Name of study plan: Cybernetics and Robotics

Faculty/Institute/Others: Faculty of Electrical Engineering Department: Branch of study guaranteed by the department: Welcome page Garantor of the study branch: Program of study: Cybernetics and Robotics Type of study: Follow-up master full-time Required credits: 102 Elective courses credits: 18 Sum of credits in the plan: 120 Note on the plan:

Name of the block: Compulsory courses in the program Minimal number of credits of the block: 60 The role of the block: P

Code of the group: 2021_MKYREP Name of the group: Compulsory subjects of the programme Requirement credits in the group: In this group you have to gain 30 credits Requirement courses in the group: In this group you have to complete 5 courses Credits in the group: 30 Note on the group:

Note on the group						
Code	Name of the course / Name of the group of courses (in case of groups of courses the list of codes of their members) Tutors, authors and guarantors (gar.)	Completion	Credits	Scope	Semester	Role
BE3M33ARO1	Autonomous Robotics Karel Zimmermann, Vojt ch Vonásek Karel Zimmermann Karel Zimmermann (Gar.)	Z,ZK	6	2P+2L	L	Р
BE3M38DIT1	Diagnostics and Testing Radislav Šmíd Radislav Šmíd Radislav Šmíd (Gar.)	Z,ZK	6	2P+2L	Z	Р
BE3M35LSY1	Linear Systems Petr Hušek Petr Hušek (Gar.)	Z,ZK	6	3P+2S	Z	Р
BE3MPROJ6	Project	Z	6	0p+6s	Z	Р
BE3MPVTY1	Teamwork Tomáš Drábek, Martin Hlinovský, Petr Drábek, Ond ej Drbohlav, Pavel Mužák, Martin Šipoš Ond ej Drbohlav Tomáš Drábek (Gar.)	Z	6	0P+4C	L	Ρ

Characteristics of the courses of this group of Study Plan: Code=2021_MKYREP Name=Compulsory subjects of the programme

Characteristics of	the courses of this group of Study Flan. Code=2021_MixTixEF Name=Compulsory subject		jrannie	
BE3M33ARO1	Autonomous Robotics	Z,ZK	6	
The Autonomous robotic	es course will explain the principles needed to develop algorithms for intelligent mobile robots such as algorithms for: (1) Map	ping and localiza	tion (SLAM)	
sensors calibration (lidar	or camera). (2) Planning the path in the existing map or planning the exploration in a partially unknown map and performing th	ne plan in the wor	ld. IMPORTANT:	
It is assumed that studer	nts of this course have a working knowledge of optimization (Gauss-Newton method, Levenberg Marquardt method, full Newto	n method), mathe	matical analysis	
(gradient, Jacobian, Hessian), linear algebra (least-squares method), probability theory (multivariate gaussian probability), statistics (maximum likelihood and maximum aposteriori				
estimate), python progra	mming and machine learning algorithms. This course is also part of the inter-university programme prg.ai Minor. It pools the	best of AI educat	ion in Prague to	
provide students with a	deeper and broader insight into the field of artificial intelligence. More information is available at https://prg.ai/minor.			
BE3M38DIT1	Diagnostics and Testing	Z,ZK	6	
The course aims to intro	duce students to the problems of modelling and fault detection, ensuring fault tolerance, monitoring the operational status of	complex industri	al components	
and autonomous system	ns, non-destructive testing and diagnostics of electronic devices with analogue and digital circuits.			
BE3M35LSY1	Linear Systems	Z,ZK	6	
The purpose of this could	se is to introduce mathematical tools for the description, analysis, and partly also synthesis, of dynamical systems. The focu	s will be on linear	time-invariant	
multi-input multi-output s	systems and their properties such as stability, controllability, observability and state realization. State feedback, state estimati	ion, and the desig	n of stabilizing	
controllers will be explain	ned in detail. Partially covered will be also time-varying and nonlinear systems. Some of the tools introduced in this course are	e readily applicabl	e to engineering	
problems such as the ar	alysis of controllability and observability in the design of flexible space structures, the design of state feedback in aircraft co	ntrol, and the esti	mation of state	
variables. The main moti	vation, however, is to pave the way for the advanced courses of the study program. The prerequsites for this course include u	ndergraduate leve	el linear algebra,	
differential equations, an	d Laplace and z transforms.			
BE3MPROJ6	Project	Z	6	
BE3MPVTY1	Teamwork	Z	6	
Teamwork is the basis o	f most of the activities that people perform in companies and their personal lives. In this course, students can try how to solv	e a technical task	in a team, how	
to cooperate, how to cor	nmunicate together and how to solve problems such as project delays, how to include external influences in the plan, etc.			

Code of the group: 2021_MKYREDIP Name of the group: Diploma Thesis Requirement credits in the group: In this group you have to gain 30 credits Requirement courses in the group: In this group you have to complete 1 course Credits in the group: 30

Note on the group:

Code	Name of the course / Name of the group of courses (in case of groups of courses the list of codes of their members) Tutors, authors and guarantors (gar.)	Completion	Credits	Scope	Semester	Role
BDIP30	Diploma Thesis	Z	30	22s	L	Р

Characteristics of the courses of this group of Study Plan: Code=2021_MKYREDIP Name=Diploma Thesis

BDIP30	Diploma Thesis	Z	30	
Independent final comp	rehensive work for the Master's degree study programme. A student will choose a topic from a range of topics related to his of	or her branch of s	tudy, which will	
be specified by branch department or branch departments. The diploma thesis will be defended in front of the board of examiners for the comprehensive final examination.				

