Syllabus
Course Program

Motion control methods for robotic systems

Specialty
122 – Computer science

Institute
Institute of Computer Modeling, Applied Physics and Mathematics

Educational program
Computer science. Modeling, design, and computer graphics

Department
Computer modeling of processes and systems

Level of education
Master's level

Course type
Special (professional),

Semester
1

Language of instruction
English

Lecturers and course developers

Lavinskiy Denys Volodymyrovych
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Doctor of Technical Science, Associated Professor, Head of the Department "Theoretical Mechanics and Strength of Materials"

Specialist in the field of mechanics of deformable solids. The main scientific interests are in the study of the influence of physical fields on the processes of elastic and inelastic deformation of contact-interacting systems of bodies. He has more than 100 scientific and methodical works, including 3 textbooks. Basic courses: Theoretical Mechanics, Analytical Mechanics, Technical (Engineering) Mechanics
More about the lecturer on the department's website

General information

Summary

Motion control methods for robotic systems is a professional discipline studied by computer science students specializing in robotics in the master's degree at the Department of Computer Modeling of Processes and Systems. This is a subject that provides knowledge of the modern science of controlling the mechanical movement of robotic systems in the process of performing and preparing work operations. Due to the fact that the links of modern robot systems in the vast majority perform spherical and spatial movements, a significant amount of time in the course is devoted to familiarizing students with modern mathematical methods of tasks, description and analysis of kinematics and dynamics of systems whose links perform such movements. This is, first of all, the theory of quaternions, its application in kinematics and dynamics of mechanical systems, methods of classical analytical mechanics and modern computer methods of compiling equations of kinematics, statics and dynamics. The modern theory of controlling of the specified objects is taught in the necessary volume. Formulations and solutions of the first and second problems of dynamics, problems of identification of mechanical models of robots are considered. The usefulness of the course is determined by the fact that it gives students the competencies necessary for mathematical computer modeling of mechanical processes and their control in the design and operation of robotic systems.

Course objectives and goals

To provide students with the basic knowledge necessary for further understanding and rational use of concepts, laws and methods of theoretical and analytical mechanics of robotic systems, control theory of such systems; to increase the mathematical, mechanical and algorithmic culture of students; to indicate the ways of using modern methods of mechanics and the theory of control of robotic systems in practice using modern computer approaches and programs, to develop skills in solving the main problems of robot mechanics, to teach how to use the methods of robot mechanics to build mechanical and mathematical models, set up and solve problems of applied mathematics and programming. All this will lay the foundation for the productive work of graduates of the department in the field of robotics

Format of classes

Lectures, laboratories, self-study work, consultations. The final control is an exam.

Competencies

1) Ability to mathematically formalize the statement of the task;
2) Ability to choose and apply mathematical methods for solving practical problems of research, modeling, analysis, design, management, forecasting, decision-making;
3) Ability to conduct mathematical and computer modeling, data analysis and processing, computational experiments, solving formalized problems using specialized software tools;
4) The ability to understand the statement of the task formulated in the language of a certain subject area, to formulate a mathematical statement of the problem based on the statement in the language of the subject area and to choose a method of its solution, which ensures the required accuracy and reliability of the result;
5) Ability to use mathematical methods and techniques for the analytical solution of problems described by differential equations;
6) The ability to use mathematical methods and special algorithms for the numerical solution of mechanics problems, in particular the mechanics of robotic systems;
7) Ability to use mathematical methods and techniques to solve management theory problems;
8) Ability to use the methods of theoretical and analytical mechanics and mathematics to solve problems of solid body dynamics in the field of robotics;
9) Have knowledge of the fundamental foundations of theoretical, analytical and experimental mechanics, which provide an understanding of the processes and phenomena that take place in design objects in applied engineering applications;
10) Ability to perform computer modeling of complex objects and processes by means of modern software complexes, within the framework of solving design problems. Have an idea about modern technologies and tools for the implementation of CAD

Learning outcomes

1) Formalize tasks formulated in the language of a specific subject area; formulate their mathematical statement and choose a rational solution method; to solve the obtained problems by analytical and numerical methods, to evaluate the accuracy and reliability of the obtained results;
2) Develop mathematical models in the form of systems of differential equations using the methods of theoretical and analytical mechanics;
3) Choose rational methods and algorithms for solving mathematical problems of optimization, operations research, optimal management and decision-making, data analysis;
4) Be able to apply modern technologies of programming and software development, software implementation of numerical and symbolic algorithms;
5) To be able to use mathematical methods and techniques for the analytical solution of problems described by differential equations;
6) To be able to use mathematical methods and special algorithms for the numerical solution of problems of robot mechanics;
7) To be able to use mathematical methods and techniques to solve management theory problems;
8) To be able to use the methods of theoretical and analytical mechanics and mathematics to solve the problems of solid body dynamics;

9) To be able to use modern software complexes in engineering calculations based on the use of methods and software tools for computer modeling of complex objects and processes.

