellman equation
- Pontryagin maximum principle
- Infinite and finite-horizon optimal control, LQ optimal control
- Numerical solution approaches for optimal control problems
- Introduction to model predictive control (MPC)

2 Learning objectives / Learning Outcomes

The students learn how to formulate, analyze, and solve optimal control problems. The course focuses on key ideas and concepts of optimal control. The students learn standard methods for computing and implementing optimal control strategies.

3 Recommended prerequisite for participation

Basic lecture of control engineering and system theory with a focus on state space formulations

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 120 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

MSc etit
MSc MEC
MSc Wi-etit
Open for other departments and Study Programmes

7 Grade bonus compliant to §25 (2)

8 References

Lecture notes and slides will be provided in the elearning system
Further recommended literature:
Optimal Control

- R. Bellman. Dynamic Programming. Princeton University Press, Princeton, New Jersey, 1957.
- L.D. Berkovitz. Optimal Control Theory. Springer-Verlag, New York, 1974.
- D.P. Bertsekas. Dynamic Programming and Optimal Control. Athena Scientific Press. 2nd edition, 2000.
- L.M. Hocking. Optimal Control. An Introduction to the Theory with Applications. Oxford Applied Mathematics and Computing Science Series. Oxford University Press, Oxford, 1991.
- J.L. Troutmann. Variational Calculus and Optimal Control. Undergraduate Texts in Mathematics. Springer, 1991.

Optimization

- S. Boyd, L. Vandenberghe. Convex Optimization. Cambridge University Press, 2004.
- J. Nocedal, S. Wright. Numerical Optimization. Springer, 2006.

Model Predictive Control

- J.B. Rawlings, D.Q. Mayne, M. Diehl. Model Predictive Control: Theory and Design, 2009.

Courses

Course Nr.	**Course name**		
18-fi-2010-vl	Optimal and Predictive Control		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Rolf Findeisen		Lecture	2
Course Nr.	**Course name**		
18-fi-2010-ue	Optimal and Predictive Control		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Rolf Findeisen		Practice	1

Module name Computer Vision in Engineering					
Module Nr. 18-ad-2090	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Jürgen Adamy		

1	**Content**
	A Basics
	• Scene Representation2D and 3D Geomtery
	• Image Acquisition
	  – Geometric Projections Camera Calibration
	• Objective and Illumination
	• Discrete 2D signals
	  – Separability, Sampling
	  – Transformation, Interpolation
	  – Convolution, Correlation
	  – Discrete Fourier Transformation
	
	B Basics of Image Analysis
	• Filtering
	  – Basics2D Filter Design
	  – Linear Filtering
	  – Nichtlinear Filtering
	• Image Decompositions
	  – Multi-scale Representation
	  – Pyramids
	  – Filter Banks
	• Image Features
	  – Structure
	  – Moments, Histograms

2	**Learning objectives / Learning Outcomes** The lecture communicates mathematical basics needed to solve computer vision problems in the field of engineering. The focus is on methods that are relevant for measuring and control tasks. Applications range from visual quality inspection, visual robotics, photogrammetry, visual odometry up to visually guided driver assistance etc. The students should obtain a good understanding for the relations between the three-dimensional world and its two-dimensional projection onto the image plane of a camera. They also should learn about methods that exist to infer knowledge from the world given image data. They should develop some feeling for the different kinds of problems that arise in computer vision and how to choose an efficient solution in terms of algorithms.
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading**

	Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc iST, MSc CE, MSc iST
7	**Grade bonus compliant to §25 (2)**
8	**References** References / Textbooks: Lecture slides, exercise sheets and matlab-code. Further reading • Yi Ma, Stefano Soatto, Jana Kosecka und Shankar S. Sastry, An Invitation to 3-D Vision - From Images to Geometric Models, Springer, 2003. • Richard Hartley and Andrew Zisserman, Multiple View Geometry in Computer Vision, Second Edition, Cambridge University Press, 2004. • Karl Kraus, Photogrammetrie, Band 1 Geometrische Informationen aus Photographien und Laserscanneraufnahmen 7. Auflage, de Gruyter Lehrbuch, 2004. • Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer 2006. • Bernd Jähne, Digital Image Processing, 6. Auflage, 2005.

Courses

Course Nr.	Course name		
18-ad-2090-vl	Computer Vision in Engineering		
Instructor		**Type**	**SWS**
Dr.-Ing. Thomas Guthier, Prof. Dr.-Ing. Jürgen Adamy		Lecture	2
Course Nr.	**Course name**		
18-ad-2090-ue	Computer Vision in Engineering		
Instructor		**Type**	**SWS**
Dr.-Ing. Thomas Guthier		Practice	1

Module name					
Power Electronics					
Module Nr. 18-gt-1010	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 90 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Gerd Griepentrog		

1 Content

Power electronic devices convert the energy from the distribution network to the form required by the load. This conversion does not wear out, can be controlled very fast and has a high efficiency. In lecture "Power Electronics" the most important circuits required for the energy conversion are treated, using ideal switches.
The main chapters are
I.) Line commutated converters in order to understand the basic concepts of power electronic systems.
II.) Self- commutated converters (one, two and four quadrant converters, 3-phase- VSI)

2 Learning objectives / Learning Outcomes

After an active participation in the lecture, as well as by solving all exercises prior to the respective tutorial students should be able to:

