Faculty Engineering and Technology
Department «Automation, information technology and urban planning»

The program of the entrance exams to PhD-doctoral studies in the group of educational program D100 - Automation and Control

Semey – 2024

1 DEVELOPED

Compilers:

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2 DISCUSSED

At the meeting of the department «Automation, information technology and urban planning»

Protocol № 10 «31» May 2024

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3 AGREED

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4 APPROVED

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1. Introduction

The entrance examination program for the PhD doctoral specialty is formulated based on the programs of preceding levels of higher education (bachelor's) and postgraduate education (master's).

A candidate applying for a PhD program should:

have an understanding of:

- the measurements of technological parameters and their specificity;
- the elements of modern automatic control theory, problems, tasks, methods of their solution, advantages and disadvantages.
- about the main characteristics of control objects, standard automatic regulators, principles of tuning industrial control systems, methods for calculating optimal regulators for objects with delay;

to know:

- The main principles of functioning of modern integrated computer-aided design systems;
- Fundamental principles of building control systems;
- Principles of operation and mathematical description of components of mechatronic and robotic systems (information, electromechanical, electrohydraulic, electronic elements, and computing devices).
- Principles of construction of modern automated control systems in technical systems, their composition and structure, the content of types of software and hardware of control systems, their interrelation.
- Principles of organization and architecture of automatic and automated control systems for objects and processes in various industrial sectors;
- Perspectives and trends in the development of automation and control tools and systems;
- Principles, methods, and techniques of hardware and software integration for creating automation and control systems;
- Rules, methods, and tools for preparing technical documentation.

To be able to:

- Practically implement automatic control in conditions of incomplete a priori information during the operation of the system in the current situation and arising circumstances;
- Determine the main parameters of automated systems in static and dynamic conditions based on known characteristics of elements;
- Synthesize functional and algorithmic diagrams of control systems for technical systems;
- Master methods for researching complex technological processes using modern computing tools;
- Program microcontrollers and industrial controllers.

Have the skills:

- Designing autonomous subsystems for mathematical, informational, linguistic, software, technical, organizational, and ergonomic support of automated process control systems (APCS).
- Proficiency in working with network equipment, configuring it to meet the needs of specific users under the operating conditions of designated operating systems.
- Acquiring practical skills in applying systems approach principles, fundamental aspects of technical system automation tasks, basic methods and algorithms of analysis and synthesis of analog and digital control systems for technological processes.
- Selection of industrial instruments and means for automation and control systems.

be competent:

- In the development of control algorithms ensuring the high-quality functioning of technical systems.
- In the rational selection of calculation methods and determination of optimal parameters for instruments and equipment.
- In the utilization of instruments for conducting experimental research.
- In the development of computer models of researched processes and systems and applying them to determine optimal design, engineering, and technological solutions.

2. The name of the discipline and its main sections

1. Methods of describing control objects in state-space coordinates

The concept of state space. Methods of obtaining mathematical models of processes and systems in state-space coordinates. Structural representations of systems described in state space.

2. Observability, identifiability, controllability, adaptability

Observability. Identifiability. Controllability. Adaptability.

3. Stability of processes in state space. Methods of absolute stability theory

Concepts of stability in state space. Criteria for stability of motion "in large". Criteria for stability of motion "in small". Static and astatic systems in state space. Invariance in control theory. Methods of absolute stability theory.

4. Methods and algorithms for estimating dynamic processes

Classification of estimation tasks. Some general provisions of applied estimation theory for continuous processes. Algorithm for estimating continuous processes. Mathematical description of discrete processes. Algorithms for estimating discrete-time processes. Continuous field estimation algorithms.

5. Methods and algorithms for identification of dynamic systems

General classification of identification problems. Classical methods of nonparametric identification of linear dynamic systems. Direct methods of parametric identification. Searchless identification algorithms with adaptive model. Search-based identification algorithms with adaptive model. Identification algorithms based on process estimation theory. Recurrent identification algorithms with correlated noises. Optimal joint estimation and parametric identification in discrete linear systems.

6. Criteria for optimization of control

Single-objective and multi-objective optimization. Methodology for choosing the minimized functional. Expanded forms of functionals for optimization of continuous deterministic processes. Expanded forms of functionals for optimization of continuous deterministic processes with discrete time. Functionals for optimization of control of stochastic processes.

7. Some general methods of optimal control theory

Classical variational calculus and modern optimization problems of dynamic systems. Maximum principle.

