

Automatic Control & Robotics

Robotics

Graduate Program

The duration of the study is 3 semesters (1.5 academic year) (97 ECTS assigned to obligatory courses and up to 8 ECTS assigned to elective courses) split into 3 almost equally loaded semesters.

The program is designed as a high-quality educational offer in the area of advanced and intelligent robotics. After graduation the students will have mastered the diverse areas of robotics (mathematical modeling, control engineering, computer engineering, mechanical design) to an extent to be able to deal with robotics systems as a whole rather than just to focus on one particular area. The future career prospects for graduates are very good as the proposed courses are relevant to today's advanced technology society and because the current output of universities is insufficient to meet the demand of industry and research programmes. Students may take the master as a professional terminal degree, or join PhD programmes afterwards.

The graduate of the ***Robotics*** studies will demonstrate both the knowledge and abilities necessary for creative work in design, construction, programming and analysis of automation and control systems, as well as industrial and service robot systems. He/she will be capable of solving complex, interdisciplinary problems dealing with control and robotics. The graduate will have general and engineering knowledge at the level enabling him/her to conduct research in RTD centres. The graduate can be employed as senior management in mechanical, electrotechnical, chemical and related industrial sectors. He/she will be capable of designing and analysing complex robotics systems with the use of modern advanced design and analytical tools. He/she will be provided with the theoretical background enabling the solution of research problems in the field of control and robotics.

ADMISSION RULES TO GRADUATE STUDIES IN Robotics

1. The following persons can apply for the graduate studies: graduates of higher education institutions (state and non-state; full-time and extramural studies) who have a Bachelor of Science degree in engineering, in the field of *Control and Robotics* or in other technical fields.
2. Enrolment for full-time graduate studies is held in September and February, with allowance for a flexible studies scheme.
3. The qualifying procedure is carried out by the Facultyt Enrolment Committee on the basis of analysing diplomas and supplementary documents, and in special cases also individual interviews with candidates.
4. In the case of candidates whose undergraduate specialisation has been different, one supplementary courses could be assigned. The credit for the course should be received before the end of the first term. The scope of material for the course is determined by field tutors.

Admission requiriements:

A. List of documents required from Polish citizens

- application for the graduate studies
- CV
- a secondary education certificate (e.g. *maturity certificate*)
- a copy of B.Sc. diploma in engineering
- a photocopy of identity card or passport
- 4 photographs sized 37x52 mm, bareheaded, against a bright background, with the first name and family name written on the back
- a standard letter-size envelope with the candidate's address, postal code and a stamp stuck on it
- proof of admission fee payment***

6. Date and place of submitting the documents will be annoced by Faculties coordinating the Robotics programme.

1. Faculty of Mechatronics
<http://www.mchtr.pw.edu.pl>

2. Faculty of Electronics and Information Technology
<http://www.elka.pw.edu.pl>

3. Faculty of Power and Aeronautical Engineering
<http://www.meil.pw.edu.pl>

The questions about admission and courses details are answered by:
Faculty of Power and Aeronautical Engineering Dean's Assistant for studies in English:

e-mail: service@meil.pw.edu.pl

B. Requirements obligatory for non-EU citizens:

1. Undergraduade study diploma or the study record if the applicant finishes his/her first degree education. The first degree education must be completed in engineering fields
2. Proficiency in English

3. Other formal requirements are listed on the web page:

<http://www.cwm.pw.edu.pl/EN>

The admission documents must be addressed to:

Faculty of Mechatronics

Address: 02-525 Warsaw,

ul.Sw.Andrzeja Boboli 8

Faculty Dean

e-mail: dziekan@mchtr.pw.edu.pl

with note: ROBOTICS - IInd degree studies

*** The students (EU and non-EU citizens) accepted in the frame of **PO KL** shall not pay an admission and tuition fee.

*** For the EU citizens non refundable admission fee is PLN 85, payable to the account of the Warsaw University of Technology: **47 1240 1053 5111 1865 0010 0091**

. *** For non-EU citizens the non refundable admission fee is 200E

The first semester modules

The student will take 7 obligatory modules (35 ECTS/26hrs per week) from the following:

Modules	Plan: hrs per week	ECTS	Passing method
Modeling and control of manipulators	2L 2T	5	CA+E
Real-time systems	2L 2La 1P	5	CA+E
Fundamentals of Mechanics in Robotic Systems	2L 1La 1T 1P	5	CA
Computer vision	2L 2La 1P	5	CA
Control Theory	2L 1T 1P	5	CA
Neural networks	2L 1T	5	CA+E
Industrial Control Systems	2L 2T	5	CA

Explanation:

L – lecture

T – tutorial

La – laboratory

P – project

E – end-of-semester exam

CA – continous asesment, class works

For example: 2L2T means 2 lectures and 2 tutorials in every week

The second semester modules

The student will take seven obligatory modules (32ECTS/24hrs per week) from the following:

Modules	Plan: hrs per week	ECTS	Passing method
Group Project	2P	5	P
Design methods in robotics	2L 2La	5	CA+E
Robot programming methods	2L 2T	4	CA+E
Mobile robots	2L 2T	4	CA
Artificial intelligence	2L 1T	4	CA+E
Modelling and identification methods	2L 2T	5	CA
Mathematical fundamentals of optimization techniques	2L 1T	5	CA+E

Student can choose 2 supplementary modules (up to 8ECTS/6hrs per week) from the modules of other graduate programs.

