Ministry of Science and Higher Education of the Russian Federation
Federal State Autonomous Educational Institution of Higher Education
Perm National Research Polytechnic University

APPROVED BY
Pro-rector for Academic Affairs
_____ N.V. Lobov
"25" 11 2021

ACADEMIC COURSE WORKING PROGRAM

Academic course: Fundamentals of Distributed Robotics Control Science
(Name)

Form of education: Full-time studies
(full-time / part-time / correspondence)

Level of higher education: Bachelor's program
(Bachelor's program / Specialist program / Master's program)

Workload in hours (in credits): 216 (6)
(Hours (CU))

Training program (degree): 15.03.06 Mechatronics and Robotics
(Code and denomination of degree)

Direction: Mechatronics and Robotics
(Title of curriculum)

Perm 2021

1 General Provisions

1.1 Goals and Objectives of the Course

The goal of the course is to prepare students to engineering on developing methods of robots' control and robotics systems.

Tasks:

1. Studying mathematical models of robotics systems, their subsystems and separate elements, and units, including information, electrotechnical, hydraulic, electrohydraulic, electronic devices.
2. Acquiring capability to make calculations and designing new separate devices and subsystems of mechatronic and robotics systems using standard executive and control units, automation equipment, measuring and computer equipment.

1.2 Prescribed Objects of the Course

Robots and robotics systems

1.3 Starting Conditions

Unstipulated

2 Planned Results of the Course Training

Competence	Indicator's Index	Planned Results of the Course Training (to know, to be able, to master)	Indicator of Attaining Competence which the planned results of training are correlated with	Means of Assessment
PC-2.6	**IA-1$_{PC-2.6}$**	**To know:** - Mathematical forms of models' representation of robotics systems' individual elements; - methods of models' dynamic qualities analysis in temporary or frequency domain; - methods of modelling transformation from one to another, qualities of elementary dynamic elements.	**Knows** methods of determining functional indicators of flexible production systems.	Exam

PC-2.6	**IA-2$_{PC-2.6}$**	**To be able to** - construct mathematical models of robotic systems' separate elements; - to provide computational experiments using software packages aimed to research mathematical models.	**Is able to** calculate performance indicators for flexible production systems.	Exam
PC-2.6	**IA-3$_{PC-2.6}$**	**To master the skills** of analytic production technology and researching of mathematical models' elements and systems; of computational modelling and systems' analysis using standard software packages.	**Has mastered the skills** of definition of functional indicators of flexible production systems.	Exam

3. Full time and forms of academic work

Form of academic work	**Hours in all**	**Distribution in hours according to semesters**
		Number of semester
		6
1 Holding classes (including results monitoring) in the form: 1.1 Contact classwork, including:	80	80
- lectures (L)	40	40
- laboratory work (LW)		
- practice, seminars and/or other seminar-type work (PW)	36	36
- control of self-work (CSW)	4	4
- test paper		
1.2 Students' self-work (SSW)	100	100
2 Interim/midterm assessment		
Exam	36	36
Grading test		
Test		
Course Project (CP)		
Course Work (CW)		
Workload in hours	**216**	**216**

4 Course contents

Course units with brief contents	Full time of classroom activity in hours according to the forms			Full time of extracurricular work in hours according to the forms
	L	LW	PW	SSW
6th semester				
General information about robotics systems control.	4	0	2	4
Classification of robotics systems control according to positioning modes, element base, production principles of control action. Composition of control system. Levels of robotics systems control and current tasks.				
Forward and inverse problems about position and rate, reserved motion rate control.	8	0	8	22
Kinematic equation of standard form. Matrix of Jacobi. Forward and inverse kinematics solutions about position and rate. Forward solution in angular system of coordinates. Kinematic algorithm of zero order. Structural circuit's system controlled by position vector. Kinematic algorithm of the first order. Structural circuit's system controlled by rate vector.				
Planning of robot's actions in joint coordinate space.	6	0	4	10
Defining spline functions. The style of reference-input signals of zero and the first order. Spline functions of the second and third order. Continuity and proximity conditions during trajectory interpolation with the help of cubic splines. Expressions for rate determination of changing internal coordinates in the next time intervals. The condition of rates integrity. The boundary conditions. System of linear algebraic equations for defining parameters of cubic spline.				
Mathematical models of industrial robots.	10	0	8	24
Assumptions in manipulator's analysis of amplitude attribute. Lagrange equation of the second order. Equations of the executive mechanism motion with n degrees of freedom. Design model of the XYZ manipulator with the Cartesian coordinates. Equations of motion of the XYZ manipulator with the Cartesian coordinates. Vector form of recording equations of motion. Powek circuit of mechanical actuator. Mathematical description of the motor. Equations of manipulator's motion with the Cartesian coordinates and taking into account the servomotor.				

