ÖMG-TAGUNG 18.–22.9.2023

CONFERENCE OVERVIEW as of 2023-08-17

Monday 18. September

	HS 12.01	HS 11.01	HS 11.02
09:00 – 09:10	Opening		
09:10 – 10:00	Schnass		
10:00 – 10:30	Coffee break		
	Continuous Optimization Methods	Additive Combinatorics	Theory and Numerics of Evolution Eqs
10:30 – 11:00	Benko	Helfgott	Achleitner
11:00 – 11:30	Bùi	Elsholtz	Fellner
11.30 – 12:00	Malitsky	Wurzinger	Gimperlein
12:00 – 12:30	Schichl	Hegyvári	
12:30 – 14:00	Lunch break		
14:00 – 15:00	Scheichl		
15:00 – 15:30	Coffee break		
	Continuous Optimization Methods	Additive Combinatorics	Theory and Numerics of Evolution Eqs
15:30 – 16:00	D.K. Nguyen	de Roton	Linß
16:00 – 16:30	Ulbrich	Bienvenue	Nigsch
16:30 – 17:00	Wachsmuth	Naslund	Thalhammer
17:00 – 17:30		Pach	
18:00 – 20:00	Welcome reception at Meerscheinschlössl		

	HS 11.03	UR 11.04	SR 11.05
09:00 – 10:00			
10:00 – 10:30	Coffee break		
	Computational Topology and Geometry	Stochastic Mass Transport	Mathematical Modeling for Biomedicine
10:30 – 11:00	Huszár	Riess	Fumagalli
11:00 – 11:30	Heiss	Grass	Gillette
11.30 – 12:00	Roll	Huesmann	Zappon
12:00 – 12:30	Schnider		
12:30 – 14:00	Lunch break		
14:00 – 15:00			
15:00 – 15:30	Coffee break		
	Computational Topology and Geometry	Stochastic Mass Transport	
15:30 – 16:00	Maus	Källblad	
16:00 – 16:30	Asinowski	Pammer	
16:30 – 17:00	Brötzner	Schrott	
17:00 – 17:30	Parada		
18:00 – 20:00	Welcome reception at Meerscheinschlössl		

Tuesday 19. September

	HS 12.01	HS 11.01	HS 11.02	HS 11.03
09:00 – 10:00	Albrecher			
10:00 – 10:30	Coffee break			
	Probabilistic Methods in Convexity	Diophantine Analysis and Equidistribution		PDEs and Mathematical Biology
10:30 – 11:00	Brauner	Borda		Kollár
11:00 – 11:30	Knoerr	Ziegler		Kollár
11.30 – 12:00	Ortega-Moreno	Zafeiropoulos		Bod'ová
12:00 – 12:30		Summerer		Schertzer
12:30 – 14:00	Lunch break			
14:00 – 15:00	Rüland			
15:00 – 15:30	Coffee break			
	Open-source software for discrete mathematics	Diophantine Analysis and Equidistribution	Inverse Problems in Imaging	Contributed talks
15:30 – 16:00	Brosch	Spiegelhofer	Chenchene	Windisch
16:00 – 16:30	Hackl	Madritsch	Dittmer	Li
16:30 – 17:00	Heuberger	Rossi	Wolf	Anabanti
17:00 – 17:30		Bruin	Breger	Grabner

	UR 11.04	SR 11.05	SR 11.06
09:00 – 10:00		.	
10:00 – 10:30	Coffee break		
	High-Dimensional Approximation	Algebra, Geometry and Physics	Financial and Actuarial Mathematics
10:30 – 11:00	Ehler	Baur	Hochgerner
11:00 – 11:30	Gröchenig	Beil	Hasenbichler
11.30 – 12:00	Feichtinger	Faber	Aichinger
12:00 – 12:30	Feischl	Gorsky	
12:30 – 14:00	Lunch break		
14:00 – 15:00			
15:00 – 15:30	Coffee break		
	High-Dimensional Approximation	Algebra, Geometry and Physics	Financial and Actuarial Mathematics
15:30 – 16:00	Krieg	Carqueville	Frey
16:00 – 16:30	Pereverzyev	Wang	Palmowski
16:30 – 17:00	Pillichshammer	Scheimbauer	Pojer
17:00 – 17:30			

Wednesday 20. September

	HS 12.01
09:00 – 10:00	Hairer
10:00 – 10:30	Coffee break
10:30 – 11:30	Sauermann
11:30 – 22:30	Discussions/Lunch/Excursions/Dinner

Thursday 21. September

	HS 12.01	HS 11.01	HS 11.02
09:00 – 10:00	Beiglböck		
10:00 – 10:30	Coffee break		
	Probabilistic Methods in Convexity	Additive Combinatorics	Inverse Problems in Imaging
10:30 – 11:00	Besau	Zhong	Blumenthal
11:00 – 11:30	Kotrbatý	Sauermann	López
11.30 – 12:00	Ludwig	Tringali	Assereto
12:00 – 12:30	Mussnig	Roche-Newton	
12:30 – 14:00	Lunch break		
14:00 – 15:00	Schindler		
15:00 – 15:30	Coffee break		
	Probabilistic Methods in Convexity	Diophantine Analysis and Equidistribution	Inverse Problems in Imaging
15:30 – 16:00	Frühwirth	Hilgart	Felisi
16:00 – 16:30	Juhos	Vukusic	Mauritz
16:30 – 17:00	Sonnleitner	Stadlmann	Morina
17:00 – 17:30		Technau	
17:30 – 18:00	Break		
18:00 – 19:00	Grohs		

	HS 11.03	UR 11.04	SR 11.05
09:00 – 10:00			
10:00 – 10:30	Coffee break		
		Contributed Talks	Set Theory
10:30 – 11:00		Brauchart	Gappo
11:00 – 11:30		Woess	Lietz
11.30 – 12:00		Blatt	Mohammadpour
12:00 – 12:30		Kebiche	Montoya
12:30 – 14:00	Lunch break		
14:00 – 15:00			
15:00 – 15:30	Coffee break		
	PDEs and Mathematical Biology	Contributed Talks	Set Theory
15:30 – 16:00	Brocchieri	Fetz	Moreno
16:00 – 16:30	Merino-Aceituno	D.H. Nguyen	Schembecker
16:30 – 17:00	Reisch	Randrianasolo	Sobota
17:00 – 17:30	Wytrzens	Roberti	
17:30 – 18:00	Break		
18:00 – 19:00			

Friday 22. September

	HS 12.01	HS 11.02	HS 11.03
09:00 – 10:00	Werner		
10:00 – 10:30	Coffee break		
	Probabilistic Methods in Convexity	Inverse Problems in Imaging	PDEs and Mathematical Biology
10:30 – 11:00	Ellmeyer	Kaltenbacher	Bondesan
11:00 – 11:30	Kabluchko	Mejri	St. Müller
11.30 – 12:00	Johnston	Huber	Tran
12:00 – 13:30	Lunch break		
13:30 – 14:00	Award Ceremony		
14:00 – 14:45	Roche-Newton		
14:50 – 15:15	Coffee break		
15:15 – 16:00	S. Müller		
16:05 – 16:50	Smertnig		
16:50 – 17:00	Break		
17:00 – 18:00	ÖMG General Assembly		

	HS 11.01	UR 10.04	SR 11.06
	Teachers' Day		
09:00 – 09:30	Eröffnung		
09:30 – 09:40	Break		
09:40 – 10:30	Weinhandl	Bücherausstellung	Benölken
10:30 – 11:00	Coffee break		
11:00 – 12:00	Sebök	Bücherausstellung	Lerchenberger
12:00 – 12:20	Break		
12:20 – 13:00	Podiums-diskussion		
13:00 – 14:00	Lunch break		
14:00 – 14:50	Fischer, Steinbauer	Bücherausstellung	Karner
14:50 – 15:00	Break		
15:00 – 16:00	Büchter	Bücherausstellung	
16:00 – 18:00	Buffet		

Social Events

Mon Sep 18, 19:00: *Welcome Reception*
Wed Sep 20, 14:15: *Excursions 1, 2*
Wed Sep 20, 15:30: *Excursions 3, 4*
Wed Sep 20, 19:00: *Conference Dinner*

Monday Sep 18 Morning

09:00–09:10 : *Opening Ceremony*

Plenary Talk (Chair K. Fellner, HS 12.01)
09:00–10:00 : Karin Schnass

Additive Combinatorics
(Chair W. Schmid, HS 11.01)
10:30–11:00 : Harald A. Helfgott
11:00–11:30 : Christian Elsholtz
11:30–12:00 : Lena Wurzinger
12:00–12:30 : Norbert Hegyvári

Computational Topology and Geometry
(Chair M. Kerber, HS 11.03)
10:30–11:00 : Kristóf Huszár
11:00–11:30 : Teresa Heiss
11:30–12:00 : Fabian Roll
12:00–12:30 : Patrick Schnider

Stochastic Mass Transport
(Chair G. Pammer, UR 11.04)
10:30–11:00 : Lorenz Riess
11:00–11:30 : Annemarie Grass
11:30–12:00 : Martin Huesmann

Continuous Optimization Methods
(Chair Radu Boţ, HS 12.01)
10:30–11:00 : Matúš Benko
11:00–11:30 : Minh N. Bùi
11:30–12:00 : Yura Malitsky
12:00–12:30 : Hermann Schichl

Mathematical modelling for biomedicine
(Chair F. Caforio, SR 11.05)
10:30–11:00 : Ivan Fumagalli
11:00–11:30 : Karli Gillette
11:30–12:00 : Elena Zappon

Theory and numerics of evolution equations
(Chair M. Thalhammer, HS 11.02)
10:30–11:00 : Franz Achleitner
11:00–11:30 : Klemens Fellner
11:30–12:00 : Heiko Gimperlein

Monday Sep 18 Afternoon

Plenary Talk (Chair G. Haase, HS 12.01)
14:00–15:00 : Robert Scheichl

Additive Combinatorics
(Chair H. Helfgott, HS 11.01)
15:30–16:00 : Anne de Roton
16:00–16:30 : Pierre Bienvenu
16:30–17:00 : Eric Naslund
17:00–17:30 : Péter P. Pach

Computational Topology and Geometry
(Chair B. Vogtenhuber, HS 11.03)
15:30–16:00 : Yannic Maus
16:00–16:30 : Andrei Asinowski
16:30–17:00 : Anna Brötzner
17:00–17:30 : Irene Parada

Stochastic Mass Transport
(Chair M. Beiglböck, UR 11.04)
15:30–16:00 : Sigrid Källblad
16:00–16:30 : Gudmund Pammer
16:30–17:00 : Stefan Schrott

Continuous Optimization Methods
(Chair C. Clason, HS 12.01)
15:30–16:00 : Dang-Khoa Nguyen
16:00–16:30 : Michael Ulbrich
16:30–17:00 : Daniel Wachsmuth

Theory and numerics of evolution equations
(Chair B. Kaltenbacher, HS 11.02)
15:30–16:00 : Torsten Linß
16:00–16:30 : Eduard A. Nigsch
16:30–17:00 : Mechthild Thalhammer

Tuesday Sep 19 Morning

Plenary Talk (Chair S. Thonhauser, HS 12.01)
09:00–10:00 : Hansjörg Albrecher

Financial and Actuarial Mathematics
(Chair S. Thonhauser, SR 11.06)
10:30–11:00 : Simon Hochgerner
11:00–11:30 : Manuel Hasenbichler
11:30–12:00 : Florian Aichinger

High-Dimensional Approximation
(Chair D. Krieg, UR 11.04)
10:30–11:00 : Martin Ehler
11:00–11:30 : Karlheinz Gröchenig
11:30–12:00 : Hans Georg Feichtinger
12:00–12:30 : Michael Feischl

Probabilistic Methods in Convexity
(Chair J. Prochno, HS 12.01)
10:30–11:00 : Leo Brauner
11:00–11:30 : Jonas Knoerr
11:30–12:00 : Oscar Ortega-Moreno

Diophantine analysis and equidistribution
(Chair C. Aistleitner, HS 11.01)
10:30–11:00 : Bence Borda
11:00–11:30 : Volker Ziegler
11:30–12:00 : Agamemnon Zafeiropoulos
12:00–12:30 : Leonhard Summerer

Algebra, Geometry and Physics
(Chair M. Kalck, SR 11.05)
10:30–11:00 : Karin Baur
11:00–11:30 : Charlie Beil
11:30–12:00 : Eleonore Faber

12:00–12:30 : Mikhail Gorsky

PDEs and Mathematical Biology
(Chair K. Fellner, HS 11.03)
10:30–11:30 : Richard Kollár
11:30–12:00 : Katarína Boďová
12:00–12:30 : Emmanuel Schertzer

Tuesday Sep 19 Afternoon

Plenary Talk (Chair C. Clason, HS 12.01)
14:00–15:00 : Angkana Rüland

Inverse Problems in Imaging
(Chair K. Bredies, HS 11.02)
15:30–16:00 : Enis Chenchene
16:00–16:30 : Sören Dittmer
16:30–17:00 : Tobias Wolf
17:00–17:30 : Anna Breger

Financial and Actuarial Mathematics
(Chair S. Thonhauser, SR 11.06)
15:30–16:00 : Rüdiger Frey
16:00–16:30 : Zbigniew Palmowski
16:30–17:00 : Simon Pojer

High-Dimensional Approximation
(Chair M. Ullrich, UR 11.04)
15:30–16:00 : David Krieg
16:00–16:30 : Sergei Pereverzyev
16:30–17:00 : Friedrich Pillichshammer

Diophantine analysis and equidistribution
(Chair J. Thuswaldner, HS 11.01)
15:30–16:00 : Lukas Spiegelhofer
16:00–16:30 : Manfred Madritsch
16:30–17:00 : Lucía Rossi
17:00–17:30 : Henk Bruin

Algebra, Geometry and Physics
(Chair E. Faber, SR 11.05)
15:30–16:00 : Nils Carqueville
16:00–16:30 : Zhengfang Wang
16:30–17:00 : Claudia I. Scheimbauer

Open-source software for discrete mathematics
(Chair B. Hackl, HS 12.01)
15:30–16:00 : Daniel Brosch
16:00–16:30 : Benjamin Hackl
16:30–17:00 : Clemens Heuberger

Contributed Talks (Chair D. Smertnig, HS 11.03)
15:30–16:00 : Daniel Windisch
16:00–16:30 : Aihua Li
16:30–17:00 : Chimere S. Anabanti
17:00–17:30 : Peter Grabner

Wednesday Sep 20 Morning

Plenary Talk (Chair M. Szölgyenyi, HS 12.01)
09:00–10:00 : Martin Hairer

Plenary Talk (Chair M. Kang, HS 12.01)
10:30–11:30 : Lisa Sauermann

Thursday Sep 21 Morning

Plenary Talk (Chair W. Woess, HS 12.01)
09:00–10:00 : Mathias Beiglböck

Additive Combinatorics
(Chair C. Elsholtz, HS 11.01)
10:30–11:00 : Qinghai Zhong
11:00–11:30 : Lisa Sauermann
11:30–12:00 : Salvatore Tringali
12:00–12:30 : Oliver Roche-Newton

Inverse Problems in Imaging
(Chair M. Holler, HS 11.02)
10:30–11:00 : Moritz Blumenthal
11:00–11:30 : Pablo Arratia López
11:30–12:00 : Rodolfo Assereto

Probabilistic Methods in Convexity
(Chair E. Werner, HS 12.01)
10:30–11:00 : Florian Besau
11:00–11:30 : Jan Kotrbatý
11:30–12:00 : Monika Ludwig
12:00–12:30 : Fabian Mussnig

Set Theory (Chair V. Fischer, SR 11.05)
10:30–11:00 : Takehiko Gappo
11:00–11:30 : Andreas Lietz
11:30–12:00 : Rahman Mohammadpour
12:00–12:30 : Diana Carolina Montoya

Contributed Talks (Chair S. Blatt, HS 11.04)
10:30–11:00 : Johann S. Brauchart
11:00–11:30 : Wolfgang Woess
11:30–12:00 : Simon Blatt
12:00–12:30 : Djamel eddine Kebiche

Thursday Sep 21 Afternoon

Plenary Talk (Chair C. Aistleitner, HS 12.01)
14:00–15:00 : Damaris Schindler

Inverse Problems in Imaging
(Chair M. Holler, HS 11.02)
15:30–16:00 : Alessandro Felisi
16:00–16:30 : Marco Mauritz
16:30–17:00 : Erion Morina

Probabilistic Methods in Convexity
(Chair E. Werner, HS 12.01)
15:30–16:00 : Lorenz Frühwirth
16:00–16:30 : Michael L. Juhos
16:30–17:00 : Mathias Sonnleitner

Set Theory (Chair V. Fischer, SR 11.05)
15:30–16:00 : Miguel Moreno
16:00–16:30 : Lukas Schembecker
16:30–17:00 : Damian Sobota

Diophantine analysis and equidistribution
(Chair V. Ziegler, HS 11.01)
15:30–16:00 : Tobias Hilgart
16:00–16:30 : Ingrid Vukusic
16:30–17:00 : Julia Stadlmann
17:00–17:30 : Niclas Technau

PDEs and Mathematical Biology
(Chair C. Soresina, HS 11.03)
15:30–16:00 : Elisabetta Brocchieri
16:00–16:30 : Sara Merino-Aceituno
16:30–17:00 : Cordula Reisch
17:00–17:30 : Claudia Wytrzens

Contributed Talks (Chair T. Fetz, UR 11.04)
15:30–16:00 : Thomas Fetz
16:00–16:30 : Duc-Hoan Nguyen
16:30–17:00 : Tsiry Randrianasolo
17:00–17:30 : Luigi Roberti

Plenary Talk (Chair J. Wallner, HS 12.01)
18:00–19:00 : Philipp Grohs

Friday Sep 22 Morning

Plenary Talk (Chair M. Ludwig, HS 12.01)
09:00–10:00 : Elisabeth M. Werner

Inverse Problems in Imaging
(Chair K. Bredies, HS 11.02)
10:30–11:00 : Barbara Kaltenbacher
11:00–11:30 : Bochra Mejri
11:30–12:00 : Richard Huber

Probabilistic Methods in Convexity
(Chair J. Prochno, HS 12.01)
10:30–11:00 : Simon Ellmeyer
11:00–11:30 : Zakhar Kabluchko
11:30–12:00 : Samuel G. G. Johnston

PDEs and Mathematical Biology
(Chair Quoc Bao Tang, HS 11.03)
10:30–11:00 : Andrea Bondesan
11:00–11:30 : Stefan Müller
11:30–12:00 : Bao-Ngoc Tran

Lehrerinnen- und Lehrertag
(Chair C. Dorner, HS 11.01)
09:40–10:30 : Robert Weinhandl
11:00–12:00 : Kata Sebök

Lehrerinnen- und Lehrertag
(Chair C Krause, SR 11.06)
09:40–10:30 : Ralf Benölken
11:00–12:00 : Evita Lerchenberger

Friday Sep 22 Afternoon

ÖMG Events
13:30–14:00 Award Ceremony
17:00–18:00 General Assembly of the Austrian Mathematical Society

Plenary Talk (Chair R. Tichy, HS 12.01)
14:00–14:45 : Oliver Roche-Newton

Plenary Talk (Chair V. Fischer, HS 12.01)
15:15–16:00 : Sandra Müller

Plenary Talk (Chair A. Geroldinger, HS 12.01)
16:05–16:50 : Daniel Smertnig

Lehrerinnen- und Lehrertag
(Chair C. Dorner, HS 11.01)
14:00–14:50 : Ilse Fischer, Roland Steinbauer

Lehrerinnen- und Lehrertag
(Chair C. Krause, SR 11.06)
14:00–14:50 : Andrea Karner
15:00–16:00 : Andreas Büchter

Dictionary Learning – Sparse Matrix Factorisation

Karin Schnass, Univ. Innsbruck
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Coauthor(s): Simon Ruetz

In this talk we will describe the problem of dictionary learning as the problem of factorising a short fat data matrix into an approximately square matrix, called dictionary, and another short fat but sparse matrix, called the sparse coefficients or codes. We will present simple algorithms for finding such a factorisation, that are based on the optimisation of an energy functional and alternating minimisation. Keeping different variables fixed, leads to different algorithms such as the three golden classics of dictionary learning algorithms – the Method of Optimal Directions (Mod), the Online Dictionary Learning algorithm (Odl) and the K-Singular Value Decomposition (Ksvd).