The list of suggested modules will be provided.

Suggested elective modules	Plan: hrs per week	ECTS	Passing method

The third semester modules

The student will take 5 modules from the following (30 ECTS/9hrs+15):

This semester is mainly devoted to the work on the Master Thesis, valued at 20 ECTS credits. Each student will be jointly supervised by two advisors from two Faculties (the principal advisor and supporting advisor). The research topic could be supervised and located in the industrial R&D department. The research work is finalised by a written dissertation of the Masters Thesis, which must be done individually and contain an element of original work. The dissertation must be defended in the presence of a committee of experts.

Modules	Plan: hrs per week	ECTS	Passing method
Bio-robotics	2L	2	P
Dynamics of multibody systems	1La 1P	3	CA+E
Production scheduling	2L	2	CA
Parallel and distributed computations	2L 1T	3	P
Work on diploma thesis	15hrs	20	

Syllabus of first semester

Modelling and control of manipulators			
ECTS: 5 Semester 1 Compulsory: Yes			
Format	Lectures 30h	Tutorials 30h	Private study 90 h
Lectures: prof. C.Zielinski, prof. P.Tatjewski			
<p>Objectives: This course presents the fundamentals of the modelling and control techniques of serial manipulators. Topics include robot architectures, geometric modelling, kinematic models, dynamic modelling and its applications, as well as the classical PID controller and computed torques controller.</p> <p>Contents: The following subjects will be treated:</p> <ul style="list-style-type: none"> Robot architectures, joint space, operational space, Homogenous transformation matrices, Description of manipulator kinematics using modified Denavit and Hartenberg notations, Direct geometric model, Inverse geometric models using Paul's method, Piper's method and general methods, Calculation of kinematic Jacobian matrix, Inverse kinematics for regular and redundant robots, Dynamic modelling using the Lagrange formalism, Dynamic modelling using recursive Newton-Euler method, Trajectory generation between two points in the joint space and in the operational space, Classical PID control Computed torque Control 			
<p>Abilities: After completing this course the students will be able to:</p> <ul style="list-style-type: none"> Understanding the fundamentals of the mathematical models of serial robot manipulators and its applications in robots design, control and simulation. Understanding the effect of the kinematic parameters on the manipulator characteristics. Use the most convenient methods to obtain the required models, Understand practical applications of the mathematical modelling of manipulators, Use of symbolic and numerical software packages (Matlab, Simulink, Maple, Mathematica, ...), 			
<p>Assessment: 20% continuous assessment, 80% from end of semester examination.</p> <p>Practical Work: Exercises will be set, which will involve modeling some manipulators, simulation of control laws.</p>			
<p>Recommended texts: will be added</p> <ul style="list-style-type: none"> - W. Khalil, and E. Dombre, <i>Modelling, identification and control of robots</i>, Hermes Penton, London, 2002. <p>Further readings:</p> <ul style="list-style-type: none"> - C.Canudas, B. Siciliano, G.Bastin (editors), <i>Theory of Robot Control</i>, Springer-Verlag, 1996 - J. Angeles, <i>Fundamentals of Robotic Mechanical Systems</i>, Springer-Verlag, New York, 2002. 			
Prerequisites: No			

Real-time systems			
Credits: 5 Semester 1 Compulsory: Yes			
Format	Lectures 30 h	Laboratory: 30h Guided project 15 h	Private study 50 h
Lectures: assist.prof. B.J.Kubica			
<p>Objectives: To learn about designing real-time systems, specific features of such systems and about real-time operating systems.</p> <p>Contents: The program of the lecture:</p> <ol style="list-style-type: none"> 1.Real-time systems, its features, hard and soft variant of a real-time system. 2.Production process of a real-time system. 3.Real-time operating systems, examples of such systems: VX Works, VERTEX, QNX Neutrino, etc. 4.Real-time variants of Linux. 5.Specific features of QNX Neutrino [or alternatively of RT Linux, depending on the platform that will be used on project classes] – about four or five lectures. 6.Basics of real-time programming languages, programming in ADA. 7.Task scheduling in real-time systems. 8.Examples of real-time systems. 			
<p>Abilities: After completing this course the students will be able to specify and implement a simple real-time based system , with: tasks scheduling, process specification implementation using one of the explained systems.</p>			
<p>Assessment: 60% continuous assessment basis on laboratory work, 40% exam Practical Work: project /laboratory classes, where students will design and implement a simple real-time system, e.g. a control program for a simple robot</p>			
<p>Recommended texts:</p> <ol style="list-style-type: none"> 1) Jane W.S. Liu, Real-Time Systems, Prentice Hall, 2000. 2) Giorgio C. Buttazo, Hard Real-time Computing Systems, Kluwer Academic publishers, 1997. 3) Documentation on http://www.qnx.com . <p>Further readings:</p> <ul style="list-style-type: none"> - W.A.Halang, K.M.Sacha: Real-time Systems. World Scientific 1992 - will be provided by lecturer 			
Prerequisites: No			

