Fakultät für Informatik und Ingenieurwissenschaften

Module Handbook

Master Program

Automation & IT

Degree Master of Engineering (M.Eng.)

Date October 26, 2022

Technology
Arts Sciences
TH Köln

Contents

Module Handbook | Automation & IT, M.Eng.

1 Study Plan

Module	Submodule	Sem.	ECTS	Semester			
				1	2	3	4
Industrial Communication and Information Security in Industrial Automation	Industrial Communication	1	12	3			
	Industrial IoT	1		5			
	IT-Security	2			4		
				ECTS			
Integration of Technical and Business Information Systems	Object oriented Programming for Data Science	1	9	3			
	Relational Databases	1		3			
	Enterprise Resource Planning Systems	1			3		
Modelling and Simulation of Technical Systems	Modelling and Simulation of Continuous Systems	2	15		4		
	Modelling and Simulation of Discrete Event Systems	2			2		
	Data-driven Modelling and Model Optimization	2			5		
	Modelling and Simulation of Electrical Energy Systems	1		4			
Control of Technical Systems	Digital Signal Processing and Optoelectronics	2	14		4		
	Linear, Nonlinear and Model Predictive Control	1		5			
	Automation of Discrete Event Systems	1			2		
	Protection Automation and Control in Electrical Energy Supply	2			3		
Optimization of Technical Systems	Numerical Methods	1	10	3			
	Optimization	1		4			
	Machine Learning and AI	2			3		
Case Studies	Case Study I	3	30			10	
	Case Study II	3				10	
	Case Study III	3				10	
Master Thesis	Thesis	4	30				20
	Colloquium	4					10
Sum ECTS			**120**	**30**	**30**	**30**	**30**

2 Study Plan for Part Time Study

Module	Submodule	Sem.	ECTS	ECTS/ Semester					
				1	2	3	4	5	6
Industrial Communication and Information Security in Industrial Automation	Industrial Communication	1	12	3					
	Industrial IoT	1				5			
	IT-Security	2					4		
				ECTS					
Integration of Technical and Business Information Systems	Object oriented Programming for Data Science	1	9	3					
	Relational Databases	1				3			
	Enterprise Resource Planning Systems	1					3		
Modelling and Simulation of Technical Systems	Modelling and Simulation of Continuous Systems	2	15		4				
	Modelling and Simulation of Discrete Event Systems	2			2				
	Data-driven Modelling and Model Optimization	2			5				
	Modelling and Simulation of Electrical Energy Systems	1		4					
Control of Technical Systems	Digital Signal Processing and Optoelectronics	2	14				4		
	Linear, Nonlinear and Model Predictive Control	1		5					
	Automation of Discrete Event Systems	1					2		
	Protection Automation and Control in Electrical Energy Supply	2			3				
Optimization of Technical Systems	Numerical Methods	1	10	3					
	Optimization	1				4			
	Machine Learning and AI	2					3		
Case Studies	Case Study I	3	30			10			
	Case Study II	3						10	
	Case Study III	3						10	
Master Thesis	Thesis	4	30						20
	Colloquium	4							10
Sum ECTS			**120**	**18**	**14**	**22**	**16**	**20**	**30**

3 Module

3.1 Industrial Communication and Information Security in Industrial Automation

Module Code:	IN-01
Module Title:	Industrial Communication and Information Security in Industrial Automation
Type of Module:	Mandatory
ECTS Credits:	12 CP
Language:	English
Duration of Module:	2 Terms
Recommended for Semester:	1. + 2. Semester
Frequency:	Every year
Person Responsible for this Module:	Prof. Dr. Felix Hackelöer
Lecturers:	Prof. Dr. Felix Hackelöer, Prof. Dr. Frithjof Klasen
Learning Outcome:	Students can - evaluate, plan and configure industrial communication systems - evaluate, plan and configure industrial IT/IoT systems - evaluate, plan and configure industrial IT-security systems by - understanding the principles of real-time Ethernet solutions and their applications in Automation including e.g. TSN, PROFINET and OPC UA - understanding the difference of horizontal and vertical communication - gaining detailed knowledge and experience in PROFINET regarding concept, engineering, diagnosis and maintenance - understanding the requirements and functionality of network devices and controllers - analyzing and evaluating network traffic in real-time applications by means of tools - installing and configuring network devices - planning and commissioning of network installations - understanding connectivity architectures, current technologies and protocols for Industrial Internet of Things (IIoT) - understanding the special prerequisites of industrial IT technologies vs. office environments - evaluating the pros and cons of various protocols - understanding industrial security objectives (availability, integrity, confidentiality) - analyzing security objectives in IT and industrial automation scenarios - comprehending international security standards for automation such as IEC 62443 or VDI 2182 - understanding the roles of vendors, system integrators and asset owners (end users) - determining and evaluating system security vulnerabilities - understanding and applying risk analysis methods to develop and evaluate measures - evaluating typical threats, risks and measures in industrial automation scenarios - developing methods to determine vulnerabilities - understand encryption methodology incl. signatures - estimating security tool limitations - understanding, planning and configuring firewall technology - summarizing results in reports - presenting results in oral presentations to - be able to design, manage and maintain industrial automation systems - be qualified for a professional career as automation engineer

