

## SYLLABUS

### 1. Data about the program of study

1.1	Institution	The Technical University of Cluj-Napoca
1.2	Faculty	Faculty of Automation and Computer Science
1.3	Department	Automation
1.4	Field of study	Systems Engineering
1.5	Cycle of study	Master
1.6	Program of study/Qualification	Cyber-Physical Systems
1.7	Form of education	Full time

### 2. Data about the subject

2.1	Subject name	Reinforcement Learning	Subject code	14.00
2.2	Course responsible/lecturer	Prof. dr. eng. Busoniu Lucian – <a href="mailto:Lucian.Busoniu@aut.utcluj.ro">Lucian.Busoniu@aut.utcluj.ro</a>		
2.3	Teachers in charge of seminars	Drd.eng. Pirje Stefan		
2.4	Year of study	2	2.5 Semester	1
			2.6 Assessment	Exam
2.7	Subject category	Formative category		DS
		Optionality		DI

### 3. Estimated total time

3.1	Number of hours per week	3	of which	3.2 Course	2	3.3 Seminars	0	3.3 Laboratory	1	3.3 Project	0
3.4	Number of hours per semester	42	of which	3.5 Course	28	3.6 Seminars	0	3.6 Laboratory	14	3.6 Project	0
3.7 Individual study:											
(a) Manual, lecture material and notes, bibliography											26
(b) Supplementary study in the library, online and in the field											9
(c) Preparation for seminars/laboratory works, homework, reports, portfolios, essays											9
(d) Tutoring											1
(e) Exams and tests											3
(f) Other activities											10
3.8	Total hours of individual study (summ (3.7(a)...3.7(f)))					58					
3.9	Total hours per semester (3.4+3.8)					100					
3.10	Number of credit points					4					

### 4. Pre-requisites (where appropriate)

4.1	Curriculum	Discrete-time systems, basics of probabilities and nonlinear systems, basics of optimization
4.2	Competence	Analytical and programming competencies

### 5. Requirements (where appropriate)

5.1	For the course	Attendance is not mandatory, but optional graded quizzes will be taken during the lectures
5.2	For the applications seminarului / laboratorului / proiectului	Lab solutions are mandatory and graded; each consists of Matlab/Python code and a report document

## 6. Specific competences

Professional competences	<ul style="list-style-type: none"> <li>• Demonstrates disciplinary expertise</li> <li>• Thinks abstractly</li> <li>• Performs data analysis</li> <li>• Analyzes test data</li> <li>• Presents analysis results</li> <li>• Synthesizes information</li> <li>• Uses software libraries</li> <li>• Develops software prototypes</li> <li>• Communicates scientific findings</li> <li>• Writes scientific and academic papers and technical documentation</li> <li>• Applies the principles of scientific ethics and integrity in research activities</li> </ul>
Transversal competences	<ul style="list-style-type: none"> <li>• Think analytically</li> <li>• Apply scientific, technological, and engineering knowledge</li> <li>• Work in teams</li> </ul>

## 7. Expected Learning Outcomes

Knowledge	<p>The student will know:</p> <ul style="list-style-type: none"> <li>• advanced concepts, principles, and methodologies in systems engineering, automation, and cyber-physical systems</li> <li>• principles of design, operation, and evaluation for complex control systems</li> <li>• advanced applications of AI and machine learning technologies in industrial contexts, including their integration into control systems and automation</li> <li>• interdisciplinary concepts from mathematics, signal processing, automation, control theory, and computer science applicable to the design and optimization of complex systems</li> <li>• the principles of scientific ethics and academic integrity</li> </ul>
Skills	<p>The student will be able to:</p> <ul style="list-style-type: none"> <li>• conduct scientific and interdisciplinary research, analyze data, and communicate results effectively to professional and academic audiences</li> <li>• design, develop, and implement software and control applications for cyber-physical systems</li> <li>• use modeling, simulation, AI, and machine learning to develop intelligent, autonomous, and automated solutions</li> <li>• apply ethical principles, academic integrity, and responsible research practices in professional activities</li> </ul>
Responsibilities and autonomy	<ul style="list-style-type: none"> <li>• The student will be responsible for carrying out professional or research projects</li> <li>• The student will be responsible for ensuring ethical conduct and academic integrity</li> <li>• The student will be responsible for promoting collaboration, teamwork, knowledge transfer, and innovation within professional and research environments</li> </ul>

