Studijní plán

Název plánu: Cybernetics and Robotics - Senzors and Instrumention

Součást ČVUT (fakulta/ústav/další): Fakulta elektrotechnická
Katedra: katedra měření
Obor studia, garantovaný katedrou: Senzory a přístrojová technika
Garant oboru studia.: prof. Ing. Pavel Ripka, CSc.
Program studia: Kybernetika a robotika
Typ studia: Navazující magisterské prezenční
Předepsané kredity: 102
Kredity z volitelných předmětů: 18
Kredity v rámci plánu celkem: 120
Poznámka k plánu:

Název bloku: Povinné předměty programu
Minimální počet kreditů bloku: 66
Role bloku: P

Kód skupiny: 2015_MKYREP
Název skupiny: Compulsory subjects of the programme
Podmínka kredity skupiny: V této skupině musíte získat 36 kreditů
Podmínka předměty skupiny: V této skupině musíte absolvovat 5 předmětů
Kredity skupiny: 36
Poznámka ke skupině:

Kód	**Název předmětu / Název skupiny předmětů** ***(u skupiny předmětů seznam kódů jejích členů)*** *Vyučující,* ***autoři*** *a garanti (gar.)*	Zakončení	Kredity	Rozsah	Semestr	Role
BE3M33ARO	**Autonomous Robotics** *Karel Zimmermann, Václav Hlaváč* ***Václav Hlaváč*** *Václav Hlaváč (Gar.)*	Z,ZK	7	3p+2l	L	P
BE3M38DIT	**Diagnostics and Testing** *Radislav Šmíd* ***Radislav Šmíd*** *Radislav Šmíd (Gar.)*	Z,ZK	7	3P+2L	L	P
BE3M35LSY	**Linear Systems** *Petr Hušek* ***Petr Hušek*** *Petr Hušek (Gar.)*	Z,ZK	8	4p+2c	Z	P
BE3MPROJ8	**Project** *Jana Zichová, Martin Hlinovský, Jaroslava Matějková*	Z	8	0p+6s	Z	P
BE3MPVT	**Team Work** *Pavel Burget* ***Pavel Burget*** *Pavel Burget (Gar.)*	KZ	6	0p+4s	L	P

Charakteristiky předmetů této skupiny studijního plánu: Kód=2015_MKYREP Název=Compulsory subjects of the programme

BE3M33ARO	Autonomous Robotics	Z,ZK	7
The subject teaches principles allowing to build/explore robots perceiving surrounding world and understanding activities in it including the abilities to modify it. Various architectures of robots with cognitive abilities and their realizations will be explained. Students will experiment with cognitive robots in practical assignments. Studied material is applicable more widely while building intelligent machines.			
BE3M38DIT	Diagnostics and Testing	Z,ZK	7
The course introduces the fundamentals of the fault-detection, fault tolerance, machine condition monitoring, vibrations based diagnostics, non-destructive testing and testing of analog and digital circuits.			
BE3M35LSY	Linear Systems	Z,ZK	8
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.			
BE3MPROJ8	Project	Z	8
BE3MPVT	Team Work	KZ	6

Kód skupiny: 2015_MKYREDIP
Název skupiny: Diploma Thesis
Podmínka kredity skupiny: V této skupině musíte získat 30 kreditů
Podmínka předměty skupiny: V této skupině musíte absolvovat 1 předmět
Kredity skupiny: 30

Poznámka ke skupině:

Kód	**Název předmětu / Název skupiny předmětů** ***(u skupiny předmětů seznam kódů jejích členů)*** *Vyučující, **autoři** a garanti (gar.)*	Zakončení	Kredity	Rozsah	Semestr	Role
BDIP30	**Diplomová práce - Diploma Thesis**	Z	30	22s	L	P

Charakteristiky předmětů této skupiny studijního plánu: Kód=2015_MKYREDIP Název=Diploma Thesis

BDIP30	Diplomová práce - Diploma Thesis	Z	30
Samostatná závěrečná práce inženýrského studia komplexního charakteru. Téma práce si student vybere z nabídky témat souvisejících se studovaným oborem, která vypíše oborová katedra či katedry. Práce bude obhajována před komisí pro státní závěrečné zkoušky.			