Fundamentals of mechanics in robotic systems			
Credits: 5 Semester 1 Compulsory: Yes			
Format	Lectures 30h	Guided project 15h Laboratory 15h Tutorials 15h	Private study 50h
Lectures: prof. J. Frączek, assist. prof. M. Wojtyra			
<p>Objectives: The goals of this course are:</p> <ol style="list-style-type: none"> 1. To present basics of kinematics and dynamics of rigid body in planar and spatial motion using matrix-vector notation. 2. To discuss kinematics and dynamics of planar and spatial mechanisms of robots. 3. To show and to exploit the possibilities of automated kinematics and dynamics calculations. 			
<p>Contents: The following subjects will be discussed:</p> <p>Basic definitions: kinematical pairs, mobility and redundant constraints, constraints equations in mechanics.</p> <p>Typical problems of mechanics: kinematics, statics, direct and inverse dynamics.</p> <p>Mathematical description and numerical methods: vectors and matrices, linear equations sets, vector functions and their derivatives, Newton-Raphson method of solving nonlinear algebraic equations.</p> <p>Spatial and planar kinematics of point and body: algebraic vectors, direction cosines matrix, Euler angles, linear and angular velocity and acceleration, spatial motion of point and body, planar motion.</p> <p>Kinematics of mechanisms: kinematics problem formulation (position, velocity and acceleration), symbolic vs. numerical solution, general methods of solving the kinematics problems (driving constraints appending vs. coordinate partitioning), kinematics in joint, natural and absolute coordinates, examples (Stewart platform kinematics).</p> <p>Advanced problems of kinematics: general purpose kinematics analysis program, dependent constraints, singular positions, mechanism assembling.</p> <p>Rigid body dynamics: forces and torques, static equilibrium conditions, mass distribution (centre of mass, moments and products of inertia), Newton-Euler equations of motion.</p> <p>Inverse dynamics of mechanisms: dynamic force equilibrium, inertia forces, reactions in kinematical pairs, examples (manipulator kinetostatics).</p> <p>Direct dynamics of mechanisms: dynamics of a system of bodies (unconstrained and constrained), generalized forces, constraint equations and constraint reaction, interpretation of Lagrange multipliers, direct dynamics problem formulation.</p> <p>Numerical methods in dynamics: numerical integration of ordinary differential and differential algebraic equations, constraint violation stabilization methods, coordinate partitioning method, examples of calculations (robot dynamics).</p> <p>Advanced problems of dynamics: general purpose dynamics analysis program, joint friction, collision.</p>			
<p>Abilities: After completing this course the students will understand the basics of mechanisms kinematics and dynamics. The students will be able to formulate and solve equations describing kinematics and dynamics of mechanisms used in robot design. They will be able to</p>			

use professional software dedicated to mechanical systems analysis and simulation.
Assessment: 60% continuous assessment, 40% exam
Practical Work: The computer laboratory will be devoted to kinematical and dynamical analysis of various mechanisms using professional CAE package. The guided project will be devoted to kinematic and dynamic analysis of spinal cord type multi-segment manipulator.
Recommended texts: Shigley J.E., Uicker J.J.: <i>Theory of Machines and Mechanisms</i> , McGraw Hill 1995. Nikravesh P.E.: <i>Computer-Aided Analysis of Mechanical Systems</i> . Prentice Hall, 1988. Shabana A.A.: <i>Computational Dynamics</i> . Wiley & Sons, 2001.
Further readings: Haug E.J.: <i>Computer-Aided Kinematics and Dynamics of Mechanical Systems. Volume I: Basic Methods</i> , Allyn and Bacon, 1989.
Prerequisites: No

Computer vision			
Credits: 5 Semester 1 Compulsory: No			
Format	Lectures 30h	Laboratory 30 Guided project 15h	Private study 50 h
Lectures: prof. M. Kujawińska, assist. prof. R. Sitnik			
Objectives: The course introduces fundamentals of computer vision (CV). It starts from common detectors characterization (eye, CCD, CMOS) together with different color spaces definitions. Geometrical, arithmetical, morphological and filtering operations in image space are explained. DFT, FFT, Hough and Wavelet transforms are introduced. Basic recognition techniques are presented. Coding and compression methods for images and image sequences are described. Camera calibration together with 2D/3D correlation, 3D/4D capture techniques and their data processing algorithms.			
Contents:			
<ol style="list-style-type: none"> 1. Introduction. Definitions. Digital versus analog representation. Sampling and quantization. Eye versus matrix detector (CCD/CMOS). Electromagnetic spectrum. Color spaces. 2. Image space operations. Geometrical operations. Image correction. Camera calibration. Arithmetical operations. LUT. Histogram. Multi image operations. Binarization. Filtering operations (convolution, statistical, etc.). 3. Image transforms. Fourier transform (DFT, FFT). Wavelet transform. Hough transform. Image space filtering versus transform based filtering. 4. Coding and compression. Image and image sequences coding. Coding and compression versus eye properties. Loss and lossless compression. Basic algorithms. Standards. 5. Morphological operations and Segmentation. Morphological operations (opening, closing, skeleton operators). Segmentation. 6. Recognition. Basing recognition techniques. Features based on geometry, topology, texture. Examples. 7. Camera calibration. Camera calibration methods: Direct Linear Transformation, camera calibration toolbox for Matlab, 3DMADMAC. 8. 2D/3D correlation. In-plane and out-of plane measurements and tracking. 9. 3D/4D capture. Incoherent 3D/4D capture, calibration, analysis and recognition methods overview (photogrammetry, structured light, laser triangulation, time of light, deflectometry). Exemplary applications. 10. 3D/4D data processing. Overview of data processing methods in CV based on optical 3D/4D measurements. 			
Abilities: The students will be able to prepare vision system depending on different computer vision tasks. They will know the diverse image processing methods, and will know the what processing results are obtained. They will be able to select the image processing method for the specific purpose including 2D/3D and 4D measurement and recognition techniques. The students will gain the ability to use the vision for robot motion guidance or tracking.			
Assessment: 40% lecture exam, 40% project, 20% laboratory			
Practical Work: Exercises on image processing for recognition purposes			
Recommended texts:			
[1] W.K. Pratt, Digital Image Processing, 3rd edition, John Willey & Sons, New York, 2001.			
[2] J.C. Russ, The Image Processing Handbook, 3rd edition, CRC Press, London, 1998.			
[3] B. Cyganek, J.P. Siebert, "An Introduction to 3D Computer Vision Techniques and Algorithms", Villey, 2009.			
Further readings: will be provided by lecturer			
Prerequisites: No			

