Biennial Report

Department of Mathematics
2021 and 2022

TECHNISCHE
UNIVERSITÄT
DARMSTADT

Dear reader,

this biennial report provides a comprehensive overview of the research and teaching activities at the Department of Mathematics at TU Darmstadt during the years 2021 and 2022. These years have sometimes been difficult organizationally and personally due to the COVID 19 pandemic with a strong impact on teaching, in particular. Research, however, stayed strong as can be seen in the following.
A characteristic of our department is the broad area of topics that are covered both in research and teaching. This is, for instance, reflected by the organization into eight diverse working groups: Algebra, Analysis, Applied Geometry, Didactics and Pedagogics of Mathematics, Logic, Numerical Analysis and Scientific Computing, Optimization and Stochastics. The research activities are demonstrated by several joint research endeavors like Collaborative Research Centers, e.g., the SFB/Transregio GAUS ("Geometry and Arithmetic of Uniformized Structures"), as well as Graduate Schools, LOEWE centers, and, last but not least, a large number of personal contacts.
Inter-disciplinary work, for instance in cooperation with mechanical and electrical engineering, forms one of the main pillars of research at our department. We are also very well connected to other research groups – at the TU Darmstadt, in the Rhein-Main-Neckar area, within Germany, and far beyond. As such, our department is one of the largest and strongest departments of mathematics in Germany.
The wealth of research areas is also represented in the different teaching activities. On the one hand, we provide several well established degrees in mathematics, including the English master in mathematics. Moreover, our department offers a significant number of courses for thousands of students in each semester, mostly coming from other departments at the TU Darmstadt. In all of the these courses, we are dedicated to excellent and innovative teaching.
The present report is meant to provide information about all research and teaching activities, about publications and prizes, presentations and events, from every single graduation thesis to our activities for high schools, and many other details that taken together represent our work in the last two years. We hope that this report forms an interesting and enjoyable reading experience.

With kind regards,

Marc Pfetsch

Prof. Dr. Marc Pfetsch
(Dean of the department)

Contents

1 Research Groups

This section gives a brief overview of the research done in the eight research groups.

1.1 Algebra

The main research areas of this group are algebraic geometry, arithmetic geometry, number theory and conformal field theory.
We are interested in arithmetic moduli spaces and automorphic forms and their applications in geometry and arithmetic.

Members of the research group

Professors

Jan Hendrik Bruinier, Yingkun Li, Timo Richarz, Nils Scheithauer, Torsten Wedhorn

Retired professors

Karl-Heinrich Hofmann

Postdocs

Gabriele Bogo, Moritz Dittmann, Thomas Driscoll-Spittler, Konstantin Jakob, Christina Röhrig, Fabio Tanania, Can Yaylali, Riccardo Zufetti

Research Associates

Patrick Bieker, Rizacan Ciloglu, Johannes Buck, Anton Güthge, Paul Kiefer, Christopher Lang, Catrin Mair, Ingmar Metzler, Manuel Müller, Felix Pennig, Paul Siemon, Thibaud van den Hove, Janik Wilhelm

Secretaries

Renate Drießler, Ute Fahrholz, Anja Spangenberg

Project: Higher automorphic Green functions

In this project we investigate automorphic Green functions on orthogonal Shimura varieties at higher integral values of the spectral parameter.
Gross and Zagier conjectured that the CM values (of certain Hecke translates) of the automorphic Green function $G_s(z_1, z_2)$ for the elliptic modular group at positive integral spectral parameter s are given by logarithms of algebraic numbers in suitable class fields. In joint work with S. Ehlen and T. Yang we prove a partial average version of this conjecture, where we sum in the first variable z_1 over all CM points of a fixed discriminant d_1 (twisted by a genus character), and allow in the second variable the evaluation at individual CM points of discriminant d_2. This result is deduced from more general statements for automorphic Green functions on Shimura varieties associated with the group $\mathrm{GSpin}(n, 2)$. We also use our approach to prove a Gross-Kohnen-Zagier theorem for higher Heegner divisors on Kuga-Sato varieties over modular curves.
In subsequent work with Y. Li and T. Yang we complete the proof of the algebraicity conjecture of Gross and Zagier. To this end we construct new analogues of weight 1 incoherent Hilbert Eisenstein series by means of deformed theta integrals.

Partner: S. Ehlen, Universität Köln; T. Yang, University of Wisconsin at Madison

Support: DFG, LOEWE

Contact: J. H. Bruinier, Y. Li

References

[1] C. Alfes-Neumann and M. Schwagenscheidt. On a theta lift related to the Shintani lift. *Advances in Mathematics*, 328:858–889, 2018.

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Project: Arithmetic intersection theory on Shimura varieties

We study special cycles on integral models of Shimura varieties associated with unitary similitude groups of signature $(n-1, 1)$.

In joint work with Howard, Kudla, Rapoport, and Yang we proved that the generating series of arithmetic Kudla Rapoport divisors is an elliptic modular form of weight n with values in the arithmetic Chow group. This can be used to define an arithmetic theta lift from weight n cusp forms to the arithmetic Chow group. As applications, one obtains Gross-Zagier type formulas for heights of CM cycles in this setting as well as a proof of the Colmez conjecture in cases where the CM field is the compositum of a totally real field and an imaginary quadratic field.

The integral model of a unitary Shimura variety carries a universal abelian scheme over it, and the dual top exterior power of its Lie algebra carries a natural hermitian metric. In ongoing work with Howard we express the arithmetic volume of this metrized line bundle, defined as an iterated self-intersection in the Gillet-Soulé arithmetic Chow ring, in terms of logarithmic derivatives of Dirichlet L-functions. Moreover, we compute the arithmetic volumes of Kudla-Rapoport divisors. We show that their generating series is related to a specific weight n elliptic Eisenstein series.

Partner: B. Howard, Boston College; S. Kudla, University of Toronto; M. Rapoport, Universität Bonn; T. Yang, University of Wisconsin at Madison

Support: DFG, NSF, AIM

Contact: J. H. Bruinier

References

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[3] J. H. Bruinier, B. Howard, S. Kudla, M. Rapoport, and T. Yang. Modularity of generating series of divisors on unitary Shimura varieties II: arithmetic applications. *Astérisque*, 421:127–186, 2020.

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Project: Special cycles on orthogonal Shimura varieties

Orthogonal Shimura varieties that arise from even lattices of signature $(n, 2)$ carry a natural family of algebraic cycles, called special cycles, which arise from embedded even lattices of signature $(n', 2)$ with $0 \leq n' \leq n$. The codimension of such a special cycle is given by $n - n'$. Generalizing the pioneering work of Hirzebruch and Zagier for Hilbert modular surfaces, Kudla and Millson showed that generating series of the cohomology classes of such special cycles of codimension r define Siegel modular forms of genus r and weight $1 + n/2$. According to work of M. Raum, W. Zhang and myself, an analogous result holds for the classes of special cycles in Chow groups. The present project deals with generalizations and refinements of these results.

First, we study special cycles on *toroidal compactifications* of orthogonal Shimura varieties. Kudla asked whether there are completions of special cycles by suitable boundary cycles such that the generating series of the completed cycles is again a Siegel modular form. In joint work with S. Zemel we answered this question in the affirmative for the case of codimension 1. We defined completed special divisors and proved that their generating series is an elliptic modular form of weight $1 + n/2$. Currently, together with E. Rosu, we work on the case of higher codimension special cycles.

Second, in ongoing work with R. Zuffetti, we investigate the *Lefschetz decomposition* of special cycles in cohomology. Here we work on the uncompactified Shimura variety using L^2-cohomology. It turns out that the Lefschetz decomposition can be elegantly described by means of the decomposition of the Kudla-Millson generating series in terms of Klingen-Eisenstein series. In particular, the primitive part of the generating series corresponds to the projection on the cuspidal part of the Siegel modular form.

Partner: T. Yang, University of Wisconsin at Madison; S. Zemel, Hebrew University; E. Rosu, Leiden University

Support: DFG, LOEWE

Contact: J. H. Bruinier, R. Zuffetti

References

[1] J. H. Bruinier and M. Westerholt-Raum. Kudla's modularity conjecture and formal Fourier-Jacobi series. *Forum of Mathematics, Pi*, 3:30pp., 2015.

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[4] S. S. Kudla. Special cycles and derivatives of Eisenstein series. In *Heegner points and Rankin L-series*, volume 49 of *Math. Sci. Res. Inst. Publ.*, pages 243–270. Cambridge Univ. Press, Cambridge, 2004.

Project: Shintani lifts of nearly holomorphic modular forms.

In the 1970's, Shimura developed the Hecke theory on the spaces of half-integral weight modular forms, and related them to the spaces of integral weight modular forms. This correspondence has been generalized in various directions and can be realized using theta lifts. The fundamental work of Borcherds expanded the input space for this type of theta lifts to include modular forms with singularities at the cusps. Also, nearly holomorphic modular forms, i.e. those annihilated by repeated application of anti-holomorphic differentiation, are allowed as inputs. In the opposite direction, Shintani studied theta lifts from integral weight forms to half-integral weight forms. These are called the Shintani lift, and can be used to give an inverse map to the Shimura correspondence. The idea of Borcherds to include input with singularities in the theta lift has also been considered for Shintani lifts and produced interesting results. For example, Bruinier, Funke and Imamoglu considered such lifts of modular functions and produced harmonic Maass forms of weight $1/2$, and gave another construction of the modular generating series involving the cycle integral of the j-function studied by Duke, Imamoglu and Toth. In the case of higher weights, Alfes-Neumann and Schwagenscheidt calculated the Shintani lifts of harmonic Maass forms, and produced harmonic Maass forms of half-integral weights, whose holomorphic part Fourier coefficients involve cycle integrals of harmonic Maass forms. In a joint work with Dr. Shaul Zemel from the Einstein Institute of Mathematics in Jerusalem, we considered the Shintani lift of nearly holomorphic modular forms, and computed their Fourier expansion. This generalizes the works of Bruinier, Funke, Imamoglu, and Alfes-Neumann, Schwagenscheidt in a different direction, and produces real-analytic modular completions of generating series of cycle integrals of nearly holomorphic modular forms.

Partner: S. Zemel (Hebrew University of Jerusalem)

Support: LOEWE

Contact: Y. Li

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[1] Y. Li and S. Zemel. Shintani lifts of nearly holomorphic modular forms. *Canadian Journal of Mathematics*, pages 1–49, Aug. 2022.

Project: Differences of Singular Moduli are not units

The values of the modular j-invariant at CM points are called singular moduli. By the classical theory of complex multiplication, they are algebraic integers generating ring class fields of imaginary quadratic fields. Numerically, the norm of the difference of two singular moduli seems to increase quickly with respect to the discriminant. Yet they tend to have small prime divisors. The precise factorization formula was proved in a seminal work by Gross and Zagier. On the other hand, it is not clear from the formula that this norm could every be 1. Recently, Bilu, Habegger and Kühne proved that this could not to happen when one singular modulus is 0. Though the technique could be applied to the difference of two singular moduli, the need for checking finitely many cases using a computer prevents the same strategy to be carried out. Using higher Green's function studied by Gross, Kohnen and Zagier, I gave a different approach to this problem. Combining with the original result of Gross and Zagier, and their generalizations by Schofer, Bruinier, Kudla and Yang, and Bruinier, Ehlen and Yang, I was able to give another proof of the aforementioned result of Bilu, Habegger and Kühne , and generalize it to show that the difference of two singular moduli is never a unit.

Support: LOEWE

Contact: Y. Li

References

[1] Y. Li. Singular units and isogenies between CM elliptic curves. *Compos. Math.*, 157(5):1022–1035, 2021.

Project: Mock modular forms with integral Fourier coefficients.

In his last letter to Hardy, Ramanujan gave several examples of holomorphic q-series, which he called "mock theta functions". These functions satisfy beautiful analytic properties, very similar to those satisfied by the usual theta functions. Yet they lack the modularity property, which makes proving claims about these functions difficult. In his ground breaking thesis, Zwegers showed that the mock theta functions recover the modularity property after certain real-analytic functions are added. This breakthrough enabled one to rigorously define the notion of mock modular forms and study their properties. Under the lowering operator, a mock modular form is annihilated and the real-analytic function becomes a classical, holomorphic modular form. This is called the "shadow" of the mock modular form. It turns out that the Fourier coefficients of mock modular forms encode interesting arithmetic information about its shadow. Their rationality could imply the vanishing of derivative of twisted modular L-functions, and Lehmer's conjecture on the non-vanishing of the Ramanujan tau function. In a joint work with Dr. Markus Schwagenscheidt from ETH, we constructed mock modular forms with integral Fourier coefficients, whose shadows are unary theta functions. From the previous work of Bruinier and Schwagenscheidt, it is known that these Fourier coefficients are rational. However, an explicit upper bound on the denominator is not known. Such a bound would give a denominator bound on the regularized inner product involving unary theta functions and weakly holomorphic modular forms. Using Fourier expansions of Borcherds lifts on hyperbolic spaces, we are able to give a closed expression for these regularized inner products, and from them reconstruct the desired mock modular forms with explicitly bounded denominators.

Partner: M. Schwagenscheidt (ETH)

Support: LOEWE

Contact: Y. Li

References

[1] Y. Li and M. Schwagenscheidt. Mock modular forms with integral Fourier coefficients. *Adv. Math.*, 399:Paper No. 108264, 30, 2022.

Project: LOEWE-Start-Professorship

The LOEWE-Start-Professorship for Algebra is working on new techniques for the solvability of polynomial equations, as grouped under the so-called Langlands program. The program builds on the work of the Canadian mathematician Robert Langlands from the 1960s. It is one of the largest research projects in abstract mathematics. Langlands suspected a close connection between the solvability of polynomial equations and the theory of automorphic forms. Two areas of mathematics, which appear fundamentally different at the first moment. The LOEWE-Start-Professorship contributes to the understanding of the interplay of both areas.

Support: LOEWE Excellence Initiative of Hesse, Funding period: 04.05.2022 - 05.05.2028, Funding sum: 1,976,692 Euro

Project: Motives and the Langlands Program

The project "MotLang – Motives and the Langlands program" is devoted to the Langlands program and the theory of motives. The first one aims to find laws that govern the behaviour of solution sets of polynomial equations. The theory of motives exists within algebraic geometry in an effort to unify a set of theories, so-called cohomology theories, that typically relate to topology. These are two different theories that should be closely combined. The MotLang project aims at going further steps to combine both theories.

Support: PI in ERC Starting Grant, Funding period: 01.04.2022 - 31.03.2027, Funding sum: 1,409,163 Euro

Project: Modular representation theory of reductive algebraic groups and local geometric Langlands duality

The project "RedLang - Modular representation theory of reductive algebraic groups and local geometric Langlands duality" investigates the representation theory of reductive algebraic groups related to the calculation of character formulas for simple and indecomposable tilting modules. Geometry and categorization offer new perspectives that go beyond the already developed techniques. These perspectives are to be explored. The main geometric contribution will be the development of a modular branched geometric Satake equivalence. In particular, applications in the study of tilting modules are expected, for example their behavior when restricted to reductive subgroups and their multiplicative properties.

Partner: Simon Riche, Clermont-Ferrand

Support: Partner in ERC Consolidator Grant of Simon Riche, Funding period: 01.09.2021-31.08.2026, Funding sum: 350,090 Euro

Project: The invariants of the Weil representation of $\mathrm{SL}_2(\mathbb{Z})$

The Weil representation of $\mathrm{SL}_2(\mathbb{Z})$ plays an important role in the theory of automorphic forms. It describes the transformation behaviour of the vector valued theta function of a positive-definite even lattice of even rank. For many applications it is important to have an explicit description of the invariants of the Weil representation of $\mathrm{SL}_2(\mathbb{Z})$. For example the space of Jacobi forms of lattice index L and singular weight is naturally isomorphic to the space of invariants $\mathbb{C}[L'/L]^{\mathrm{SL}_2(\mathbb{Z})}$. If the corresponding discriminant form possesses self-dual isotropic subgroups the invariants have been described by Skoruppa in 2008. They are generated by the characteristic functions of these groups. In [1] we give a complete description of the invariants for arbitrary discriminant forms. We show that they are induced from 5 fundamental invariants.

Contact: N. Scheithauer

Partner: M. K.-H. Müller

References

[1] M. K.-H. Müller and N. R. Scheithauer. The invariants of the Weil representation of $\mathrm{SL}_2(\mathbb{Z})$. arxiv:2208.01921, submitted, 2022.

Project: Construction and classification of holomorphic vertex operator algebras

Vertex operator algebras give a mathematically rigorous description of 2-dimensional quantum field theories. The theory of these algebras is in many aspects similar to the theory of positive-definite even lattices. The analogue of Niemeier's classification of positive-definite even lattices of rank 24 is Schellekens' list. The weight-1 subspace of a holomorphic vertex operator algebra of central charge 24 is a reductive Lie algebra. There are exactly 71 possibilities for this Lie algebra. If the Lie algebra is non-zero it determines the vertex operator algebra up to isomorphism. In [2] we show that all 70 holomorphic vertex operator algebra of central charge 24 with non-trivial weight-1 subspace can be constructed as orbifolds of the vertex operator algebra V_Λ associated with the Leech lattice Λ. More precisely we show that there is a bijection between certain extremal automorphisms of V_Λ, called generalised deep holes, and the holomorphic vertex operator algebras of central charge 24 with non-trivial weight-1 space. The generalised deep holes in $\mathrm{Aut}(V_\Lambda)$ can be classified similarly to the deep holes in the Leech lattice by diagram methods. In this way we obtain a new geometric classification of the holomorphic vertex operator algebras of central charge 24 with non-trivial weight-1 space [1].