Název bloku: Povinné předměty oboru
Minimální počet kreditů bloku: 30
Role bloku: PO

Kód skupiny: 2015_MKYREPO2
Název skupiny: Compulsory subjects of the branch
Podmínka kredity skupiny: V této skupině musíte získat 30 kreditů
Podmínka předměty skupiny: V této skupině musíte absolvovat 5 předmětů
Kredity skupiny: 30
Poznámka ke skupině:

Kód	**Název předmětu / Název skupiny předmětů** ***(u skupiny předmětů seznam kódů jejích členů)*** *Vyučující, **autoři** a garanti (gar.)*	Zakončení	Kredity	Rozsah	Semestr	Role
BE3M38ZDS	**Analog Signal Processing and Digitalization** *Josef Vedral **Josef Vedral***	Z,ZK	6	2P+2L	Z	PO
BE3M38SPD	**Data Acquisition and Transfer** *Radislav Šmíd, Jan Včelák **Radislav Šmíd** Radislav Šmíd (Gar.)*	Z,ZK	6	2P+2L	Z	PO
BE3M38MSE	**Modern Sensors** *Antonín Platil, Pavel Ripka **Antonín Platil** Antonín Platil (Gar.)*	Z,ZK	6	2P+2L	Z	PO
BE3M38VBM	**Videometry and Contactless Measurement** *Jan Fischer **Jan Fischer** Jan Fischer (Gar.)*	Z,ZK	6	2P+2L	Z	PO
BE3M38VIN	**Virtual Instrumentation** *Antonín Platil, Jaroslav Roztočil **Antonín Platil** Antonín Platil (Gar.)*	Z,ZK	6	2P+2L	L	PO

Charakteristiky předmětů této skupiny studijního plánu: Kód=2015_MKYREPO2 Název=Compulsory subjects of the branch

BE3M38ZDS	Analog Signal Processing and Digitalization	Z,ZK	6
The course is dedicated to methods for preprocessing, digitalization and reconstruction of continuis signals. It is focused to the methods for achieving of high precision of transmission and suppression of spurious components. The laboratory exercises are divided into two parts: the first part is classical tasks; the second one is individual project of design of typically data acqusition system. The teaching is supported by the CAD system for measuring circuits.			
BE3M38SPD	Data Acquisition and Transfer	Z,ZK	6
The aim of the course is to acquaint students with principles and limits of data transmission from sensors and similar sources of information for IoT and M2M, wireless sensor networks and specific algorithms, respecting the limiting conditions of their function. The basic algorithms of distributed information processing in sensor networks, as well as technology for energy harvesting for powering the wireless nodes of the network, will be studied.			
BE3M38MSE	Modern Sensors	Z,ZK	6
An overview of sensors of physical quantities used in industry and in research and methods of signal processing.			
BE3M38VBM	Videometry and Contactless Measurement	Z,ZK	6
This course focuses on CCD and CMOS video sensors, and optoelectronic sensors in general and their use in contactless videometric measurement systems. Further optical radiation, its features, behavior and its use for acquiring object parameters, optical projection system, design of measurement cameras and processing of their signal will be presented. Students will design, realize and debug an individual project "optoelectronic reflective sensor" during labs.			
BE3M38VIN	Virtual Instrumentation	Z,ZK	6
The course deals with modern measuring instruments, virtual instruments (VI) a data acquisition systems (DAQ). It presents instruments and systems for measurement in laboratory and industrial environment, selected methods of measurement and standards for programing VI and DAQ systems.			

Název bloku: Povinně volitelné předměty
Minimální počet kreditů bloku: 6
Role bloku: PV

Kód skupiny: 2015_MKYREPV2
Název skupiny: Compulsory subjects of the programme
Podmínka kredity skupiny: V této skupině musíte získat alespoň 6 kreditů (maximálně 90)
Podmínka předměty skupiny: V této skupině musíte absolvovat alespoň 1 předmět (maximálně 15)
Kredity skupiny: 6
Poznámka ke skupině:

