Study plan

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:

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, Vojtěch Vonásek* ***Karel Zimmermann*** *Karel Zimmermann (Gar.)*	Z,ZK	6	2P+2L	L	P
BE3M38DIT1	**Diagnostics and Testing** *Radislav Šmíd* ***Radislav Šmíd*** *Radislav Šmíd (Gar.)*	Z,ZK	6	2P+2L	Z	P
BE3M35LSY1	**Linear Systems** *Petr Hušek* ***Petr Hušek*** *Petr Hušek (Gar.)*	Z,ZK	6	3P+2S	Z	P
BE3MPROJ6	**Project**	Z	6	0p+6s	Z	P
BE3MPVTY1	**Teamwork** *Tomáš Drábek, Tomáš Haniš, Petr Drábek, Ondřej Drbohlav* ***Ondřej Drbohlav*** *Tomáš Drábek (Gar.)*	Z	6	0P+4C	L	P

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

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 and localization (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 plan in the world. IMPORTANT: It is assumed that students of this course have a working knowledge of optimization (Gauss-Newton method, Levenberg Marquardt method, full Newton method), mathematical analysis (gradient, Jacobian, Hessian), linear algebra (least-squares method), probability theory (multivariate gaussian probability), statistics (maximum likelihood and maximum aposteriori estimate), python programming and machine learning algorithms. This course is also part 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 of artificial intelligence. More information is available at https://prg.ai/minor.

BE3M38DIT1	Diagnostics and Testing	Z,ZK	6

The course aims to introduce students to the problems of modelling and fault detection, ensuring fault tolerance, monitoring the operational status of complex industrial components and autonomous systems, non-destructive testing and diagnostics of electronic devices with analogue and digital circuits.

BE3M35LSY1	Linear Systems	Z,ZK	6

The purpose of this course is to introduce mathematical tools for the description, analysis, and partly also synthesis, of dynamical systems. The focus will be on linear time-invariant multi-input multi-output systems and their properties such as stability, controllability, observability and state realization. State feedback, state estimation, and the design of stabilizing controllers will be explained in detail. Partially covered will be also time-varying and nonlinear systems. Some of the tools introduced in this course are readily applicable to engineering problems such as the analysis of controllability and observability in the design of flexible space structures, the design of state feedback in aircraft control, and the estimation 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 undergraduate level linear algebra, differential equations, and Laplace and z transforms.

BE3MPROJ6	Project	Z	6
BE3MPVTY1	Teamwork	Z	6

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 solve a technical task in a team, how to cooperate, how to communicate 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	P

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

BDIP30	Diploma Thesis	Z	30

Independent final comprehensive work for the Master's degree study programme. A student will choose a topic from a range of topics related to his or her branch of study, 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, Jiří Matas, Jan Čech, Dmytro Mishkin, Torsten Sattler* ***Jiří Matas*** *Jiří Matas (Gar.)*	Z,ZK	6	2P+2C	L	PV
BE3M38SPD1	**Data acquisition and transfer** *Radislav Šmíd* ***Radislav Šmíd*** *Radislav Šmíd (Gar.)*	Z,ZK	6	2P+2L	L	PV
BE3M35OFD	**Estimation, Filtering and Detection** *Vladimír Havlena* ***Vladimír Havlena*** *Vladimír Havlena (Gar.)*	Z,ZK	6	2P+2C	Z	PV
BECM33MLF	**Machine Learning Fundamentals** *Vojtěch Franc* ***Vojtěch Franc*** *Vojtěch Franc (Gar.)*	Z,ZK	6	2P+2C	L,Z	PV
BE3M35ORR	**Optimal and Robust Control** *Zdeněk Hurák* ***Zdeněk Hurák*** *Zdeněk 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

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 core computer vision problems: search for correspondences between images, 3D reconstruction, object detection, recognition, segmentation of objects in images and videos, image retrieval from large databases and tracking of objects in video sequences. In the labs, the students implement selected methods and test performance on real-world problems. This course is also part 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 of artificial intelligence. 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 IoT and M2M communication, 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 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 and methods for their estimation. Based on bayesian problem formulation principles of rational behavior under uncertainty will be analyzed and used to develop algorithms for parameter estimations (ARX models, Gaussian process regression), filtering (Kalman filter) and detection (likelihood ratio theory) . We will demonstrate numerically robust implementation of the algorithms applicable in real life problems for the areas of industrial process control, robotics and avionics.

