COURSE DESCRIPTION CARD - SYLLABUS

Course name
Control of Robot Manipulators

Course

Field of study	Year/Semester
Automatic Control and Robotics	1 / 1
Area of study (specialization)	Profile of study
Control and robotics systems	general academic
Level of study	Course offered in
Second-cycle studies	polish
Form of study	Requirements
full-time	compulsory

Number of hours

Lecture	Laboratory classes	Other (e.g. online)
30	30	0
Tutorials	Projects/seminars	
0	0	

Number of credit points

4

Lecturers

Responsible for the course/lecturer:
dr. inż. Piotr Dutkiewicz

email: Piotr.Dutkiewicz@put.poznan.pl

tel. 61 6652368

Faculty of Control, Robotics and Electrical Engineering

ul. Piotrowo 3a, 60-965 Poznań

Responsible for the course/lecturer:

Prerequisites

Students starting this course should have a basic knowledge about basics robotics (kinematics manipulator, differential kinematics of manipulator, jacobian of manipulator, dynamics of manipulator, robot trajectory) and from basics of electrical servo drive. One should have ability to solve basics problems regarding linear systems (description in the state space, feedback control, feedforward control, linearization) as well as ability to gain information from particular sources. Must have the ability to solve basic problems from the scope of the required knowledge and the ability to obtain information from the indicated sources. Student should understand the need to extend his/her competences.

In addition, in respect to the social skills the student should show attitudes as honesty, responsibility, perseverance, curiosity, creativity, manners, and respect for other people.

Course objective

1. Teaching students about robotics: control of robot manipulators and modeling dynamics of manipulators; synthesis and analysis of control systems of robots.

2. Developing ability to resolve problems connected with control manipulators especially practical usage of control algorithms and their implementation.

3. Forming ability to choose a control law and strategy based on mathematic model, simulations and proper evaluation of the quality of the action proposed controller.

Course-related learning outcomes

Knowledge

The student:

1. has extended knowledge regarding modeling nonlinear dynamics of manipulators and indentification of model parameters; - [K2_W5]

2. has structured, theoretically based, detailed knowledge of the methods of analysis and design of manipulators control systems; - [K2_W7]

3. has a structured and in-depth knowledge of adaptive systems; - [K2_W9]

4. has extended knowledge in selected areas of robotics and in particular in the issues related to the use of robot manipulators; - [K2_W10]

Skills

The student is able to:

1. simulate and analyze working of complex automatic system (robot manipulator) and plan as well as do simulative and experimental verification. - [K2_U9]

2. determine the mathematical models of the dynamics of the manipulator, and use it for analysis and synthesis of the control system of the robots. - [K2_U10]

3. make a critical analysis of the functioning of the control system of manipulators, and will have the ability to select an appropriate control strategies. - [K2_U19]

4. critically evaluate and select appropriate methods and tools to solve the task in the field of robotics, will be able to use rapid prototyping tool for designing unconventional robot control system, and according to the needs of the driver will be able to shape the dynamic properties of the measuring circuits; - [K2_U22]

Social competences

1.The student is aware of the need for a professional approach to technical issues, careful look at the documentation and the environmental conditions in which the devices and their components can operate; - [K2_K4]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Formative assessment:

a) tutorials:

• based on an assessment of the progress of the task,

b) laboratory classes:

• evaluation of doing correctly assigned tasks (following provided lab. instructions).

Total assessment:

a) verification of assumed learning objectives related to lectures:

• assessment of knowledge and skills listed on the written test, which consists of five problem tasks for which you can get 25 points (5 points for the task) and a multiple-choice T consisting of 11 questions for which you can get 22 points - the final evaluation set is based on the weighted by W = T 2 * Z (score 3.0 requires the result of the test W = 36 points). In justified cases (e.g. remote work) the exam is conducted in the form of an extended test - a positive assessment requires obtaining at least half of the maximum number of points possible to obtain;

• assessment of knowledge and skills based on an individual discuss the results of the written exam (additional questions);

• in the case of outstanding students (prerequisite: very good marks from the laboratory) who show high activity in classes, a possibility of exam exemption is foreseen.

b) verification of assumed learning objectives related to lab exercises is provided by:

• assessment of student preparation for each session of the laboratory and assess the skills associated with laboratory exercises;

• continuous assessment for each course (oral response) - rewarding increase in ability to use new principles and methods;

• assess the performance of simulation programs prepared partly in the classroom and partly after the end of the appraisal also includes the ability to work in a team;

• assessment of knowledge and skills associated with laboratory tasks through one final test (oral from the laboratory);

• assessment and "defense" by the student reports on the implementation of the project tasks independently performed in the laboratory.

Programme content

The lecture cover the following topics:

1. A mathematical model of the manipulator and methods of its derive:

• Derivation of the formula for the kinetic energy (inertia tensor of links) and the potential energy of links manipula-tor

• Derivation of the formula for the total kinetic energy of the manipulator (manipulator mass matrix)

• Lagrange equation of the second kind, recursive Newton-Euler algorithm, jacobian method for deriving the equa-tions of the dynamics of the manipulator,

• Passivity property of the mechanical system,

• Friction models.