Kód	Název předmětu / Název skupiny předmětů *(u skupiny předmětů seznam kódů jejích členů)* *Vyučující,* ***autoři*** *a garanti (gar.)*	Zakončení	Kredity	Rozsah	Semestr	Role
BE3M33PRO	**Advanced robotics** *Tomáš Pajdla, Pavel Trutman, Čeněk Albl, Michal Polic, Vladimír Smutný* ***Tomáš Pajdla*** *Tomáš Pajdla (Gar.)*	Z,ZK	6	2p+2c	Z	PV
BE3M37LRS	**Aeronautical radio systems** *Pavel Kovář* ***Pavel Kovář*** *Pavel Kovář (Gar.)*	Z,ZK	6	2p+2l	Z	PV
BE3M38PSL	**Aircraft Avionics** *Jan Roháč* ***Jan Roháč*** *Jan Roháč (Gar.)*	Z,ZK	6	2P+2L	Z	PV
BE3M33UI	**Artificial Intelligence** *Petr Pošík, Radek Mařík* ***Petr Pošík*** *Petr Pošík (Gar.)*	Z,ZK	6	2p+2c	L	PV
BE3M35SDU	**Discrete Event Systems** *Pavel Burget* ***Pavel Burget*** *Pavel Burget (Gar.)*	Z,ZK	6	2P+2L	Z	PV
BE3M35DRS	**Dynamics and Control of Networks** *Kristian Hengster-Movric* ***Zdeněk Hurák*** *Michael Šebek (Gar.)*	Z,ZK	6	2p+2c	Z	PV
BE3M35OFD	**Estimation, filtering and detection** *Vladimír Havlena* ***Martin Hromčík*** *Vladimír Havlena (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
BE3M33PIS	**Industrial Information Systems** *Petr Kadera, Václav Jirkovský, Jiří Vyskočil* ***Petr Kadera*** *Petr Kadera (Gar.)*	Z,ZK	6	2+2c	Z	PV
BE3M38INA	**Integrated Modular Avionics** *Martin Šipoš* ***Martin Šipoš*** *Martin Šipoš (Gar.)*	Z,ZK	6	2P+2L	L	PV
BE3M33MKR	**Mobile and Collective Robotics** *Libor Přeučil, Miroslav Kulich* ***Miroslav Kulich*** *Libor Přeučil (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
BE3M35ORR	**Optimal and robust control** *Zdeněk Hurák* ***Zdeněk Hurák*** *Zdeněk Hurák (Gar.)*	Z,ZK	6	2p+2c	L	PV
BE3M35PSR	**Real -Time Systems Programming** *Michal Sojka* ***Michal Sojka***	Z,ZK	6	2p+2c	Z	PV
BE3M37KIN	**Space Engineering** *René Hudec, Stanislav Vítek, Martin Urban* ***Stanislav Vítek*** *René Hudec (Gar.)*	Z,ZK	6	2p+2l	Z	PV

Charakteristiky předmetů této skupiny studijního plánu: Kód=2015_MKYREPV2 Název=Compulsory subjects of the programme

BE3M33PRO	Advanced robotics	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.

BE3M37LRS	Aeronautical radio systems	Z,ZK	6

The course introduces students to the aeronautical radio engineering, aeronautical analogue, digital and satellite communication systems, aeronautical radio navigation including satellites navigation, primary secondary and passive radiolocation. The course gets students theoretical and practical knowledge of the operation of the aeronautical radio systems and their integration to the aircraft systems.

BE3M38PSL	Aircraft Avionics	Z,ZK	6

The subject is focused into a field of aircraft avionics including principles, sensors, measurement and evaluation systems and signal/data processing methods. The subject goes into details of studied systems, i.e. engine and aircraft monitoring systems, power systems, pressure-based systems, low-frequency navigation means, and flight recorders. The subject introduces currently used technology and methodology on aircraft and thus serves to understand fundamentals of avionics. Inertial navigation systems are discussed in more details as well as their aiding systems and sensors. The course focuses on both small and large aircraft as well as on UAV suited avionics.