- Understand the ideal concept of power semiconductors
- Calculate and sketch the time-characteristics of all currents and voltages in a line-commutated converter using defined simplifications as well as represent the behavior of currents and voltages during commutation in line-commutated converters for center –tapped as well as for bridge circuits.
- Specify the basic circuit diagrams for one, two and four quadrant DC/DC converters and calculate the characteristics of voltages and currents in these circuits.
- Explain the function of single-phase and three-phase voltage source inverters and calculate the currents and voltages in these circuits using defined simplifications.
- Understannd the concept und operation of HVDC converter

3 Recommended prerequisite for participation

Mathe I und II, ETiT I und II, Energietechnik

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc MEC, Wi-ETiT

7 Grade bonus compliant to §25 (2)

8 References

Lecture notes, instructions for exercises are available for download in Moodle.
Literature:
Probst U.: „Leistungselektronik für Bachelors: Grundlagen und praktische Anwendungen“, Carl Hanser Verlag GmbH & Co. KG, 2011
Jäger, R.: „Leistungselektronik: Grundlagen und Anwendungen“, VDE-Verlag; Auflage 2011
Heumann, K.: „Grundlagen der Leistungselektronik“; Teubner; Stuttgart; 1985
Lappe, R.: „Leistungselektronik“; Springer-Verlag; 1988
Mohan, Undeland, Robbins: Power Electronics: Converters, Applications and Design; John Wiley Verlag; New York; 2003

Courses				
	Course Nr. 18-gt-1010-vl	**Course name** Power Electronics		
	Instructor Prof. Dr.-Ing. Gerd Griepentrog		**Type** Lecture	**SWS** 2
	Course Nr. 18-gt-1010-ue	**Course name** Power Electronics		
	Instructor Prof. Dr.-Ing. Gerd Griepentrog, M.Sc. Milad Khani		**Type** Practice	**SWS** 2

Module name Materials of Electrical Engineering					
Module Nr. 11-01-6410	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** Every 2. Sem.
Language German			**Module owner** Prof. Dr. rer. nat. Lambert Alff		

1	**Content**
2	**Learning objectives / Learning Outcomes**
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Eccompanying Examination: • [11-01-6410-vl] (Technical Examination, Technical Examination, Standard BWS)
5	**Grading** Module Eccompanying Examination: • [11-01-6410-vl] (Technical Examination, Technical Examination, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References**

Courses

	Course Nr. 11-01-6410-vl	**Course name** Materials of Electrical Engineering		
	Instructor		**Type** Lecture	**SWS** 2

Module name Numerical Methods for Ordinary Differential Equations for Engineers					
Module Nr. 04-10-0042/de	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 105 h	**Duration** 1	**Cycle offered** Every 2. Sem.
Language German			**Module owner** Prof. Dr. rer. nat. Jens Lang		

1	**Content** initial value problems: one-step methods, multi-step methods; convergence analysis, notions of stability; boundary-value problems: Shooting methods, finite difference methods, stability and convergence;
2	**Learning objectives / Learning Outcomes** Students know the basic numerical solution concepts for ordinary differential equations and they are able to analyze, compare, and apply them.
3	**Recommended prerequisite for participation** recommended: Analysis, Linear Algebra, Ordinary Differential Equations, Introduction to Numerical Analysis or similar knowledge as taught in an engineering programme.
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Technical Examination, Standard Grading System) • Module Examination (Study Achievement, Special Form, Pass/Fail Grading System) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Technical Examination, Weighting: 100 %) • Module Examination (Study Achievement, Special Form, Weighting: 0 %)
6	**Usability of this module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
7	**Grade bonus compliant to §25 (2)**
8	**References** Deuflhard, Bornemann: Numerische Mathematik 2 Stoer, Bulirsch: Numerische Mathematik 2

Courses

Course Nr.	Course name		
04-10-0134-vu			
Instructor		**Type**	**SWS**
Prof. Dr. techn. Herbert Egger		Lecture & Practice	3

Module name Numerical Linear Algebra					
Module Nr. 04-10-0043/de	**Credit Points** 5 CP	**Workload** 150 h	**Self study** 105 h	**Duration** 1	**Cycle offered** Every 2. Sem.
Language German			**Module owner** Dr. rer. nat. Alf Gerisch		

1	**Content** Systems of linear equations: iterative methods, singular value decomposition, eigenvalue problems.
2	**Learning objectives / Learning Outcomes** Students know about the most important numerical methods of linear algebra and they are able to explain, classify, and apply them.
3	**Recommended prerequisite for participation** recommended: Linear Algebra, Introduction to Numerical Analysis or similar knowledge
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Technical Examination, Standard Grading System) • Module Examination (Study Achievement, Special Form, Pass/Fail Grading System) Fachprüfung: Usually the exam is taken in form of a written test, except when there are only a small number of potential participants. In this case, the exam can be taken in the form of an oral exam. The decision about the form of the exam is taken and communicated during the first two weeks of the lecture, based on the prospective number of students taking the exam. Studienleistung: Usually this means that the student successfully completes a certain proportion of the homework assignments. The precise proportion of necessary assignments and the marking scheme will be communicated by the instructor during the first lecture.
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Technical Examination, Weighting: 100 %) • Module Examination (Study Achievement, Special Form, Weighting: 0 %)
6	**Usability of this module** B.Sc. Mathematik, M.Sc Mathematik, M.Sc. Mathematics
7	**Grade bonus compliant to §25 (2)**
8	**References** Trefethen/Bau: Numerical Linear Algebra, SIAM Demmel: Applied Numerical Linear Algebra, SIAM Stoer/Bulirsch: Numerische Mathematik 2, Springer