Contact: N. Scheithauer

Partner: S. Möller

References

[1] S. Möller and N. R. Scheithauer. A geometric classification of the holomorphic vertex operator algebras of central charge 24. arxiv:2112.12291, submitted, 2021.

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1.2 Analysis

The research group Analysis consists of seven professors, D. Bothe, M. Egert (appointed in September 2021), R. Farwig (retired in March 2021), R. Haller-Dintelmann (apl.), M. Hieber, S. Modena (was appointed as professor at GS, L'Aquila in September 2021), S. Roch (apl.) and Chr. Stinner (apl.), and about 30 assistants as state employees or paid by third party funding. The field of research of this group covers theory and applications of partial differential equations and of integral equations as well as mathematical modeling. The analysis group at TU Darmstadt is open to new mathematical problems and scientific challenges. The group of D. Bothe has close contact to the departments of engineering and natural sciences.

One focal point of research activities is the investigation of nonlinear PDEs in fluid dynamics including methods from evolution equations, maximal regularity and harmonic analysis. Of particular interest are geophysical flows, nematic liquid crystals, complex fluids and stochastic forces. Equations of fluid dynamics are also studied using methods of convex integration, which have been proven in recent years to be a fundamental tool in order to prove "low-regularity" results and to explain mathematically longstanding open problems in the theory of turbulent fluids. A famous open problem concerning the existence of smooth solutions of the Navier-Stokes equations is one of the seven Millennium Problems of Clay Mathematics Institute.

Another focal point addresses harmonic analysis and its applications to PDEs, in particular parabolic and elliptic systems in divergence form. Of special interest are functional calculus, heat kernel estimates and rough and complex coefficients.

A third focus point is put on the mathematical modeling and computational analysis of complex flow problems, in particular two-phase flows with transport processes occurring at fluid interfaces and dynamic wetting phenomena. The research builds on continuum mechanical modeling employing and further developing sharp-interface as well as diffuse

interface models with increasing levels of physico-chemical interface properties. For a deep understanding of the elementary transport and transfer processes, direct numerical simulations with complementary numerical methods such as Volume-of-Fluid, Interface Tracking and combined Level Set / Front Tracking are employed and further developed.
Further focal points concern the analysis and numerical approximation techniques for singular integral equations which can be applied in fluid mechanics, computer tomography and image processing, the analysis of elliptic and parabolic equations on non-smooth domains with mixed boundary conditions as well as the investigation of various chemotaxis models.
The research group Analysis presents two “Research Seminars” on a regular weekly basis, introductory seminars on functional analytic tools in the theory of partial differential equations as well as graduate seminars on recent questions in the above-mentioned fields of research.
In addition to basic courses on analysis, the research group offers lectures on analysis for majors in mathematics as well as advanced courses on partial differential equations and on related fields for graduate students.
The analysis group was involved in the organization of several events in 2022 at MFO in Oberwolfach: M. Egert coorganized an MFO-seminar on Operator-Adapted Spaces and M. Hieber coorganized an MFO-workshop on Geophysical Flows.
M. Hieber was awarded in 2022 with the Jean Morlet Chair at CIRM in Luminy, France. He organized there a special semester on Nonlinear PDEs in Fluid Dynamics including several research schools and conferences at CIRM in 2022. The semester was supported by the European Mathematical Society (EMS) and the Clay Mathematics Institute (CMI). He is also the host of Dr. Arnab Roy, who joined the analysis group in October 2022 as a Humboldt Fellow.
M. Egert was awarded in 2022 (jointly with P. Auscher) with the Ferran Sunyer i Balaguer Prize.
A prize for excellent scientific work was given to Felix Brandt in 2022 for his Master thesis by the Friends of TU Darmstadt.
The research group Analysis also participates with Principal Investigators in various research networks such as the CRC 1194 (Bothe, Gründing, Marschall), the CRC-Transregio 75 (Bothe), the CRC-Transregio 150 (Marschall) and the Priority Programm 1740 (Bothe, Marschall), all funded by the DFG. More recently, a new Research Unit on Geophysical Flows (FOR 5528) was approved by DFG. M. Hieber acts there as the spokesperson and Principal Investigator.
One of our Postdocs obtained an offer for an assistant professorship. More specifically, Simone Ciani was appointed as Assistant Professor at the University of Bologna in Italy.
Matthias Hieber serves as the vice director of the Mathematical Research Institute in Oberwolfach (MFO).

Members of the research group

Professors

Dieter Bothe, Reinhard Farwig, Moritz Egert, Robert Haller-Dintelmann, Matthias Hieber, Stefano Modena, Steffen Roch, Christian Stinner

Postdocs

Björn Augner, Tim Binz, Simone Cani, Pierre-Etienne Druet, Tomislac Maric, Holger Marschall, Arnab Roy

Research Associates

Heba Alkafri, Muhammad Hassan Asghar, Milad Bagheri, Francisco Bodzionyr, Tim Böhnlein, Niloufar Bordbar, Felix Brandt, Miriam Buck, Elwardi Fadeli, Mathis Fricke, Lisanne Gossel, Constantin Habes, Jun Liu, Matthias Niethammer, Suraj Raju, Moritz Schwarzmeier, Tobias Tolle, Tarek Zöchling

Scholarship holder

Arnab Roy

Secretaries

Renate Driessler, Lilli Jundt-Becker, Anke Meier-Dörnberg

Project: Modeling and analysis of heterogeneous catalysis systems

In chemical engineering, catalytic processes play an extremly important role. In contrast to homogeneous catalysts (cf. enzymes) which are added as a catalytically active substance to a fluid mixture to accelerate required chemical reactions and to reduce the production of by-products, catalytic surface structures often have advantageous properties. For example, in contrast to homogeneous catalysts, no filtration technique is required to extract the catalyst from the product, as the chemical reactions typically take place mainly on the catalytic surface. Also some heterogeneous catalysts are more efficients than competing homogeneous catalysts by several orders of magnitude. The project consists of several sub-projects listed below:

- Modeling of multi-component fluids with cross-diffusion and bulk-surface interaction: Modeling of physically relevant models from heterogeneous catalysis should be based on general thermodynamic principles as energy conservation and entropy production. For multi-component systems, closure relations following this modeling paradigm inevitably lead to cross-diffusion effects for diffusive fluxes $j_i = j_i(\vec{c})$ – in contrast to Fickean diffusion $(j_i = -d_i \nabla c_i)$. Resulting models include, but are not limited to, Maxwell–Stefan diffusion and Fick–Onsager diffusion.

- Existence, uniqueness and long-time behaviour for heterogeneous reaction-diffusion-advection-sorption systems: By coupling a reaction-diffusion-advection system in the bulk phase of a chemical reactor with a reaction-diffusion-advection system on the catalytic surface of this reactor, one faces with several mathematical challenges: Besides the quasi-linear (instead of semi-linear) nature of the Maxwell–Stefan diffusion for maximal regularity of the linearised bulk-surface system, substantially more difficult conditions have to be checked. Currently we are working on an application of the mathematical theory developed in [10] and [11] to a prototype case of a chemical reactor with a dilut bulk and Maxwell-Stefan surface diffusion. We are, in particular, interested in the existence and uniqueness of strong solutions and there long-time behaviour (global-in-time existence, convergence to equilibria).

- Modeling and analysis of heterogeneous catalysis systems with fast sorption and fast surface chemistry: Since for heterogeneous catalysis systems, the surface chemistry, i.e. chemical reactions on the active surface, and ad- and desorption between bulk phase and surface is extremely fast, it makes sense to consider the fast sorption and fast surface chemistry limit of such systems, where the surface chemistry and the sorption processes instantaneously attain an equilibrium configuration. Based on thermodynamic principles, in [5] we showed how (for a prototypical reactor) such a reduced fast limit system can be derived: Dynamic boundary conditions are thereby replaced by nonlinear equilibrium conditions on the surface chemistry and homogeneous boundary conditions for the fluxes, corresponding to conserved quantities under chemical reactions. The resulting systems of reaction-diffusion equations with combined type boundary conditions constitute an interesting class of reaction-diffusion systems [5], [4].

Partner: W. Dreyer (WIAS Berlin), P.-E. Druet (WIAS Berlin)

Contact: Björn Augner, Dieter Bothe

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[1] B. Augner. L_p-maximal regularity for parabolic and elliptic boundary value problems with boundary conditions of varying differentiability orders. Accepted (subject to minor revision) for Journal of Differential Equations.

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[3] B. Augner and D. Bothe. Modelling and analysis of a heterogeneous catalysis system with site-conserving Maxwell-Stefan diffusion on the surface. In preparation.

[4] B. Augner and D. Bothe. Analysis of some heterogeneous catalysis models with fast sorption and fast surface chemistry. *Journal of Evolution Equations*, 21(3):3521–3552, 2021.

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[8] D. Bothe and P.-E. Druet. On the structure of continuum thermodynamical diffusion fluxes – a novel closure scheme and its relation to the Maxwell-Stefan and the Fick-Onsager approach, 2020. Preprint.

[9] D. Bothe, M. Köhne, S. Maier, and J. Saal. Global strong solutions for a class of heterogeneous catalysis models. *J. Math. Anal. Appl.*, 445(1):677–709, 2017.

[10] R. Denk, J. Prüss, and R. Zacher. Maximal L_p-regularity of parabolic problems with boundary dynamics of relaxation type. *J. Funct. Anal.*, 255(11):3149–3187, 2008.

[11] R. Schnaubelt. Stable and unstable manifolds for quasilinear parabolic problems with fully nonlinear dynamical boundary conditions. *Adv. Differential Equations*, 22(7-8):541–592, 2017.

[12] O. Soucek, V. Orava, J. Málek, and D. Bothe. A continuum model of heterogeneous catalysis: thermodynamic framework for multicomponent bulk and surface phenomena coupled by sorption. *Internat. J. Engrg. Sci.*, 138:28–117, 2019.

Project: The structure of continuum thermodynamical diffusion fluxes

Multicomponent diffusion in fluid systems is commonly modeled via the Fick-Onsager or the generalized Maxwell-Stefan approach. The latter has the advantage that resulting fluxes are consistent with the non-negativity of the partial densities for non-singular and non-degenerate Maxwell-Stefan diffusivities. On the other hand, this approach requires computationally expensive matrix inversions since the fluxes are only implicitly given. We explore a novel and more direct closure which avoids inversion of the Maxwell-Stefan equations, while their structural advantages are preserved by the use of appropriate regular diffusivity coefficients. It is shown that all three closures are actually equivalent under natural positivity requirements, thus revealing the general structure of continuum thermodynamical diffusion fluxes. Additional aims of the project are: 1. To provide a rigorous footing for recent extensions of the Darken equation from so-called weakly associated constituents to the case of general mixtures, and 2. To discuss open issues on the sign of diffusion coefficients.

Partner: Pierre-Étienne Druet

Contact: Dieter Bothe

References

[1] D. Bothe and P.-E. Druet. On the structure of continuum thermodynamical diffusion fluxes-A novel closure scheme and its relation to the Maxwell-Stefan and the Fick-Onsager approach. *International Journal of Engineering Science*, 184:103818, 2023.

Project: Mathematical modeling of mass transfer across actual fluid interfaces

Fluid interfaces in technical or industrial processes are often contaminated with surface active agents (surfactants), either on purpose or due to impurities. This has a strong influence on mass transfer because of (i) the back-effect of the adsorbed surfactant onto the hydrodynamics via changes in interfacial tension and (ii) the local hindrance of mass transfer due to interface coverage. We develop and investigate mathematical models which quantitatively capture these phenomena in a thermodynamically consistent way. Such models account for sharp-interface continuum thermodynamics of multicomponent fluid systems with interfacial species mass. Depending on the description of the interfacial free energy, these models can incorporate Langmuir's energy barrier effect in a consistent and local manner.

Partner: Akio Tomiyama

Contact: Dieter Bothe

References

[1] D. Bothe. Sharp-interface continuum thermodynamics of multicomponent fluid systems with interfacial mass. *International Journal of Engineering Science*, 179:103731, 2022.

Project: Mathematical modeling and analysis of multicomponent fluids

Real world fluids like solutions, electrolytes, fluid mixtures etc. are composed of several constituents, i.e. are multicomponent fluids. Their sound and quantitative description requires a consistent coupling of species advection, multicomponent diffusion, chemical reactions and further purely mechanical phenomena. We investigate the thermodynamically consistent mathematical modeling of multicomponent fluids, both in the compressible as well as incompressible case. For fluid mixtures, incompressibility is defined as independence of the average volume on pressure at given temperature and composition. Under full exploitation of the postulates of thermodynamic stability, we show that this definition implies that a weighted sum of the partial mass densities stays constant. Moreover, we study the impact of this finding on other thermodynamic functions, for instance on the Helmholtz free energy, by means of a rigorous method involving the technique of Gamma-convergence.

We also analyse the resulting PDEs, which are of mixed parabolic-hyperbolic type. We study their well-posedness in classes of strong solutions and obtain existence and uniqueness for short-times. If the initial data are sufficiently close to an equilibrium solution, well-posedness holds on arbitrary large, but finite time intervals. In the incompressible setting, non-solenoidal effects still affect the velocity field in the Navier-Stokes equations of multicomponent fluids and, due to different specific volumes of the species, the pressure remains connected to the densities by algebraic formula. By means of a carefully tailored change of variables, we bring the PDE system in elliptic-parabolic-hyperbolic normal form as to eliminate positivity and incompressibility constraints. We again obtain well-posedness results in classes of strong solutions.

Partner: Wolfgang Dreyer, Pierre-Étienne Druet

Contact: Dieter Bothe

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Project: Eliminating symmetry and permitting singularity in periodic homogenization

Recent breakthroughs in solvability for minimal regularity boundary value problems beyond the symmetric paradigm have focused on potential-free Laplace-type operators. The associated homogenization theory, meanwhile, is now primed for development. We aspire to be the first team to target the periodic homogenization of such operators with rapidly oscillating coefficients and singular Schrödinger potentials. Our approach is motivated by a mutual appreciation for functional calculus and the framework it offers for creating solutions in tremendous generality whilst also being sufficiently robust for the use of harmonic analysis. The objectives are the first steps in our longer-term goal to deliver a quantitative homogenization theory for minimal regularity operators without symmetry.

Partner: Andrew Morris (University of Birmingham), Pascal Auscher (Paris-Saclay University).

Support: The Royal Society.

Contact: Moritz Egert

Project: Direct Numerical Simulation of Locally Coupled Transport Processes at Dynamic Contact Lines (SFB 1194)

The interaction between a liquid and a solid surface is omnipresent in both our daily lives and many industrial applications. For example, you may think about rain moving over the windshield of a car or liquid drops in a lab-on-a-chip application. The subproject B02 within the Collaborative Research Center 1194 is concerned with the numerical modeling and simulation of these dynamic wetting processes. As a numerical method, an arbitrary Lagrangian-Eulerian (ALE) method with moving meshes (originally developed by Tukovic and

Jasak) using the numerical platform OpenFOAM is adopted and further developed (see PhD Thesis by D. Gründing, TU Darmstadt, 2020) to model dynamic wetting flows. This approach allows to incorporate additional physical effects such as mass transfer across the interface [4] or surface-active substances that locally change the surface tension. To support the validation of the numerical methods, an analytical reference solution for transient channel flow with boundary slip is established [2]. This is an important validation step because boundary slip plays an important role in the dynamics of wetting. Moreover, a novel initialization algorithm to compute volume fraction data from arbitrary triangulated surfaces (using the STL-format) is developed [3]. The latter algorithm has proven to be very useful for the numerical investigation of capillary flows. These developments allow us, in cooperation with our partners inside the Collaborative Research Centre 1194, to investigate a variety of wetting processes. Among other things, we study the dynamics of the rise of a liquid column in a cylindrical capillary with a focus on the phenomenon of rise height oscillations (joint work with J. De Coninck, Universite libre de Bruxelles, Belgium), the capillary rise in a rotating experimental device [1] and the evaporation of a liquid film in a printing application.

Partner: Z. Tukovic (University of Zagreb, Croatia), J. De Coninck (Free University of Brussels, Belgium)

Support: German Research Association (DFG) - SFB 1194.

