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Abstracts Book

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Plenary talks

Separation of periodic points in holomorphic dynamics

Núria Fagella
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Non-repelling periodic points play an important role in any discrete dynamical system, and their relation to the singularities of the inverse function has been one of the keys for the development of the theory of holomorphic dynamics. In this setting, we will show how non-repelling fixed points can be separated from each other by means of "external rays" (invariant curves with trivial dynamics). During the talk, we will explain the first Separation Theorem for polynomials, by Goldberg and Milnor, and its generalization to wider classes of maps. Finally we will comment on recent advances on the topic.

Catalytic computation

Michal Koucký
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How much space (memory) does one need to solve a system of linear equations, reachability on a directed graph or satisfiability of a Boolean formula? We do not know a good answer to this question but our best algorithms for all of these problems require working memory of size at least linear – that is proportional to the number of variables of the system or the number of vertices in the graphs. Can we do better?

In this talk I will show that under some circumstances you can do much better. We introduce the concept of catalytic computation where we allow the algorithm to use memory that is occupied by data of someone else under the promise that our algorithm does not destroy the data. We show that such catalytic memory can be useful. This is somewhat counter-intuitive as the foreign data might be entirely incompressible and one cannot erase them. Currently, we know just few algorithmic techniques that can take advantage of the catalytic memory. It is an intriguing open problem to devise more such techniques and establish exact bounds on the extra power provided by the catalytic memory.

Geometric Classification

Monika Ludwig

Technische Universität Wien, Austria

A fundamental theorem of Hadwiger classifies all rigid-motion invariant and continuous functionals on convex bodies (that is, compact convex sets) in $\mathbb{R}^n$ that satisfy the inclusion-exclusion principle,

$$\mathrm{Z}(K) + \mathrm{Z}(L) = \mathrm{Z}(K \cup L) + \mathrm{Z}(K \cap L)$$

for convex bodies K, L such that $K \cup L$ is convex. Under weak additional assumptions, such a functional Z is a finitely additive measure and hence Hadwiger's theorem is a counterpart to the classification of Haar measures.

Hadwiger's theorem characterizes the most important functionals in Euclidean geometry, the $n+1$ intrinsic volumes, which include volume, surface area, and the Euler characteristic. In recent years, numerous further functions and operators defined on the space of convex bodies and more generally on function spaces were characterized by their properties.

An overview of these results will be given.

Terwilliger algebra of a distance-regular graph

Miklavič Štelko

Department of Mathematics, University of Primorska, Slovenia

The aim of this talk is to introduce Terwilliger algebra of a graph. We will first define Terwilliger algebra of an arbitrary connected simple graph, and its (irreducible) modules. We will show that in the context of Terwilliger algebras, distance-regular graphs arise quite naturally. In the second part of the talk we will therefore focus on this class of graphs. We will be interested in the interplay between certain combinatorial properties of a distance-regular graph and the module structure of the associated Terwilliger algebra.

Evolution of manifolds with a specially designed tangential component

MARIANA REMEŠÍKOVÁ

Slovak Technical University, Slovakia

We focus on Lagrangian models of manifold evolution and discuss their various applications as well as some important issues concerning their discrete solutions. Contrarily to the level-set approach, Lagrangian models describe the evolution of a manifold explicitly which has both advantages and drawbacks. We focus on the problem of controlling the discretization mesh quality during the computation, which seems to be crucial, if we want to obtain a good approximation of the solution to the continuous problem. We present a technique for designing a special tangential component of the evolution velocity field that allows us to adjust the mesh according to our needs as the discretized manifold evolves. For example, we can converge to a mesh with equally sized elements or to modify the density of the grid points according to the curvature of the manifold. We present various practical examples concerning curve and surface evolution.

Large values of the Riemann zeta function in the critical strip

CHRISTOPH AISTLEITNER

TU Graz, Austria

One of the major aims of contemporary number theory is to understand the behavior of the Riemann zeta function in the critical strip. A famous open problems is the so-called Lindelf hypothesis, which asserts that the order of the zeta function along the line 1/2+it is bounded by an arbitrarily small power of t. In the opposite direction, lower bounds for extremal values of the zeta function are known but have not been improved for more than 40 years. In this talk we present the so-called resonance method, introduced by K. Soundararajan, which is a tool for obtaining such lower bounds for large value of the zeta function. We will explain the functionality of the method in an accessible way, discuss the relation to problems from Diophantine approximation, and indicate how a recent refinement

of the method has finally lead to improved lower bounds for large values of the zeta function.

Mathematical Finance

On the link between the implied volatility skew and the Malliavin derivative operator

Elisa Alòs
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In this talk, we use Malliavin calculus techniques to obtain an expression for the short-time behavior of the at-the-money implied volatility skew. This expression depends on the derivative of the volatility in the sense of Malliavin calculus. We will show that this result can be useful in applications, as in modeling problems or in option pricing approximation.

Pricing under rough volatility

Christian Bayer
(in collaboration with Peter K. Friz and Jim Gatheral)
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From an analysis of the time series of realized variance (RV) using recent high frequency data, Gatheral, Jaisson and Rosenbaum [1] previously showed that log-RV behaves essentially as a fractional Brownian motion with Hurst exponent H of order 0.1, at any reasonable time scale. The resulting Rough Fractional Stochastic Volatility (RFSV) model is remarkably consistent with financial time series data. We now show how the RFSV model can be used to price claims on both the underlying and integrated variance. We analyze in detail a simple case of this model, the rBergomi model. In particular, we find that the rBergomi model fits the SPX volatility markedly better than conventional Markovian stochastic volatility models, and with fewer parameters. Finally, we show that actual SPX variance swap curves seem to be consistent with model forecasts, with particular dramatic examples from the weekend of the collapse of Lehman Brothers and the Flash Crash.

References

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CoCos under-short term uncertainty

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In this paper, see [1], we analyze an extension of the Jeanblanc and Valchev [4] model by considering a short-term uncertainty model with two noises. It is a combination of the ideas of Duffie and Lando [2] and Jeanblanc and Valchev [4]: share quotations of the firm are available at the financial market, and these can be seen as noisy information about the fundamental value, or the firm's asset, from which a low level produces the credit event. We assume there are also reports of the firm, release times, where this short-term uncertainty disappears. This credit event model is used to describe conversion and default in a CoCo bond.

References

[1] J.M. Corcuera and A. Valdivia. (2016). CoCos under short-term uncertainty. Stochastics, 1-15, 2016.

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A truncated two–scales realized volatility estimator

Eulalia Nualart
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In this talk we introduce a novel estimator of the integrated volatility of asset prices based on high frequency data that is consistent in the presence of price jumps and market microstructure noise. We begin by introducing a jump signaling indicator based on a local average of intra-daily returns that allows to detect jumps when the price is contaminated by noise. We then combine this technique with the two-scales realized volatility estimator to introduce the so called truncated two-scales realized volatility estimator (TTSRV). We establish consistency of the TTSRV in the presence of finite or infinity activity jumps and noise. In case of finite activity jumps, we also establish the asymptotic distribution of the estimator. A simulation study shows that the TTSRV performs satisfactorily in finite samples and that it out–performs a number of alternative estimators recently proposed in the literature.

Sensitivity analysis in a market with memory

Giulia Di Nunno
(in collaboration with D.R. Baños, H. Haferkorn, F. Proske)
Department of Mathematics, University of Oslo, Norway

A general market model with memory is considered. The formulation is given in terms of stochastic functional differential equations, which allow for flexibility in the modelling of market memory and delays. We focus on the sensitivity analysis of the dependence of option prices on the memory. This implies a generalization of the concept of delta. Our techniques use Malliavin calculus and Fréchet derivation. When it comes to option prices, we compute the delta of a financial derivative, which may depend on the history of the underlying.

Option Pricing in the Moderate Deviations Regime

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Small-time asymptotics of option prices have received considerable attention in the literature. In diffusion models, two small-time regimes have been studied extensively so far: At-the-money (related to central limit theorems) and fixed-strike out-of-the money (related to large deviations). With the present work, we aim to fill the gap in between of these regimes. We thus consider "moderately out of the money" strikes that vary with maturity. For small maturity, call prices then exhibit moderate deviations behavior, with a quadratic rate function. Our approximations are easy to evaluate numerically (which is not always the case in the large deviations regime), and involve the model parameters in a transparent way. They also reflect the market reality that strikes far out of the money are not traded at short expiry. First and higher order small-time moderate deviation estimates of call prices and implied volatility are obtained. They lead to a novel relation between implied volatility and the small-time at-the-money implied variance skew. We illustrate our results in the Heston model.

References

[1] Friz P., Gerhold S., Pinter A., Option Pricing in the Moderate Deviations Regime. *Preprint*, 2016.

Data-driven regression Monte Carlo

Emmanuel Gobet

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Our goal is to solve certain dynamic programming equations associated to a given Markov chain X, using a regression-based Monte Carlo algorithm. This type of equation arises when computing price of American options or solving non-linear pricing rules. More specifically, we assume that the model for X is not known in full detail and only a root sample of size M of such process is available. We are investigating a new method that by-passes the calibration step. By a stratification of the space and a suitable choice of a probability measure ν, we design a new resampling scheme that allows to compute local regressions (on basis functions) in each stratum. The combination of the stratification and the resampling allows to compute the solution to the dynamic programming equation (possibly in large dimensions) using only a relatively small set of root paths. To assess the accuracy of the algorithm, we establish non-asymptotic error estimates in $L_2(\nu)$. Our numerical experiments illustrate the good performance, even with $M = 20$ - 40 root paths.

References

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Lévy forward price approach for multiple yield curves and low/negative interest rates

Zorana Grbac
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In this talk we present a framework for discretely compounding interest rates which is based on the forward price process approach. This approach has a number of advantages, in particular in the current market environment. Compared to the classical Libor market models, it allows in a natural way for negative interest rates and has superb calibration properties even in the presence of extremely low rates. Moreover, the measure changes along the tenor structure are simplified significantly. These properties make it an excellent base for a post-crisis multiple curve setup. Three variants for multiple curve constructions are discussed. As driving processes we use time-inhomogeneous Lévy processes, which allow to derive semi-explicit formulas for the valuation of various interest rate products using Fourier transform techniques. Based on these formulas we present the calibration results for the three model variants using market data for caplets.

At the end of the talk we shall outline a different class of models in the same forward price framework, namely we shall present examples of local volatility models driven by a Brownian motion, where pricing methods are based on asymptotic expansions (work in progress with D. Krief and P. Tankov).