Courses

Course Nr.	**Course name**		
04-00-0139-vu	Numerical Linear Algebra		
Instructor Dr. rer. nat. Alf Gerisch		**Type** Lecture & Practice	**SWS** 3

Module name					
Laboratory Matlab/Simulink II					
Module Nr. 18-ko-2070	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 60 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German			**Module owner** Prof. Dr.-Ing. Ulrich Konigorski		

1	**Content** The lab is split into the two parts Simulink and Control Engineering II. First the fundamentals of the simulation tool Simulink are introduced and their application to problems from different fields of application is trained. In the second part, the knowledge gained in the first part is applied to autonomously solve several control design problems as well as simulation tasks.
2	**Learning objectives / Learning Outcomes** The students will be able to work with the tool MatLab/Simulink on their own and can solve tasks from the areas of control engineering and numericial simulation. The students will know the different design methods of the control system toolbox and the fundamental concepts of the simulation tool Simulink. They can practically apply the knowledge gathered in the lectures "System Dynamics and Control Systems I and II" and "Modelling and Simulation".
3	**Recommended prerequisite for participation** The lab should be attended in parallel or after the lectures "System Dynamics and Control Systems II" and "Modelling and Simulation"
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSC MEC
7	**Grade bonus compliant to §25 (2)**
8	**References** Lecture notes for the lab tutorial can be obtained at the secretariat

Courses

Course Nr.	Course name		
18-ko-2070-pr	Laboratory Matlab/Simulink II		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Ulrich Konigorski, M.Sc. Marcel Bonnert		Internship	4

Module name Project Seminar Automatic Control Systems					
Module Nr. 18-ad-2080	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Jürgen Adamy		

1	**Content** The students work in small groups, supervised by a scientific staff member, on individual problems taken from the field of automatic control. A compulsory training course is part of the project course and will cover the topics 1. team work and project management, 2. professional presentation skills, and 3. scientific writing skills.
2	**Learning objectives / Learning Outcomes** After attending the project course, a student is capable of: 1. planing a small project, 2. organizing the work within a project team, 3. searching for scientific background information on a given project, 4. creating ideas on how to solve problems arising in the project, 5. presenting the results in a scientific report, and 6. giving a talk on the results of the project.
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Duration: 30 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC, MSc iST, MSc WI-ETiT, MSc iCE, MSc EPE, MSc CE, MSc Informatik
7	**Grade bonus compliant to §25 (2)**
8	**References** Training course material

Courses

Course Nr.	**Course name**		
18-ad-2080-pj	Project Seminar Automatic Control Systems		
Instructor Prof. Dr.-Ing. Jürgen Adamy		**Type** Project Seminar	**SWS** 4

Module name					
Project Course Practical Application of Mechatronics					
Module Nr. 18-ko-2130	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Ulrich Konigorski		

1	**Content** Teams of 2-4 students work on different mechatronic projects under the guidance of a project coordinator from the institute.The projects mainly cover the following subject areas: • Modeling, analysis, and design of mechatronic systems • Robust control design • System analysis, supervision and fault diagnosis • Modeling and identification Application areas are mechatronic actuators, machine tools, production lines, test benches, automobiles, quadrocopters.
2	**Learning objectives / Learning Outcomes** After completing the project, the students will be familiar with the individual steps of investigating a mechatronic project. This includes in particular the compilation of a system specification as well as critical discussions and systematic selection of appropriate mechatronic solutions and their real technical implementation. Doing so, the students learn the practical application of mechatronic methods taught in the lectures to real world problems. Additionally, in this project course, the students are supposed to improve their professional skills. These skills include e.g. teamwork, presentation techniques and systematic information retrieval.
3	**Recommended prerequisite for participation** Lectures „System Dynamics and Automatic Control Systems I“, „System Dynamics and Automatic Control Systems II“
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC, MSc iST
7	**Grade bonus compliant to §25 (2)**
8	**References** Handouts will be distributed at start of the project (e.g. hints for writing project documentation, etc.)

Courses

Course Nr.	Course name		
18-ko-2130-pj	Project Course Practical Application of Mechatronics		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Ulrich Konigorski, M.Sc. Julian Zeiß		Project Seminar	4

Module name					
Project Course Control Engineering					
Module Nr. 18-ko-2090	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** SoSe
Language German			**Module owner** Prof. Dr.-Ing. Ulrich Konigorski		

1 Content

Teams of 2 - 4 students work on different control engineering projects under the guidance of a project coordinator from the institute. The projects mainly cover the following subject areas:

- Modelling, analysis and design of multivariable control systems
- Modelling, analysis and design of distributed parameter systems
- Robust control design
- System analysis, supervision and fault diagnosis
- Modelling and identification

Application areas are machine tools, production lines, test benches, process control, automobiles.