Name of the block: Compulsory elective courses Minimal number of credits of the block: 42 The role of the block: PV

Code of the group: 2021_MKYREPV1 Name of the group: Compulsory elective subjects of the programme - Group 1 Requirement credits in the group: In this group you have to gain at least 18 credits (at most 36) Requirement courses in the group: In this group you have to complete at least 3 courses (at most 6) Credits in the group: 18

Note on the group:

Code	Name of the course / Name of the group of courses (in case of groups of courses the list of codes of their members) Tutors, authors and guarantors (gar.)	Completion	Credits	Scope	Semester	Role
BE4M33MPV	Computer Vision Methods Georgios Tolias, Ji í Matas, Jan ech, Dmytro Mishkin Ond ej Drbohlav Ji í Matas (Gar.)	Z,ZK	6	2P+2C	L	PV
BE3M38SPD1	Data acquisition and transfer Radislav Šmíd Radislav Šmíd (Gar.)	Z,ZK	6	2P+2L	L	PV
BE3M35OFD	Estimation, Filtering and Detection Vladimír Havlena Vladimír Havlena (Gar.)	Z,ZK	6	2P+2C	Z	PV
BE3M35ORR	Optimal and Robust Control Zden k Hurák Zden k Hurák Zden k Hurák (Gar.)	Z,ZK	6	2P+2C	L	PV
BE3M38ZDS1	Signal processing and digitization Jan Holub Jan Holub Jan Holub (Gar.)	Z,ZK	6	2P+2L	Z	PV
BE4M33SSU	Statistical Machine Learning Jan Drchal, Vojt ch Franc Vojt ch Franc (Gar.)	Z,ZK	6	2P+2C	Z	PV

Characteristics of the courses of this group of Study Plan: Code=2021_MKYREPV1 Name=Compulsory elective subjects of the programme - Group 1

BE4M33MPV Computer Vision Methods	Z,ZK	6
The course covers selected computer vision problems: search for correspondences between images via interest point detection, description and ma	tching, image stit	ching, detection,
recognition and segmentation of objects in images and videos, image retrieval from large databases and tracking of objects in video sequences. This	s course is also p	art of the
inter-university programme prg.ai Minor. It pools the best of AI education in Prague to provide students with a deeper and broader insight into the field	ld of artificial intel	lligence. More
information is available at https://prg.ai/minor.		
BE3M38SPD1 Data acquisition and transfer	Z,ZK	6
The aim of the course is to acquaint students with the principles and limits of data transmission from sensors and similar sources of information for la	oT and M2M com	munication,
wireless sensor networks, and specific algorithms used in them, respecting the limiting conditions of their function. The basic algorithms of distributed	information proc	essing in sensor
networks will be studied, as well as technologies for obtaining energy for powering wireless nodes of the network.		
BE3M35OFD Estimation, Filtering and Detection	Z,ZK	6
This course will cover description of the uncertainty of hidden variables (parameters and state of a dynamic system) using the probability language a	and methods for th	heir estimation.
Based on bayesian problem formulation principles of rational behavior under uncertainty will be analyzed and used to develop algorithms for parameters	eter estimations (/	ARX models,
Gaussian process regression), filtering (Kalman filter) and detection (likelihood ratio theory). We will demonstrate numerically robust implementation	of the algorithms	s applicable in
real life problems for the areas of industrial process control, robotics and avionics.		
BE3M35ORR Optimal and Robust Control	Z,ZK	6
This advanced course will be focused on design methods for optimal and robust control. Major emphasis will be put on practical computational skills	and realistically of	complex problem
assignments.		
BE3M38ZDS1 Signal processing and digitization	Z,ZK	6
Students will gain knowledge for the design and implementation of systems for processing and digitization of analog signals. They will deepen the knowledge for the design and implementation of systems for processing and digitization of analog signals.	nowledge acquire	d in previous
theoretical subject and gain practical experience in the design and analysis of systems for signal processing, AD conversion and data acquisitation.	Emphasis is place	ed on reducing
uncertainties speed stability and resistence to interfering signals		

BE4M33SSU Statistical Machine Learning

The aim of statistical machine learning is to develop systems (models and algorithms) for learning to solve tasks given a set of examples and some prior knowledge about the task. This includes typical tasks in speech and image recognition. The course has the following two main objectives 1. to present fundamental learning concepts such as risk minimisation, maximum likelihood estimation and Bayesian learning including their theoretical aspects, 2. to consider important state-of-the-art models for classification and regression and to show how they can be learned by those concepts.