References

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Calibration of stochastic volatility models via second order approximation

Josep Vives
(in collaboration with Elisa Alòs, Rafael De Santiago, and Raúl Merino)

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In this talk we present a decomposition of the pricing formula for a plain vanilla option for a general stochastic volatility diffusion model, obtained in [2]. In particular we develop a methodology to obtain an approximation of the implied volatility. In the case of the Heston model, in [1], we use this approximation to calibrate the full set of parameters of the Heston model.

References

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A dimension reduction method for option pricing

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We present a robust and highly efficient Shannon-wavelet based dimension reduction method for computing plain-vanilla European option prices under general jump-diffusion models with stochastic variance and multi-factor Gaussian interest rates. Using the conditional Monte Carlo technique applied to the variance factor, the option price can be expressed as a two-level nested conditional expectation. The inner expectation is then evaluated analytically, with the variances associated with all the interest rates factors completely removed from the analytical solution. The outer expectation is approximated very efficiently by means of the Shannon Wavelets Inverse Fourier Technique (SWIFT) via evaluating a single integral that involves only the variance factor. Central to this process is a highly efficient recovery of the conditional density of the time-integrated variance process using the SWIFT method. Furthermore, the SWIFT method also allows us to develop sharp approximation error bounds for the option price. Numerical experiments confirm the robustness and efficiency of the proposed pricing method.

References

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Duality formulas for robust pricing and hedging in discrete time

Michael Kupper
(in collaboration with Patrick Cheridito and Ludovic Tangpi)
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We focus on robust super- and subhedging dualities for contingent claims that can depend on several underlying assets. In addition to strict super- and subhedging, we also consider relaxed versions which, instead of eliminating the shortfall risk completely, aim to reduce it to an acceptable level. This yields robust price bounds with tighter spreads. As applications we study strict super- and subhedging with general convex transaction costs and trading constraints as well as risk based hedging with respect to robust versions of the average value at risk and entropic risk measure. Our approach is based on representation results for increasing convex functionals and allows for general financial market structures. As a side result it yields a robust version of the fundamental theorem of asset pricing. The talk is based on joint work with Patrick Cheridito and Ludovic Tangpi.

Brownian Trading Excursions

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We study the stochastic heat equation with multiplicative noise as a model for the relative volume distribution in a Brownian limit order book model, and express its solution as a local time functional. Moreover, in a model corresponding to the fundamental solution, we classify different trading times and derive the Laplace transforms of the times to various types of trades. This gets applied to order avalanches.

Asymptotics and calibration for American options

Stefano De Marco
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Based on a suitable representation of the exercise boundary for American options in a diffusion model, we derive an approximation of the exercise boundary close to maturity that refines the expansions known so far in the literature. By means of the early exercise formula, this allows to derive semi-closed expressions for the price of the American Put/Call. The final product is a calibration recipe of a local volatility surface to American option data, with a complexity equivalent to the application of Dupire's formula. This is an important step when only American options, and no European options, are available on the market (as it typically happens in the case of single stocks).

Geometric Ergodicity of the Multivariate Continuous-time GARCH(1,1) Process

Stelzer Robert
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In this talk we consider the multivariate continuous-time GARCH(1,1) process driven by a Lévy process emphasising stationarity properties. The focus is on the volatility process which takes values in the positive semi-definite matrices.

In the univariate model existence and uniqueness of the stationary distribution as well as geometric ergodicity are well-understood, whereas for the multivariate model only an existence criterion is known as far as strict stationarity is concerned. We shall first review the multivariate COGARCH(1,1) model and its properties focussing on strict and weak stationarity. Thereafter, the main part of the talk is devoted to establishing sufficient conditions for geometric ergodicity and thereby for uniqueness of the stationary distribution and exponential strong mixing.

We follow a classical Markov/Feller process approach based on a Foster-Lyapunov drift condition on the generator. Apart from finding an appropriate test function for the drift criterion, the main challenge is to prove an appropriate irreducibility condition due to the degenerate structure of the jumps of the volatility process, which are all rank one matrices. We present a sufficient condition for irreducibility in the case of the driving Lévy process being compound Poisson.

References

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Applications of categories in Algebra and Topology

A family of irretractable square-free solutions of the Yang-Baxter equation

Ferran Cedó

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In this talk we will present a new family of non-degenerate involutive set-theoretic solutions of the Yang-Baxter equation. All these solutions are strong twisted unions of multipermutation solutions of multipermutation level at most two. A large subfamily consists of irretractable and square-free solutions. This subfamily includes a recent example of Vendramin [3, Example 3.9]. All of them are counterexamples to Gateva-Ivanova's Strong Conjecture [1, Strong Conjecture 2.28(I)] and also they answer a question of Cameron and Gateva-Ivanova [2, Open Questions 6.13 (II)(4)].

References

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The category of Cuntz semigroups

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In this talk we will survey recent results concerning the category Cu of abstract Cuntz semigroups. This is a category of commutative semigroups with an ordered topological structure which has recently played an important role in the classification of C*-algebras.

In particular, we will overview the definition of a tensor product that makes Cu into a symmetric monoidal category. We will also show how this construction is related to the so-called strongly self-absorbing C*-algebras and solid rings.

Möbius inversion and bialgebras from decomposition spaces

Imma Gálvez
(in collaboration with Joachim Kock and Andy Tonks)
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Decomposition spaces are simplicial infinity-groupoids that send generic (endpoint preserving) and free (distance preserving) pushout squares in the simplicial category Δ to (homotopy) pullbacks. They encode the information needed for an 'objective' generalisation of the notion of incidence (co)algebra of a poset, and turn out to coincide with the unital 2-Segal spaces of Dyckerhoff and Kapranov. Conditions for these coalgebras to have Möbius inversion can be given and a universal Möbius decomposition space can be constructed. Relevant constructions in many areas, in particular in combinatorics and algebraic topology, can be observed in this framework. Important examples of bialgebras in topology and theoretical physics arise from monoidal decomposition spaces.

On models for equivariant ∞-operads

Javier J. Gutiérrez
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Higher operad theory can be formalized by means of different models. These include dendroidal sets, simplicial operads, and dendroidal spaces, among others. By using tools developed by M. Stephan, we will describe G-equivariant versions of these models, for G an arbitrary discrete group, and we will prove that they are all equivalent. This generalizes and extends previous work by J. Bergner on models for equivariant $(\infty,1)$-categories. This is joint work in progress with J. Bergner.

Homotopy theory of derived A_∞-algebras

Joana Cirici
(in collaboration with Daniela Egas, Muriel Livernet and Sarah Whitehouse)

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Derived A_∞-algebras were introduced by Sagave in order to extend a classical result due to Kadeishvili on the existence of minimal models of A_∞-algebras over a field, to algebras defined over an arbitrary ring. These objects combine, via a bigrading, the notion of multicomplex with that of an A_∞-algebra. In this talk, I will use operadic machinery to relate derived A_∞-algebras with filtered A_∞-algebras. I will then discuss homotopies between morphisms of derived A_∞-algebras and explain their interplay with spectral sequences. This is a work in progress with Daniela Egas, Muriel Livernet and Sarah Whitehouse.

Taxotopy: Ordered homotopy with adjunctions

Amit Kuber
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Is it possible to use purely category-theoretic language to say that a functor between small categories can be continuously deformed into another (in a way that is not necessarily reversible)? Morphisms of adjunctions provide an answer to define a 'taxotopy' preorder on the set of functors; such data can be combined into the fundamental poset of the ordered pair of categories.

In the talk I will discuss parallels between homotopy and taxotopy. I will focus on the fundamental posets $\Lambda(\mathbf{1}, P)$ and $\Lambda(\mathbb{Z}, P)$, for a poset P, and how they relate to the concepts of path, contractibility, cover and van Kampen theorem.

References

[1] Kuber A., Wilding, D. Taxotopy theory of posets I: van Kampen theorems Preprint available at http://arxiv.org/abs/1510.08921, 2015.

Spectra of definable additive categories

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Associated to any definable additive category (these include, for instance, finitely accessible additive categories with products) there are two topologies (on the same set of points): the Ziegler spectrum and its Hochster-dual, the Zariski spectrum. The latter is so called because it generalises the Zariski spectrum of a commutative noetherian ring, see [3] (also [1], [2]). There is associated "geometry", embodied in various presheaves (of rings, categories and representations). This suggests that a 4th vertex might be added to the triangle of (anti-)equivalences between 2-categories described in [4] (the 2-categories are those of: small abelian categories and exact functors; definable additive categories and interpretation functors; locally coherent Grothendieck categories and regular morphisms). I will outline the general picture and give some specific examples.

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Trace ideal of a pure projective module

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Trace ideals seem to be a useful tool to study direct sum decomposition of projective modules. For example, they can be used to prove that every indecomposable projective module over an integral group ring of a finite group is finitely generated.

In this talk I will present the notion of a trace ideal of a pure projective module and briefly discuss which properties of traces of projective modules proved in [1] have extension to pure projective setting.

References

[1] Herbera D., Příhoda, P. Reconstructing projective modules from its trace ideal *J. Algebra*, **416**, 25-57, 2014.

Abstract bivariant Cuntz semigroups

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We present a general construction for sets with a transitive relation which produces a domain (in the lattice theoretical sense). This construction, when appropriately applied to some generalized morphisms in the category Cu of abstract Cuntz semigroups, shows that the latter is a closed monoidal category.

We will see how this tools can be used in the setting of C^*-algebras and, motivated by the success of KK-theory, indicate how it could be used to obtain a bivariant theory of Cuntz semigroups.

Higher weak colimits

George Raptis
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I will present some ideas towards a theory of higher weak colimits regarded as an intermediate notion between weak colimits and homotopy colimits. I will also discuss connections with derivators and derivator K-theory.

Derived categories, recollements and applications

Steffen Koenig
(in collaboration with Lidia Angeleri Hügel, Yiping Chen, Ming Fang, Wei Hu, Qunhua Liu and Dong Yang)
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Equivalences and recollements of derived categories can be used to determine properties and invariants of algebras, for instance homological dimensions (such as global and dominant dimension), K-theory and ring structure (such as being symmetric or self-injective). Some examples and methods will be presented.