Module Content:	Lectures:
	a) Industrial Communication
	b) Industrial IoT
	c) IT-Security
	
	Lecturer:
	a) Prof. Dr. Klasen
	b) Prof. Dr. Hackelöer
	c) Prof. Dr. Hackelöer
	
	Credit Points:
	a) 3 CP
	b) 5 CP
	c) 4 CP
	
	Content:
	
	a) Industrial Communication
	- Ethernet-based industrial communication (focus on PROFINET)
	- Network analysis of real-time Ethernet networks
	- Network devices (switches, routers)
	- Architecture of plant networks vs. corporate networks
	- Integration of plant network and corporate network
	- Practical part:
	  - PROFINET engineering and commissioning Workshop
	  - Configuring network devices
	  - Designing and configuring PROFINET applications including M2M
	
	b) Industrial IoT
	- Introduction into Industrial IoT and 'Industrie 4.0'
	- Designating factors of industrial IoT applications
	- IIoT connectivity, interfaces and protocols, such as MQTT, OPC UA
	- Interfacing systems via OPC UA
	- Architecture of vertical and horizontal IIoT applications
	- IoT platforms and cloud-based systems
	- IIoT Semantics and their implementation, e.g. via OPC UA
	- Digital twins
	- Handling of data
	- Principles and terminology of MES (ISA-95)
	- Industrial implementation examples, focus on OPC UA and MQTT
	
	c) IT-Security
	- Introduction into basic terms of IT security (security objectives, mechanisms, example scenarios)
	- The Information security management system – instruments and methods used by management to systematically control (i.e., plan, put in place, implement, monitor, and improve) tasks and activities relating to IT security
	- International standards on IT security, e.g. IEC 62443
	- Cryptographic procedures as mechanisms to achieve security objectives - current cryptographic standards
	- Principles and mechanisms of authentication
	- TCP/IP based network and service security (weaknesses, attacks, examples)
	- Firewall and IPS systems (application level gateways, packet filters, remote access)
	- Specific requirements and conditions of industrial automation
	- Threads and risk assessment
	- Security aspects of Ethernet based automation protocols
	- Functional security limitations and interfaces
	- Design aspects and typical architectures of secure automation devices and systems
	- Vulnerability Test and development of test cases for benchmarks and audits
	- Security & Safety

Teaching and Learning Methods:	Lecture, Tutorial, Laboratory Course

Assessment Method:	a) Written examination, oral examination, course work assignment b) Written examination, oral examination, course work assignment c) Written examination, oral examination, course work assignment Weighting factors for finale module marking: (3 * a) + 5 * b) + 4 * c)) / 12
Workload (25 - 30 h ≙ 1 ECTS credit):	360 h
Contact hours:	160 h
Self-study:	200 h
Recommended Prerequisites:	-
Recommended Reading:	- Klasen, F. et al.; Industrial Communication with Fieldbus and Ethernet VDE Verlag, 9.11.2011, ISBN 978-3-8007-3358-3 - Anderson, Ross: Security Engineering, John Wiley & Sons Inc, 2001 - Eckert, Claudia: IT-Sicherheit. Konzepte - Verfahren - Protokolle, Oldenbourg, 2006 - Schneier, Bruce : Practical Cryptography, John Wiley & Sons, 2003 - Schneier, Bruce : Secrets & Lies. IT-Sicherheit in einer vernetzten Welt, Dpunkt Verlag, 2006 - http://www.securityfocus.com (aktuelle Sicherheitsmeldungen) - Normen und Richtlinien: Manufacturing and Control Systems Security ISA SP99 - VDE/VDI 2182 - Meyer, H., Fuchs, F., Thiel, K.: Manufacturing Execution Systems: Optimal Design, Planning, and Deployment. Mcgraw Hill Book Co, 2009. - Kletti, H.(Editor): Manufacturing Execution System - MES. Springer Berlin Heidelberg, 2010. - Schleipen: Praxishandbuch OPC UA, ISBN 978-3-8343-3413-8 - Lea: Internet of Things for Architects, ISBN 978-1-78847-059-9 - http://mqtt.org/ - https://www.amqp.org/ - IEC 62443 international norm
Use of the Module in Other Degree Programs:	-
Particularities:	-
Last update:	October 26, 2022