Z.ZK

6

Code of the group: 2021_MKYREPV2 Name of the group: Compulsory elective subjects of the programme - Group 2 Requirement credits in the group: In this group you have to gain at least 24 credits (at most 114) Requirement courses in the group: In this group you have to complete at least 4 courses (at most 19) Credits in the group: 24 Note on the group:

Code	Name of the course / Name of the group of courses (in case of groups of courses the list of codes of their members) Tutors, authors and guarantors (gar.)	Completion	Credits	Scope	Semester	Role
BE3M33PKR	Advanced robot kinematics Viktor Korotynskiy, Tomáš Pajdla Tomáš Pajdla (Gar.)	Z,ZK	6	2P+2C	Z	PV
BE3M38POS	Advanced sensors Antonín Platil, Michal Janošek Antonín Platil Antonín Platil (Gar.)	Z,ZK	6	2P+2L	Z	PV
BE3M38PSL1	Aircraft Avionics Martin Šipoš, Jan Rohá Jan Rohá Jan Rohá (Gar.)	Z,ZK	6	2P+2L	Z	PV
BE4M36UIR	Artificial Intelligence in Robotics Miloš Prágr, Jan Faigl Jan Faigl Jan Faigl (Gar.)	Z,ZK	6	2P+2C	Z	PV
BE3M35RSA	Automotive Control Systems Tomáš Haniš Tomáš Haniš (Gar.)	Z,ZK	6	2P+2S		PV
BE3M38ASE	Automotive sensors and networks Antonín Platil, Ji í Novák, Jan Sobotka Ji í Novák Ji í Novák (Gar.)	Z,ZK	6	2P+2L	L	PV
BE3M35KOA	Combinatorial Algorithms Zden k Hanzálek Zden k Hanzálek (Gar.)	Z,ZK	6	2P+2C	L	PV
BE3M35DRS	Dynamics and Control of Networks Kristian Hengster-Movric Kristian Hengster-Movric Kristian Hengster-Movric (Gar.)	Z,ZK	6	2P+2C	Z	PV
BE3M35SRL	Flight Control Systems Martin Hrom ik Martin Hrom ik Martin Hrom ik (Gar.)	Z,ZK	6	2P+2L	Z	PV
BE3M33HRO	Humanoid robots Mat j Hoffmann, Lukáš Rustler Mat j Hoffmann Mat j Hoffmann (Gar.)	Z,ZK	6	2P+2C	L	PV
BE3M35HYS	Hybrid Systems Zden k Hurák Zden k Hurák Zden k Hurák (Gar.)	Z,ZK	6	2P+2C		PV
BE3M38INA1	Integrated avionics Martin Šipoš, Jan Rohá Jan Rohá Jan Rohá (Gar.)	Z,ZK	6	2P+2L	L	PV
BE2M32MKSA	Mobile Networks Robert Bešák, Zden k Be vá, Pavel Mach Pavel Mach Zden k Be vá (Gar.)	Z,ZK	6	2P + 2L	Z	PV
BE3M33MRS	Multi-robot aerial systems Tomáš Bá a, Martin Saska, Robert P ni ka Martin Saska Martin Saska (Gar.)	Z,ZK	6	2P+2L	Z	PV
BE3M35NES	Nonlinear Systems Kristian Hengster-Movric, Sergej elikovský Sergej elikovský Sergej elikovský (Gar.)	Z,ZK	6	2P+2C	z	PV
BE3M35PSR	Real-time Systems Programming Michal Sojka Michal Sojka	Z,ZK	6	2P+2C	Z	PV
BE4M33TDV	Three-dimensional Computer Vision Radim Šára Radim Šára Radim Šára (Gar.)	Z,ZK	6	2P+2C	Z	PV
BE3M38VBM1	Videometry and Contactless Measurement	Z,ZK	6	2P+2L	Z	PV
BE3M38VIN1	Virtual Instrumentation Antonín Platil, Jaroslav Rozto il Antonín Platil Antonín Platil (Gar.)	Z,ZK	6	2P+2L	L	PV

Characteristics of the courses of this group of Study Plan: Code=2021_MKYREPV2 Name=Compulsory elective subjects of the programme - Group 2

BE3M33PKR	Advanced robot kinematics	Z,ZK	6
We will explain and dem	onstrate techniques for modelling, analyzing and identifying robot kinematics. We will explain more advanced principles of the	representation of	motion in space
and the robot description	ns suitable for identification of kinematic parameters from measured data. We will explain how to solve the inverse kinematic	task of 6DOF ser	ial manipulators
and how it can be used	to identify its kinematic parameters. Theory will be demonstrated on simulated tasks and verified on a real industrial robot.		
BE3M38POS	Advanced sensors	Z,ZK	6
Overview of sensors of p	physical quantities used in industry and research and associated methods of signal processing. Students will gain advanced k	nowledge of sense	ors and methods
of signal processing. The	ey will gain practical experience with measurement of physical quantities with various types of sensors.		
BE3M38PSL1	Aircraft Avionics	Z,ZK	6
The course acquaints st	udents with the current technology used in aircraft instruments and unmanned aerial vehicles, ie systems and sensors worki	ng in the low frequ	lency range and
methods used to proces	s their data. The course includes a detailed description of aircraft instrumentation and its resistance to external influences, a de	scription of aircraf	t power sources,
analysis of instruments	and systems for measuring engine and aerometric quantities, and a description of emergency and operational diagnostics. T	he course also de	als with the field
of inertial navigation aid	s, used sensors and systems, their modeling and description. It analyzes in detail the principles of calculations of navigation	equations, includ	ing methods of
fusion of navigation data	a and their processing.		

