# 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:

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

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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, Martin Hlinovský, Petr Drábek, Ondřej Drbohlav, Pavel Mužák, Martin Šipoš **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 |
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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 |
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| BE3MPVTY1 | Teamwork | Z | 6 |
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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.

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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** *Ondřej Drbohlav, Georgios Tolias, Jiří Matas, Jan Čech, Dmytro Mishkin **Ondřej Drbohlav** 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 |
| 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 |
| BE4M33SSU | **Statistical Machine Learning** *Jan Drchal, Vojtěch Franc, Boris Flach **Vojtěch Franc** Boris Flach (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 |
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The course covers selected computer vision problems: search for correspondences between images via interest point detection, description and matching, image stitching, detection, recognition and segmentation of objects in images and videos, image retrieval from large databases and tracking of objects in video sequences. 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 |
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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 |
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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 |
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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.

| BE4M33SSU | Statistical Machine Learning | Z,ZK | 6 |
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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.

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 |
|---|---|---|---|---|---|---|
| BE3M38POS | **Advanced sensors** *Antonín Platil **Antonín Platil** Antonín Platil (Gar.)* | Z,ZK | 6 | 2P+2L | Z | PV |
| BE3M38PSL1 | **Aircraft Avionics** *Martin Šipoš, Jan Roháč **Jan Roháč** Jan Roháč (Gar.)* | Z,ZK | 6 | 2P+2L | Z | PV |
| BE4M36UIR | **Artificial Intelligence in Robotics** *Stefan Edelkamp, Tomáš Kroupa, 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, Jiří Novák, Jan Sobotka **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** *Matěj Hoffmann **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, Jan Roháč **Jan Roháč** Jan Roháč (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** *Robert Pěnička, Tomáš Báča, Martin Saska **Martin Saska** Martin Saska (Gar.)* | Z,ZK | 6 | 2P+2L | Z | PV |
| BE3M35NES | **Nonlinear Systems** *Sergej Čelikovský **Sergej Čelikovský** Sergej Čelikovský (Gar.)* | Z,ZK | 6 | 2P+2C | Z | PV |
| BE3M33PKR | **Advanced robot kinematics** *Tomáš Pajdla **Tomáš Pajdla** Tomáš Pajdla (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** *Jan Fischer **Jan Fischer** Jan Fischer (Gar.)* | 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**

| BE3M38POS | Advanced sensors | Z,ZK | 6 |
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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 |
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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.

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| 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 |
| 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 |
| 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. 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. | | | |
| 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 representation of motion in space and the robot descriptions suitable for identification of kinematic parameters from measured data. We will explain how to solve the inverse kinematic task of 6DOF serial 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. | | | |
| 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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| 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 |
| 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. | | | |
| 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. | | | |
| 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 representation of motion in space and the robot descriptions suitable for identification of kinematic parameters from measured data. We will explain how to solve the inverse kinematic task of 6DOF serial 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. | | | |
| 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 | | | |

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| 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 |
| 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. | | | |
| BE3M35RSA | Automotive Control Systems | Z,ZK | 6 |
| 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 | | | |
| 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. | | | |
| 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. | | | |
| 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. | | | |
| 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. | | | |
| 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. | | | |

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| 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. | | | |
| 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. | | | |
| 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. | | | |
| 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 matching, image stitching, detection, recognition and segmentation of objects in images and videos, image retrieval from large databases and tracking of objects in video sequences. 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. | | | |
| BE4M33SSU | Statistical Machine Learning | Z,ZK | 6 |
| 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. | | | |
| 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. | | | |
| 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. | | | |

For updated information see http://bilakniha.cvut.cz/en/f3.html
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