BECM33MLF	Machine Learning Fundamentals	Z,ZK	6

The aim of this course is to provide a comprehensive understanding of the fundamental principles underlying machine learning algorithms and to explain their use in basic machine learning algorithms. The goal of statistical machine learning is to design systems incorporating models and algorithms capable of learning to solve problems based on the examples provided and prior knowledge of the problem. This course is designed with two main objectives. First, it seeks to clarify the basic principles of learning, such as risk minimization, maximum likelihood learning, and Bayesian learning, and to delve into their theoretical foundations. Second, it seeks to explore the basic models for classification and regression and show how these models can be effectively learned by applying these basic concepts.

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 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 acquired 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 placed on reducing uncertainties, speed, stability and resistence to interfering signals.			

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** *Tomáš Pajdla* ***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* ***Martin Šipoš*** *Martin Šipoš (Gar.)*	Z,ZK	6	2P+2L	Z	PV
BE4M36UIR	**Artificial Intelligence in Robotics** *Jan Faigl* ***Jan Faigl*** *Jan Faigl (Gar.)*	Z,ZK	6	2P+2C	Z	PV
BE3M35RSA	**Automotive Control Systems** *Tomáš Haniš* ***Tomáš Haniš*** *Tomáš Haniš (Gar.)*	Z,ZK	6	2P+2S		PV
BE3M38ASE	**Automotive sensors and networks** *Antonín Platil, Jan Sobotka, Jiří Novák* ***Jiří Novák*** *Jiří Novák (Gar.)*	Z,ZK	6	2P+2L	L	PV
BE3M35KOA	**Combinatorial Algorithms** *Zdeněk Hanzálek* ***Zdeněk Hanzálek*** *Zdeněk 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 Hromčík* ***Martin Hromčík*** *Martin Hromčík (Gar.)*	Z,ZK	6	2P+2L	Z	PV
BE3M33HRO	**Humanoid robots** *Giulia D´Angelo, Matěj Hoffmann, Lukáš Rustler* ***Matěj Hoffmann*** *Matěj Hoffmann (Gar.)*	Z,ZK	6	2P+2C	L	PV
BE3M35HYS	**Hybrid Systems** *Zdeněk Hurák* ***Zdeněk Hurák*** *Zdeněk Hurák (Gar.)*	Z,ZK	6	2P+2C		PV
BE3M38INA1	**Integrated avionics** *Martin Šipoš* ***Martin Šipoš*** *Martin Šipoš (Gar.)*	Z,ZK	6	2P+2L	L	PV
BE2M32MKSA	**Mobile Networks** *Robert Bešťák, Zdeněk Bečvář, Pavel Mach* ***Pavel Mach*** *Zdeněk Bečvář (Gar.)*	Z,ZK	6	2P + 2L	Z	PV
BE3M33MRS	**Multi-robot aerial systems** *Tomáš Báča, Martin Saska, Robert Pěnička* ***Martin Saska*** *Martin Saska (Gar.)*	Z,ZK	6	2P+2L	Z	PV
BE3M35NES	**Nonlinear Systems** *Kristian Hengster-Movric, Sergej Čelikovský* ***Sergej Čelikovský*** *Sergej Čelikovský (Gar.)*	Z,ZK	6	2P+2C	Z	PV
BE3M35PSR	**Real-time Systems Programming** *Michal Sojka* ***Ján Tomlain***	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 Roztočil* ***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
The course will explain and demonstrate theoretical and computational methods for describing and analyzing the kinematics of industrial robots, the principles of representing spatial motionrotation matrices, quaternions, Euler vectors, and Cayley parametrizationand robot description using the DenavitHartenberg convention for the kinematic analysis of manipulators. The main topics will be: a) solving the inverse kinematics problem for a general 6-DOF serial manipulator, and b) analyzing its singularities. The fundamental theoretical and computational tools will be linear and polynomial algebra, as well as methods of computational algebraic geometry. The theoretical techniques will be verified through implementation tasks using simulations. The course is theoretical and suitable for students interested in mathematics and interested in pursuing an academic career.			
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 knowledge of sensors and methods of signal processing. They will gain practical experience with measurement of physical quantities with various types of sensors.			