2 Learning objectives / Learning Outcomes

After completing the project the students will be familiar with the individual steps of investigating a control engineering project. This includes in particular the compilation of a system specification as well as critical discussions and systematic selection of appropriate control engineering solutions and their real technical implementation. Doing so the students learn the practical application of control engineering methods taught in the lecture “System Dynamics and Control Systems I” to real world problems. Additionally, in this project course the students are supposed to improve their professional skills. These skills include e.g. teamwork, presentation techniques and systematic information retrieval.

3 Recommended prerequisite for participation

Lecture “System Dynamics and Control Systems I”

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Optional, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Study Achievement, Optional, Weighting: 100 %)

6 Usability of this module

MSc ETiT, MSc MEC

7 Grade bonus compliant to §25 (2)

8 References

Handouts will be distributed at start of the project (e.g. Hints for writing a project documentation, etc.)

Courses

Course Nr.	Course name		
18-ko-2090-pj	Project Course Control Engineering		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Ulrich Konigorski		Project Seminar	4

Module name					
Project Seminar Robotics and Computational Intelligence					
Module Nr. 18-ad-2070	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** SoSe
Language German			**Module owner** Prof. Dr.-Ing. Jürgen Adamy		

1	**Content** The following topics are taught in the lecture: **Industrial robots** • Types and applications • Geometry and kinematics • Dynamic model • Control of industrial robots **Mobile robots** • Types and applications • Sensors • Environmental maps and map building • Trajectory planning Group projects are arranged in parallel to the lectures in order to apply the taught material in practical exercises.
2	**Learning objectives / Learning Outcomes** After attending the lecture, a student is capable of: 1. recalling the basic elements of industrial robots, 2. recalling the dynamic equations of industrial robots and be able to apply them to describe the dynamics of a given robot, 3. stating model problems and solutions to standard problems in mobile robotics, 4. planing a small project, 5. organizing the work load in a project team, 6. searching for additional background information on a given project, 7. creating ideas on how to solve problems arising in the project, 8. writing an scientific report about the outcome of the project 8. presenting the results of the project.
3	**Recommended prerequisite for participation**
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC, MSc iST, MSc WI-ETiT, MSc iCE, MSc EPE, MSc CE, MSc Informatik
7	**Grade bonus compliant to §25 (2)**
8	**References** Adamy: Lecture notes (available for purchase at the FG office)

Courses

Course Nr.	Course name		
18-ad-2070-pj	Project Seminar Robotics and Computational Intelligence		
Instructor Prof. Dr.-Ing. Jürgen Adamy		**Type** Project Seminar	**SWS** 4

Module name Computer Systems I					
Module Nr. 18-hb-1020	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language German			**Module owner** Prof. Dr.-Ing. Christian Hochberger		

1	**Content** Types of instruction sets, memory organization and its impact on the runtime, pipelining, instruction level parallelism, superscalar processors, VLIW processors, floating point numbers and operations, memory subsystem, cache types, virtual address spaces, benchmarking and performance prediction, system architecture and bus systems, peripheral devices
2	**Learning objectives / Learning Outcomes** Successful students can analyze and evaluate processors, memory systems and bus systems. They can transform structures of high-level programming languages like subroutine calls into sequences of machine instructions. They are able to measure the performance of computers. They know how instructions are executed in modern processors and thus, they can predict the influence of a specific memory hierarchy onto the execution time of a given program. They know how internal and external bus systems work and can define the essential parameters for their dimension and operation.
3	**Recommended prerequisite for participation** Basic knowledge of digital design as it can be obtained by the lecture "Logic Design".
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written Examination, Weighting: 100 %)
6	**Usability of this module** BSc ETiT, BSc Wi-ETiT
7	**Grade bonus compliant to §25 (2)**
8	**References** Harris & Harris: Digital Design and Computer Architecture Hennessy/Patterson: Computer architecture - a quantitative approach

Courses

Course Nr.	Course name	Instructor	Type	SWS
18-hb-1020-vl	Computer Systems I	Prof. Dr.-Ing. Christian Hochberger	Lecture	3
18-hb-1020-ue	Computer Systems I	Prof. Dr.-Ing. Christian Hochberger	Practice	1

Module name Autonomous Driving Lab I					
Module Nr. 18-su-2070	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 135 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr. rer. nat. Andreas Schürr		

1 Content

- Hands-on programming experience with C++ in the development of embedded software systems for autonomous driving based on a model car
- Application of control methods from the area of autonomous driving
- Application of software engineering techniques (design, documentation, test, ...) of a non-trivial embedded software system with hard real-time requirements and limited resources (memory, ...)
- Use of a given software framework and further libraries including a modular (real-time) operating system
- Hands-on experience using source code management systems, time management and other project management tools
- Presentations of the project results

2 Learning objectives / Learning Outcomes

During this project seminar students gain practical experience in software development for embedded systems in the field of autonomous driving using a model car. In teamwork, they learn to cope with an extensive task. In order to solve this task they practice to use the theoretical knowledge available in the group (from other courses such as real-time systems, software engineering - introduction, C++ lab, digital control systems).