BE4M36UIR	Artificial Intelligence in Robotics	Z,ZK	6
The course aims to acc	uaint students with the use of planning approaches and decision-making techniques of artificial intelligence for solving proble	ems arising in auto	onomous robotic
	e course are employing knowledge of planning algorithms, game theory, and solving optimization problems in selected applic		
	itectures of autonomous systems based on reactive and behavioral models of autonomous systems. The considered application		-
	persistent environmental monitoring, robotic exploration of unknown environments, online real-time decision-making, deconfli		-
-	c conflicts. In laboratory exercises, students practice their problem formulations of robotic challenges and practical solutions i		
	s. This course is also part of the inter-university programme prg.ai Minor. It pools the best of AI education in Prague to provid	e students with a c	beeper and
-	field of artificial intelligence. More information is available at https://prg.ai/minor.	774	0
BE3M35RSA	Automotive Control Systems	Z,ZK	6
BE3M38ASE	Automotive sensors and networks	Z,ZK	6
-	Idents with a deeper insight into the functional principles of advanced sensor systems in cars, methods of signal processing in	-	
	ems. It also deals with distributed vehicle systems for real-time control and methods of their testing. Theoretical lectures are cor ents (ECUs, sensors) of modern vehicles.	inplemented by pra	ictical laboratory
BE3M35KOA	Combinatorial Algorithms	Z.ZK	6
	problems and algorithms of combinatorial optimization (often called discrete optimization; there is a strong overlap with the ter	1 / 1	-
-	gebra, graph theory, and basics of optimization, we show optimization techniques based on graphs, integer linear programm	-	
	ace search methods. We focus on application of optimization in stores, ground transportation, flight transportation, logistics,		
	n lines, message routing, scheduling in parallel computers.	plaining of flama	
BE3M35DRS	Dynamics and Control of Networks	Z,ZK	6
	p an ever-increasing demand for understanding contemporary networks large-scale complex systems composed of many co	1 1	
	ngle distributed entity. Herein, we will consider fundamental similarities between diverse areas such as e.g. forecasting the sp	-	-
	nanipulation of communities through social media, formation controls for unmanned vehicles, energy generation and distribution	• •	
such compelling issues	goes far beyond the boundaries of any single physical, technological or scientific domain. Therefore, we will analyze phenom	nena across differe	ent domains,
involving societal, ecor	omic and biological networks. For such networked systems, the resulting behavior depends not only on the characteristics of	their individual co	mponents and
details of their physical	or logical interactions, but also on a precise way those components are interconnected the detailed interconnection topology	. For that reason, t	the first part of
the course introduces f	undamental theoretical and abstract computational network analysis concepts; in particular, the algebraic graph theory, netwo	ork measures and	metrics and
	gorithms. The second part of the course subsequently views networks as dynamical systems, studies their properties and wa	ays in which these	are controlled,
<u> </u>	of automatic control theory.		
BE3M35SRL	Flight Control Systems	Z,ZK	6
	o classical and modern control design techniques for autopilots and flight control systems. Particular levels are discussed, st	-	-
	dance and navigation systems. Next to the design itself, important aspects of aircraft modelling, both as a rigid body and con	sidering flexibility	of the structure,
are discussed			
BE3M33HRO	Humanoid robots	Z,ZK	6
	human-centered robotics: humanoid robots and human-robot interaction. Motivated by the vision of robot companions in our		
	logy and its specific challenges and opportunities: (i) design, kinematics and inverse kinematics of humanoids, (ii) multimoda		
inertial sensing, etc., (ii) walking and balancing, and (ii) grasping. The second part of the course centers on human-robot interaction (HRI), which include		
collaborative robots) ar	d cognitive/social HRI - how to design robots and behaviors to be acceptable for people		(Salety aspects,
	d cognitive/social HRI - how to design robots and behaviors to be acceptable for people.		
BE3M35HYS	Hybrid Systems	Z,ZK	6
BE3M35HYS Hybrid dynamical syste	Hybrid Systems ms, sometimes also referred to as cyber-physical systems, contain both subsystems governed by physical laws and subsyste	Z,ZK	6 ording to logical
BE3M35HYS Hybrid dynamical syste rules and regulations, o	Hybrid Systems ms, sometimes also referred to as cyber-physical systems, contain both subsystems governed by physical laws and subsyst ften encoded in the form of algorithms and implemented in software. The behaviour of the former can be described by real q	Z,ZK ems behaving acc uantities whose ev	6 ording to logical volution in
BE3M35HYS Hybrid dynamical syste rules and regulations, of continuous or discrete	Hybrid Systems ms, sometimes also referred to as cyber-physical systems, contain both subsystems governed by physical laws and subsyste ften encoded in the form of algorithms and implemented in software. The behaviour of the former can be described by real q ime is commonly modelled by differential or difference equations. The behaviour of the latter is commonly described by quant	Z,ZK ems behaving acc uantities whose ev ities taking on a co	6 ording to logical <i>r</i> olution in puntable or finite
BE3M35HYS Hybrid dynamical syste rules and regulations, of continuous or discrete number of values (or en	Hybrid Systems ms, sometimes also referred to as cyber-physical systems, contain both subsystems governed by physical laws and subsyst ften encoded in the form of algorithms and implemented in software. The behaviour of the former can be described by real q	Z,ZK ems behaving acc uantities whose ev ities taking on a co Petri nets. In the m	6 ording to logical volution in puntable or finite odelling and
BE3M35HYS Hybrid dynamical syste rules and regulations, of continuous or discrete number of values (or en analysis of hybrid syste	Hybrid Systems ms, sometimes also referred to as cyber-physical systems, contain both subsystems governed by physical laws and subsyste ften encoded in the form of algorithms and implemented in software. The behaviour of the former can be described by real q ime is commonly modelled by differential or difference equations. The behaviour of the latter is commonly described by quant ren just two in the case of binary quantities), whose evolution is modelled by logical models such as finite state automata or F	Z,ZK ems behaving acc uantities whose ev ities taking on a co Petri nets. In the m also be hybrid. Ar	6 ording to logical volution in puntable or finite odelling and nd the industrial
BE3M35HYS Hybrid dynamical syste rules and regulations, o continuous or discrete number of values (or e analysis of hybrid syste reality is that practical of	Hybrid Systems ms, sometimes also referred to as cyber-physical systems, contain both subsystems governed by physical laws and subsyste ften encoded in the form of algorithms and implemented in software. The behaviour of the former can be described by real q ime is commonly modelled by differential or difference equations. The behaviour of the latter is commonly described by quant ren just two in the case of binary quantities), whose evolution is modelled by logical models such as finite state automata or F ms and the design of control systems for them, these two classes of models intersect. However, the control system itself can	Z,ZK ems behaving acc uantities whose ev ities taking on a co Petri nets. In the m also be hybrid. Ar em or component	6 ording to logical rolution in puntable or finite odelling and nd the industrial evaluating the