Finally, assuming that the data matrix follows a sparse model based on a well-behaved generating dictionary, where each of the K dictionary elements may be used with different probability, we show the following: Given enough training signals and starting with a well-behaved initialisation, that is either within distance at most $1/\log K$ to the generating dictionary or has a special structure ensuring that each element of the initialisation dictionary corresponds to exactly one element of the generating dictionary, Mod and Odl converge with geometric convergence rate to the generating dictionary.

The presented results are joint work with Simon Ruetz.

From Quantum Entanglement to Efficient Bayesian Inference and Learning

Robert Scheichl, Heidelberg University
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Coauthor(s): Tiangang Cui, Tim Dodwell, Sergey Dolgov, Colin Fox, Lars Grasedyck, Mikkel Lykkegaard, Grigorios Mingas, Paul Rohrbach

In the last decade, parallel to the rise of data science and machine learning there has also been a vast growth in the interest and contributions from numerical analysis and scientific computing in high-dimensional Bayesian statistics. As in scientific machine learning, the aim is to efficiently combine data and physical models for a better understanding and control of scientific and engineering problems with a quantitative measure of the remaining uncertainty. However, in most scientific and engineering applications the data is sparse and the parametrisations are high-dimensional. On the other hand, we have reached a high level of sophistication in mathematical modelling and in scientific software to simulate such problems numerically. Nevertheless, accurate model runs are expensive and thus a huge amount of current research effort goes into the development of model order reduction techniques and surrogates, including a growing number of deep operator learning approaches. In this talk, I will instead argue for exploiting the vast array of computational tools for high-dimensional approximation and quadrature developed in quantum physics in the last 50 years. I will present two exemplary approaches with their origin in the study of quantum entanglement that use surrogates to significantly accelerate Bayesian computation in high-dimensional

PDE-constrained applications: multilevel delayed acceptance MCMC [Lykkegaard et al, 2023], as well as a measure-transport approach based on low-rank tensor approximations [Cui et al, 2022].

Matrix Distributions and Insurance Risk Models

Hansjörg Albrecher, University of Lausanne
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Abstract: In this talk, some recent developments on matrix distributions and their connection to absorption times of inhomogeneous Markov processes are discussed. We show how and why such constructions are natural tools for the modelling of insurance risks, for both non-life and life insurance applications. A particular emphasis will be given on the higher-dimensional case. We also illustrate how certain extensions to the non-Markovian case involve fractional calculus and lead to matrix Mittag-Leffler distributions, which turn out to be a flexible and parsimonious class for the modelling of large but rare insurance loss events.

On the Fractional Calderón Problem

Angkana Rüland, Univ. Bonn
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Coauthor(s): G. Covi, T. Ghosh, M. Salo, G. Uhlmann

In this talk, I introduce and discuss the fractional Calderón problem as a prototypical nonlocal, elliptic inverse problem in which one seeks to recover unknown conductivities or potentials from indirect measurements. In discussing this problem, firstly, I will show that – due to nonlocality – very strong uniqueness and reconstruction properties hold for the fractional Calderón problem which are open for its local counterpart, the classical Calderón problem. Secondly, I will draw a connection between the local and nonlocal Calderón problems. This is based on joint work with G. Covi, T. Ghosh, M. Salo and G. Uhlmann.

Stochastic Quantisation of Yang-Mills

Martin Hairer, EPFL
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Coauthor(s): Ajay Chandra, Ilya Chevyrev, Hao Shen

We report on recent progress on the problem of building a stochastic process that admits the hypothetical Yang-Mills measure as its invariant measure. One interesting feature of our construction is that it preserves gauge-covariance in the limit even though it is broken by our UV regularisation. This is based on joint work with Ajay Chandra, Ilya Chevyrev, and Hao Shen.

Unit and distinct distances in typical norms

Lisa Sauermann, University of Bonn
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Coauthor(s): Noga Alon and Matija Bucić

Given n points in the plane, how many pairs among these points can have distance exactly 1? More formally, what is the maximum possible number of unit distances among a set of n points in the plane? This problem is a very famous and still largely open problem, called the Erdős unit distance problem. One can also study this problem for other norms on $\mathbb{R}^2$ (or more generally on $\mathbb{R}^d$ for any dimension d) that are different from the Euclidean norm. This direction has been suggested in the 1980s by Ulam and Erdős and attracted a lot of attention over the years. We give an almost tight answer to this question for almost all norms on $\mathbb{R}^d$ (for any given d). Furthermore, for almost all norms on $\mathbb{R}^d$, we prove an asymptotically tight bound for a related problem, the so-called Erdős distinct distances problem. Our proofs combine combinatorial and geometric ideas with algebraic and topological tools. Joint work with Noga Alon and Matija Bucić.

Adapted optimal transport

Mathias Beiglböck, Universität Wien
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Adapted transport theory and adapted Wasserstein distance aim to extend classical transport theory for probability measures to the case of stochastic processes. A fundamental difference is that it takes the temporal flow of information into account.

In contrast to other topologies for stochastic processes, one obtains that probabilistic operations such as the Doob-decomposition, optimal stopping, and stochastic control are continuous with respect to the adapted Wasserstein distance. Moreover, adapted transport enjoys desirable properties similar to classical theory. E.g. it turns the set of stochastic processes into a geodesic space, isometric to a classical Wasserstein space and allows for Talagrand-type inequalities as recently established by Föllmer.

Density of rational points near manifolds

Damaris Schindler, Goettingen University
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Coauthor(s): Rajula Srivastava, Niclas Technau, Shuntaro Yamagishi

Given a bounded submanifold $\mathcal{M}$ in $\mathbb{R}^n$, how many rational points with common bounded denominator are there in a small thickening of $\mathcal{M}$? Under what conditions can we count them asymptotically as the size of the denominator goes to infinity? We discuss some recent work in this direction and arithmetic applications such as Serre's dimension growth conjecture.

Die Mathematik hinter künstlicher Intelligenz

Philipp Grohs, Univ. Wien
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Die Künstliche Intelligenz und Maschinelles Lernen haben in den letzten Jahrzehnten unglauliche Fortschritte erfahren, sei es in der Bilderkennung, der Sprachverarbeitung oder der personalisierten Werbung. Auch in der Wissenschaft konnten dank dieser Fortschritte in den letzten Jahren bedeutende Durchbrüche erzielt werden, zum Beispiel in der Simulation der Proteinfaltung. In diesem Vortrag werden wir die Rolle der Mathematik in der Künstlichen Intelligenz erörtern, sowie einige grundlegenden mathematischen Resultate besprechen.

Convex bodies – barely floating

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In analogy to the classical surface area, a notion of affine surface area – invariant under affine transformations – has been defined. The isoperimetric inequality states that the usual surface area is minimized for a Euclidean ball. Affine isoperimetric inequality states that affine surface area is maximized for ellipsoids.

Due to this inequality and its many other remarkable properties, the affine surface area finds applications in many areas of mathematics and applied mathematics. This has led to intense research in recent years and numerous new directions have been developed.

We will discuss some of them and we will show how affine surface area is related to a geometric object, that is interesting in its own right, the floating body.

Elementary methods for the sum-product problem

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The sum-product phenomenon captures the idea that additive and multiplicative structures cannot coexist in a finite set. In this introductory talk, I will describe this problem, mentioning some things that we do know, and many more that we do not. The talk will emphasise recent progress that can be made using elementary techniques, and in particular the "squeezing" method.

Independence Phenomena in Mathematics: Current Obstacles and Scenarios for Solutions

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The standard axioms of set theory, the Zermelo-Fraenkel axioms (ZFC), do not suffice to answer all questions in mathematics. While this follows abstractly from Kurt Gödel's famous incompleteness theorems, we nowadays know numerous concrete examples for such questions. A large number of problems in set theory, for example, regularity properties such as Lebesgue measurability and the Baire property are not decided - for even rather simple (for example, projective) sets of reals - by ZFC. Even many problems outside of set theory have been showed to be unsolvable, meaning neither their truth nor their failure can be proven from ZFC. A major part of set theory is devoted to attacking this problem by studying various extensions of ZFC and their properties. I will outline some of these extensions and explain current obstacles in understanding their impact on the set theoretical universe together with recent progress on these questions and future scenarios. This work is related to the overall goal to identify the "right" axioms for mathematics.

On factorizations in noncommutative rings

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Over the last decades, a comprehensive factorization theory has been developed in commutative domains and cancellative monoids. In large classes of rings, this theory yields satisfying answers to questions about uniqueness and non-uniqueness of factorizations, and it provides a powerful machinery to study phenomena of non-unique factorizations. At its algebraic core, it relates arithmetical properties of rings and monoids to algebraic invariants. In the last years part of this theory has been successfully extended to noncommutative settings. In the talk I will survey some of the key results and phenomena of factorizations in non-commutative domains and prime rings, and put them in relation to the (more well-known) commutative situation. The aim is to convey an understanding for key properties that appear due to the noncommutativity, and to outline the current state of the art as well as open problems.

New growth estimates and diameter bounds for linear algebraic groups

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Babai's conjecture states that, for any finite simple non-abelian group G, the diameter of G is bounded by $(\log |G|)^C$, where C is a constant. A series of results since (Helfgott, 2005–2008) has given us cases of Babai's conjecture for different families of groups. However, for linear algebraic groups G, the dependence of C on the rank of G has been very poor (exponential-tower).

(a) How much can one improve the bound, while keeping the general inductive idea in Larsen-Pink (1998–2011) (which they used to classify subgroups in SL_n; generalized for use in this context by Breuillard-Green-Tao, 2010–2011) or in (Pyber-Szabo, 2010–2016)?

(b) Can one change the strategy and prove a yet better bound?

On (a), we will show the main ideas that have allowed us to make C exponential on the rank, while keeping an inductive argument that resembles those used before. (Actually keeping the Larsen-Pink inductive process gives a worse but still exponential bound, if combined with our other improvements.) We will also discuss (b): changing the strategy – from general dimensional bounds as in Larsen-Pink – we have been able to make C polynomial on the rank.

Improving high dimensional constructions, for caps and progression-free sets, by studying medium dimensions

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We study point sets in $\mathbb{F}_p^n$, where p is prime, when n tends to infinity, especially with the constraint that they do not contain any arithmetic progression of length k, or that there are no three collinear points (so called caps).

We present a new method which transfers the problem of avoiding, for example, 3-progressions mod p in the large dimension n to avoiding more or less 4-progressions mod $m(p)$, with some milder constraints, in a much smaller dimension. In this way we improve lower bound constructions by Edel and Bierbrauer, and Lin and Wolf, and more recent ones by the speaker with Lipnik and Klahn.

In particular, we prove the existence of caps in $\mathbb{F}_5^n$, where the "density" of points is larger than the currently known "density" in $\mathbb{F}_3^n$. Here "density" is measured by an admissible coefficent $\mu(p)$ with the size of caps $|C_p^n| \gg p^{\mu(p)\,n}$.

Sumsets in the set of squares

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We discuss results pertaining to sumsets $A + B \subseteq S \cap [1, N]$ contained in the set of squares bounded by some positive integer N. Sumsets of this type have been studied by various authors; particularly, Gyarmati [1, Theorem 9] showed that if $|A| \geq 9 \log N$, then $|B| \leq 8 \log N$. We prove the following new result:

Theorem. *Let m be a positive integer, or a function $m = m(N)$ taking values in the positive integers. Then there are constants C_1, C_2 (independent of m) such that, if*

$$|A| \geq C_1 m^2 \log N,$$

then

$$|B| \leq C_2 m (\log N)^{1/m}.$$

The proof uses sumsets in quadratic residues and sieve methods. The extension became possible as we also employ a high moment estimate of character sums.

[1] K. Gyarmati, On a problem of Diophantus, Acta Arithmetica 97 (2001), 53–65.

On the distribution of subset sums of certain sets in $\mathbb{Z}_p^2$

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A given subset A of natural numbers is said to be complete if every element of $\mathbb{N}$ is the sum of distinct terms taken from A. This topic is strongly connected to the knapsack problem which is known to be NP complete.

Interestingly if A and B are complete sequences then $A \times B$ is not necessarily complete in $\mathbb{N}^2$. In this paper we consider a modular version of this problem, motivated by the communication complexity problem. Some cases are also discussed in the integer grid.

Small iterated sumsets of integers

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Iterated sums of arithmetic progressions grow linearly with the number of summands and this is the smallest growth one can expect. Precisely, if A is a finite subset of integers, then for any positive integer k, we have $|kA| \geq k(|A|-1)+1$ and the equality holds if and only if A is an arithmetic progression.
In this talk, we shall give a structural description of sets of integers for which $|kA|$ grows less than quadratically in k. Precisely, we shall describe sets A of integers for which

$$|kA| < \frac{k(k+1)}{2}|A| - (k+1)$$

for some integer $k \geq 2$.
The proof relies on modular reduction and on a theorem of Grynkiewicz [1] improving on the Kemperman structural theorem [2] which describes subsets of an abelian group with small sumset.

[1] D. J. Grynkiewicz. Iterated Sumsets and Subsequence Sums, *J. Comb. Theory* Ser. A **160** (2018), 136–167.
[2] J. H. B. Kemperman. On small sumsets in an abelian group, *Acta Math.* **103** (1960), 63–88.

Additive decomposability in multiplicative number theory

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Given two subsets $\mathcal{A}, \mathcal{B}$ of $\mathbb{Z}$, their sum set $\mathcal{A}+\mathcal{B}$ is the set $\{a+b : (a,b) \in \mathcal{A}\times\mathcal{B}\}$. A set $\mathcal{C} \subset \mathbb{N}$ is called *additively decomposable* (resp. *asymptotically additively decomposable*) if there exist sets $\mathcal{A}, \mathcal{B} \subset \mathbb{N}$ of cardinality at least two each such that $\mathcal{C} = \mathcal{A}+\mathcal{B}$ (resp. $\mathcal{C} \sim \mathcal{A}+\mathcal{B}$). Similarly, a set $\mathcal{C} \subset \mathbb{N}$ is called *additively $\mathbb{Z}$-decomposable* (resp *asymptotically additively $\mathbb{Z}$-decomposable*) if there exist sets $\mathcal{A}, \mathcal{B} \subset \mathbb{Z}$ of cardinality at least two each such that $\mathcal{C}_{\mathbb{Z}} = \mathcal{A}+\mathcal{B}$ (resp. $\mathcal{C}_{\mathbb{Z}} \sim \mathcal{A}+\mathcal{B}$), where $\mathcal{C}_{\mathbb{Z}} = \mathcal{C} \cup -\mathcal{C}$.

We review results about additive decomposability of sets occurring in multiplicative number theory. This includes ongoing joint work with J. Konieczny and O. Klurman.

Lower Bounds for the Shannon Capacity of Hypergraphs

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In this talk paper we develop the theory of the Shannon Capacity of hypergraphs. We provide a new recursive approach for lower bounding hypergraph capacity problems, which allows us to improve the best existing lower bounds for the capset problem [1] and the Erdös-Szemerédi-Sunflower problem [2]. Previous lower bounding methods rely on the product of small examples, whereas our approach can solve capacity problems, and as a proof of concept, we solve a hypergraph capacity problem raised by Edel [3].

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[3] Y. Edel, Extensions of generalized product caps. *Des. Codes Cryptogr.* **31** (2004), 5–14.

On sumsets of nonbases of maximum size

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Let G be a finite abelian group. A nonempty subset A in G is called a basis of order h if $hA = G$; when $hA \neq G$, it is called a nonbasis of order h. Our interest is in all possible sizes of hA when A is a nonbasis of order h in G of maximum size; we provide the complete answer when $h = 2$ or $h = 3$.

Sequences over Groups: The Isomorphism Problem and the Characterization Problem

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Let $(G, \cdot, 1_G)$ be a group. A sequence S over G is a finite unordered sequence of terms from G, where repetition is allowed. We say S is a product-one sequence if its terms can be ordered such that their product equals the identity element 1_G of G. We denote by $\mathcal{B}(G)$ the set of all product-one sequences over G, which is a monoid with the concantination of sequences as the operation.

Suppose G is abelian. We usually use additive notation and hence $G = (G, +, 0)$. Let $S = g_1 \cdot \ldots \cdot g_\ell$ be a sequence over G. We say S is a zero-sum sequence if $g_1 + \ldots + g_\ell = 0$ and a plus-minus weighted zero-sum sequence if there are $\varepsilon_1, \ldots, \varepsilon_\ell \in \{-1, 1\}$ such that $\varepsilon_1 g_1 + \ldots + \varepsilon_\ell g_\ell = 0$. We denote by $\mathcal{B}(G)$ the monoid of all zero-sum sequences over G and by $\mathcal{B}_\pm(G)$ the monoid of all plus-minus weighted zero-sum sequences over G.

For those three classes of monoids of sequences (monoids of product-one sequences, zero-sum sequences, and plus-minus weighted zero-sum sequences), we will consider the following problems.

The Isomorphism Problem. Let G_1 and G_2 be groups and let $\mathsf{B}(G_1)$ and $\mathsf{B}(G_2)$ be monoids of sequences, as introduced above. Suppose that $\mathsf{B}(G_1)$ and $\mathsf{B}(G_2)$ are isomorphic. Are the groups G_1 and G_2 isomorphic?

The Characterization Problem. Let G_1 and G_2 be finite groups whose Davenport constants are at least four, and let $\mathsf{B}(G_1)$ and $\mathsf{B}(G_2)$ be monoids of sequences, as introduced above. Suppose that their systems of sets of lengths $\mathcal{L}\big(\mathsf{B}(G_1)\big)$ and $\mathcal{L}\big(\mathsf{B}(G_2)\big)$ coincide. Are the groups G_1 and G_2 isomorphic?

We discuss the state of the art on these problems, with respect to the three classes of monoids of sequences.

[1] F. Fabsits, A. Geroldinger, A. Reinhart, and Q. Zhong, *On monoids of plus-minus weighted zero-sum sequences: The isomorphism problem and the characterization problem*, https://arxiv.org/abs/2304.14777.

[2] A. Geroldinger and J.S. Oh, *On the isomorphism problem of monoids of product-one sequences*, https://arxiv.org/abs/2304.01459.

[3] A. Geroldinger and W.A. Schmid, *A characterization of class groups via sets of lengths*, J. Korean Math. Soc. **56** (2019), 869 – 915.

[4] Q. Zhong, *A characterization of finite abelian groups via sets of lengths in transfer Krull monoids*, Commun. Algebra **46** (2018), 4021 – 4041.

[5] ______, *Sets of minimal distances and characterizations of class groups of Krull monoids*, Ramanujan J. **45** (2018), 719 – 737.

On the Erdős-Ginzburg-Ziv Problem in large dimension

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The Erdős-Ginzburg-Ziv Problem is a classical, but still wide open problem. Given positive integers m and n, the problem asks about the smallest number s such that among any s points in the integer lattice $\mathbb{Z}^n$, one can find m points whose centroid is again a lattice point. Equivalently, one can phrase the problem as asking about the smallest number s, such that any sequence of length s with entries in $\mathbb{Z}_m^n$ has a subsequence of length m whose entries sum to zero in $\mathbb{Z}_m^n$. For fixed dimension n, Alon and Dubiner proved that the answer grows linearly with m. In this talk, we discuss new bounds for the opposite case, where the number m is fixed and the dimension n is large. Joint work with Dmitrii Zakharov.