3.2 Integration of Technical and Business Information Systems

Module Code:	IS-01
Module Title:	Integration of Technical and Business Information Systems
Type of Module:	Mandatory
ECTS Credits:	11 CP
Language:	English
Duration of Module:	2 Terms
Recommended for Semester:	1. + 2. Semester
Frequency:	Every year
Person Responsible for this Module:	Prof. Dr. Rainer Scheuring
Lecturers:	Prof. Dr. Johann Schaible, Prof. Dr. Hartmut Westenberger, Prof. Dr. Christian Wolf
Learning Outcome:	Students can - design and write object oriented program code using the Python language - use relational databases - evaluate technologies of Industrial Internet of Things and Manufacturing Execution Systems - understand Enterprise Ressource Planning Systems by - understanding and using abstract classes, composition and data analysis functions - comprehending the theoretical principles of database systems and their application to modelling and implementing databases, - creating complex database queries, data definitions and data changes using SQL programming - using transactions, multi-user synchronisation and procedures for fault recovery and ensuring data integrity - understanding active database concepts and applying them with Oracle PL/SQL - understand and evaluate Internet of Things (IoT) technologies - understand protocols of IoT - evaluate architectures of industrial IoT applications and environments - handle data within IoT systems - comprehending MES architectures (Manufacturing Execution System) - understanding the functionalities of central MES components and their evaluation - using and parameterizing MES interfaces to superior and inferior systems - comprehending basic technologies of information systems (client/server, web services, communication in client/server and service oriented structures) and their pros and cons - modeling business processes and implementing small examples of business functions in an enterprise resource planning environment - analyzing complex application systems in reference models - evaluating the technology of application systems - comprehending various integration models and integrating sub-systems - summarizing results in reports - presenting results in oral presentations to - be able to solve data science problems by developing fast and reliable object-oriented software - be able to integrate automation systems, technical information systems and business information systems - be qualified for a professional career as automation engineer
Module Content:	Lectures: a) Object oriented Programming for Data Science b) Relational Databases

	c) Industrial IoT and Manufacturing Execution Systems d) Enterprise Resource Planning Systems Lecturer: a) Prof. Dr. Christian Wolf b) Prof. Dr. Johann Schaible d) Prof. Dr. Hartmut Westenberger Credit Points: a) 3 CP b) 3 CP d) 3 CP Content: a) Object oriented Programming for Data Science - Abstract data types, classes, objects, messages, Instance variables, methods, encapsulation, private and public access, class variables, constructors, class interface, class implementation - Classes and objects, private and public class members, constructors, initialization list, static data members, overloading, inline, separation of interface and implementation - Data structures, iterators and containers - Design, code and test a series of object-oriented programs to reenforce lecture content - Exception handling - Function overloading, operator overloading - Generic Types, Static and Dynamic Binding, Polymorphism, Overloading - Inheritance: Types of Inheritance, Construction, Destruction, Multiple Inheritance b) Relational Databases - Basic terms and architectures of databases - Database system creation - Principles of the relational model (relational algebra, query optimisation, functional dependencies, data integrity and normalisation) - Data modelling (Entity Relationship Model) - Implementation using a relational database system as an example - Database language SQL: DDL, DML, DAL - Constraints of the current SQL standard (SQL 2003) - Transaction concepts - Multi-user synchronisation - Fault recovery and data security - Active database concepts and fundamentals of Oracle PL/SQL c) Enterprise Resource Planning Systems (ERP) - Structure of ERP Systems, ERP Paradigms - Basic Technologies (client/server, SOAP) and Technical Architecture - Business Transaction and Transaction Monitor - Process Modelling - Programming and Implementation of Business Functions - Middleware and Integration Models - Web Service Based Integration
Teaching and Learning Methods:	Lecture, Tutorial, Team Project
Assessment Method:	a) Written examination, oral examination, course work assignment b) Written examination, oral examination, course work assignment c) Written examination, oral examination, course work assignment Weighting factors for finale module marking: (3 * a) + 3 * b) + 3 * c)) / 9
Workload (25 - 30 h ≙ 1 ECTS credit):	270 h
Contact hours:	120 h

Self-study:	150 h
Recommended Prerequisites:	-
Recommended Reading:	- Lutz, M.: Programming Python - Powerful Object-Oriented Programming (ISBN: 0596158106) - Gamma, E., Helm, R.: Design Patterns - Elements of Reusable Object-Oriented Software (ISBN: 0201633612) - VanderPlas, J.: Python Data Science Handbook - Essential Tools for Working with Data (ISBN: 9781491912058) - Geron, A.: Hands-On Machine Learning with Scikit-Learn and TensorFlow - Concepts, Tools, and Techniques to Build Intelligent Systems (ISBN: 1491962291) - Chappell D. A.: Enterprise Service Bus. O'Reilly, 2004. - Current publications of major manufacturers such as ORACLE, SAP, SIEMENS, etc. - Elmasri, R, Navathe, R.: Fundamentals of Database Systems.Prentice Hall International, 6th edition, Global Edition, 2010. - Garcia-Molina, Jeffrey D. Ullman Jennifer Widom, Database Systems: The Complete Book, Prentice Hall International, 2008. - Josuttis N., M.: Soa in Practise. O'Reilly Media, 2007. - Van der Hoven H.: ERP and Business Processes. Llumina Press, 2009.
Use of the Module in Other Degree Programs:	-
Particularities:	-
Last update:	October 19, 2022