Contact: Suraj Raju, Tomislav Maric, Dieter Bothe, Mathis Fricke

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Project: Continuum mechanical modeling of dynamic wetting

The physically sound and *predictive* mathematical modeling of dynamic wetting processes is one of the core scientific challenges in the Collaborative Research Center 1194. Remarkably, many open questions remain in the field despite a long history of active research over several decades. In this project, we are looking for appropriate constitutive equations, boundary and transmission conditions to model the physics of wetting in the framework of the two-phase Navier Stokes equations. As a prototypical example of a dynamic wetting problem, we study the dynamics of the capillary rise problem in detail in a joint work with J. De Coninck. In particular, we study the phenomenon of rise height oscillations with a novel analytical theory. Motivated by some recent findings about the kinematics of moving contact lines (Fricke, Köhne & Bothe, Physica D, 2019), we are working on force-based models for dynamic wetting based on the “Generalized Navier Slip condition” (joint work with S. Zaleski, Sorbonne

University, Paris). We show that the moving contact line singularity is fully regularized in this modeling approach, leading to finite values of pressure and curvature at the moving contact line. Moreover, interesting connections to the Molecular Kinetic Theory of Wetting and Phase Field models are revealed.

In a recently published work, we revisit the sharp-interface continuum thermodynamics of two-phase multicomponent fluid systems with interfacial mass [2]. As one interesting application, we derive a thermodynamically consistent model of the hindrance effect on the mass transfer across a fluid interface caused by the presence of adsorbed substances (surfactants).

In another branch of research, we are looking at modifications of the level set transport equations with improved geometrical properties, in particular, an (exact or approximate) conservation of the local signed-distance property of the level set function. This approach shows interesting properties in the numerical simulation of wetting problems [3]. Moreover, we study the well-posedness of this (typically strongly non-linear) modifications in a joint work with Prof. K. Soga (Keio Univeristy, Tokyo).

Partner: J. De Coninck (Free University of Brussels, Belgium), S. Zaleski (Sorbonne University, Paris), K. Soga (Keio Univeristy, Tokyo)

Contact: Mathis Fricke and Dieter Bothe

Support: German Research Association (DFG) - SFB 1194.

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Project: Scale- and complexity-reduced modeling of chemically reactive (particulate) flows

In the cluster project Clean Circles, a circular energy economy using iron and iron-oxide powder as carbon-free carrier for renewable electricity is investigated in strongly transdisciplinary way. Within the cluster, multiple scale and complexity regimes are covered, from detailed particle reaction models on the micro-scale to holistic logistic and thermodynamic models including political and economical assessments on the global scale.

Our subproject is located on the bridge between detailed particle reaction mechanisms and a thermodynamic holistic model of the energy cycle and aims at providing complexity-reduced mathematical and numerical models of iron-oxidation and iron-oxide-reduction reactors.

In order to enable the optimization of reactor design and operation, key data (e.g. iron oxidation or reduction grades) must be made available in broad parameter ranges. This can neither be achieved by the experiment nor by detailed, but costly Computational Fluid Dynamics (CFD) simulations. To overcome this, complexity-reduced compartment models (i.e. Chemical Reactor Networks, CRNs) are used and developed in this project.

Our activities cover different issues in making compartment models usable for scale-bridging in Clean Circles. Three main tasks have been pursued in 2022. Firstly, the development of

robust CRN construction algorithms together with our collaboration partners at TU Darmstadt and Polytechnic University of Milan has been started. Secondly, robust optimization routines for the calibration of the CRNs to the experiment have been investigated together with partners from the Clean Circles cluster, including partners from the math department of TU Darmstadt. Thirdly, our main focus in 2022 has been on enhancing the modeling of non-ideal mixing in CRNs. Therefore, a new component, employing the axial dispersion model has been implemented to our CRN framework.
Our first application tests reveal that applying this model can have a strong influence on species predictions but further improvements in terms of computational efficiency are required [1]. Therefore, modeling non-ideal mixing in CRNs will be further investigated within the project.

Support: Funded by the Hessian Ministry of Higher Education, Research, Science and the Arts - cluster project Clean Circles.

Partner: T. Faravelli, A. Stagni (Polytechnic University of Milan), H. Nicolai, C. Hasse (TU Darmstadt)

Contact: L. Gossel, M. Fricke, D. Bothe

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Project: Extendability of functions with partially vanishing trace

The aim is a result in the spirit of the Jones Theorem for the extension of Sobolev functions on domains to the whole space adapted for mixed boundary conditions. For this we take full advantage of the fact that the extension over the Dirichlet part of the boundary should be possible without any boundary regularity, while all known results need some regularity near the interface between the boundary parts. In order to achieve this, the construction does not rely on any boundary charts

Partner: Russell Brown, University of Kentucky, USA, Patrick Tolksdorf, Universität, Mainz, and Sebastian Bechtel, TU Darmstadt

Contact: R. Haller

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Project: Second order elliptic operators in divergence form with complex coefficients

Given a complex, elliptic coefficient function we investigate for which values of p the corresponding second-order divergence form operator, complemented with Dirichlet, Neumann or mixed boundary conditions, generates a strongly continuous semigroup on $L^p(\Omega)$. Additional properties like analyticity of the semigroup, H^∞-calculus and maximal regularity are also discussed. Finally we head for a perturbation result for real coefficients that gives the whole range of p's for small imaginary parts of the coefficients. We base on the recent notion of p-ellipticity, reverse Hölder inequalities and Gaussian estimates for the real coefficients.

Partner: Tom ter Elst, University of Auckland, New Zealand, Joachim Rehberg, WIAS Berlin, and Patrick Tolksdorf, Universität Mainz

Contact: R. Haller

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[2] M. Egert. On p-elliptic divergence form operators and holomorphic semigroups. *J. Evol. Equ.*, 20(3):705–724, 2020.

Project: Third-order accurate initialization of volume fractions on unstructured meshes with arbitrary polyhedral cells

For the numerical treatment of incompressible two-phase flows, especially if large deformations and topological changes occur, the Volume-of-Fluid (VOF) of [1] is commonly used. The respective phases are encoded by volume fractions, which, in the absence of phase change, are passively advected by the flow. In order to obtain reliable results, it is crucial to accurately initialize the volume fractions. Hence, this project addresses the development of a method for the efficient and accurate computation of volume fractions on unstructured polyhedral meshes, where the phase boundary is an orientable hypersurface, implicitly given as the iso-contour of a sufficiently smooth level-set function. We develop a face-based formulation, which allows for the applicability to unstructured meshes and considerably simplifies the numerical procedure for applications in three spatial dimensions.

Support: DFG TRR 75

Contact: Dieter Bothe

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Project: Unstructured Level Set / Front Tracking Method

The aim of this research project is to investigate the unstructured finite volume Level Set / Front Tracking method for incompressible two-phase flows, and to address the challenges that arise in its implementation. Specifically, the study focuses on the accurate approximation of surface tension forces, which play a crucial role in the dynamics of interfacial flows. Additionally, the research addresses the difficulties in pressure-velocity coupling, which are known to arise in two-phase flow simulations. Finally, the project tackles the challenge of high density ratios, which can lead to numerical instabilities and require careful consideration in the design of numerical schemes. By developing improved techniques for addressing these challenges, the research aims to advance the state-of-the-art in two-phase flow simulation and contribute to the development of more accurate and reliable computational tools for a wide range of applications in science and engineering.

Partner: LISN (CNRS), Hongik University

Contact: Tomislav Maric

References

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Project: Unstructure geometrical Volume-of-Fluid Method

The goal of this research project is to investigate the geometrical un-split unstructured Volume-of-Fluid (VOF) method and develop improvements that address several critical challenges in simulating multiphase flows. In particular, the project focuses on the handling of high density ratios, improve the approximation of surface tension forces, and develop more accurate techniques for the advection and reconstruction of the fluid interface. Finally, the project seeks to reduce parasitic currents that are inherent to the VOF method and can lead to instabilities in simulations. By addressing these key challenges, the research aims to advance the capabilities of VOF-based methods and enable more accurate and reliable simulation of complex multiphase flows in a range of scientific and engineering applications.

Partner: ONERA, Roskilde University, BOSCH Corporate Research

Support: BOSCH Corporate Research

Contact: Tomislav Maric

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Project: Scale bridging simulation of dynamic wetting based on the phase field method

Within the DFG Collaborative Research Centre SFB 1194 on "Interaction between Transport and Wetting Processes", the project B07 aims at the fundamental understanding of local transport processes at the contact line in multiscale, dynamic wetting processes on complex substrates. A flow solver based on the diffuse-interface phase-field method and developed in

OpenFOAM is used. This solver has been enhanced by a moving reference frame technique, by load-balanced adaptive mesh refinement on polyhedral meshes as well as the capability to capture the dynamics of multiple immiscible fluid phases. The method enables the description of imbibition and penetration processes in porous/structured substrates, especially during capillarity-dominated wetting. Focus lies on the disclosure of the influence of local heterogeneities (pore size distribution, roughness, functionalization) as well as on a scale bridging methodology, to be realized by combining modern HPC techniques, DG methods and the hybrid atomistic-continuum method.

Support: DFG CRC 1194 "Interaction between Transport and Wetting Processes", Project B07

Contact: Holger Marschall, Francisco Bodziony

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Project: Numerical simulation of the interaction between a drop and a liquid wall film

Within the DFG Collaborative Research Centre SFB/TRR 150 on "Turbulent, chemically reactive, multi-phase flows near walls", the subproject B08 contributes to a central scientific goal of the SFB: the understanding of the relevant physico-chemically processes in turbulent, chemical reacting multiphase flows near walls. By means of direct numerical simulation and in close cooperation with experimental subprojects, the droplet impact on a wall film is investigated for different immiscible and miscible liquids, which is highly relevant for the leading examples of the SFB/Transregio.

Partner: Martin Wörner (Karlsruhe Institute of Technology)

Support: DFG CRC TRR 150 "Turbulent, chemically reactive, multi-phase flows near walls", Project B08

Contact: Holger Marschall, Milad Bagheri

References

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Project: Direct Numerical Simulation of bubble formation and dynamics in water electrolysis using the phase-field method

The goal of the PrometH2eus project is the application-oriented catalyst and electrode development for alkaline water electrolysis for the production of green hydrogen, which outperforms existing materials in both energy and cost efficiency. During water electrolysis, electrolyte convection occurs at the bubble interface due to concentration and temperature gradients as well as field inhomogeneities near the electrode. In addition to material properties such as roughness and wettability, this convection significantly influences the detachment behavior of the bubbles and thus the overall process performance, which is to be investigated in detail by numerical simulations in the subproject.

Support: BMBF H2Giga-Project PrometH2eus

Contact: Holger Marschall, Niloufar Bordbar

Project: NHR4CES Simulation and Data Lab SDL: Energy Conversion

The NHR4CES Simulation and Data Lab (SDL) Energy Conversion aims to enable computationally efficient simulations of real-scale combustion devices by developing HPC-ready reactive CFD (rCFD) software and methods by a co-design process. Highly optimized numerical approaches are being developed, tested, validated, and packaged in different forms. Resulting HPC modules are being optimized for Tier-2 architectures, also providing efficient usage on Tier-1 machines. For instance, Dynamic Load Balancing for rCFD in OpenFOAM (usable as dynamically linked library) has been developed and successfully tested.

Partner: Christian Hasse

Support: NHR4CES (NHR for Computational Engineering Science) / NHR (National High-Performance Computing Alliance)

Contact: Holger Marschall, M. Elwardi Fadeli

Project: Direct numerical simulation of viscoelastic flows

Direct numerical simulation (DNS) of viscoelastic flows poses a significant challenge because all numerical methods tend to become unstable beyond a certain degree of fluid elasticity, characterized by a critical Weissenberg number. This numerical instability is known as the "high Weissenberg number problem". This project is concerned with the stabilization of DNS

methods for highly viscoelastic flows and the numerical investigation of rheological flow phenomena, stemming from the non-linear dependence of the stress on the deformation gradient history.
The project focuses on studying rheological flow phenomena exhibited by rising bubbles in a viscoelastic fluid matrix, including the well-known jump discontinuity of the rise velocity when the critical bubble volume is exceeded. Direct numerical simulations in 3D were conducted to analyze the polymer conformation tensor and explain the underlying physical mechanism of the jump phenomenon. The analysis found that polymer molecules traveling along the upper bubble hemisphere are stretched in the circumferential direction due to the flow kinematics, and the relaxation time scale of the polymer determines whether the stored elastic energy is unloaded above or below the bubble's equator, resulting in either a slow down or acceleration of the bubble. When the relaxation time scale is shorter than the time scale of Lagrangian transport of polymer molecules along the bubble contour, the velocity of motion of the polymer molecules is increased, causing the bubble rise velocity to jump to a higher level. This conclusion was confirmed by experimental measurements.

Support: DFG CRC 1194

Partner: G. Brenn (TU Graz, Austria)

Contact: Matthias Niethammer, Dieter Bothe

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Project: Fractal C^*-Algebras in numerical analysis

For the numerical solution of an operator equation on an infinite-dimensional space, one discretizes the operator to obtain a sequence of $n \times n$ matrices A_n. Interesting asymptotic properties of the sequence (A_n) can be studied by embedding this sequence in an appropriate C^*-algebra and by studying the structure of that algebra. Of particular interest are algebras of operator sequences which are fractal (or self-similar) in the following sense: Every sequence in the algebra can be reconstructed from each of its infinite subsequences modulo a sequence tending to zero in the norm. Examples of fractal algebras arise, for instance, from the finite sections discretization for Toeplitz or singular integral operators. Sequences (A_n) in fractal algebras are distinguished by their excellent asymptotic properties: for example, the pseudospectra of the A_n converge with respect to the Hausdorff metric. A basic tool to analyse algebras of matrix sequences is a Fredholm theory of sequences, which has also found interesting applications: a proof of the Arveson dichotomy for self-adjoint sequences, a proof of the index formula for band-dominated operators, and the creation of an algorithm to determine partial indices of matrix functions numerically, for instance. We derived results along these lines for spatial discretizations of several classes of C^*-algebras including Cuntz algebras, reduced group C^*-algebras and algebras generated by truncated Toeplitz operators on model spaces. The goal of this project is a comprehensive text on fractal C^*-algebras arising in the field of numerical analysis.

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Contact: Steffen Roch

Project: Chemotaxis systems with split population

We study chemotaxis systems with split population. In a particular model, the population is split into moving and static individuals and, apart from diffusion, the motion of the moving individuals is biased toward regions of high concentrations of a chemoattractant which in turn is produced by the static individuals. For this model, where the mass of the whole population is conserved, we establish a critical mass phenomenon distinguishing between global and bounded solutions for subcritical mass and the existence of solutions blowing up in infinite time for supercritical mass. We aim to study the behavior of solutions for more general models with split population.

Partner: Ph. Laurençot (University Savoy Mont Blanc)

Contact: C. Stinner.

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[1] P. Laurençot and C. Stinner. Mass threshold for infinite-time blowup in a chemotaxis model with split population. *SIAM J. Math. Anal.*, 53:3385–3419, 2021.

Project: Features of taxis models

We study chemotaxis and haptotaxis systems which are connected to the Keller-Segel system. Our aim is to prove specific features which are either rarely observed in the context of taxis systems or connected with unusual variants of taxis systems. As a first example, in a haptotaxis model with a specific type of degenerate diffusion, called myopic diffusion, we refine the asymptotic behavior of the solutions based on proving improved regularity of the solution.

Partner: M. Winkler (Universität Paderborn)

Contact: C. Stinner.

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1.3 Geometry and Approximation

The research group “Geometry and Approximation” investigates geometric objects, typically surfaces, and ways to approximate them.
Classical *Differential Geometry* and *Geometric Analysis* studies surfaces minimizing geometric functionals for which examples arise in the sciences and engineering. In the simplest case, say for a biological cell, a bounding surface encloses a given volume in such a way that the area is minimized. Other interfaces minimize functionals involving curvatures, for instance the Willmore functional. Critical points are characterized by Euler Lagrange equations which are non-linear partial differential equations. The mathematical goal is to establish new solutions or properties of solutions, not only in Euclidean 3-space but also in other Riemannian ambient spaces using methods of analysis and Riemannian Geometry.
In *Geometric Modeling*, mathematical tools for the explicit description of geometric objects are developed and analyzed. Here the focus is on complex structures, as they arise in various applications: One may think of a car body, a piece of cloth, or a dinosaur in an animated film. The surfaces considered in Differential Geometry and Geometric Modeling typically have a fairly complicated structure. For processing, it is necessary to approximate them in a function space of reduced complexity, say a spline space. For that reason, the development of tools for efficient approximation of geometric objects is an important task, giving rise to interesting mathematical questions in the field of multivariate approximation theory.

Members of the research group
Professors
Karsten Große-Brauckmann, Elena Mäder-Baumdicker, Ulrich Reif

Research Associates
Kai Bouaraba, Ba-Duong Chu, Alexander Dietz, Ömer Genc, Anna-Lisa Ihrig, Philipp Käse, Nils Neumann, Melanie Rothe, Jona Seidel, Sukie-Christin Vetter

Secretary
Tanja Douglas, Monika Kammer

Project: Surfaces in homogeneous manifolds

Minimal and constant mean curvature surfaces are a traditional subject in Euclidean space or in spheres, while the case of homogeneous 3-manifolds as ambient spaces has been studied more recently. Generalizing results of a PhD thesis by Tristan Alex new minimal examples are found by a direct Plateau method and Schwarz reflection. The construction uses the structure of the spaces as Riemannian fibrations. In particular, for the Hopf fibration, the method establishes minimal surfaces in the 3-sphere, where examples are rare. Other applications are constant mean curvature surfaces obtained by a conjugate surface method described by B. Daniel.