8. Algorithms of optimal control

Classification of algorithms for optimal automatic control. Synthesis of control laws for continuous deterministic processes with classical forms of functionals. Synthesis of control laws for deterministic processes with discrete time with classical forms of functionals. Synthesis of control laws for stochastic processes with classical type functionals. Solution to the problem of minimizing the criterion of generalized work in general form. Synthesis of optimal and suboptimal nonlinear controls at the system design stage with generalized work functionals. Synthesis of control laws for linear processes with generalized work functional (AKOR method). Optimal controls synthesized during system operation in real time (combined synthesis). Model control algorithms.

9. Optimization of dynamic systems with random structure

Key definitions. Equations of systems with random structure. Optimal filtering of processes with random structure. Control in systems with random structure.

10. Algorithms of adaptive automatic control systems

Classification of adaptive automatic control systems. Adaptive optimal control systems with a full model of controlled processes. Adaptive suboptimal control systems with simplified models of controlled processes. Searchless direct adaptive control systems. Searchless adaptive systems with implicit reference models. Searchless adaptive systems with linear estimation based on reference model.

11. Method of recurrent target inequalities in adaptive control

Formal description of adaptive system. Description of the method of recurrent target inequalities. Main convergent algorithms for solving an infinite system of recurrent inequalities. Adaptive suboptimal control of minimal-phase objects. Adaptive systems with reference model. Adaptive stabilization of non-minimum-phase objects and adaptive modal control. Adaptive control of nonlinear static objects.

12. Extremal regulation systems

General concepts. Influence of drift on stability. Transient processes and periodic motions. Improvement of work quality.

13. Methods and algorithms of estimation in correlation-extremal systems

Classification of correlation-extremal systems. Methods and algorithms of estimation in correlation-extremal systems.

14. Methods of sensitivity theory

Sensitivity models of continuous and discontinuous systems. Sensitivity of solutions to boundary value problems. Sensitivity functions and coefficients for non-temporal characteristics and optimality indicators of control systems. Sensitivity invariants. Applied problems of sensitivity theory.

15. Search methods for automation of design

Problem statement of automation of control system design process. Structure of optimization search algorithm. Local parametric search algorithm. Accounting for constraints in random search processes. Global search. Optimization in the presence of random disturbances. Structural optimization.

16. Automation of control system design

Principles of automation of control system design. Methods of building automated design systems.

Literature:

1. Rotach V.Ya. Theory of Automatic Control. - Moscow: MEI, 2004. - 400 p.
2. Theory of Automatic Control, edited by Yu.M. Solomentsev. - Moscow: Higher School, 2007. - 268 p.
3. Pletnev G.P. Automation of Technological Processes and Productions in Heat Power Engineering. - Moscow: MEI, 2005. - 352 p.
4. Dorf R., Bishop R. Modern Control Systems. - Moscow: Laboratory of Basic Knowledge, 2010. - 832 p.
5. Stefani E.P. Fundamentals of Setting Regulators for Thermal Power Processes. - Moscow: Energia, 1972. - 376 p.
6. Stefani E.P., Panko M.A., Pikina G.A. Collection of Problems on Fundamentals of Automatic Regulation of Thermal Power Processes. - Moscow: Energia, 1973. - 336 p.
7. Theory of Automatic Control. Parts 1, 2. /Voronov A.A. - Moscow: Higher School, 1986.
8. Tsypkin Ya.Z. Fundamentals of Automatic Systems Theory. - Moscow: Nauka, 1977.
9. Pervozvanskiy A.A. Course of Automatic Control Theory. - Moscow: Nauka, 1986.
10. Handbook of Automatic Control Theory, edited by A.A. Krasovsky. - Moscow: Nauka, 1987.
11. Yu.I. Topcheev. Atlas for Designing Automatic Regulation Systems. - Moscow: Mashinostroenie, 1989.
12. Imaev D.Kh., Krasnoshporina A.A., Yakovlev V.B. Theory of Automatic Control. Part 1. Linear Automatic Control Systems. - Kiev: Higher School, 1992.
13. Alexeev A.A., Imaev D.Kh., Kuzmin N.N., Yakovlev V.B. Control Theory. - St. Petersburg: TETU Publishing, 1999.
14. V.F. Komissarchik. Automatic Regulation of Technological Processes. Tver State Technical University. Tutorial. Tver, 2001.

15. T.Ya. Lazareva, Yu.F. Martemyanov. Linear Systems of Automatic Regulation. Tver State Technical University. Tutorial. Tver, 2001.

16. E.A. Nikulin. Theory of Automatic Control. Polynomial Analysis. Methodical Instructions for Laboratory, Practical, and Course Works. Nizhny Novgorod, 1998.