Control Theory			
Credits: 5 Semester 1 Compulsory: Yes			
Format	Lectures 30h	Tutorials 15h Guided project 15H	Private study 50 h
Lectures: prof. T.Zielinska, assist.prof. T.Dziewonski			
<p>Objectives: To learn about complex control systems, its features and analysis methods</p> <p>Contents:</p> <p>The following subjects will be discussed:</p> <ul style="list-style-type: none"> - Definition, description method and examples of multidimensional complex control systems. - Stability evaluation using Lapunov methods - Multidimensional control systems: designing the state feedback, obtaining the controllable and observable form of state equation, evaluation of transition matrix in time domain 			
Abilities: Ability to analyse and desing of multivariable control systems			
Assessment: End-semester exam			
Practical Work:			
<p>Recommended texts: Ogata Katsuhiko: Modern Control Engineering, Prentice Hall</p> <p>Further readings: T.Lueth, R.Dillman, P.Dario, H.Worn: Dustributed Autonomous Robotic Systems, Springer 1998</p>			
Prerequisites: No			

Neural networks			
Credits: 4 Semester 1 Compulsory: Yes			
Format	Lectures 30h	Tutorials 15h	Private study 50 h
Lectures: prof. J. Kurek			
<p>Objectives: The goal of the class is to present neural networks as tools for pattern classification, function approximation, and system modeling and prediction. Neural methodology will be thus treated as a step in development of dynamic systems. Neural networks are presented as static or dynamic systems whose main distinctive properties are modularity and adaptability. They are presented in the context of classification, function approximation, dynamical system modeling, and other applications.</p>			
<p>Contents: Classification abilities are discussed for contemporary versions of Rosenblatt's perceptron, support vector machines, and multi-layer perceptrons. They are complemented with elements of learning theory and probably approximately correct estimators. Approximation properties of neural networks are outlined for multilayer perceptrons and for radial basis function networks, and connected to linear regression models. In particular, approximation quality and generalization problems are discussed. Back-propagation is derived as an effective way to calculate gradients in large systems. Theoretical abilities of function approximation properties of multi-layer perceptrons and radial basis function networks are also analyzed. Dynamic neural networks are outlined in the context of dynamical system modeling, contents-addressable memories, and combinatorial system optimization. Neural ARMA models will be derived as a generalization of ARMA models, and their properties will be analyzed. Stability of dynamic networks is discussed in the context of system optimization and contents-addressable memories.</p>			
<p>Abilities: The students will be able to choose the neural network considering the specific classification and identification task. They will gain a practical experience how to utilize neural network methods to classification problems. They will be able to approximate diverse functions by neural networks. They will know how to set-up a dynamical neural model.</p>			
<p>Assessment: : 60% continuous assessment , 40% class work</p>			
<p>Practical Work: Exercises on the application of the neural networks</p>			
<p>Recommended texts: - G.C.Bekey, K.Y.Goldberg: Neural Networks in Robotics. Kluwer 1993</p>			
<p>Further readings: will be provided by lecturer</p>			
<p>Prerequisites: No</p>			

Industrial Control Systems			
Credits: 4 Semester 1 Compulsory: Yes			
Format	Lectures 30h	Tutorials 30h	Private study 50 h
Lectures: assist.prof. M. Bartyś, assist.prof. M. Syfert			
Objectives: To gain the fundamentals of automatized industrial systems			
Contents:			
The following subjects will be discussed:			
1. Functional and hardware structures of industrial control systems The functions of control systems. Features of functional structure. Elements of hardware structures. Features of contemporary hardware-software structures: decentralisation, distribution.			
2. Classification of control systems Classification of control systems. Application fields of different control systems.			
3. Programming languages Standard programming languages - IEC 611-31.			
4. Fieldbus networked systems Fieldbus systems. Applications areas in process automation.			
5. Control units Controllers, programmable controllers, operating stations.			
6. Process monitoring systems SCADA systems. Structure, function, programming, applications.			
7. Integrated systems DCS and hybrid systems. Description, hardware structure, redundancy, programming, applications.			
8. SCADA + PLC systems Combined systems SCADA+PLC+controllers. General description, programming, applications.			
9. Soft-control technology Features, structures, programming, applications.			
10. Development trends Trends in the development of industrial control systems. Comparison of the integrated systems, SCADA+PLC and soft-control systems.			
Abilities: Getting familiarised with the numerous industrial control systems. Ability of the selection of the appropriate control systems for a given automation problem.			
Assessment: End-semester exam			
Practical Work:			
1) PLC Controllers – configuration and programming for a given automation task			
2) DCS systems – configuration and tests of the integrated system – Industrial IT or DeltaV			
3) Application of AS-I fieldbus system for automation of conveyor system			
Recommended texts: need to be prepared			
Further readings:			
Prerequisites: No			

