

**STUDENT INTERNSHIPS AT THE MATHEMATICAL INSTITUTE SANU
JUNE 2023**



Functional calculus on algebras of matrices and operators, and its applications

Mentors. Nebojša Dinčić, Bogdan Đorđević

Description. Students would familiarize themselves with analytic and measurable functional calculus defined on algebras of square matrices and on elements of operator algebras. They would study their properties and relations, and they would also apply this calculus in order to solve certain matrix and operator equations.

Prerequisites. Linear algebra, analysis of vector-valued functions over \mathbb{R} , matrix analysis, functional analysis, measure theory, complex analysis, operator theory.

Developing metaheuristic algorithms for optimization problems

Mentors. Tatjana Davidović, Tatjana Jakšić Kruger, Dragan Urošević

Description. This topic belongs to the field of Operations research and management science. The main research topics are directed towards the development of mathematical models and (meta)heuristic optimization methods for various world-known optimization problems (optimization on graphs, scheduling, transportation, location, etc). Beside the application of different general purpose exact solution methods (CPLEX, Gurobi, LINGO, etc.), problem specific exact and heuristic algorithms will be developed. Although working with various metaheuristic methods, we particularly promote the ones developed by Serbian researchers: Variable Neighborhood Search (VNS) and Bee Colony Optimization (BCO). In addition, our current research project investigates parallelization, theoretical and empirical evaluation of metaheuristics. Our interest is also directed towards the integration of Artificial Intelligence (AI) and optimization methods to deal with real-life optimization problems that occur in science and industry.

Suggested material.

- Talbi, El-Ghazali, *Metaheuristics: from design to implementation*, John Wiley & Sons, 2009.
- Hansen, Pierre, et al., *Variable neighborhood search: basics and variants*, EURO Journal on Computational Optimization 5(3):423–454, 2017.
- Davidovi, T., *Bee Colony Optimization: Recent Developments and Applications*, (plenary talk), Proc. Balkan Conference on Operational Research, BALCOR 2015, Constanta, Romania, Sept. 9–12, 2015. Mircea cel Batran Naval Academy Scientific Bulletin, 18(2):225-235, 2015.

Logical reasoning in the presence of uncertainty

Mentors. Šejla Dautović, Zoran Ognjanović

Description. Probabilistic logics as generalization of classical logics. Syntax and semantics, basic theorems of these logics (correctness, deduction theorem, completeness theorem). Decidability results. Logical formalization of the notion of confirmation. Combination with other non-classical logics.

Prerequisites. Familiarity with classical mathematical logic.

Suggested literature.

- Zoran Ognjanović, Nenad Krdžavac, Teorijsko računarstvo, <http://www.mi.sanu.ac.rs/zorano/ti/2013/TeorijskoRacunarstvo.pdf>.
- G.E. Hughes, M.J. Cresswell, A Companion to Modal Logic.
- Zoran Ognjanović, Miodrag Rašković, Zoran Marković, Probability Logics: Probability-Based Formalization of Uncertain Reasoning, Springer, 2016.
- Zoran Ognjanović, editor, Probabilistic Extensions of Various Logical Systems, Springer, 2020.

Polyhedral Products over Neighborly Polytopes

Mentor. Đorđe Baralić

Description. Toric topology studies torus actions on topological spaces arising from combinatorial constructions and the most well-known such a class is that of the polyhedral products. Neighborly polytopes are important class of polytopes which is not understood sufficiently well. In this project we study the cohomology ring and its properties for the moment angle and the real moment angle complexes over neighborly polytopes.

Research in combinatorics

Mentor. Luka Milićević

Description. Each candidate will get three open problems in combinatorics. During the first week, every candidate will choose a single problem and work on it for the remaining duration of the project. In order to help the students develop their own mathematical interests further, each of the three problems will come from a different area of combinatorics, such as combinatorial geometry, extremal combinatorics or graph theory.

Lie groups and Dynkin diagrams

Mentors. Borislav Gajić, Vladimir Dragović, Božidar Jovanović

Description. The aim of this topic is to familiarize students with basic examples of Lie groups and algebras, as well as with the classification problem for semi-simple Lie algebras.

Integrable mechanical systems

Mentors. Borislav Gajić, Vladimir Dragović, Božidar Jovanović

Description. Given that this topic is rather broad, its details and realization will depend on the candidate's level of previous exposure to this field.

Selected topics in mechanics

Mentors. Borislav Gajić, Vladimir Dragović, Božidar Jovanović

Description. Given that this topic is rather broad, its details and realization will depend on the candidate's level of previous exposure to this field.

Research in categorical proof theory

Mentor. Mladen Zekić

Description. Categorical proof theory is a field of mathematics that lies on the border between category theory and logic. The student would first become familiar with basic concepts in category theory, such as functors, natural transformations, adjunction and monoidal categories. Next, a relationship between formal systems and categories would be introduced; namely, objects correspond to formulas and arrows (morphisms) correspond to proofs. Special arrows in the category theory are axioms, and operations on arrows are deduction rules. This connection allows us to use results from proof theory in category theory. The main aim of this topic is to familiarize the student with proof theory techniques that are applied in category theory. One of the most important such techniques is the Gentzen's Cut Elimination Theorem, which is crucial for solving problems concerning the equalities of arrows in certain types of categories. Such results are known as coherence results. Given that equalities of arrows in a category correspond to equalities of proofs in a formal system, coherence also answers the question of equalities of proofs.

Machine learning in action: performance analysis of algorithms for solving problems in various subfields

Mentor. Radmila Janković Babić

Description. Interested students would be offered a selection of problems from various subfields of machine learning, including classification, prediction and segmentation. The aim of this approach is to enable students to develop their own interests in different fields of application of machine learning, while simultaneously developing their skills in practical problem solving and the use of different algorithms.

Support systems for healthcare decision making

Mentor. Anđelka Zečević

Description. Artificial intelligence algorithms have found their application in the healthcare where their role is to facilitate complex decision making. During this internship, the students would familiarize themselves with principles of medical data processing, they would develop classification algorithms, and they would analyze the obtained results, both quantitatively and qualitatively. Students who

prefer working with images and computer vision models would have the opportunity of developing a system for melanoma diagnosis, while the students who prefer working with textual data and language models would have the opportunity to develop a system for dementia diagnosis. In both cases, open and publicly available datasets would be used.

Prerequisites. Basic machine learning concepts, familiarity with Python programming language and Jupyter Notebook environment.