Partner: Rob Kusner (Amherst, MA)

Contact: K. Große-Brauckmann

Project: Morse theoretical questions of Willmore surfaces

In [1] we compute the Morse Index of immersed Willmore spheres in the Euclidean three-space. It turns out that the size of the kernel of a certain partial differential equation on complete, non-compact minimal surfaces are crucial for this computation. Certain elements in that kernel with logarithmical growth are particularly of interest. In this project we study the relation of geometric properties of complete minimal spheres with finite total curvature to Morse theoretical questions of Willmore surfaces. In a recent article [2] we extend the result and are able to express the formula of the Morse index only in terms of Willmore energy of the surface. We also extend the result to real projective planes.

Partner: Jonas Hirsch (Universität Leipzig), Rob Kusner (University of Massachusetts at Amherst)

Support: German Research Association (DFG).

Contact: Elena Mäder-Baumdicker

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[1] J. Hirsch and E. Mäder-Baumdicker. On the Morse Index of Willmore Spheres. arXiv:1905.04185, to appear in Journal of Differential Geometry, 2019.

[2] R. Kusner, J. Hirsch, and E. Mäder-Baumdicker. Geometry of complete minimal surfaces at infinity and the Willmore index of their inversions. Preprint, arXiv:2110.14367, 2021.

Project: The Volume preserving Mean curvature flow

In this project, we study the classical extrinsic geometric flow which is the Mean curvature flow. In [3], we proved that the property of being Alexandrov immersed is preserved under the Mean curvature flow. As a consequence, we are able to extend the surgery procedure of Brendle-Huisken [1] to Alexandrov immersed surfaces in $\mathbb{R}^3$. We also study constrained curvature flows. We focus on the volume preserving Mean curvature flow [2] and prove L^2-in-time estimates on the Lagrange parameter of the flow. This allows us to study the asymptotic behavior of the flow in finite time singularities. Furthermore, we show that Alexandrov immersedness is preserved under the flow if the Lagrange parameter does not change its sign. We continue studying this flow. We will focus on the difference of the short-time and the long-time behavior of constrained flows.

Partner: Ben Lambert (University of Leeds), Fabian Rupp (Universität Wien)

Support: German Research Association (DFG).

Contact: Elena Mäder-Baumdicker

References

[1] S. Brendle and G. Huisken. Mean curvature flow with surgery of mean convex surfaces in $\mathbb{R}^3$. *Invent. Math.*, 203(2):615–654, 2016.

[2] B. Lambert and E. Mäder-Baumdicker. Nonlocal estimates for the Volume Preserving Mean Curvature Flow and applications. Preprint, arXiv:2207.01123, 2022.

[3] B. Lambert and E. Mäder-Baumdicker. A note on Alexandrov immersed mean curvature flow. Preprint, arXiv:2206.14060, 2022.

Project: Minimal surfaces with high codimension in spheres

We would like to find examples of non-orientable, embedded minimal surfaces in spheres with low area. As such objects do not exist in the three-sphere, we have to deal with higher codimension. In a first step, we study whether known construction procedures such as bipolar surfaces in the five-sphere are useful to find the desired surfaces. We found out [1] that the desired surfaces can not be found among the bipolar surfaces of Lawson's η- and ξ-surfaces. While studying those surfaces we were able to determine their topological type and the highest multiplicity. We expect to be able to extend our results to bipolar surfaces of other symmetric minimal surfaces in the 3-sphere.

Support: German Research Association (DFG).

Contact: Elena Mäder-Baumdicker, Melanie Rothe

References

[1] E. Mäder-Baumdicker and M. Rothe. Topology and Embeddedness of Lawson's Bipolar Surfaces in the 5-sphere. Preprint, arXiv:2207.01123, 2022.

Project: ABC Surfaces

Non-Uniform Rational B-Splines (NURBS), the standard of industrial modeling, reveal severe drawbacks. In particular, the contact of neighboring patches is in general discontinuous due to the complicated structure of trimming curves. In this project, we develop new methods to represent Gk continuous composite surfaces for industrial use. A patent is pending.

Partner: Dr. Florian Martin

Contact: U. Reif

Project: Geometric Hermite Subdivision

In this project we develop and analyze nonlinear subdivision algorithms which generate smooth curves from point and normal data. Such schemes are useful in applications with highest demands concerning the fairness of the curves to be constructed, as appearing for instance in the automotive industry.

Partner: Prof. Andreas Weinmann

Contact: U. Reif

Project: Determination of the Joint Spectral Radius

In this project we develop new algorithms for the exact and approximate determination of the joint spectral radius of finite families of matrices. These algorithms combine the advantages of the finite-tree approach, developed by U. Reif, and the polytope approach, developed by Th. Mejstrik.

Partner: Dr. Thomas Mejstrik

Contact: U. Reif

1.4 Didactics and Pedagogics of Mathematics

The working group on subject didactics accommodates two lines of research

The working group on subject didactics with Katja Krüger focusses on theoretically and empirically founded concepts of course development for secondary levels I and II and on historical research of mathematics education in the 19^{th} and 20^{th} century.

Subject didactics in the field of probability theory and statistics has built a strong network throughout the German-speaking areas. In this context we develop and test teaching materials

for contemporary data-oriented stochastics teaching based on current research results. Our focal research methods are Design based research and empirical quantitative studies with regard to statistical literacy.
The second research line deals with analysis and modernization of valuable historical theoretical approaches and practical suggestions for teaching mathematics. Both reforms of higher mathematics education for boys and for girls at the beginning of the 20th century brought forth new subjects and goals in German high schools such as calculus and education in functional thinking. Historical- hermeneutical analyses of contemporary textbooks are used to work out how today's didactic principles of mathematics teaching evolved. Insights from the field of the history of mathematics education promote an understanding of the traditions that underlie our current teaching goals und subjects.

Research Group in Operator Algebras and Mathematical Physics
Quantum probability is an extension of classical probability theory that allows to treat also probabilistic effects of quantum systems. Operator algebras allow a unified treatment of both cases, classical probability as well as probability in quantum systems. All basic notions of probability like expectations, random variables, stochastic processes, martingales, etc. can be formulated in the language of operator algebras in such a way that they reduce to the notions of classical probability whenever the operator algebra is commutative.
Our **research interests** range from theoretical mathematical investigations to physical applications. Consequently, the members of our research group as well as our research partners range from pure mathematicians to physicists.
Common to most of our research is its focus on certain **dynamical behaviour**, be it the dynamics of classical and quantum stochastic processes (Markov processes, noise, quantum trajectories, filtering, etc.), be it the dynamics generated by completely positive maps (ergodic and spectral properties, existence and numerical computation of equilibrium states, quantum state preparation, etc.). The coupling representation of a Markov process has also opened the door to a scattering theory for such processes and to research on quantum coding. It links quantum probability in a new and unexpected way with the fields of quantum information and quantum control.
Recently the **geometry of entangled states** came into the focus of our research interests, in particular entanglement on infinite systems, multipartite entanglement, and criteria for entanglement by methods from convex algebraic geometry.

Working Group on discrete structures
The research group on discrete structures lead by Pascal Schweitzer[1] since 2021/04, focuses structural and algorithmic graph and group theory. Within the ERC-project "EngageS: Next generation algorithms for grabbing and exploiting symmetry" the group in particular investigates practical and theoretical aspects of the graph isomorphism problem. A major focus is algorithmic symmetry detection and exploitation. There are connections with other research in the logics group, in particular with aspects of finite model theory. Furthermore the research expands into combinatorial questions for example on structural and algebraic graph theory and applications in areas such as machine learning on graphs and SAT solving. Finally there the group also investigates computer algebraic questions in connection with the SFB TRR 195 on Symbolic Tools in Mathematics and their Application.

[1]jointly affiliated with the research group Logics; see there for description of the ERC-project EngageS

Members of the research group
Professors

Katja Krüger, Pascal Schweitzer

Research Associates

Markus Anders, Jendrik Brachter, Sofia Brenner, Judith Eilers, Julian Fischer, Irene Heinrich, Jan Herzog, Paul Jägemann, Felix Johlke, Eda Kaja, Thomas Klein, Albrun Knof, Sandra Lang, Moritz Lichter, Malte Ott, Simon Raßmann, Judith Schilling, Thomas Schneider, Franziska Siebel, Felix Voigt

Secretaries

Sigrid Hartmann, Heike Müller

Project: Knowledge qualities for mathematical proof processes in the field of analysis in the first semester

The project is located in the research area on the transition between school and university with a focus on the influence of mathematical knowledge and its quality on proving processes. The objectives of the project were the description and further development of the knowledge qualities derived from activity theory, which have already been adapted by Nora Feldt-Caesar and Oliver Schmitt for basic knowledge and basic skills, as well as conclusions for diagnostic instruments and acquisition materials for knowledge on the corresponding quality. A first investigation of the relationship between the quality of knowledge of a concept and the proving process for a theorem is carried out by a qualitative interview study using the ϵ-δ-definition of continuity as an example. Based on the interview study, the theoretical models for diagnosis and support are also being tested, evaluated and revised.

Contact: I. Apel

References

[1] I. Apel. *Zum Einfluss von Kenntnisqualitäten auf Beweisprozesse am Beginn eines Mathematikstudiums aus tätigkeitstheoretischer Perspektive - Exemplarische Untersuchung am Beispiel der ϵ-δ-Definition von Stetigkeit*. Dissertation, TU Darmstadt, 2022.

Project: "Löwenstark" - Topic-specific support courses in mathematics (HKM)

In 2021, the federal government of Germany launched a programme to support children and their families overcoming the consequences of Corona. It was implemented in Hesse with the programme "Löwenstark" , which finances projects to help students catch up on educational deficits generated by school closings and homeschooling.

As one of these projects, the working group on subject didactics offers support courses for students from classes 6 to 8. We deploy specifically designed working materials to individually support pupils from all school forms catch up on learning gaps in different topics. These include fractions, terms and variables as well as elementary geometry.

Since the start of our first courses in October 2022, we have been able to reach 175 students. Because of their great learning gains and positive response, the duration of the project is planned to be extended by a second year.

Details: `https://www.mathematik.tu-darmstadt.de/didaktik/ag_schule/loewenstark_projekt/index.de.jsp` and `https://www.loewenstark-hessen.de/`

Contact: J. Eilers, K. Krüger

Support: Hessian Ministry of Culture (HKM)

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[1] R. Deiler. Analyse, Weiterentwicklung und Erprobung von Fördermateriealien zur Bruchrechnung vor dem Hintergrund von Störungen im Lernprozess, 2022.

[2] S. Lundt. Entwicklung eines Förderkurses für Schüler*innen mit starken Lernrückständen zum Sichern von geometrischen Grundwissen- und -können der Jahrgangsstufen 5-7, 2022.

Project: Statistical Literacy of High School Graduates - Investigation of Statistical Competencies of Young Adults

The project is located in the research area of statistical literacy and focuses on the competence development of students towards the end of upper secondary school. The aim is to construct an instrument that allows a diagnosis of the statistical competencies necessary for citizens to deal with statistical information. For this purpose, existing international research instruments will be adapted to the requirements of German high schools. In exchange with experts in statistics education from schools and universities, suitable teaching objectives will be formulated and diagnostic tasks will be developed. These will then be empirically evaluated in several steps using qualitative and quantitative methods.

Contact: J. Herzog

References

[1] J. Herzog. Statistical Literacy bei Abiturient*innen: Entwicklung eines Diagnoseinstrumentes. In *Beiträge zum Mathematikunterricht 2023*. WTM Verlag, forthcoming.

Project: Stationary States, Recurrence and Transience for Quantum Dynamics

Probabilistic Markovian behavior is described by semigroups of transition matrices or, more generally, by transition kernels. In quantum probability, this generalizes to semigroups of completely positive operators on the algebra of observables. As in classical probability, existence, uniqueness, and convergence to stationary states—states generalize probability distributions – are an important issue whenever one is interested in the long time behavior of such a dynamics. For finite systems a Perron-Frobenius type theory is available, for infinite systems, notions of recurrence and transience become crucial.

Starting from a noncommutative version of the Riesz decomposition theorem we develop a coherent approach to recurrence and transience. It leads to a classification of idempotent Markov operators, thereby identifying concretely the Choi-Effros product, and to an abstract Poisson integral. The paradigmatic case of semigroups on the algebra $\mathcal{B}(\mathcal{H})$ of all bounded operators on a Hilbert space was studied in more detail. These may be viewed as a quantum version of Markovian semigroups on countably many states.

Current activities regard the decomposition of the dynamics on finite system into irreducible components. A structure theorem for the asymptotically non-vanishing observables was derived by applying the aforementioned Perron-Frobenius theory. This leads to a transfer of the above results from the projection on the fix space to the projection on the space of non-decaying observables. Future work may include further understanding of the concrete applications of this new decomposition and the possibilities of generalizing to infinite systems.

Partner: R. Gohm (Aberystwyth)

Contact: M. Brandy, B. Kümmerer

References

[1] A. Gärtner and B. Kümmerer. A Coherent Approach to Recurrence and Transience for Quantum Markov Operators. Preprint arXiv:1211.6876, TU Darmstadt, 2012.

Project: Measures of Entanglement and Norms on Tensor Products

It is one of the basic problems of quantum information to measure degrees of entanglement for quantum states.
A quantum system is described by a state on a Hilbert space, i. e. a non-negative trace class operator with trace one. For the description of composed quantum systems one has to use a state on the tensor product of the corresponding Hilbert spaces. For example, a tensor product of states describes a joining of independent quantum systems. Since the state space of a quantum system is a convex set one can consider the convex hull of the product states: The set of *separable states*. But not all states on the tensor product Hilbert space are separable. Such states are called *entangled*. Experiments show that only entangled states behave truely quantum mechanically as they may violate Bell's inequalities and can be used for quantum cryptography and quantum computation.
There exist various notions in the literature of how to measure the degree of entanglement: it should measure the usability of an entangled state for true quantum effects. But most of these notions are bound to bi-partite or finite dimensional systems. Recently, W. Arveson established a universal measure of entanglement which is geometrically motivated and may attain the value "infinity" for certain states. However, in the finite case this measure equals the maximal or projective tensor norm previously proposed by O. Rudolph. In this project we aim to gain a deeper understanding of the structure of Arveson's measure of entanglement. For example, we try to compute its value for some interesting states on multipartite systems or give better bounds for it. Moreover, we intend to apply Arveson's measure to more general notions of physical entanglement such as entanglement of fermionic or bosonic particles, genuine multipartite entanglement and others. Due to the existence of "infinitely entangled states" we also address the problem of explicitly characterizing this set and try to find concrete physical examples for such states.
More recently, by using methods from convex algebraic geometry we find new criteria for entanglement.

Contact: B. Kümmerer, S. Lang

References

[1] F. Sokoli and G. Alber. Generalized Schmidt decomposability and its relation to projective norms in multipartite entanglement. *J. Phys. A*, 47, 2013.

Project: Stationary Quantum Stochastic Processes, Unitary Cocycles, and Their Cohomology

We resume an older project (cf. [1]) on the structure of stationary quantum stochastic processes.

A stationary quantum stochastic process with values in the $n \times n$-matrices M_n is given by a quadruple $(\mathcal{A}, \varphi, (T_t)_t, i)$, where $\mathcal{A}$ is a von Neuman algebra with a faithful normal state φ, $(T_t)_t$ is a stationary group of automorphisms of $(\mathcal{A}, \varphi)$ with time parameter $t \in \mathbb{Z}$ or $t \in \mathbb{R}$ (in the latter case we assume continuity in the pointwise strong operator topology), $i : M_n \to \mathcal{A}$ is a *-homomorphism such that there exists the conditional expectation from $(\mathcal{A}, \varphi)$ onto $i(M_n)$. The random variables are then given by the family $(i_t)_t$ with $i_t := T_t \circ i$. It follows that for every t there is a unitary $u_t \in \mathcal{A}$ such that $i_t(x) = u_t^* i(x) u_t$ for $x \in M_n$. Two problems are considered:

1. Under which conditions can u_t be chosen in the centralizer of $(\mathcal{A}, \varphi)$?

2. In the case of continuous time, i.e. $t \in \mathbb{R}$, under which conditions can we choose the unitaries $(u_t)_t$ such that they form a strongly continuous cocycle of the automorphism group $(T_t)_t$, i.e., such that $u_{s+t} = u_s \cdot T_s(u_t)$?

If both conditions are fullfilled, then the automorphism group $(T_t)_t$ can be considered as a perturbation of an evolution $(S_t)_t$ of $(\mathcal{A}, \varphi)$ with $S_t(x) := u_t T_t(x) u_t^*$. It leaves the subalgebra $i(M_n) \subseteq \mathcal{A}$ pointwise fixed and hence can be considered as a *f*ree evolution of the relative commutant of $i(M_n)$ in $\mathcal{A}$ which may be considered as a heat bath. If the stochastic process has the Markov property then the free evolution becomes a white noise.