Syllabus of second semester

Group Project			
Credits: 5 Semester 2 Compulsory: Yes			
Format	Lectures	Examples Project meetings 30h	Private study 70h
Lectures: teaching staff			
Objectives: To elaborate a project concerning the basic robotic problem			
Contents: The topic follow the research expertise of the partner group. It will be oriented towards the control algorithm synthesis, or to the specification of the technical documentation for newly designed robot, or to the practical synthesis (with implementation) of the robot motion considering available diverse robots.			
Abilities: The abilities to solve independently the basic technical problem and to produce the comprehensive and complete work report.			
Assessment: Basis on the written report			
Practical Work:			
Recommended texts: Project is guided by the supervisor who recommends the readings			
Further readings:			
Prerequisites: All compulsory modules from first semester			

Design methods in robotics			
Credits: 5 Semester 2 Compulsory: Yes			
Format	Lectures 30 h	Laboratory project 30 h	Private study 50 h
Lectures: assist.prof. K.Mianowski, assist.prof. B.Kuberacki			
<p>Objectives: This course presents the overview of the design process – specification, conceptual design, product design. The students will learn basic principles of industrial robot design.</p> <p>Contents: The following subjects will be discussed:</p> <ul style="list-style-type: none"> - conceptual design: concept generation, concept evaluation. - product design: documentation, product generation, evaluation for function and performance, evaluation for cost, ease of assembly and other measures. - computer aids for mechanical design. CAD/CAE/CAM systems. - the design of robotic production cell. - fundamentals of integrated design of control and drive systems taking into account measurement, gearing and transmission systems. - design of a serial robot manipulator.(using CAD) 			
<p>Abilities: After completing this course the students will be able to design the serial robotic manipulator.</p> <p>They will be able :</p> <ul style="list-style-type: none"> - to formulate properly the needed information for conceptual design (requirements), - to use the CAD on the basic level for the design of typical mechanism (serial arm), - to elaborate the design on general level without material, drive systems and actuators consideration, - to provide the conceptual documentation for the arm design. 			
Assessment: 60% continuous assessment, 40% - exam.			
Practical Work: CAD design of manipulator			
<p>Recommended texts: K.C.Gupta: <i>Mechanics and Control of Robots</i>. Springer 1997 J.E.Shigley, J.J.Uicker: <i>Theory of Machines and Mechanisms</i>, McGraw Hill 1995 (and newer editions)</p> <p>Further readings: CAD software documentation</p>			
Prerequisites: Fundamentals of Mechanic in Robotics Systems			

Robot programming methods			
Credits: 4 Semester 2 Compulsory: Yes			
Format	Lectures 30 h	Tutorials 30 h	Private study 40h
Lectures: prof. C.Zielinski, assist.prof. W.Szynkiewicz			
<p>Objectives: The learn the robot programming methods</p> <p>Contents: A broad view of robot programming will be assumed. Both the expression of tasks that the robot has to execute and software controlling robots will be discussed. In the introduction the concepts of: receptors, effectors, virtual sensors, robot ontologies, agents, multi-agent systems will be explained. Several historic and currently used specialised robot programming languages will be presented. Then focus will shift to robot programming frameworks, i.e.: libraries of modules, a pattern according to which they have to be assembled and tools for producing new modules. Robot will be treated as an embodied agent and its operation will be described formally in terms of transition functions. Both sequential and concurrent decompositions of those functions will be considered. Competitive and cooperative composition of results and the definition of complex behaviours will be the subject of presentation. The transition from synchronous to event driven systems will be shown. Deliberative vs. behavioural, fuzzy vs. crisp, deterministic vs. indeterministic systems will be described from the point of view of the definition of the transition functions governing their behaviour. Cooperation and coordination in multi-robot systems will be described. The course will also cover implementation issues, especially programming paradigms (procedural, object-oriented, component based). Error handling and debugging issues will also be explained. The presentation of implementation structures (methods of merging specialized languages and programming frameworks and the influence on the compilation/interpretation of the resulting code) will follow. An introduction to formal languages and how to build a simple compiler of a robot language will be shown. MRROC++ robot programming framework will be used for presenting examples of complex systems, e.g. capable of two-handed manipulation with force sensing, visual servoing, voice communication and capability to reason. The course will conclude with the description of software for swarms of autonomous robots and coordinated multi-robot systems requiring utility based task allocation.</p>			
<p>Abilities: After completing this course the students will be able to:</p> <ul style="list-style-type: none"> - to use the typical robot programming language, - to elaborate his own robot programming framework for a single robot, - to decompose the system into the modules, - to specify the programming framework for the multi-robot systems, 			
Assessment: 60% class work, 40% exam			
Practical Work:			
<p>Recommended texts: Zieliński C.: <i>Robot Programming Methods</i>. Warsaw University of Technology Publishing House, 1995. Zieliński C.: <i>Transition-Function Based Approach to Structuring Robot Control Software</i>. In: <i>Robot Motion and Control: Recent Developments</i>. Ed. K. Kozłowski, Lecture Notes in Control and Information Sciences, Vol.335, Springer Verlag. 2006. pp 265–286</p>			
Further readings: will be provided by lecturer			
Prerequisites: Modeling and control of manipulators			