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 working in the low frequency 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.

BE4M36UIR	Artificial Intelligence in Robotics	Z,ZK	6

The course aims to acquaint students with the use of planning approaches and decision-making techniques of artificial intelligence for solving problems arising in autonomous robotic systems. Students in the course are employing knowledge of planning algorithms, game theory, and solving optimization problems in selected application scenarios of mobile robotics. Students first learn architectures of autonomous systems based on reactive and behavioral models of autonomous systems. The considered application scenarios and robotic problems include path planning, persistent environmental monitoring, robotic exploration of unknown environments, online real-time decision-making, deconfliction in autonomous systems, and solutions of antagonistic conflicts. In laboratory exercises, students practice their problem formulations of robotic challenges and practical solutions in a realistic robotic simulator or consumer mobile robots. This course is also part 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 of artificial intelligence. More information is available at https://prg.ai/minor.

BE3M35RSA	Automotive Control Systems	Z,ZK	6

The course introduces students to the fundamentals of control systems in modern automobiles. Students will learn basic methods for modeling vehicle dynamics, gain an overview of the main vehicle components, and become familiar with the principles of control algorithms for driver assistance and autonomous systems. The course combines theoretical lectures with practical demonstrations of selected systems, such as ABS, traction control, adaptive cruise control, ESC, and lane-keeping systems.

BE3M38ASE	Automotive sensors and networks	Z,ZK	6

The course provides students with a deeper insight into the functional principles of advanced sensor systems in cars, methods of signal processing in sensors and explains how to use them in vehicle subsystems. It also deals with distributed vehicle systems for real-time control and methods of their testing. Theoretical lectures are complemented by practical laboratory teaching with real elements (ECUs, sensors) of modern vehicles.

BE3M35KOA	Combinatorial Algorithms	Z,ZK	6

The goal is to show the problems and algorithms of combinatorial optimization (often called discrete optimization; there is a strong overlap with the term operations research). Following the courses on linear algebra, graph theory, and basics of optimization, we show optimization techniques based on graphs, integer linear programming, heuristics, approximation algorithms and state space search methods. We focus on application of optimization in stores, ground transportation, flight transportation, logistics, planning of human resources, scheduling in production lines, message routing, scheduling in parallel computers.

BE3M35DRS	Dynamics and Control of Networks	Z,ZK	6

This course responds to an ever-increasing demand for understanding contemporary networks large-scale complex systems composed of many components and subsystems interconnected into a single distributed entity. Herein, we will consider fundamental similarities between diverse areas such as e.g. forecasting the spread of global pandemics, public opinion dynamics and manipulation of communities through social media, formation controls for unmanned vehicles, energy generation and distribution in power grids, etc. Understanding such compelling issues goes far beyond the boundaries of any single physical, technological or scientific domain. Therefore, we will analyze phenomena across different domains, involving societal, economic and biological networks. For such networked systems, the resulting behavior depends not only on the characteristics of their individual components 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, the first part of the course introduces fundamental theoretical and abstract computational network analysis concepts; in particular, the algebraic graph theory, network measures and metrics and fundamental network algorithms. The second part of the course subsequently views networks as dynamical systems, studies their properties and ways in which these are controlled, using mainly methods of automatic control theory.

BE3M35SRL	Flight Control Systems	Z,ZK	6

The course is devoted to classical and modern control design techniques for autopilots and flight control systems. Particular levels are discussed, starting with the dampers attitude angle stabilizers, to guidance and navigation systems. Next to the design itself, important aspects of aircraft modelling, both as a rigid body and considering flexibility of the structure, are discussed

BE3M33HRO	Humanoid robots	Z,ZK	6

The course focuses on human-centered robotics: humanoid robots and human-robot interaction. Motivated by the vision of robot companions in our homes, this course introduces humanoid robot technology and its specific challenges and opportunities: (i) design, kinematics and inverse kinematics of humanoids, (ii) multimodal sensing - vision, touch, hearing, inertial sensing, etc., (iii) walking and balancing, and (ii) grasping. The second part of the course centers on human-robot interaction (HRI), which includes physical HRI (safety aspects, collaborative robots) and cognitive/social HRI - how to design robots and behaviors to be acceptable for people.