Contact: B. Kümmerer, F. Voigt

References

[1] B. Kümmerer. Stochastic Processes with Values in M_n as Couplings to Free Evolutions. Preprint, University of Tübingen, 1993.

Project: Asymptotic Completeness and Synchronizing Words

Given finite sets A and C then a surjective map $\gamma : A \times C \to A$ may be identified with a road-coloured directed graph with vertices A and C a set of colours labeling its edges with a road-colouring. A probability distribution on C induces transition probabilities between the vertices of A. Dually, γ induces an injective *-homorphism $i : \mathcal{A} \to \mathcal{A} \otimes \mathcal{C}$ where $\mathcal{A}$ and $\mathcal{C}$ denote the commutative algebras of functions on A and C. Iterating the map i leads to an algebraic version of the Markov process for the given transition probabilities. In [3] we have shown that it is asymptotically complete if and only if the road coloured-graph admits a synchronizing word. Presently, the following two problems are considered:

1. For infinite sets A and B an analogous approach suggests the notion of synchronizing words for infinite graphs which is presently studied.

2. Admitting also non-commutative algebras $\mathcal{A}$ and $\mathcal{C}$ then an injective *-homomorphism $i : \mathcal{A} \to \mathcal{A} \otimes \mathcal{C}$ may be interpreted as a non-commutative version of a road-coloured graph, but the notion of asymptotic completeness makes still sense. A criterion for asymptotic completeness is provided by regularity of an associated extended transition operator ([3], [1]). Classically (i.e., for commutative algebras), this translates into regularity of the adjacency matrix of the road-colored graph's label product with itself. In this case the transition operator corresponds to a sum of tensor products and it exhibits strong positivity properties. The question arises, whether this structure can be transferred to the non-commutative case.

Partner: R. Gohm, Aberystwyth University

Contact: A. Knof, B. Kümmerer

References

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[2] R. Gohm, F. Haag, and B. Kümmerer. Synchronizing for Infinite Road-Coloured Graphs. Preprint, TU Darmstadt, 2020.

[3] R. Gohm, B. Kümmerer, and T. Lang. Noncommutative Symbolic Coding. *Ergodic Theory and Dynamical Systems*, 26:1521 – 1548, 2006.

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Project: Mathematics: The Common Language of Natural Sciences (Mathematik als gemeinsame Sprache der Naturwissenschaften)

In this project we develop an innovative multidisciplinary lecture course to be attended by all teacher students who study at least one of the subjects mathematics, physics, chemistry, biology, or informatics. It is a building block of the recently founded “interlinking area” (“Vernetzungsbereich”), which is established as a part of the MINTplus initiative of the Technical University Darmstadt to profile the teachers education at our university. It is financially supported by German Bundesministerium für Bildung und Forschung as a part of the “Qualititätsoffensive Lehrerbildung”.
The course supports the usage of mathematical language and the handling of mathematical formulas in the respective subjects, thereby reflecting the role of mathematics as common language of natural sciences, in particular, possibilities and limitations of mathematical modelling in natural sciences. The common mathematical language provides a link between different natural sciences and fosters crossover cooperations in school teaching. Examples from the history of mathematics illuminate the mutual dependence between the developments of mathematics and of natural sciences.

Support: BMBF (Bundesministerium für Bildung und Forschung, Ministry for Education and Research)

Contact: B. Kümmerer, S. Lang

References

[1] R. Bruder and B. Kümmerer. Mathematik verbindet. Ein neuer Ansatz für das gymnasiale Lehramt im Darmstädter Projekt MINTplus in der Qualitätsoffensive Lehrerbildung. *GDM-Mitteilungen*, 107:27 – 32, 2019.

Project: Exhibition “himmelwärts” on the occasion of the 450th birthday of Johannes Kepler

As one of the curators, in cooperation with the Kepler Society Weil der Stadt and the 5th Institute of Physics of the University of Stuttgart, I contributed to the exhibition "himmelwärts" on the occasion of the 450th birthday of Johannes Kepler. I was especially responsible for the mathematical parts. The exhibition took place from February 14 to February 28 in Stuttgart in the Haus der Wirtschaft and from March 11 to May 8 in Regensburg in the Historisches Museum. For further details we refer to https://www.project.uni-stuttgart.de/kepler2022/

Support: Wilhelm und Else Heraeus-Stiftung, Klaus Tschira Stiftung, Integrated Quantum and Technology, Ministerium für Wirtschaft, Arbeit und Tourismus Baden-Württemberg, University of Stuttgart, University of Tübingen

Partner: Hildrun Bäzner-Zehender, Hermann Faber, Wolfgang Pleithner (Kepler-Gesellschaft e.V.), Robert Löw, Karin Otter (University of Stuttgart)

Contact: B. Kümmerer

Project: Coordination of the interdisciplinary "Vernetzungsbereich" (interlinking area) at the TU Darmstadt

The STEM-orientated "Vernetzungsbereich" (interlinking area) for teacher students comprises 12 modules from mathematics, computer science, physics, pedagogy, philosophy, languages, and sports. Each of these modules has STEM-orientated interdisciplinary components, and some of these modules were developed specifically for the "Vernetzungsbereich". The teachers of the "Vernetzungsbereich" interlink each other: They exchange information about the contents of their modules, refer to each other in their courses and collaborate so that the subjects grow together. In the summer semester of 2022, the "Vernetzungsbereich" has organized a lecture series on the topic of "Das Ganze im Blick - vernetzt denken und lehren"

Support: Pojects MINTplus and MINTplus2 supported by the BMBF (Bundesministerium für Bildung und Forschung)

References

[1] R. Bruder and B. Kümmerer. Mathematik verbindet. Ein neuer Ansatz für das gymnasiale Lehramt im Darmstädter Projekt MINTplus in der Qualitätsoffensive Lehrerbildung. *GDM-Mitteilungen*, 107:27 – 32, 2019.

Contact: B. Kümmerer

Project: Practical and theoretical aspects of the group isomorphism problem

The group isomorphism problem is the computational problem that asks whether two given groups are isomorphic. The problem is one of the central problems in algorithmic group theory. The project investigates theoretical and practical aspects of the group isomorphism problem and related algorithmic tasks. Specifically we study the computational complexity of the group isomorphism problem, (for abstract finite groups and for finite permutations groups), we test practical viability of theoretical/already implemented/newly developed group isomorphism algorithms and develop canonization algorithms, and we pinpoint combinatorial properties that determine the structure of a finite group. The project is part of the the DFG Collaborative Research Centre SFB/TRR 195: Symbolic Tools in Mathematics and their Application.

Support: DFG.

Contact: P. Schweitzer.

1.5 Logic

The research group in *Mathematical Logic and Foundations of Computer Science* represents the subject area of Mathematical Logic viewed as an applied foundational discipline between mathematics and computer science. Research activities focus on the application of proof-theoretic, recursion-theoretic, category-theoretic, algebraic and model-theoretic methods from mathematical logic to mathematics and computer science. Besides classical mathematical logic (represented with proof theory, recursion theory and model theory) this involves constructive type theory, categorical logic, universal algebra, domain and lattice theory, finite model theory and complexity theory.

Within mathematics, a primary field of applications in the proof- and recursion-theoretic setting is the extraction of new information from proofs in classical mathematics (proof mining: Kohlenbach). This concerns qualitative aspects (e.g., independence of existence assertions from certain parameters) as well as quantitative aspects of computability and complexity of solutions, extraction of algorithms and bounds from proofs, and links with exact real arithmetic and computational mathematics (Kohlenbach, Streicher). Model-theoretic investigations make intra-mathematical links with algebra and discrete mathematics, e.g. relating to the analysis of definability and symmetries in graphs and relational structures (Eickmeyer, Otto, Schweitzer). Connections with discrete mathematics are also investigated in the Emmy Noether project with the title 'Continuous Order Transformations: A Bridge Between Ordinal Analysis, Reverse Mathematics, and Combinatorics' (Freund).

Concerning the mathematical foundations of computer science, major activities revolve around issues of semantics. On the one hand, this involves the mathematical foundation of the semantics of programming languages (Streicher); on the other hand, logics and formal systems are investigated, in the sense of model-theoretic semantics, w.r.t. expressiveness, algorithmic complexity and definability, with an emphasis on computational aspects (algorithmic and finite model theory, descriptive complexity: Eickmeyer, Otto, Schweitzer). Besides specific application domains in computer science, as, e.g., verification, data bases and knowledge representation, there is work on foundational issues in the areas of computability and complexity, as well as type theory and category theory (Streicher).

Overall, the logic group forms an internationally well connected cluster of expertise, with a characteristic emphasis on the connections that mathematical logic has to offer, both w.r.t. other areas within mathematics and w.r.t. the 'Logic in Computer Science' spectrum.

Members of the research group

Professors

Anton Freund, Ulrich Kohlenbach, Martin Otto, Pascal Schweitzer[2], Thomas Streicher

Retired professors

Christian Herrmann, Peter Zahn

Lecturers

Kord Eickmeyer

Postdocs

Ulrik Buchholtz, Paolo Capriotti, Emanuele Frittaion (Humboldt fellow), Pedro Pinto

Research Associates

Moritz Lichter, Davide Manca, Nicholas Pischke, Simon Raßmann, Marius Tritschler, Patrick Uftring, Jonathan Weinberger

[2]jointly affiliated with the Didactics and Logic groups

Secretaries

Betina Schubotz

Project: Emmy Noether Research Group on 'Continuous Order Transformations: A Bridge Between Ordinal Analysis, Reverse Mathematics, and Combinatorics'

The following question is central for several branches of mathematical logic: Which axiom systems are strong enough to prove a given mathematical theorem? In addition to its intrinsic intellectual interest, an answer to this question does often yield further information about the theorem in question, for example on the quality of approximations or the complexity of algorithmic solutions.
Our project aims to deepen connections between two branches of mathematical logic, which are both concerned with the central question formulated above: ordinal analysis and reverse mathematics. As a bridge between the two approaches, we use continuous transformations (finite-type functionals) over the categories of partial and linear orders. This will allow us to answer the central question in cases where it is currently open. Specifically, we want to analyze theorems of combinatorics, mostly related to Kruskal's tree theorem, the graph minor theorem, and the theory of better quasi orders. We also aim at a general framework, in which known and new results can be explained in a uniform way.

Support: Deutsche Forschungsgemeinschaft (DFG) – Project number 460597863

Contact: Anton Freund

Project: Proof Mining for Set-Valued Operators

This project develops a general proof-theoretic framework for various classes of (maximal) set-valued monotone or accretive operators in Hilbert and Banach spaces and their resolvents ([5]). The framework is then extended to cover cyclically monotone and rectangular operators as well as a treatment of sums of set-valued operators A, B such that all of the previous fits into logical metatheorems on bound extractions ([4]). In particular, we introduce quantitative forms for A being (weakly) uniformly rectangular with witnessing moduli. This framework is used to give quantitative forms of the Brezis-Haraux theorem which use such moduli as input and explains why these moduli could be extracted in the case studies ([1, 7]). Our results explain recent proof minings in the context of Bauschke's solution to the zero displacement conjecture and its extensions to other classes of functions than metric projections, the quantitative analysis of various forms of the proximal point algorithm as well as an analysis of Moudafi's algorithm for the computation of zeros of differences on monotone operators ([1, 2, 3, 6, 7]) as instances of logical bound extraction metatheorems.

Support: DFG Project KO 1737/6-2

Contact: U. Kohlenbach, N. Pischke.

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[3] U. Kohlenbach. On the Proximal Point Algorithm and its Halpern-type variant for generalized monotone operators in Hilbert space. *Optimization Letters*, 16:611–621, 2022.

[4] U. Kohlenbach and N. Pischke. Proof theory and nonsmooth analysis. *Philosophical Transactions of the Royal Society A*, 381(2248):21pp, 2023.

[5] N. Pischke. Logical metatheorems for accretive and (generalized) monotone set-valued operators. *Journal of Mathematical Logic*, 2023. To appear.

[6] N. Pischke. Quantitative results on algorithms for zeros of differences of monotone operators in Hilbert space. *Journal of Convex Analysis*, 30(1):295–315, 2023.

[7] A. Sipoş. Quantitative inconsistent feasibility for averaged mappings. *Optimization Letters*, 16:1915–1925, 2022.

Project: Viscosity methods in nonlinear analysis

In the setting of hyperbolic spaces, we show that the convergence of Browder-type sequences and Halpern iterations respectively entail the convergence of their viscosity version with a Rakotch map. We also show that the convergence of a hybrid viscosity version of the Krasnoselskii-Mann iteration follows from the convergence of the Browder type sequence. Our results follow from proof-theoretic techniques (proof mining). From an analysis of theorems due to T. Suzuki, we extract a transformation of rates for the original Browder type and Halpern iterations into rates for the corresponding viscosity versions. We show that these transformations can be applied to earlier quantitative studies of these iterations. Finally, in uniformly convex Banach spaces we study a strong notion of accretive operator due to Brezis and Sibony and extract an uniform modulus of uniqueness for the property of being a zero point. In this context, we show that it is possible to obtain Cauchy rates for the Browder type and the Halpern iterations (and hence also for their viscosity versions).

Support: TU Darmstadt Future Talent Fellowship (P. Pinto), DFG Project KO 1737/6-1 (U. Kohlenbach, P. Pinto)

Contact: U. Kohlenbach, P. Pinto.

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Project: Linear rates of convergence for the Tikhonov regularization method in hyperbolic spaces

The modified Halpern iteration due to T.-H. Kim and H.-K. Xu and studied further by A. Cuntavenapit and B. Panyanak and the Tikhonov-Mann iteration introduced by H. Cheval and L. Leuştean as a generalization of the Tikhonov regularization method recently studied by Boţ et al. can be reduced to each other in general geodesic settings. This, in particular, gives a new proof of the convergence result in Boţ et al. together with a generalization from Hilbert to CAT(0) spaces. Moreover, quantitative rates of asymptotic regularity and metastability due to K. Schade and U. Kohlenbach can be adapted and transformed into rates for the Tikhonov-Mann iteration corresponding to recent quantitative results on the latter of H. Cheval, L. Leuştean and B. Dinis, P. Pinto, respectively. For a particular choice of scalars we obtain rates of asymptotic regularity of order $O(1/n)$ for both the modified Halpern and the Tikhonov-Mann iteration in a general geodesic setting.

Partner: H. Cheval (U Bucharest), L. Leusţean (U Bucharest)

Support: DFG Project KO 1737/6-2

Contact: U. Kohlenbach.

References

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Project: Proof Mining in Ergodic Theory

We extract explicit effective rates of asymptotic regularity as well as metastability for an asymptotic regularity theorem for ergodic averages ([1]) and a strong ergodic theorem ([2]) in uniformly convex Banach spaces due to R.E. Bruck as well as K. Kobayasi and I. Miyadera resp. The former result makes use of a quantitative form of Pisier's theorem on the Rademacher property of uniformly nonsquare Banach spaces.

Support: DFG Projects 460597863, DFG KO 1737/6-1 and DFG KO 1737/6-2.

Contact: A. Freund, U. Kohlenbach.

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[1] A. Freund and U. Kohlenbach. R.E. Bruck, proof mining and a rate of asymptotic regularity for ergodic averages in Banach spaces. *Applied Set-Valued Analysis and Optimization*, 4:323–336, 2022.

[2] A. Freund and U. Kohlenbach. Bounds for a nonlinear ergodic theorem for Banach spaces. *Ergodic Theory and Dynamical Systems*, 2023. To appear.

Project: Inquisitive Modal Logic

Inquisitive logic provides a formal framework for dealing with knowledge representation issues including information updates. It can thus model cognitive and linguistic phenomena related not just to assertions but also to questions [1]. Model-theoretic aspects of corresponding extensions of modal logics are closely related to team semantics and have been at the core of a co-operation with Ivano Ciardelli. This co-operation, since around 2016, has led to the proposal and analysis of corresponding notions of inquisitive bisimulation [2, 3]. Key results obtained so far concern natural charaterisations of inquisitive modal logics as fragments of two-sorted first-order logic. Related work with Silke Meißner starting from [4] has further illuminated the relationship between inquisitive modal logic and classical logic, including recent applications of classical model-theoretic tools in [5].

Partner: Ivano Ciardelli, Padova

Contact: M. Otto.

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Project: Finite Inverse Monoids and Groupoids

Inverse semigroups or monoids and groupoids have a longstanding tradition in the analysis of partial symmetries of discrete structures and especially graphs (compare the classical relationship between groups and their Cayley graphs, and the Wagner–Preston representation theorem for inverse semigroups). The construction of finite groups or groupoids that reflect or approximate certain generic features of free groups, in relation to given finite graph structures, may be seen as one of the challenges behind the longstanding open question of Henckell–Rhodes concerning finite F-inverse covers. The connection between constructions in precursors to [4] and a positive solution to the Henckell–Rhodes problem was first established in [3, 2]. It has since led to a fruitful collaboration that explored and improved key elements of the constructions in [4] to give a more purely algebraic presentation [1] directly aimed at the Henckell–Rhodes problem. Potential ramifications of the underlying combinatorial-algebraic concepts, as well as their further applications in, e.g., locally acyclic hypergraph coverings or extension properties for partial automorphisms of finite structures are topics of ongoing research.