Student workload

The total volume of the course is 90 hours (3 ECTS credits): lectures - 32 hours, laboratory classes - 16 hours, self-study - 42 hours.

Course prerequisites

The course is based on the disciplines of the mechanical and informational namely mathematical analysis, matrix theory, control theory, information technologies.

Features of the course, teaching and learning methods, and technologies

The teaching methods that distinguish the course: peer-to-peer, teamwork

Program of the course

Topics of the lectures

Topic 1. Modern robotic systems. Their role in production, scientific research.

Topic 2. Problems of setting and solving tasks of mechanics and controlling spatial mechanisms with neutralizing constraints

Topic 3. Open kinematic chains are the basis of kinematics of modern robotic devices. Basics of a Kinematics.

Topic 4. Kinematics of motions of rigid bodies – links (elements) of robots.

Topic 5. Kinematics of a rotational motion.

Topic 6. Kinematics of a plane-parallel motion.

Topic 7. Kinematics of spherical and free motions of rigid bodies.

Topic 8. The concept of final turns of the body. Rodrigue-Hamilton parameters.

Topic 9. The concept of quaternions. Algebra of quaternions.

Topic 10. Quaternion description of rigid body rotation.

Topic 11. Determining the position of points and links of robots using four-dimensional matrices.

Topic 12. Solving the direct and inverse problem of robot kinematics.

Topic 13. Basics of kinetostatics as an effective method of compiling differential equations of motion of robotic systems.

Topic 14. Problem statements of robot dynamics. Newton-Euler differential equations of spatial motion of a rigid body.

Topic 15. The inverse problem of the dynamics of spatial robotic mechanisms.

Topic 16. Controlling of robotic devices based on solving the inverse problem of dynamics.

Topics of the workshops

Not included in the curriculum

Topics of the laboratory classes

Topic 1. Study of the movement of manipulator robot links based on particle kinematics.

Topic 2. Study of the movement of manipulator robot links based on solid body kinematics. Part 1.

Topic 3. Study of the movement of manipulator robot links based on solid body kinematics. Part 2.

Topic 4. Study of the movement of manipulator robot links based on kinematics of plane-parallel motion. Part 1.

Topic 5. Study of the movement of manipulator robot links based on kinematics of plane-parallel motion. Part 2.

Topic 6. Research on the equilibrium of systems of solid bodies - models of manipulator robots.

Topic 7. Research on the dynamics of robotic systems. Part 1.

Topic 8. Research on the dynamics of robotic systems. Part 2.

Self-study

Manual (vector) and computer (analytical) description and solution of problems of kinematics of spherical motion.
Use of quaternions to describe and solve problems of kinematics of spherical motion.
Using the Denavit-Hartenberg method to describe the kinematics of manipulators and robot movement mechanisms.
Comparison of the KiDiM method of describing the kinematics of manipulators and robot movement mechanisms.
Verification of the knowledge acquired by the student during self-study work is carried out during personal interviews during the verification of laboratory tasks.

Course materials and recommended reading

1. John Craig. Introduction to Robotics: Mechanics and Control (3rd Edition). - 2006.
2. Kevin M. Lynch and Frank C. Park. Modern Robotics: Mechanics, Planning, and Control. - 2017.
3. Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, Giuseppe Oriolo Robotics: Modelling, Planning and Control (Advanced Textbooks in Control and Signal Processing). - 2009.

Assessment and grading

Criteria for assessment of student performance, and the final score structure

The work on the questions submitted for independent work is evaluated by the lecturer at the colloquium at the end of the academic semester, and in the case of a positive evaluation, the student is admitted to the exam.
Points are awarded according to the following ratio:
• exam: 100% of the semester grade.

Grading scale

Total points	National	ECTS
90–100	Excellent	A
82–89	Good	B
75–81	Good	C
64–74	Satisfactory	D
60–63	Satisfactory	E
35–59	Unsatisfactory (requires additional learning)	FX
1–34	Unsatisfactory (requires repetition of the course)	F

Norms of academic integrity and course policy

The student must adhere to the Code of Ethics of Academic Relations and Integrity of NTU "KhPI": to demonstrate discipline, good manners, kindness, honesty, and responsibility. Conflict situations should be openly discussed in academic groups with a lecturer, and if it is impossible to resolve the conflict, they should be brought to the attention of the Institute's management.
Regulatory and legal documents related to the implementation of the principles of academic integrity at NTU "KhPI" are available on the website: http://blogs.kpi.kharkov.ua/v2/nv/akademichna-dobrochesnist/

Approval

Approved by

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