BE3M35HYS	Hybrid Systems	Z,ZK	6

Hybrid dynamical systems, sometimes also referred to as cyber-physical systems, contain both subsystems governed by physical laws and subsystems behaving according to logical rules and regulations, often encoded in the form of algorithms and implemented in software. The behaviour of the former can be described by real quantities whose evolution in continuous or discrete time is commonly modelled by differential or difference equations. The behaviour of the latter is commonly described by quantities taking on a countable or finite number of values (or even just two in the case of binary quantities), whose evolution is modelled by logical models such as finite state automata or Petri nets. In the modelling and analysis of hybrid systems and the design of control systems for them, these two classes of models intersect. However, the control system itself can also be hybrid. And the industrial reality is that practical control systems contain, in addition to the continuous subsystems represented by PID controllers or Kalman filters, a subsystem or component evaluating the satisfaction of logic conditions. Switched linear controllers (gain scheduling), supervisory control, sliding mode control or reset control are examples of such controllers with hybrid dynamics. Hybrid control methods are also becoming particularly important in a networked environment, where measurements or controls are sent over the network only when some condition is met, in order to minimize network traffic (event triggered control). Hybrid dynamical systems thus represent a suitable theoretical and extremely practical framework for modelling, analysis and synthesis of a large number of practical control systems. The aim of this advanced course is to help students acquire basic competences (knowledge but also practical design/computational skills) in this practically very relevant and theoretically still intensively developed area.

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 transition 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 instruments.

BE2M32MKSA	Mobile Networks	Z,ZK	6

The lectures introduce principles and functionalities of mobile networks with special focus on currently deployed technologies and future mobile networks. Furthermore, architecture 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.

BE3M33MRS	Multi-robot aerial systems	Z,ZK	6

The course offers the introduction to multirotor autonomous aerial systems (UAV). Standard senzors and principles of estimate and control of UAV will be introduced. The problems of motion planning, path planning, localization, mapping and exploration will be discussed for sigle moving UAV as well as multiple UAVs moving in a formation.

BE3M35NES	Nonlinear Systems	Z,ZK	6
The goal of this course is to introduce basics of the modern approaches to the theory and applications of nonlinear control. Fundamental difference when dealing with nonlinear systems control compared with linear case is that the state space approach prevails. Indeed, the frequency response approach is almost useless in nonlinear control. State space models are based mainly on ordinary differential equations, therefore, an introduction to solving these equations is part of the course. More importantly, the qualitative methods for ordinary differential equations will be presented, among them Lyapunov stability theory is crucial. More specifically, the focus will be on Lyapunov function method enabling to analyse stability of nonlinear systems, not only that of linear ones. Furthermore, stabilization desing methods will be studied in detail, among them the so-called control Lyapunov function concept and related backstepping method. Special stress will be, nevertheless, given by this course to introduce and study methods how to transform complex nonlinear models to simpler forms where more standard linear methods would be applicable. Such an approach is usually refered to as the so-called exact nonlinearity compensation. Contrary to the well-known approximate linearization this method does not ignore nonlinearities but compensates them up to the best possible extent. The course introduces some interesting case studies as well, e.g. the planar vertical take off and landing plane ("planar VTOL"), or a simple 2-dimensional model of the walking robot.			
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 embedded applications. 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 formally verify timing correctness such systems. Another set of lectures will introduce methods and techniques used for development of safety-critical systems, whose failure may have catastrophic consequences. 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 and hardware (Xilinx Zynq). The obtained metrics represent the typical criteria for assessing the suitability of a given platform for the given application. After the simple tasks, students will solve complex task of 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++) language.			
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 well 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 source, or for computing 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 system 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 radiation 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 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 principles of instruments and 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
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 comprehensive work for the Master's degree study programme. A student will choose a topic from a range of topics related to his or her branch of study, 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.			
BE2M32MKSA	Mobile Networks	Z,ZK	6
The lectures introduce principles and functionalities of mobile networks with special focus on currently deployed technologies and future mobile networks. Furthermore, architecture 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 and localization (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 plan in the world. IMPORTANT: It is assumed that students of this course have a working knowledge of optimization (Gauss-Newton method, Levenberg Marquardt method, full Newton method), mathematical analysis (gradient, Jacobian, Hessian), linear algebra (least-squares method), probability theory (multivariate gaussian probability), statistics (maximum likelihood and maximum aposteriori estimate), python programming and machine learning algorithms. This course is also part 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 of artificial intelligence. More information is available at https://prg.ai/minor.			