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Derived equivalences induced by big tilting modules

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A well-known theorem due to Happel [7] and Cline, Parshall and Scott [3] states that if R is a ring, $T \in \mathrm{Mod}R$ is a classical tilting module (in the sense of Miyashita) and $S = \mathrm{End}_R(T)$, then there is a derived equivalence

$$\mathbf{R}\mathrm{Hom}_R(T, -)\colon \quad \mathrm{D}(\mathrm{Mod}R) \rightleftarrows \mathrm{D}(\mathrm{Mod}S) \quad : - \otimes^{\mathbf{L}}_S T.$$

More recently, Bazzoni and collaborators [1, 2] showed that if T is an infinitely generated tilting module, one obtains a localization rather than equivalence.

In this talk, I would like to offer a new perspective on this situation. If T is an infinitely generated tilting module, then S is naturally a topological ring and one can consider contramodules over S (= modules which admit certain infinite R-linear combinations). By restriction of the codomain of $\mathbf{R}\mathrm{Hom}_R(T, -)$ to S-contramodules (which follows the spirit of [4, 5, 6]), we recover the derived equivalence above.

This all fits into a more general framework of a correspondence between big tilting modules in Grothendieck categories and big cotilting contramodules.

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Algorithmic computation of groups of equivariant homotopy classes of maps

Lukáš Vokřínek
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I will outline an algorithm for the computation of the set $[X, Y]^A$ of G-equivariant homotopy classes of maps $X \to Y$ extending a given map $A \to Y$ defined on a subsapce $A \subseteq X$ (simply connected Y, finite G); this algorithm works under a certain "stability assumption", defined by the requirement $\dim X^H \leq 2 \cdot \operatorname{conn} Y^H$ on the dimension and the connectivity of the fixed point sets for all subgroups $H \leq G$.

(When the stability assumption is dropped – but Y is still assumed simply connected – it is already impossible to decide if $[X, Y]^A$ is non-empty; this is a result of our previous work that I will also try to briefly summarize.)

Relative resolutions via truncations

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Our aim is to present a framework to do relative homological algebra. By this we mean that, if homological algebra is understood as a way to study objects in abelian categories through invariants determined by their injective resolutions, then we want to construct resolutions using as "injectives" a priori any class of objects. This idea we borrowed from homotopy theory, where the closely related idea of cellularization and A-homotopy theory (with an a priori space A and its suspensions taking the place usually devoted to the spheres) developed for instance by Farjoun has proved to be extremely fruitful. A convenient way to resolve unbounded complex X is to build a tower of left truncations of X, resolve each truncation in the usual way and then glue the resolutions back into a full resolution of X. The main problem arises in the "gluing back" process and is related to the fact that infinite products may fail to be exact. To solve this we will introduce a relative version of an extension of Grothendieck's axiom AB4* due to Roos.

Differential geometry and mathematical physics

Homogeneous geodesics and g.o. manifolds

Zdeněk Dušek

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A geodesic in a homogeneous pseudo-Riemannian or affine manifold is homogeneous if it is an orbit of a 1-parameter group of isometries, or of affine diffeomorphisms. A homogeneous manifold is called a g.o. manifold if all geodesics are homogeneous.

Homogeneous geodesics were studied first in Riemannian manifolds. It is well known that in the symmetric space, all geoesics are homogeneous. A result by O. Kowalski and J. Szenthe says that in any homogeneous Riemannian manifold there exist at least one homogeneous geodesic through arbitrary point. Riemannian g.o. manifolds were studied by many authors and many examples were given. The interesting examples appear from dimension 6, because lower dimensional g.o. manifolds are naturally reductive. In pseudo-Riemannian manifolds, new phenomena appear. For example, for some light-like homogeneous geodesics, the natural parameter of the orbit is not the affine parameter of the geodesic. Further, the so-called almost g.o. manifolds appear. And the most interesting situation is with the nonreductive pseudo-Riemannian spaces, where the method used so far, and based on the reductive decomposition, fails. These spaces can be handled by the new, more fundamental, affine method, which was developed by the author, O. Kowalski and Z. Vlášek in [1]. The affine approach was also successfully applied in [2] and [3] to generalize the result on the existence of a homogeneous geodesic to pseudo-Riemannian and affine manifolds.

The present talk will be a survey on the interesting phenomena and examples related with this topic.

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Sonya Kowalevsky and Emmy Noether

Eliška Beránková
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In this talk I will present fates and theorems of two important female mathematicians of the second half of 19^{th} and the first half of the 20^{th} century, Sonya Kowalevsky and Emmy Noether. Firstly I will mention their life stories with stress to their mathematical career and then I will describe their theorems from the area of differential equations and from the calculus of variations, which made them famous. The theorems will be presented on the background of the historical context, in which the theorems arised.

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b^m-Symplectic structures: going to infinity and coming back

Eva Miranda

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Several problems from celestial mechanics (like the elliptic restricted 3-body problem) and their singularities ("collisions") can be described using symplectic forms away from a critical set (known in the literature of celestial mechanics as the line at infinity or the collision manifold). In these examples the symplectic form either vanishes or goes to infinity along the critical set. It is possible to give a global description of these objects using b^m-symplectic forms and folded symplectic forms. We will present some of these examples [1] and we will quickly review some results concerning dynamics ([4], [5]).

We will explain a desingularization procedure called deblogging [3] which associates a family of symplectic forms or folded symplectic forms to a given b^m-symplectic form depending on the parity of m. Time permitting, several applications of this procedure will be discussed.

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The inverse problem of the calculus of variations and applications to control theory

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The inverse problem of the calculus of variations consists in determining whether a given system of second order differential equations is equivalent to some regular Lagrangian system. I will explain some results and applications of the inverse problem to stabilization of controlled Lagrangian systems.

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Optical flow methods based on level set motion

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In this talk we present new methods for finding optical flow between two images. The methods are based on previous works published in [1, 2] that are extended in several aspects. Numerical experiments will be given to illustrate the properties of our optical flow methods.

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Holonomy groups of Lorentz-Kähler manifolds

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The holonomy group of a pseudo-Riemannian manifold (M, g) is an important invariant that gives rich information about the geometry of (M, g). This motivates the classification problem for holonomy groups of pseudo-Riemannian manifolds. The problem is solved only for connected holonomy groups of Riemannian and Lorentzian manifolds [1]. We obtain the classification of the connected holonomy groups for pseudo-Kählerian manifolds of complex index one [2]. In particular, we construct metrics with each possible connected holonomy group by giving their pseudo-Kählerian potential.

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Hamilton–Jacobi theory, dynamical systems, and geometric structures

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Hamilton–Jacobi theory can be understood as a way to organise the solutions of a differential equation in terms of a collection of dynamics in lower-dimensional submanifolds. We study the interplay of this interpretation with other usual geometric structures.

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Remarks on Local Lie algebras of pairs of functions

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An almost-cosymplectic-contact structure of an $(2n+1)$-dimensional manifold is given by a pair (ω, Ω) of a 1-form ω and a 2-form Ω such that $\omega \wedge \Omega^n \neq 0$ and $d\Omega = 0$, see [1]. We study local Lie algebras of pairs of functions which generate infinitesimal symmetries of the pair (ω, Ω).

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Order reduction and constraints of second-order field theories and higher-order mechanics. Applications to Einstein-Hilbert lagrangian

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The projectability of Cartan form onto a lower-order jet bundle is a consequence of the degenerate character of the corresponding Lagrangian. These systems have special properties, in particular, the order of the corresponding Euler-Lagrange equations is lower than expected. We analyze them using the constraint algorithm for second-order field theories as well as for higher-order mechanics. The results are applied to study the Hilbert Lagrangian for the Einstein equations (in vacuum) from a multisymplectic point of view.

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Holditch's theorem in space forms

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Consider a point on a chord of fixed length whose endpoints are moving on a closed convex planar curve. The locus of that point is a new closed curve. Holditch's theorem states that the area of the new curve is less than that of the original curve by $\pi\, p\, q$, being p and q the lengths of the pieces in which the chord is divided by the point.

A generalization of Holditch's theorem in space forms is studied, where it is possible to give a linear formula but now depending on the size of the original curve. This result was firsly obtained by Vidal Abascal and Rodeja (see [1] and [2]). Afterwards, Santaló gave a simpler proof of the same formula using differential forms, [3]. Our contribution is to give another proof focusing on the spherical and a hyperbolic version of the theorem without using differential forms and a to note a relation between the involved area and a quartic curve related to a kind of algebraic curves called cruciform curves.

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Hamilton-Jacobi equation

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The aim of this talk is to emphasize several meanings and interpretations of the classical Hamilton-Jacobi equation. It turns out that in a proper geometric setting the (same looking) Hamilton-Jacobi equation represents a coordinate expression for different phenomena. This fact becomes essential particularly when the Hamilton-Jacobi equation is (to be) generalized to non-classical systems, e.g. higher-order Lagrangians, degenerate Lagrangians, field theory, non-variational equations, etc.

Inverse Approach In Ordinary Differential Equations And Nambu Bracket

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In the theory of ordinary differential equations we can find two fundamental problems. The direct problem which consists in a broad sense in to find the solutions of a given ordinary differential equation, and the inverse problem. An inverse problem of ordinary differential equations is to find the more general differential system satisfying a set of given properties.

Probably the first inverse problem appeared in Celestial Mechanics, it was stated and solved by Newton (1687) in Philosophie Naturalis Principia Mathematica, and it concerns with the determination of the potential field of force that ensures the planetary motion in accordance to the observed properties, namely the Kepler's laws.

The first statement of the inverse problem as the problem of finding the more general differential system of first order satisfying a set of given properties was stated by Erugin [1] and developed in [2]).

The new approach of an inverse problem which we propose uses as an essential tool the Nambu bracket.

In the seventies Nambu in [4] proposed a new approach to the classical dynamics based on an N dimensional Nambu–Poisson manifold replacing the even dimensional Poisson manifold and on $N-1$ Hamiltonian $H_1, \ldots, H_{N-1}$ instead of a single Hamiltonian H. In the canonical Hamiltonian formulation, the equation of motion (Hamilton equations) are defined via the Poisson bracket . In Nambu's formulation, the Poisson bracket is replaced by the Nambu bracket. Nambu had originally considered the case $N = 3$. Although the Nambu formalism is a generalization of the Hamiltonian formalism its real applications are not as rich as the applications of this last one. We deduce new properties of this bracket which plays a very important role in the proof of all the results of this work and in its applications [3]. We observe that the applications of the Nambu bracket which we will give in this communication are original and represent a new direction in order to develop the Nambu ideas.

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Holonomic and semiholonomic higher-order jets of submanifolds

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It is well known that higher order jet bundles are not the same as repeated jet bundles; the former may be regarded as being contained in the latter as 'holonomic' sub-bundles, with intermediate structures calles 'semiholonomic' jet bundles which are relevant to questions of integrablity. In this talk I shall describe how similar structures appear when we consider jets of submanifolds.