Students that have successfully participated in this project seminar are able to organize and set-up a non-trivial software project in an interdisciplinary team according to a given problem independently. The participants acquire the following skills in detail:

- Independent familiarization with a given software framework and ready-made libraries
- Transfer of theoretic knowledge into a software system
- Extensive use of tools for version, configuration, and change management
- Realistic time and resource management (project management)
- Development of hardware/software systems with C++ considering important limitations of embedded systems
- Planning and implementation of extensive quality assurance measures
- Collaboration and communication in and between teams

3 Recommended prerequisite for participation

Recommended prerequisites are:

- ETiT/DT, iST, Informatik, WI-ET/DT: Basic software technology knowledge and advanced knowledge of object-oriented programming languages (especially C++)

Additionally desired:

- Basic knowledge of the development of real-time systems or image processing
- ETiT/AUT, MEC: Basic knowledge in control engineering including state space control design, some additional basic knowledge in digital control design may be helpful

4 Form of examination

Module Final Examination:

- Module Examination (Study Achievement, Oral Examination, Duration: 30 min, Standard Grading System)

5 Grading

	Module Final Examination: • Module Examination (Study Achievement, Oral Examination, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, BSc iST
7	**Grade bonus compliant to §25 (2)**
8	**References** https://www.es.tu-darmstadt.de/lehre/aktuelle-veranstaltungen/ps-af-i/ and Moodle

Courses

Course Nr.	**Course name**
18-su-2070-pj	Autonomous Driving Lab I

Instructor	**Type**	**SWS**
Prof. Dr. rer. nat. Andreas Schürr, Dr. Ing. Eric Lenz, M.Sc. Stefan Tomaszek	Project Seminar	3

Module name Robust Control					
Module Nr. 18-ko-2140	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** SoSe
Language German			**Module owner** Prof. Dr.-Ing. Ulrich Konigorski		

1	**Content**
	• Basics (SVD, norms, system representations)
	• Control design in the frequency domain
	  – Expressing control tasks as H2 and Hinf optimization problems
	  – Design of H2 and Hinf optimal controllers
	
	• Robust Control
	  – Uncertainity representations (Additive und multiplicative uncertainities, multi model representations)
	  – Analysis of robustness (Small-Gain-theorem, mu-analysis)
	  – Robust control design in the frequency domainRobust control design by region-based pole placement

2	**Learning objectives / Learning Outcomes** The students are able to express control tasks as H2 and H8 optimization problems, to represent uncertainities of a system in a suitable form and to design a controller which ensures robust stability and robust performance.
3	**Recommended prerequisite for participation** Systemdynamik und Regelungstechnik I und II
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module** MSc ETiT, MSc MEC
7	**Grade bonus compliant to §25 (2)**
8	**References** • S. Skogestad, I. Postlethwaite, Multivariable Feedback Control,2. Auflage, 2005, Wiley • K. Zhou, Essentials of Robust Control, 1998, Prentice-Hall • O. Föllinger, Regelungstechnik, 11. Auflage, 2013, VDE Verlag

Courses

Course Nr.	**Course name**		
18-ko-2140-vl	Robust Control		
Instructor Dr. Ing. Eric Lenz		**Type** Lecture	**SWS** 2

Module name Matrix Analysis and Computations					
Module Nr. 18-pe-2070	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Marius Pesavento		

1	**Content** This graduate course is a foundation class on matrix analysis and computations, which are widely used in many different fields, e.g., machine learning, computer vision, systems and control, signal and image processing, communications, networks, optimization, and many more... Apart from the theory this course will also cover the design of efficient algorithm and it considers many different examples from the aforementioned fields including examples from social media and big data analysis, image processing and medical imaging, communication network optimization, and written text classification. Specific topics: (i) basic matrix concepts, subspace, norms, (ii) linear least squares (iii) eigendecomposition, singular value decomposition, positive semidenite matrices, (iv) linear system of equations, LU decomposition, Cholesky decomposition (v) pseudo-inverse, QR decomposition (vi) advanced tensor decomposition, advanced matrix calculus, compressive sensing, structured matrix factorization
2	**Learning objectives / Learning Outcomes** Students will learn matrix analysis and computations at an advanced or research level.
3	**Recommended prerequisite for participation** Basic knowledge in linear algebra.
4	**Form of examination** Module Final Examination: • Module Examination (Technical Examination, Optional, Standard Grading System)
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Optional, Weighting: 100 %)
6	**Usability of this module**
7	**Grade bonus compliant to §25 (2)**
8	**References** 1.Gene H. Golub and Charles F. van Loan, Matrix Computations (Fourth Edition), John Hopkins University Press, 2013. 2.Roger A. Horn and Charles R. Johnson, Matrix Analysis (Second Edition), Cambridge University Press, 2012. 3.Jan R. Magnus and Heinz Neudecker, Matrix Differential Calculus with Applications in Statistics and Econometrics (Third Edition), John Wiley and Sons, New York, 2007. 4.Giuseppe Calaore and Laurent El Ghaoui, Optimization Models, Cambridge University Press, 2014. ECE 712 Course Notes by Prof. Jim Reilly, McMaster University, Canada (friendly notes for engineers) http://www.ece.mcmaster.ca/faculty/reilly/ece712/course_notes.htm

Courses

Course Nr. 18-pe-2070-vl	**Course name** Matrix Analysis and Computations		
Instructor Prof. Dr.-Ing. Marius Pesavento		**Type** Lecture	**SWS** 3

	Course Nr.	Course name		
	18-pe-2070-ue	Matrix Analysis and Computations		
	Instructor		**Type**	**SWS**
	Prof. Dr.-Ing. Marius Pesavento		Practice	1