On the automorphism group of a power monoid

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Let H be a (multiplicatively written) monoid. Equipped with the operation of setwise multiplication induced by H, the non-empty finite subsets of H containing the identity 1_H themselves form a monoid, called the reduced (finitary) power monoid of H and denoted by $\mathcal{P}_{\mathrm{fin},1}(H)$. Motivated by an old problem posed by Tamura and Shafer [2] in the late 1960s and a conjecture by Bienvenu and Geroldinger [1], we address the problem of describing the group of monoid automorphisms of $\mathcal{P}_{\mathrm{fin},1}(H)$ and determine it in the fundamental case where H is (isomorphic to) the additive monoid of non-negative integers [3, 4].

[1] P.-Y. Bienvenu and A. Geroldinger, *On algebraic properties of power monoids of numerical monoids*, to appear in Israel J. Math. (https://arxiv.org/abs/2205.00982).

[2] T. Tamura and J. Shafer, *Power semigroups*, Mathematica Japonicae **12** (1967), 25–32; Errata, *ibid.* **29** (1984), No. 4, 679.

[3] S. Tringali and W. Yan, *A conjecture of Bienvenu and Geroldinger on power monoids*, manuscript.

[4] S. Tringali and W. Yan, *On power monoids and their automorphisms*, manuscript.

The Elekes-Szabó Theorem and applications

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The Elekes-Szabó Theorem gives an upper bound for the intersection between a Cartesian product and the zero set of a sufficiently complicated polynomial. This theorem was motivated by applications for some beautiful problems in discrete geometry related to the Erdős distinct distances problem. This talk will introduce the Elekes-Szabó Theorem and discuss some of these geometric applications, as well as some more recent applications in the context of the sum-product problem.

Graph parameters in low-dimensional topology

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Over the past decade, parameterized algorithms have been gaining prominence in low-dimensional topology. It has been shown that several computationally hard problems about triangulated 3-manifolds admit efficient algorithmic solutions, whenever the dual graph of the input triangulation has small treewidth. Moreover, many of these algorithms have been implemented, thereby providing practical tools for researchers in topology [1]. Finding such "thin" triangulations is therefore an important task, however, it can be limited by topological properties of the underlying manifold.

In this talk I present recent results that connect the treewidth and other graph parameters associated with triangulations to classical topological invariants of 3-manifolds in a quantitative way. In particular, we show that, for certain 3-manifolds every triangulation must have dual graph of large treewidth [2, 3].

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[3] K. Huszár, J. Spreer, and U. Wagner. On the treewidth of triangulated 3-manifolds. *J. Comput. Geom.*, 10(2):70–98, 2019. https://doi.org/10.20382/jogc.v10i2a5.

Persistent Homology of Periodic Filtrations: The Periodic Merge Tree

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Persistent homology is well-defined and well studied for tame filtrations, for example various ones arising from finite point sets. However, periodic filtrations — for example used to study periodic point sets, like the atom positions of a crystal — are not tame, because there are infinitely many periodic copies of a homology class appearing at the same filtration value. We therefore extend the definition of persistent homology to periodic filtrations, which is a surprisingly difficult endeavor. We succeeded so far in homological dimension zero, by defining and computing a periodic merge tree. In contrast to related work, we quantify how fast the multiplicities of persistence pairs tend to infinity with increasing window size, in a way that is stable under perturbations and invariant under different finite representations of the infinite periodic filtration. This project is still ongoing research, but I'll explain what we already know and what we don't know yet.

Connecting Morse theory and persistent homology of geometric complexes

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I will discuss some recent results on the interplay between discrete Morse theory and persistent homology, in the setting of geometric complexes. This concerns constructions like Čech, Delaunay, and Wrap complexes, which are fundamental constructions in topological data analysis. In particular, I will explain how one can relate optimal representative cycles for persistent homology to the industry-tested Wrap surface reconstruction algorithm.

Topological universality and computational hardness

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In 1988, Mnëv proved his famous universality theorem, showing that realization spaces of order types can be arbitrarily complicated (in some well-defined sense). His proof also implies that the computational problem of order type realizability is $\exists\mathbb{R}$-complete, so likely even harder than NP-hard. Mnëv's result sparked two lines of research, one about topological properties of certain realization spaces, and one about the computational complexity of decision problems. Interestingly, for many problems that admit some universality theorem in the style of Mnëv, it could also be shown that the corresponding decision problem of realizability is computationally hard, or vice versa. In this talk I will discuss several such results for different types of topological universality and computational hardness.

A new proof of Brooks' Theorem for Graph Coloring

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Brooks' Theorem states that any graph that is neither a clique nor an odd cycle can be colored with Δ colors where Δ is the maximum degree of the graph.

In this talk we present distributed message passing algorithms for the problem when $\Delta \geq 3$. For the case of sufficiently large Δ (a constant $\ll 1000$ is enough) one of these algorithms can be seen as an efficient reduction to a constant number of $deg+1$-list coloring instances. In the the latter problem each node of a graph has to output a color from a private list of colors whose size exceeds its degree. The problem is solvable by a simple greedy algorithm. The reduction together with that greedy algorithm can be used to prove Brooks' theorem and does not require any other deep graph-theoretic results.

The talk is mainly based on the paper *Fast Distributed Brooks' Theorem* by Fischer, Halldorsson, and Maus from SODA 2023.

Permutations and rectangulations: posets and mesh patterns

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A *rectangulation* is a partition of an axes-aligned rectangle into smaller rectangles. The study of rectangulations in computational geometry is motivated, in particular, by their role in geometric algorithms, applications in visualization of scientific data, and by the fact that they constitute a basic model for integrated circuit layout.

In order to regard rectangulations as combinatorial objects, one has to consider some equivalence relation, formalizing the idea of rectangulations "having the same structure". There are two natural ways to do this: the *weak equivalence* which preserves rectangle–segment adjacencies, and the *strong equivalence* which preserves rectangle–rectangle adjacencies.

The structural and enumerative aspects of rectangulations are typically studied via mappings and bijections between rectangulations and permutation classes defined by pattern avoidance [1, 2, 3]. Our first result is a general framework that unifies and generalizes many earlier results. In particular we show that posets defined by geometric relations between rectangles of a rectangulation play a crucial role for understanding the structure of rectangulations: all the permutations that arise in the permutation-rectangulation mappings, are linear extensions of these posets, for both kinds of equivalence.

Our second result concerns rectangulations with a simple recursive structure — *guillotine* rectangulations. We present two *mesh patterns* whose avoidance in a permutation is equivalent to being the corresponding rectangulation guillotine — under all known permutation-rectangulation mappings. On the one hand, this is another manifestation of the generality of our approach. On the other hand, this yields the first known representation of "strong" guillotine rectangulations by a permutation class.

MSC: 05A15, 05B45, 52C20

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[2] E. Meehan. The Hopf algebra of generic rectangulations. Preprint, https://arxiv.org/abs/1903.09874

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The Art Gallery Problem and Its Variations

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The art gallery problem is one of the best known problems in computational geometry. Given the layout of a modern art gallery as a simple polygon, the aim is to minimize the number of guards that are necessary to see all of the gallery's interior. For a polygon with n vertices, Fisk [2] proved that $\lfloor \frac{n}{3} \rfloor$ guards are always sufficient, and this bound is tight. However, the decision problem, meaning answering the question whether a given polygon can be guarded with k guards, was shown to be NP-hard [1, 3].

Nowadays, new technologies are used to monitor buildings or cover areas with wireless network signal. These advances have led to numerous variations and generalizations of the art gallery problem. In this talk I will present some alternative types of guards and notions of visibility, and give an overview of various results in connection with different types of domains.

[1] Alok Aggarwal, The art gallery theorem: its variations, applications and algorithmic aspects. *Ph.D. Dissertation, Johns Hopkins University* (1984)

[2] S. Fisk, A short proof of Chvátal's Watchman Theorem. *J. Comb. Theory, Ser. B* **24** (1978), 347

[3] D. Lee and A. Lin, Computational complexity of art gallery problems. *IEEE Transactions on Information Theory* **32** (1986), 276-282

Geometric algorithms to reconfigure robots

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Modular self-reconfigurable robots consist of individual units that can move and connect to one another to form a larger, more complex shape. A central problem that arises is how to efficiently reconfigure these robots from one shape to another while maintaining connectivity.

We will explore efficient algorithms and the computational complexity of the reconfiguration problem for the most fundamental lattice-based models of modular robots. Specifically, we will examine how the reconfiguration problem differs depending on the lattice and movement capabilities of the units. We will discuss efficient algorithms for universal reconfiguration in some models using geometric and graph algorithms, while in other models the problem is PSPACE-complete, which implies that it is computationally intractable. For those cases, we discuss simple conditions that allow for efficient reconfiguration.

The geometry of financial institutions – Wasserstein clustering of financial data

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The increasing availability of granular and big data on various objects of interest has made it necessary to develop methods for condensing this information into a representative and intelligible map. Financial regulation is a field that exemplifies this need, as regulators require diverse and often highly granular data from financial institutions to monitor and assess their activities. However, processing and analyzing such data can be a daunting task, especially given the challenges of dealing with missing values and identifying clusters based on specific features. To address these challenges, we propose a variant of Lloyd's algorithm that applies to probability distributions and uses generalized Wasserstein barycenters to construct a metric space which represents given data on various objects in condensed form. By applying our method to the financial regulation context, we demonstrate its usefulness in dealing with the specific challenges faced by regulators in this domain.

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Optimal Stopping Characterizations of Solutions to the Skorokhod Embedding Problem and their Applications to Robust Mathematical Finance

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The Skorokhod Embedding Problem (SEP) is to represent a given probability measure as a Brownian motion stopped at a specific stopping time. It is a classic problem in probability theory but also has numerous applications, most notably in robust mathematical finance. There are many different solutions to the SEP known today, all featuring different additional optimality properties. However, most of these solutions are given via existence results and still only a few computable solutions are known. We present a simple probabilistic argument to represent two of the most well known solutions, namely the Root and Rost solutions, as optimizers of respective optimal stopping problems. Such a representation allows for numerical computation of the solution. Moreover, we extend the argument to treat the multi-martingale case which opens the possibility to numerically compute robust bounds on variance options given option market data quoted for multiple maturities.

Recent progress on the optimal matching problem

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The optimal matching problem is one of the classical optimization problems in probability. There has been a revived interest in the last years due to a new PDE approach proposed in the physics literature. In this talk, we will explain this ansatz, why it is justified, and which results it allows us to obtain so far.

Adapted Wasserstein distance between the laws of SDEs

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We consider an adapted optimal transport problem between the laws of Markovian stochastic differential equations (SDEs) and establish optimality of the so-called synchronous coupling between the given laws. The proof of this result is based on time-discretisation methods and reveals an interesting connection between the synchronous coupling and the celebrated discrete-time Knothe–Rosenblatt rearrangement. We also provide a related result on equality of various topologies when restricted to certain laws of continuous-time stochastic processes. The result is of relevance for the study of stability with respect to model specification in mathematical finance.

Stretched Brownian Motion: Analysis of a Fixed-Point Scheme

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The fitting problem is a classical challenge in mathematical finance about finding martingales that satisfy specific marginal constraints. Building on the Bass solution to the Skorokhod embedding problem and optimal transport, Backhoff, Beiglböck, Huesmann, and Källblad [1] propose a solution for the two-marginal problem: the stretched Brownian motion. Notably rich in structure, this process is an Ito diffusion and a continuous, strong Markov martingale.

Following a similar approach, Conze and Henry-Larbordère [2] recently introduced a novel local volatility model. This model, rooted in an extension of the Bass construction, is efficiently computable through a fixed-point scheme. In our presentation, we reveal the fixed-point scheme's intricate connection to the stretched Brownian motion and analyse its convergence.

[1] J. Backhoff, M. Beiglböck, M. Huesmann and S. Källblad, Martingale Benamou–Brenier: A probabilistic perspective. *Ann. Probab.*, **48**(5), (2020), 2258–2289.

[2] A. Conze and P. Henry-Labordère. Bass Construction with Multi-Marginals: Lightspeed Computation in a New Local Volatility Model. *SSRN*, (2021).

The Wasserstein space of stochastic processes in continuous time

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Researchers from different areas have independently defined extensions of the usual weak topology between laws of stochastic processes. This includes Aldous' extended weak convergence, Hellwig's information topology and convergence in adapted distribution in the sense of Hoover-Keisler. We show that on the set of continuous processes with canonical filtration these topologies coincide and are metrized by a suitable *adapted Wasserstein distance* $\mathcal{AW}$. Moreover we show that the resulting topology is the weakest topology that guarantees continuity of optimal stopping.

While the set of processes with natural filtration is not complete, we establish that its completion consists precisely in the space processes with filtration FP.

We also observe that $(FP, \mathcal{AW})$ exhibts several desirable properties. Specifically, $(FP, \mathcal{AW})$ is Polish, martingales form a closed subset and approximation results like Donsker's theorem extend to $\mathcal{AW}$.

A Hybrid Proximal Generalized Conditional Gradient method and application to total variation parameter learning

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We present the Hybrid Proximal Conditional Gradient method (HPGCG), a new method for solving optimization problems involving the sum of two proper, convex, lower semicontinuous functions, one of which has a Lipschitz continuous gradient. The proposed method has a hybrid nature that combines the advantages of the classical forward–backward and the generalized conditional gradient methods. Indeed, it allows for low cost-per-iteration of generalized conditional gradient-type methods while enabling a broader range of applicability and stronger convergence guarantees in the spirit of forward–backward schemes. We discuss convergence results, and demonstrate that HPGCG can efficiently solve a novel approach to the regularization parameter learning problem associated with total-variation-based denoising according to the Rudin–Osher–Fatemi model, which cannot be easily addressed with other existing methods.

SELTO: Sample-Efficient Learned Topology Optimization

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This talk will present a sample-efficient deep learning strategy for topology optimiza- tion that includes physics-based preprocessing and equivariant networks. We will analyze how different components of our deep learning pipeline affect the required training sam- ples via a large-scale comparison. Our results demonstrate that incorporating physical concepts yields significant improvements in terms of sample efficiency and the physi- cal correctness of predictions. Furthermore, we will discuss two topology optimization datasets we have published, which contain problems and corresponding ground truth solutions.

Coincidence of the Multiscale Hierarchical Decomposition Method and generalized Tikhonov regularization

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The Multiscale Hierarchical Decomposition Method (MHDM) is a popular method originating from mathematical imaging. In its original context, it is very well suited to recover approximations with fine details from blurred and noise-corrupted images. The main idea is to decompose an image into levels of information at different scales by solving ROF minimization problems with the residual of the previous step as input. We consider the algorithm for more general penalty terms than the total variation. In particular, we also consider non-convex functionals. In this talk, we focus on comparing the MHDM to generalized Tikhonov regularization with seminorm regularizers. We propose a necessary and sufficient condition for the iterates of the MHDM to coincide with the minimizers of the Tikhonov regularization. We illustrate the result on finite-dimensional ℓ^1 regularization and one-dimensional total variation denoising.

IQA for the evaluation of novel algorithms in medical imaging

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Assessing digital image quality (IQ) is of high importance in numerous imaging research areas, such as image acquisition, reconstruction or processing. Automated evaluation is needed since manual evaluation is too time-consuming and expensive for huge data sets and, furthermore, may be biased or introduce inconsistencies. The choice of an adequate objective IQ measure is very important, determining the outcome of the examination of a novel method or even controlling the development of the method itself. When evaluating novel imaging algorithms in a full reference (FR) setting (e.g. reconstruction with phantom data), the problem translates into comparing two images, being especially important for the development of appropriate algorithms in the area of medical imaging. Where specialised medical experts know what to look for, scientists/engineers from a non-medical background do not have this expertise and rely on automated quantification. Most commonly used FR-IQ methods have been developed and optimized for natural images and cannot be translated directly to medical imaging tasks. Nevertheless, they are still used to validate the effectiveness of novel medical imaging algorithms. In this talk I will give a short introduction to IQ assessment and provide examples of failure when applying standard FR-IQ measures to varied medical imaging tasks. Moreover, I will discuss alternatives and suggestions for future improvements.

Self-Supervised Learning for Non-Linear Inverse Problems in MRI

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Magnetic resonance image reconstruction is usually formulated as a linear inverse problem where the measurement of k-space data is modelled by the linear SENSE operator $A = \mathcal{PFC}$ consisting of a pointwise multiplication of the image with the $\mathcal{C}$oil sensitivity maps, the $\mathcal{F}$ourrier transform, and the sampling $\mathcal{P}$attern. In recent years, physics-based reconstruction networks [1] which are motivated by classical optimization algorithms and learned regularization terms have improved the image quality of reconstructions from undersampled data. Despite the success of these networks, they have one major problem, i.e. they require a ground truth reconstruction for training which is often not available for example due to movement.

In this talk, we consider the reconstruction of highly undersampled cardiac real-time data which is obviously affected by motion. We estimate the coil sensitivity maps as part of the reconstruction by formulating a non-linear – in fact bilinear – inverse problem. A classical reconstruction method is RT-NLINV [2] using the iteratively regularized Gauss-Newton method (IRGNM) with temporal regularization. Motivated by RT-NLINV, we unroll the IRGNM and replace the temporal regularization by neural network based denoisers. The resulting network is termed RT-NLINV-Net. To train RT-NLINV-Net, we use the self-supervision via data undersampling (SSDU) method [3]. The undersampled k-space data is split randomly into two subsets from which one is used for reconstruction and the other is used as reference data. RT-NLINV-Net shows improved reconstruction quality compared to RT-NLINV.

[1] K. Hammernik et al. Learning a variational network for reconstruction of accelerated MRI data. *Magn. Reson. Med.* **79** (2018) 3055–3071

[2] M. Uecker et al. Real-time MRI at a resolution of 20 ms. *NMR. Biomed.* **23** (2010) 986–994

[3] B. Yaman et al. Self-supervised learning of physics-guided reconstruction neural networks without fully sampled reference data. *Magn. Reson. Med.* **84** (2020) 3172–3191

WarpPINN: Image Registration with Physics-Informed Neural Networks for Cardiac Imaging.

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In this talk, I will consider Physics-Informed Neural Networks (PINNs) to solve Inverse Problems with physical constraints. The concrete application here is in cardiac imaging, where the goal is to determine the deformation field of the heart during the cardiac cycle from MRI images, information that can then be used to asses cardiac diseases. To this end, we propose *WarpPINN*, a physics-informed neural network designed to solve image registration problems with a hyper-elastic regularizer. The network aims to approximate the deformation field, thus, it takes as input a point x in the domain of the reference frame and some time t, and outputs the new position of the point at the time t. The physics-informed part comes from the nearly incompressible behavior of the heart during the cardiac cycle, which we impose by constraining the determinant of the jacobian of the transformation to be close to 1.

[1] P. Arratia, WarpPINN: Cine-MR image registration with physics-informed neural networks, preprint, https://arxiv.org/abs/2211.12549

An Optimal Transport-based approach to Total-Variation regularization for the Diffusion MRI problem

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Diffusion Magnetic Resonance Imaging (dMRI) is a non-invasive imaging technique that draws structural information from the interaction between water molecules and biological tissues. Common ways of tackling the derived inverse problem include, among others, Diffusion Tensor Imaging (DTI), High Angular Resolution Diffusion Imaging (HARDI) and Diffusion Spectrum Imaging (DSI). However, these methods are structurally unable to recover the full diffusion distribution, only providing partial information about particle displacement. In our work, we introduce a Total-Variation (TV) regularization defined from an optimal transport perspective using 1-Wasserstein distances. Such a formulation produces a variational problem that can be handled by well-known algorithms enjoying good convergence properties, such as the primal-dual proximal method by Chambolle and Pock. It allows for the reconstruction of the complete diffusion spectrum from measured undersampled k/q space data.