BE3M35HYS Hybrid dynamical syste rules and regulations, o continuous or discrete number of values (or e analysis of hybrid syste reality is that practical o satisfaction of logic cor	Hybrid Systems ms, sometimes also referred to as cyber-physical systems, contain both subsystems governed by physical laws and subsyste fren encoded in the form of algorithms and implemented in software. The behaviour of the former can be described by real q ime is commonly modelled by differential or difference equations. The behaviour of the latter is commonly described by quant ren just two in the case of binary quantities), whose evolution is modelled by logical models such as finite state automata or F ms and the design of control systems for them, these two classes of models intersect. However, the control system itself can control systems contain, in addition to the continuous subsystems represented by PID controllers or Kalman filters, a subsystem	Z,ZK ems behaving acc uantities whose ex- ities taking on a co Petri nets. In the m also be hybrid. Ar em or component of such controllers	6 ording to logical volution in puntable or finite odelling and nd the industrial evaluating the s with hybrid
BE3M35HYS Hybrid dynamical syste rules and regulations, of continuous or discrete number of values (or er analysis of hybrid syste reality is that practical of satisfaction of logic cor dynamics. Hybrid contr condition is met, in ord	Hybrid Systems ms, sometimes also referred to as cyber-physical systems, contain both subsystems governed by physical laws and subsyste fiten encoded in the form of algorithms and implemented in software. The behaviour of the former can be described by real q ime is commonly modelled by differential or difference equations. The behaviour of the latter is commonly described by quant ren just two in the case of binary quantities), whose evolution is modelled by logical models such as finite state automata or F ms and the design of control systems for them, these two classes of models intersect. However, the control system itself can control systems contain, in addition to the continuous subsystems represented by PID controllers or Kalman filters, a subsyste ditions. Switched linear controllers (gain scheduling), supervisory control, sliding mode control or reset control are examples of methods are also becoming particularly important in a networked environment, where measurements or controls are sent or to minimize network traffic (event triggered control). Hybrid dynamical systems thus represent a suitable theoretical and ex	Z,ZK ems behaving acc uantities whose ev ities taking on a co Petri nets. In the m also be hybrid. An em or component of such controllers over the network of tremely practical f	6 ording to logical volution in buntable or finite odelling and nd the industrial evaluating the s with hybrid only when some ramework for
BE3M35HYS Hybrid dynamical syste rules and regulations, of continuous or discrete number of values (or er analysis of hybrid syste reality is that practical of satisfaction of logic cor dynamics. Hybrid contr condition is met, in ord modelling, analysis and	Hybrid Systems ms, sometimes also referred to as cyber-physical systems, contain both subsystems governed by physical laws and subsyste fiten encoded in the form of algorithms and implemented in software. The behaviour of the former can be described by real q ime is commonly modelled by differential or difference equations. The behaviour of the latter is commonly described by quant ren just two in the case of binary quantities), whose evolution is modelled by logical models such as finite state automata or F ms and the design of control systems for them, these two classes of models intersect. However, the control system itself can control systems contain, in addition to the continuous subsystems represented by PID controllers or Kalman filters, a subsyste ditions. Switched linear controllers (gain scheduling), supervisory control, sliding mode control or reset control are examples of methods are also becoming particularly important in a networked environment, where measurements or controls are sent or to minimize network traffic (event triggered control). Hybrid dynamical systems thus represent a suitable theoretical and ex synthesis of a large number of practical control systems. The aim of this advanced course is to help students acquire basic	Z,ZK ems behaving acc uantities whose ev ities taking on a co Petri nets. In the m also be hybrid. An em or component of such controllers over the network of tremely practical f	6 ording to logical volution in buntable or finite odelling and nd the industrial evaluating the s with hybrid only when some ramework for
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BE3M35PSR Real-time Systems Programming	Z.ZK	6
The goal of this course is to provide students with basic knowledge about software development for real-time systems, for example in control and en	,	ons. The main
focus is on embedded systems equipped with a real-time operating system (RTOS). Lectures will cover real-time systems theory, which can be used to		
such systems. Another set of lectures will introduce methods and techniques used for development of safety-critical systems, whose failure may have		•
During labs, students will first solve a few simple tasks to familiarize them with basic components of VxWorks RTOS and to benchmark the used OS		
obtained metrics represent the typical criteria for assessing the suitability of a given platform for the given application. After the simple tasks, student	,	
time-critical motion control application which will require full utilization of RTOS features. All the tasks at the labs will be implemented in C (or C++) la		
BE4M33TDV Three-dimensional Computer Vision	Z,ZK	6
This course introduces methods and algorithms for 3D geometric scene reconstruction from images. The student will understand these methods and	their essence we	ell enough to be
able to build variants of simple systems for reconstruction of 3D objects from a set of images or video, for inserting virtual objects to video-signal sou	Irce, or for compu	iting ego-motion
trajectory from a sequence of images. The labs will be hands-on, the student will be gradually building a small functional 3D scene reconstruction sy	stem and using it	to compute a
virtual 3D model of an object of his/her choice.		
BE3M38VBM1 Videometry and Contactless Measurement	Z,ZK	6
The course deals with optoelectronic sensors and their use in non-contact measurement systems based on the principles of videometry; problems of rad	diation and waves	, their properties,
behavior; optical projection system. The course deals with the lab. tasks, it is further solved, practically realized and presented the evaluated project	of the optoelectric	c sensor.
BE3M38VIN1 Virtual Instrumentation	Z,ZK	6
The subject deals with modern measuring instruments, virtual instruments (VI) and data acquisition and processing systems (DAQ). It presents principle	s of instruments a	nd measurement
systems in laboratory and industrial environment, selected measurement methods and standards for programming of VI and DAQ systems.		
Name of the block: Elective courses		