Module name					
Machine Learning and Deep Learning for Automation Systems					
Module Nr. 18-ad-2100	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** SoSe
Language German			**Module owner** Prof. Dr.-Ing. Jürgen Adamy		

1 Content

- Concepts of machine learning
- Linear methods
- Support vector machines
- Trees and ensembles
- Training and assessment
- Unsupervised learning
- Neural networks and deep learning
- Convolutional neuronal networks (CNNs)
- CNN applications
- Recurrent neural networks (RNNs)

2 Learning objectives / Learning Outcomes

Students will get a broad and practical view on the field of machine learning. First, the most relevant algorithm classes of supervised and unsupervised learning are discussed. After that, the course addresses deep neural networks, which enable many of today's applications in image and signal processing. The fundamental characteristics of all algorithms are compiled and demonstrated by programming examples. Students will be able to assess the methods and apply them to practical tasks.

3 Recommended prerequisite for participation

Fundamental knowledge in linear algebra and statistics
Preferred: Lecture "Fuzzy logic, neural networks and evolutionary algorithms"

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written/Oral Examination, Duration: 90 min, Standard Grading System)

The examination takes place in form of a written exam (duration: 90 minutes). If one can estimate that less than 7 students register, the examination will be an oral examination (duration: 30 min.). The type of examination will be announced in the beginning of the lecture.

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written/Oral Examination, Weighting: 100 %)

6 Usability of this module

7 Grade bonus compliant to §25 (2)

8 References

- T. Hastie et al.: The Elements of Statistical Learning. 2. Aufl., Springer, 2008
- I. Goodfellow et al.: Deep Learning. MIT Press, 2016
- A. Géron: Hands-On Machine Learning with Scikit-Learn, Keras and TensorFlow. 2. Aufl., O'Reilly, 2019

Courses

	Course Nr.	Course name		
	18-ad-2100-vl	Machine Learning and Deep Learning for Automation Systems		
	Instructor		**Type**	**SWS**
	Dr.-Ing. Michael Vogt		Lecture	2

Module name Fundamentals of Reinforcement Learning					
Module Nr. 18-kl-2070	**Credit Points** 4 CP	**Workload** 120 h	**Self study** 75 h	**Duration** 1	**Cycle offered** SoSe
Language English			**Module owner** Prof. Dr.-Ing. Anja Klein		

1 Content

- Review of Probability Theory
- Markov Property and Markov Decision Processes
- The Multi-Armed Bandit Problem vs. the Full Reinforcement Learning Problem
- Taxonomy of Multi-Armed Bandit Problems (e.g., Stochastic vs. Adversarial Rewards, Contextual MAB)
- Algorithms for Multi-Armed Bandit Problems (e.g., Upper Confidence Interval (UCB), Epsilon-Greedy, SoftMax, LinUCB) and their Application to Cyber-Physical Networking
- Fundamentals of Dynamic Programming and Bellman Equations
- Taxonomy of Approaches for the Full Reinforcement Learning Problem (e.g., Temporal-Difference Learning, Policy Gradient and Actor-Critic)
- Algorithms for the Full Reinforcement Learning Problem (e.g., Q-Learning, SARSA, Policy Gradient, Actor-Critic) and their Application to Cyber-Physical Networking
- Linear Function Approximation
- Non-linear Function Approximation

2 Learning objectives / Learning Outcomes

The students are able to

- define the Markov property and identify the elements that constitute a Markov decision process. They will be able to use these concepts to model decision-making problems in Cyber-Physical Networking.
- determine the characteristics of the Multi-Armed Bandit (MAB) Problem and compare them to the characteristics of the Full Reinforcement Learning (RL) Problem.
- determine under which conditions the MAB or the full RL formulation should be used to solve decision-making problems.
- differentiate the main MAB strategies, e.g., Upper Confidence Interval (UCB), Epsilon-Greedy and Softmax.
- choose appropriate MAB strategies for the solution of MAB problems.
- formulate and solve Contextual-MAB problems.
- determine under which conditions Dynamic Programming can be used to solve decision-making problems.
- explain the difference between Dynamic Programming and RL methods.
- differentiate between Temporal-Difference, Policy Gradient and Actor-Critic RL techniques.
- identify the limitations of MAB and full RL problems.
- explain the need for generalization in MAB and full RL problems.
- choose appropriate approximation techniques and use them in combination with MAB and full RL strategies.
- apply algorithmic techniques to solve MAB and full RL problems and obtain valid solutions.
- judge the reasonableness and consistency of the obtained solutions.

3 Recommended prerequisite for participation

- Python or Matlab: basic knowledge
- Engineering mathematics and probability theory

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written/Oral Examination, Duration: 60 min, Standard Grading System)

	The examination takes place in form of a written exam (duration: 60 minutes). If one can estimate that less than 21 students register, the examination will be an oral examination (duration: 20 min.). The type of examination will be announced in the beginning of the lecture.
5	**Grading** Module Final Examination: • Module Examination (Technical Examination, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** M.Sc. etit: AUT & KTS, M.Sc. ICE, B.Sc. / M.Sc. iST, M.Sc. WI-etit, M.Sc. MEC
7	**Grade bonus compliant to §25 (2)**
8	**References** • Richard S. Sutton and Andrew G. Barto, “Reinforcement Learning: An Introduction”, A Bradford Book, Cambridge, MA, USA, 2018. • Aleksandrs Slivkins, “Introduction to Multi-Armed Bandits”, Foundations and Trends in Machine Learning, Vol. 12: No. 1-2, 2019.