2. Algorithms for independent control of the manipulator links:

• Modeling the dynamics of the electrical and mechanical system in the control simplified

• Simple controls (P, PD, PID), their properties, tuning, practical implementation tacho feedback

• Analysis of the stability and astaticism the reference signal and the interference signal

• Control algorithm using feedforward and compensation of gravity (PID + FF + G)

• Sliding control.

3. Centralized control algorithms:

• Control with gravity compensation,

• Control of inverse dynamics,

• Adaptive algorithms for the manipulator,

• Algorithms of robust control.

4. Modelling of electric drive using synchronous motors.

5. Force control algorithms and hybrid position/force control.

Model is derived in detail the dynamics of two links planar manipulator by all methods. This model is a case study for all control algorithms. At the beginning a simplified control system independent interface keypad (link with the dynamics of the actuator and gearbox) is analyzed and synthesized. Synthesis of the control system takes account of the stability and control quality criteria and characteristics that must have the manipulator when making a move. Next, teacher design a centralized control systems including the control of inverse dynamics control, adaptive control, robust control etc.

The laboratory consists of fifteen two-hour practice, which take place in the laboratory, followed by a 2-hour instructional session at the beginning of the semester. Classes are conducted by teams of two students. The laboratory consists of exercise blocks. The final method of organization and procedure for crediting the laboratory is determined by the teacher and communicated to students at the first meeting.

Example of lab organization:

B1 - Unit introducing practice

C1. Manipulator model PM2R. Foward and inverse dynamics. Reference signal generator.

C2. Independent control of axes of the manipulator - a synthesis of control systems with two degrees of freedom.

C3. The implementation of the control signal by modulating the PWM. Measurement of the position and velocity estimation of the drive. Input current (torque) and voltage control signal.

C4. The manipulator with linearization feedback. The sensitivity of the method to the uncertainty of the model.

B2 – Unit consisting tasks of problem (hardware/simulation)

Z1. Universal program for symbolic derivation of dynamics of a robot manipulator (3D structure - at least three degrees of freedom with modelled dynamic load) - symbolic calculations - Matlab.

Z2. Implementation of PID + FF-corrected effect of wind-up - the keypad PM1R A.

Z3. The implementation of robust control regulator ROOS - the keypad PM2R D.

Z4. Implementation of the sliding control - the keypad PM1R B.

Z5. Implementation of control PD + FF + G - manipulator PM1R C.

Z6. The implementation of adaptive control Slotine-Li for one level of freedom - a robot gantry 3DCrane / specified 3D manipulator.

Z7. Quality control of the immune regulator ROOS for two limited areas of the controls:

hipersphere and hipercuboid - specified 3D manipulator Matlab-Simulink.

Z8. Sliding control for SISO/MIMO system. Resistance regulators slide - specified 3D manipulator Matlab-Simulink.

Z9. Slotin-Li adaptive controller for the manipulator model PM2R - Matlab-Simulink.

All groups perform exercises from unit B1. Then each group chooses and performs one hardware exercise from unit B2 (tasks Z1 to Z5) or all three simulation exercises from unit B3 (task Z6 to Z8).

All groups perform the exercises from block B1 and exercise Z1 from block B2 in conjunction with exercise C4. Then each group choose and performs one hardware exercise from block B2 (tasks Z2 to Z5) or at least two simulation exercises from block B2 (tasks Z6 to Z9).

Teaching methods

1. Lectures: presentation illustrated with examples supplied on the board, multimedia presentations

2. Tutorials: problem solving, case studies

3. Laboratory classes: the pursuit of simulation experiments and hardware, discussion, working in pairs, multimedia presenta-tion, demonstration of the manipulator control system and measurement systems, solving practical problems by teams

Bibliography

Basic

1. Wprowadzenie do robotyki. Mechanika i sterowanie, J.J. Craig, WNT Warszawa, 1993.

2. Dynamika i sterowanie robotów, M.W. Spong, M. Vidyasagar, WNT, Warszawa 1997.

3. Manipulatory i roboty mobilne. Modele, planowanie ruchu, sterowanie, K. Tchoń, A. Mazur, I. Dulęba, R. Hossa, R. Muszyński, Akademicka Oficyna Wydawnicza, Warszawa, 2000.

4. Modelowanie I sterowanie robotów, K. Kozłowski, P. Dutkiewicz, W. Wróblewski, Wydawnictwo Naukowe PWN, Warszawa, 2003.

Additional

1. Modeling and Control of Robot Manipulators, Sciavicco, B. Siciliano, Springer-Verlag, London, 2000.

Breakdown of average student's workload

	Hours	ECTS
Total workload	100	4,0
Classes requiring direct contact with the teacher	60	2,5
Student's own work (literature studies, preparation for laboratory classes, preparation for tests/exam, project preparation) [1]	40	1,5

[1] delete or add other activities as appropriate