COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
Artificial intelligence	

Annotation
This course is aimed at students of physics and other physical sciences interested in advanced systems of information technologies, looking to find out mathematical principles and implementation algorithms behind them. The course material will discuss social, scientific and technological concepts of artificial intelligence (AI), present the most popular AI-related techniques (such as big data analysis, machine learning, logical reasoning and natural systems' modeling) and their applications in problem solving/ planning, robotics, computer vision and natural language processing. The course is developed with emphasis on practical programming exercises of both model and realistic applications.

Lecturer(s)	Department(s) where the course unit (module) is delivered
Coordinator: Dr. Stepas Toliautas	**Faculty of Physics**

Study cycle	Type of the course unit (module)
Second cycle (master studies)	Compulsory

Mode of delivery	Period when the course unit (module) is delivered	Language(s) of instruction
Contact (on-site) teaching	3rd (autumn) semester	Lithuanian, English

Requirements for students	
Prerequisites: programming (practical skills are critical), calculus and probability theory (bachelor level)	**Additional requirements (if any):** none

Course (module) volume in credits	Total student's workload	Contact hours	Self-study hours
5	140 hours	64	76

Purpose of the course unit (module): programme competences to be developed		
To familiarize students with the principles and algorithms used in advanced information-processing and problem-solving systems (rational agents); to deepen programming skills needed to create programs that control or perform tasks given to such systems; to acquire competences of formulation and solving of naturally arising interdisciplinary problems in physical sciences and technology.		
Learning outcomes of the course unit (module)	**Teaching and learning methods**	**Assessment methods**
Students will learn programming principles and techniques used to solve various problems incorporating uncertainty, knowledge acquisition and need for imperfect decisions in areas of information technology, engineering, natural sciences etc.	Lectures, case studies, exercises and homework problems	Homework solutions, oral report, written exam (open questions)
Students are expected to apply presented techniques to solve typical model problems in given areas, to assess limitations of created or provided solutions and their applicability to real-world cases	Code reviews, homework problems, research project (programming and write-up)	Solutions to programming tasks, research presentation

Content: breakdown of the topics	Contact hours							Self-study work: time and assignments	
	Lectures	Tutorials	Seminars	Exercises	Laboratory work	Internship/work placement	**Contact hours**	**Self-study hours**	**Assignments**
1. **AI context.** History of defining field of artificial intelligence. AI research: brain machinery, knowledge-based, results-oriented. Concept of rational agent and its (work-)environment. AI success stories.	2		2				**4**	**4**	*Python* primer
2. **Problem solving by search.** Prerequisites for searching. Search algorithm, implementations and complexity. Blind and informed search algorithms. Path costs, heuristic functions. Local search and search in continuous parameter spaces. *Constraint-satisfaction problems.*	4		4				**8**	**6**	Homework assignments Research project
3. **Bayesian networks.** Partially observable states. Models of probabilistic relations. Bayes theorem. Probabilistic inference in Bayesian networks by enumeration and sampling.	2		2				**4**	**4**	
4. **Machine learning.** Knowledge acquisition task. Supervised learning: classification, regression. Data smoothing and regulatization. Cross-validation of learning outcomes. Unsupervised learning: *k*-means, expectation maximization, affinity-based methods (principal component analysis). *Decision trees. Learning in artificial neural networks.*	4		4				**8**	**8**	
5. **Logic and planning.** Formal logic: Boolean, first order logic. Planning in partially observable environment: belief states, prediction-update cycle. Classical planning concepts and extensions. Planning software, *PDDL. Situation calculus. Knowledge representation theory. Fuzzy logic.*	2		2				**4**	**6**	
6. **Utility**. Types of uncertainty. Uncertainty of actions. Markov decision process, utility function, execution (action) policy. Utility by value iteration. Reinforcement learning: temporal difference, Q-learning, generalization, exploration vs. exploitation.	4		4				**8**	**8**	
7. **Decisions with multiple agents.** Games as environment models. Single-player and zero-sum multi-player game. Adversarial search: *min-max*, pruning, evaluation functions, stochastic games. Game theory: dominant and mixed strategies, Nash equilibrium, Pareto optimum. Inverse game theory: truth-revealing rules, auctions.	4		4				**8**	**6**	
8. **Computer vision.** Formation of two-dimensional images: light collection by pinhole and lens, perspective projection, invariant transform. Image elements: pixels, edges, corners, unique signatures. Image detection: edge filters, Harris corner detector. Depth perception and reconstruction. Stereoscopic images, correspondence using disparity maps and alignment. Structure from motion equations.	4		4				**8**	**8**	
9. **Robotics.** Localization problem: hidden Markov models and particle filters. Monte Carlo localization.	2		2				**4**	**6**	

Sensors, actuators, robotic movement planning.									
10. **Natural language processing.** Probabilistic language models (*n*-grams) and extensions: frequency analysis, semantic classification (phrasing). Segmentation and auto-correcting tasks. Lexical language models: parsing, context-free grammars. Machine translation. *Speech recognition.*	2		2				**4**	**4**	
11. ***Information in natural systems*.** Structure of neuron, biological and artificial neuron models. Artificial neural networks: back-propagation, hidden layers, Hopfield (associative) networks. Genetic algorithms: selection, crossover, mutation. Evolution functions: cellular automata, fractals.	2		2				**4**	**8**	Oral report
12. **Course review before examination.**								**8**	
Total	**32**			**32**			**64**	**76**	

Assessment strategy	**Weight, %**	**Deadline**	**Assessment criteria**
Homework exercises	40 %	2–3 weeks after each assignment	*For each exercise*: correct solution – 1 point, partial solution – 0,5 point, incorrect/ no solution – 0 points. Final grade is a sum of individual exercise grades.
Oral report on a given subject and code presentation	20 % *	Special lecture / seminar	*Report*: clear presentation – 2 points, weak argumentation – 1 point, no report – 0 points. *Assignment*: correct solution – 2 points, partial solution – 1 point, incorrect/ no solution – 0 points.
Research project (programming, write-up and presentation)	40 % *	Week 16	*Code*: correct, efficient and clear solution – 2 points, partial or inept solution – 1 point, incorrect/ no solution – 0 points. *Write-up and presentation*: problem context, narrowing/ interpretation and means of proposed solution (1 point), test choices, results and analysis (1 point).
Written exam	30 %	Exam period	Open questions. Final grade is a percentage of correct answers.
* **Coursework-based** grade is a sum of grades for all completed assignments (rows 1–3). **Examination-based** grade is a sum of homework grades (40 %), *average* of individual assignments (rows 2–3, 30 %) and grade of the final exam (30 %).			

Author	**Year of publication**	**Title**	**Issue of a periodical or volume of a publication**	**Publishing place and house or web link**
Compulsory reading				
S. J. Russell, P. Norvig	2010	Artificial Intelligence: A Modern Approach	3rd edition	Prentice Hall, Upper Saddle River, NJ
T. Munakata	2008	Fundamentals of the New Artificial Intelligence	2nd edition	Springer-Verlag, London
Optional reading				
M. Lungarella, F. Iida, J. Bongard, R. Pfeifer (Eds.)	2007	50 Years of Artificial Intelligence: Essays		Springer-Verlag, Berlin/ Heidelberg
J. van Benthem, J. van Eijck, H. van Ditmarsch, J. Jaspars	2016	Logic in Action (open access course)		www.logicinaction.org
S. Sumathi, T. Hamsapriya, P. Surekha	2008	Evolutionary Intelligence		Springer-Verlag, Berlin/ Heidelberg