BE3M33UI	Artificial Intelligence	Z,ZK	6

The course deepens and enriches knowledge of AI gained in the bachelor course Cybernetics and Artificial Intelligence. Students will get an overview of other methods used in AI, and will get a hands-on experience with some of them. They will master other required abilities to build intelligent agents. By applying new models, they will reiterate the basic principles of machine learning, techniques to evaluate models, and methods for overfitting prevention. They will learn about planning and scheduling tasks, and about methods used to solve them. Student will also get ackquainted with the basics of probabilistic graphical models, Bayesian networks and Markov models, and will learn their applications. Part of the course will introduce students to the area of again populat neural networks, with an emphasis to new methods for deep learning.

BE3M35SDU	Discrete Event Systems	Z,ZK	6

Discrete event systems (DES) will be defined formally regarding their description and modelling. Students will learn to understand and use several ways of DES modelling and verification. The acquired knowledge will be evaluated at real (in most cases) industrial applications.

BE3M35DRS	Dynamics and Control of Networks	Z,ZK	6

The course offers a response to the increasing demand for understanding of networks - large-scale and complex dynamical systems that are created by interconnecting components and subsystems. We will not restrict ourselves to one physical or technological domain. Quite the opposite, we will analyze the network-related phenomena found in several domains, including societal, economic, or biological. We will analyze the fundamental similarities among flight control of formations of unmanned aerial vehicles, tigh distance regulation in platoons of trucks on highways, generation and distribution of energy in smart grids, realization of a phone call in a cellular phone network, manipulation of a community through Facebook, or even forecasting the epidemics spread over a globe. For such networks, the resulting behavior is given not only by the individual components and subsystems but also by the way in which they are interconnected (topology of the network). Understanding these issues goes far beyond the boundaries of individual physical and technological or scientific domains. In the first part of the course we will introduce fundamental theoretical and computational concepts for analysis of networks, in particular, we will introduce basics of algebraic graph theory and network algorithms. In the second half of the course we will view the network as a dynamic system and we will study its properties and the ways in which these properties can be affected (controlled). We will use the methodologies from the automatic control theory. Finally, we will introduce some interesting tools for analysis and synthesis of networked systems such as wave and scattering description and distributed optimization.

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.

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			
BE3M33PIS	Industrial Information Systems	Z,ZK	6
Cílem tohoto předmětu je poskytnout studentů základní sadu dovednosti, která je nutná pro návrh a správu moderních výrobních systémů. V první části kurzu se studenti seznámí s metodami modelování a simulování diskrétních výrobních systémů. Následně studenti získají vhled do možností datové analýzy pro optimalizaci provozu výrobních prostředků a do metod dolování procesů (angl. process mining). Závěrečná část kurzu se zabývá metodami datového a znalostního modelování, které jsou nutné pro explicitní zachycení a strojové využívání informací a znalostí o výrobě.			
BE3M38INA	Integrated Modular Avionics	Z,ZK	6
Integrated Modular Avionics (IMA) course focuses on the latest concept used to the development and design of aircraft electronics (avionics), which is building on software units instead of a distributed hardware systems. The IMA concept uses high-speed data links to exchange data in scheduled air transport services. The current regulatory basis and shared airspace define the requirements for accuracy, reliability and functionality of electronic systems and their behavior in case of a failure. Students will learn the details regarding the requirements of the safety-critical multi-sensor systems, methods of data processing of overdetermined systems, fault detection algorithms, the method of primary/secondary system switching of a control system in parallel architectures, data bus technologies and methods of avionics testing/certification.			
BE3M33MKR	Mobile and Collective Robotics	Z,ZK	6
The course introduces a basic mobile robot structure design together with control methods aimed to achieve autonomous and collective behaviors for robots. Methods and tool s for data acquisition and processing are presented herein with the overall goal to resolve the task of autonomous navigation for mobile robots comprising the tasks of sensor fusion, environmental modeling including Simultaneous Localization And Mapping (SLAM) approaches. Besides sensor-processing related tasks, methods for robot trajectory planning will be introduced. The central topic of the course stands in specific usage of the afore methods capable of execution with groups of robots and taking the advantage of their cooperation and coordination in groups. Labs and seminars are organized in a form of an Open Laboratory whereas the students will implement some fundamental algorithms and study their properties on real data.			
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. Finally, the course introduces basics of chaotic systems theory and some their examples.			
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. The unifying concept is that of minimization of some optimization criterion. The properties of the resulting controller depend upon which criterion is minimized. Minimizing the popular integral-of-square-of criterion seeks a trade-off between a regulation error and a control effort. The modern theory introduces the concept of a system norm. Minimizing the H2 norm generalizes the classical LQ/LQG control. Minimizing the Hinf norm gives a controller which is robust (insensitive) to inaccuracies in the mathematical model of the system. The mu-synthesis is then an extension of Hinf methodology for systems with structured uncertainty. Hence robust control can be viewed as an offspring of the powerful paradigm of optimal control. The presented optimization-based control design can be solved either offline, or online. In the latter case the optimization can be done by invoking some nonlinear programming solver in every sampling period. This is the essence of model predictive control, which will be briefly introduced in this course. Also included in this course will be methods for time optimal and suboptimal control, which have already been found useful in applications with stringent timing requirements. In addition, semidefinite optimization and linear matrix inequalities will be introduced as these constitute a very flexible framework both for analysis and for numerical computation in robust control. Finally, computational methods for reduction of model and controller order will be covered in the course.			
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.			
BE3M37KIN	Space Engineering	Z,ZK	6
The subject acquaints students with the basics of physics of the space environment and the technologies used in space systems, satellites, spacecrafts and launchers and methods used for the design and preparation of space missions. Subject matter includes a detailed description of the instrumentation of satellites and spacecrafts and its resistance to external influences of the space environment, and analysis of instruments and systems for spacecratfts and methods of their testing. It provides a basic overview of the trajectories of spacecrafts and their applications. The course also covers optoelectronics in space systems, sensors used, their modeling and description. It discusses the principles of underlying calculations, simulations and their processing.			