Cohomoloy operators and Lie algebroids

José A. Vallejo

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I will explain how naturally Lie algebroids appear when quantizing field theories with constraints. This leads to the consideration of cohomology operators

associated to Lie algebroids, and I will explore the relation between these two structures, in particular the construction of Lie algebroids once such an operator on the algebra of differential forms of a manifold is given.

Characterization of spherical immersions

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In the classical study of surfaces in $\mathbb{R}^3$, the Gauss curvature and the mean curvature are the basic invariant scalar functions which can characterize different geometrical properties of a surface. Working with surfaces in $\mathbb{R}^{n+2}$ it is found new invariant scalar functions necessary in order to characterize each surface. In this talk we review the generalizations of the scalar invariants for immersions of surfaces in $\mathbb{R}^{n+2}$ from the previous works by J. A. Little, [1], and by A. Montesinos-Amilibia, [3], and we study the surfaces whose image is contained in a hypersphere.

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Dirac's equation in the light of geometric algebra

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The main goals will be to review how Dirac's relativistic theory of the electron can be cast into the language of geometric algebra, to point out the advantages of this translation, to present some recent developments along these lines, and to show how effective computations can be carried out. As background, the talk will include a full presentation of Pauli's and Dirac's (geometric) algebras and the Riesz form of Maxwell's equations.

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Approximability of Lie groups

Pasha Zusmanovich

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Recently, Boris Zilber has put forward a program to revise foundations of physics based on model theory. I will present my understanding of (a small part of) this program, and discuss arising questions about approximability, in model-theoretic terms, of compact Lie groups by finite groups.

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Mathematical models in image processing

A 2D nonlinear algorithm for monotone piecewise bicubic interpolation

Francesc Arandiga

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In this talk we present an algorithm for monotonic interpolation to monotone data on a rectangular mesh by piecewise bicubic functions. Carlton and Fritsch develop conditions on the Hermite derivatives that are sufficient for such a function to be monotonic. Here we obtain nonlinear approximations to the first partial and first mixed partial derivatives at the mesh points. We prove that we get a monotone piecewise bicubic interpolant and analize the order of this nonlinear interpolant. We also present some numerical experiments were we compare the results we obtain our algorithm with the obtained using linear techniques.

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Iterative Reconstruction for Inverse Medium Scattering

Kamil S. Kazimierski
(in collaboration with Florian Bürgel and Armin Lechleiter of University Bremen, Germany)
University of Graz, Austria

The Inverse Medium Scattering Problem deals with the reconstruction of material properties of an object from the electro-magnetic or acoustic field scattered by that object. Due to the properties of the measured data as well as the underlying operator efficient reconstruction is considered challenging.

In this talk I present a novel, iterative reconstruction methodology for that problem. Further, I will discuss the performance properties on several synthetic and real-world examples.

Optical Flow on Evolving Sphere-Like Surfaces

Lukas F. Lang
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Johann Radon Institute for Computational and Applied Mathematics, Austrian Academy of Sciences, Altenberger Str. 69, 4040 Linz, Austria

In [1], we consider optical flow on evolving surfaces which can be parametrised from the 2-sphere. Our main motivation is to estimate cell motion in time-lapse volumetric microscopy images depicting fluorescently labelled cells of a live zebrafish embryo. We exploit the fact that the recorded cells float on the surface of the embryo and allow for the extraction of an image sequence together with a sphere-like surface. We solve the resulting variational problem by means of a Galerkin method based on vector spherical harmonics and present numerical results.

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Convex Color Image Segmentation with Optimal transport Distances

NICOLAS PAPADAKIS

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This work concerns the histogram-based segmentation of a color image in two regions. In the considered framework, fixed exemplar histograms define a prior on the statistical features of the two regions in competition. We investigate the use of regularized transport-based cost functions as discrepancy measures between color histograms and consider a spatial regularization of the segmentation map with total variation. We finally rely on a primal-dual algorithm to solve the obtained convex optimization problem. Experiments illustrate the robustness of the proposed method for the segmentation of natural color

References

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Data Compression by nonlinear MR transforms

Rosa Donat
(in collaboration with F. Aràndiga$_1$ and J.J. Noguera$_2$)
Department of Mathematics, Universitat de València, Vallència, Spain

In this talk we will recall the theory of nonlinear multiresolution transformations and review their potential in image compression, specially for synthetic images. It will based, essentially, on previous works of the author and his collaborators, and some recent work on the ENO-wavelet transform.

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How to improve local optima of optical flow energies using discrete matches

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In this talk we introduce a large displacement optical flow method that introduces a new strategy to compute a good local minimum of any optical flow energy functional. The method requires a given set of discrete matches, which can be extremely sparse, and an energy functional which locally guides the interpolation from those matches. In particular, the matches are used to guide a structured coordinate-descent of the energy functional around these keypoints. It results in a two-step minimization method at the finest scale which is very robust to the inevitable outliers of the sparse matcher and able to capture large displacements of small objects. Its benefits over other variational methods that also rely on a set of sparse matches are its robustness against very few matches, high levels of noise and outliers. We validate our proposal using several optical flow variational models. The results consistently outperform the coarse-to-fine approaches and achieve good qualitative and quantitative performance on the standard optical flow benchmarks. It will based, essentially, on previous works of the author and his collaborators (see, for instance [1] and references therein).

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On Non-Smooth Non-Convex Non-Local Optimization

Emanuele Schiavi

(in collaboration with E. Alcaín[1], G. Galiano[2], A. Martín[3], A.I. Muñoz Montalvo[4], I. Ramírez[5], and S. Segura de León[6])

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Smooth Convex Optimization was the *paradigma* in Image Processing at the very beginning of this field through the celebrated Tikhonov Regularization for ill-posed inverse problems. It was in the 1990s when Perona and Malik, [1], introduced the necessity of nonlinearities in the flux of the diffusion equations. Soon after Rudin, Osher and Fatemi, [2] proposed a non-differentiable flux in the associated Euler-Lagrange Equation that was solved in a gradient descent approach for energy minimization. Non-smooth optimization emerged.

The Total Variation Operator and its famous counter-part in the Euler-Lagrange Equations, the 1− Laplacian Elliptic operator, surged ubiquitous in the Image Processing community. Since then an enormous quantity of models based on Bayesian modelling, energy minimization, elliptic and parabolic partial differential equations have appeared to cope with the (non exhaustive list of) image processing tasks of filtering, denoising, deblurring, deconvolution, segmentation, registration, impainting, superresolution.

To show the evolution of these ideas overcoming the *paradigma* of Convex and Local Optimization we shall consider hyper-Laplacian operators and related PDE to promote gradient sparse edge preserving solutions and non-local analysis.

In this talk I will present recent numerical results on some model problems that appear in Image Reconstruction as well as in more advanced tasks such as video sequences tracking and saliency for Human Activity Recognition. This presentation shall be based, essentially, on previous and current works of the author and his collaborators (see, for instance [3], [4], [5] and references therein).

Acknowledgements

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Tracking of cells in early animal embryogenesis by PDEs methods of image processing and validation of the results

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We present results of the cell tracking by our novel algorithm obtained for large-scale 3D+time microscopy images of early stages of embryo development of various organisms. In our data processing we first start with geodesic mean curvature flow filtering of the raw data [1], then we continue using level-set center detection [2] and then we extract the cell trajectories forming the lineage tree from potential field calculated from combination of distance functions computed inside 4D segmentations of the processed data [3]. By careful choice and tuning of algorithm parameters we can adapt the calculations to the microscope images of different vertebrae species. Then we can compare the results with gold standard tracking obtained by manual checking of cell links by biologists and measure the accuracy of our algorithm. Using visualisation tool displaying our results, gold standard and original 3D images simultaneously we can easily verify the correctness of the tracking.

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Combinatorics and graph theory

Limit laws of vertex degree distribution in planar maps

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We consider the family of rooted planar maps where the vertex degrees belong to a (possibly infinite) set of positive integers. Using a classical bijection with mobiles and some refined analytic tools to deal with the systems of equations that arise, we first recover the universal asymptotic behaviour of planar maps. Furthermore we establish that the expected number of vertices of a given degree satisfies a multi-dimensional central limit theorem. We also discuss some possible extension to maps of higher genus.

Colouring diamond-free graphs

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The Colouring problem is that of deciding, given a graph G and an integer k, whether G admits a (proper) k-colouring. For all graphs H up to five vertices, we classify the computational complexity of Colouring for (diamond, H)-free graphs. Our proof is based on combining known results together with proving that the clique-width is bounded for (diamond, P_1+2P_2)-free graphs. Our technique for handling this case is to reduce the graph under consideration to a k-partite graph that has a very specific decomposition. As a by-product of this general technique we are also able to prove boundedness of clique-width for four other new classes of (H_1, H_2)-free graphs. As such, our work also continues a recent systematic study into the (un)boundedness of clique-width of (H_1, H_2)-free graphs, and our five new classes of bounded clique-width reduce the number of open cases from 13 to 8 (see [1]).

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Graph limits of random graphs from a subset of connected k-trees

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For any set Ω of non-negative integers which contains $0, 1$ and at least one integer greater than 1, we consider a random Ω-k-tree $\mathsf{G}_{n,k}$ that is uniformly selected from the class of connected k-trees of $(n + k)$ vertices such that the number of $(k + 1)$-cliques that contain any fixed k-clique belongs to the set Ω.

We establish the scaling limit and a local weak limit of this random Ω-k-tree $\mathsf{G}_{n,k}$. Since 1-trees are just trees, it is well-known that the random 1-tree with n vertices admits the Continuum Random Tree $\mathcal{T}_{\mathsf{e}}$ as the scaling limit and converges locally toward a modified Galton-Watson tree; see [1, 2, 3, 4]. We prove that the random Ω-k-tree $\mathsf{G}_{n,k}$, scaled by $(kH_k\sigma_\Omega)/(2\sqrt{n})$ where H_k is the k-th Harmonic number and σ_Ω is a positive constant, converges to the Continuum Random Tree $\mathcal{T}_{\mathsf{e}}$, too. In particular this shows that the diameter as well as the expected distance of two vertices in a random Ω-k-tree $\mathsf{G}_{n,k}$ are of order $\sqrt{n}$. Furthermore, we prove the local convergence of the random Ω-k-tree $\mathsf{G}_{n,k}$ to an infinite but locally finite random Ω-k-tree $\mathsf{G}_{\infty,k}$.