## 8. Discipline objectives (as results from the *key competences gained*)

8.1	General objective	The student will be able to choose and successfully apply a reinforcement learning method for a given nonlinear, possibly stochastic optimal control problem where the system model is unknown
8.2	Specific objectives	<p>The student will be able to:</p> <ul style="list-style-type: none"> <li>• Formulate an optimal control problem in the Markov decision process (MDP) setting</li> <li>• Characterize the optimal solution in the MDP setting</li> <li>• Understand and apply exact dynamic programming and reinforcement learning methods</li> </ul>

	<ul style="list-style-type: none"> <li>• Understand classical and deep-network-based function approximation</li> <li>• Understand and apply approximate (classical and deep) reinforcement learning methods</li> <li>• Given a new problem, be able to select an algorithm among exact, approximate, and deep reinforcement learning</li> </ul>
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## 9. Contents

9.1. Lectures	Hours	Teaching methods	Notes
1. The reinforcement learning problem	2	<ul style="list-style-type: none"> <li>• Presentation based on videoprojector slides</li> <li>• Interactive discussions (questions, exercises etc.)</li> <li>• Lecture quizzes</li> </ul>	
2. The optimal solution	2		
3. Dynamic programming	3		
4. Classical reinforcement learning	3		
5. Classical function approximation	3		
6. Approximate dynamic programming	3		
7. Approximate reinforcement learning	3		
8. Deep neural networks	3		
9. Deep value-based reinforcement learning	3		
10. Deep policy-gradient reinforcement learning	3		
<b>Bibliography</b> <ol style="list-style-type: none"> <li>1. "Reinforcement learning". Lecture notes in the form of slides.</li> <li>2. L. Busoniu, R. Babuska, B. De Schutter, D. Ernst, Reinforcement Learning and Dynamic Programming Using Function Approximators, CRC Press, Automation and Control Engineering Series. April 2010.</li> <li>3. D. P. Bertsekas. Dynamic Programming and Optimal Control, volume 2. Athena Scientific, 4th edition, 2017.</li> <li>4. R. S. Sutton and A. G. Barto. Reinforcement Learning: An Introduction. Bradford, 2018, 2<sup>nd</sup> ed.</li> </ol>			
9.2. Applications - Seminars /Laboratory/Project	Hours	Teaching methods	Notes
1. Dynamic programming: Q-value and policy iteration	3	<ul style="list-style-type: none"> <li>• Reminder about the objective and method of each lab</li> <li>• Method implementation and usage in Matlab or Python</li> <li>• Interaction with students and solution grading</li> </ul>	
2. Exact reinforcement learning: Q-learning	3		
3. Approximate reinforcement learning	3		
4. Deep neural networks	2		
5. Deep reinforcement learning: deep Q-networks	3		
<b>Bibliography</b> <ol style="list-style-type: none"> <li>1. "Reinforcement learning". Lecture notes in the form of slides.</li> <li>2. L. Busoniu, R. Babuska, B. De Schutter, D. Ernst, Reinforcement Learning and Dynamic Programming Using Function Approximators, CRC Press, Automation and Control Engineering Series. April 2010.</li> <li>3. D. P. Bertsekas. Dynamic Programming and Optimal Control, volume 2. Athena Scientific, 4th edition, 2017.</li> <li>4. R. S. Sutton and A. G. Barto. Reinforcement Learning: An Introduction. Bradford, 2018, 2<sup>nd</sup> ed.</li> </ol>			

**10. Bridging course contents with the expectations of the representatives of the community, professional associations and employers in the field**

The course provides control methods for systems that are insufficiently known and/or too complex (nonlinear, stochastic behavior) to apply classical control methods. These methods are relevant in advanced applications and research into the control of cyber-physical and other systems.

**11. Evaluation**

Activity type	11.1 Assessment criteria	11.2 Assessment methods (and evaluation form: continuing/final)	11.3 Weight in the final grade
11.4 Course	Correct solution of the proposed questions	Written exam (final evaluation)	50%
11.5 Seminars /Laboratory/Project	Correct Matlab/Python usage for reinforcement learning	Solutions to the lab (code, report), electronically submitted (continuing evaluation)	50%
11.6 Minimum standard of performance			
Original lab solutions (code and report) submitted; at least a rounded grade of 5 combined across the written test, lab solutions, and optional lecture quizzes.			

Date of filling in:		Title Surname Name	Signature
01.09.2025	Lecturer	Prof. dr. eng. Busoniu Lucian	
	Teachers in charge of application	Drd.ing. Pirje Stefan	

Date of approval in the department of Automation _____	Head of department, Prof.dr.eng. Honoriu VĂLEAN
Date of approval in the Faculty of Automation and Computer Science Council _____	Dean, Prof.dr.eng. Vlad MUREȘAN