Název bloku: Volitelné předměty
Minimální počet kreditů bloku: 0
Role bloku: V

Kód skupiny: 2015_MKYREVOL
Název skupiny: Elective subjects
Podmínka kredity skupiny:
Podmínka předměty skupiny:
Kredity skupiny: 0
Poznámka ke skupině: ~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

Seznam předmětů tohoto průchodu:

Kód	Název předmětu	Zakončení	Kredity
BDIP30	Diplomová práce - Diploma Thesis	Z	30
Samostatná závěrečná práce inženýrského studia komplexního charakteru. Téma práce si student vybere z nabídky témat souvisejících se studovaným oborem, která vypíše oborová katedra či katedry. Práce bude obhajována před komisí pro státní závěrečné zkoušky.			
BE3M33ARO	Autonomous Robotics	Z,ZK	7
The subject teaches principles allowing to build/explore robots perceiving surrounding world and understanding activities in it including the abilities to modify it. Various architectures of robots with cognitive abilities and their realizations will be explained. Students will experiment with cognitive robots in practical assignments. Studied material is applicable more widely while building intelligent machines.			
BE3M33MKR	Mobile and Collective Robotics	Z,ZK	6
The course introduces a basic mobile robot structure design together with control methods aimed to achieve autonomous and collective behaviors for robots. Methods and tool s for data acquisition and processing are presented herein with the overall goal to resolve the task of autonomous navigation for mobile robots comprising the tasks of sensor fusion, environmental modeling including Simultaneous Localization And Mapping (SLAM) approaches. Besides sensor-processing related tasks, methods for robot trajectory planning will be introduced. The central topic of the course stands in specific usage of the afore methods capable of execution with groups of robots and taking the advantage of their cooperation and coordination in groups. Labs and seminars are organized in a form of an Open Laboratory whereas the students will implement some fundamental algorithms and study their properties on real data.			
BE3M33PIS	Industrial Information Systems	Z,ZK	6
Cílem tohoto předmětu je poskytnout studentů základní sadu dovednosti, která je nutná pro návrh a správu moderních výrobních systémů. V první části kurzu se studenti seznámí s metodami modelování a simulování diskrétních výrobních systémů. Následně studenti získají vhled do možností datové analýzy pro optimalizaci provozu výrobních prostředků a do metod dolování procesů (angl. process mining). Závěrečná část kurzu se zabývá metodami datového a znalostního modelování, které jsou nutné pro explicitní zachycení a strojové využívání informací a znalostí o výrobě.			
BE3M33PRO	Advanced robotics	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.			
BE3M33UI	Artificial Intelligence	Z,ZK	6
The course deepens and enriches knowledge of AI gained in the bachelor course Cybernetics and Artificial Intelligence. Students will get an overview of other methods used in AI, and will get a hands-on experience with some of them. They will master other required abilities to build intelligent agents. By applying new models, they will reiterate the basic principles of machine learning, techniques to evaluate models, and methods for overfitting prevention. They will learn about planning and scheduling tasks, and about methods used to solve them. Student will also get ackquainted with the basics of probabilistic graphical models, Bayesian networks and Markov models, and will learn their applications. Part of the course will introduce students to the area of again populat neural networks, with an emphasis to new methods for deep learning.			
BE3M35DRS	Dynamics and Control of Networks	Z,ZK	6
The course offers a response to the increasing demand for understanding of networks - large-scale and complex dynamical systems that are created by interconnecting components and subsystems. We will not restrict ourselves to one physical or technological domain. Quite the opposite, we will analyze the network-related phenomena found in several domains, including societal, economic, or biological. We will analyze the fundamental similarities among flight control of formations of unmanned aerial vehicles, tigh distance regulation in platoons of trucks on highways, generation and distribution of energy in smart grids, realization of a phone call in a cellular phone network, manipulation of a community through Facebook, or even forecasting the epidemics spread over a globe. For such networks, the resulting behavior is given not only by the individual components and subsystems but also by the way in which they are interconnected (topology of the network). Understanding these issues goes far beyond the boundaries of individual physical and technological or scientific domains. In the first part of the course we will introduce fundamental theoretical and computational concepts for analysis of networks, in particular, we will introduce basics of algebraic graph theory and network algorithms. In the second half of the course we will view the network as a dynamic system and we will study its properties and the ways in which these properties can be affected (controlled). We will use the methodologies from the automatic control theory. Finally, we will introduce some interesting tools for analysis and synthesis of networked systems such as wave and scattering description and distributed optimization.			
BE3M35LSY	Linear Systems	Z,ZK	8
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. Finally, the course introduces basics of chaotic systems theory and some their examples.			

