Course title: MULTI-AGENT SYSTEMS

Lecturers	Full Prof. Markus Schatten, Ph.D. Bogdan Okreša Đurić, Ph.D. Tomislav Peharda, M.Inf.
Language of instruction	Croatian and English
Study level	Master
Study programme	Databases and Knowledge Bases
Semester	3rd (winter)
ECTS	4
Goal	The main objective of the course is to introduce students to the fundamental theoretical and practical principles of multi-agent systems. The course is focused on the formalization of multi-agent systems' features by applying various approaches including reasoning about knowledge, game theory, swarm theory, organization theory, automated negotiation, logic argumentation and automated planning. At the end of this course students should be able to: present several application domains as a multi-agent system, model multi-agent systems using various formalisms including Kripke structures, finite automata, matrix algebra; analyze the features of multi-agent systems (calculating satisfiability of formuale) in the context of a given Kripke structure by using PLKT (a formal multi-agent system language) and understand multi-agent system implementation problems. Students will also be introduced to multi-agent system implementation methodology and applications of agent technology by implementing a multi-agent system of their own.
General and specific learning outcomes	
Content	**1. Introduction** Overview. Global computing. Agents – a definition. Multi-agent systems (MAS). MAS interdisciplinarity (distributed systems, artificial intelligence, game theory, social science). Some views on MAS. Critics of MAS. **2. Symbolic logics** Preposition logic: syntax, semantics, logic consequence, catalogue of equality for preposition logic. First order logics: syntax, semantics, logic consequence, catalogue of equality for first order logic **3. Intelligent agents** What is an agent? Agent and objects. Agents and expert systems. Agents and artificial intelligence. Environments. Agents as intentional systems. Intelligent agent's abstract architecture (formalization). **4. Deductive reasoning agents** Introduction. Agents as theory provers. Selection of actions through deductive reasoning. Belief-desire-intention (BDI) agent model. Finite automata. Agent oriented programming. **5. Practical reasoning agents** Practical reasoning. Intentions in practical reasoning. Intentions vs. desires. Automated planning. Box world. STRIPS. Implementing practical reasoning agents. Agent control loop. **6. Interaction and agreement**

	Introduction. Agent interaction. Game theory. Nash equilibrium. Prisoners Dilemma (PD). Iterated (PD). Backward induction. Axelrod's tournament. Other symetric games. Agreement. Protocols. Auctions. Negotiation. Biateral negotiation. Qualitative valuations. Fuzzy sets. Multilateral negotiation. Negotiation strategies. Argumentation. Logic argumentation. Abstract argumentation. **7.** Reasoning about knowledge Possible worlds' model. PLK language (proposition logics + knowledge). Examples of knowledge calculations in Kripke structures. General knowledge and distributed knowledge. Group knowledge. Characteristics of agent knowledge. Temporal operators: temporal operators for the future, temporal operators for the past. PLKT language. PLKT language graphic representation. Forgetfulness operators and PLKTF. Graphical PLKTF (GPLKTF). **8.** Methodologies Introduction. MAS methodologies overview. Network science. Graph theory. MetaMatrix model. Matrix algebra. Modeling dynamics. Organizational design of MAS. **9.** Swarm intelligence Introduction. Swarms in nature. Characteristics of swarms. Stigmergy. Self-organization. Social insects. Ants. Agent based modelling of ant colonies. Spanning trees. Minimal spanning trees. Combinatorial optimization. Ant colony optimization (ACO). ACO algorithms. Travelling salesman problem (TSP). ACO for TSP.
Exercises	During the whole semester laboratory exercises will introduce students to the practical aspects of the theoretical knowledge presented in the lectures. Content of exercises: 1. Simple agents 2. Agent behavior 3. Agent communication 4. Agent's and system's services 5. Agents with finite state machine behavior 6. Agents with event (trigger) behavior 7. BDI agent infrastructure 8. Agent's knowledge base 9. Automated planning 10. Auctions 11. Negotiation 12. Example MAS applications
Realization and examination	Classes: Lectures, Laboratory exercises; Examination: Practical project, written and oral examination.
Related courses	1. Imperial College, London, Department of Computing, Multi-Agent Systems 2. Stanford University, Department of Computer Science, Multi-Agent Systems 3. Rice University, Department of Computer Science, Reasoning about Knowledge
Literature	Basic: Lectures Fagin, R. et al. Reasoning About Knowledge, The MIT Press, 2001. Wooldridge, M. An Introduction to MultiAgent Systems, John Wiley & Sons, 2002 Additional:

	Maleković, M. Agent Properties in Multi-Agent Systems. Informatica, An International Journal of Computing and Informatics, 1999, 23, 283-288.

	2. Maleković, M. and M. Čubrilo. Some Properties of Forgetfulness in Multi-Agent Systems. Proceedings, 2002 IEEE International Conference on Intelligent Engineering Systems, INES 2002, pp. 361-362. **3.** Minker, J. Logic Based AI, Kluver Academic Publishers, Boston, 2000 **4.** Subrahmanian, V. S. et al. Heterogeneous Agent Systems, The MIT Press, 2000
Internet sources	http://www.multiagent.com