Mobile robots			
Credits: 4 Semester 2 Compulsory: Yes			
Format	Lectures 30 h	Tutorials 30h	Private study 20 h
Lectures: prof. A. Masłowski			
<p>Objectives: This course presents fundamentals of mobile robots design and motion synthesis.</p> <p>Contents: The following subjects will be discussed: driving systems of wheeled mobile robots. velocity and acceleration analysis. formulation of direct and inverse kinematics and dynamics problem. Serial and parallel manipulator structures – kinematics description examples. structure of wheeled robots, design solutions and actuating systems. self-location problem, sensory based environment recognition and representation. Robot dynamics. auxiliary equipment – construction and application survey.</p>			
<p>Abilities: After completing this course the students will be able to evaluate the mobility of the specific mobile robot and describe its motion trajectories considering the motion constraints. They will be able to navigate the robot equipped in typical external sensors around the obstacles.</p>			
Assessment: 100% class works - continuous assessment			
Practical Work:			
<p>Recommended texts: I.Duleba: Algorithms of Motion Planning for Nonholonomic Robots. Wroclaw University Publishing House 1998 Ch.Ahikenchekh, A.Seireg: Optimized-Motion Planning; Theory and Implementation. John Wiley 1994</p> <p>Further readings: will be provided by lecturer</p>			
<p>Prerequisites: Modeling and control of manipulators Fundamentals of Mechanic in Robotics Systems</p>			

Artificial intelligence			
Credits: 4 Semester 2 Compulsory: Yes			
Format	Lectures 30 h	Tutorials 15h	Private study 40h
Lectures: prof. W.Kasprzk, prof. C.Zielinski			
<p>Objectives: The goal of the course is to present advanced issues of artificial intelligence from the perspective of a computerized autonomous agent</p> <p>Contents: The first part covers basic methods of artificial intelligence – the logic of knowledge representation, inference rules and problem solving including: uniformed search, informed search with heuristic functions, constraint satisfaction problems and adversarial games. The second part deals with practical planning and acting of an autonomous agent (i.e., situation space, plan space, plan decomposition, hierarchic decomposition, contingency planning), and with probabilistic reasoning. The third part discusses agent design problems in the area of knowledge acquisition (learning from observations, in neural networks and reinforcement learning), and machine perception (image and speech understanding).</p>			
<p>Abilities: After completing this course the students will be able to: to produce and analyse the knowledge inference rules, to acquire the knowledge using: active observation, neural networks processing. to process the visual information and to recognize the speech using the machine perception.</p>			
Assessment: 60% continuous assessment, 40% from end-semester examination.			
Practical Work:			
<p>Recommended texts: - S. Russell, P. Norvig. <i>Artificial Intelligence: A Modern Approach</i>. Prentice Hall, Upper Saddle River, N.J., 2002.</p> <p>Further readings: G.F.Luger, W.A.Stubblefield: <i>Artificial Intelligence. Structures and Strategies for Complex Problem Solving</i>. Addison Wesley, 1997 J-P.Delahaye: <i>Formal Methods in Artificial Intelligence</i>. Oxford 1987</p>			
Prerequisites: No			

Modelling and identification methods			
Credits: 5 Semester 2 Compulsory: Yes			
Format	Lectures 30h	Tutorials 30h	Private study 50 h
Lectures: assist. prof. P. Wnuk			
<p>Objectives: This lecture presents identification theory for linear, fuzzy and neural network models. Shows batch and recursive identification algorithms. Presents practical identification examples.</p> <p>Contents: The following subjects will be discussed: Structures of the models. Static vs dynamic models Linear model of system dynamics. Possible estimators: LS, ML, IV – assumptions, theory and when to use. Recursive parameters estimation – on-line identification and adaptation of the model. Nonlinear model structures. Fuzzy models: Mandami and Takagi-Sugeno approach. Identification of fuzzy model structure: grouping (c-means) and genetic approach. Neural network as a model of system static. How to include system dynamics in neural network model. Model validation: stability, uncertainty. Practical applications of identified models.</p>			
<p>Abilities: To prepare and conduct identification experiment. To use specialized software to model identification. To prepare identification data, find model type and structure, estimate parameters and validate model.</p>			
<p>Assessment: End-semester exam</p> <p>Practical Work: How to carry out identification experiment – three tank system. Data preprocessing. Identification of linear model – examples. Linear model of the tank. Rank and delays determination. Model analysis – Nyquist plots, zero-pole analysis, model simulation. Fuzzy modelling – the model of the valve flow, pneumatic drive model. Neural network modelling - valve flow, pneumatic drive, NOx generation. Simulation and validation of the models</p>			
<p>Recommended texts: Further readings: Babuska R., "Fuzzy Modeling for Control", Kluwer Academic Publishers, Boston 1998 Jang J., Sun C., Mizutani E., "Neuro-fuzzy and soft computing", Prentice Hall, New York 1997 Ljung L., "System Identification. Theory for the user.", Prentice Hall, New Jersey 1987 Soderstrom T., Stoica P., "System Identification"</p>			