Compressed sensing for the sparse Radon transform

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Compressed sensing allows for the recovery of sparse signals from few measurements, whose number is proportional, up to logarithmic factors, to the sparsity of the unknown signal. The classical theory mostly considers either random linear measurements or subsampled isometries. In particular, the case with the subsampled Fourier transform finds applications to undersampled magnetic resonance imaging. In this talk, I will show how the theory of compressed sensing can also be rigorously applied to the sparse Radon transform, in which only a finite number of angles are considered. In the case when the unknown signal is s-sparse with respect to an orthonormal basis of compactly supported wavelets, we prove stable recovery from a finite number of angles $\theta_1, \ldots, \theta_m$ under the condition $m \geq s$, up to logarithmic factors. One of the main novelties consists in the fact that the Radon transform is associated to an ill-posed inverse problem, and the result follows from a new theory of compressed sensing for abstract infinite-dimensional ill-posed problems.

[1] G. S. Alberti, A. Felisi, M. Santacesaria, S. I. Trapasso, Compressed sensing for inverse problems and the sample complexity of the sparse Radon transform, preprint, https://arxiv.org/abs/2302.03577, 2023

Exact Reconstrution and Super Resolution in a 2D PET-Model

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In the paper *Exact reconstruction using Beurling minimal extrapolation* [1] de Castro and Gamboa showed that point sources can be reconstructed exactly from incomplete measurements (see also [2], [3] for similar works). In this talk, we will be looking at a simple two dimensional Positron Emission Tomography model where the inexact measurements are due to detectors having a finite size λ, i.e. locations of photon detections can't be determined exactly. We are interested in whether such inexact measurements are sufficient for reconstructing point sources exactly. Even though it turns out that this is not possible, the model still possesses a super resolution property: A single point source can be reconstructed with asymptotic accuracy λ^4.
At the end of the talk we will give an outlook for the case of noisy measurements and multiple point sources.

[1] Y. de Castro, F. Gamboa. Exact reconstruction using Beurling minimal extrapolation *J. Math. Anal. Appl.* **395** (2012), 336-354

[2] Q. Denoyelle, V. Duval, G. Peyré. Support Recovery for Sparse Deconvolution of Positive Measures. *preprint* (2016).

[3] E. Candès, F. Granda. Towards a Mathematical Theory of Super-resolution *Comm. Pure Appl. Math.* **67**(6) (2014), 906–956

Exact Parameter Identification in PET Pharmacokinetic Modeling Using the Irreversible Two Tissue Compartment Model

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In this talk we consider the identifiability of metabolic parameters from multi-region measurement data in quantitative positron emission tomography (PET) imaging, a non-invasive clinical technique that images the distribution of a radio tracer in-vivo.

We discuss how, for the frequently used two-tissue compartment model and under reasonable assumptions, it is possible to uniquely identify metabolic tissue parameters from standard PET measurements, without the need of additional concentration measurements from blood samples. The core assumption requirements for this result are that PET measurements are available at sufficiently many time points, and that the arterial tracer concentration is parametrized by a polyexponential, an approach that is commonly used in practice. Our analytic identifiability result, which holds in the idealized, noiseless scenario, indicates that costly concentration measurements from blood samples in quantitative PET imaging can be avoided in principle. The connection to noisy measurement data is made via a consistency result in Tikhonov regularization theory, showing that exact reconstruction is maintained in the vanishing noise limit.

We further present numerical experiments with a regularization approach based on the Iteratively Regularized Gauss-Newton Method (IRGNM)

supporting these analytic results in an application example.

Multiharmonic expansions for nonlinearity identification in wave type equations

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We consider an undetermined coefficient inverse problem for a nonlinear partial differential equation occuring in high intensity ultrasound propagation as used in acoustic tomography. In particular, we investigate the recovery of the nonlinearity coefficient commonly labeled as B/A in the literature, which is part of a space dependent coefficient κ in the Westervelt equation governing nonlinear acoustics. Corresponding to the typical measurement setup, the overposed data consists of time trace measurements on some zero or one dimensional set Σ representing the receiving transducer array. In this talk, we will show some recent results pertaining to the formulation of this problem in frequency domain and numerical reconstruction of piecewise constant coefficients in two space dimensions [1].

[1] Barbara Kaltenbacher and William Rundell, Nonlinearity parameter imaging in the frequency domain, preprint, arXiv:2303.09796 [math.NA] and submitted

The Range of Projection Pair Operators

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Tomographic techniques have become a vital tool in medicine, allowing doctors to observe patients' interior features. This is achieved by taking various independent measurements – called projections –, for example, x-ray images from different directions. Modeling the measurement process (and the underlying physics) is a certain class of integration operators we call projection operators. Those feature the integration of functions along certain collections of curves (typically straight lines representing paths of radiation) with weights representing physical effects. These operators are accordingly subdivided into individual projections. It is reasonable to expect that the data of two projections carry some overlapping information (e.g., the total mass in two x-ray images of the same object coincide). Using such information, one can verify whether the data associated to a pair of projections is consistent with the model. Hence, such (pairwise) consistency conditions have proven useful in various tomography-related applications [1-3], such as geometric calibration, parameter identification, or corruption detection. While such conditions are known for the most widely used projection operators, they remain unknown for more specialized tomographic methods. We present the framework of

projection pair operators that allows for a unified investigation of consistency conditions as range conditions for these operators. Thus, we discuss these operators' ranges, finding that at most one consistency condition exists for any projection pair and a method for determining it. In fact, unlike previously suspected, there is no guarantee for the existence of consistency conditions. Indeed, the existence is connected to the algebraic properties of the curves and weights in the operators and are quite restrictive, implying that many models do not yield pairwise consistency conditions.

[1] F. Natterer. "Computerized Tomography with Unknown Sources". SIAM Journal on Applied Mathematics 43.5 (1983), pp. 1201–1212. DOI : 10.1137/0143079.

[2] J. Xu, K. Taguchi, and B. Tsui. "Statistical Projection Completion in X-ray CT Using Consistency Conditions". IEEE Trans. Med. Imaging 29 (2010), pp. 1528–1540. DOI : 10.1109/TMI.2010. 2048335.

[3] R. Clackdoyle and L. Desbat. "Data consistency conditions for truncated fanbeam and parallel projections." Medical physics 42 2 (2015), pp. 831–45

Diffraction Tomography: Elastic parameters reconstructions

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In this talk, we introduce an elastic imaging method where elastic properties (i.e. mass density and Lamé parameters) of a weakly scatterer are reconstructed from full-field data of scattered waves. We linearise the inverse scattering problem under consideration using Born's, Rytov's or Kirchhoff's approximation. Primarily, one appeal to the Fourier diffraction theorem developed in our previous work [1] for the pressure-pressure mode (i.e. generating Pressure incident plane waves and measuring the Pressure part of the scattered data). Then, we reconstruct the inverse Fourier transform of the pressure-pressure scattering potential using the inverse *nonequispaced discrete Fourier transform* for 2D transmission acquisition experiments. Finally, we quantify the elastic parameter distributions with different plane wave excitations.

[1] B. Mejri, O. Scherzer., A new inversion scheme for elastic diffraction tomography, arXiv:2212.02798, 2022 https://arxiv.org/abs/2212.02798

Estimation of future discretionary benefits (FDB) in traditional life insurance

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In the context of life insurance with profit participation, the future discretionary benefits (FDB), which are a central item for Solvency II reporting, are generally calculated by computationally expensive Monte Carlo algorithms. We derive analytic formulas to estimate lower and upper bounds for the FDB. The method is designed for real world applications, and examples involving public and anonymized reporting data will be provided in the talk. Moreover, I will discuss the assumptions underpinning the estimation and numerical evidence from a comprehensive asset liability management (ALM) model.

On the Mean-Field LIBOR market model: Controlling long-term forward volatilities

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It is well-known that market models that describe nearly risk-free forward rates such as the EURIBOR can suffer from so-called interest rate explosions. These refer to events where a considerable number of simulated forward rates are unrealistically high (e.g. higher than 70%) which cause a variety of technical and economical problems. To reduce the probability of interest rate explosions, that are often observed in long-term out-of-sample predictions of forward rates, we apply the mean-field LIBOR market model introduced in [1] to damp the forward rates' variances in a market consistent and arbitrage-free way, which is of particular importance in the life insurance sector. To this end, we also propose a consistent framework which provides tools to measure the methodology's effectiveness in reducing interest rate explosions before running large-scale simulations and that allows for the simulation of forward rates from the associated McKean-Vlasov stochastic differential equations without time-consuming nested simulations.

[1] Desmettre, Sascha et al. (2022). "A mean-field extension of the LIBOR market model". International Journal of Theoretical and Applied Finance 25.

Modeling Large Spot Price Deviations in Electricity Markets

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Increased insecurities on the energy markets have caused massive fluctuations of the electricity spot price within the past two years. In this work, we investigate the fit of a classical 3-factor model with a Gaussian base signal as well as one positive and one negative jump signal in this new market environment. We also study the influence of adding a second Gaussian base signal to the model. For the calibration of our model we use a Markov Chain Monte Carlo algorithm based on the so-called Gibbs sampling. The resulting 4-factor model is then compared to the 3-factor model in different time periods of particular interest and evaluated using posterior predictive checking. Additionally, we derive closed-form solutions for the price of futures contracts in our 4-factor spot price model.

We find that the 4-factor model outperforms the 3-factor model in times of non-crises. In times of crises, the second Gaussian base signal does not lead to a better the fit of the model. To the best of our knowledge, this is the first study regarding stochastic electricity spot price models in this new market environment. Hence, it serves as a solid base for future research.

On the impact of tax uncertainty on optimal investment into carbon abatement technology

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In this paper we study the problem of a profit maximizing electricity producer who decides on investments in technologies for abatement of CO_2 emissions based on the tax policy which is in force. The objective of the company is to maximize the expected future revenues. We compare two scenarios: in the first scenario, the taxation policy is deterministic; in the second scenario we allow for exogenous deviations from the deterministic setting, which arrive at exponential times, which may either increase or decrease the taxes. Using continuous-time stochastic control methods We show that in certain scenarios the uncertainty on the future taxation makes the company less willing to make investment and hence a clear and a priori fixed strategy would instead maximise the actions for emission reduction. Moreover, we tackle the same problem using differential games and the Bellman Isaacs equation.

Implicit control for Lévy-type dividend-impulse problem

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Assume the capital or surplus of an insurance company evolves randomly over time as the spectrally negative Lévy process but where in addition the company has the possibility to pay out dividends to shareholders and to inject capital at a cost from shareholders. We impose that when the resulting surplus becomes negative the company has to decide whether to inject capital to get to a positive surplus level in order for the company to survive or to let ruin occur. The objective is to find the combined dividends and capital injections strategy that maximises the expected paid out dividends minus cost of injected capital, discounted at a constant rate, until ruin. We consider the setting where the cost of capital is level-dependent in the sense that it is higher when the surplus is below 0 than when it is above 0. We investigate optimality of a 3-parameter strategy with parameters $-r < 0 < c < b$ where dividends are paid out to keep the surplus below b, capital injections are made in order to keep the surplus above c unless capital drops below the level $-r$ in which case the company decides to let ruin occur. The proof is based on some monotonicity properties for the solution of the renewal equations with log-convex kernel.

Exact asymptotics of ruin probabilities with linear Hawkes arrivals

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One way to generalize the classical Cramér-Lundberg model is to replace the Poisson process with a more general counting process, driven by a stochastic intensity. In our model, we consider a risk process, whose counting process is a Markovian marked Hawkes process. Hawkes processes are characterized by their self-exciting property, which means that every jump of the process itself increases the probability of further jumps, a behaviour that can be observed in the occurrence of cyber-attacks. By the Markovian structure of the underlying model, we identify suitable exponential martingales and corresponding alternative measures under which ruin occurs almost surely. Exploiting the positive Harris recurrence of the intensity process and its stationary distribution, we use a renewal equation to determine the asymptotic behaviour of the ruin probability.

t-design curves on manifolds

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In analogy to classical spherical t-design points, we introduce the concept of t-design curves on a compact Riemannian manifold. This means that the line integral along a t-design curve integrates "polynomials" of degree t exactly.

We derive lower asymptotic bounds for the length of t-design curves. For specific manifolds, namely the d-dimensional tori, we construct t-design curves that match these lower asymptotic bounds. Hence they are asymptotically optimal. For the unit sphere in $\mathbb{R}^3$, we present examples of t-design curves with small t.

Spherical t-design curves

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A spherical t-design curve is a curve on the d-dimensional sphere such that the corresponding line integral integrates polynomials of degree t exactly. Spherical t-design curves can be used for mobile sampling and reconstruction of functions on the sphere.

We investigate such curves and prove the existence of asymptotically optimal t-design curves in the Euclidean 2-sphere. This construction is based on and uses the existence of t-design points verified by Bondarenko, Radchenko, and Viazovska (2013). For higher-dimensional spheres we inductively prove the existence of t-design curves. However this inductive construction does not lead to asymptotic optimal length.

[1] A. Bondarenko, D. Radchenko, and M. Viazovska. Optimal asymptotic bounds for spherical designs. *Ann. Math.*, 178(2):443–452, 2013.

[2] M. Ehler, K. Gröchenig. Preprint, https://arxiv.org/pdf/2306.13152.pdf

On the Foundations of Computational Time-Frequency Analysis

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Classical Fourier Analysis stands at the beginning of Approximation Theory as an important discipline within Mathematical Analysis. One may ask, for example, what rate of approximation can be granted for a given summability method on certain subspaces of smooth functions (e.g. satisfying Lipschitz conditions with respect to L_p-norms).

Time-Frequency Analysis is making use of the Short-Time (or Windowed) Fourier Transform (STFT) and is thus opens the way to a large family of new function spaces (the so-called modulation spaces, introduced in 1983). Restricting our attention to the unweighted cases we find that the spaces $\left(\boldsymbol{M}^{p,q}(\mathbb{R}^d), \|\cdot\|_{\boldsymbol{M}^{p,q}}\right)$ are all isometrically invariant under time-shifts and multiplication with pure frequencies $\chi_s(t) = exp(2\pi ist)$. The smallest Banach space (in fact Banach Algebra) is $\left(\boldsymbol{S}_0(\mathbb{R}^d), \|\cdot\|_{\boldsymbol{S}_0}\right) = (\boldsymbol{M}^1(\mathbb{R}^d), \|\cdot\|_{\boldsymbol{M}^1})$, and the biggest is the dual space $(\boldsymbol{S}_0'(\mathbb{R}^d), \|\cdot\|_{\boldsymbol{S}_0'}) = (\boldsymbol{M}^\infty(\mathbb{R}^d), \|\cdot\|_{\boldsymbol{M}^\infty})$, the space of *mild distributions*. Together with the Hilbert space $\left(\boldsymbol{L}^2(\mathbb{R}^d), \|\cdot\|_2\right)$ they form the so-called Banach Gelfand Triple $(\boldsymbol{S}_0, \boldsymbol{L}^2, \boldsymbol{S}_0')(\mathbb{R}^d)$, with embeddings

$$\left(\boldsymbol{S}_0(\mathbb{R}^d), \|\cdot\|_{\boldsymbol{S}_0}\right) \hookrightarrow \left(\boldsymbol{L}^p(\mathbb{R}^d), \|\cdot\|_p\right)$$
$$\hookrightarrow (\boldsymbol{S}_0'(\mathbb{R}^d), \|\cdot\|_{\boldsymbol{S}_0'}), \text{ for } p \in [1, \infty].$$

Moreover, $\left(\boldsymbol{S}_0(\mathbb{R}^d), \|\cdot\|_{\boldsymbol{S}_0}\right)$ is isometrically invariant under the Fourier transform (hence also $(\boldsymbol{S}_0'(\mathbb{R}^d), \|\cdot\|_{\boldsymbol{S}_0'}))$ and a Banach algebra with respect to convolution (Feichtinger's Algebra). Among the remarkable properties we have a Kernel Theorem (comparable to the Schwartz Kernel Theorem), allowing to identify the Banach Gelfand triple $(\boldsymbol{S}_0, \boldsymbol{L}^2, \boldsymbol{S}_0')(\mathbb{R}^{2d})$ with the operator Banach Gelfand Triple $(\boldsymbol{B}, \mathcal{HS}, \boldsymbol{B}')$, with duality given by $\langle T, S\rangle_{\mathcal{HS}} = \mathrm{trace}(TS^*)$, with $\mathcal{HS}$ the Hilbert-Schmidt operators, and $\mathcal{B} = \mathcal{L}(\boldsymbol{S}_0', \boldsymbol{S}_0)$, the $w^*-$to-norm continuous operators from $\boldsymbol{S}_0'(\mathbb{R}^d)$ to $\boldsymbol{S}_0(\mathbb{R}^d)$.

An additional advantage of abstract TF-analysis (as opposed to wavelet theory) is the fact that it can be realized in a natural way over general LCA (locally compact Abelian), hence also over finite Abelian groups. Thus we will discuss in this talk different cases, where problems in TF-Analysis can be solved using the idea of *structure preserving approximation*. A simple example is the approximate computation of the Fourier transform of a function $f \in \boldsymbol{S}_0(\mathbb{R})$ by first sampling the function, fine enough over a sufficiently long interval, then taking the FFT of the resulting vector of sampling values, and then applying piecewise linear interpolation in order to get a good $\boldsymbol{S}_0$-approximation of $\widehat{f}$ (for any given precision). Similar questions can be answered, making use of the properties of $\boldsymbol{S}_0$, using only basic functional analytic considerations. Recent findings imply that such methods can be also used to establish the foundations of Computational Quantum Harmonic Analysis in the sense of R. Werner [5], making use of recent work of F. Luef and his students such as [4].

In short, using the appropriate function spaces one can guarantee that the transition from a *continuous problem* to the *corresponding finite model* (which can be implemented, e.g. using MATLAB) leads to arbitrary good approximation. So far war have only qualitative results.

[1] H. G. Feichtinger. On a new Segal algebra. *Monatsh. Math.*, 92:269–289, 1981.

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[3] M. S. Jakobsen. On a (no longer) New Segal Algebra: a review of the Feichtinger algebra. *J. Fourier Anal. Appl.*, 24(6):1579–1660, 2018.

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Stochastic collocation for dynamic micromagnetism

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We consider the stochastic Landau-Lifschitz-Gilbert equation, an SPDE model for dynamic micromagnetism. We first convert the problem to a (highly nonlinear) PDE with parametric coefficients using the Doss-Sussmann transform and the Lévy-Ciesielsky parametrization of the Brownian motion. We prove analytic regularity of the parameter-to-solution map and estimate its derivatives. These estimates are used to prove convergence rates for piecewise-polynomial sparse grid methods. Moreover, we propose novel time-stepping methods to solve the underlying deterministic equations

Sampling widths of function classes

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Let F be a class of continuous complex-valued functions on a compact domain D. The nth sampling width of F in $L_p(D)$ is defined by

$$g_n(F, L_p) = \inf_{\substack{x_1,\dots,x_n \in D \\ \phi\colon \mathbb{C}^n \to L_p(D)}} \sup_{f \in F} \left\| f - \phi\big(f(x_1), \dots, f(x_n)\big) \right\|_p .$$

It measures the minimal worst case error that can be achieved when recovering functions from F using at most n samples. We discuss recent upper bounds on the sampling widths for general function classes F.

The first type of upper bounds is in terms of the Kolmogorov widths in $C(D)$, which measure the approximability of the class F by an n-dimensional vector space V_n in $C(D)$, namely,

$$d_n(F) = \inf_{V_n} \sup_{f \in F} \inf_{g \in V_n} \|f - g\|_\infty .$$

We show that there is a universal constant $c > 0$ such that, for all $2 \le p \le \infty$,

$$g_{4n}(F, L_p) \le c\, n^{1/2-1/p}\, d_n(F) .$$

The second type of upper bounds is in terms of the Kolmogorov widths of the class in $L_2(D)$. Those are smaller than the Kolmogorov widths in $C(D)$, but the upper bounds are more involved. The bounds are sharp, for example, if F is a ball in a Sobolev Hilbert space on a compact Riemannian manifold D and $1 \leq p \leq \infty$.

