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Book of Abstracts

of the

11th Day of Doctoral Students
of the School of Mathematics

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Preface

In the beginning of 2014, the Management of the Faculty of Mathematics and Physics decided that the traditional conference of PhD students called the WDS (Week of Doctoral Students) would not be organized as an activity of the entire faculty. Instead, the decision as to whether to organize the conference or not was left to the respective Schools (of Computer Science, of Mathematics, and of Physics).

Since then, the School of Mathematics organized this event as WDS-M (Week of Doctoral Students of the School of Mathematics). Except for 2014, WDS-M was always a one-day conference and therefore, the new name DDS-M (Day of Doctoral Students of the School of Mathematics) was introduced four years ago. Since WDS-M was not organized in 2020 due to the COVID-19 Pandemic, the conference of PhD students at the School of Mathematics is organized for the 11th time in this year, see also `http://www.karlin.mff.cuni.cz/~knobloch/DDS-M/2025/`. The original WDS continued at the School of Physics in its 34th edition (June 3–5, 2025) as a conference for PhD students of physical study programs, see `http://www.mff.cuni.cz/veda/konference/wds/`.

This year, 21 students have registered as active participants to the conference. The abstracts of their lectures are contained in this Book of Abstracts. We believe that this event, which takes place in the "mathematical" Karlín building of the faculty, will attract the attention of the students but also of the broad mathematical audience. We thus encourage all of those interested in the scientific activities of our doctoral students to attend this meeting.

Prague, June 9, 2025

prof. Mgr. Petr Knobloch, Dr., DSc.
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Contents

Morita theory for contramodules

Mgr. Martin Boroš

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Study branch: P4M1
Year of study: 2
Supervisor: RNDr. Michal Hrbek, Ph.D.

Abstract

In classical morita theory there is a result that says that the rings R and S are morita equivalent if and only if R is isomorphic to the endomorphism ring of a projective generator in the category of modules over S. In an unpublished work, we have proved an analogous result in the case where instead of categories of modules we consider categories of contramodules and discrete modules.

Matrix representations of finite Frobenius rings

RNDr. Dominik Krasula

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Abstract

A Peirce decomposition of a ring induces a representation as a formal matrix ring. This talk will show how the general theory of formal matrix rings can be used to study finite Frobenius rings.

A combinatorial criterion is given to decide whether a formal matrix ring has a prescribed Nakayama permutation. A finite Frobenius ring R can be represented as a block matrix ring, where the blocks on the diagonal are Frobenius rings corresponding to cycles in the Nakayama permutation of R. Local corner rings in each block are isomorphic rings with self-duality.

At the end of the talk, it is outlined how to glue two indecomposable Frobenius rings to a new indecomposable Frobenius ring, as long as there is a skew field K such that both rings have a simple module whose endomorphism ring is isomorphic to K.

Consecutive real cyclotomic fields with large class numbers

M.Sc. Om Prakash

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Abstract

It is well-known that unique factorization generally fails, e.g., in $\mathbb{Z}[\sqrt{-5}]$. Less well-known is that the failure of unique factorization is measured by the size of a group (the class group), known as the class number. The behavior of class numbers is erratic in general; even in the case of quadratic fields, we don't know much. In this talk, I will discuss the class numbers of real cyclotomic fields. Weber's conjecture states that all real cyclotomic fields of the form $\mathbb{Q}(\zeta_{2^m} + \zeta_{2^m}^{-1})$ have class number 1. Surprisingly, I will show that there exist arbitrarily long consecutive real cyclotomic fields with large class numbers.

Normal bases over finite fields

Mgr. Yağmur Sak

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Abstract

Optimal Normal Bases make it easier to use large finite fields in hardware, which helps improve the security and efficiency of many cryptographic systems. In this talk, we will begin by introducing the concept of complexity in the context of normal bases. We will then examine the conditions that define an optimal basis and give some characterizations of optimal normal bases. Finally, we present some explicit constructions of non-optimal normal bases with low complexity.

Principal bundles and differential structures in noncommutative geometry

M.Sc. Antonio Del Donno

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Supervisor: Dr. Reamonn O' Buachalla

Abstract

In this talk, I'll discuss quantum principal bundles understood as faithfully flat Hopf–Galois extensions: the structure Hopf algebra coacts on the total space, and the base is recovered as the subalgebra of coinvariants. We equip such bundles with a differential structure asking the coaction to extend to a morphism of differential graded algebras. This gives rise to an exact noncommutative Atiyah sequence, a graded Hopf–Galois extension of differential forms, and a canonical braiding. I will briefly recall this framework and illustrate explicit examples, including the noncommutative 2-torus and the quantum Hopf fibration. Time permitting, I will also briefly discuss connections and gauge transformations.

LCH capacities and Lagrangian cobordisms

Mgr. Daniel Komárek

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Supervisor: doc. Roman Golovko, Ph.D.