3.3 Modelling and Simulation of Technical Systems

Module Code:	MS-01
Module Title:	Modelling and Simulation of Technical Systems
Type of Module:	Mandatory
ECTS Credits:	14 CP
Language:	English
Duration of Module:	2 Terms
Recommended for Semester:	1. + 2. Semester
Frequency:	Every year
Person Responsible for this Module:	Prof. Dr. Rainer Scheuring
Lecturers:	Prof. Dr. Rainer Scheuring, Prof. Dr. Bartz-Beielstein, Prof. Dr. Michael Freiburg
Learning Outcome:	Students can - model and simulate continuous systems - model and simulate discrete event systems - model data based systems (big data) - model and simulate electrical energy systems by - understanding and applying the concepts of modelling of continuous systems, discrete event systems, data based systems, and electrical energy systems - understanding the concepts of continuous and discrete event simulators - evaluating advantages and disadvantages of numerical integration methods - applying modelling and simulation concepts to real-world technical problems - designing simulation models of technical systems - evaluating the quality of the simulation models - performing simulation experiments - using tools from statistical learning for modeling and understanding complex data sets - applying standardized processes (e.g., the CRISP-DM process) to investigate complex data - summarizing results in reports - presenting results in oral presentations to - develop a deep understanding of the behavior of technical systems - analyze and understand data from these systems - be able to carry out design tasks such as system or plant design, controller design, etc. with the aid of simulation tools - be qualified for a professional career as automation engineer
Module Content:	Lectures: a) Modelling and Simulation of Continuous Systems b) Modelling and Simulation of Discrete Event Systems c) Data-driven Modelling and Model Optimization d) Modelling and Simulation of Electrical Energy Systems Lecturer: a) Prof. Dr. Rainer Scheuring b) Prof. Dr. Rainer Scheuring c) Prof. Dr. Thomas Bartz-Beielstein d) Prof. Dr. Michael Freiburg

	Credit Points:
	a) 4 CP
	b) 2 CP
	c) 5 CP
	d) 4 CP
	
	Content:
	
	a) Modelling and Simulation of Continuous Systems
	- Modelling mechanical systems and process-engineering systems (thermodynamics, data on chemical media, valves, pumps, reactors, distillation columns, etc.)
	- Design and organization of a simulator
	- Sequential-modular simulation
	- Dynamic simulation
	- Introduction to UniSim
	- Process industry applications
	
	b) Modelling and Simulation of Discrete Event Systems
	- Specifications of discrete event systems
	- Compositional modelling of discrete event systems
	- Object-oriented simulation of discrete event systems
	- Introduction to Arena and Plant Simulation (formerly Simple ++, eM-Plant)
	- Probability distribution
	- Queuing theory
	- Process and production industry application examples
	
	c) Data-driven Modelling and Model Optimization
	- Data from real-world problems (industry, economy, science)
	- Data preparation
	- Linear regression, logistic regression
	- Hypothesis testing
	- Classification, Linear discriminant analysis
	- Tree-based methods
	- Sequential parameter optimization (SPO)
	- Model selection
	- Treatment of missing values and huge data sets
	- Data visualization
	- Data mining, CRISP-DM Process
	- Learning, especially advanced modelling techniques: Bootstrap, bagging, meta learner (e.g. random forests), empirical learning problems
	- Evaluation of modelling results (e.g., error measures, overfitting, cross validation, precision and recall)
	
	d) Modelling and Simulation of Electrical Energy Systems
	- System requirements
	- Electrical grids and grid components
	- Grid operation
	  - Transmission line theory
	  - Stability aspects
	  - Network planning
	  - Network simulation
	- Distributed energy resources
	- Smart grids
	- Power quality

Teaching and Learning Methods:	Lecture, Tutorial, Laboratory Course, Team Project
Assessment Method:	a) Written examination, oral examination, course work assignment b) Written examination, oral examination, course work assignment c) Written examination, oral examination, course work assignment d) Written examination, oral examination, course work assignment Weighting factors for finale module marking: (4 * a) + 2 * b) + 5 * c) + 4 * d)) / 15

Workload (25 - 30 h ≙ 1 ECTS credit):	450 h
Contact hours:	200 h
Self-study:	250 h
Recommended Prerequisites:	-
Recommended Reading:	- Stoer, J., et.al.: Introduction to numerical analysis. ISBN 0-387-95452-X - Kincaid, D., et.al.: Numerical analysis. ISBN 0-534-38905-8 - Brenan, K., et.al.: Numerical solution of initial value problems in differential algebraic equations, 99 TLS 1067, ISBN 0-444-01511-6 - UniSim-Documentation, Honeywell 2006 - Kelton, W.D., Sadowski, R.P., Sadowski, D.A.: Simulation with Arena. McCraw-Hill 2002 - Banks, J.: Discrete-Event System Simulation, Prentice-Hall, 1996 - Liebl: Simulation. 2nd revision, Munich. Oldenbourg 1995 - Greasley A.: Simulation Modelling for Business. Ashgate Hants 2004. - Feldmann K., Reinhardt G. (Hrsg.): Simulationsbasierte Planungssysteme für Organisation und Produktion. Springer Berlin 1999. - Fishman G.S.: Discrete-Event Simulation. Springer Series in Operations Research. Springer 2001. - Kelton, W.D., Sadowski, R.P., Sadowski, D.A.: Simulation with Arena. McGraw-Hill 2002 - Witten, I. H., Frank, E.: Data Mining, Hanser, 2nd ed., 2005. - Hastie, T., Tibshirani, R., Friedeman, J.: The Elements of Statistical Learning. Springer, 2001. - James, G., Witten, D., Hastie, T., and Tibshirani, R.: An Introduction to Statistical Learning with Applications in R. Springer, 4th edition, 2014. - Law, A.M., Kelton, W.D.: Simulation Modeling and Analysis. McGraw-Hill, Boston. 2000. - Bartz-Beielstein, T. et al.: Experimental Methods for the Analysis of Optimization Algorithms. Springer, 2010. - Williams, G.: Data Mining with Rattle and R: The Art of Excavating Data for Knowledge Discovery. Springer, New York, 2011. - Papailiou: Handbook of Power Systems. Springer, CIGRE. - Gomez-Exposito, A.; Conejo, A.; Canizares, C.: Electric Energy Systems - Analysis and Operation. CRC Press - Elgerd, O.: Electric Energy Systems Theory - An Introduction. McGraw Hill - Mc Donald, J.: Electric Power Substations Engineering. CRC Press - ABB: Distribution Automation Handbook - Elements of power distribution systems. Online available. - Schwab, A.J.: Elektroenergiesysteme. Springer Vieweg.
Use of the Module in Other Degree Programs:	-
Particularities:	-
Last update:	October 19, 2022