Mathematical fundamentals of optimization techniques			
Credits: 5 Semester 2 Compulsory: Yes			
Format	Lectures 30h	Tutorials 15h	Private study 50 h
Lectures: prof. W.Ogryczak, assist.prof. A.Stachurski			
<p>Objectives: The lecture presents various theoretical and computational aspects of solution methods for optimization problems in engineering and robotics.</p> <p>Contents: The following subjects will be discussed: 9.Basic concepts of optimization, 10.Unconstrained optimization algorithms, 11.Theory and methods for constrained optimization, 12.Linear Programming, 13.Multiple objective optimization, 14.Evolutionary algorithms, 15.Optimization tools and programming aspects.</p>			
<p>Abilities: The students will be able to:</p> <ul style="list-style-type: none"> – Understand various theoretical and computational aspects of a wide range of optimization methods, – Realize the capabilities offered by various optimization methods, – Use of optimization toolboxes. 			
<p>Assessment: 40% continuous assessment, 60% exam</p> <p>Practical Work: Project assignments require individual edition and analysis of examples of mathematical models with the use of either MATLAB or algebraic modeling languages such as GAMS, AMPL. After model edition, the assignment assumes the selection and use of optimization algorithms from a library in order to perform given type of model analysis, or the development of some dedicated optimization procedures.</p>			
<p>Recommended texts: A.P. Ruszczyński, Nonlinear Optimization, Princeton Univ. Press, 2006. R.J. Vanderbei, Linear Programming: Foundations and Extensions, Springer, 2008</p> <p>Further readings: R. Sarker, M. Mohamadian, Y. Xin, Evolutionary Optimization, Springer, 2002. R. Fletcher, Practical methods of Optimization, Wiley, 2001. M. Ehrgott, Multicriteria Optimization, Springer, 2005.</p>			
Prerequisites: No			

Syllabus of third semester

Bio-robotics			
Credits: 2 Semester 3 Compulsory: Yes			
Format	Lectures 30h	Project /lab.	Private study 30 h
Lectures: prof. T.Zielinska, assist.prof. A.Chmielniak			
<p>Objectives: This course presents the fundamentals to the bio-inspired robotics. The topics include the biological motion properties, motion planning and biological sensors. It will be presented how the knowledge of biological motion properties is transformed into robotics.</p> <p>Contents: The following subjects will be discussed:</p> <ul style="list-style-type: none"> historical background, - motion properties of simple animals and its body build, - motion properties of complex animals and its body build, - summary of biological motion principles - robotics motion rules using biological inspirations, - design solutions inspired by biology, - discussion of the autonomy and adaptability observed in living world and autonomy obtained in robotics, - guided project on biologically inspired motion synthesis of mobile robot or on the novel kinematics structure of the autonomous moving robot. - 			
<p>Abilities: After completing this course the students will be able to:</p> <ul style="list-style-type: none"> understanding the aim of the use of biological patterns in robotics - understand the fundamentals of biologically inspired motion synthesis, - introduce novel kinematics structures using biological inspirations, - to synthesise the movements behaviours basis on the biological reactions/reflexes - to implement it in the simple biologically inspired robot 			
<p>Assessment: 100% project, Practical Work: includes project elaboration using real mobile robots or professional design software</p>			
<p>Recommended texts:</p> <ul style="list-style-type: none"> - T.Zielinska, Biological Aspects of Locomotion (In: F.Pfeiffer, T.Zielinska eds. Walking: Biological and Technological Aspects) Springer 2004, ISBN 3-211-22134-4 <p>Further readings: T.Zielinska: Motion Synthesis (In: F.Pfeiffer, T.Zielinska eds. Walking: Biological and Technological Aspects) Springer 2004, ISBN 3-211-22134-4</p>			
<p>Prerequisites: Modeling and control of manipulators Fundamentals of Mechanic in Robotics Systems</p>			