17. N.V. Klinachyov. Theory of Automatic Regulation Systems. Educational-methodical complex.

18. V.N. Tyukin. Control Theory. Part 1. Ordinary Linear Control Systems. Lecture Notes. Vologda, 2000.

1. Concept of state space.
2. Methods of obtaining mathematical models of processes and systems in state-space coordinates.
3. Concepts of stability in state space. Criteria for stability of motion "in large".
4. Concepts of stability in state space. Criteria for stability of motion "in small".
5. Methods of absolute stability theory.
6. Classification of estimation problems.
7. Algorithm for estimating continuous processes.
8. Algorithms for estimating discrete-time processes.
9. General classification of identification problems.
10. Classical methods of nonparametric identification of linear dynamic systems.
11. Direct methods of parametric identification.
12. Searchless identification algorithms with adaptive model.
13. Search-based identification algorithms with adaptive model.
14. Single-objective and multi-objective optimization.
15. Methodology for choosing the minimized functional.
16. Classical variational calculus and modern optimization problems of dynamic systems.
17. Classification of algorithms for optimal automatic control.
18. Synthesis of optimal and suboptimal nonlinear controls at the system design stage with generalized work functionals.
19. Synthesis of control laws for linear processes with generalized work functional.
20. Optimal filtering of processes with random structure.
21. Classification of adaptive automatic control systems.
22. Adaptive optimal control systems with a full model of controlled processes.
23. Formal description of adaptive system.
24. General concepts of extremal regulation systems.
25. Methods and algorithms of estimation in correlation-extremal systems.

Discipline: «Automation of technical systems»

Topics: Key concepts of technical systems automation. Overview of the current level and prospects of development.

Research on the quality of transient processes in combined, cascaded, and multivariable control systems with analog and/or digital controllers. Classification of control systems by levels of automation. Basic principles of technical systems automation.

Controlled objects in technical systems, their classification. Properties and characteristics of controlled objects in technical systems.

Industrial automatic control systems (ACS). Principles of construction. Typical ACS and control systems.

Properties and characteristics. Principles of design, tuning, and commissioning. Industrial automatic control systems (ACS). Typical ACS and control systems. Properties and characteristics. Principles of design, tuning, and commissioning.

Logical control systems (ACS). Principles of construction. Technical base. Design methods. Principles of construction and technical implementation.

Industrial automatic control systems (ACS). Typical ACS and control systems. Properties and characteristics. Principles of design, tuning, and commissioning.

Hardware and software complexes for designing and implementing automated technical systems.

Automation of typical technical processes. Mathematical models and mathematical modeling of control and monitoring objects.

Integrated systems for managing technological processes and production.

Identification of technical control objects (TCOs): obtaining information about TCOs; transformation of technological information; types and forms of signals, active and passive methods of TCO identification.

Microprocessor devices, complexes, and industrial controllers.

Digital communications in TCO management.

Literature:

1. Technical Automation and Control Devices. Edited by O. Kolosov, Moscow: Yurayt, 2017. 290 pages.

2. Gustav Olson, Gianguido Piani. Digital Automation and Control Systems. St. Petersburg: Nevsky Dialect, 2011. 557 pages.

3. Dorf R. Modern Control Systems. R. Dorf, R. Bishop. Translated by B.I. Kopylov. Moscow: Laboratory of Basic Knowledge, 2012. 832 pages.

4. Automation of Typical Technological Processes and Installations: Textbook for Universities. A.M. Korytin, N.K. Petrov, S.N. Radimov, N.K. Shaparev. Moscow: Energoatomizdat, 1988. 432 pages.

5. Demenkov N.P. SCADA Systems as a Tool for Designing ACS TP: Textbook. Moscow: Publishing House of Bauman Moscow State Technical University, 2004. 328 pages.

6. Design of Automation Systems for Technological Processes: Reference Book. [A.S. Klyuev, B.V. Glazov, A.Kh. Dubrovsky, A.A. Klyuev]; Edited by A.S. Klyuev. Moscow: Energoatomizdat, 1990. 464 pages.

7. Technique for Reading Automatic Control and Technological Control Schemes. [A.S. Klyuev, B.V. Glazov, M.B. Mindin, S.A. Klyuev]; Edited by A.S. Klyuev. Moscow: Energoatomizdat, 1990. 432 pages.

