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
1.8	Subject code	14.00

2. Data about the subject

2.1	Subject name			Reinforcement Learning			
2.2	Course responsible/lecturer			Prof. dr. eng. Busoniu Lucian – Lucian.Busoniu@aut.utcluj.ro			
2.3	Teachers in charge of seminars			Prof. dr. eng. Busoniu Lucian – Lucian.Busoniu@aut.utcluj.ro			
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 Seminar	0	3.3 Laborator	1	3.3 Proiect	0
3.4 Total hours in the curriculum	42	of which	3.5 Course	28	3.6 Seminar	0	3.6 Laborator	14	3.6 Proiect	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 competence	C1 Analysis and solution of control system modelling and design problems using advanced mathematical knowledge and fundamental concepts from automatic systems theory
Cross competences	CT2 Managing roles, responsibilities and communication in a team, monitoring and controlling the activities carried out to effectively achieve objectives.

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

7.1	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
7.2	Specific objectives	The student will be able to: • Formulate an optimal control problem in the Markov decision process (MDP) setting • Characterize the optimal solution in the MDP setting • Understand and apply exact dynamic programming and reinforcement learning methods • Understand classical and deep-network-based function approximation • Understand and apply approximate (classical and deep) reinforcement learning methods • Given a new problem, be able to select an algorithm among exact, approximate, and deep reinforcement learning

8. Contents

8.1. Lecture (syllabus)	Number of hours	Teaching methods	Notes
1. The reinforcement learning problem	2	• Presentation based on videoprojector slides • Interactive discussions (questions, exercises etc.)	
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	• Lecture quizzes	
8. Deep neural networks	3		
9. Deep value-based reinforcement learning	3		
10. Deep policy-gradient reinforcement learning	3		

Bibliography

1. "Reinforcement learning". Lecture notes in the form of slides.
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.
3. D. P. Bertsekas. Dynamic Programming and Optimal Control, volume 2. Athena Scientific, 4th edition, 2017.
4. R. S. Sutton and A. G. Barto. Reinforcement Learning: An Introduction. Bradford, 2018, 2nd ed.

8.2. Seminars /Laboratory/Project	Number of hours	Teaching methods	Notes
1. Dynamic programming: Q-value and policy iteration	3	• Reminder about the objective and method of each lab • Method implementation and usage in Matlab or Python • Interaction with students and solution grading	
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		

Bibliography

1. "Reinforcement learning". Lecture notes in the form of slides.
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.
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9. 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.

10. Evaluation

Activity type	10.1 Assessment criteria	10.2 Assessment methods	10.3 Weight in the final grade
10.4 Course	Correct solution of the proposed questions	Written exam	50%

10.5 Seminars /Laboratory/Project	Correct Matlab/Python usage for reinforcement learning	Solutions to the lab (code, report), electronically submitted	50%
10.6 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: 16.03.2023		**Title Surname Name**	**Signature**
	Lecturer	Prof. dr. eng. Busoniu Lucian	
	Teachers in charge of application	Prof. dr. eng. Busoniu Lucian	

Date of approval in the Department of Automation _____	Head of department Prof.dr.ing. Honoriu Valean
Date of approval in the faculty of Automation and Computer Science _____	Dean Prof.dr.ing. Liviu Miclea