[1] Matthieu Dolbeault, David Krieg, Mario Ullrich. A sharp upper bound for sampling numbers in L_2. *Applied and Computational Harmonic Analysis* **63** (2023), 113–134.

[2] David Krieg, Kateryna Pozharska, Mario Ullrich, Tino Ullrich. Sampling recovery in uniform and other norms, preprint, https://arxiv.org/abs/2305.07539

A Strategy for identifying informative variables for the prediction from imbalanced datasets

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We discuss the problem of detecting the most informative coordinates of input vectors that allow an accurate reconstruction of the corresponding outputs from previously unseen inputs. This problem appears in a wide variety of applications. In our study we are motivated by predicting neurodevelopmental outcomes of preterm neonates from the ratios of the amplitudes of the peaks of metabolite spectra provided by magnetic proton spectroscopy (MRS).

The curse of dimensionality for the L_p-discrepancy with finite p

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The L_p-discrepancy for $p \in [1, \infty]$ is a quantitative measure for the irregularity of distribution of an N-element point set in the d-dimensional unit cube, which is closely related to the worst-case error of quasi-Monte Carlo algorithms for numerical integration. Its inverse for dimension d and error threshold $\varepsilon \in (0, 1)$ is the minimal number of points in $[0, 1)^d$ required such that the minimal normalized L_p-discrepancy is less or equal ε. It is well known, that the inverse of L_2-discrepancy grows exponentially fast with the dimension d, i.e., we have the curse of dimensionality, whereas the inverse of L_∞-discrepancy depends exactly linearly on d. The behavior of inverse of L_p-discrepancy for general $p \notin \{2, \infty\}$ has been an open problem for many years.

In this talk we address this kind of problem, present an answer for a sequence of specific values of p and discuss a possible way how to solve the question for general $p \in [1, \infty)$.

Fixed Points of Mean Section Operators

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Several geometric inequalities for Minkowski valuations can be reduced to the determination of their fixed points. In this talk, we prove that for a large class of Minkowski valuations, including the Mean Section Operators, there is a neighborhood of the unit ball where the only fixed points are Euclidean balls. Our approach unifies and extends previous results by Ivaki, Schuster, and Ortega-Moreno.

Valuations and distributions

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In recent years, valuations on functions arose as a natural generalization of valuations on convex bodies and due to their intimate relation to convex bodies, valuations on convex functions have been the focus of intense research. I will present a construction that allows us to interpret a certain class of valutions on convex functions as distributions with special properties and we will discuss how this interpretation can in turn be used to obtain strong characterization results of certain classes of valuations.

Iterations of Minkowski valuations

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In this talk, we show that for any sufficiently regular even Minkowski valuation Φ which is homogeneous and intertwines rotations, and for any convex body K in a smooth neighbourhood of the unit ball, there exists a sequence of positive numbers $(\gamma_m)_{m=1}^{\infty}$ such that $(\gamma_m \Phi^m K)_{m=1}^{\infty}$ converges to the unit ball with respect to the Hausdorff metric.

Spherical Centroid Bodies

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We introduce the spherical centroid body of a centrally-symmetric spherically convex body. Much like its Euclidean counterpart, our notion allows for two equivalent definitions–one geometric, the other probabilistic in nature. The geometric approach is used to establish a number of basic properties, while the probabilistic approach inspires the proof of an spherical isoperimetric inequality that is in the spirit of the classical polar Busemann–Petty centroid inequality.

[1] F. Besau, T. Hack, P. Pivovarov, F. E. Schuster, *Spherical centroid bodies*, Amer. J. Math. **145** (2023), 515–542.

Inequalities for higher-rank mixed volumes

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Going back to H. Minkowski, the concept of mixed volume assigns to an n-tuple of convex bodies in an n-dimensional vector space a natural numerical quantity which satisfies the fundamental Alexandrov–Fenchel inequality. In a joint work with Thomas Wannerer, we introduce an array of new numerical invariants, mixed volumes of rank $k = 1, \dots, n-1$, subsuming the classical mixed volume for $k = 1$. We prove that also the opposite boundary case $k = n-1$ satisfies an Alexandrov–Fenchel-type inequality and that this new inequality sharpens, in turn, the classical Alexandrov–Fenchel inequality, when applied to lower-dimensional convex bodies.

Affine Hardy–Littlewood–Sobolev inequalities

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Sharp affine Hardy–Littlewood–Sobolev inequalities are established, which are stronger than and directly imply the sharp Hardy–Littlewood–Sobolev inequalities by Lieb and by Beckner, Dou, and Zhu. In addition, sharp reverse inequalities for the new inequalities and the affine fractional L^2 Sobolev inequalities are obtained for log-concave functions.

[2] J. Haddad, M. Ludwig. Affine fractional Sobolev and isoperimetric inequalities, preprint, https://arxiv.org/abs/2207.06375

[2] J. Haddad, M. Ludwig. Affine fractional L^p Sobolev inequalities. Math. Ann., in press, https://link.springer.com/article/10.1007/s00208-022-02540-3

[2] J. Haddad, M. Ludwig. Affine Hardy–Littlewood–Sobolev inequalities, preprint, https://arxiv.org/abs/2212.12194

Integral Geometry and Supports of Mixed Measures

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We show that a special class of mixed area measures has nested supports. Among others, we use new Cauchy–Kubota type formulas to obtain this result. We will also discuss how these results can be applied to mixed Monge–Ampère measures of convex functions and how they generalize previous results.

Diophantine conditions in the law of the iterated logarithm for lacunary systems

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It is a classical observation that lacunary function systems exhibit many properties which are typical for systems of independent random variables. However, it had already been observed by Erdős and Fortet in the 1950s that probability theory's limit theorems may fail for lacunary sums $\sum f(n_k x)$ if the sequence $(n_k)_{k\geq 1}$ has a strong arithmetic "structure". The presence of such structure can be assessed in terms of the number of solutions of two-term linear Diophantine equations $an_k - bn_l = c$. As Aistleitner and Berkes proved in 2010, saving an (arbitrarily small) unbounded factor for the number of solutions of such equations rules out pathological situations as in the Erdős–Fortet example, and guarantees that $\sum f(n_k x)$ satisfies the central limit theorem (CLT) in a form which is in accordance with true independence. In contrast, for the law of the iterated logarithm (LIL) the Diophantine condition which suffices to ensure "truly independent" behavior requires saving a factor of logarithmic order. In this talk we present the remarkable fact that the arithmetic condition required of $(n_k)_{k\geq 1}$ to ensure that $\sum f(n_k x)$ shows "true random" behavior is a different one at the level of the CLT than it is at the level of the LIL: the LIL requires a stronger arithmetic condition than the CLT does.

Limit theorems for mixed/norm sequence spaces with applications to volume distribution

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Let $p, q \in (0, \infty]$ and $\ell_p^m(\ell_q^n)$ be the mixed-norm sequence space of real matrices $x = (x_{i,j})_{i \le m, j \le n}$ endowed with the (quasi-)norm $\|x\|_{p,q} := \big\| \big(\|(x_{i,j})_{j \le n}\|_q \big)_{i \le m} \big\|_p$. We shall prove a Poincaré–Maxwell–Borel lemma for suitably scaled matrices chosen uniformly at random in the $\ell_p^m(\ell_q^n)$-unit balls $\mathbb{B}_{p,q}^{m,n}$, and obtain both central and non-central limit theorems for their $\ell_p(\ell_q)$-norms. We use those limit theorems to study the asymptotic volume distribution in the intersection of two mixed-norm sequence balls. Our approach is based on a new probabilistic representation of the uniform distribution on $\mathbb{B}_{p,q}^{m,n}$.

A probabilistic approach to Lorentz balls

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In this talk, we present a probabilistic approach to understand volumetric and geometric properties of unit balls of finite-dimensional Lorentz spaces when the dimension tends to infinity. These spaces form a natural generalization of ℓ_p-spaces and appear in various contexts related to functional analysis, approximation theory and L-statistics.

For a special case of parameters, we present a probabilistic representation of a random vector sampled uniformly in a Lorentz ball. We use this to derive the asymptotic distribution of a coordinate, a weak Poincaré-Maxwell-Borel lemma, and limit theorems for norms. In this setting, we discover phenomena, some of which do not appear in the special case of ℓ_p-balls. This is related to statistical mechanics and large deviations via the maximum entropy principle.

[1] Z. Kabluchko, J. Prochno and M. Sonnleitner, A probabilistic approach to Lorentz balls, preprint, 2023, https://arxiv.org/abs/2303.04728

Complex L_p-Intersection Bodies

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Interpolating between the classical notions of intersection and polar centroid bodies, (real) L_p-intersection bodies, for $-1 < p < 1$, play an important role in the dual L_p-Brunn–Minkowski theory. Inspired by the recent construction of complex centroid bodies, a complex version of L_p-intersection bodies, with range extended to $p > -2$, is introduced, interpolating between polar complex centroid and complex intersection bodies. This is joint work with Georg C. Hofstätter.

Angles of random simplices and face numbers of random polytopes

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The angle sum of any plane triangle is the same, but the angle sums of tetrahedra are not constant. In fact, two kinds of angle sums can be associated with a tetrahedron: one for solid angles at vertices and one for dihedral angles at edges, and neither of these sums is constant. What are the maximal and minimal values of these sums? Are there any relations satisfied by these sums? What are their average values? For example, if we take 4 points uniformly at random on the unit sphere in $\mathbb{R}^3$ (or in the unit ball), what are the expected values of the angle sums of the tetrahedron they span? We shall review results on these questions in the general setting of random simplices whose vertices follow the so-called beta or beta' distributions. The expected angle sums of these beta and beta' simplices can be determined exactly. As it turns out, several objects in stochastic geometry such as the typical cell of the Poisson-Voronoi tessellation or the zero cell of the homogeneous Poisson hyperplane tessellation (in Euclidean space or on the sphere) can be reduced to random polytopes whose vertices follow the beta' distribution. The expected face numbers of these polytopes can be expressed exactly through the expected angle sums of the random beta' simplices.

A Maxwell principle for generalized Orlicz balls.

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Over a century ago, Borel observed that if one chooses a random vector uniformly from the Euclidean sphere in dimension N, then when N is large any given coordinate of the random vector is approximately Gaussian distributed. Borel attributed this result to Maxwell, and as such this result is commonly known as the Maxwell-Borel lemma or the Maxwell principle.

In the 1980s, in a paper [1] titled *A dozen de Finetti-style results in search of a theory*, Diaconis and Freedman noted a similar phenomenon in the context of the simplex: if one chooses a random vector uniformly from the simplex in N dimensions, then when N is large any given coordinate of the random vector is approximately exponentially distributed. In the following decades, work by Rachev and Rüschendorf [4] and by Naor and Romik [3] unified these results in the setting of ℓ_p^N balls, of which the simplex (up to symmetry) and the Euclidean sphere are both examples.

In joint work with Joscha Prochno [2], we show use arguments from large deviations and statistical physics to show that these phenomena may be cast as part of a significantly broader framework in terms of *generalised Orlicz balls*, i.e. sets of the form $B_{\phi,t}^N := \{(s_1, \dots, s_N) : \sum_{i=1}^N \phi(s_i) \leq tN\}$.

[1] Diaconis, P. & Freedman, D. (1987). A dozen de Finetti-style results in search of a theory. In Annales de l'IHP Probabilités et statistiques (Vol. 23, No. S2, pp. 397–423).

[2] Johnston, S. G. G. & Prochno, J. (2020). A Maxwell principle for generalized Orlicz balls. To appear in Annales de l'IHP Probabilités et statistiques arXiv:2012.11568.

[3] Naor, A. & Romik, D. (2003). Projecting the surface measure of the sphere of ℓ_p^n. In Annales de l'IHP Probabilités et statistiques (Vol. 39, No. 2, pp. 241–261).

[4] Rachev, S. T. & Rüschendorf, L. (1991). Approximate independence of distributions on spheres and their stability properties. The Annals of Probability (Vol. 19, pp. 1311–1337).

Chang-type models of determinacy

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A new model of the Axiom of Determinacy, called Chang models over derived models, was introduced by Grigor Sargsyan recently. This model is "Chang-type," in the sense that it contains δ^ω for some ordinal $\delta > \Theta$. First we will present two results using such a Chang-type model of determinacy. One is the proof of determinacy in the Chang model from a hod mouse with a Woodin limit of Woodin cardinals, and the other is a consistency result on ω-strongly measurable cardinals in HOD. We will also introduce a Chang-type model of determinacy with supercompact measures, which extends the aforementioned result of Sargsyan. This talk is based on several joint works with Navin Aksornthong, James Holland, Sandra Müller, and Grigor Sargsyan.

Convergence of measures and filters on ω

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We will give an overview of some maximality principles in Set Theory, namely forcing axioms and Woodin's $(*)$-axioms from the world of determinacy. We will discuss the surprising connection between those due to Asperó-Schindler and some recent results of myself building on this resulting in a solution to a question of Woodin about the nonstationary ideal on ω_1 from the late 90s.

The saturation of the nonstationary ideal

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I will talk about the problem of saturation of the non-stationary ideal. I will give an overview of some known results and point to a major open problem in this area of research, on which I will propose a strategy.

Almost disjointness and singular cardinals

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Throughout the last few years, many generalizations from classical cardinal characteristics of the Baire space have been studied. Particularly, special interest has been given to the study of the combinatorics of the generalized Baire spaces κ^κ when κ is an uncountable regular cardinal (or even a large cardinal). In this talk, I will present some results regarding a generalization to the context of singular cardinals of the concept of maximal almost disjointness. The first known result in this area is due to Erdös and Hechler, who introduced the concept of almost disjointness for families of subsets of a singular cardinal λ and proved many interesting results: for instance, if λ is a singular cardinal of cofinality $\kappa < \lambda$ and there is an almost disjoint family at κ of size γ, then there is a maximal almost disjoint family at λ of the same size. The main result of this talk is the construction of a generic extension in which the inequality $\mathfrak{a}(\lambda) < \mathfrak{a}$ holds for λ a singular cardinal of countable cofinality. The model combines the classical technique of Brendle to get a model in which $\mathfrak{b} < \mathfrak{a}$ together with the use of Příkrý type forcings which change the cofinality of a given large cardinal κ to be countable and, at the same time control the size of the power set of this given cardinal.

Classification theory in generalized descriptive set theory

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In 1989, Friemand and Stanley introduced the Borel reducibility as a descriptive set-theoretic complexity notion between classes of countable structures in [1], in the isomorphism relation of of theories for countable models. In 1990 Shelah developed the classification theory of first order countable theories, to solve Morley's conjecture, and provide us with model-theoretic notions of complexity in [2].

One may ask whether the notion of Borel reducibility correlates with model-theoretic notions of complexity. This has been studied by Koerwien, Laskowski, Shelah, and others, for countable structures.

In 1993 Mekler and Väänänen initiated the study of the generalized Baire spaces, by studing the descriptive set theory of the space $\omega_1^{\omega_1}$ in [3]. This set the grounds to study the generalized Borel reducibility of the isomorphism relation of theories for uncountable models. In 2014 Friedman, Hyttinen, and Weinstein (né Kulikov) studied the interaction between the generalized Borel reducibility and Shelah's classification theory, in [4]. The main results of [4] establish an interesting correspondence between the model-theoretic complexity of countable first-order theories and the descriptive set-theoretic complexities of its isomorphism relation for uncountable models. One of the main motivations behind [4] was to find a Borel reducibility counterpart for Shelah's Main Gap (the division line between classifiable theories and non-classifiable theories). It was conjectured that the isomorphism relation of any classifiable theory is Borel reducible to the isomorphism relation of any non-classifiable theory (for uncountable models).

In this talk we will show that under the assumptions $\kappa^{<\kappa}\kappa = \lambda^+ = 2^\lambda$ and $2^{\mathfrak{c}} \leq \lambda = \lambda^{\omega_1}$, the isomorphism relation of models of size κ of any classifiable theory is Borel reducible to the isomorphism relation of models of size κ of any non-classifiable theory.

We will show that if $\kappa^{<\kappa}\kappa$, then there is a $<\kappa$-closed κ^+-cc forcing extension in which for any countable first-order theory in a countable vocabulary (not necessarily complete), T, one of the following holds:

- the isomorphism relation of T, of models of size κ, is analytic co-analytic;
- any analytic equivalence relation is Borel reducible to the isomorphism relation of T, of models of size κ.

[1] H. Friedman, L. Stanley, A Borel Reducibility Theory for Classes of Countable Structures. *The Journal of Symbolic Logic* **54** (1989), 894–914.

[2] S. Shelah. Classification Theory and the Number of Nonisomorphic Models (2nd edition). *Studies in Logic and the Foundations of Mathematics* **92**. Amsterdam: North-Holland. (1990).

[3] A. Mekler, J. Väänänen. Trees and Π^1_1-subsets of ${}^{\omega_1}\omega_1$. *The Journal of Symbolic Logic* **58** (1993), 1052–1052.

[4] S. Friedman, T. Hyttinen, V. Kulikov. Generalized descriptive set theory and classification theory. *Mem. Amer. Math. Soc.* **230** (2014).

Spectra of combinatorial families

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I will give a brief overview of the theory of possible spectra of various combinatorial families such as mad families, independent families and other similar types of families. Further, extending the result of W. Brian in [1], I will sketch recent work of how to realize uncountable spectra of $\mathfrak{a}_T$, i.e. given an uncountable set C of cardinals (with some extra assumptions) how to construct a model which has partitions of Cantor space into closed sets of exactly the sizes prescribed in C.

[1] W. Brian, Partitioning the real line into Borel sets, to appear in Journal of Symbolic Logic

Convergence of measures and filters on ω

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During my talk I will discuss relations between the following three items:

(1) existence of complemented copies of the Banach space c_0 in spaces $C(K)$ of continuous functions on compact spaces K,
(2) existence of sequences of finitely supported measures on Tychonoff spaces related to the classical Josefson–Nissenzweig theorem from Banach space theory,
(3) Katětov ordering of Borel filters on ω.

Sensitivity analysis of the solution mapping for a large class of optimization problems

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In this talk, we focus on behavior of local solutions to finite-dimensional parameterized optimization problems in a very general setting. Lipschitzian stability of these solutions has been a crucial topic in optimization theory for decades and while it is understood fairly well - an abstract characterization has been available since the introduction of the particular perturbation scheme in 2000 by Levy, Poliquin, and Rockafellar - there are still many open questions. We propose a new interpretation of this characterization, which also enables us to derive a new sufficient condition for the Lipschitzian stability in case of the standard nonlinear programs. Moreover, thanks to the recent developments in variational analysis, we are able to compute the graphical derivative of the local solution mapping. We connect the graphical derivative with a solution of certain optimization subproblem defined via second subderivatives of the original objective function. Our ultimate goal, motivated by the desire to articulate solution dynamics via a one-sided differential equation, is to develop conditions ensuring that the solution mapping - single-valued and Lipschitz continuous, but nonsmooth - possesses one-sided directional derivatives. As this is an ongoing project, sometimes we provide only partial answers and we also propose some related open questions.

Interchange Rules for Integral Functions

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We present an abstract principle for the interchange of infimization and integration over spaces of mappings taking values in topological spaces. Conditions on the underlying space and the integrand are then introduced to convert this principle into concrete scenarios that are shown to capture those of various existing interchange rules. These results are leveraged to improve state-of-the-art interchange rules for evaluating Legendre conjugates, subdifferentials, recessions, Moreau envelopes, and proximity operators of integral functions by bringing the corresponding operations under the integral sign.