<table>
<tr><td>BE3M35OFD</td><td>Estimation, filtering and detection</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>BE3M35ORR</td><td>Optimal and robust control</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">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. The unifying concept is that of minimization of some optimization criterion. The properties of the resulting controller depend upon which criterion is minimized. Minimizing the popular integral-of-square-of criterion seeks a trade-off between a regulation error and a control effort. The modern theory introduces the concept of a system norm. Minimizing the H2 norm generalizes the classical LQ/LQG control. Minimizing the Hinf norm gives a controller which is robust (insensitive) to inaccuracies in the mathematical model of the system. The mu-synthesis is then an extension of Hinf methodology for systems with structured uncertainty. Hence robust control can be viewed as an offspring of the powerful paradigm of optimal control. The presented optimization-based control design can be solved either offline, or online. In the latter case the optimization can be done by invoking some nonlinear programming solver in every sampling period. This is the essence of model predictive control, which will be briefly introduced in this course. Also included in this course will be methods for time optimal and suboptimal control, which have already been found useful in applications with stringent timing requirements. In addition, semidefinite optimization and linear matrix inequalities will be introduced as these constitute a very flexible framework both for analysis and for numerical computation in robust control. Finally, computational methods for reduction of model and controller order will be covered in the course.</td></tr>
<tr><td>BE3M35PSR</td><td>Real -Time Systems Programming</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">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.</td></tr>
<tr><td>BE3M35SDU</td><td>Discrete Event Systems</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">Discrete event systems (DES) will be defined formally regarding their description and modelling. Students will learn to understand and use several ways of DES modelling and verification. The acquired knowledge will be evaluated at real (in most cases) industrial applications.</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>BE3M37KIN</td><td>Space Engineering</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The subject acquaints students with the basics of physics of the space environment and the technologies used in space systems, satellites, spacecrafts and launchers and methods used for the design and preparation of space missions. Subject matter includes a detailed description of the instrumentation of satellites and spacecrafts and its resistance to external influences of the space environment, and analysis of instruments and systems for spacecratfts and methods of their testing. It provides a basic overview of the trajectories of spacecrafts and their applications. The course also covers optoelectronics in space systems, sensors used, their modeling and description. It discusses the principles of underlying calculations, simulations and their processing.</td></tr>
<tr><td>BE3M37LRS</td><td>Aeronautical radio systems</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course introduces students to the aeronautical radio engineering, aeronautical analogue, digital and satellite communication systems, aeronautical radio navigation including satellites navigation, primary secondary and passive radiolocation. The course gets students theoretical and practical knowledge of the operation of the aeronautical radio systems and their integration to the aircraft systems.</td></tr>
<tr><td>BE3M38DIT</td><td>Diagnostics and Testing</td><td>Z,ZK</td><td>7</td></tr>
<tr><td colspan="4">The course introduces the fundamentals of the fault-detection, fault tolerance, machine condition monitoring, vibrations based diagnostics, non-destructive testing and testing of analog and digital circuits.</td></tr>