BE3M33HRO	Humanoid robots	Z,ZK	6
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BE3M33PKR	Advanced robot kinematics	Z,ZK	6
The course will explain and demonstrate theoretical and computational methods for describing and analyzing the kinematics of industrial robots, the principles of representing spatial motionrotation matrices, quaternions, Euler vectors, and Cayley parametrizationand robot description using the DenavitHartenberg convention for the kinematic analysis of manipulators. The main topics will be: a) solving the inverse kinematics problem for a general 6-DOF serial manipulator, and b) analyzing its singularities. The fundamental theoretical and computational tools will be linear and polynomial algebra, as well as methods of computational algebraic geometry. The theoretical techniques will be verified through implementation tasks using simulations. The course is theoretical and suitable for students interested in mathematics and interested in pursuing an academic career.			
BE3M35DRS	Dynamics and Control of Networks	Z,ZK	6
This course responds to an ever-increasing demand for understanding contemporary networks large-scale complex systems composed of many components and subsystems interconnected into a single distributed entity. Herein, we will consider fundamental similarities between diverse areas such as e.g. forecasting the spread of global pandemics, public opinion dynamics and manipulation of communities through social media, formation controls for unmanned vehicles, energy generation and distribution in power grids, etc. Understanding such compelling issues goes far beyond the boundaries of any single physical, technological or scientific domain. Therefore, we will analyze phenomena across different domains, involving societal, economic and biological networks. For such networked systems, the resulting behavior depends not only on the characteristics of their individual components 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, the first part of the course introduces fundamental theoretical and abstract computational network analysis concepts; in particular, the algebraic graph theory, network measures and metrics and fundamental network algorithms. The second part of the course subsequently views networks as dynamical systems, studies their properties and ways in which these are controlled, using mainly methods of automatic control theory.			
BE3M35HYS	Hybrid Systems	Z,ZK	6
Hybrid dynamical systems, sometimes also referred to as cyber-physical systems, contain both subsystems governed by physical laws and subsystems behaving according to logical rules and regulations, often encoded in the form of algorithms and implemented in software. The behaviour of the former can be described by real quantities whose evolution in continuous or discrete time is commonly modelled by differential or difference equations. The behaviour of the latter is commonly described by quantities taking on a countable or finite number of values (or even just two in the case of binary quantities), whose evolution is modelled by logical models such as finite state automata or Petri nets. In the modelling and analysis of hybrid systems and the design of control systems for them, these two classes of models intersect. However, the control system itself can also be hybrid. And the industrial reality is that practical control systems contain, in addition to the continuous subsystems represented by PID controllers or Kalman filters, a subsystem or component evaluating the satisfaction of logic conditions. Switched linear controllers (gain scheduling), supervisory control, sliding mode control or reset control are examples of such controllers with hybrid dynamics. Hybrid control methods are also becoming particularly important in a networked environment, where measurements or controls are sent over the network only when some condition is met, in order to minimize network traffic (event triggered control). Hybrid dynamical systems thus represent a suitable theoretical and extremely practical framework for modelling, analysis and synthesis of a large number of practical control systems. The aim of this advanced course is to help students acquire basic competences (knowledge but also practical design/computational skills) in this practically very relevant and theoretically still intensively developed area.			
