**Syllabus**

1. Course Description
   1. Title of a Course, Research seminar “Computational Logic and Artificial Intelligence”, Научно-исследовательский семинар “Вычислительная логика и искусственный интеллект” (in English)
   2. Pre-requisites, “Discrete Mathematics” (optional)
   3. Course Type (compulsory, elective, optional)

Abstract: Research seminar aims to cover modern aspects of computational logic and its application to the problems of constructing different models of artificial intelligence and decision making modules, data extraction and reasoning.

Learning Objectives:

The aims of this course are to

1. introduce the theoretical foundations of the mathematical logic and to
2. provide the students with practical skills of using diverse methods to implement logical constructions .

Learning Outcomes:

By the end of the course, the student should be able to:

1. understand fundamental concepts, advantages and limits of the computational logic;
2. understand and use the RDF framework and associated technologies such as RDFa and SPARQL;
3. understand and use methods of program verification;
4. know non-classical logics and their applications;
5. know modern methods of functional expressibility by Lupanov’s school and their extensions to many-valued logics.
6. Course Plan
7. **Description logic.**

This area of Computer Science logic is concerned with knowledge representation formalisms that

1. are interesting in the context of applications (e.g., in the Semantic Web, Linked Data, healthcare, etc. ontologies, ontology-based data access), and
2. can be supported by efficient reasoning algorithms (unlike first-order logic). The area is vibrant and fast developing, and the aim of the seminar is to give an overview of some interesting trends and results.
3. **Ontology-based data access.**

Ontology-based data access (OBDA) is regarded as a key ingredient for the new generation of information systems, especially for Semantic Web applications that involve large amounts of data. In the OBDA paradigm, an ontology defines a high-level global schema and provides a vocabulary for user queries, thus isolating the user from the details of the structure of data sources (which can be relational databases, triple stores, datalog engines, etc.). The OBDA system transforms user queries into the vocabulary of the data and then delegates the actual query evaluation to the data sources. The aim of the seminars is to introduce some basic ideas and techniques used in OBDA systems, as well as the theoretical foundations.

1. **Spatial and temporal logics.**

These are classical areas of Knowledge Representation, having their roots in philosophical and mathematical logic. The aim of the seminar is to overview recent developments from the computational complexity point of view. In particular, we are going to consider Region Connection Calculus and related logics, as well as Allen’s interval logic and its multi-dimensional generalisations.

1. **Non-traditional logics in the traditional AI planning.**

The aim is to use Girard's linear logic as an efficient and comprehensive logical tool for a typical AI problem of making a plan of the actions to be performed by a robot so that it could get into a final situation, if it started with a certain initial situation. A particular focus is on strong planning under uncertainty caused by actions with non-deterministic effects and actions that may have quantitatively delayed effects in continuous time. The ultimate goal is to show that for many planning problems - that are known to be a considerable obstruction to computer-aided planners, linear logic is especially effective and leads to a dramatic contraction of the search space from exponential to polynomial in size.

1. **Non-traditional logics for Formal verification of software.**

As an effective language for reasoning about heap memory models, we use the formalism of separation logic. Besides the intrinsic technical/theoretical interest of

its principles, such as the frame rule and abduction, local reasoning and compositionality, separation logic provides new insights which could be of use in practical applications of logic to program analysis.

1. **Non-traditional logics for assured information sharing within collaborative systems and security protocols.**

The aim is to develop efficient and comprehensive logical systems and programming tools to enable multiple parties to share information and at the same time enforce confidentiality, privacy, trust, release, dissemination, data quality and provenance policies. The formal systems should be capable of handling important properties of real-time collaborative systems such as safety, liveness, schedulability, surviveness, simulation, monitoring, etc. The aim is to develop efficient logical systems capable of handling security protocols in software, distributed systems, and concurrent systems.

1. **Basic modal language and semantics. Provability logic. Fixed-point modal logics and computation.**

In modal logics, one can reason not only about what is true or false, but also about what was or will be true, may or must be true, or, say, what agents know or believe to be true and how these beliefs change when new information becomes available. Modal formulas are interpreted in terms of possible worlds semantics: a statement may be true in one possible world and false in another one.