Partner: Karl Auinger, Wien

Contact: M. Otto.

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[3] J. Bitterlich. *Investigations into the Universal Algebra of Hypergraph Coverings and Applications*. PhD thesis, TU Darmstadt, 2019.

[4] M. Otto. Acyclicity in finite groups and groupoids. Preprint, revised, 2022. 60 pages, arXiv:1806.08664.

Project: Proof mining and the development of novel strongly convergent splitting methods

In the general nonlinear context of CAT(0) spaces, we introduce a new splitting algorithm for approximating fixed points common to two nonexpansive maps. This method follows an iterative schema which alternates between Halpern and Krasnoselski-Mann style iterations, and was dubbed the alternating Halpern-Mann iteration. Under simple conditions, we show the strong convergence of this algorithm benefiting in a crucial way from ideas and techniques from the proof mining program. Additionally, we give quantitative information in the form of effective rates of asymptotic regularity and of metastability (in the sense of Terence Tao). Motivated by these results, we also obtain strongly convergent versions of the forward-backward and the Douglas-Rachford algorithms. Our results generalize recent work by R.I. Boţ, E.R. Csetnek and D. Meier, and H. Cheval and L. Leuştean.

Partner: B. Dinis (U Évora)

Support: FCT projects UIDP/04561/2020 and UIDP/04674/2020 (B. Dinis), DFG Project KO 1737/6-2 (P. Pinto)

Contact: P. Pinto.

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[1] B. Dinis and P. Pinto. Strong convergence for the alternating Halpern-Mann iteration in CAT(0) spaces. *SIAM Journal on Optimization*, 33(2):785–815, 2023.

Project: Generalization of asymptotic regularity results

We extend to UCW-hyperbolic spaces the asymptotic regularity results for the alternating Halpern-Mann iteration first studied in the setting of CAT(0) spaces [1]. We obtain highly uniform rates of asymptotic regularity and these results are new even for uniformly convex normed spaces. Furthermore, for a particular choice of the parameter sequences, we compute linear rates of asymptotic regularity in W-hyperbolic spaces and quadratic rates of T- and U-asymptotic regularity in CAT(0) spaces.

Partner: L. Leuştean (U Bucharest)

Support: DFG Project KO 1737/6-2

Contact: P. Pinto.

References

[1] B. Dinis and P. Pinto. Strong convergence for the alternating Halpern-Mann iteration in CAT(0) spaces. *SIAM Journal on Optimization*, 33(2):785–815, 2023.

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Project: Proof mining and the study of evolution equations

In this project, we provide quantitative versions of results on the asymptotic behavior of nonlinear semigroups generated by an accretive operator due to O. Nevanlinna and S. Reich as well as H.-K. Xu. These results themselves rely on a particular assumption on the underlying operator introduced by A. Pazy under the name of 'convergence condition'. Based on logical techniques from proof mining, we derive various notions of a 'convergence condition with modulus' which provide quantitative information on this condition in different ways. These techniques then also facilitate the extraction of quantitative information on the convergence results of Nevanlinna and Reich as well as Xu, in particular also in the form of rates of convergence which depend on these moduli for the convergence condition. These results in particular point to differential equations as a new area of applications for proof mining in the future.

Contact: P. Pinto and N. Pischke.

Support: DFG Project KO 1737/6-2

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Project: Quantitative studies on strongly convergent variants of the proximal point algorithm

The proximal point algorithm is a well-known method to approximate zeros of maximal monotone operators. Since this algorithm only converges weakly, several variants were developed to ensure strong convergence. In this project, we investigate several such algorithms, Halpern-type, Mann-type, multi-parameter, etc., from a finitary perspective (proof mining). Using proof-theoretical methods, we give quantitative analyses of various non-effective mathematical proofs and obtain effective information like rates of metastability (in the sense of Terence Tao) and rates of asymptotic regularity. Moreover, in several instances it was possible to bypass more complicated theoretical principles (like countable choice or weak compactness) which played an essential role in the original proofs and are shown to not be needed in our quantitative results. This work follows from recent quantitative studies on the proximal point algorithm and on the elimination of weak compactness in proof mining.

Partner: B. Dinis (U Évora), L. Leuştean (U Bucharest).

Support: FCT projects UIDB/04561/2020 and UIDP/04561/2020 (B. Dinis and P. Pinto), TU Darmstadt Future Talent Fellowship (P. Pinto), DFG Project KO 1737/6-1 (P. Pinto)

Contact: P. Pinto.

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1.6 Numerical Analysis and Scientific Computing

The research focus of the group for *Numerical Analysis and Scientific Computing* lies in the development, analysis, and implementation of novel, efficient, accurate, and reliable numerical methods for the solution of complex problems of practical interest. This includes the derivation and simplification of models, their analysis, the construction of appropriate numerical schemes for their simulation, the analysis of these numerical methods, the design of theoretical tools for the purpose of the latter, the derivation of a priori and a-posteriori error estimates, the adaptive solution, and the consideration of related optimization and inverse problems.
The long-term goal of the group is to contribute to the fundamental research topics in the area of numerical mathematics and scientific computing, but also to provide software and expertise for the tackling of specific problems in engineering and the natural sciences. The group is currently engaged in projects in various application areas, e.g., in computational medicine and biology, in simulation and optimal control of gas and water supply networks, in inverse problems for fluid dynamics and non-destructive testing, in acoustic and optical

tomography, in multiscale modeling and numerical approximation of soft matter systems, in simulation of transient acoustic and electromagnetic phenomena, in modeling and simulation in energy science, in modeling and simulation of compressible single- and multi-phase flows, in geophysical flow problems with dispersion, as well as non-Newtonian fluid flow.
Particular research directions in the area of numerical mathematics that are pursued along these applications are, e.g., the development and numerical analysis of novel discretization schemes, approximation and (quasi-)optimality results, the design and analysis of *a posteriori* error estimates, the uncertainty quantification for problems with variable inputs, and the structure preserving model reduction and approximation as well as the design and the analysis of model-adaptive schemes.
The research group *Numerical Analysis and Scientific Computing* has been and is engaged among others in various coordinated research activities, e.g., in the Graduate Schools *Computational Engineering* and *Energy Science and Engineering*, the Transregional Collaborative Research Centers (Transregio/SFB) TRR 154 Mathematical Modelling, Simulation and Optimization Using the Example of Gas Networks and TRR 146 Multiscale Simulation Methods for Soft Matter Systems.

Members of the research group

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Elke Dehnert, Dagmar Thies

Project: Neural networks for approximation of nonlinear hyperbolic conservation laws

Recently, neural networks have found success in approximating solutions of PDEs, especially for high-dimensional problems. However, for nonlinear hyperbolic conservation laws, the established approach of *Physics Informed Neural Networks* (PINNs) fails. Nonlinear hyperbolic conservation laws exhibit discontinuous solutions after finite time even for smooth initial data, which leads to the failure of standard PINNs in these situations. The project develops alternative training strategies that can be understood as learning the weak formulation of the PDE instead. Solutions of the weak formulation may be non-unique. We look at entropy inequalities to learn only entropy solutions. So far we have studied problems with periodic boundary conditions. Given Dirichlet boundary data on a bounded domain, for hyperbolic conservation laws it depends on the state of the solution if the boundary data is achieved or not, such that boundary data must be understood in a suitable weak sense. We aim to extend our learning framework to incorporate boundary data weakly.

Contact: Aidan Chaumet, Jan Giesselmann

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[1] A. Chaumet and J. Giesselmann. Efficient wPINN-approximations to entropy solutions of hyperbolic conservation laws. arXiv:2211.12393, 2022.

Project: Projection methods for shallow water models with dispersion

We consider the nonlinear and dispersive Green–Naghdi system of equations which models free surface flows. The dispersive pressure terms lead to a non-hyperbolic structure for which common strategies for instance to impose boundary conditions are not available anymore. This motivates the use of the Green-Naghdi system in projection structure consisting of four equations for the water height, averaged horizontal and vertical velocities and standard deviation of vertical velocity and two constraints. The projection structure allows for a splitting scheme into an advection step and a correction step after introducing a time stepping. The simplest version does not take the pressure into account in the first step. This leads to a shallow water and advection step as a first step and the second step is a correction step that incorporates the constraints by means of introducing the pressure functions. This can even be done for the case of non-homogeneous boundary conditions in an entropy stable manner [1]. However, to obtain more flexibility on the way of prescribing boundary conditions on the pressure and to ensure that no artificial boundary conditions are imposed, the method needs refinement. For this reason we are investigating an incremental method that includes the pressure terms in the first step as source terms and updates only pressure differences in the correction step. This may also allow for insights on the significance of an inf-sup condition.

Partner: Martin Parisot (Inria, University of Bordeaux, France); Sebastian Noelle (RWTH Aachen)

Contact: Franziska Eickmann, Tabea Tscherpel

References

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Project: Uncertainty quantification guided parameter selection in a fully coupled molecular dynamics-finite element model of the mechanical behavior of polymers

The objective of investigating macroscopic polymer properties with a low computing cost and a high resolution has led to the development of efficient hybrid simulation tools. Systems generated from such simulation tools can fail in service if the effect of uncertainty of model inputs on its outputs is not accounted for. This work focuses on quantifying the effect of parametric uncertainty in our coarse-grained molecular dynamics-finite element coupling approach using uncertainty quantification. We consider uniaxial deformation simulations of a polystyrene sample at $T = 100$K in our study. Parametric uncertainty is assumed to originate from parameters in the molecular dynamics model with a nonperiodic boundary (the force constant between polymer beads and anchor points, the number of anchor points and the size of the surrounding dissipative particle dynamics domain) and a parameter to blend the energies of particles and continuum (weighting factor). Key issues that arise in uncertainty quantification are discussed on the basis of the quantities of interest including mass density, end-to-end distance and radial distribution function. This work reveals the influence of key input parameters on the properties of polymer structure and facilitates the determination of those parameters in the application of this hybrid molecular dynamics-finite element approach.

Partner: Yunfeng Mao (Tongji University, China); Michael C. Böhm (TU Darmstadt); Florian Müller-Plathe (TU Darmstadt)

Contact: Jens Lang, Alf Gerisch

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Project: Mathematical modeling of and numerical methods for time-dependent PDE problems arising in mathematical biology

Biological processes like the invasion of tissue by cancer cells, the adhesion-driven reorganization of tissue, the healing of tissue wounds, mechanical interactions in tissue development and the cascade of steps in fracture healing can be modeled as time-dependent PDEs. We consider models that include cross-diffusion processes, study the effect of multiple adhesion terms of different forms and consider mechanochemical models of pattern formation.

For the reliable, efficient and accurate simulation of these models, dedicated numerical schemes are required. We focus on general methods for taxis-diffusion-reaction systems and on particular schemes for the evaluation of the spatially nonlocal terms in models of cellular adhesion. Mechanochemical models lead to implicit PDEs which require a dedicated numerical treatment. In our approaches, we follow the method of lines with finite volumes in space and linearly-implicit methods in time.

Partner: Mark A. J. Chaplain (University of St. Andrews, UK); Kevin J. Painter (Politecnico di Torino, Italy); Chiara Villa (Sorbonne University, Paris, France); Mariya Ptashnyk (Heriot-Watt University, Edinburgh, UK); Anja Voß-Böhme (HTW Dresden); Jonathan Sherratt (Heriot-Watt University, Edinburgh, UK)

Contact: Alf Gerisch

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[3] A. Voss-Böhme and A. Gerisch. Multi-scale analysis of contact-dependent interaction in tissue aggregation and invasion. In O. Wolkenhauer, editor, *Systems Medicine: Integrative, Qualitative and Computational Approaches*, pages 156–168. Academic Press, Oxford, 2021.

Project: Regularized moment methods for kinetic equations

Moment equations employing entropy closures are an established method for solving kinetic equations since they lead to equations that share many properties with compressible fluid mechanics equations and possess a natural entropy structure. However, solving these equations numerically is rather delicate since the entropy closure makes it necessary to solve constrained minimization problems for each flux evaluation and numerical errors might make these problems unfeasible. This difficulty can be overcome using regularized minimization problems, as introduced in [2]. We have proven convergence in relative entropy of solutions to the regularized moment system to solutions of the non-regularized moment system in case the regularization parameter goes to zero.

Partner: Martin Frank (KIT); Graham W. Alldredge

Contact: Jan Giesselmann

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[1] G. W. Alldredge, M. Frank, and J. Giesselmann. On the convergence of the regularized entropy-based moment method for kinetic equations. *SMAI-JCM*, 9:1–29, 2023.

[2] G. W. Alldredge, M. Frank, and C. D. Hauck. A regularized entropy-based moment method for kinetic equations. *SIAM J. Appl. Math.*, 79(5):1627–1653, 2019.

Project: A posteriori error estimates for Keller-Segel models with linear and non-linear diffusion

Keller Segel models are a family of models describing the movement of bacteria attracted by a chemical substance that they also create. Many of these models lead to finite time blow-up (mass concentration) for certain initial data which makes the construction and error analysis of numerical schemes challenging. We focus on the derivation of conditional a posteriori error estimates for finite volume and discontinuous Galerkin schemes that provide computable upper bounds for the difference between exact and numerical solutions. The estimates are conditional in the sense that some numerical quantity can be evaluated and if it is below a certain threshold the error bound is valid.

Partner: Kiwoong Kwon (Kyungpook National University, Republic of Korea); Niklas Kolbe (RWTH Aachen)

Contact: Jan Giesselmann

Project: A posteriori error estimates for hyperbolic conservation laws based on a-contraction

The goal of this project is to derive novel a posteriori error estimates for systems of hyperbolic conservation laws in one space dimension. The goal is to obtain error estimators that are of the same order as the error if the solution is smooth and that converge even when the exact solution is discontinuous thereby vastly improving upon the state of the art. In a first step we focus on scalar model problems with convex flux but restrict ourselves to techniques that shall be extensible to systems. We decompose the computational domain into parts where the initial data are increasing and parts where they are decreasing. In the increasing parts we use classical finite volume schemes and reconstructions as in [1] while we use wave-front tracking in the decreasing parts. The a-contraction methodology [2] will allow us to relate residuals and errors in an optimal way.

Partner: Sam Krupa (MPI Leipzig)

Contact: Jan Giesselmann

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[2] S. G. Krupa. Criteria for the a-contraction and stability for the piecewise-smooth solutions to hyperbolic balance laws. *Commun. Math. Sci.*, 18(6):1493–1537, 2020.

Project: A posteriori error control for statistical solutions of barotropic Navier-Stokes equations

This project addresses the numerical approximation of statistical solutions of the barotropic Navier-Stokes equations, one of the fundamental equations in fluid mechanics. Statistical solutions are a novel solution concept for compressible Navier-Stokes equations that is motivated by turbulence modeling and is thought to address issues with well-posedness that persist for deterministic solution concepts. Statistical solutions can be understood as time-parametrized probability measures on function spaces induced by a random initial datum. Hence, a statistical solution can be approximated by an empirical measure obtained from samples from the initial distribution that are evolved with a numerical scheme for the deterministic, barotropic Navier-Stokes equations. In the convection-dominated case that we focus on, a typical numerical scheme would be of Runge-Kutta discontinuous Galerkin type. We aim to provide reliable, efficient, and robust a posteriori error estimators for these schemes, i.e., upper error bounds for errors caused by discretization in space-time and stochastic space that are computable from the numerical solution. We will combine the relative entropy stability framework with suitable reconstructions of the numerical solution to establish these error bounds. Furthermore, we plan to employ our a posteriori error estimator to construct adaptive, highly efficient multi-level Monte Carlo schemes for approximating quantities of interest pertinent to statistical solutions.

Partner: Sebastian Krumscheid (KIT)

Contact: Jan Giesselmann

Project: Dissipative solutions for the Navier-Stokes-Korteweg system and their numerical treatment

Many problems in computational fluid dynamics are described by the compressible Euler or Navier-Stokes (NS) equations. Recently, dissipative weak (DW) solutions have been introduced as a generalization to classical solution concepts. In a series of works, DW solutions have been established as a meaningful concept from the analytical and numerical points of view. DW solutions do not have to fulfill the equations weakly but only up to some defect and oscillations measures. They can be identified as limits of consistent and stable approximations and convergence towards DW solutions has been demonstrated for several structure-preserving numerical methods. Further, they are a natural extension of classical solutions since DW solutions coincide with them if either the classical solution exists, referred to as weak-strong uniqueness principle, or if DW solutions enjoy certain smoothness. A further extension to the Navier-Stokes system is the Navier-Stokes-Korteweg (NSK) system which includes capillarity terms in the equations. Our motivation for considering NSK in our project is driven by the recent observations made by Slemrod that the rigorous passage of solutions from the mesoscopic equations (Boltzmann) to macroscopic systems, known as Hilbert sixth's problem, will fail for the classical systems (NS and Euler) because of the appearance of van der Waals–Korteweg capillarity terms in a macroscopic description. Therefore, Korteweg systems are more suitable for describing real fluid motions. In our project, we will extend the framework of DW solutions to NSK equations. We will define DW solutions in such a way that they form a natural extension of classical solutions, i.e. such that they satisfy a weak-strong uniqueness principle, for the local and non-local NSK model. In addition, we plan to prove their global existence by demonstrating convergence of structure-preserving numerical schemes. First, structure-preserving low order schemes will be constructed and analyzed, whereas later we focus as well on the development and convergence properties of higher order finite element schemes.