Courses

Course Nr.	Course name		
18-kl-2070-vl	Fundamentals of Reinforcement Learning		
Instructor		**Type**	**SWS**
Dr. rer. nat. Sabrina Klos, Dr.-Ing. Andrea Patricia Ortiz Jimenez		Lecture	2
Course Nr.	**Course name**		
18-kl-2070-ue	Fundamentals of Reinforcement Learning		
Instructor		**Type**	**SWS**
Dr. rer. nat. Sabrina Klos, Dr.-Ing. Andrea Patricia Ortiz Jimenez		Practice	1

Module name Artificial Intelligence in Medicine Challenge					
Module Nr. 18-ha-2010	**Credit Points** 8 CP	**Workload** 240 h	**Self study** 180 h	**Duration** 1	**Cycle offered** WiSe/SoSe
Language German			**Module owner** Prof. Dr.-Ing. Christoph Hoog Antink		

1	**Content** Within this module, students will work independently in small groups on a given problem from the realm of artificial intelligence (AI) in medicine. The nature of the problem can be the automatic classification or prediction of a disease from medical signals or data, the extraction of a physiological parameter, etc. All groups will be given the same problem but will have to develop their own algorithms, which will be evaluated on a hidden dataset. In the end, a ranking of the best-performing algorithms is provided.
2	**Learning objectives / Learning Outcomes** Within this module, students will work independently in small groups on a given problem from the realm of artificial intelligence (AI) in medicine. The nature of the problem can be the automatic classification or prediction of a disease from medical signals or data, the extraction of a physiological parameter, etc. All groups will be given the same problem but will have to develop their own algorithms, which will be evaluated on a hidden dataset. In the end, a ranking of the best-performing algorithms is provided.
3	**Recommended prerequisite for participation** • Basic programming skills in Python • 18-zo-1030 Fundamentals of Signal Processing
4	**Form of examination** Module Final Examination: • Module Examination (Study Achievement, Written/Oral Examination, Standard Grading System) Report and/or Presentation. The type of examination will be announced in the beginning of the lecture.
5	**Grading** Module Final Examination: • Module Examination (Study Achievement, Written/Oral Examination, Weighting: 100 %)
6	**Usability of this module** BSc/MSc (WI-)etit, AUT, DT, KTS BSc/MSc iST MSc iCE
7	**Grade bonus compliant to §25 (2)**
8	**References** • Friedman, Jerome, Trevor Hastie, and Robert Tibshirani. The elements of statistical learning. Vol. 1. No. 10. New York: Springer series in statistics, 2001. • Bishop, Christopher M. Pattern recognition and machine learning. springer, 2006.

Courses

Course Nr.	**Course name**		
18-ha-2010-pj	Artificial Intelligence in Medicine Challenge		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Christoph Hoog Antink		Project Seminar	4

Module name Automated Driving					
Module Nr. 18-ad-2110	**Credit Points** 3 CP	**Workload** 90 h	**Self study** 60 h	**Duration** 1	**Cycle offered** WiSe
Language English			**Module owner** Prof. Dr.-Ing. Jürgen Adamy		

1 Content

- History of Automated Driving
- Terminology and Paths towards Automated Driving
- Architectures, Building Blocks, and Components
- Perception & Environment Models
- Data Fusion & State Estimation
  - Deep Dive: Target Tracking & Traffic Participant Fusion
  - Deep Dive: Grid Fusion & Free Space Estimation
  - Deep Dive: Road Model Fusion
- Localization, Digital Maps, and Vehicle-To-X Communication
- Situation Understanding, Prediction, and Criticality Assessment
  - Deep Dive: Probabilistic Driving Maneuver Detection
- Behavior & Trajectory Planning, Decision Making
- Automated Driving Software Development & Test
- Open Challenges & State-of-the-Art Research Topics

2 Learning objectives / Learning Outcomes

After visiting the lecture, the student

- is familiar with the history and terminology of automated driving systems,
- knows important architectures, building blocks, and components of automated vehicles,
- understands different perception, environment model, and data fusion approaches,
- has an idea about relevant methods (e.g. Bayesian Inference & Probabilistic Graphical Models, State Estimation, Deep Learning, Dempster-Shafer Theory) and knows how they can be beneficially applied in different of automated driving areas (e.g. detection, target tracking & traffic participant fusion, grid fusion, road model fusion, localization),
- is familiar with the challenges of situation understanding, prediction, and criticality assessment and knows exemplary methods to tackle the problem,
- is aware of exemplary behavior & trajectory planning approaches,
- knows best practices about automated driving software development & test (e.g. continuous integration, verification & validation, test-driven development, key performance indicators), and
- is familiar with open challenges and research topics.