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Scattering Number and Hamilton-Connectivity of Interval Graphs

Jiří Fiala

(in collaboration with Hajo Broersma, Petr A. Golovach, Tomáš Kaiser, Daniël Paulusma, Andrzej Proskurowski)

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We prove that for all $k \leq -1$ an interval graph is $-(k+1)$-Hamilton-connected if and only if its scattering number is at most k. This complements a previously known fact that an interval graph has a nonnegative scattering number if and only if it contains a Hamilton cycle, as well as a characterization of interval graphs with positive scattering numbers in terms of the minimum size of a path cover.

Minimal graphs containing k perfect matchings

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Let G be a graph. An *odd subdivision* of a graph G is obtained by replacing every edge of G with a path of odd length connecting its endvertices, so that these paths are internally disjoint. The replacement paths may also be of length one, making a graph an odd subdivision of itself.

Assuming G' is an odd subdivision of G there exists a natural bijective correspondence between perfect matchings in G and those in G'.

A graph G is *minimally k-matchable* if it has at least k distinct perfect matchings but deleting an arbitrary edge results in a graph which has fewer than k perfect matchings.

Let $k \geq 1$ be an integer. We show that there exists a *finite* set of graphs $\mathcal{G}_k$ so that every minimally k-matchable graph is isomorphic to a disjoint union of an odd subdivision of some graph from $\mathcal{G}_k$ and several copies of K_2.

Asymptotic enumeration of unary-binary tree-like structures with restrictions on the unary height

Bernhard Gittenberger
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We consider various classes of Motzkin trees as well as lambda-terms for which we derive asymptotic enumeration results. These classes are defined through restrictions concerning the unary nodes or abstractions, respectively. The enumeration is done by means of a generating function approach and singularity analysis.

The generating functions are composed of nested square roots and exhibit unexpected phenomena in some of the cases.

Extreme diagonally and antidiagonally symmetric alternating sign matrices of odd order

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For each $\alpha \in \{0, 1, -1\}$, we count alternating sign matrices of fixed odd order that are invariant under the reflections in the diagonal and in the antidiagonal (DASASMs) and that have a maximal number of α's along the diagonal and the antidiagonal, as well as DASASMs with a minimal number of α's along the diagonal and the antidiagonal if $\alpha = 0$. In these enumerations, we encounter round numbers that have previously appeared in plane partition or ASM counting, namely the number of all ASMs, the number of cyclically symmetric plane partitions in a given box, and the number of vertically and horizontally symmetric ASMs.

Enumeration and asymptotic properties of tanglegrams

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Tanglegrams are a class of graphs arising in computer science and in biological research on cospeciation and coevolution. They are formed by identifying the leaves of two rooted binary trees. We give an explicit formula to count the number of distinct binary rooted tanglegrams with n matched leaves, along with a simple asymptotic formula and an algorithm for choosing a tanglegram uniformly at random. The enumeration formula is then extended to count the number of tangled chains of binary trees of any length. This includes a new formula for the number of binary trees with n leaves. We also show that the two halves of a random tanglegram essentially look like two independently chosen random plane binary trees. This fact is used to derive a number of results on the shape of random tanglegrams, including theorems on the number of cherries and generally occurrences of subtrees, the root branches, the number of automorphisms, and the height. For each of these, we obtain limiting probabilities or distributions. Finally, we investigate the number of matched cherries, for which the limiting distribution is identified as well.

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Partial Extensions and Simultaneous Embeddings

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Extending partial solutions is often more difficult than to build solutions from scratch. Somewhat surprisingly, in case of geometric representations of graphs, in most of the cases when the computationally complexity of the problem is known, the compelxity is the same as of the plain recognition problem. Another closely related problem are simultaneous representations of graphs. Closely related, but not always of the same computational complexity. We will survey the known results, and compare them, for several well known classes of graphs and types of embedding in the plane.

The reconstruction problem for infinite graphs

Florian Lehner
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An important open question in the theory of finite graphs is whether it is possible to reconstruct any large enough finite graph from the family of subgraphs which can be obtained by removing individual vertices. The same problems for various classes of infinite graphs, such as trees or locally finite connected infinite graphs, has also remained open for the last few decades. We resolve these questions about infinite graphs by exhibiting locally finite trees which are not reconstructible.

Permutation snarks

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A permutation snark is a cubic graph with no 3-edge-colouring that contains a 2-factor consisting of two induced circuits. In the talk we analyse the basic properties of permutation snarks, focusing on the structure of edge-cuts of size 4 and 5. As an application of our knowledge we provide rich families of cyclically 4-edge-connected and 5-edge-connected permutation snarks of order 8n+2 for each integer $n \geq 2$ and $n \geq 4$, respectively, superseding a recent work of J. Hägglund and A. Hoffmann-Ostenhof [1].

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Subgraph Statistics in Subcritical Graph Classes

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We prove that the number of occurrences of a given subgraph H of subcritical graph class satisfies a central limit theorem with mean and variance that are asymptotically linear in the number of vertices. The proof is based on the analysis of infinite systems of generating functions.

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Automorphism Groups of Planar Graphs and Spherical Groups

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By Frucht's Theorem, every abstract finite group is isomorphic to the automorphism group of some graph. In my talk I will consider the problem of characterisation of groups that acts as groups of symmetries of planar graphs. There are two important subfamilies of planar graphs. Namely, trees and polyhedral graphs. In 1869 Jordan gave an inductive characterisation of the automorphism groups of trees. The primitive groups are the symmetric groups, and operations used in the induction are direct and wreath products. As concerns the polyhedral graphs, their groups of symmetries are the well-known spherical groups. In 1975, Babai characterized the automorphism groups of planar graphs. However, it is not so easy to understand Babai's result. In the talk, we give a more detailed and understandable description of these groups following the approach by Jordan. We first describe stabilisers of vertices in the action of the automorphism groups of connected planar graphs as the class of groups closed under the direct product and certain semidirect products with symmetric, dihedral and cyclic groups. After that the automorphism group of a connected planar graph is obtained as a semidirect product of a direct product of these stabilizers with a spherical group. In order to understand the action of the spherical group on the complement we need to study in details the distribution of vertex- and edge-orbits in the action of a spherical group of a prescribed type on polyhedra. It seems that the best language to investigate it offers the concept of a map on the associated 2-dimensional quotient orbifold.

General Caching Is Hard: Even with Small Pages

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Caching (also known as *paging*) is a classical problem concerning page replacement policies in two-level memory systems. *General caching* is the variant with pages of different sizes and fault costs. The strong NP-hardness of its two important cases, the *fault model* (each page has unit fault cost) and the *bit model* (each page has the same fault cost as size) has been established in 2010 by Chrobak et al. [1], however, the reduction uses pages as large as half of the cache size. We prove that the strong NP-hardness holds already when page sizes are bounded by a small constant: The bit and fault models are strongly NP-complete even when page sizes are limited to $\{1, 2, 3\}$.

Considering only the decision versions of the problems, general caching is equivalent to the *unsplittable flow on a path problem* and therefore our results also improve the hardness results for this problem.

The results were presented in Proceedings of the 26th International Symposium on Algorithms and Computation (ISAAC 2015) [2].

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Enumeration of orientably-regular maps on twisted linear fractional groups

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The twisted linear fractional groups $M(q^2)$ for q an odd prime power are well known as the 'other' family of Zassenhaus' sharply 3-transitive groups (of degree $q+1$), the better known such family being the groups $\mathrm{PGL}(2,q)$. We will look at these two families from the perspective of representing orientably-regular maps, that is, graph embeddings with the 'highest level' of orientation-preserving symmetry. This turns out to be equivalent to representing the groups as smooth quotients of triangle groups. While the situation for $\mathrm{PGL}(2,q)$ (and also $\mathrm{PSL}(2,q)$) has been well understood, the family of groups $M(q^2)$ have been somewhat neglected. In this talk we will present results on enumeration of orientably-regular maps with automorphism group isomorphic to $M(q^2)$, or, equivalently, on triangle groups admitting $M(q^2)$ as a smooth quotient.

Efficient automorphism breaking in graphs

Wilfried Imrich

(in collaboration with Florian Lehner[1] and Simon Mark Smith[2])

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A graph G is called 2-distinguishable if it has a 2-partition $\{V_1, V_2\}$ of its set of vertices that is only preserved by the identity automorphism. The size of the smaller one of the sets V_1, V_2 is called the *cost* of breaking $\mathrm{Aut}(G)$.

Infinite locally finite graphs G are 2-distinguishable and have finite cost if and only if $\mathrm{Aut}(G)$ is countable. We present new bounds for for the cost of such graphs and for countable graphs with countable group that are not locally finite.

For infinite 2-distinguishable graphs with uncountable automorphism group the cost is infinite, but one of the sets V_1, V_2 may have zero density in $V(G)$. We show that this is the case for infinite, homogeneous trees, tree-like graphs and graphs of low growth.

Improved approximative multicoloring of hexagonal graphs

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In 1999, McDiarmid and Reed [1] conjectured that the approximation ratio 9/8 of multichromatic number to weighted clique number asymptotically is the best possible for general weighted hexagonal graphs. Until now, the best approximation algorithms for general hexagonal graphs give 4/3 approximations [1, 2, 4] while 7/6 is the best approximation ratio for triangle free hexagonal graphs [3, 5] (and even 9/8 in a special case [6]). We propose a technique for decomposition of an arbitrary hexagonal graph into three triangle free hexagonal graphs that may provide improved aproximation algorithms for general case.

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Low dimensional discrete dynamical systems

Quasi-periodic normally hyperbolic invariant tori: existence, persistence and mechanisms of breakdown

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We present a KAM-like theorem in a posteriori format for the existence of real-analytic quasi-periodic normally hyperbolic invariant tori in smooth families of real-analytic dynamical systems. The proof is based on the parameterization method. Moreover, the KAM scheme leads to fast and efficient algorithms of computation of invariant tori, even in cases these objects are about to break. We present several numerical computations that suggest conjectures on some mechanisms of breakdown.

Complexity and Simplicity in the dynamics of Totally Transitive graph maps

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Transitivity, the existence of periodic points and positive topological entropy can be used to characterize complexity in dynamical systems. It is known that for graphs that are not trees, for every $\varepsilon > 0$, there exist (complicate) totally transitive map (then with cofinite set of periods) such that the topological entropy is smaller than ε (simplicity).