Distributive algorithms for saddle point problems

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In this talk, we consider an arbitrary connected network of finitely many agents working cooperatively to solve a min-max problem with convex-concave structure. Our goal is to develop methods with good convergence guarantee (large steps), with small communication rounds and that are tailored specifically to the properties of the problem. First, we will look at how to solve such a problem in a pure minimization setting and then will try to apply a similar approach to our problem of interest.

Manifolds of solutions in deterministic global optimization

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Continuous symmetries and submanifolds of solutions frequently pose problems for deterministic global optimization problems. Usually, this leads to excessive box splitting in the vicinity of the solutions and exponential running times. We will develop verified computing methods for symmetries based on matrix Lie groups and present some verified continuation techniques that lead to inclusion/exclusion areas around solution manifolds.

Convergence rate of the Tikhonov regularization method for finding zeros of monotone operators

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We study in continuous time dynamics as well as numerical algorithms for the problem of finding zeros of a single-valued monotone and continuous operator M. As a starting point, we consider a first-order dynamical system with a Tikhonov regularization $\varepsilon(t)$. Under suitable conditions of $\varepsilon(t)$, we show that the Tikhonov regularization leads to a fast convergence rate for $\|M(x(t))\|$, besides guaranteeing the generated trajectory $x(t)$ converges strongly to the minimum norm solution. We then discuss the connection with other first-order and second-order dynamics for which the regularization term may not appear explicitly. Consequently, their convergence results can be obtained without making use of the Lyapunov analysis. Temporal discretizations of the dynamical system lead to numerical methods that share the same features as their continuous counterpart. We also recover the Halpern method and the Accelerated Proximal Point Methods as specific instances.

A semismooth Newton stochastic proximal point algorithm with variance reduction

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We develop an implementable stochastic proximal point (SPP) method for optimization problems as they typically arise in statistical learning. The objective function is composed by a weakly convex, finite-sum loss function and a nonsmooth, convex regularization term. In general, the SPP method requires to solve an implicit equation and therefore it is often only analyzed from a theoretical perspective. We propose an efficient way of implementing the SPP update by a semismooth Newton method, using Fenchel duality and allowing for inexact solves in our convergence theory. The method also includes an SVRG-type variance reduction technique. We obtain convergence to a stationary point with a sublinear rate for constant step sizes and Lipschitz-smooth loss functions. In the strongly convex case we obtain linear convergence to the minimizer, similar to results for variance-reduced stochastic (proximal) gradient methods such as SVRG. Numerical experiments show that the proposed algorithm can compete with state-of-the art methods and achieves higher robustness with respect to the step size selection.

A topological derivative-based algorithm to solve optimal control problems with $L^0(\Omega)$ control cost

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We consider optimization problems with L^0-cost of the controls. Here, we take the support of the control as independent optimization variable. Topological derivatives of the corresponding value function with respect to variations of the support are derived. These topological derivatives are used in a novel gradient descent algorithm with Armijo line-search. Under suitable assumptions, the algorithm produces a minimizing sequence.

Extreme values of Birkhoff sums and quantum modular forms

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The notion of a quantum modular form was introduced in a seminal paper of Zagier in 2010 to describe the rich arithmetic structure of certain quantum knot invariants coming from algebraic topology. In this talk we demonstrate that quantum modular behavior also emerges in the ergodic theory of circle rotations. In particular, we consider the extreme values as well as exponential moments of the classical Birkhoff sum $\sum_{n=1}^{N}(\{nr\}-1/2)$, $0 \leq N < \mathrm{denom}(r)$ as functions of $r \in \mathbb{Q}$, and establish remarkable transformation properties with respect to the Gauss map that reveal an interesting self-similar structure. Transferring this framework to the irrational setting, as an application we find the limit distribution (after suitable centering and scaling) of $\max_{1\leq N\leq M}\sum_{n=1}^{N} f(n\alpha)$ and $\min_{1\leq N\leq M}\sum_{n=1}^{N} f(n\alpha)$ with $f(x)=\{x\}-1/2$ and a randomly chosen real $\alpha \in [0,1]$. The same limit law holds with f being the indicator of a rational interval extended with period 1.

On Pillai's problem involving Recurrence sequences

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Let $U = (U_n)_{n\geq 0}$ be a recurrence sequence, $b > 1$ and c fixed integers, then the Diophantine equation $U_n - b^m = c$ has been studied by many authors. The typical result is that the Diophantine equation has at most one solution, provided that c is large enough with respect to U and b. In this talk we restrict ourselves to Lucas sequences of the second kind, i.e. binary recurrence sequences of the form $U_{n+2} = AU_{n+1} - BU_n$ with $\gcd(A, B) = 1$ and initial values $U_0 = 2$ and $U_1 = A$.

Assuming that $A > |B| > 0$ and that $A^2 + 4B > 0$ is not a perfect square, we show that for any fixed integer $b > 2$ there exist only finitely many (effectively computable) Lucas sequences $(U_n)_{n\geq 0}$ of the second kind, such that the Diophantine equation $U_n - b^m = c$ has more than two solutions $(n, m) \in \mathbb{N}^2$. In particular, we show that in the case that three solutions exist, $b = 2$ and $c > 0$, then we have $\log |A| < 2 \cdot 10^{13}$.

A variant of Kaufman's measures in two dimensions

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Coauthor(s): Joint work with Sam Chow and Evgeniy Zorin.

An old result of Kaufman showed that the set **Bad** of badly approximable numbers supports a family of probabilty measures with polynomial decay rate on their Fourier transform. We show that the same phenomenon can be observed in a two-dimensional setup: we consider the set

$$\mathcal{B} = \{(\alpha, \gamma) \in [0,1]^2 : \inf \|q\alpha - \gamma\| > 0\}$$

and we prove that it supports certain probability measures with Frostman dimension arbitrarily close to 2 and Fourier transform woth polynomial decay rate.

Packings and Tilings in $\mathbb{Z}$

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Consider finite subsets $A \subset \mathbb{Z}$. For which A is it possible to tile $\mathbb{Z}$ with translates of A? If tiling $\mathbb{Z}$ is impossible, what is the densest packing that can be obtained using only translates of A?
These and related questions have been investigated for almost hundred years and are still far from being answered completely. This talk gives account on some key results and some recent progress in this topic. Tilings of the integers by translates of a finite set A of cardinality n are quite well understood if the prime factorisation of n is not to complicated and we present a very general method to generate such tilings. Regarding packing, even for $n = 4$ very simple to formulate problems remain unsolved.

Thue–Morse along the sequence of cubes

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Let $\mathtt{t} = \mathtt{01101001}\cdots$ be the Thue–Morse word over the alphabet $\{\mathtt{0}, \mathtt{1}\}$. This *automatic sequence* can be defined as the binary sum-of-digits function along $\mathbb{N}$, reduced modulo 2. We prove that the asymptotic density of the set of natural numbers n satisfying $\mathtt{t}(n^3) = \mathtt{0}$ equals $1/2$. Comparable results, featuring asymptotic equivalence along a polynomial as in our theorem, were previously only known for the linear case [1], and for the sequence of squares. The main theorem in [2] was the first result for the latter case.

Concerning the Thue–Morse sequence along polynomials p of degree at least three, previous results were restricted to inequalities, such as a lower bound for the quantities $\#\{n < N : \mathtt{t}(p(n)) = \mathtt{0}\}$ (while there exist sharper theorems concerning the sum-of-digits function with respect to "large bases"). By proving an asymptotic equivalence for the case of a cubic polynomial, we move one step closer to the solution of the third *Gelfond problem* on the sum-of-digits function (1967/1968) [1].

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Construction of a normal number whose inverse is also normal

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Let $b \geq 2$ be an integer and $\mathcal{N}_b = \{0, 1, \ldots, b-1\}$ be the associated set of digits. Every real number $x \in [0,1]$ admits a representation of the form

$$x = \sum_{k \geq 1} a_k b^{-k} = 0.a_1 a_2 a_3 \ldots,$$

with $a_k \in \mathcal{N}_b$, called the b-ary representation. We call the real x normal to base b if for every integer $\ell \geq 1$ every block $(d_1, \ldots, d_\ell) \in \mathcal{N}_b^\ell$ of length ℓ occurs with the same frequency $b^{-\ell}$ in the b-ary representation, *i.e.*

$$\lim_{n \to \infty} \frac{1}{n} \# \{0 \leq k < n \colon a_{k+1} = d_1, \ldots, a_{k+\ell} = d_\ell\} = b^{-\ell}.$$

Michel Mendès France asked for the existence of a real number x such that x and $1/x$ are both normal in binary representation. In the present talk we construct such a real number in polynomial time. In fact, we show that our construction yields a number x such that x and $1/x$ are normal with respect to every base $b \geq 2$ as well as with respect to the continued fraction expansion.

Tilings for rational number systems

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A number system is a way to represent elements of a space using a base and a set of digits. Many of them are related to self-affine sets with a fractal structure, one famous example being Knuth's Twin Dragon. We consider the case of rational number systems, and by that we mean that the base is an algebraic number or a rational matrix. The classical setting of self-affine tiles does not work for non integer basis. We introduce a representation space for these number systems which has a p-adic component, which allows to define the so-called rational self-affine tiles.

[1] Lucía Rossi, Wolfgang Steiner and Jörg Thuswaldner. "Rational self-affine tiles associated to standard and nonstandard digit systems", Panoramas et Synthéses by Société Mathématique de France (to appear). https://arxiv.org/abs/2110.09112

Weak mixing of interval translation maps

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Interval translation maps (ITMs) are piecewise isometries of the interval, but unlike interval exchange transformations (IETs), they are not invertible. They are of infinite type, if no part can be reduced to an IET. In this case, they have a Cantor attractor. In this talk we study a particular class of such infinite type ITMs, using a particular renormalization scheme which allows us to view the action on the attractor (X, T) as an S-adic transformation. Bressaud et al. [1] formulated conditions for weak mixing of the (unique) T-invariant measure. In verifying these conditions, we encounter a certain subtractive algorithm the study of which is of interest also for its own sake.

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On a conjecture of Levesque and Waldschmidt

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One of the first parametrised Thue equations over the integers,

$$\left|x^3-(n-1)x^2y-(n+2)xy^2-y^3\right|=1,$$

was solved by E. Thomas in 1990. If we interpret this as a norm-form equation, we can write this as

$$\left|N_{K/\mathbb{Q}}\left(x-\lambda_0 y\right)\right| = \left|\left(x-\lambda_0 y\right)\left(x-\lambda_1 y\right)\left(x-\lambda_2 y\right)\right|=1$$

if $\lambda_0,\lambda_1,\lambda_2$ are, for each n, the roots of the defining irreducible polynomial, and K the corresponding number field.

Levesque and Waldschmidt twisted this norm-form equation by an exponential parameter s and looked, among other things, at the equation

$$\left|N_{K/\mathbb{Q}}\left(x-\lambda_0^s y\right)\right|=1.$$

They solved this effectively and conjectured that introducing a second exponential parameter t and looking at

$$\left|N_{K/\mathbb{Q}}\left(x-\lambda_0^s\lambda_1^t y\right)\right|=1$$

does not change the effective solvability.

We want to partially confirm this, given that

$$\min\left(|2s-t|,|2t-s|,|s+t|\right)>\varepsilon\cdot\max\left(|s|,|t|\right)>2,$$

i.e. the two exponents do not almost cancel in specific cases.

MSC: 11D25,11D57

On sums of two Fibonacci numbers that are powers of integers with sparse Zeckendorf representation

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In 2018, Luca and Patel conjectured that the largest perfect power representable as the sum of two Fibonacci numbers is $38642 = F_{36} + F_{12}$. In other words, they conjectured that the equation

$$y^a = F_n + F_m$$

has no solutions with $a \geq 2$ and $y^a > 38642$. While this is still an open problem, there exist several partial results. For example, recently Kebli, Kihel, Larone and Luca (2021) proved an explicit upper bound for y^a, which depends on the size of y.

In this talk, we find an explicit upper bound for y^a, which only depends on the Hamming weight of y with respect to the Zeckendorf representation.

MSC: 11D61

Primes in arithmetic progressions to smooth moduli

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The Bombieri-Vinogradov theorem asserts that for $q < x^{1/2}\log(x)^{-A}$, the number of primes $p < x$ with $p \equiv a \bmod q$ is on average very close to $\pi(x)/\phi(q)$. An extension of this result to $q > x^{1/2}$ is a longstanding open problem. Following Zhang's breakthrough result on bounded gaps between primes [1], attention turned towards moduli q which are x^{δ}-smooth. Polymath [2] showed that the primes have exponent of distribution $0.52\dot{3}$ to smooth moduli.

Following the arguments of Polymath [3], in this talk we sketch how equidistribution estimates for primes in arithmetic progressions to smooth moduli can be used to give bounds on $H_m = \liminf_{n\to\infty}(p_{n+m} - p_n)$. We also show how an alternative version of the q-van der Corput method can be used to improve the exponent of distribution to smooth moduli to 0.525.

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Dispersion and Diophantine Approximation

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The dispersion of a finite set, say, in $[0, 1)$ is a quantitative measure of its denseness. It is defined to be the largest gap between neighbouring elements and, unsurprisingly, was studied in the classical theory of uniform distribution modulo one. We report on a link between dispersion and multiplicative Diophantine approximation. This link allows us to improve several results in the literature by, roughly, the square-root of a logarithm.

Tiled surfaces and their laminations

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We introduce laminations for tiled surfaces. These give rise to classes of infinite dimensional modules for locally gentle algebras. We study the properties of these laminations, in particular, we determine the size of maximal laminations. We expect that these laminations correspond to maximal rigid objects.

This is joint work with with B. Marsh.

Finitistic global dimensions of ghor algebras

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A ghor algebra is a special kind of noncommutative algebra that is constructed from an oriented graph (a dimer quiver) that embeds in a compact surface, with relations that identify homologous paths. The center R of such an algebra A is in general a non-noetherian coordinate ring of an affine toric variety with a 'positive dimensional point'. I will describe relationships between the finitistic global dimensions of the localizations of A at each maximal ideal of R, the Krull dimension of R, the dimension of the toric variety, and the genus of the surface the graph is embedded in. This is joint work with Karin Baur.

Reduction of friezes and Frobenius extriangulated categories

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Iyama and Yoshino introduced a reduction technique for 2-Calabi-Yau triangulated categories in their 2008 paper. This produces a new 2-Calabi-Yau triangulated category as a subquotient of the original category in a way that works particularly nicely for cluster categories. We give a reduction technique that applies to stably 2-Calabi-Yau Frobenius extriangulated categories.

As an application, we show that this provides a categorical model for the reduction of so-called Conway-Coxeter frieze patterns to frieze patterns with coefficients in the sense of Cuntz, Holm, and Jørgensen.

Deep points in cluster varieties and homological mirror symmetry

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Many important algebraic varieties, such as open positroid strata in Grassmannians or augmentation varieties of certain Legendrian links, are known to admit cluster structures. In particular, each such variety is covered, up to codimension 2, by a collection of overlapping open tori. In this talk, I will discuss the "deep locus" of a cluster variety, that is, the complement to the union of all cluster toric charts. I will explain a conjectural relation between the deep locus and the natural torus action compatible with the cluster structure. For many positroid strata in $\mathrm{Gr}(2, n)$ and $\mathrm{Gr}(3, n)$, and for cluster varieties of types ADE with principal coefficients, this relation is made precise: we show that the deep locus consists precisely of the points with non-trivial stabilizer for this action. If time permits, I will explain how we combine this with earlier work of M. Castronovo to establish the homological mirror symmetry for $\mathrm{Gr}(2, 2k + 1)$.

The talk is based on joint work in progress with Marco Castronovo, José Simental, and David Speyer.

Extended defect TQFTs

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According to the cobordism hypothesis with singularities, fully extended topological quantum field theories with defects are equivalently described in terms of coherent full duality data for objects and (higher) morphisms as well as appropriate homotopy fixed point structures. We discuss the 2-dimensional oriented case in some detail and apply it to truncated affine Rozansky-Witten models, which are under very explicit computational control thanks to the prominence of matrix factorisations.

A description of singularity categories via dg Leavitt path algebras

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We show that the singularity category of any finite dimensional algebra (given by a quiver with relations) is triangle equivalent to the perfect derived category of a dg Leavitt path algebra. This generalises the well-known result by Chen-Yang and Smith for singularity categories of radical-square-zero algebras. We also provide a deformation-theoretic perspective of our result. This is a joint work with Xiao-Wu Chen.

How to get rid of pointings for constructing TFTs

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Factorization algebras – which you can think of as a multiplicative version of a cosheaf – were designed to encode the structure of the observables of a quantum field theory. They generalize algebras, pointed bimodules, (possibly braided) tensor categories, Gerstenhaber algebras, and E_n-algebras. Factorization algebras automatically are pointed objects, coming from including empty sets into any other space or open set.

On the other hand, dualizability and higher versions thereof appear centrally when studying fully local versions of topological field theories described via the Atiyah–Segal functorial approach. Vector spaces having "duals" are automatically finite dimensional, and this is the case for those appearing as values of TFTs. However, if we assume that the vector spaces are pointed, they are automatically one dimensional (lines).

We will give a gentle introduction to factorization algebras and explain a modification of factorization algebras allowing to get rid of the pointings. This is the key ingredient to proving a conjecture by Lurie about extended field theories.

A discontinuous Galerkin method based on polytopal grids for the multiphysics modeling of the cerebrospinal fluid

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The Cerebrospinal Fluid (CSF) plays a crucial role in brain physiology and neurodegenerative diseases, e.g. due to its waste clearance function. This study focuses on the modeling of CSF dynamics in the brain, coupling its filtration through the cerebral tissue and its flow in three-dimensional regions like the ventricles. Additionally, CSF generation is closely linked to blood perfusion in the brain. In particular, we propose a multiphysics model that combines dynamic Multiple-Network Poroelastic (MPE) equations for tissue poromechanics [1] and Navier-Stokes equations [2] for three-dimensional CSF flow.

The MPE model takes into account multiple scales of blood vessels and the extracellular component of CSF, with interface conditions describing the exchange of mass and stress at a physiological level [3]. To accurately represent the intricate interface geometry between the two physical domains, a discontinuous Galerkin method based on polytopal grids is introduced for the spatial discretization of the model. We present an a priori analysis of this method, expanding on [1] by incorporating interface terms.

For the time discretization, a combination of the Newmark β-method and the θ-method is utilized. Verification tests are conducted using simplified and realistic geometries, along with patient-specific simulations based on magnetic resonance images.

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Exploring role of accessory pathway location and timing in Wolff-Parkinson-White syndrome in a model of whole heart electrophysiology using global sensitivity analysis

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Wolff-Parkinson-White syndrome is characterized by the presence of at least one fast-conducting accessory pathway (AP) facilitating abnormal electrical conduction between the atria and ventricles in the heart. To better guide and expedite ablation of the AP in clinical practice, preprocedural localization using diagnostic trees can be performed using the 12 lead electrocardiogram (ECG). Established diagnostic trees, however, lack specificity and fail under more complex manifestations of the disease. Quantifying how the timing and location of APs influence 12 lead ECG morphology could help to improve the diagnostic trees.

We aimed to use global sensitivity analysis to assess how the location of an AP influences the morphology of 12 lead ECG, and thus the clinical localization with a diagnostic tree, using a physiologically-detailed whole heart model of electrophysiology.

In previous work, a physiologically-detailed model of whole heart electrophysiology was built and personalized for a single subject to generate a realistic normal sinus rhythm [1]. A synthetic ECG database was generated by automatically sampling approximately 10k locations of APs across the basal surface at varying ventricular insertion depths using universal ventricular coordinates. Corresponding 12 lead ECGs were computed assuming that the APs were antegrade and led to premature ventricular excitation at a specified time. 12 lead ECGs were evaluated for standard clinical markers and morphology. Global sensitivity analysis based on the entire time signal was performed on the synthetic ECG database [2].