Production scheduling			
Credits: 2 Semester 3 Compulsory: Yes			
Format	Lectures 30h	Tutorials: h	Private study 60 h
Lectures: prof. M. Olszewski			
<p>Objectives: To learn how efficiently distribute the tasks along the production line</p> <p>Contents: Definition of scheduling problem and terminology: jobs, tasks (operations), resources, typical constraints, scheduling objectives. Sequencing and task allocation - classification of scheduling problems. Classical models and algorithms of operations scheduling. Scheduling on parallel processors, flow-shop, job-shop and open-shop scheduling problems. Scheduling under resource constraints – multiprocessor tasks. Modelling of concurrent processes execution. Scheduling with finite capacity buffers. Deadlocks: causes, conditions, prevention. Scheduling in assembly systems. Flexible Manufacturing Systems: problems of task allocation, scheduling in robotic cells, routing.</p>			
<p>Abilities: Ability to arrange the tasks scheduling in an industrial lines. The students will be able:</p> <ul style="list-style-type: none"> to describe the industrial line in the terms of tasks, its allocations and the time requirements, to solve the scheduling problem for flow-shop, job-shop and open-shop, to perform the scheduling for concurrent processes with deadlock avoidance and in the situation of limited capacity buffers, 			
Assessment: 100% class work – continuous assessment			
Practical Work:			
<p>Recommended texts: - Blazewicz J., Ecker K.H., Pesch E., Schmidt G., Weglarz J., Scheduling Computer and Manufacturing Processes, Springer-Verlag, 1996.</p> <p>Further readings: will be provided by lecturer</p>			
Prerequisites: No			

Dynamics of multibody systems			
Credits: 3 Semester 3 Compulsory: Yes			
Format	Lectures	Guided project 15h Laboratory 15h	Private study 20h
Lectures: prof. J. Fraćzek, assist. prof .M. Wojtyra			
<p>Objectives: The goal of this course is to learn and practise the methods of simulation and analysis of complex technical systems consisting of mechanism, actuators and control unit.</p>			
<p>Contents: The computer laboratory will be devoted to learning the methods of virtual prototyping. A simulational model of planar manipulator, its electrical motors and control system will be built. General purpose multibody software will be used for mechanism modeling and control system simulation package will be used to modeling of control process. The co-simulations will be performed to analyze the system behavior. The guided project will be devoted to building a virtual prototype of hydraulically (or electrically) driven parallel manipulator (Stewart platform) and its control system. Various control methods will be analyzed (PID control, computed torque method).</p>			
<p>Abilities: After completing this course the students will be able to build a virtual prototype, i.e. a simulational model of complex mechanical system, its actuators and control system. They will be able to verify the model and to analyze obtained results. They will be able to solve practical problems using modern CAE software.</p>			
Assessment: 60% continuous assessment, 40% final test			
<p>Practical Work: Building and testing simulational models of robots using modern CAE packages.</p>			
<p>Recommended texts: Garcia de Jalon J., Bayo E.: <i>Kinematic and Dynamic Simulation of Multibody Systems</i>. Springer-Verlag, 1994 MATLAB/Simulink technical documentation ADAMS technical documentation</p>			
Further readings: will be provided by lecturers			
Prerequisites: Fundamentals of Mechanics in Robotics Systems			

Parallel and distributed computations			
Credits: 2 Semester 3 Compulsory: Yes			
Format	Lectures 30h	Tutorials 15h	Private study 40h
Lectures: assist.prof. A.Karbowski			
<p>Objectives: The aim of the lecture is to present the basic knowledge on parallel and distributed computations implemented on parallel computers and in networks of computers (virtual parallel computers), clusters and grids</p> <p>Contents:</p> <ol style="list-style-type: none"> 1. History of parallel systems and parallel algorithms. 2. Types and architectures of multiprocessor and multicore computers, speed-up and efficiency measures 3. Mechanisms for synchronization and communication in parallel and distributed systems 4. Languages and environments for parallel algorithms programming and distributed processing 5. Basic structures of distributed applications:client-server, farm, peer-to-peer; environments: Sun RPC, .NET Remoting, Web Services 6. API based on Virtual Shared Memory Paradigm: Linda, HPF, CAF, UPC, Intel Cluster OpenMP 7. Types of parallelizations of numerical methods: that of operation, that of code, that of algorithm and that of task 8. Synchronous computational algorithms: solution of systems of linear and nonlinear equations, parallel solvers for ODE and PDE, dynamic programming, decomposition of optimization algorithms 9. Totally and partially asynchronous algorithms, synthesis of optimal closed-loop control policies, page ranking in Web searchers 10. Problems related to parallel event-driven simulation: event-driven versus times-driven simulation, global and local synchronization and event lists, causality error and deadlock in asynchronous simulation. 			
<p>Abilities: After completing this course the students will be able to developed a distributed programming algorithm. They will be able :</p> <ul style="list-style-type: none"> to distribute the complex computation algorithm into the parallel parts usign or operation, or code, or algorithm prallelization, to implement a basic synchronous, partly-synchronous and asynchronous algorithm, to simulate the event-driven processes using parallelization to speed up the numerical computations .using the distributed calculations. 			
Assessment: 100% class project,			
Practical Work: The aim of the associated project is to acquire practical skills and first-hand experience through developing distributed applications and parallel algorithms, programming them and implementing on a parallel machine with shared memory and in a cluster.			

Recommended texts:

1. Grama A., Kumar V., Gupta A., Karypis G., *Introduction to Parallel Computing, 2/E*, Addison Wesley , 2003.
2. Dongarra J, et al., *The Sourcebook of Parallel Computing*, Morgan Kaufmann (Elsevier), 2003.
3. Freeman T.L. and Phillips C., *Parallel Numerical Algorithms*, Prentice Hall, 1992.
4. Bertsekas D.P. and Tsitsiklis J.N., *Parallel and Distributed Computation: Numerical Methods*, Prentice Hall, 1989

Further readings: will be given by lecturer

Prerequisites: No