1. Data transmission at the controller level of the ACS TP.
2. Data transmission at the controller level of the ACS TP. ASI protocols.
3. Data transmission at the controller level of the ACS TP. LON protocols.
4. Multiloop ACS. Classification, examples of practical implementation.
5. Principles of building ACS TP (centralized and decentralized).
6. Algorithms for synthesizing combinational control systems.
7. Development of requirements for automation systems for TP.
8. Functional diagrams of automation for TP.
9. Algorithms for synthesizing sequential schemes based on transition tables and Karnaugh maps.
10. Data transmission at the controller level of the ACS TP. PROFIBUS protocols.
11. Composition and content of project documentation for automation of technological processes.
12. Transient processes. Key performance indicators of regulation.
13. Industrial ACS TP network. Principles of constructing an industrial network.
14. Methods of describing TP as control objects.
15. Data transmission at the controller level of the ACS TP. Ethernet protocols.
16. Typical transient processes.
17. Concept of identification of automatic control objects.
18. Methods of tuning ACS with typical controllers for monotonic objects with delay.
19. Increasing the reliability of initial information.
20. Principles of technical and software implementation of ACS using SCADA systems.
21. Methods for calculating cascade ACS.
22. Principles of building automation systems, taking into account the advantages of various branches of technical means.
23. Methods for calculating combined ACS.
24. Interrelated control systems.
25. Data transmission at the controller level of the ACS TP. CAN protocols.

Discipline: "Executive Systems of Industrial Robots"

Topics:

1. General information about drives of mechatronic and robotic devices
2. Types of drives for industrial robots

3. Executive devices based on electric drives
4. Electric drive for industrial robots
5. Drives based on electromagnetic clutches (EMCs)
6. Executive devices based on pneumatic drive
7. Pneumatic drive for industrial robots
8. Executive devices based on hydraulic drive
9. Executive systems of industrial robots
10. Composition and purpose of executive systems of industrial robots
11. Features of different types of automatic control systems for industrial robots
12. Types of control systems for industrial robots
13. Control systems for electric drive of industrial robots
14. Control systems for pneumatic drive of industrial robots
15. Control systems for hydraulic drive of industrial robots
16. Control systems for micromovements based on piezoceramics
17. Cyclical control systems and their features
18. Positional control systems
19. Contour control systems
20. Adaptive control systems for industrial robots.

Questions:

1. What is a robot and a robotic system?
2. The purpose of robots.
3. Classification of robots.
4. General scheme of control system for an intelligent robot.
5. Adaptation and learning in robotics.
6. Main simulated procedures in robot automation.
7. Classification of adaptive control systems for robots.
8. Tasks of adaptation and learning for robots.
9. Problems in creating adaptive robots.
10. Pneumatic drive for robots.
11. Functional composition of pneumatic drives for robots.
12. Actuators of pneumatic drives for robots. Purpose and types.
13. Relay actuators for industrial robots' pneumatic drives.
14. Tracking pneumatic drive for industrial robots.
15. Damping of pneumatic drives. Types and purposes.
16. Hydraulic drive for robots. Application area.
17. Composition of hydraulic drive for robots.
18. Control systems for gyrodynamics of robots.
19. Piezoelectric motors. Application area.
20. Cyclical control systems for robots.
21. Executive systems based on electric drives.
22. Executive system based on asynchronous ED.
23. Executive system based on DC ED.

24. Executive system based on stepper motor.

25. Role and place of executive system in the structure of a robot.

Literature:

1. Usoltsev A.A. Electric Drive. Textbook. St. Petersburg: ITMO University, 2012. 238 p.

2. Borisov A.M., Nesterov A.S., Loginova N.A. Programmable Automation Devices: Textbook. Chelyabinsk: Publishing Center of South Ural State University, 2010. 186 p.

3. Bulgakov A.G., Vorobyov V.A. Industrial Robots: Kinematics, Dynamics, Control and Management. Series "Engineer's Library". Moscow: SOLON-PRESS, 2008. 488 p. (in Russian)

4. Popov E.P., Pis'menny G.V. Fundamentals of Robotics: Introduction to the Specialty: Textbook for Universities. Moscow: Higher School, 1990. 224 p.

5. Kochtyuk V.I., Gavrish A.P., Karlov A.G. Industrial Robots: Design, Control, Operation. Higher School, 1985.

6. Usoltsev A.A. Electric Drive. [Online resource]. URL: http://e.lanbook.com/view/book/71195/. Accessed: 28.07.2019.

7. Bulgakov A.G., Vorobyov V.A. Industrial Robots: Kinematics, Dynamics, Control and Management. Series "Engineer's Library". [Online resource]. URL: http://e.lanbook.com/view/book/13760/page475/ Accessed: 28.07.2019.