3.4 Control of Technical Systems

Module Code:	CT-01
Module Title:	Control of Technical Systems
Type of Module:	Mandatory
ECTS Credits:	13 CP
Language:	English
Duration of Module:	2 Terms
Recommended for Semester:	1. + 2. Semester
Frequency:	Every year
Person Responsible for this Module:	Prof. Dr. Rainer Scheuring
Lecturers:	Prof. Dr. Sebastian Kraft, Prof. Dr. Michael Freiburg, Prof. Dr. Rainer Scheuring
Learning Outcome:	Students can - generate, manipulate and analyze digital and optical signals - design, analyze, evaluate and control continuous systems - design, analyze, evaluate and control discrete event systems - design, analyze, evaluate, control and protect electrical energy systems by - understanding and applying digital signal processing theory - understanding and applying theoretical concepts of optoelectronics - understanding and applying linear, nonlinear and model predictive control theory - understanding and applying discrete event control theory - understanding and applying electrical system theory - using “state of the art” analysis and design software - summarizing results in reports - presenting results in oral presentations to - be able to carry out design tasks such as system or plant design, controller design, etc. - be qualified for a professional career as automation engineer
Module Content:	Lectures: a) Digital Signal Processing and Optoelectronics b) Linear, Nonlinear and Model Predictive Control c) Automation of Discrete Event Systems d) Protection, Automation and Control in Electrical Energy Supply Lecturer: a) Prof. Dr. Sebastian Kraft b) Prof. Dr. Rainer Scheuring c) Prof. Dr. Rainer Scheuring d) Prof. Dr. Michael Freiburg Credit Points: a) 4 CP b) 5 CP c) 2 CP d) 3 CP Content: a) Digital Signal Processing and Optoelectronics - Conversion of signals (D/A, D/A), discrete level and time, impact of analogue environment - Transfer functions in S plane

	- Sampling theory fundamentals, Z-transformation, mapping S-Z-plane - Fundamentals of digitals filters, transposed systems, DFT/FFT - Multi-rate signal processing, sample rate conversion - Optical signals - Fourier optics (fourier basics, transfer function, convolution, autocorrelation, filtering (high pass, low pass,...), point spread function, sampling theorem, applications) - Statistical optics (intensity, coherence functions, interference, coherence tomography) - Acousto optics - Fibers and switches - Laser spectroscopy b) Linear, Nonlinear and Model Predictive Control - Control matrix algebra - Matrix norms - State space approach - Interconnected systems and feedback - Stability, Ljapunow stability and I/O stability - Reachability, Observability and Controllability - State feedback and output feedback - Observers - Multivariable poles and zeros - Structural characteristics of non-linear systems - Nonlinearity measures - Input-output linearization - Model-based predictive control systems - Internal model control and Smith predictor - Linear model predictive control (MPC) - Nonlinear model predictive control (NMPC) - Implementation concepts of major manufacturers c) Automation of Discrete Event Systems - Analysis of discrete event systems - Design of discrete event systems - Safety oriented discrete event systems - Automation of hybrid dynamic systems d) Protection, Automation and Control in Electrical Energy Supply - Information systems in electric energy grids - Protection systems - Substation communication - State estimation - Voltage and reactive power control - Testing and Monitoring
Teaching and Learning Methods:	Lecture, Tutorial, Laboratory Course, Team Project
Assessment Method:	a) Written examination, oral examination, course work assignment b) Written examination, oral examination, course work assignment c) Written examination, oral examination, course work assignment d) Written examination, oral examination, course work assignment Weighting factors for finale module marking: (4 * a) + 5 * b) + 2 * c) + 3 * d)) / 14
Workload (25 - 30 h ≙ 1 ECTS credit):	420 h
Contact hours:	185 h
Self-study:	235 h
Recommended Prerequisites:	-
Recommended Reading:	- B.E.A. Saleh and M.C. Teich: Fundamentals of Photonics, Wiley, 2007