<tr><td>BE3M38INA</td><td>Integrated Modular Avionics</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">Integrated Modular Avionics (IMA) course focuses on the latest concept used to the development and design of aircraft electronics (avionics), which is building on software units instead of a distributed hardware systems. The IMA concept uses high-speed data links to exchange data in scheduled air transport services. The current regulatory basis and shared airspace define the requirements for accuracy, reliability and functionality of electronic systems and their behavior in case of a failure. Students will learn the details regarding the requirements of the safety-critical multi-sensor systems, methods of data processing of overdetermined systems, fault detection algorithms, the method of primary/secondary system switching of a control system in parallel architectures, data bus technologies and methods of avionics testing/certification.</td></tr>
<tr><td>BE3M38MSE</td><td>Modern Sensors</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">An overview of sensors of physical quantities used in industry and in research and methods of signal processing.</td></tr>
<tr><td>BE3M38PSL</td><td>Aircraft Avionics</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The subject is focused into a field of aircraft avionics including principles, sensors, measurement and evaluation systems and signal/data processing methods. The subject goes into details of studied systems, i.e. engine and aircraft monitoring systems, power systems, pressure-based systems, low-frequency navigation means, and flight recorders. The subject introduces currently used technology and methodology on aircraft and thus serves to understand fundamentals of avionics. Inertial navigation systems are discussed in more details as well as their aiding systems and sensors. The course focuses on both small and large aircraft as well as on UAV suited avionics.</td></tr>
<tr><td>BE3M38SPD</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 principles and limits of data transmission from sensors and similar sources of information for IoT and M2M, wireless sensor networks and specific algorithms, respecting the limiting conditions of their function. The basic algorithms of distributed information processing in sensor networks, as well as technology for energy harvesting for powering the wireless nodes of the network, will be studied.</td></tr>
<tr><td>BE3M38VBM</td><td>Videometry and Contactless Measurement</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">This course focuses on CCD and CMOS video sensors, and optoelectronic sensors in general and their use in contactless videometric measurement systems. Further optical radiation, its features, behavior and its use for acquiring object parameters, optical projection system, design of measurement cameras and processing of their signal will be presented. Students will design, realize and debug an individual project "optoelectronic reflective sensor" during labs.</td></tr>
<tr><td>BE3M38VIN</td><td>Virtual Instrumentation</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course deals with modern measuring instruments, virtual instruments (VI) a data acquisition systems (DAQ). It presents instruments and systems for measurement in laboratory and industrial environment, selected methods of measurement and standards for programing VI and DAQ systems.</td></tr>
<tr><td>BE3M38ZDS</td><td>Analog Signal Processing and Digitalization</td><td>Z,ZK</td><td>6</td></tr>
<tr><td colspan="4">The course is dedicated to methods for preprocessing, digitalization and reconstruction of continuis signals. It is focused to the methods for achieving of high precision of transmission and suppression of spurious components. The laboratory exercises are divided into two parts: the first part is classical tasks; the second one is individual project of design of typically data acqusition system. The teaching is supported by the CAD system for measuring circuits.</td></tr>
<tr><td>BE3MPROJ8</td><td>Project</td><td>Z</td><td>8</td></tr>
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BE3MPVT	Team Work	KZ	6

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