Abstract

We will define basic notions in contact geometry (contact manifolds, Legendrian submanifolds and Lagrangian cobordism between them) and subsequently we define Legendrian contact homology. In addition, we provide basic outline how to construct LCH capacities and show some examples of them.

Lie group approach to envelope surfaces

Mgr. Michal Molnár

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Abstract

The construction and analysis of envelope surfaces are of great interest from both theoretical and practical perspectives. Certain special cases, such as the envelopes of (truncated) cones undergoing Euclidean motion, are particularly relevant for applications in CNC manufacturing. We describe 1-parameter systems of surfaces as curves in the homogeneous spaces of appropriate Lie groups. Using the Lie group formalism, we rigorously express the inherent symmetry and linearity in the computation of the envelope. Furthermore, we provide an explicit method for obtaining rational parameterizations of these envelopes and performing the truncation required for practical applications.

Generic actions on the Cantor space

M.Sc. Ange Zugmeyer

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Supervisor: Mgr. Michal Doucha, Ph.D.

Abstract

I present what will be the starting point for my research during the PhD. We will see how the study of continuous group actions on the Cantor space is connected to the study of the structure of the space of subshifts over those groups, linking topological dynamics to symbolic dynamics and combinatorial group theory. To this end we will see some basic definitions, and I present some recent results in the field (based on a paper by Michal Doucha "Strong topological Rokhlin property, shadowing, and symbolic dynamics of countable groups"), as well as some possible generalizations that I will be focusing on for the next year.

Reduction principle for potential convolution operators

RNDr. Ladislav Drážný

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Abstract

In this talk we will investigate potential convolution operators with nonnegative radially nonincreasing kernels. Let us consider a kernel K on $\mathbb{R}^n \setminus \{0\}$ and the respective potential convolution operator $Tf(x) = K * f(x) = \int_{\mathbb{R}^n} f(y)K(x-y)d\mu(y)$. Operators of this type include the classical Riesz potential. We will present here the reduction principle for these operators. In other words we will present the optimal conditions under which the convolution operator $T\colon X(\mathbb{R}^n, \mu) \to Y(\mathbb{R}^n, \nu)$ is bounded as the operator between two general rearrangement-invariant function spaces X, Y defined on measure spaces with different measures. We will also discuss compactness of these convolution operators.

Interpolation between Lorentz spaces

RNDr. David Kubíček

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Abstract

We briefly summarize known results concerning interpolation theory in the setting of Lorentz spaces and mention how classical operators behave in this setting. Finally we recall standard Calderón's interpolation theorem about operators of joint weak type on rearrangement-invariant spaces and explore its generalization for the operators exhibiting boundedness on non-standard end-point Lorentz spaces.

Almost-invariant elements of group actions on Lip0 spaces

RNDr. Tomáš Raunig

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Abstract

The paper is motivated by a question published in a paper of E. Glasner coming from the work of D. Kazhdan and A. Yom Din regarding the possibility to approximate functionals on a Banach space which are almost invariant with respect to an action of a discrete group by functionals that are invariant. We study the case when the Banach space is a Lipschitz-free space equipped with an action induced by an action by isometries on the underlaying space. We find a few different conditions sufficient for the answer to be positive; for example the case of free or finitely presented groups endowed with left-invariant metrics acting on themselves by translations.

Domain decomposition preconditioners for the Discontinuous Galerkin method

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Abstract

We present the use and efficiency of domain decomposition preconditioners to accelerate the solution of linear systems arising from the Discontinuous Galerkin (DG) method. While the DG method offers flexibility and high accuracy for solving partial differential equations, it often leads to large, ill-conditioned systems that are challenging to solve efficiently. Domain decomposition techniques provide a natural framework for parallelization and can significantly improve the convergence of iterative solvers when used as preconditioners. We discuss several domain decomposition strategies, show some theoretical results and demonstrate their effectiveness through numerical experiments. Special attention is given to the use of coarse space in the non-overlapping methods, where we need to have two layers to assure the convergence of traditional Schwarz algorithm.

Nonconforming virtual element method for the fully nonlinear Monge-Ampère equation

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Abstract

Fully nonlinear partial differential equations (PDEs) are known as the class of nonlinear PDEs that are nonlinear in the highest order derivatives of the unknown function. A well known example of a fully nonlinear second-order PDE is the Monge-Ampère equation. Using the vanishing moment method, the fully nonlinear Monge-Ampère equation is approximated by a fourth order quasilinear PDE. The C^1 nonconforming - C^0 conforming Virtual Element Method is applied to this quasilinear PDE. Well-posedness and optimal apriori error estimates for the discrete form are proven by a Banach fixed point theorem, and the errors are shown to be comparable to the existing error estimates for the finite element method for the vanishing moment problem.