1. **Modern methods in Boolean Logic**

Description of closed classes of Boolean logic, extended E.L.Post theorem.

Normal forms in different bases, the properties of canonical forms.

Statement of the problem there is a finite total equivalence systems (FTES), the second R.C. Lyndon theorem. Extended Lyndon theorem, description of FTES for closed classes of Boolean logic.

Universal methods of synthesis of circuits and formulas, asymptotically best O.B. Lupanov synthesis. The uniformity of the closed classes of Boolean logic.

Counter-examples in many-valued logic, reason, generalizations.

The course lasts 28 academic hours.

1. Reading List:
2. Pascal Hitzler, Markus Kroetzsch and Sebastian Rudolph. Foundations of Semantic Web Technologies. Chapman & Hall, 2009. ISBN 978-1420090505.
3. David Wood, Marsha Zaidman and Luke Ruth. Linked Data. Manning Publications, 2013. ISBN 9781617290398.
4. Max Kanovich and Jacqueline Vauzeilles. Linear logic as a tool for planning under temporal uncertainty. Theoretical Computer Science, 412, 2011, pp.2072-2092
5. Reynolds, J.~C. 2002. Separation logic: A logic for shared mutable data structures. In Proceedings of LICS-17. IEEE Computer Society, 55--74.
6. N.Gorogiannis, M.Kanovich, and P.O'Hearn. The Complexity of Abduction for Separated Heap Abstractions. The 18th International Static Analysis Symposium (SAS 2011), Sept~14-16, Venice, Italy
7. James Brotherston and Max Kanovich. J. ACM 61(2): 14 (2014), 43 pages.
8. Undecidability of Propositional Separation Logic and Its Neighbours (with James Brotherston). J. ACM 61(2): 14 (2014), 43 pages.
9. Max Kanovich, T.Ban Kirigin, V.Nigam, A.Scedrov, and C.Talcott. Discrete vs Dense Times in the Verification of Cyber-Physical Security Protocols. 4th Conference on Principles of Security and Trust (POST 2015) ETAPS 2015: 11-18 April 2015, London, UK
10. Max Kanovich, T.Ban Kirigin, V.Nigam, and A.Scedrov. Bounded Memory Protocols Computer Languages, Systems and Structures, 40 (2014), 137–154.
11. Max Kanovich, T.Ban Kirigin, V.Nigam, and A.Scedrov. Bounded memory Dolev-Yao adversaries in collaborative systems. Information and Computation, 238 (2014) 233-261.
12. Max Kanovich, T.Ban Kirigin, V.Nigam, A.Scedrov, and C.Talcott.
13. Towards Timed Models for Cyber-Physical Security Protocols FCS-FCC 2014, Joint Workshop on Foundations of Computer Security and Formal and Computational Cryptography, affiliated to CSF 2014, Vienna, Austria.
14. Gasquet, O., Herzig, A., Said, B., Schwarzentruber, F. "Studies in Universal Logic: Kripke’s Worlds", Birkhäuser Mathematics, 2014
15. **Patrick Blackburn, Maarten de Rijke, and Yde Venema, Modal Logic, Cambridge University Press, 2002**
16. Johan Van Benthem, Modal Logic for Open Minds, Center for the Study of Language and Information, 2010
17. D. Lau. Function algebras on finite sets. Springer Monographs in Mathematics. Springer-Verlag, Berlin, 2006. A basic course on many-valued logic and clone theory.
18. R. C. Lyndon. Identities in two-valued calculi. Trans. Amer. Math. Soc., 71:457–465, 1951.
19. R. C. Lyndon. Identities in finite algebras. Proc. Amer. Math. Soc., 5:8–9, 1954.
20. I. Makarov. Existence of finite total equivalence systems for certain closed classes of 3-valued logic functions. Logica Universalis, 9(1):1–26, 2015.
21. Grading System: 3 homeworks, 3 in-class tests and an examination.
22. Guidelines for Knowledge Assessment

Students have to study a new topic each module.

1. Methods of Instruction

Practical classes using PC. Individual course projects.

1. Special Equipment and Software Support (if required)

Sufficient PC quantity for students.