First we will show by means of examples that for any graph that is is not a tree the relatively simple maps (with small entropy) which are totally transitive (and hence robustly complicate) can be constructed so that the set of periods is also relatively simple. To numerically measure the complexity of the set of periods we introduce the notion of *boundary of cofiniteness* defined as the smallest positive integer n such that the set of periods contains $\{n, n+1, n+2, \dots\}$. Larger boundary of cofiniteness means simpler set of periods. With the help of the notion of boundary of cofiniteness we can state precisely what do we mean by extending the entropy simplicity result to the set of periods: *there exist relatively simple maps such that the boundary of cofiniteness is arbitrarily large (simplicity) which are totally transitive (and hence robustly complicate).*

Moreover, we will show tat that, for circle and sigma maps, the above statement is a theorem. This is a good example on how the lack of knowledge about the structure of the set of periods can be overcome with appropriate simple arguments.

A landing theorem for hairs and dreadlocks of entire functions with bounded post-singular sets

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The *Douady-Hubbard landing theorem* for periodic external rays is one of the cornerstones of the successful study of polynomial dynamics. It states that, for a complex polynomial f with bounded postcritical set, every periodic external ray lands at a repelling or parabolic periodic point, and conversely every repelling or parabolic point is the landing point of at least one periodic external ray.

We prove an analogue of the theorem for entire functions with bounded postsingular set. If such f additionally has finite order of growth, then our result states precisely that every periodic hair of f lands at a repelling or parabolic point, and again conversely every repelling or parabolic point is the landing point of at least one periodic hair. (Here a *periodic hair* is a curve consisting of escaping points of f that is invariant under an iterate of f.) For general f with bounded postsingular set, but not necessarily of finite order, the role of hairs is taken by more general connected sets of escaping sets, which we call *dreadlocks*.

On minimal homeomorphisms on Peano continua

Jozef Bobok
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Following the question of Artigue we construct a minimal homeomorphism $g\colon X \to X$ on a Peano continuum X with the following property: there exist a positive number ε and a dense G_δ subset E of X such that every non-trivial subcontinuum of X intersecting E expands under iterations of g to a continuum of diameter greater than ε.

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Rotational dynamics on cofrontiers

Jan Boroński

AGH Kraków & IT4Innovations Ostrava

A *cofrontier* Λ in the plane is a compact, connected set that irreducibly separates the plane into exactly two components and is the boundary of each. In my talk I shall discuss some recent results on rotational dynamics of cofrontiers.

Self-similarity in the non-matching parameter set for a family of piecewise continuous linear maps

Henk Bruin

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Faculty of Mathematics, University of Vienna, Vienna, Austria

This talk is about the parameter space of a family of piecewise linear maps in regard to the property of "matching". This means that at some iterate, the left and right limit of the discontinuity point merge again. The prevalence of this phenomenon is observed only under specific number-theoretic conditions. I want to present new results regarding the self-similarity of the set of non-matching parameters. This has distant relations to the renormalization structure of the logistic family conditions.

Planar embeddings of inverse limit spaces of unimodal maps

Jernej Činč

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Given a point x from an inverse limit space of unimodal maps X we construct a planar embedding of X making the point x accessible from the complement of X. With this construction described in [1] we obtain uncountably many embeddings of X which are not equivalent to two well-known standard embeddings, described in [2] and [3]. I will also discuss the extendability of the shift homeomorphism σ on the plane for the constructed embeddings.

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On the minimum entropy for irreducible interval cycles

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The class $\mathcal{C}_n$ of interval cycles of period n can be divided into two disjoint families $\mathcal{R}_n \cup \mathcal{I}_n$. A cycle P belongs to $\mathcal{R}_n$ and is called *reducible* if there exists an underlying cycle Q whose period $k > 1$ divides n such that P is obtained from expanding any point of Q to a block of n/k points and the blocks are cyclically permuted according to Q. On the other hand, a cycle belongs to $\mathcal{I}_n$ and is called *irreducible* if it is "genuine" in the sense that it cannot be obtained from a cycle of smaller period after replacing points by blocks. The cycles with minimum entropy in $\mathcal{C}_n$ are well known, since they have to be *primary* (forcing minimal) and the primary interval cycles are completely characterized in the literature. When n is odd, the entropy-minimal n-cycles are Stefan cycles, in particular irreducible. But for n even they turn out to be reducible. So, finding the cycles of minimum entropy in the class $\mathcal{I}_n$ for n even is a natural (and open) problem. For any n even we define an irreducible unimodal cycle P_n and prove that P_n is primary in $\mathcal{I}_n$. It follows that P_n minimizes the entropy in the set (contained in $\mathcal{I}_n$) of unimodal irreducible cycles of period n. We conjecture that P_n has in fact the minimum entropy in the whole class $\mathcal{I}_n$.

A smooth Kerékjártó Theorem

Armengol Gasull
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A continuous map $F : \mathbb{R}^n \to \mathbb{R}^n$ satisfying $F^m = \mathrm{Id}$ is called *m-periodic*. Here $F^j = F \circ F^{j-1}$ and m is the smallest positive natural number with this property. Usually, 2-periodic maps are called *involutions*.

Given $k = 0, 1, 2, \ldots, \infty$, we say that a map $F : \mathbb{R}^n \to \mathbb{R}^n$ of class $\mathcal{C}^k$ is (globally) $\mathcal{C}^k$*-linearizable* if it is conjugate to a linear map L via a $\mathcal{C}^k$-homeomorphism $\psi : \mathbb{R}^n \to \mathbb{R}^n$, that is, if $L = \psi \circ F \circ \psi^{-1}$. In dimension $n = 1$ it is not hard to prove that all periodic maps are $\mathcal{C}^0$-linearizable with $L(x) = x$ or $L(x) = -x$. A similar result holds for $n = 2$, now L is either the symmetry or a rotation of angle commensurable with 2π.

Kerékjártó Theorem. *Let $F : \mathbb{R}^2 \to \mathbb{R}^2$ be a continuous m-periodic map. Then F is $\mathcal{C}^0$-linearizable.*

This result goes back to 1919 and appeared in the works of Brouwer and Kerékjártó. Currently it is known as Kerékjártó theorem. A complete proof was presented by Eilenberg in 1934 (see [2] for more details). In 1964 it was discovered by Bing that this theorem cannot be extended to higher dimensions.

In dimension $n = 1$, for any k, it is well-known that every non-trivial $\mathcal{C}^k$-periodic map is an involution and is $\mathcal{C}^k$-linearizable. In this talk we will give the key steps for proving the following $\mathcal{C}^k$ version of Kerékjártó theorem given in [1]:

Theorem. *Let $F : \mathbb{R}^2 \to \mathbb{R}^2$ be a $\mathcal{C}^k$-differentiable m-periodic map with $k \in \{1, 2, \ldots, \infty\}$. Then F is $\mathcal{C}^k$-linearizable.*

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Dense orbits of flows and homeomorphisms on topological spaces

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Existence of a dense orbit (topological transitivity) or a stronger property of all orbits being dense (topological minimality) have strong consequences for the behaviour of a dynamical system and related questions belong to the core of topological dynamics. In this talk I discuss these notions for continuous as well as discrete time systems in a general setting without assuming compactness of the underlying space. Then I proceed to discuss hereditariness of minimality and total minimality, particularly the one relating density of orbits of flows and corresponding t-maps, and density of full orbits versus density of forward or backward semi-orbits.

On the construction and differentiability of minimal non-invertible skew-product maps of 2-manifolds

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In [5] the authors constructed a non-invertible minimal map of a torus, in [1] it was proven that the only 2-dimensional manifolds admitting minimal maps are tori and Klein bottles and their unions. Examples of such homeomorphisms are known since 1960's (e.g. [3] or [6]). On the other hand, the question whether there exists a non-invertible minimal map of a Klein bottle remained open until recently, [7].

The construction of such mapping (using methods from [4]) is the cornerstone of this talk. Also it is known due to [2] that there is no analytic minimal non-invertible map on a 2-manifold. Hence the differentiability and Lipschitz continuity of minimal non-invertible maps of 2-manifolds will be discussed as well.

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A fractalization process for invariant curves in affine skew products of the plane

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Quasi-periodically forced maps are discrete dynamical systems of the form

$$\left.\begin{aligned} \tilde{x} &= f(x,\theta,\mu), \\ \tilde{\theta} &= \theta+\omega, \end{aligned}\right\} \tag{1}$$

where $x \in \mathbb{R}^n$, $\theta \in \mathbb{T}$, ω is irrational and μ is a real parameter. The map f is usually assumed to be of class C^r, $r \geq 1$. An invariant curve is the graph of a C^1 map $\theta \mapsto x(\theta)$ such that $f(x(\theta), \theta, \mu) = x(\theta + \omega)$. Assume that, for a given value of the parameter $\mu = \mu_0$, the system (1) has an attracting invariant curve, and that when μ goes from μ_0 to a critical value μ_1 this Lyapunov exponent goes to zero. We are interested in the possible behaviours of the invariant curve when μ approaches μ_1. In particular, we are interested in fractalization phenomena that might give rise to the appearance of a Strange Non-Chaotic Attractor.

To study this phenomenon we will focus on a simpler situation, given by the affine system

$$\left.\begin{array}{rcl} \tilde{x} &=& \mu A(\theta)x + b(\theta), \\ \tilde{\theta} &=& \theta + \omega, \end{array}\right\} \tag{2}$$

where ω is the golden mean, $x \in \mathbb{R}^2$ and, for each θ, $A(\theta)$ is a 2×2 real matrix and $b(\theta)$ a two-dimensional real vector. Moreover, we will assume that the corresponding linear system

$$\left.\begin{array}{rcl} \tilde{x} &=& \mu A(\theta)x, \\ \tilde{\theta} &=& \theta + \omega, \end{array}\right\}$$

is non-reducible due to a topological obstruction. A remarkable example of such a non-reducible system is given by

$$A(\theta) = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}.$$

We will prove that (2) has an invariant curve that displays a fractalization process when μ goes to a critical value.

On properties of dynamical systems on dendrites

Zdeněk Kočan

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We take a list of properties of continuous maps on compact metric spaces, e.g., the existence of an arc horseshoe, the positivity of topological entropy, the existence of a homoclinic trajectory, the existence of an omega-limit set containing two minimal sets, and others. Our aim is to find the relations between the properties in the case of dendrite maps. Here we present the known relations between the properties in this case, e.g., some examples of dendrite maps with properties which show that some implications between the properties do not hold in this case.