Partner: Philipp Öffner (Universität Mainz)

Contact: Jan Giesselmann

Project: Spinodal decomposition of polymer-solvent systems

The goal of the project is to obtain stable and consistent descriptions of flow dynamics on multiple scales in a class of systems exhibiting highly complex non-equilibrium dynamics, namely phase-separating polymer solutions. This is done by combining (i) the derivation, analysis, and simulation of macroscopic two-fluid models describing the dynamics of viscoelastic phase separation, (ii) the mesoscopic simulation of viscoelastic phase separation by extension of a coupled Lattice-Boltzmann / Molecular Dynamics method, and (iii) the calibration of the macroscopic models to results from mesoscopic simulations by means of parameter estimation and inverse problems methodology.

Partner: Mária Lukácová-Medvidová, Aaron Brunk (Universität Mainz); Burkhard Dünweg, Dominic Spiller (Max-Planck-Institut für Polymerforschung Mainz)

Support: DFG TRR 146

Contact: Herbert Egger

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[3] D. Spiller, A. Brunk, O. Habrich, H. Egger, M. Lukacova-Medvidova, and B. Duenweg. Systematic derivation of hydrodynamic equations for viscoelastic phase separation. *J. Phys.: Condens. Matter*, 33:364001, 2021.

Project: Simulation of reactive flows by projection onto time- and space-variable quasi-steady states

The simulation of a reactive flow leads to a partial differential equation, which usually contains a large number of unknown variables. Furthermore, the time scales of the different chemical reactions cover several orders of magnitude. In addition to the size the obtained partial differential equation is also very stiff and solving the partial differential equation is very time consuming. However, the fastest chemical reactions have small timescales and eventually reach their equilibrium in a period of time shorter than the timestep of the solver. In this case we can replace these chemical reactions by an algebraic equation. This approach leads to simulations of the chemical reaction system on a lower dimensional manifold describing the partial equilibrium of the fast reactions. Though, the state of the system can differ in time and space, the reaction rates depend on the state. For this reason the manifold changes in time and space. The goal of the project is to develop a model, which dynamically switches in space and time between the description of the chemical reactions via the kinetic model and the partial thermodynamic equilibrium.

Contact: Martin Kiehl

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Project: Observer-based data assimilation for barotropic gas transport using distributed measurements

The goal of data assimilation is to estimate the state of some physical system by combining available measurement data with a physical model of the system. In our case, we consider the flow of gas through gas pipe networks described by the one-dimensional barotropic Euler equations complemented with energy-conserving coupling conditions at the pipe junctions. Then, we set up an observer system that contains additional source terms of Luenberger type depending on distributed measurements of one of the state variables. Using an extension of the relative energy method we show that the state of the observer system converges exponentially in the long time limit towards the original system state, i.e., we reconstruct the complete system state from measurements of only one state variable.

Partner: Martin Gugat (Universität Erlangen-Nürnberg)

Support: DFG TRR 154

Contact: Jan Giesselmann, Teresa Kunkel

Project: Relative energy estimates, asymptotic stability and structure preserving discretization for isentropic flow in gas networks

Gas transport in one-dimensional pipe networks can be described as an abstract dissipative Hamiltonian system, for which quantitative stability bounds can be derived by means of relative energy estimates. This allows us to conclude stability of solutions to subsonic flow problems with respect to perturbations in initial and boundary data as well as model parameters. In addition, we can prove convergence to the parabolic limit problem in the practically relevant high friction/low Mach regime. Furthermore, the stability estimates are inherited almost verbatim by variational discretization schemes, like mixed finite elements in space and the implicit Euler method in time, leading to quantitative convergence rates and asymptotic stability in the limiting high friction/low Mach regime. The results are first derived for the flow on a single pipe, but in the spirit of the port-Hamiltonian formalism, they naturally extend to pipe networks.

Support: DFG TRR 154

Contact: Herbert Egger, Jan Giesselmann, Teresa Kunkel, Nora Philippi

References

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Project: Implicit Peer triplets for ODE constrained optimal control problems

It is well known that in the first-discretize-then-optimize approach in the control of ordinary differential equations the discrete adjoint method may converge under additional order conditions only. For Peer two-step methods we derive such adjoint order conditions and pay special attention to different formulations and boundary steps. For s-stage methods, we prove convergence of order s for the state variables if the adjoint method satisfies the conditions for order $s-1$, at least. We remove some bottlenecks at the boundaries encountered in an earlier paper published in J. Comput. Appl. Math., 262:73–86, 2014, and discuss the construction of 3-stage methods for the order pair (3,2) in detail. The impact of nodes having equal differences is highlighted. It turns out that the most attractive methods are related to backward differentiation formulas. Three 3-stage methods are constructed, which show the expected orders in numerical tests.
Further, we are concerned with the construction and convergence analysis of novel implicit Peer triplets of two-step nature with four stages for nonlinear ODE constrained optimal control problems. We combine the property of super-convergence of some standard Peer method for inner grid points with carefully designed starting and end methods to achieve order four for the state variables and order three for the adjoint variables in a first-discretize-then-optimize approach together with A-stability. The notion triplets emphasize that these three different Peer methods have to satisfy additional matching conditions. Four such Peer triplets of practical interest are constructed. In addition, as a benchmark method, the well-known backward differentiation formula BDF4, which is only $A(73.35^o)$-stable, is extended to a special Peer triplet to supply an adjoint consistent method of higher order and BDF type with equidistant nodes. Within the class of Peer triplets, we found a diagonally implicit $A(84^o)$-stable method with nodes symmetric in $[0,1]$ to a common center that performs equally well. Numerical tests with four well established optimal control problems confirm the theoretical findings also concerning A-stability.

Partner: Bernhard A. Schmitt (Universität Marburg)

Contact: Jens Lang

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Project: Gas transport in large-scale networks

We are concerned with the simulation and optimization of large-scale gas pipeline systems in an error-controlled environment. The gas flow dynamics is locally approximated by sufficiently

accurate physical models taken from a hierarchy of decreasing complexity and varying over time. Feasible work regions of compressor stations consisting of several turbo compressors are included by semi-convex approximations of aggregated characteristic fields. A discrete adjoint approach within a first-discretize-then-optimize strategy is proposed and a sequential quadratic programming with an active set strategy is applied to solve the nonlinear constrained optimization problems resulting from a validation of nominations. The method proposed here accelerates the computation of near-term forecasts of sudden changes in the gas management and allows for an economic control of intra-day gas flow schedules in large networks. Case studies for real gas pipeline systems show the remarkable performance of the new method.
We also investigate quantification of uncertainties that arise from intra-day oscillations in the demand for natural gas transported through large-scale networks. The short-term transient dynamics of the gas flow is modelled by a hierarchy of hyperbolic systems of balance laws based on the isentropic Euler equations. We extend a novel adaptive strategy for solving elliptic PDEs with random data, recently proposed and analysed by Lang, Scheichl, and Silvester [J. Comput. Phys., 419:109692, 2020], to uncertain gas transport problems. Sample-dependent adaptive meshes and a model refinement in the physical space is combined with adaptive anisotropic sparse Smolyak grids in the stochastic space. A single-level approach which balances the discretization errors of the physical and stochastic approximations and a multilevel approach which additionally minimizes the computational costs are considered. Two examples taken from a public gas library demonstrate the reliability of the error control of expectations calculated from random quantities of interest, and the further use of stochastic interpolants to, e.g., approximate probability density functions of minimum and maximum pressure values at the exits of the network.
In a further step, we considered both a stationary and a dynamic flow model with uncertain boundary data on networks. We introduce two different ways how to compute the probability for random boundary data to be feasible, discussing their advantages and disadvantages. In this context, feasible means that the flow corresponding to the random boundary data meets some box constraints at the network junctions. The first method is the spheric radial decomposition and the second method is a kernel density estimation. In both settings, we consider certain optimization problems and we compute derivatives of the probabilistic constraint using the kernel density estimator. Moreover, we derive necessary optimality conditions for an approximated problem for the stationary and the dynamic case. Throughout the study, we use numerical examples to illustrate our results by comparing them with a classical Monte Carlo approach to compute the desired probability.

Partner: Pia Domschke (Frankfurt School of Finance & Management); Martin Gugat, Michael Schuster (Universität Erlangen-Nürnberg)

Contact: Jens Lang, Elisa Strauch

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[3] M. Schuster, E. Strauch, M. Gugat, and J. Lang. Probabilistic constrained optimization on flow networks. *Optim. Eng.*, 23(2):983–1032, 2022.

Project: Quantification of bore path uncertainty in borehole heat exchanger arrays

Borehole heat exchanger arrays have become a common implement for the utilization of thermal energy in the soil. Building these facilities is expensive, especially the drilling of boreholes, into which closed-pipe heat exchangers are inserted. Therefore, cost-reducing drilling methods are common practice, which can produce inaccuracies of varying degree. This brings into question how much these inaccuracies could potentially affect the performance of a planned system. In the presented case study, an uncertainty quantification for seasonally operated borehole heat exchanger arrays is performed to analyze the impact of the bore paths' deviations. We introduce an adaptive, anisotropic stochastic collocation method, known as the generalized Smolyak algorithm, which was previously unused in this context and apply it to a numerical model of the borehole heat exchanger array. Our results show that the borehole heat exchanger array performance is surprisingly reliable even with potentially severe implementation errors during their construction. This, coupled with the potential uses of the presented method in similar applications gives planners and investors valuable information regarding the viability of borehole heat exchanger arrays in the face of uncertainty. With this project, we hope to provide a powerful statistical tool to the field of geothermal energy, in which uncertainty quantification methods are still rarely used at this point. The discussed case study represents a jumping-off point for further investigations on the effects of uncertainty on borehole heat exchanger arrays and borehole thermal energy storage systems.

Partner: Ingo Sass (Deutsches Geoforschungszentrum Potsdam)

Contact: Jens Lang

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Project: A-priori error estimates to smooth solutions of Runge-Kutta discontinuous Galerkin (RKDG) methods for scalar fractional conservation laws

Fractional conservation laws (FCLs) are generalizations of convection-diffusion equations where the local diffusion may depend on the global dynamics. They appear in many different contexts such as overdriven gas detonation, mathematical finance and flow in porous media. It is well known that solutions to FCLs may develop shocks in finite time if the diffusion fails to counterbalance the convection and thus an entropy formulation is needed to guarantee well-posedness. Accordingly, in the context of numerical methods, low convergence rates have to be expected and are indeed already available in the literature. Contrary to these worst-case estimates, one may be interested in achievable convergence rates when dealing with sufficiently smooth solutions to obtain a more differentiated picture of the numerical performance. This line of reasoning has been customary in the setting of pure conservation laws which often times share similar properties with FCLs. In fact, for conservation laws, optimal error estimates to smooth solutions of higher order RKDG methods are well known. We aim to establish comparable results for a certain class of FCLs in this project.

Contact: Jan Giesselmann, Fabio Leotta

Project: Reduced order models for convection-diffusion-reaction equations with deterministic and random data based on adaptive snapshots

This project is concerned with the efficient solution of convection-diffusion-reaction equations with sets of deterministic and stochastic input data. We are particularly interested in the multi-query context where the stochastic problem must be solved for a large number of values of the deterministic parameters. In order to solve this task we consider a two step approach: Initially, we compute a fixed number of snapshots of the solution on a predefined set of points in the deterministic parameter domain using adaptively constructed stochastic Galerkin finite element subspaces. Then, we use these snapshots to set up a Galerkin reduced order model based on proper orthogonal decomposition or a greedy procedure. Using adaptive discretizations reduces the computational costs in the setup phase of the reduced order model but also introduces additional error terms. We derive an upper bound for the error of the reduced solution which contains all error sources involved. For every error source, we derive computable upper bounds which are used to steer the construction of the reduced order model.

Contact: Christopher Müller, Jens Lang

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Project: Analysis and numerical approximation of singularly perturbed transport equations on networks

Transport processes on network structures, described by one-dimensional metric graphs, arise in the modelling of various physical phenomena, e.g., the transport of gas mixtures in gas networks, the contaminant transport in water supply networks or networks of 1D cracks, as well as the heat transport in district heating networks. Related problems also appear in the context of traffic flow. In this project, we are particularly interested in singularly perturbed convection-diffusion processes and their limiting behavior to pure transport. For vanishing diffusion, boundary layers arise at network junctions due to a change in the coupling in the transport limit. Moreover, we investigate the systematic numerical treatment of such problems. A hybrid discontinuous Galerkin method and an adaptive strategy turns out to guarantee stability and uniform error estimates in the asymptotic regime.

Support: DFG TRR 154

Contact: Herbert Egger, Nora Philippi

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[3] H. Egger and N. Philippi. An asymptotic preserving hybrid-dG method for convection-diffusion equations on pipe networks. arXiv:2209.04238, 2022.

Project: Kinetic models for chemotaxis and diffusion limits

The movement of bacteria in presence of a chemical substance is called chemotaxis and can be described by kinetic models. The bacteria react to the chemoattractant and approach more favorable environments. In general, the movement is composed into two phases, a "run" phase of directed moving in straight lines and a "tumble phase" of reorientation influenced by the chemoattractant, which itself depends on the bacteria density. In this project, we consider chemotaxis on networks described by one-dimensional metric graphs. Within edges bacteria can only move in two directions, whereas at network junctions, they can enter each incident edge. In the macroscopic limit, chemotaxis is described by the Keller-Segel model. We are now particularly interested in the existence of solutions, and the convergence of the kinetic model to the limit problem.

Partner: Kathrin Hellmuth (Universität Würzburg); Matthias Schlottbom (University of Twente, The Netherlands)

Contact: Herbert Egger, Nora Philippi

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[1] R. Borsche, J. Kall, A. Klar, and T. N. H. Pham. Kinetic and related macroscopic models for chemotaxis on networks. *Math. Models Methods Appl. Sci.*, 26(6):1219–1242, 2016.

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[3] H. Egger and L. Schöbel-Kröhn. Chemotaxis on networks: analysis and numerical approximation. *ESAIM Math. Model. Numer. Anal.*, 54(4):1339–1372, 2020.

Project: Interaction between boundary layers and domain singularities

In this project singularly perturbed partial differential equations including microperforated layers with emphasis on corner singularities shall be analyzed. Singularly perturbed partial differential equations are characterized by microscopic solution behaviour, especially boundary layers. Such a solution behaviour is caused by small (material) parameters in front of the leading order differential operator, like small viscosities, or equivalently large parameters in front of lower order terms as for highly conductive media in electromagnetism. Also, geometrically small features like for thin layers or sheets that may even possess a microstructure leads to boundary layers in the solution. Solution representations taking into account the interaction of boundary layers and domain singularities can be used to construct efficient numerical schemes.

Partner: Bérangère Delourme (University of Paris 13), Monique Dauge (University of Rennes 1), Ralf Hiptmair (ETH Zürich)

Contact: Kersten Schmidt

References

[1] A. Semin, B. Delourme, and K. Schmidt. On the homogenization of the Helmholtz problem with thin perforated walls of finite length. *ESAIM: Math. Model. Numer. Anal.*, 52(1):29–67, 2018.

Project: Impedance conditions for visco-acoustic models

The acoustic damping in gas turbines and aero-engines relies to a great extent on acoustic liners that consist of a cavity and a perforated face sheet. The prediction of the impedance of the liners by direct numerical simulation is nowadays not feasible due to the hundreds to thousands of repetitions of tiny holes. We aim to obtain impedance conditions in viscous gases, especially for multiperforated acoustic absorbers, based on higher order asymptotic expansions and matched asymptotic expansion techniques.

Partner: Friedrich Bake (BAM), Anita Schulz (HTW Berlin)

Contact: Kersten Schmidt

References

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[3] K. Schmidt and A. Thöns-Zueva. Impedance boundary conditions for acoustic time harmonic wave propagation in viscous gases in two dimensions. *Math. Meth. Appl. Sci.*, 45(12):7404–7425, 2022.

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Project: Magnetic oriented approach for modelling and simulation of electric circuits

The modified nodal analysis (MNA) is probably the most widely used formulation for the modeling and simulation of electric circuits. Its conventional form uses electric node potentials and currents across inductors and voltage sources as unknowns, thus taking an electrical viewpoint. In this project, we develop and analyze an alternative magnetic oriented nodal analysis (MONA) approach, which is based on flux linkage potentials and charge differences across capacitors and voltage sources. Despite the different modeling perspective, the approach is applicable to the same general class of circuits and leads to regular systems of differential algebraic equations under the same topological assumptions as required for the MNA. Moreover, while the MNA leads to systems of index ≤ 2, the index of the MONA systems is ≤ 1, which facilitates the numerical treatment.