Name of the block: Elective courses Minimal number of credits of the block: 0 The role of the block: V

Code of the group: 2021_MKYREVOL

Name of the group: Elective subjects

Requirement credits in the group:

Requirement courses in the group:

Credits in the group: 0

Note on the group: ~Student can choose arbitrary subject of themagister's program (EEM - Electrical Engineering, Power Engineering and Management, EK - Electronics and Communications, KYR - Cybernetics and Robotics, OI - Open Informatics, OES - Open Electronics Systems) which is not part of his curriculum. Student can choose with consideration of recommendation of the branch guarantee.You can find a selection of optional courses organized by the departments on the web site http://www.fel.cvut.cz/cz/education/volitelne-predmety.html

List of courses of this pass:

Code	Name of the course	Completion	Credits
BDIP30	Diploma Thesis	Z	30
Independent final of	comprehensive work for the Master's degree study programme. A student will choose a topic from a range of topics related to his or r	ner branch of study	, which will
be specified b	y branch department or branch departments. The diploma thesis will be defended in front of the board of examiners for the comprehe	ensive final examir	nation.
BE2M32MKSA	Mobile Networks	Z,ZK	6
The lectures introc	uce principles and functionalities of mobile networks with special focus on currently deployed technologies and future mobile networ	ks. Furthermore, a	rchitecture
and fundamental principles of GSM, UMTS, LTE/LTE-A, and 5G will be explained. Then, selected key technologies for future mobile networks (6G) will be explained.			
BE3M33ARO1	Autonomous Robotics	Z,ZK	6
The Autonomous	robotics course will explain the principles needed to develop algorithms for intelligent mobile robots such as algorithms for: (1) Mapping	ing and localizatio	n (SLAM)
sensors calibration	(lidar or camera). (2) Planning the path in the existing map or planning the exploration in a partially unknown map and performing the p	lan in the world. IN	IPORTANT:
It is assumed that st	udents of this course have a working knowledge of optimization (Gauss-Newton method, Levenberg Marquardt method, full Newton m	ethod), mathemati	cal analysis
(gradient, Jacobia	n, Hessian), linear algebra (least-squares method), probability theory (multivariate gaussian probability), statistics (maximum likeliho	od and maximum a	aposteriori
estimate), python p	rogramming and machine learning algorithms. This course is also part of the inter-university programme prg.ai Minor. It pools the bes	st of AI education i	n Prague to
	provide students with a deeper and broader insight into the field of artificial intelligence. More information is available at https://prg.	ai/minor.	
BE3M33HRO	Humanoid robots	Z,ZK	6
The course focus	es on human-centered robotics: humanoid robots and human-robot interaction. Motivated by the vision of robot companions in our ho	omes, this course i	ntroduces
	hnology and its specific challenges and opportunities: (i) design, kinematics and inverse kinematics of humanoids, (ii) multimodal se	e .	
inertial sensing, etc	, (iii) walking and balancing, and (ii) grasping. The second part of the course centers on human-robot interaction (HRI), which includes	s physical HRI (saf	ety aspects,
	collaborative robots) and cognitive/social HRI - how to design robots and behaviors to be acceptable for people.		
BE3M33MRS	Multi-robot aerial systems	Z,ZK	6
The course offers the	ne introduction to multirotor autonomous aerial systems (UAV). Standard senzors and principles of estimate and control of UAV will b	e introduced. The	problems of
motion	planning, path planning, localization, mapping and exploration will be discussed for sigle moving UAV as well as multiple UAVs movi	ng in a formation.	
BE3M33PKR	Advanced robot kinematics	Z,ZK	6
We will explain and	demonstrate techniques for modelling, analyzing and identifying robot kinematics. We will explain more advanced principles of the rep	resentation of mot	ion in space
and the robot descr	iptions suitable for identification of kinematic parameters from measured data. We will explain how to solve the inverse kinematic tas	k of 6DOF serial m	nanipulators
а	nd how it can be used to identify its kinematic parameters. Theory will be demonstrated on simulated tasks and verified on a real indu	ustrial robot.	

