1. Course title: HIERARCHICAL CONTROL

2. Course code


4. Level of studies: 1st cycle of higher education

5. Mode of studies: intramural studies

6. Field of study: MACRO COURSE (FACULTY SYMBOL)

7. Profile of studies:

8. Programme: Automatic Control

9. Semester: 7

10. Faculty teaching the course: Institute of Automatic Control, RAu1

11. Course instructor: dr hab. Krzysztof Fujarewicz

12. Course classification: common courses

13. Course status: compulsory

14. Language of instruction: English

15. Pre-requisite qualifications: Students should have completed courses of: Mathematical analysis, Optimization and decision making, Control fundamentals.

16. Course objectives: This course is addressed to students interested in systems analysis, control engineering, management and decision making. It covers basic methods used in solving control and optimization problems associated with large-scale and complex systems. After completing the course student has basic knowledge in optimization and control of large scale systems. This knowledge consists of methods of analysis of composite systems, solving structured optimization problems and designing hierarchical and decentralized feedback systems.

17. Description of learning outcomes:

<table>
<thead>
<tr>
<th>Nr</th>
<th>Learning outcomes description</th>
<th>Method of assessment</th>
<th>Teaching methods</th>
<th>Learning outcomes reference code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Students understand terms: large-scale system, complex system, hierarchical structure, and know basic structures of control and optimization of complex systems.</td>
<td>SP</td>
<td>WT, WM</td>
<td>T1A_W02, T1A_W03,</td>
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<tr>
<td>2.</td>
<td>Students know methods of mathematical description of complex systems and they are able to numerically model and simulate such systems.</td>
<td>SP</td>
<td>WT, WM</td>
<td>T1A_U01, T1A_U02, T1A_U09.</td>
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<tr>
<td>3.</td>
<td>Students know how to decompose given complex optimization problem and apply the direct (parametric) method of coordination.</td>
<td>CL, PS</td>
<td>L</td>
<td>T1A_U01, T1A_U02, T1A_U03, T1A_U15.</td>
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<tr>
<td>4.</td>
<td>Students can decompose given complex optimization problem and apply the price method of coordination.</td>
<td>CL, PS</td>
<td>L</td>
<td>T1A_U06, T1A_U07.</td>
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<tr>
<td>5.</td>
<td>Students can perform the sensitivity analysis of a given complex system.</td>
<td>CL, PS</td>
<td>L</td>
<td>T1A_U04, T1A_U06.</td>
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<tr>
<td>6.</td>
<td>Students can apply the sensitivity analysis to solve problems of parameter estimation and control optimization for complex and non-linear systems.</td>
<td>CL, PS</td>
<td>L</td>
<td>T1A_U01, T1A_U02, T1A_U09.</td>
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</table>
7. Students understand differences between problems of control and optimization for simple and complex structures.

SP

WT, WM

T1A_K01, T1A_K03.

18. Teaching modes and hours

Lecture: 30 hours, Laboratory: 30 hours

19. Syllabus description:

Lectures:
Introduction and the terminology. Large scale systems, complex systems, decomposition coordination. Different types of hierarchical structures: multilayer structure and multilevel structure.
Mathematical models of systems. Static models. Mathematical model of the planning problem for the oil refinery. Dynamical models. Concentrated-parameter models and distributed-parameter models.
Description of complex systems, subsystems, the structure matrix. Static characteristics.

Laboratory:
The aim of the exercise is modeling of a stirred-tank continuous-flow reactor, finding its static characteristics, and designing control system for the reactor.
Exercise 2. Oil refinery optimization
The aim of the exercise is to solve the problem of optimal production in an oil refinery. The problem is formulated as a linear programming (LP) problem which is solved using Matlab software.
Exercise 3. Direct method of coordination
The aim of the laboratory exercise is to apply the direct method of coordination to a complex static system composed of three cross-coupled subsystems.
Exercise 4. Price method of coordination
The aim of the laboratory exercise is to apply the price method of coordination to a complex static system composed of three cross-coupled subsystems.
Exercise 5. Dynamic programming
The aim of the exercise is to apply dynamic programming method in order to optimize an example of multistage process.
Exercise 6. Identification of complex systems
Students make use of the sensitivity analysis to parameter estimation of nonlinear Hammerstein model.
Exercise 7. Control of complex systems
During the laboratory students perform gradient-based optimization of close-loop control system.
Exercise 8. Control of complex systems
Students make use of the adjoint sensitivity analysis in order to gradient-based optimization of a control signal for given non-linear system.

20. Examination: without an exam

21. Primary sources:

22. Secondary sources:
23. Total workload required to achieve learning outcomes

<table>
<thead>
<tr>
<th>Lp</th>
<th>Teaching mode</th>
<th>Contact hours / Student workload hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lecture</td>
<td>30/15</td>
</tr>
<tr>
<td>2</td>
<td>Classes</td>
<td>/</td>
</tr>
<tr>
<td>3</td>
<td>Laboratory</td>
<td>30/15</td>
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<tr>
<td>4</td>
<td>Project</td>
<td>/</td>
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<td>5</td>
<td>BA/MA Seminar</td>
<td>/</td>
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<tr>
<td>6</td>
<td>Other</td>
<td>/</td>
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<tr>
<td></td>
<td>Total number of hours</td>
<td>60/30</td>
</tr>
</tbody>
</table>

24. Total hours: 90

25. Number of ECTS credits: 3

26. Number of ECTS credits allocated for contact: 1

27. Number of ECTS credits allocated for in-practice hours (laboratory classes, projects): 2

26. Comments:

Approved:

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(date, Instructor’s signature) (date, the Director of the Faculty Unit signature)