BE3M35KOA	Combinatorial Algorithms	Z,ZK	6
The goal is to show the problems and algorithms of combinatorial optimization (often called discrete optimization; there is a strong overlap with the term operations research). Following the courses on linear algebra, graph theory, and basics of optimization, we show optimization techniques based on graphs, integer linear programming, heuristics, approximation algorithms and state space search methods. We focus on application of optimization in stores, ground transportation, flight transportation, logistics, planning of human resources, scheduling in production lines, message routing, scheduling in parallel computers.			
BE3M35LSY1	Linear Systems	Z,ZK	6
The purpose of this course is to introduce mathematical tools for the description, analysis, and partly also synthesis, of dynamical systems. The focus will be on linear time-invariant multi-input multi-output systems and their properties such as stability, controllability, observability and state realization. State feedback, state estimation, and the design of stabilizing controllers will be explained in detail. Partially covered will be also time-varying and nonlinear systems. Some of the tools introduced in this course are readily applicable to engineering problems such as the analysis of controllability and observability in the design of flexible space structures, the design of state feedback in aircraft control, and the estimation 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 undergraduate level linear algebra, differential equations, and Laplace and z transforms.			
BE3M35NES	Nonlinear Systems	Z,ZK	6
The goal of this course is to introduce basics of the modern approaches to the theory and applications of nonlinear control. Fundamental difference when dealing with nonlinear systems control compared with linear case is that the state space approach prevails. Indeed, the frequency response approach is almost useless in nonlinear control. State space models are based mainly on ordinary differential equations, therefore, an introduction to solving these equations is part of the course. More importantly, the qualitative methods for ordinary differential equations will be presented, among them Lyapunov stability theory is crucial. More specifically, the focus will be on Lyapunov function method enabling to analyse stability of nonlinear systems, not only that of linear ones. Furthemore, stabilization desing methods will be studied in detail, among them the so-called control Lyapunov function concept and related backstepping method. Special stress will be, nevertheless, given by this course to introduce and study methods how to transform complex nonlinear models to simpler forms where more standard linear methods would be applicable. Such an approach is usually refered to as the so-called exact nonlinearity compensation. Contrary to the well-known approximate linearization this method does not ignore nonlinearities but compensates them up to the best possible extent. The course introduces some interesting case studies as well, e.g. the planar vertical take off and landing plane ("planar VTOL"), or a simple 2-dimensional model of the walking robot.			
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 and methods for their estimation. Based on bayesian problem formulation principles of rational behavior under uncertainty will be analyzed and used to develop algorithms for parameter estimations (ARX models, Gaussian process regression), filtering (Kalman filter) and detection (likelihood ratio theory) . We will demonstrate numerically robust implementation of the algorithms 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 complex problem assignments.			
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 embedded applications. 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 formally verify timing correctness such systems. Another set of lectures will introduce methods and techniques used for development of safety-critical systems, whose failure may have catastrophic consequences. 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 and hardware (Xilinx Zynq). The obtained metrics represent the typical criteria for assessing the suitability of a given platform for the given application. After the simple tasks, students will solve complex task of 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++) language.			