In the synthetic ECG database, expected morphological features are present within the 12 lead ECGs for the single subject at various AP locations. In right-sided APs, second-order sensitivities dominate and indicate that the limb and Goldberger leads are primarily influenced by a joint contribution of time and rotational placement. In left-sided APs, the highest first-order sensitivities are observed in leads I and V4 due to variations in excitation time. Second-order sensitivities indicate a joint contribution of both time and ventricular insertion depth strongly influences V4, whereas time and rotational placement jointly influence lead III.

[1] K. Gillette, *et al.*, A Personalized Real-time Virtual Model of Whole Heart Electrophysiology, *Frontiers in Physiology*, **13** (2022).

[2] B. Winkler, *et al.*, Global Sensitivity Analysis and Uncertainty Quantification for Simulated Atrial Electrocardiograms, *Metrology*, **3** (2022),

An electromechanical-torso model for the generation of the electrocardiograms

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The electrocardiogram (ECG) is one of the most commonly-used non-invasive diagnostic technique to gain insights into the electrical behavior of the heart, and detect a broad range of cardiovascular diseases. Being able to compute realistic ECGs, however, is not an easy task due to their high sensitivity on physical, numerical and geometrical parameters. Moreover, the myocardial contraction determines a change in the heart shape and, thus, a corresponding displacement of the electrical sources responsible for the ECG generation. However, the influence of the heart deformation on the ECG have often been overlook in *in silico* models.

In this work we aim at accounting for such deformations proposing a new 3D-0D closed-loop electromechanical-torso model, coupling an electromechanical model for the heart [2] and a generalized Laplace equation to simulate the torso electrophysiology. The displacement of the heart-torso interface surface due to the myocardial contraction, is achieved in the torso domain by means of a lifting method, whereas the corresponding effect on the torso electrophysiology is included by incorporating mechano-electric feedbacks in the generalized Laplace equation. Differently from previous work [1], we solve

the EMT model on static *reference configurations* of the cardiac and torso domains, thus avoiding online remeshing at each time step of the numerical simulation. Moreover, we implement a suitable segregated-intergrid-staggered numerical scheme to handle the different space-time scales required by the different core models involved [2].

Numerical tests are carried out on a realistic 3D in-silico biventricular geometry and on a realistic torso. Both healthy and pathological conditions, e.g. ventricular tachycardia, are simulated considering either static of moving domains. Fairness of the comparison is ensured by prescribing the same numerical and parameters setting in all simulations.

[1] R. Moss, *et al.*, A Fully-Coupled Electro-Mechanical Whole-Heart Computational Model: Influence of Cardiac Contraction on the ECG, *Frontiers in Physiology*, **12** (2021).

[2] R. Piersanti, *et al.*, 3D-0D closed-loop model for the simulation of cardiac biventricular electromechanics, *Computer Methods in Applied Mechanics and Engineering*, **391** (2022), 701–712-

Three lessons learned about the epidemiological models during SARS-CoV-2 pandemics

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Historically, traditional compartmental models have been highly effective in explaining the dynamics of epidemics. However, the recent pandemic has exposed numerous shortcomings and deviations from the assumptions made by these models. In this talk, we will share three significant lessons that we have gleaned from analyzing both global pandemic statistics and the outcomes of a unique mass testing initiative conducted in Slovakia during the autumn of 2020. We demonstrate that the data suggests an apparent gradual decline of the reproduction number over time during individual waves of the pandemic, following an algebraic decay pattern. Additionally, our analysis reveals that the spatial distribution of incidence exhibits an exponential nature. We also investigate statistical properties of fragmented random networks, shedding light on how the notion of herd immunity, often assumed by a broad range of compartmental models, falters in a scenario that is anticipated during the ongoing pandemic.

Dynamic maximum entropy approximation for understanding complex stochastic dynamics

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Realistic models of biological processes typically involve interacting components on multiple scales, driven by changing environment and inherent stochasticity. Such models are often analytically and numerically intractable. I will present a dynamic maximum entropy (DME) method, which approximates the full dynamics by a low-dimensional system of ODEs describing the system. The method circumvents the problem of closing an infinite hierarchy of moment equations by choosing a suitable set of functions, whose averages are followed in time. Using a quasi-stationarity assumption, the problem reduces to low-dimensional dynamics, which show great accuracy even in non-stationary problems. While estimating accuracy of the method is still an open problem (I will indicate why), I will present a couple of applications ranging in complexity where: (1) the approximation recovers the exact solution, (2) the approximation is accurate but not exact, (3) the approximation fails.

Pushed and pulled waves in population genetics

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This talk is motivated by the stochastic F-KPP equation with Allee Effect

$$\partial_t u \;=\; \frac{1}{2}\partial_{xx} u + u(1-u)(1+Bu) + \sqrt{\frac{1}{N}u(1-u)}\eta$$

where η is a space-time white noise. Numerical results and heuristics by Physicists suggest the existence of an interesting phase transition between a pulled, a semi pushed and a fully pushed regime. First, I will start with a brief explanation of the three regimes and their biological implications. I will then introduce a toy model which mimics the qualitative behavior of the aforementioned model. This is a class of critical branching Brownian motions with inhomogeneous branching rates which can be treated analytically using recent methods which are interesting on their own (moments of random trees, k-spines). This is joint work with J. Tourniaire (University of Vienna/ISTA) and Felix Foutel-Rodier (Oxford).

Cross-diffusion system driven by populations structured by dietary diversity

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Cross-diffusion systems are nonlinear parabolic systems that model the evolution of densities or concentrations of multi-component populations in interaction. In this talk, we study the evolutionary dynamics of two species in competition, modeled by a triangular cross-diffusion system driven by dietary diversity. More precisely, we show the existence of weak solutions by rigorously proving the passage from an approximating Lotka-Volterra reaction-diffusion system with linear diffusion, towards a cross-diffusion system at the fast reaction limit. The resulting limit yields a cross-diffusion system of starvation-driven type. The main tools used to pass to the limit rigorously involve a priori estimates, given by the analysis of a family of entropy functionals, and compactness arguments. This work is based on [1, 2].

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Bifurcations in collective dynamics: ordered and disordered behaviour in models for collective behavior and emergent phenomena

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In this talk, I will review some questions that arise around the classical Vicsek model – which is a model for collective dynamics where agents move at a constant speed while trying to adopt the averaged orientation of their neighbours, up to some noise. I will discuss the emergence of bifurcations leading to disordered and ordered motion, depending on the local density of the agents. This is a very interesting phenomenon: it showcases how two completely different observed behaviours can appear simultaneously from agents that interact following the same rules.

Spatially heterogeneous reaction-diffusion equations arising from applications

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Real-world applications often have spatially heterogeneous features that affect the dynamical behavior. Mathematical models provide insight into the change of behavior due to the spatially heterogeneous mechanisms. In this talk, I present reaction-diffusion models for different applications where the spatial heterogeneous part is crucial. First, a model for the dynamics during liver inflammation is presented. The spatially heterogeneous mechanisms is a non-local integral term, changing the system's behavior from decaying to the trivial solution towards a stationary heterogeneous steady state. Second, the traveling wave of mosquito-spread is stopped by a space-dependent intervention term. Third, in a comparable setting but with different mechanisms, the spread of a wildfire is modeled. The spatial heterogeneous landscape influences the speed of propagation of the fire front. Depending on the width of a low-biomass sector, firebreaks may stop the propagation.

Investigations into the sensitivity of the system's behavior with respect to the heterogeneous mechanism and numerical simulation give impressions of the importance of the mechanisms. Further, analytical results for selected scenarios prove the influence of the spatially heterogeneity.

Continuum Model for Volume Exclusion Particle Interactions via Anisotropic Repulsion Potentials

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Volume exclusion interactions play a key role in many biological systems. In particular, it seems to be the key to explaining spontaneous alignment of anisotropic particles, for example, alignment of myxobacteria or fibers in a network. Most individual-based models impose this type of alignment in their equations. Here we do not wish to impose this type of alignment, but to investigate how it might emerge from volume exclusion interactions.

To carry this out, volume exclusion interactions will be modelled via a soft anisotropic repulsion potential (which are vastly used in the literature of liquid crystals). We will present an individual-based model based on this potential and derive the corresponding kinetic and macroscopic equations. This approach allows us to understand how alignment emerges from volume exclusion and how it also affects not only the orientation of the particles, but also their positions.

Diffusion limits of the Boltzmann multi-species equation through perturbation of hypocoercivity

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We present the rigorous derivation of hydrodynamic limits of the Boltzmann equation modelling inert or reactive gaseous mixtures, when the Mach and Knudsen numbers vanish at the same rate. Solutions of the kinetic system are constructed as fluctuations around local (possibly non-equilibrium) Maxwellians, whose physical observables solve the limiting macroscopic model of interest. A general hypocoercive formalism is used to develop a uniform (with respect to the small diffusion parameter) Cauchy theory for this perturbative setting. We will discuss two possible applications of the method, to derive the Maxwell–Stefan equations and a four-species reaction–diffusion system.

Parametrized systems of polynomial inequalitites with real exponents via linear algebra and convex geometry

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We consider parametrized systems of generalized polynomial inequalitites (with real exponents) in n positive variables x and involving m monomial terms $c \circ x^B$ (with exponent matrix B, positive parameters c, and component-wise product $\circ$). More generally, we study solutions $x \in \mathbb{R}^n_>$ to $(c \circ x^B) \in C$ for a "coefficient" cone $C \subseteq \mathbb{R}^m_>$. Our framework encompasses systems of generalized polynomial equations, as studied in real fewnomial and reaction network theory.

We identify the relevant geometric objects of the problem, namely a bounded set P arising from the coefficient cone and two subspaces representing monomial differences and dependencies. The dimension of the latter subspace (the monomial dependency d) is crucial.

As our main result, we rewrite the problem in terms of d binomial equations on the "coefficient" set P, involving d monomials in the parameters. If $d = 0$, solutions exist (for all positive c) and can be parametrized explicitly, thereby generalizing monomial parametrizations (of the solutions). Even if $d > 0$, solutions on the coefficient set can often be determined more easily than solutions of the original problem.

Our theory allows a unified treatment of multivariate polynomial inequalities, based on linear algebra and convex geometry. We demonstrate its novelty and strength in applications to real fewnomial and reaction network theory.

Rigorous derivation of Michaelis-Menten kinetics in the presence of diffusion

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Reactions with enzymes are critical in biochemistry, where the enzymes act as catalysis in the process. One of the most used mechanisms for modeling enzyme-catalyzed reactions is the Michaelis-Menten (MM) kinetic. In the ODE level, i.e. concentrations are only on time-dependent, this kinetic can be rigorously derived from mass action law using quasi-steady-state approximation. This issue in the PDE setting, for instance when molecular diffusion is taken into account, is considerably more challenging and only formal derivations have been established. In the talk, which is based on [1], we prove this derivation rigorously and obtain MM kinetic in the presence of spatial diffusion. In particular, we show that, in general, the reduced problem is a cross-diffusion-reaction system. Our proof is based on improved duality method, heat regularisation and a suitable modified energy function. To the best of our knowledge, this work provides the first rigorous derivation of MM kinetic from mass action kinetic in the PDE setting.

[1] Bao Quoc Tang, Bao-Ngoc Tran, Rigorous derivation of Michaelis-Menten kinetics in the presence of diffusion, https://arxiv.org/pdf/2303.07913.pdf

The Hypocoercivity Index for the short time behavior of linear time-invariant ODE systems

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We consider the class of conservative-dissipative ODE systems, which is a subclass of Lyapunov stable, linear time-invariant ODE systems. We characterize asymptotically stable, conservative-dissipative ODE systems via the hypocoercivity (theory) of their system matrices. Our main result is a concise characterization of the hypocoercivity index (an algebraic structural property of matrices with positive semi-definite Hermitian part introduced in *Achleitner, Arnold, and Carlen (2018)*) in terms of the short time behavior of the norm of the matrix exponential for the associated conservative-dissipative ODE system.

[1] F. Achleitner, A. Arnold, and E.A. Carlen, On multi-dimensional hypocoercive BGK models, *Kinet. Relat. Models* **11** (2018), no. 4, 953–1009.

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Oscillatory behaviour of a Becker-Döring type model and insights into prion dynamics

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Prions are able to self-propagate biological information through the transfer of structural information from a misfolded/infectious protein in a prion state to a protein in a non-prion state. Prions cause diseases like Creuzfeldt-Jakob. Prion-like mechanisms are associated to Alzheimer, Parkinson ans Huntington diseases. We present a fundamental bi-monomeric, nonlinear Becker-Döring type model, which aims to explain experiments in the lab of Human Rezaei showing sustained oscillatory behaviour over multiple hours, [1]. Besides two types of monomers, our model suggests a nonlinear depolymerisation process as crucial for the oscillatory behaviour. Since then, experimental evidence seems to confirm this process. We provide details on the mechanism of oscillatory behaviour and show numerical simulations.

[1] M. Doumic, K. Fellner, M. Mezache, H. Rezaei, A bi-monomeric nonlinear Becker-Döring type system to capture oscillatory aggregation kinetics in prion dynamics, *Journal of Theoretical Biology*, **480** (2019) 241–261.

Fractional diffusion: Modelling and numerical approximation

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This talk discusses diffusion processes beyond Brownian motion and their description by nonlocal differential operators, such as the fractional Laplacian. The long range movement of certain organisms in the presence of a chemoattractant can be governed by long distance runs, according to an approximate Levy distribution. Starting from a microscopic velocity-jump model for the movement, we derive nonlocal Patlak-Keller-Segel equations for the macroscopic evolution of the density. For their numerical simulation, recent analytic results for fractional PDEs give rise to efficient finite element methods. We survey our recent work on the modelling and numerical analysis, including applications to the movement of immune cells and the design of swarm robotic systems.

Resolving singularities in parabolic initial-boundary value problems

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We consider a time-dependent reaction-diffusion equation with a singularity arising from incompatible initial and boundary conditions:

$$u_t - u_{xx} + b(x,t)u = f \qquad \text{in } (0,\ell)\times(0,T],$$

subject to boundary conditions

$$u(0,t) = \phi_0(t), \quad u(\ell,t) = \phi_\ell(t), \quad t\in(0,T],$$

and the initial condition

$$u(x,0) = 0, \qquad x\in(0,\ell)\,,$$

with $\phi_0(0)\neq 0$.

The discrepancy between initial and boundary conditions causes the formation of a singularity in the vicinity of the corner $(0,0)$. This singularity s can be characterised as the solution of

$$s_t - s_{xx} + b(0,0)s = 0 \qquad \text{in } \ (0,\infty)\times(0,T],$$

subject to the boundary condition

$$s(0,t) = \phi_0(0), \quad t\in(0,T],$$

and the initial condition

$$s(x,0) = 0, \qquad x\in(0,\infty)\,.$$

This in turn can be given analytically using the error function.

Now, the interesting question is: How can the remainder $y = u - s$ be resolved numerically?

We derive bounds on the derivative of y — under significantly less restrictive assumptions then previously assumed by other authors — and show how a numerical approximation can be obtained using an appropriately designed mesh.

Hypocoercivity in Hilbert Spaces

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The concept of hypocoercivity for linear evolution equations with dissipation is discussed and equivalent characterizations that were developed for the finite-dimensional case are extended to separable Hilbert spaces. Using the concept of a hypocoercivity index, quantitative estimates on the short-time and long-time decay behavior of a hypocoercive system are derived. As a useful tool for analyzing the structural properties, an infinite-dimensional staircase form is also derived. The results are applied to the Lorentz kinetic equation.

Novel approaches for the reliable and efficient numerical integration of the Landau equation

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When applying Hamiltonian operator splitting methods for the time integration of multi-species Vlasov–Maxwell–Landau systems, the reliable and efficient numerical approximation of the Landau equation represents a fundamental component of the entire algorithm. Substantial computational issues arise from the treatment of the physically most relevant three-dimensional case with Coulomb interaction.

In this talk, novel approaches for the evaluation of the Landau collision operator will be introduced. In the spirit of collocation, common tools are the identification of fundamental integrals, series expansions of the integral kernel and the density function on the main part of the velocity domain, and interpolation as well as quadrature approximation nearby the singularity of the kernel. Focusing on the favourable choice of the Fourier spectral method, their practical implementation uses the reduction to basic integrals, fast Fourier techniques, and summations along certain directions. Moreover, an important observation is that a significant percentage of the overall computational effort can be transferred to precomputations which are independent of the density function.

For the purpose of exposition and numerical validation, the cases of constant, regular, and singular integral kernels are distinguished, and the procedure is adapted accordingly to the increasing complexity of the problem. With regard to the time integration of the Landau equation, the most

expedient approach is applied in such a manner that the conservation of mass is ensured.

Extremal Combinatorics in Julia

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Flag algebras, first introduced by Alexander Razborov in 2007 [1], are a systematic tool to attack problems in extremal combinatorics. We introduce the Julia software package `FlagSOS.jl`, with the goal of making the method more accessible, flexible, efficient and generalizable. The package implements various flag sums-of-squares hierarchies and extensions as described in the thesis of the author [2], such as the fully symmetry-reduced Lasserre and Razborov hierarchies in finite and asymptotic settings. In contrast to existing packages (such as Flagmatic [3]), the implementation is not for a specific flag algebra, but instead implemented in a generic fashion (based on Razborov's model theoretic approach), making use of Julia's multiple dispatch paradigm. In this talk I will, after a quick introduction to the method, showcase a few applications of the package, such as to directed graphs without directed cycles, error correcting codes, and limits of phylogenetic trees.

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Extracting Coefficient Diagonals of Rational Multivariate Generating Functions in SageMath

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For a wide range of problems in enumerative combinatorics, sequences of interest (like a counting sequence or a sequence modeling a given parameter associated to a given discrete structure) can be encoded as diagonals of rational generating functions. That is, given multivariate polynomials $G(\mathbf{z})$ and $H(\mathbf{z})$ we are interested in the coefficients of the generating function

$$F(\mathbf{z}) = \frac{G(\mathbf{z})}{H(\mathbf{z})} = \sum_{j_1,\ldots,j_d \geq 0} f_{j_1,\ldots,j_d} z_1^{j_1} \cdots z_d^{j_d}$$

along a given direction $\mathbf{r} \in \mathbb{N}^d$, i.e., $(f_{nr_1,\ldots,nr_d})_{n\geq 0}$.

While the univariate case is well understood and a rich toolbox for extracting coefficients (asymptotically) is available [1], as a consequence of the more complicated geometry of the variety describing singular points, (asymptotic) extraction is more delicate in the multivariate case [2].

In this talk, we will discuss a basic systematic approach (developed within the *Analytic Combinatorics in Several Variables* framework) which allows — under mild conditions with respect to $F(\mathbf{z})$ — to extract the asymptotic growth of the coefficient array along a given diagonal. In particular, we will introduce the recently developed `sage_acsv` module [3] for the computer mathematics system SageMath, which allows to do the required computations automatically and rigorously.

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Regular Sequences and their Implementation in SageMath

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Regular Sequences have been introduced by Allouche and Shallit [1]: the elements of a regular sequence can be described as matrix products depending on the digit expansion of the index. Prominent examples are the sum of digit function and sequences induced by the divide-and-conquer paradigm.

In this talk, we will discuss definitions and examples of regular sequences (and a related variant, recursive sequences [2]) and their implementation in the open source software system SageMath.

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[2] C. Heuberger, D. Krenn, G. F. Lipnik. Asymptotic analysis of q-recursive sequences. *Algorithmica* **84** (2022), 2480–2532.

From integral schemes to factorizations and back

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In this talk, I will emphasize a possible connection of geometric properties of integral schemes and the behaviour of multiplicative factorizations of the elements of their local and global rings as products of irreducible elements. The linking piece between the two supposedly unrelated topics is the theory of divisors.