3 Recommended prerequisite for participation

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Duration: 90 min, Standard Grading System)

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Written Examination, Weighting: 100 %)

6 Usability of this module

Msc etit, Msc MEC, Msc Wi-etit, Msc ICE, Msc CE, Msc Informatik

7	**Grade bonus compliant to §25 (2)**
8	**References** Own lecture slides are distributed in advance of any lecture. For more detailed insights into the topic area, the following books can be recommended: • Eskandarian, A.: Handbook of Intelligent Vehicles. Springer, London, 2012. • Siciliano, B.; Khatib, O.: Springer Handbook of Robotics. 2nd Edition, Springer, Berlin Heidelberg 2016. • Thrun, S.; Burgard, W.; Fox, D.: Probabilistic Robotics. Intelligent Robotics and Autonomous Agents. The MIT Press, Cambridge, 2006. • Watzenig, D.; Horn, M.: Automated Driving. Safer and More Efficient Future Driving. Springer, Switzerland, 2017. • Winner, H. et al.: Handbook of Driver Assistance Systems. Basic Information, Components and Systems for Active Safety and Comfort. Springer, Switzerland, 2016.

Courses

Course Nr.	Course name		
18-ad-2110-vl	Automated Driving		
Instructor		**Type**	**SWS**
Prof. Dr.-Ing. Jürgen Adamy		Lecture	2

Module name Fundamental Fluid Mechanics					
Module Nr. 16-11-5010	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 120 h	**Duration** 1	**Cycle offered** SoSe
Language German			**Module owner** Prof. Dr.-Ing. Jeanette Hussong		

1 Content

Properties of fluids, flow kinematics, conservation equations, constitutive equations, equations of motion, Navier-Stokes equations, hydrostatics, exact solutions, turbulent flows, stream filament theory, flow around bodies.

2 Learning objectives / Learning Outcomes

On successful completion of this module, students should be able to:

- Explain the origins and limitations of the basic conservation equations of fluid mechanics (mass, momentum, moment of momentum, energy).
- Choose the correct equations, simplifications, and boundary conditions for a given application and recognise avenues for solution.
- Use stream filament theory and loss coefficients to compute flow networks. These capabilities are developed for incompressible, single phase flows.

3 Recommended prerequisite for participation

knowledge of ordinary and partial differential equations

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Technical Examination, Standard Grading System)

Written exam 2x 150 min

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Technical Examination, Weighting: 100 %)

6 Usability of this module

Bachelor MPE Pflicht
Master ETiT AUT; Bachelor Mechatronik

7 Grade bonus compliant to §25 (2)

8 References

Spurk: Strömungslehre, Springer Verlag.
Spurk: Aufgaben zur Strömungslehre, Springer Verlag.

Courses

Course Nr.	**Course name**	**Instructor**	**Type**	**SWS**
16-11-5010-vl	Fundamental Fluid Mechanics		Lecture	3
16-11-5010-ue	Fundamental Fluid Mechanics		Practice	1

Module name Technical Thermodynamics I					
Module Nr. 16-14-5010	**Credit Points** 6 CP	**Workload** 180 h	**Self study** 105 h	**Duration** 1	**Cycle offered** WiSe
Language German			**Module owner** Prof. Dr.-Ing. Peter Christian Stephan		

1 Content

Fundamental terms of thermodynamics; thermodynamic equilibrium and temperature; different forms of energy (internal energy, heat, work, enthalpy); properties and equations of state for gases and incompressible substances; first law of thermodynamics and energy balances for technical systems; second law of thermodynamics and entropy balances for technical systems; exergy analysis; thermodynamic behaviour during phase change; the carnot cycle for power generation or refrigeration; energy efficiency and coefficient of performance; cyclic processes for gas turbines, combustion engines, power plants, refrigerators and heat pumps.

2 Learning objectives / Learning Outcomes

On successful completion of this module, students should be able to:

- Explain the relationships between thermodynamic properties and the thermodynamic state of a system and apply them within calculations of thermal system behaviour.
- Distinguish between different types of energy (e.g. work, heat, internal energy, enthalpy) and define them.
- Analyse technical systems and processes using energy balances and equations of state.
- Assess energy conversion processes by means of an entropy balance or an exergy analysis.
- Characterise the thermal behaviour of gases, liquids and solids and corresponding phase change processes.
- Apply this basic knowledge (1.-5.) to examine machines (turbines, pumps etc.) and processes for energy conversion (combustion engine, power plants, refrigerators, heat pumps).

3 Recommended prerequisite for participation

None

4 Form of examination

Module Final Examination:

- Module Examination (Technical Examination, Technical Examination, Standard Grading System)

Written exam 150 min

5 Grading

Module Final Examination:

- Module Examination (Technical Examination, Technical Examination, Weighting: 100 %)

6 Usability of this module

Bachelor MPE Pflicht
Bachelor WI-MB
Master ETiT MFT, Bachelor Mechatronik

7 Grade bonus compliant to §25 (2)

8 References

P. Stephan; K. Schaber; K. Stephan; F. Mayinger: Thermodynamik, Band 1: Einstoffsysteme, Springer Verlag.
Further material (slides, collection of exercises, table of fomulas etc.) is available through the Moodle system of TU Darmstadt.

Courses

	Course Nr. 16-14-5010-vl	**Course name** Technical Thermodynamics I		
	Instructor		**Type** Lecture	**SWS** 3
	Course Nr. 16-14-5010-hü	**Course name** Technical Thermodynamics I		
	Instructor		**Type** Lecture Hall Practice	**SWS** 1
	Course Nr. 16-14-5010-gü	**Course name** Technical Thermodynamics I - Group Exercise		
	Instructor		**Type** Group Practice	**SWS** 1