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<tr><td>BE3M35RSA</td><td>Automotive Control Systems</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course introduces students to the fundamentals of control systems in modern automobiles. Students will learn basic methods for modeling vehicle dynamics, gain an overview of the main vehicle components, and become familiar with the principles of control algorithms for driver assistance and autonomous systems. The course combines theoretical lectures with practical demonstrations of selected systems, such as ABS, traction control, adaptive cruise control, ESC, and lane-keeping systems.</td></tr>
<tr><td>BE3M35SRL</td><td>Flight Control Systems</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course is devoted to classical and modern control design techniques for autopilots and flight control systems. Particular levels are discussed, starting with the dampers attitude angle stabilizers, to guidance and navigation systems. Next to the design itself, important aspects of aircraft modelling, both as a rigid body and considering flexibility of the structure, are discussed</td></tr>
<tr><td>BE3M38ASE</td><td>Automotive sensors and networks</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course provides students with a deeper insight into the functional principles of advanced sensor systems in cars, methods of signal processing in sensors and explains how to use them in vehicle subsystems. It also deals with distributed vehicle systems for real-time control and methods of their testing. Theoretical lectures are complemented by practical laboratory teaching with real elements (ECUs, sensors) of modern vehicles.</td></tr>
<tr><td>BE3M38DIT1</td><td>Diagnostics and Testing</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course aims to introduce students to the problems of modelling and fault detection, ensuring fault tolerance, monitoring the operational status of complex industrial components and autonomous systems, non-destructive testing and diagnostics of electronic devices with analogue and digital circuits.</td></tr>
<tr><td>BE3M38INA1</td><td>Integrated avionics</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">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 transition 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 instruments.</td></tr>
<tr><td>BE3M38POS</td><td>Advanced sensors</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">Overview of sensors of physical quantities used in industry and research and associated methods of signal processing. Students will gain advanced knowledge of sensors and methods of signal processing. They will gain practical experience with measurement of physical quantities with various types of sensors.</td></tr>
<tr><td>BE3M38PSL1</td><td>Aircraft Avionics</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course acquaints students with the current technology used in aircraft instruments and unmanned aerial vehicles, ie systems and sensors working in the low frequency 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.</td></tr>
<tr><td>BE3M38SPD1</td><td>Data acquisition and transfer</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">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 IoT and M2M communication, 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 network.</td></tr>
<tr><td>BE3M38VBM1</td><td>Videometry and Contactless Measurement</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course deals with optoelectronic sensors and their use in non-contact measurement systems based on the principles of videometry; problems of radiation 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 sensor.</td></tr>
<tr><td>BE3M38VIN1</td><td>Virtual Instrumentation</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The subject deals with modern measuring instruments, virtual instruments (VI) and data acquisition and processing systems (DAQ). It presents principles of instruments and measurement systems in laboratory and industrial environment, selected measurement methods and standards for programming of VI and DAQ systems.</td></tr>
<tr><td>BE3M38ZDS1</td><td>Signal processing and digitization</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">Students will gain knowledge for the design and implementation of systems for processing and digitization of analog signals. They will deepen the knowledge acquired 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 placed on reducing uncertainties, speed, stability and resistence to interfering signals.</td></tr>
<tr><td>BE3MPROJ6</td><td>Project</td><td>Z</td><td>6</td></tr>
<tr><td>BE3MPVTY1</td><td>Teamwork</td><td>Z</td><td>6</td></tr>
<tr><td colspan="4">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 solve a technical task in a team, how to cooperate, how to communicate together and how to solve problems such as project delays, how to include external influences in the plan, etc.</td></tr>
<tr><td>BE4M33MPV</td><td>Computer Vision Methods</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course covers core computer vision problems: search for correspondences between images, 3D reconstruction, object detection, recognition, segmentation of objects in images and videos, image retrieval from large databases and tracking of objects in video sequences. In the labs, the students implement selected methods and test performance on real-world problems. This course is also part 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 of artificial intelligence. More information is available at https://prg.ai/minor.</td></tr>
<tr><td>BE4M33TDV</td><td>Three-dimensional Computer Vision</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">This course introduces methods and algorithms for 3D geometric scene reconstruction from images. The student will understand these methods and their essence well 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 source, or for computing 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 system and using it to compute a virtual 3D model of an object of his/her choice.</td></tr>
<tr><td>BE4M36UIR</td><td>Artificial Intelligence in Robotics</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course aims to acquaint students with the use of planning approaches and decision-making techniques of artificial intelligence for solving problems arising in autonomous robotic systems. Students in the course are employing knowledge of planning algorithms, game theory, and solving optimization problems in selected application scenarios of mobile robotics. Students first learn architectures of autonomous systems based on reactive and behavioral models of autonomous systems. The considered application scenarios and robotic problems include path planning, persistent environmental monitoring, robotic exploration of unknown environments, online real-time decision-making, deconfliction in autonomous systems, and solutions of antagonistic conflicts. In laboratory exercises, students practice their problem formulations of robotic challenges and practical solutions in a realistic robotic simulator or consumer mobile robots. This course is also part 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 of artificial intelligence. More information is available at https://prg.ai/minor.</td></tr>
<tr><td>BECM33MLF</td><td>Machine Learning Fundamentals</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The aim of this course is to provide a comprehensive understanding of the fundamental principles underlying machine learning algorithms and to explain their use in basic machine learning algorithms. The goal of statistical machine learning is to design systems incorporating models and algorithms capable of learning to solve problems based on the examples provided and prior knowledge of the problem. This course is designed with two main objectives. First, it seeks to clarify the basic principles of learning, such as risk minimization,</td></tr>
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maximum likelihood learning, and Bayesian learning, and to delve into their theoretical foundations. Second, it seeks to explore the basic models for classification and regression and show how these models can be effectively learned by applying these basic concepts.

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