Samuel conjectured in 1961 that a (Noetherian) local complete intersection ring which is a UFD (unique factorization domain) in codimension at most three is itself a UFD. It is said that Grothendieck invented local cohomology to prove this fact. Following the philosophy that a UFD is nothing else than a normal domain with trivial divisor class group, I will talk about the following generalization:

Suppose that A is a normal domain and a complete intersection. Then the divisor class group of A is a subgroup of the projective limit of the divisor class groups of the localizations A_p, where p runs through all prime ideals of height at most 3 in A.

Implications of this result on the relation of Weil and Cartier divisors of integral separated Noetherian schemes are presented.

Moreover, based on a seemingly forgotten theorem of Samuel from the 60s, I will propose a connection (again via divisors) between the existence of rational points on an algebraic variety and non-unique factorizations of its coordinate ring.

MSC: primary: 14M10, 13C40; secondary: 13H10, 14C22, 13F05, 13C20

Restricted Edge Connectivity of Alternating Group Graphs

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For a positive integer n, an n-alternating group graph is constructed from the alternating group of degree n and is denoted as AG_n. In this research, we study restricted edge-cut sets and the related restricted edge-connectivity of the alternating group graphs AG_n. For a positive integer m, a subset S of the edge set of AG_n is called a restricted edge-cut of order m if $G-S$ is disconnected with each component consisting of at least m vertices. The m-restricted edge-connectivity of G is the minimum cardinality of all the restricted edge-cuts of order m, denoted $\lambda_m(G)$. We give formulas for the $\lambda_m(AG_n)$ for all $n \in \mathbb{Z}$ when m is small. In particular, we prove that $\lambda_3(AG_n) = 6n-18$, $\lambda_4(AG_n) = 8n-24$, and $\lambda_5(AG_n) = 10n-32$.

On the finiteness or otherwise of the number of groups containing a fixed number of nonpower subgroups

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A subgroup H of a group G is called a *power subgroup* of G if there exists a non-negative integer m such that $H = \langle g^m : g \in G \rangle$. Any subgroup of G which is not a power subgroup is called a *nonpower subgroup* of G. In 2007, Zhou, Shi and Duan proved that cyclic groups have no nonpower subgroups, and infinite non-cyclic groups have infinite nonpower subgroups. They showed further that no group has exactly 1 or exactly 2 nonpower subgroups, and then asked: for each integer k greater than 2, does at least one group possess exactly k nonpower subgroups? In this talk, we answer this question affirmatively and also show the finiteness or otherwise of the number of groups that contain a fixed number of nonpower subgroups.

Upper and lower bounds for Riesz and Green energies on projective spaces

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We study Riesz, Green and logarithmic energy on two-point homogeneous spaces. More precisely we consider the real, the complex, the quaternionic and the Cayley projective spaces. For each of these spaces we provide upper estimates for the mentioned energies using determinantal point processes. Moreover, we determine lower bounds for these energies.

Recent Progress on Discrepancy and WCE of constructible point sets on spheres

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We report on our recent results on the L_2-discrepancy and worst-case error (and compare them with optimal bounds) for constructible N-point sets that arise from mapping rational lattice points in the plane to the sphere using an area preserving Lambert transformation. In particular, we consider spherical Fibonacci point configurations defined by a Fibonacci lattice in the unit square.

MSC: 11K38, 65D30, 65C05

Polyharmonic functions on the Poincaré disk

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We consider the open unit disk $\mathbb{D}$ equipped with the hyperbolic metric and the associated hyperbolic Laplacian $\mathfrak{L} = \frac{(1-r^2)^2}{4}\Delta$. For $\lambda \in \mathbb{C}$ and $n \in \mathbb{N}$, a λ-polyharmonic function of order n is a function $f : \mathbb{D} \to \mathbb{C}$ such that $(\mathfrak{L} - \lambda\, I)^n f = 0$. If $n = 1$, one gets λ-harmonic functions. Based on a Theorem of Helgason on the latter functions, we prove a boundary integral representation theorem for λ-polyharmonic functions. For this purpose, we first determine n^{th}-order λ-Poisson kernels. Subsequently, we introduce the polyspherical functions and determine their asymptotics at the boundary $\partial\mathbb{D}$, i.e., the unit circle. They are used to normalise the n^{th}-order Poisson kernels and to study the boundary behaviour of λ-polyharmonic functions, starting with Dirichlet and Riquier type problems and then proceeding to Fatou type admissible boundary limits.

MSC: 31A30 43A85 58J32

Analyticity of solutions to fractional partial differential equations

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In this talk, we explore the topic of analyticity of solutions to elliptic equations in a fresh context, tracing back to Hilbert's 19th problem. While Bernstein's work in 1904 yielded early results for classical elliptic partial differential equations, fractional and non-local equations have remained less explored, with limited results available, mostly restricted to special cases like the Hartree-Fock and Boltzmann equations.

We will present known results before delving into our recent discoveries, spanning from unique fractional equations related to knot energies to semi-linear and completely non-linear integro-differential equations, encompassing s-minimal surfaces. Central to our findings is the use of novel refined estimates that account for the long-range interactions within these equations.

Singular Sobolev spaces and applications to degenerate elliptic PDE

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We present the notion of *Singular Sobolev space* $L^p_w(\Omega)$, which is the space of all measurable functions $u : \Omega \longrightarrow \mathbb{R}$ such that $wu \in L^p(\Omega)$, where $w : \Omega \longrightarrow \mathbb{R}$, $w \neq 0$ a.e. on Ω, is called *eliminate (singularities) function*. Note that $L^p_w(\Omega) = L^p(\Omega, |w|^p)$, i.e. $L^p_w(\Omega)$ is the weighted Sobolev space with the weight function $|w|^p$. Unlike in weighted Sobolev spaces, elements of $L^p_w(\Omega)$ are not assumed to be locally integrable. This justify the term "singular" in the name of the space $L^p_w(\Omega)$. In this setting, the notion of weak or distributional derivative is hence not well defined. We then define the notion of *weak-derivative in the sense of* $L^1_{w,\text{loc}}(\Omega) := \{u \mid wu \in L^1_{\text{loc}}(\Omega)\}$, which is the equivalent of the weak-derivative in the sense of $L^1_{\text{loc}}(\Omega)$, i.e. using an integration by part formula with appropriate test functions which guarantees that both sides of the formula are always finite.

For a familly $\{w_\alpha\}_\alpha$ of eliminate functions, we then consider the subspace $W^{m,p}_{\{w_\alpha\}}(\Omega)$ of $L^p_w(\Omega)$ of those functions whose weak derivative in the sense of $L^1_{w,\text{loc}}(\Omega)$ exists and belongs to $L^p_{w_\alpha}(\Omega)$ for all multi-index α with $|\alpha| \leq m$, and prove its completeness. We also define the trace operator Tr on $W^{1,p}_{\{w_\alpha\}}(\Omega)$ (which takes values either on $L^p(\partial\Omega)$ or in $L^p_w(\partial\Omega)$ depending on the assumptions satisfied by the function w).

The main aim of this construction is the study of the following Cauchy problem

$$\begin{cases} -\sum_{i,j=1}^{d} D^j(a_{ij}D^i u) + (b\cdot D)u + cu = f \text{ on } \Omega \\ \mathrm{Tr}(u) = 0 \text{ on } \partial\Omega \end{cases} \tag{1}$$

where the bilinear form $\sum_{i,j=1}^{d} a_{ij}\xi_i\xi_j$ is positive (almost everywhere in Ω, and for all $\xi := (\xi_1, ..., \xi_d) \in \mathbb{R}^d$) and degenerates on some negligible set N of Ω.

The solution of problem (1) is generally sought on weighted Sobolev space (see [3] and reference therein) or on Degenerate Sobolev space (see [4]). Since elements of these two types of spaces are necessary locally integrable, the solution (when it exists) is necessary locally integrable as well.

In our paper, we will seek the solution of (1) in $H^1_{\{w^{|\alpha|+1}\},0}(\Omega) := W^{1,2}_{\{w^{|\alpha|+1}\},0}(\Omega)$ which is the subspace of $W^{1,2}_{\{w^{|\alpha|+1}\}}(\Omega)$ whose elements have a null trace (in general, the solution is not necessary locally integrable). The main tool used is the Lax-Milgram theorem in the Hilbert space $H^1_{\{w^{|\alpha|+1}\},0}(\Omega)$. Additional tools like Poincaré inequality (adapted to our framework) and density of compactly supported smooth functions (in $H^1_{\{w^{|\alpha|+1}\},0}(\Omega)$) have been proved.

Moreover, we also show that the solution of (1) satisfies the differential equation in the sense of $\mathcal{D}'(\Omega\backslash N)$ as well.

Finally, we establish the interior elliptic regularity, that is, the solution u is in $H^{m+2}_{\mathrm{loc}}(\Omega\backslash N)$ provided that the coefficients are in $\mathcal{C}^{m+1}(\Omega\backslash N)$ and $f \in H^m_{\mathrm{loc}}(\Omega\backslash N)$.

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Computing upper probabilities of failure using global optimization algorithms together with importance sampling and reweighting

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Let a family $(f_t)_{t \in T}$ of smooth density functions f_t (e.g. $f_t \sim \mathcal{N}(\mu(t), \Sigma(t))$) be given to describe the uncertainty about the values of parameters x of an engineering structure (geometrical and material properties) in the case where the use of one single distribution is not sufficient enough. Further, let D be the set of all parameter values x leading to failure of the structure. Then the upper probability $\overline{p}_f$ of failure is the solution of a global optimization problem $\overline{p}_f = \max_{t \in T} p(t)$ with objective function $p(t) = \int \mathrm{I}_D(x) f_t(x)\,\mathrm{d}x$. The probabilities $p(t)$ are estimated using Monte Carlo simulation which means to evaluate the expensive indicator function I_D of set D (finite element computations) for each of N sample points. Since in addition a global optimization algorithm requires a large number of function evaluations $p(t_1), p(t_2), \ldots$ the computational effort is very high. In our presentation we use importance sampling and reweighting techniques [1,2,3] for computing the derivatives needed in the global optimization algorithms and for significantly reducing the sample sizes N_k for estimating $p(t_k)$ by means of recycling the samples used for previous estimates $p(t_i)$, $i < k$. An engineering example will demonstrate the new approach.

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Regularized Radon-Nikodym differentiation

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We discuss the problem of estimating of Radon-Nikodym derivatives. This problem appears in various applications, such as covariate shift adaptation, likelihood-ratio testing, mutual information estimation, and conditional probability estimation. To address the above problem, we employ the general regularization scheme in reproducing kernel Hilbert spaces. The convergence rate of the corresponding regularized algorithm is established by taking into account both the smoothness of the derivative and the capacity of the space in which it is estimated. This is done in terms of general source conditions and the regularized Christoffel functions. We also find that the reconstruction of Radon-Nikodym derivatives at any particular point can be done with high order of accuracy. Our theoretical results are illustrated by numerical simulations.

Numerical approximation of Dynkin games with asymmetric information

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A Dynkin game is a gametheoretical version of an optimal stopping problem that was first introduced by Dynkin [1]. The game is set up between two players A and B. Each Player can stop the game at any time for an observable payoff. If a player chooses to stop the game, B receives some premium from A. In such a game, B attempts to maximize the amount he receives, while A tries to minimize the payout. Typically, the value of this game is a solution of a Hamilton–Jacobi–Bellman equation with two obstacles that characterizes the upper-lower limit that can take the value of the game and at which the game has to stop. In [2], Grün considered the case where one player is informed about the payoff, while the other one only knows it up to a certain probability vector p. In this configuration, a third obstacle appears. It characterizes the fact that the value of the game has to be convex or concave with respect to the probability vector p.

In this work, we propose a Feedforward Neural Network approximation of the the value of the game. The target solution depends on three variables: Time, the spatial variable, and a variable living in a symplex and representing the probability that a possible configuration of the game is played. Firstly, by relying on the probabilistic representation of the solution to the constrained PDE problem, we construct a semi-discrete

scheme with respect to time and the probability variable, and we analyze its convergence in the viscosity sense towards the target solution. Then, as a byproduct, we deduce the convergence of the Feedforward Neural Network approximation under consideration.

MSC: 65K15, 65C20, 49N70, 49L25, 35F21, 52A27, 52B55

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Weak and classical solutions to an asymptotic model for atmospheric flows

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In this talk, we present a local well-posedness result (in terms of classical solutions) for a recently derived mathematical model describing nonlinear propagation of waves in the atmosphere. This is achieved by formulating the model as a quasilinear parabolic evolution problem in an appropriate functional analytic framework and by using abstract theory for such problems. Furthermore, for L^2-initial data, we construct global weak solutions by employing a two-step approximation strategy based on a Galerkin scheme, where an equivalent formulation of the problem in terms of a new variable is used.

MSC: 35D30; 35K59; 35Q86

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Digitale Lernressourcen als Brücke zwischen Wissenschaft und Klassenzimmer

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Der Weg von wissenschaftlichen Forschungsergebnissen zu konkreten Mathematikaufgaben ist oft ein langer und beschwerlicher. Mathematikunterricht basiert zu einem großen Teil auf Aufgaben, welche zum Erlernen, Wiederholen und Überprüfen eingesetzt werden. Im Allgemeinen, aber durch die Digitalisierungsinitiative des Bundesministeriums für Bildung, Wissenschaft und Forschung im Speziellen, kommt es in jüngster Vergangenheit zu einem quantitativen Anstieg an digitalen Lernressourcen und Lernumgebungen. Diese Lernressourcen und Lernumgebungen bestehen unter anderem aus multimedialen Erläuterungen und mathematischen Aufgaben, welche mithilfe digitaler Werkzeuge gelöst werden können. Die digitalen Lernumgebungen können zusätzlich die Korrektheit der Aufgaben überprüfen und im Bedarfsfall den Lernenden Hilfestellungen anbieten. Vorteile von digitalen gegenüber konventionellen Lernressourcen sind außerdem, dass ein individualisiertes Lernen erleichtert werden kann und Adaptierungen dieser Lernressourcen schneller vorgenommen werden können. Durch diese Einfachheit und oft Unmittelbarkeit der Adaptierung besteht die Chance, dass der Weg von wissenschaftlichen Forschungsergebnissen zu konkreten Lernobjekten verkürzt wird.

Professionelles Noticing – Wie nehme ich (meinen) Unterricht wahr

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Die professionelle Wahrnehmung von Lehrenden, das sogenannte Teacher Noticing, ist ein zentraler Begriff der heutigen mathematikdidaktischen Forschung. Mit dieser theoretischen „Brille“ kann man den eigenen Blick auf das Unterrichtsgeschehen in den Mittelpunkt stellen und systematisch analysieren. Einerseits ermöglicht bewusstes Noticing einer Lehrperson, sich über die eigenen bewussten und unbewussten Beobachtungsschwerpunkte klarer zu werden — was häufig Einblicke in die Auswirkungen der eigenen Einstellungen und Vorerfahrungen liefert. Andererseits kann man durch themenspezifisches Noticing bewusst trainieren, die eigene Wahrnehmung verstärkt in eine gewünschte Richtung zu lenken. Die Forschung zeigt, dass professionelle Wahrnehmung und professionelles Handeln miteinander korrelieren — weshalb Noticing ein nützliches Werkzeug sein kann, die fachliche Weiterentwicklung als Mathematiklehrperson in die eigenen Hände zu nehmen.

Neue Mathematik für die Schule

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Die Inhalte der Mathematiklehrpläne gehen auch in der Sekundarstufe 2 kaum über die Mathematik des 19. Jahrhunderts hinaus. In diesem Vortrag gehen wir der Frage nach, warum das so ist und diskutieren, ob das auch in Zukunft so bleiben soll und kann. Wir gehen exemplarisch auf einige „moderne" Themen ein, die unserer Ansicht nach großes Potential haben, zu einem zeitgemäßen Mathematikunterricht beizutragen — insbesondere im Sinne einer höheren und fächerorientierten Allgemeinbildung.

Lernumgebungen zur Potenzial- bzw. Begabten- und Begabungsförderung im Regelunterricht des Fachs Mathematik – Eindrücke aus dem Projekt „Leistung macht Schule“

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Die Bund-Länder-Initiative „Leistung macht Schule“ widmet sich in Deutschland seit einigen Jahren der Entfaltung begabungsförderlicher Schulkulturen und der Entwicklung begabungsfördernder Lernumgebungen, für den Regelunterricht im Fach Mathematik wie auch in anderen Fächern. Charakteristisch ist diesbezüglich eine gemeinsame Entwicklungsarbeit von Schulen und Forschenden ebenso wie gemeinsame langfristig und prozessorientiert angelegte formative Evaluationen der gemeinsam entwickelten Produkte. Im Vortrag werden Beispiele ausgewählter Lernumgebungen aus diesem Kontext vorgestellt und diskutiert, insbesondere *offene, substanzielle Problemfelder* und *Blütenaufgaben*.

Das Mathe-mag-ich!-Projekt: Mit und für Mathematik begeistern

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Seit 2022 gibt es an der Universität Graz das Mathe-mag-ich!-Projekt, das Schüler*innen an Projektnachmittagen Freude an der Mathematik vermitteln soll. Hierbei werden Themen und Settings genutzt, die nicht unmittelbar mit Mathematik in Verbindung gebracht werden würden, wie beispielsweise Zaubern, Escape Rooms, Strategiespiele, Origami oder Geheimschriften. Dies soll vor allem auch diejenigen Schüler*innen animieren, die (bisher) nicht viel Interesse an Mathematik haben.

Im Workshop möchte ich einen kleinen Einblick in die Hintergründe der Idee für Mathe-mag-ich! geben und Ihnen eine Mischung von Mathe-mag-ich!-Inhalten vorstellen. Ich will Ihnen zudem die Möglichkeit bieten, den ein oder anderen Inhalt selbst auszuprobieren und Sie vielleicht sogar motivieren, die eine oder andere Aktivität in Ihren Unterricht einzubauen.

Flexibel Mathematik lernen

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In der Praxismittelschule der PH Steiermark lernen die Schüler*innen in einem Kurssystem, das flexible Lernprozesse zulässt. Die Schüler*innen arbeiten selbstständig in einer vorbereiteten Lernumgebung und lernen in einem Wechselspiel aus Input- und Übungsphasen. So ist es möglich, sich unterschiedlich lange mit Themen auseinanderzusetzen und erst dann zu neuen Inhalten überzugehen, wenn die vorhergehenden Lernziele erreicht worden sind.

Im Zuge einer Begleitstudie wurde die Umsetzung des mathematischen Kurssystems in der 5. und 6. Schulstufe im Laufe eines Schuljahres untersucht. Dazu wurden quantitative Datenerhebungen, Interviews und systematische Beobachtungen durchgeführt und Zusammenhänge zwischen Schüler*innenmerkmalen und dem Voranschreiten im Kurssystem analysiert. Die Ergebnisse zeigen, dass viele Schüler*innen vom Kurssystem profitieren. Zeitgleich führt das hohe Maß an Individualisierung aber auch zu neuen Herausforderungen.

Das Fach und die Praxis im Blick – mathematikdidaktische Forschungsansätze, Befunde und Vorschläge für den Unterricht

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Wenn Mathematikdidaktik die Spezifika der fachlichen Gegenstände sowie die Fragen und Rahmenbedingungen der Unterrichtspraxis hinreichend berücksichtigt, kann sie dazu beitragen, Mathematikunterricht besser verstehen und gestalten zu können. Dabei können (und sollten) Lehrkräfte nicht nur beforscht oder für die Erprobung von Konzepten „genutzt“ werden, sondern als Expert:innen für den Unterricht ernst genommen werden.

Im Vortrag werden das Potenzial und die Grenzen entsprechender Forschung und Entwicklung anhand der Ergebnisse aus drei Untersuchungen, die in der Sekundarstufe 1 und 2 durchgeführt wurden, exemplarisch diskutiert. Thematisch geht es dabei um die Einführung der Bruchdivision, die Entwicklung des Tangentenbegriffs und die Verschränkung von sprachlichem und fachlichem Lernen.