BE3M35DRS	Dynamics and Control of Networks	Z,ZK	6
This course resp	bonds to an ever-increasing demand for understanding contemporary networks large-scale complex systems composed of many con	· · ·	1
interconnected into	a single distributed entity. Herein, we will consider fundamental similarities between diverse areas such as e.g. forecasting the sprea	ad of global pander	mics, public
opinion dynamics ar	d manipulation of communities through social media, formation controls for unmanned vehicles, energy generation and distribution in p	oower grids, etc. Un	derstanding
	sues goes far beyond the boundaries of any single physical, technological or scientific domain. Therefore, we will analyze phenome		
0 ,	economic and biological networks. For such networked systems, the resulting behavior depends not only on the characteristics of the		
	sical or logical interactions, but also on a precise way those components are interconnected the detailed interconnection topology. For		-
	ces fundamental theoretical and abstract computational network analysis concepts; in particular, the algebraic graph theory, network		
fundamental netwo	rk algorithms. The second part of the course subsequently views networks as dynamical systems, studies their properties and ways using mainly methods of automatic control theory.	in which these are	e controlled,
BE3M35HYS	Hybrid Systems	Z,ZK	6
	rstems, sometimes also referred to as cyber-physical systems, contain both subsystems governed by physical laws and subsystems		
	tions, often encoded in the form of algorithms and implemented in software. The behaviour of the former can be described by real qu		
•	te time is commonly modelled by differential or difference equations. The behaviour of the latter is commonly described by quantities		
	(or even just two in the case of binary quantities), whose evolution is modelled by logical models such as finite state automata or Pe	0	
analysis of hybrid s	ystems and the design of control systems for them, these two classes of models intersect. However, the control system itself can als	o be hybrid. And th	ne industrial
reality is that pract	cal control systems contain, in addition to the continuous subsystems represented by PID controllers or Kalman filters, a subsystem	or component eva	aluating the
•	c conditions. Switched linear controllers (gain scheduling), supervisory control, sliding mode control or reset control are examples of		
	ontrol methods are also becoming particularly important in a networked environment, where measurements or controls are sent ove		
	n order to minimize network traffic (event triggered control). Hybrid dynamical systems thus represent a suitable theoretical and extre		
modelling, analysis	and synthesis of a large number of practical control systems. The aim of this advanced course is to help students acquire basic com practical design/computational skills) in this practically very relevant and theoretically still intensively developed area.	ipetences (knowled	age but also
BE3M35KOA	Combinatorial Algorithms	Z,ZK	6
1	the problems and algorithms of combinatorial optimization (often called discrete optimization; there is a strong overlap with the term c		-
•	ear algebra, graph theory, and basics of optimization, we show optimization techniques based on graphs, integer linear programmin	•	, .
	ate space search methods. We focus on application of optimization in stores, ground transportation, flight transportation, logistics, pl		
	scheduling in production lines, message routing, scheduling in parallel computers.	3	,
BE3M35LSY1	Linear Systems	Z.ZK	6
1	s course is to introduce mathematical tools for the description, analysis, and partly also synthesis, of dynamical systems. The focus v	· ·	1
multi-input multi-ou	tput systems and their properties such as stability, controllability, observability and state realization. State feedback, state estimation	, and the design of	f stabilizing
controllers will be ex	plained in detail. Partially covered will be also time-varying and nonlinear systems. Some of the tools introduced in this course are re	adily applicable to	engineering
problems such as t	he analysis of controllability and observability in the design of flexible space structures, the design of state feedback in aircraft contri	ol, and the estimat	ion of state
variables. The main	motivation, however, is to pave the way for the advanced courses of the study program. The prerequsites for this course include under	ergraduate level lin	ear algebra,
	differential equations, and Laplace and z transforms.		
BE3M35NES	Nonlinear Systems	Z,ZK	6
-	se is to introduce basics of the modern approaches to the theory and applications of nonlinear control. Fundamental difference when	dealing with nonline	ear systems
control compared w	with linear case is that the state space approach provoils. Indeed, the frequency response approach is almost usaless in poplingar or	ntrol State space	-
	rith linear case is that the state space approach prevails. Indeed, the frequency response approach is almost useless in nonlinear co inary differential equations, therefore, an introduction to solving these equations is part of the course. More importantly, the qualitative r		models are
based mainly on ord	inary differential equations, therefore, an introduction to solving these equations is part of the course. More importantly, the qualitative n	nethods for ordinar	models are y differential
based mainly on ord equations will be pre-		nethods for ordinar o analyse stability	models are y differential of nonlinear
based mainly on ord equations will be pro systems, not only	inary differential equations, therefore, an introduction to solving these equations is part of the course. More importantly, the qualitative newsented, among them Lyapunov stability theory is crucial. More specifically, the focus will be on Lyapunov function method enabling t	nethods for ordinar o analyse stability unction concept ar	models are y differential of nonlinear nd related