	- Girod, et.al.: Signals and Systems. ISBN 0-471-98800-6 - Proakis: Digital Signal Processing. ISBN 0-13-394289-9 - Diniz, et.al.: Digital Signal Processing. ISBN 0-521-78175-2 - Vaidyanathan, P.P.: Multirate Systems and Filter Banks. ISBN 0-13-605718-7 - Astrom, K.J., Hagglund, T.: Advanced PID Control, ISA, Research Triangle Park, 2006 - William, R.L., Lawrence, D.A.: Linear State-Space Control Systems. Wiley, 2007 - Liebermann, N.P.: Troubleshooting Process Plant Control. Wiley, 2008 - Rashid, M.: Energy Systems in Electrical Engineering, Springer - Gómez-Expósito, et al: Electric Energy Systems – Analysis and Operation, CRC Press, 2009 - Sivanagaraju, S.: Power system operation and control, Pearson, 2010 - Hewitson, L.G.; Brown, M.; Balakrishnan, R.: Practical Power System Protection. Elsevier. - Anderson, P.M.: Power System Protection. IEEE Press. - Van Cutsem, T.; Vournas, C.: Voltage stability of electric power systems. Kluwer Publisher. - Häger, U.; Rehtanz, Ch.; Voropai, N.: Monitoring, Control and Protection of Interconnected Power Systems. Springer. - Stoustrup, J.; Annaswamy, A.; Chakrabortty, A.; Qu, Z.: Smart Grid Control. Springer.
Use of the Module in Other Degree Programs:	-
Particularities:	-
Last update:	October 19, 2022

3.5 Optimization of Technical Systems

Module Code:	OS-01
Module Title:	Optimization of Technical Systems
Type of Module:	Mandatory
ECTS Credits:	10 CP
Language:	English
Duration of Module:	2 Terms
Recommended for Semester:	1. + 2. Semester
Frequency:	Every year
Person Responsible for this Module:	Prof. Dr. Thomas Bartz-Beielstein
Lecturers:	Prof. Dr. Thomas Bartz-Beielstein
Learning Outcome:	Students can - optimize technical systems - implement, train and debug neural networks - judge the importance of human-centered AI - consider fairness, transparency, and ethics in AI by - understanding, applying and evaluating numerical methods and algorithms - understanding and applying optimization theory - understanding and applying machine learning and artificial intelligence methods and algorithms - analyzing new tasks and problems - choosing suitable optimization methods - using “state of the art” optimization software and optimization algorithms - implementing representations, image features - applying optimization algorithms (stochastic gradient descent) - understanding backpropagation - choosing suitable network architectures - analyzing generative models - ascertaining and evaluation correct solutions - understanding bias in data - using tools for visualizing model states - summarizing results in reports - presenting results in oral presentations to - be able to improve the behavior of technical systems - solve practical engineering tasks in classification and prediction - be qualified for a professional career as automation engineer
Module Content:	Lectures: a) Numerical Methods b) Optimization c) Machine Learning and AI Lecturer: a) Prof. Dr. Thomas Bartz-Beielstein b) Prof. Dr. Thomas Bartz-Beielstein c) Prof. Dr. Thomas Bartz-Beielstein Credit Points: a) 3 CP b) 4 CP c) 3 CP

	Content: a) Numerical Methods - Matrices - Differences, Derivatives, and Boundary Conditions - Inverses and Delta Functions - Eigenvalues and Eigenvectors - Positive Definite Matrices - Numerical Linear Algebra: LU, QR, SVD - Numerical integration of standard differential equation systems (linear, non-linear, formal procedures (Runge-Kutta etc.) - Boundary value problems - Differential Equations of Equilibrium - Cubic Splines and Fourth Order Equations - Gradient and Divergence - Laplace's Equation - Finite Differences and Fast Poisson Solvers - The Finite Element Method - Stochastic simulation - Design and organisation of a Monte Carlo simulator b) Optimization - Optimization criteria - Optimization basics (calculus of variation, Euler formula, Hamilton formula, maximum principle, etc.) - Linear Programming (LP) - Nonlinear Programming (NLP) - Quadratic Programming (QP) - Integer Programming (IP) - Direct (extrapolation-free) searching procedures (pattern search) - Stochastic procedures (simulated annealing, evolutionary algorithms) - Application of optimization procedures to practical problems c) Machine Learning and AI - Image Classification: Data-driven Approach, k-Nearest Neighbor, train/val/test splits, L1/L2 distances, cross-validation - Linear Regression, Logistic Regression, Softmax Regression - Optimization: Stochastic Gradient Descent - Neural Networks, Backpropagation - Convolutional Neural Networks: Architectures, Convolution / Pooling Layers - Understanding and Visualizing Convolutional Neural Networks
Teaching and Learning Methods:	Lecture, Tutorial, Laboratory Course
Assessment Method:	a) Learning portfolio (alternatively: written or oral examination) b) Learning portfolio (alternatively: written or oral examination) c) Learning portfolio (alternatively: written or oral examination) Weighting factors for finale module marking: (3 * a) + 4 * b) + 3 * c)) / 10
Workload (25 - 30 h ≙ 1 ECTS credit):	300 h
Contact hours:	130 h
Self-study:	170 h
Recommended Prerequisites:	-
Recommended Reading:	- Stoer, J., et.al.: Introduction to numerical analysis. ISBN 0-387-95452-X - Kincaid, D., et.al.: Numerical analysis. ISBN 0-534-38905-8 - Gill, P.E., Murray, W., Wright, M.: Practical Optimization. Academic Press, London, 1989