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Iterative systems of Möbius transformations

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An iterative system is the action of a monoid of finite words on a compact metric space. We investigate the concepts of minimality, transitivity and attractors in iterative systems of Möbius transformations.

Escaping points and semiconjugation of holomorphic self-maps of the punctured plane

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For every holomorphic self-map of the punctured plane f, there exists an entire funtion F that is semiconjugated to f by the exponential function - we say that F is a lift of f. Each holomorphic self-map of $\mathbb{C}^*$ has an associated index, $\operatorname{ind}(f)$, which is an integer such that $F(z + 2\pi i) = F(z) + \operatorname{ind}(f) \times 2\pi i$ for all $z \in \mathbb{C}$. We show that if f is a transcendental entire function with no zeros, then the fast escaping set of a lift F of f equals the preimage under the exponential of the fast escaping set of f. Bergweiler and Hinkkanen [1] proved one of the inclusions in a more general setting, but we show that equality holds in this particular case. Moreover, we can compare the escaping set, the set of unbounded non-escaping orbits and the set of bounded orbits of f with those of a lift F of f in terms of the index of f. Similar results hold for general holomorphic self-maps of $\mathbb{C}^*$.

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On completely scrambled systems

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A dynamical system (X, T) is completely scrambled if all non-diagonal pairs $(x, y) \in X \times X$ are proximal (i.e. $\liminf_{n\to\infty} d(T^n(x), T^n(y)) = 0$) but not asymptotic (i.e. $\limsup_{n\to\infty} d(T^n(x), T^n(y)) > 0$). In this talk we will survey recent progress on characterization of such systems and their additional dynamical properties.

Stability of the topological pressure for continuously differentiable interval maps

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Assume that $T : [0,1] \to [0,1]$ is a C^1-map satisfying that $\{c \in (0,1) : T'c = 0\}$ is finite. Fix an $N \in \mathbb{N}$ with $N \geq \mathrm{card}\big(\{c \in (0,1) : T'c = 0\}\big) + 1$. Denote the family of all C^1-maps $S : [0,1] \to [0,1]$, which are piecewise monotonic with at most N intervals of monotonicity by $\mathcal{M}_N$. Obviously the conditions on T imply that $T \in \mathcal{M}_N$. The set $\mathcal{M}_N$ is endowed with the C^1-topology, this means with respect to the norm $\|S\| := \max_{x\in[0,1]} |Sx| + \sup_{x\in[0,1]} |S'x|)$. Then the stability of certain dynamical invariants of T under small perturbations is investigated. Observe that it is essential to assume that the number of intervals of monotonicity of the perturbation is bounded by the previously fixed number N, but one this number can be chosen arbitrarily large.

One obtains that for every continuous function $f : [0,1] \to \mathbb{R}$ the topological pressure is upper semi-continuous at T, this means $\limsup_{\widetilde{T}\to T} p(\widetilde{T}, f) \leq p(T, f)$. If f satisfies that $p(T, f) > \lim_{n\to\infty} \frac{1}{n} \max_{x\in[0,1]} \sum_{j=0}^{n-1} f(T^j x)$ (which is satisfied if $p(T, f) > \max_{x\in[0,1]} f(x)$ holds), then the topological pressure is continuous at T. Hence the topological entropy is continuous at T. In general the topological pressure is not lower semi-continuous. This will be shown giving an example. Suppose that $h_{\mathrm{top}}(T) > 0$ and that T has a unique measure μ of maximal entropy (this means $h_\mu(T) = h_{\text{top}}(T)$). Then there exists an open neighbourhood U of T in $\mathcal{M}_N$ (with respect to the C^1-topology), such that every $\widetilde{T} \in U$ has a unique measure $\mu_{\widetilde{T}}$ of maximal entropy. Moreover, $\lim_{\widetilde{T}\to T} \mu_{\widetilde{T}} = \mu$ in the weak star-topology.

On McMullen-like mappings

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We introduce a generalization of particular dynamical behavior for rational maps. In 1988, C. McMullen showed that the Julia set of $f_\lambda(z) = z^n + \lambda/z^d$ for $|\lambda| \neq 0$ small enough is a Cantor set of circles if and only if $1/n + 1/d < 1$ holds. Several other specific singular perturbations of polynomials have been studied in recent years, all have parameter values where a Cantor set of circles is present in the associated Julia set. We unify these examples by defining a McMullen-like mapping as a rational map f associated to a hyperbolic postcritically finite polynomial P and a pole data $\mathcal{D}$ where we encode the location of every pole of f and the local degree at each pole. As for the McMullen family f_λ, we characterize a McMullen-like mapping using an arithmetic condition depending only on $(P, \mathcal{D})$. We show how to check the definition in practice providing new explicit examples of McMullen-like mappings for which a complete topological description of their Julia sets is made.

Non-escaping endpoints of entire functions

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Let $f_a(z) = e^z + a, a < -1$. The Julia set of f_a consists of an uncountable union of disjoint curves going off to infinity (a Cantor bouquet). Following several interesting results on the endpoints of these curves, we consider the set of non-escaping

endpoints, that is, the endpoints whose iterates do not tend to infinity. We show that the union of non-escaping endpoints with infinity is a totally separated set by finding continua that separate these endpoints from infinity. This is a complementary result to the very recent result of Alhabib and Rempe-Gillen that for the same family of functions the set of escaping endpoints together with infinity is connected. Moreover, we present other functions in the exponential family as well as a function that was first studied by Fatou which share the same property of the non-escaping endpoints. Finally, we show how we can use the continua we have constructed in order to show that the union of the Fatou set with the set of points that escape to infinity'as quickly as possible' has the structure of a 'spider's web'.

Complex analysis and geometry

Convergence of formal maps

Bernhard Lamel

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In recent joint work with Nordine Mir, we were able to show that if M and M' are strictly pseudoconvex hypersurfaces in some $\mathbb{C}^N$ and some $\mathbb{C}^{N'}$, respectively, and $H\colon M \to M'$ is a formal map, then H is convergent. We will discuss this result and its proof.

Pointwise multipliers for Hardy-Sobolev spaces

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Our focus of interest comes out from the following fact in $\mathbb{R}^n$: for a nonlinear potential of a positive measure, it is enough to impose its boundedness to assure that the potential is a pointwise multiplier of the Bessel space . We will check, using different methods, an analogous result for non isotropic holomorphic potentials on the unit ball in $\mathbb{C}^n$, showing that the bounded holomorphic potentials are pointwise multipliers for the Hardy-Sobolev spaces. As a consequence, we construct nontrivial examples of such multipliers and we give some applications.

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An uncertainty principle and the $\overline{\partial}$ problem

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I will present a new uncertainty principle, and show how it allows to prove new solvability and compactness properties for certain $\overline{\partial}$ problems.

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Chern-Moser Theory in higher codimension

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We extend the Chern-Moser approach for hypersurfaces given in [1] to real submanifolds of higher codimension in complex space to derive results on jet determination for their automorphism group.

References

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Essential spectrum of the complex Laplacian on product manifolds

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I will compute the essential spectrum of the L^2 complex Laplacian on the product of two Hermitian manifolds. Applications to (non-) compactness of the associated $\overline{\partial}$-Neumann operator are given, and extensions to vector-valued differential forms are also available. The results are valid more generally for the tensor product of two Hilbert complexes.

References

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On some spectral properties of the $\overline{\partial}$-Neumann operator.

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We consider the $\overline{\partial}$-Neumann operator

$$N : L^2_{(0,q)}(\Omega) \longrightarrow L^2_{(0,q)}(\Omega),$$

where $\Omega \subset \mathbb{C}^n$ is bounded pseudoconvex domain, and

$$N_\varphi : L^2_{(0,q)}(\Omega, e^{-\varphi}) \longrightarrow L^2_{(0,q)}(\Omega, e^{-\varphi}),$$

where $\Omega \subseteq \mathbb{C}^n$ is a pseudoconvex domain and φ is a plurisubharmonic weight function. N is the inverse to the complex Laplacian $\Box = \overline{\partial}\,\overline{\partial}^* + \overline{\partial}^*\,\overline{\partial}$.

In addition, we describe spectral properties of the complex Laplacian $\Box_{\varphi,q}$ on weighted spaces $L^2(\mathbb{C}^n, e^{-\varphi})$. In this connection it is important to know whether the Fock space

$$\mathcal{A}^2(\mathbb{C}^n, e^{-\varphi}) = \{f : \mathbb{C}^n \longrightarrow \mathbb{C} \text{ entire } : \int_{\mathbb{C}^n} |f|^2 e^{-\varphi}\, d\lambda < \infty\}$$

is infinite-dimensional, which depends on the behavior at infinity of the eigenvalues of the Levi matrix of the weight function φ.

We discuss necessary conditions for compactness of the corresponding $\overline{\partial}$-Neumann operator related to Schrödinger operators with magnetic field.

Equidistribution and β-ensembles

Jordi Marzo

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In this talk we will find the precise rate at which the empirical measure associated to a β-ensemble converges to its limiting measure. In our setting the β-ensemble is a random point process on a compact complex manifolds distributed according to the β power of a determinant of sections in a positive line bundle. A particular case, is the spherical ensemble of generalized random eigenvalues of pairs of matrices with independent identically distributed Gaussian entries.

Schatten class Hankel operators on weighted Bergman spaces

Jordi Pau

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We completely characterize the simultaneous membership in the Schatten ideals S_p, $0 < p < \infty$ of the Hankel operators H_f and $H_{\overline{f}}$ on the Bergman space, in terms of the behaviour of a local mean oscillation function, proving a conjecture of Kehe Zhu from 1991.

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Borel theorem for CR-maps

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Following Henri Poincare, numerous results in Dynamics establish the curious phenomenon saying that two smooth objects (e.g. vector fields), which can be transformed into each other by means of a formal power series transformation, can be also transformed into each other by a smooth map. This is a kind of analogue of Borel Theorem on smooth realizations of formal power series. In CR-Geometry, similar phenomena hold for real-analytic CR-manifolds, and the usual outcome is that two formally equivalent CR-manifolds are also equivalent holomorphically. However, in our recent work with Shafikov [1] we proved that there exist real-analytic CR-manifolds, which are equivalent formally, but still not holomorphically. On the other hand, in our more recent work with Lamel and Stolovitch we prove that the following is true: if two 3-dimensional real-analytic CR-manifolds are equivalent formally, then they are C^∞ CR-equivalent. In this talk, I will outline the latter result.