based mainly on ord equations will be pro systems, not only backstepping meth	inary differential equations, therefore, an introduction to solving these equations is part of the course. More importantly, the qualitative n esented, among them Lyapunov stability theory is crucial. More specifically, the focus will be on Lyapunov function method enabling t that of linear ones. Furthemore, stabilization desing methods will be studied in detail, among them the so-called control Lyapunov f	nethods for ordinar o analyse stability unction concept ar odels to simpler fo	models are y differential of nonlinear nd related rms where
based mainly on ord equations will be pro- systems, not only backstepping meth more standard linea	inary differential equations, therefore, an introduction to solving these equations is part of the course. More importantly, the qualitative n esented, among them Lyapunov stability theory is crucial. More specifically, the focus will be on Lyapunov function method enabling to that of linear ones. Furthemore, stabilization desing methods will be studied in detail, among them the so-called control Lyapunov f nod. Special stress will be, nevertheless, given by this course to introduce and study methods how to transform complex nonlinear m ar methods would be applicable. Such an approach is usually refered to as the so-called exact nonlinearity compensation. Contrary t nethod does not ignore nonlinearities but compensates them up to the best possible extent. The course introduces some interesting	nethods for ordinar o analyse stability unction concept ar odels to simpler fo o the well-known a	models are y differential of nonlinear nd related rms where approximate
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BE3M38INA1 Integrated avionics	Z,ZK	6
The course Integrated Modular Avionics (IMA) focuses on a modern concept of the approach to the development and design of aircraft electronics	(avionics), where the tra	nsition from
distributed HW systems to SW blocks. They use high-speed connections to exchange data in applications related to paid air transport. The existing regulatory basis and airspace		
sharing define the requirements for the accuracy, reliability, and functionality of electronic systems even in the event of a failure. In the course, students will learn details about the		
requirements for so-called safety-critical multi-sensor systems, methods of data processing from predetermined systems, fault detection methods, selection of primary computer and		
control system in parallel architectures, bus technology, and methods of testing/certification of aircraft instrumen	nts.	
BE3M38POS Advanced sensors	Z,ZK	6
Overview of sensors of physical quantities used in industry and research and associated methods of signal processing. Students will gain advanced	d knowledge of sensors a	nd methods
of signal processing. They will gain practical experience with measurement of physical quantities with various types of		
BE3M38PSL1 Aircraft Avionics	Z,ZK	6
The course acquaints students with the current technology used in aircraft instruments and unmanned aerial vehicles, ie systems and sensors wo	rking in the low frequenc	y range and
methods used to process their data. The course includes a detailed description of aircraft instrumentation and its resistance to external influences, a description of aircraft power sources,		
analysis of instruments and systems for measuring engine and aerometric quantities, and a description of emergency and operational diagnostics. The course also deals with the field		
of inertial navigation aids, used sensors and systems, their modeling and description. It analyzes in detail the principles of calculations of navigation equations, including methods of		
fusion of navigation data and their processing.		
BE3M38SPD1 Data acquisition and transfer	Z,ZK	6
The aim of the course is to acquaint students with the principles and limits of data transmission from sensors and similar sources of information		
wireless sensor networks, and specific algorithms used in them, respecting the limiting conditions of their function. The basic algorithms of distributed information processing in sensor		
networks will be studied, as well as technologies for obtaining energy for powering wireless nodes of the networ		
BE3M38VBM1 Videometry and Contactless Measurement	Z,ZK	6
The course deals with optoelectronic sensors and their use in non-contact measurement systems based on the principles of videometry; problems of		
behavior; optical projection system. The course deals with the lab. tasks, it is further solved, practically realized and presented the evaluated project of the optoelectric sensor.		
BE3M38VIN1 Virtual Instrumentation	Z,ZK	6
The subject deals with modern measuring instruments, virtual instruments (VI) and data acquisition and processing systems (DAQ). It presents princip	oles of instruments and m	easurement
systems in laboratory and industrial environment, selected measurement methods and standards for programming of VI and	DAQ systems.	
BE3M38ZDS1 Signal processing and digitization	Z,ZK	6
Students will gain knowledge for the design and implementation of systems for processing and digitization of analog signals. They will deepen the	he knowledge acquired ir	n previous
theoretical subject and gain practical experience in the design and analysis of systems for signal processing, AD conversion and data acquisitation	on. Emphasis is placed o	n reducing
uncortaintias, speed, stability and resistance to interfering signals		
uncertainties, speed, stability and resistence to interfering signals.		
BE3MPROJ6 Project	Z	6
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BE3MPROJ6 Project BE3MPVTY1 Teamwork Teamwork is the basis of most of the activities that people perform in companies and their personal lives. In this course, students can try how to sto cooperate, how to communicate together and how to solve problems such as project delays, how to include external influence	Z solve a technical task in a	6
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