	- Edgar, T.F., Himmelblau, D.M.: Optimization of chemical processes. Mc Graw-Hill, 2001 - Gekeler, E.W.: Mathematical Methods for Mechanics with MATLAB Experiments. Springer, Berlin 2008 - Neumann, K. und Morlock, M: Operations Research. 2. Aufl. Hanser, München 2002 - Bartz-Beielstein, T.: Experimental Research in Evolutionary Computation. 1.Aufl., Springer, Berlin 2006 - Markon, S., Kita, H., Kise, H., Bartz-Beielstein, T.: Modern Supervisory and Optimal Control with Applications in the Control of Passenger Traffic Systems in Buildings. Springer, Berlin, Heidelberg, New York, 2006 - Nelli, F.: Python Data Analytics, Springer. 2015 - Moncecchi, G., Garreta, R.: Learning scikit-learn - Machine Learning in Python. 2013 - Goodfellow, I., Bengio, Y., and Courville, A.: Deep Learning. MIT press, 2016
Use of the Module in Other Degree Programs:	-
Particularities:	-
Last update:	October 19, 2022

3.6 Case Studies

Module Code:	CS-01
Module Title:	Case Studies
Type of Module:	Mandatory
ECTS Credits:	30 CP
Language:	English
Duration of Module:	1 Terms
Recommended for Semester:	3. Semester
Frequency:	Every year
Person Responsible for this Module:	Prof. Dr. Rainer Scheuring
Lecturers:	Prof. Dr. Elena Algorri, Prof. Dr. Thomas Bartz-Beielstein, Prof. Dr. Michael Freiburg, Prof. Dr. Felix Hackelöer, Prof. Dr. Frithjof Klasen, Prof. Dr. Sebastian Kraft, Prof. Dr. Johann Schaible, Prof. Dr. Rainer Scheuring, Prof. Dr. Christian Wolf
Learning Outcome:	Students can - create a case study by - understanding the technical or scientific problem - Identifying relevant previous work in the literature - developing solution approaches - evaluating the solution approaches - selecting and implementing the best approach - writing a report that describes the methods and the approach used - presenting the work in a seminar to - specialize in a sub-area of the Master's programme - develop their abilities to solve a technical or scientific problem - be qualified for a professional career as automation engineer
Module Content:	Case Study: a) Case Study Industrial Communication and Information Security (ICIS) b) Case Study Integration of Technical and Business Information Systems (ITBS) c) Case Study Modelling and Simulation of Technical Systems (MSTS) d) Case Study Control of Technical Systems (CTS) e) Case Study Optimization of Technical Systems (OTS) Lecturer: a) see Lecturers b) see Lecturers c) see Lecturers d) see Lecturers e) see Lecturers Credit Points: a) 10 CP b) 10 CP c) 10 CP d) 10 CP e) 10 CP

	Content of case studies: The content of a case study is related to the content of the corresponding module of the master program.
Teaching and Learning Methods:	Team project
Assessment Method:	a) Case study report and oral presentation b) Case study report and oral presentation c) Case study report and oral presentation d) Case study report and oral presentation e) Case study report and oral presentation Case studies have to be processed in teams. Each student has to select three case studies. Each case study has to be from a different category (i.e. a) or b) or c) or d) or e)). The module examination has two parts: the case study report and the oral presentation. Both parts have to be passed. The oral presentation is included in the grade awarded, whereby the weighting of the case study report to the oral presentation is 3:1. Weighting factors for finale module marking: Each case study has a weighting factor of 10. (10 * x) + 10 * y) + 10 * z)) / 30
Workload (25 - 30 h ≙ 1 ECTS credit):	900 h
Contact hours:	100 h
Self-study:	800 h
Recommended Prerequisites:	- Modules and lectures of 1st and 2nd semester
Recommended Reading:	- See other modules
Use of the Module in Other Degree Programs:	-
Particularities:	-
Last update:	October 19, 2022

3.7 Master Thesis

Module Code:	MT-01
Module Title:	Master Thesis
Type of Module:	Mandatory
ECTS Credits:	30 CP
Language:	English
Duration of Module:	1 Term
Recommended for Semester:	4. Semester
Frequency:	Every year
Person Responsible for this Module:	Prof. Dr. Rainer Scheuring
Lecturers:	Prof. Dr. Elena Algorri, Prof. Dr. Thomas Bartz-Beielstein, Prof. Dr. Michael Freiburg, Prof. Dr. Felix Hackelöer, Prof. Dr. Frithjof Klasen, Prof. Dr. Sebastian Kraft, Prof. Dr. Johann Schaible, Prof. Dr. Rainer Scheuring, Prof. Dr. Christian Wolf
Learning Outcome:	A student can - create a scientific thesis by - understanding the technical or scientific problem - identifying, analyzing and evaluating relevant previous work in available literature - developing solution approaches - evaluating the solution approaches - selecting the best approach - implementing the best approach - describing the problem and its solution approaches and the approach used in the form of a written final thesis - presenting the results in an oral presentation (colloquium) to - further develop and demonstrate his or her capacities for independent scientific work - further develop and demonstrate his or her ability to solve a technical or scientific problem on time - be qualified for a professional career as automation engineer
Module Content:	Lecturer: See Lecturers Content: The content of the master thesis is related to the content of the modules of the Master's programme.
Teaching and Learning Methods:	- Independent work - Obligatory and voluntary consultation - Presentation of interim results - Presentation of the master's degree thesis
Assessment Method:	Final thesis and colloquium. The module examination has two parts: the thesis and the colloquium. The colloquium is included in the grade awarded, whereby the weighting of thesis to colloquium is 2:1. The module is passed if the thesis and the colloquium are passed. Weighting factors for finale module marking: (20 * Thesis + 10 * Colloquium) / 30