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The Local Rigidity Problem for Holomorphic Mappings of Real Submanifolds

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For two germs of real submanifolds $M \subset \mathbb{C}^N$ and $M' \subset \mathbb{C}^{N'}$ consider the set $\mathcal{H}$ of germs of holomorphic mappings which locally map M into M'. The group G of local automorphisms of M and M' induces an action on $\mathcal{H}$. A map $H \in \mathcal{H}$ is called locally rigid if all maps close to H in $\mathcal{H}$ belong to the G-orbit of H. Assume that $H \in \mathcal{H}$ belongs to the class of finitely nondegenerate maps. In this case we provide sufficient conditions for local rigidity of H in terms of the space of infinitesimal deformations associated to H, which consists of holomorphic vectors whose real part is tangent to M' along the image of H.

On regular Stein neighborhoods of a union of two totally real subspaces in $\mathbb{C}^n$

Tadej Starčič

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In this talk we present a construction of regular Stein neighborhoods of a union of totally real subspaces $M = (A + iI)\mathbb{R}^n$ and $N = \mathbb{R}^n$ in $\mathbb{C}^n$, provided that the entries of a real $n \times n$ matrix A are sufficiently small. Our proof is based on a local construction of a suitable function ρ near the origin, such that the sublevel sets of ρ are strongly pseudoconvex and admit strong deformation retraction to $M \cup N$.

References

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An ultradifferentiable reflection principle

Stefan Fürdös

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In my talk I will present a reflection principle for mappings between finitely nondegenerate, generic, ultradifferentiable manifolds. Here, an ultradifferentiable manifold is a smooth manifold whose defining function belongs to some Denjoy-Carleman class $\mathcal{E}_{\mathcal{M}}$ that is determined by a weight sequence $\mathcal{M}$. The methods used in the proof are based on the ultradifferentiable wavefront set as defined by Hörmander and the almost-analytic extension of functions in $\mathcal{E}_{\mathcal{M}}$ given by Dynkin. Furthermore, if time permits, I will point out how these methods can be used to generalize a joint work with B. Lamel concerning the smooth regularity of infinitesimal CR automorphisms to the ultradifferentiable category.

Contributed talks

On the Spectrum of Dynamical systems on Trees

Jan Tesarčík

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In their famous paper Schweizer and Smítal [Trans. Amer. Math. Soc. 344 (1994) 737–754] introduced the notion of distributional chaos for continuous maps of the interval and spectrum and weak spectrum of dynamical system. Among other they have proved that in the case of continuous interval maps the both spectrum and weak spectrum is finite and generated by points from basic sets. Here we generalize mentioned results for the case of continuous maps of finite tree. While the results are similar, the original argument is not applicable directly and needs essential modifications. In particular it was necessary resolve problem of intersection of basic sets which was crucial point.

An example of one-dimensional dynamical system with infinite spectrum is presented.

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Integrally invertible graphs and their spectra

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In this talk we are concerned with integrally invertible graphs. We investigate a class of the so-called positively and negatively invertible graphs. The positively invertible graphs are invertible graphs in the usual Godsil's sence [1]. A graph is positively (resp. negatively) integrally invertible if its adjacency matrix has an integral inverse matrix which signable to a nonnegative (resp. positive) matrix. In contrast of positive invertibility, the negatively invertible graphs have not been studied before, despite the fact that this class includes important molecule models and have thus applications in chemistry.

We construct new families of integrally invertible graphs based on bridging of two such graphs over the subset of their vertices. We derive sufficient conditions for integral invertibility of bridged graphs and analyze their spectral properties. We also obtain lower bounds for their least positive eigenvalue. The presentation is based on papers [2, 3]

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Estimates for order of Nevanlinna matrices

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All solutions of an indeterminate Hamburger moment problem can be described using a Nevanlinna matrix. The entries of this matrix are entire functions of order less or equal 1. The problem is to determine the exact order of these functions.

We write the moment problem as a canonical system with Hamiltonian H. Here, $H : [0, L) \to \mathbb{R}^{2\times 2}$ is a locally integrable function whose values are a.e. positive semi-definite. The corresponding canonical system is given by the equation

$$y'(x) = zJH(x)y(x), \quad x \in (0, L),$$

where $z \in \mathbb{C}$ and $J = \left(\begin{smallmatrix} 0 & -1 \\ 1 & 0 \end{smallmatrix}\right)$. The so-called Hamburger Hamiltonians which appear here have a much easier structure.

We obtain estimates for the order by transforming a given Hamburger Hamiltonian into (the Hamiltonian associated with) a Krein-string, and apply a theorem of I.S.Kac to evaluate the order of that string. Our result an be viewed as a generalisation of a theorem by Berezanskii in the 50s.

On the way, we leave the positive definite scheme and encounter Hamiltonians which take also negative definite matrices as values.

Diffusion-type equations on discrete-space domains

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We focus on diffusion-type equations of the form

$$u^{\Delta}(x,t) = au(x+1,t) + bu(x,t) + cu(x-1,t), \quad x \in \mathbb{Z},\ t \in \mathbb{T}, \tag{1}$$

where $\mathbb{T}$ is an arbitrary time scale (i.e., a closed subset of $\mathbb{R}$), u^Δ denotes the Δ-derivative of u with respect to t, and a, b, $c \in \mathbb{R}$.

When $\mathbb{T} = \mathbb{R}$, $u^\Delta(x,t)$ becomes the usual partial derivative $u_t(x,t)$, and Eq. (1) generalizes the space-discretized version of the classical diffusion equation. For $\mathbb{T} = \mathbb{Z}$, $u^\Delta(x,t)$ reduces to the partial difference $u(x,t+1) - u(x,t)$, and Eq. (1) describes the one-dimensional (not necessarily symmetric) random walk on $\mathbb{Z}$.

We study the existence and (non)uniqueness of solutions to initial-value problems, superposition principle, space sum preservation, and maximum and minimum principles.

Eq. (1) can be generalized in various ways. For example, the spatial domain can be $\mathbb{Z}^n$ or a general graph. Another possibility is to consider nonlinear reaction-diffusion equations of the form

$$u^\Delta(x,t) = au(x+1,t)+bu(x,t)+cu(x-1,t)+f(u(x,t),x,t), \quad x \in \mathbb{Z},\ t \in \mathbb{T}. \quad (2)$$

Special cases of Eq. (2) include the Fisher and Nagumo lattice equations, or nonautonomous logistic population models with a variable carrying capacity.

References

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Posters

The spectrum of the stiff string and proposals for piano tuning

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The strings of a piano have some degree of stiffness; this can be modelled using the Euler-Bernouilli beam model. For a pinned string we compute the corresponding spectrum, which turns out to be slightly inharmonic. Therefore, equal temperament (12 equal divisions of the just octave) is not the best choice to tune a piano. We study several possible tunings aiming to improve its consonance. A good solution is obtained if one tunes a note and its fifth by forcing the beats among their third and second partials, respectively, to disappear.

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Solving the oblique derivative boundary value problem for the Laplace equation on non-uniform logically rectangular grids by the finite volume method

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(in collaboration with Karol Mikula$_1$, Róbert Čunderlík$_2$ and Marek Macák$_3$)

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In this poster we will present a new finite volume method for solving the Geodetic boundary value problem with the oblique derivative boundary condition on non-uniform logically rectangular grids. First an evolving surface approach is used to built the grid above the Earth topography. Then the Laplace equation is solved on such a grid. The main idea of the new finite volume method is in a splitting of a normal derivative on a finite volume boundary face into a derivative in a tangential direction and a derivative in a direction of a vector connecting representative points of neighbouring finite volumes. The oblique derivative boundary condition is understood as a stationary advection equation and the new upwind method is developed for its discretization. The numerical experiments will be presented. The poster will be based, essentially, on previous works of the author and his collaborators (see, for instance [1] and references therein).

References

[1] Medľa M., Mikula K., New Second Order Up-wind Scheme for Oblique Derivative Boundary Value Problem. *20th Conference on Scientific Computing, Vysoké Tatry - Podbanské, Slovakia, March 14 - 18, 2016. Proceedings of contributed papers, Editors: A. Handlovičová and D. Ševčovič Publishing House of Slovak University of Technology in Bratislava*, pp. 254-263, 2016.

The nonlinear diffusion filter influenced by the mean curvature

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In this poster we will present a new nonlinear diffusion filtering method on closed surfaces and surfaces with boundaries such as a sphere, ellipsoid and Earth's surface or its parts. The new model extends the regularized surface Perona-Malik model [1] by including a local extrema detector based on a mean curvature of processed data. The model is thus represented by a nonlinear diffusion equation which filters noise while preserves main edges, local extrema and other details important for a correct interpretation of data. We define a surface finite-volume method to approximate numerically the nonlinear parabolic partial differential equation on the surface. The surface is approximated by a polyhedral surface created by planar triangles and we use a piece-wise linear approximation of a solution in space and the backward discretization in time. Numerical experiments present nonlinear diffusion filtering of real geodetic measurements such a GOCE data and satellite-only mean dynamic topography (MDT). They aim to point out a main advantage of the new nonlinear model. The poster will be based, essentially, on previous works of the author and his collaborators (see, for instance [2] and references therein).

References

[1] Čunderlík R., Mikula K., Tunega M., Nonlinear diffusion filtering of data on the Earth's surface *Journal of Geodesy, ISSN 0949-7714*, pp. 143-160, 2012.

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New numerical method for mesh improvement of evolving triangulated surfaces

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The poster presents a new technique for improving the mesh quality of evolving triangulated surfaces. For each point on the surface the velocity of the evolution is prescribed. The evolution in the normal direction has effect on the position and shape of the surface. The tangential component moves the points along the surface only (in case of the surface with boundary, the boundary points are fixed) and can be designed to control the distribution of the points on the surface (several techniques are developed in [1]). Our new approach is based on the two-dimensional elasticity. We define an ideal shape of each mesh triangle and calculate the elastic energy [2] needed to deform the triangle from ideal shape to real one. During the evolution we exploit the tangential velocity to minimize the total deformation energy of the triangulation. We present the basic ideas and several numerical experiments illustrating the performance of the technique.

References

[1] Mikula K., Remešíková M., Sarkoci P. and Ševčovič D. Manifold evolution with tangential redistribution of points, *SIAM J. Scientific Computing*, Vol. 36, No.4 (2014), pp. A1384-A1414

[2] Delingette H. Triangular Springs for Modeling Nonlinear Membranes, *IEEE Transactions on Visualization Computer Graphics*, vol.14, no. 2, pp. 329-341, March/April 2008, doi:10.1109/TVCG.2007.70431

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