Computation of stabilization parameters using machine learning

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Abstract

In convection-dominated regimes, traditional stabilization methods often encounter significant drawbacks: they are either computationally expensive or induce numerical oscillations. In this work, we propose a novel approach that integrates a machine learning model to predict a better stabilization parameter than the standard one used in SUPG. Our methodology employs a neural network that extracts important local features of the problem from a coupled SUPG-Tabata framework, predicting a more appropriate stabilization parameter for the SUPG method. This approach not only aims to reduce computational cost but also mitigates oscillatory inaccuracies, ultimately enhancing the reliability of numerical simulations in convection-dominated environments.

HPC and Davidson method

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Abstract

One major challenge is to produce middleware software for scientific computations. The purpose of the middleware software is to hide specific implementation details from the computer hardware. A set of computational kernels, called Dwarfs, was proposed as the most needed set of problems for HPC. Following the same approach, another set of computational kernels for Data Science and Data Analytics was proposed, called The Seven Giants. Both of the proposed module sets include Computational Linear Algebra modules, and one of them is the Symmetric Eigenvalue Problem. We are interested in combining mathematical tools to take advantage of the latest trends in hardware to maximize efficiency in terms of accuracy and speed to solution. The latest hardware trends include low-precision arithmetic and distributed systems. In this work, we introduce the (Jacobi)-Davidson method for the Symmetric Eigenvalue Problem combined with the latest hardware trends.

Specification tests for integer-valued time series

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Abstract

This contribution addresses models for time series of integer-valued variables. Such series arise in various applications, often as increment series for counts of interest. A model with a GARCH-type structure with the Skellam conditional distribution is considered. We propose a novel testing procedure to assess the null hypothesis that a set of integer-valued observations follows such model.

Testing for abrupt and gradual location changes in functional time series

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Abstract

In a multivariate setting, classical test statistics such as Hotelling's t-test or the multivariate CUSUM test are usually weighted with the inverse covariance operator. For functional data, i.e., random elements in infinite-dimensional Hilbert spaces, one approach for taking the inverse covariance operator into account is based on dimension reduction techniques to a finite-dimensional subspace, possibly with principal components, followed by classical multivariate procedures. Such an approach has often been criticized as not being fully functional and losing too much information. As an alternative, tests have been proposed directly based on the functional CUSUM, but they fail to include the covariance structure. In this talk, we propose an alternative that includes the covariance structure with an offset parameter as a middle ground to produce a scale-invariant test procedure and to increase power when the change is not aligned with the first components. Some asymptotic properties are provided under mild assumptions on the dependence structure. A simulation study investigates the behavior of the proposed methods, including detecting abrupt and gradual mean changes.

Factor selection in screening designs

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Abstract

Throughout the manufacturing process in pharmaceutical research, series of factors can have impact on the quality of the product and there can be numerous interactions between these factors. Our aim is to choose the factors that possibly affect the product the most. To be able to choose as few factors which have the effect on the product as possible, penalization of the regression coefficients needs to be applied. We compare several methods of variable selection in context of data from designed experiments and show that the robustness of the methods does not necessarily need to lead to robustness in selection.

Conformal prediction and optimal transport

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Abstract

Conformal prediction for the random variable under study is a nonparametric construction of a prediction interval for a new observation based on the training data and possible covariates. However, a limitation lies in the requirement for quantile definitions, where extending the method to random vectors is not straightforward. Recent developments in constructing multivariate quantiles using optimal transport offer a way to extend conformal predictions to random vectors.

Multicomponent flow in lungs

Mgr. Lenka Košárková

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Abstract

Studying the flow of concentrated mixtures is motivated by several natural processes, for example, the air in the lungs, which is a mixture of oxygen, carbon dioxide, water vapour, nitrogen and other species. To determine the distribution of the components concentrations throughout the entire lung, both diffusion, which is dominant at smaller scales, and convection, which prevails in the upper airways, must be taken into account. The most appropriate model for diffusion in this context appears to be the Stefan-Maxwell equations, which accounts for the diffusion forces that the species can exert on one another. However, it is thus more coupled than more standard Fick model. Convection is governed by the Navier-Stokes equations. Discretizing these non-stationary, coupled equations using the finite element method and possibly accounting also for non-ideal mixture seems to be a big challange.

Existence and time continuity in non-Newtonian heat-conducting flow models

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Abstract

In this talk, we explore the behavior of a non-Newtonian, heat-conducting fluid within a bounded domain. The fluid's viscous stress response, described by the Cauchy stress tensor S, depends on the temperature and non-linearly on the velocity gradient, governed by a power-law index p.

We impose a homogeneous Dirichlet boundary condition on the velocity – ensuring no mass flows across the boundary – and a Dirichlet condition on the temperature, allowing thermal interaction with the surroundings.

Focusing on the two-dimensional case with a power-law index $p \geq 2$, we establish the existence of a suitable weak solution, i.e., one that satisfies the entropy equality. Building on this framework, we then derive estimates that yield a rigorous proof of the continuity of temperature in time.