Workload (25 - 30 h ≙ 1 ECTS credit):	900 h
Contact hours:	60 h
Self-study:	840 h
Recommended Prerequisites:	-
Recommended Reading:	-
Use of the Module in Other Degree Programs:	-
Particularities:	-
Last update:	October 19, 2022

4 Module Matrix

Module	Submodule	Fields of action			Competencies			Qualification				
		Research and Development	Project Engineering	Operation and Maintenance	Identify problems	Formulate tasks	Solve tasks	Internationalization	Interdisciplinarity	Digitization	Transfer	Exams
		CP	CP	CP								Number
Industrial Communication and Information Security in Industrial Automation (ICIS)	Industrial Communication	1	1	1	x	x	x	x	x	x		1
	Industrial IoT	2	2	1	x	x	x	x	x	x		1
	IT-Security	1	2	1	x	x	x	x	x	x		1
Integration of Technical and Business Information Systems (ITBIS)	Object oriented Program. for Data Science	2	1		x	x	x	x		x		1
	Relational Databases	2	1		x	x	x	x		x		1
	Enterprise Resource Planning Systems	2	1		x	x	x	x		x		1
Modelling and Simulation of Technical Systems (MSTS)	Modelling and Simulation of Continuous Systems	3	1		x	x	x	x		x		1
	Modelling and Simulation of Discrete Event Systems	1	1		x	x	x	x		x		1
	Data-driven Modelling and Model Optimization	3	1	1	x	x	x	x		x		1
	Modelling and Simulation of Electrical Energy Syst.	2	1	1	x	x	x	x		x		1
Control of Technical Systems (CTS)	Digital Signal Processing and Optoelectronics	3	1		x	x	x	x		x		1
	Linear, Nonlinear and Model Predictive Control	2	2	1	x	x	x	x		x		1
	Automation of Discrete Event Systems	0,5	1	0,5	x	x	x	x		x		1
	PAC in Electrical Energy Supply	1	1	1	x	x	x	x		x		1
Optimization of Technical Systems (OTS)	Numerical Methods	2	1		x	x	x	x		x		1
	Optimization	2	2		x	x	x	x		x		1
	Machine Learning and AI	3			x	x	x	x	x	x		1
Case Studies	Case Study ICIS	6	3	1	x	x	x	x	x	x	x	1
	Case Study ITBIS	6	3	1	x	x	x	x	x	x	x	1
	Case Study MSTS	6	3	1	x	x	x	x		x	x	1
	Case Study CTS	6	3	1	x	x	x	x		x	x	1
	Case Study OTS	6	3	1	x	x	x	x	x	x	x	1
Master Thesis		20	7	3	x	x	x			x	x	1

5 Exams

Module	Submodule	Sem.	Sum ECTS	ECTS	Weight	Exam		
						Written exam	Oral exam	Project work
					%	%	%	%
Industrial Communication and Information Security in Industrial Automation	Industrial Communication	1	12	3	2,5	50		50
	Industrial IoT	2		5	4,2	50		50
	IT-Security	2		4	3,3	50		50
Integration of Technical and Business Information Systems	Object oriented Programming for Data Science	1	9	3	2,5	50		50
	Relational Databases	1		3	2,5	50		50
	Enterprise Resource Planning Systems	1		3	2,5	50		50
Modelling and Simulation of Technical Systems	Modelling and Simulation of Continuous Systems	2	15	4	3,3	50		50
	Modelling and Simulation of Discrete Event Systems	2		2	1,7	50		50
	Data-driven Modelling and Model Optimization	2		5	4,2	50		50
	Modelling and Simulation of Electrical Energy Systems	1		4	3,3	50		50
Control of Technical Systems	Digital Signal Processing and Optoelectronics	2	14	4	3,3	50		50
	Linear, Nonlinear and Model Predictive Control	1		5	4,2	50		50
	Automation of Discrete Event Systems	2		2	1,7	50		50
	Protection Automation and Control in Electrical Energy Supply	2		3	2,5	50		50
Optimization of Technical Systems	Numerical Methods	1	10	3	2,5			100
	Optimization	1		4	3,3			100
	Machine Learning and AI	2		3	2,5			100
Case Studies	Case Study I	3	30	10	8,3			100
	Case Study II	3		10	8,3			100
	Case Study III	3		10	8,3			100
Master Thesis	Thesis	4	30	20	16,7			100
	Colloquium	4		10	8,3		100	
Summe ECTS			**120**	**120**				

In the majority of courses of the Master's program Automation & IT, a mixed form of assessed assignments (individual work, group work) with one or two supplementary tests is used to determine grades.

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