Dynamic control of industrial robots.	8	0	8	24
Statement of dynamic control problem. Methods of control, based on the dynamic's inverse solution. Circuit control system, made according to the "inverse solution" method. Equations of manipulator's motion with the servo driver of direct current in algebraic and matrix forms of recording. Principle of control according to acceleration. Structural system's circuit, controlled by acceleration. Position manipulator's control with the Cartesian coordinates, structural circuits of control systems. Statement of continuous path control problem using principle of control according to acceleration. Structural system's circuit of continuous path control, controlled by acceleration. Defining parameters of acceleration loop.				
Industrial robot's motion planning in the working space.	4	0	6	16
General questions of robot's motion planning. Path constraints. Theoretical approach to the program motions construction. Basic functions. Construction of program motions for the driverless truck. Construction of program motions for the manipulator.				
Total with regard to 6th semester	**40**	**0**	**36**	**100**
Total with regard to the course	**40**	**0**	**36**	**100**

Topics of exemplary practical work

№	Topic of practical (seminars) work
1	Matrix description of robot's kinematics.
2	Position and continuous path control systems.
3	Construction of structures and typical circuits of robotics complexes for different purposes.
4	Constructive elements of electrical control systems. Construction of control systems' functional circuits.
5	Study of the basic methods of pneumatic and hydraulic drills control according to speed and position.
6	Analysis of the control system tracking error the dynamics of the robot arm.
7	Motion planning of the powered truck.
8	Motion planning of the manipulator.
9	Calculating the independent PID control of the robot coupling.
10	Analysis of the robotics complex technological process and the development of the control system structure.

5. Organizational and Pedagogical Conditions

5.1 Educational Technologies Used for Competences Formation

Holding lectures in the discipline is based on the active method of training in the process of which students are not passive but active participants of the lesson answering questions of the teacher. Teacher's questions are aimed at activating the process of learning material as well as at the development of logical thinking. The questions stimulating associative thinking and connecting new material with the previous one are identified by the teacher in advance.
Practical lessons are held by realization of the method based on active training: problem areas are determined, groups are formed. The following aims are pursued in the process of practical education: use of definite disciplines knowledge and creative methods in solving problems and decision-making; students' skill-building of teamwork, interpersonal communication and development of leadership skills; consolidation of the basic theoretical knowledge.
Interactive lectures, group discussions, role-playing games, training sessions, and analysis of situations and simulation models are used in academic studies.

5.2 Students' Manual for the Course Study

Learning the course, it is advisable for students to implement the following recommendations:
1. Learning of the discipline should be done systematically.
2. After learning one of the course units with the help of the text-book or lecture notes it is recommended to reproduce the basic terms, definitions, notions of the unit from memory.
3. Special attention should be paid to the reports on practical studies and individual complex tasks for self-work.
4. The topics list for individual study is given by the teacher at the lectures. The teacher also provides students with literary sources (first of all, new ones in the periodical scientific literature) for a more detailed understanding of the issues presented at the lectures.

6. List of Teaching Materials and Information Supply for Students' Self work in the Discipline

6.1 Paper-based courseware

№	Bibliographic entry (author, title, mode of publication, place, publishing house, year of publication, number of pages)	Number of copies in the library
	1 Basic literature	
1	Kafrissen E., Stephans M. Industrial robots and robotics. Reston, Virginia. Reston Publ., 1984.	1
2	Flexible Manipulators: Modeling, Analysis and Optimum Design. electronic book / New York. Elsevier, 2012.	
	2 Additional literature	
	2.1 Educational and scientific literature	
1	Dorf R.C. Modern control systems / Reading, Massach. Addison-Wesley Publ. Co, 1990.	1
2	Dorf R.C., Bishop R.H. Modern control systems/ New Jersey. Pearson Educational Intern., 2005.	1
	2.2 Periodical literature	

2.3 Standardized and Technical literature		
3 Students' manual in mastering discipline		
4 Teaching and learning materials for students' self-work		

6.2 Electronic Courseware

Kind of literature	Name of training tool	Reference to information resource	Accessibility of EBN (Internet / local net; authorized / free access)
Additional literature	Frank L. Lewis, Darren M. Dawson, Chouki T. Abdallah Manipulator control, Theory and Practice, second edition, revised and expanded.	https://lewisgroup.uta.edu/FL%20books/Robot_Manipulator_Control_Theory_and_Practice_-_Frank_L.Lewis-%20small.pdf	authorized / free access

6.3 License and Free Distributed Software used in the Course Educational Process

Type of Software	Software branding
Operating systems	MS Windows 10 (Azure DevTools for Teaching)
Office applications	LibreOffice 6.2.4. OpenSource, free
Office applications	Microsoft Office Professional 2007. licence 42661567
General purpose application software	MATLAB 7.9 + Simulink 7.4 Academic, PNRPU 2009.

6.4 Modern Professional Databases and Inquiry Systems Used in the Course Educational Process

Branding	Reference to information resource
eLIBRARY.RU Database	https://elibrary.ru/
Scientific Library of Perm National Polytechnic Research University	http://lib.pstu.ru/
Lan' Electronic library system	https://eJanbook.com/
IPR books Electronic library system	http://www.iprbookshop.ru/
Information resources of Consultant+ web	http://www.consultant.ru/

7 Logistics of the Course Educational Process

Type of classes	Name of the necessary basic equipment	Number of units
Lecture	Laptop computer, multimedia projector	1
Practicals	Personal computer	25

8 Fund of the Course Evaluating Tools

Described in a separate document