Partner: Idoia Cortes Garcia (Eindhoven University of Technology, The Netherlands)

Support: DFG TRR 361, DFG SPP 2256, SFB F90-N, DFG GSC 233

Contact: Herbert Egger, Vsevolod Shashkov

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[1] V. Shashkov, I. Cortes Garcia, and H. Egger. MONA-A magnetic oriented nodal analysis for electric circuits. *International Journal of Circuit Theory and Applications*, 50(9):2997–3012, 2022.

Project: Structure preserving simulation in nonlinear evolution problems

The main aim of this project is to develop novel discretization schemes that preserve the inherent geometric structure of underlying physical models, e.g. conservation or dissipation of energy or the production of entropy. Such systems arise in a variety of applications, e.g., in nonlinear wave propagation problems, in acoustics or electromagnetics, but also in nonlinear partial differential equations describing phase transformation. Two classes of such systems are identified and appropriate variational space- and time discretization schemes are developed. The applicability of the new methods is demonstrated in several applications.

Partner: Bai-Xiang Xu (TU Darmstadt)

Support: DFG GSC 233, DFG SPP 2256

Contact: Herbert Egger, Vsevolod Shashkov

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Project: Efficient discretization of memory kernels

This project is devoted to the numerical solution of Volterra integro-differential equations arising in a variety of problems, e.g. multiscale models, dispersive media, boundary element methods for wave propagation, or field-circuit coupled problems. The main challenge consists in the efficient evaluation of memory terms, represented as Volterra integral operators. For a problem with N time-steps, a naive realization leads to algorithms with $O(N^2)$ complexity and requiring $O(N)$ active memory. For the efficient realization, we consider a convolution quadrature approach having $O(N \log N)$ complexity and $O(\log N)$ active memory, and we present a further improvement leading to an algorithm with optimal $O(N)$ complexity. The latter is based on $\mathcal{H}^2$-matrix compression techniques, which we make suitable for a successive evaluation needed for evolutionary problems. We further discuss the application to typical model problems in electromagnetics.

Support: DFG GSC 233, DFG TRR 146

Partner: Jürgen Dölz (Universität Bonn)

Contact: Herbert Egger, Vsevolod Shashkov

References

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Project: Physics informed neural networks for gas transport problems

Physics informed neural networks emerged from the machine learning community and offer a new way to approximate solutions of partial differential equations. Since then, numerous extensions have been proposed and applications have been studied. In this project we want to explore potential applications and examine their benefit to solve gas transport problems. These problems include simulation tasks ranging from pipes to pipeline systems as well as optimization tasks that seek energy efficient controls of elements in the pipeline system. Due to the transport nature of the underlying balance laws, these tasks have unique challenges that we want to solve with the physics informed approach.

For example, to avoid similar simulations with slightly varied controls, reduced order methods are used to speed up the optimization process. However, the commonly used reduced basis methods are not well suited to build a reduced model for gas transport. Here, we build reduced models based on physics informed neural networks. We also apply a second strategy to solve the optimization problem by solving adjoint-based optimality conditions at the same time as the simulation conditions. Both approaches can been seen as extensions to the originally described physics informed neural networks and are made possible by the great flexibility of this method.

Physics informed neural networks are not yet universally applicable in all gas transport scenarios. Special challenges arise when simulating the gas flow in real world scenarios, i.e. long pipes and a realistic speed of sound. Here, we try to understand the noticed obstacles and look into possible solutions.

Finally, we are interested in mathematical analysis of the aforementioned methods.

Partner: Marc Pfetsch (TU Darmstadt)

Support: Graduate School Computational Engineering, TU Darmstadt

Contact: Alf Gerisch, Jens Lang, Erik Laurin Strelow

Project: Local interpolation and projection operators for conforming finite element spaces

We introduce and investigate projection operators mapping to Lagrange elements for arbitrary polynomial order. More specifically, a Scott–Zhang type interpolation operator is constructed that — additionally to the usual properties — is compatible with dual spaces of Sobolev spaces, in the sense that it is stable in the corresponding negative norms. This allows for optimal rates of convergence in situations of low regularity of weak solutions. For comparison we discuss operators with similar properties such as locality, stability and the projection property. Such operators are useful tools to prove interpolation error estimates for parabolic problems and smoothen rough right-hand sides in a least squares finite element method. For first order spaces those results are contained in [1] and extensions are under investigation.

Partner: Lars Diening, Johannes Storn (Universität Bielefeld)

Contact: Tabea Tscherpel

References

[1] L. Diening, J. Storn, and T. Tscherpel. Interpolation operator on negative Sobolev spaces. arXiv:2112.08515, 2021.

Project: L^2-projection mapping to conforming finite element spaces and grading of adaptively refined meshes

In this project we investigate the L^2-projection mapping to conforming finite element spaces on a family of adaptively refined triangulations. While stability results in Sobolev spaces are available for quasi-uniform triangulations, this is not true in general for adaptively refined meshes. Indeed, certain decay properties are strongly linked to the grading of the underlying family of meshes. However, Sobolev stability of the L^2-projection is essential for the numerical analysis of parabolic problems. Even in the simple case of the heat equation it is known to be equivalent to quasioptimality for the semi-discrete approximation (Tantardini, Veeser, 2016, SIAM J. Numer. Anal.). In [1] we have extended existing results on the L^p- and $W^{1,p}$-stability of the projection mapping to Lagrange finite element spaces under realistic assumptions on the mesh grading. In particular this allows for stability results for arbitrary polynomial degrees. For several 2D adaptive refinement schemes the mesh grading has been examined in the literature. For the 3D case the mesh refinements are much more challenging to investigate and to date there are no grading results available. This is subject of ongoing research.

Partner: Lars Diening, Johannes Storn (Universität Bielefeld)

Contact: Tabea Tscherpel

References

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Project: Dimensions of divergence-free finite element spaces

Mixed finite element spaces can be used to approximate incompressible fluid equations such as the Stokes equations. In this setup to ensure stability a discrete inf-sup condition on the velocity and the pressure space is needed. For optimal error estimates on the velocity, mixed finite element spaces for which the discretely divergence-free velocity functions are also exactly divergence-free are well-suitable.

For piecewise polynomial functions on general triangulations as velocity space (Scott–Vogelius element) and the pressure space chosen as the divergence thereof, the inf-sup condition is available only for sufficiently high polynomial degree; in 3D up to now it is only on special triangulations. These assumptions can be relaxed by considering lower polynomial degree on certain split meshes. A comparison of the computational cost has to take both the local number of degrees of freedom and the effect of the split into account. Employing counting arguments in 3D we compare the Scott–Vogelius element with several split methods in terms of computational cost. This also yields insights into discrete de Rham complexes.

Partner: L. Ridgway Scott (University of Chicago, United States; Emeritus)

Contact: Tabea Tscherpel

References

[1] L. R. Scott and T. Tscherpel. Dimensions of exactly divergence-free finite element spaces in 3D. arXiv:2301.00185, 2023.

Project: Numerical analysis of fluid equations with non-standard boundary conditions

For non-Newtonian fluids complex boundary behaviour such as stick-slip or even dynamic boundary conditions are highly relevant to describe the fluid motion correctly. In the context of finite element approximations imposing non-homogeneous boundary conditions in a strong manner can lead to solutions of the homogeneous problem; this phenomenon is known as Babuska paradox. To avoid this one may impose boundary conditions weakly, e.g. by the so-called Nietsche method. The object of this project is to show convergence and error estimates for non-standard boundary conditions in fluid equations, starting with the steady case on polygonal domains and later extending this to the unsteady case. This involves the analysis of certain discrete operators that may prove useful in more general situations.

Partner: Alexei Gazca Orozco (Universität Freiburg); Erika Maringova (Institute of Science and Technology Austria)

Contact: Tabea Tscherpel

Project: Well-balanced approximation of the Green–Naghdi equations

The Green–Naghdi equations are a reduced model between the full free surface incompressible Euler equations and the shallow water equations. As such they are not hyperbolic but include extra terms responsible for dispersion. Numerical schemes that preserve stationary solutions are referred to as well-balanced. Already for the shallow water equations in the presence of a non-flat bottom such schemes have been developed and require a careful treatment of the bottom function. For the Green-Naghdi equations the situation is even more delicate, because there are more stationary solutions and more terms to be taken into account. We aim for an improved understanding of the stationary solutions of the Green–Naghdi equations and a well-balanced approximation.

Partner: Emmanuel Audusse (University Paris 13, France); Martin Parisot (Inria, University of Bordeaux, France)

Contact: Tabea Tscherpel

Project: Adaptive stochastic collocation for problems with non-smooth dependencies in the random space

In many applications we assume some uncertainties in the corresponding models, which we typically approximate with finite dimensional random spaces. It is common to investigate functionals, which map from these spaces to quantities of interest (QoI). Stochastic collocation methods allow us to gather information on stochastic quantities of these functionals, e.g. expected values. In this project we consider problems where these functionals have non-smooth regions. As a first step we investigate algorithms on sparse grids which allow us to identify regions where discontinuities in the first derivative occur. Additionally we work on sparse grid approximations, which operate differently based on the identified smoothness. We want to achieve that our method uses efficient high order approximations in smooth areas. As an application we consider gas networks: Using our method we want to calculate probabilities, in which the network operates below certain thresholds.

Contact: Jens Lang, Hendrik Wilka

Support: DFG TRR 154

1.7 Optimization

The research group **Optimization** consists of the two directions **Discrete Optimization** and **Nonlinear Optimization**, which cooperate closely. Mathematical Optimization considers the development, analysis, and application of efficient numerical methods for minimizing (or maximizing) a function under constraints. While Discrete Optimization studies mainly linear or convex combinatorial problems involving integer variables, Nonlinear Optimization focuses on nonlinear problems with continuous variables. The research group covers both research topics in a comprehensive way and cooperates in particular in the challenging field of Mixed Integer Nonlinear Programming, which considers nonlinear optimization with mixed discrete-continuous variables.

Discrete Optimization has become an important component in modern applied mathematics. Many problems from business and industry can be modeled as discrete optimization problems. The development of solution methods for these problems is the main focus of the group Discrete Optimization. This includes the development of mathematical models of real-world problems, the theoretical analysis (using methods mainly from graph theory, polyhedral combinatorics, and integer programming), and the design and implementation of fast algorithms as well as their evaluation in practice.
Experiences of the group are, for instance, in the following applied areas: public mass transportation (line planning, disruption management), energy optimization (gas transport), or optimization in mechanical engineering (truss topology optimization), see the projects for details.

Nonlinear Optimization is nowadays an important technology in applied mathematics, science, and engineering. Nonlinear optimization problems appear in many applications, e.g., shape optimization in engineering, robust portfolio optimization in finance, parameter identification, optimal control, etc. Nonlinear Optimization has emerged as a key technology in modern scientific and industrial applications. Challenging are in particular optimization problems with partial differential equations as constraints (PDE-constraints), for example optimization problems for flows, transport problems, diffusion processes, wave propagation, or mechanical structures. An efficient solution of such problems requires highly developed optimization methods, which use modern adaptive multilevel techniques of scientific computing.
The research group Nonlinear Optimization considers the development, theory, implementation, and application of efficient algorithms for nonlinear optimization. Particular research topics are PDE-constrained optimization, large scale optimization, adaptive multilevel techniques, discretization error for PDE-constrained optimization, preconditioning, global optimization, and relaxation of discrete problems.

The research group Optimization is or was engaged among others in the Darmstadt Graduate School of Excellence GSC 233 *Computational Engineering: Beyond Traditional Sciences*, the Darmstadt Graduate School of Excellence GSC 1070 *Energy Science and Engineering*, the Collaborative Research Centre (SFB) 805 *Control of Uncertainty in Load-Carrying Structures in Mechanical Engineering*, the Collaborative Research Centre (SFB) 1194 *Interaction of Transport and Wetting Processes*, the Transregional Collaborative Research Centre (Transregio/SFB) 154 *Mathematical Modelling, Simulation and Optimization on the Example of Gas Networks*, the Hessian Cluster project Clean Circles, MeFlexWärme: Mathematical Optimization of

Heating Networks, the German Research Foundation (DFG) Priority Programme (SPP) 1748 *Reliable Simulation Techniques in Solid Mechanics. Development of Non-standard Discretization Methods, Mechanical and Mathematical Analysis*, the German Research Foundation (DFG) Priority Programme (SPP) 1798 *Compressed Sensing in Information Processing* and the German Research Foundation (DFG) Priority Programme (SPP) 1962 *Non-smooth and Complementarity-based Distributed Parameter Systems: Simulation and Hierarchical Optimization*.

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Project: Numerical approximation of optimal control problems for hyperbolic conservation laws (Subproject A02 of Transregio/SFB 154, phase 2)

A lot of continuum models for physical problems, such as traffic modeling and fluid mechanics, are described by hyperbolic conservation laws. Some of these networks include switching processes like traffic flow models and water/gas network models. This motivates an analytic study and numerical approximation of optimal control problems of nonlinear hyperbolic conservation laws on networks under modal switching, where switchings are considered in the source terms as well as at boundary nodes and junctions. The main difficulty in the analysis of conservation laws arises from the fact that even in the case of a single scalar conservation law and smooth data the entropy solution usually develops shocks, which causes the solution operator to not be differentiable in the usual sense. However, encouraging progress has been achieved recently for the optimal control of conservation laws by using a generalized notion of differentiability (so called shift-differentiability). It was shown by Pfaff and Ulbrich that under weak assumptions tracking-type objective functionals are differentiable with respect to the initial and boundary control and that the reduced gradient can be represented by the reversible solution of a suitable adjoint equation. The goal of this project is a precise study of the associated adjoint and sensitivity equations and their solutions. Moreover, the project derives a detailed numerical analysis of optimal control problems for switched networks of conservation laws on bounded domains.

Partner: Transregio/SFB 154: “Mathematical Modelling, Simulation and Optimization on the Example of Gas Networks”; speaker Prof. Dr. Frauke Liers (Department of Data Science, Universität Erlangen-Nürnberg)

Support: DFG

Contact: P. Schäfer Aguilar, S. Ulbrich

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Project: Analysis and consistent numerical approximation of optimization problems for hyperbolic PDE models of gas networks (Subproject A02 of Transregio/SFB 154, phase 3)

Hyperbolic conservation laws are essential to describe certain physical problems, such as traffic modeling and fluid mechanics. The Transregio/SFB 154 relies on their analysis in the context of gas networks. The goal of the project is the mathematical analysis and consistent numerical discretization of optimal control problems for networks/systems of hyperbolic conservation laws. In order to provide a quite general setting, we consider entropy solutions and allow for controls that switch between smooth control functions. The main difficulty in the analysis of conservation laws arises from the fact that even in the case of a scalar conservation law and smooth data the entropy solution usually develops shocks, which causes the solution operator to not be differentiable in the usual sense.
We will continue the convergence analysis of discrete sensitivity and adjoint schemes for hyperbolic systems of the previous phases by extending results of the scalar case [2]. The considerations of systems of hyperbolic conservation laws brings additional difficulties for the structure of entropy solutions [1]. It requires to carefully treat the coupling of the different characteristic fields. In particular, this applies to the associated equation to ensure that its discretization converges to the correct reversible solution. Moreover, we plan to study higher order schemes and derive error estimators for the optimal control of entropy solutions.

Partner: Transregio/SFB 154: "Mathematical Modelling, Simulation and Optimization on the Example of Gas Networks"; speaker Prof. Dr. Frauke Liers (Department of Data Science, Universität Erlangen-Nürnberg)

Support: DFG

Contact: J. Breitkopf, S. Ulbrich

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Project: Mixed-integer nonlinear optimization methods for the optimization of the overall system Clean Circles under uncertainty (Subproject of Clean Circles)

The aim of this subproject is the efficient optimization of an overall model for the Clean Circles system with regard to one or multiple target objectives, e.g. energetic efficiency [1] or cost functions. It focuses on the technical components, which are modeled by coupled material, energy and cost flows. Since in general the system components are described by nonlinear algebraic or differential algebraic equations and the configuration of the overall system requires discrete decisions (combination of different technologies, choice of scenarios, etc.), the result is a mixed-integer nonlinear optimization problem. Uncertainties must be taken into account both in the modeling of the iron cycle and in the inclusion of market aspects. This requires the development of techniques for robust nonlinear optimization. The solution techniques for an efficient optimization of the overall system under uncertainty shall be combined in an algorithmic solver.

Partner: Cluster Project: "Clean Circles"; speaker Prof. Dr.-Ing. Andreas Dreizler and Prof. Dr.-Ing. Christian Hasse (Department of Mechanical Engineering, TU Darmstadt)

Support: HMWK

Contact: E. Corbean, S. Ulbrich

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Project: Simulation-based Optimization and Optimal Design of Experiments for Wetting Processes (Subproject B04 of Collaborative Research Centre (SFB) 1194)

This project is part of the Collaborative Research Centre (SFB) 1194: "Interaction of Transport and Wetting Processes" and considers the development of a simulation based optimization framework for multiphase flow in the context of wetting phenomena. We use gradient-based multilevel optimization methods for parameter identification problems and geometrical optimization tasks. The aim is to optimize material and operational properties of fluids or surfaces to design wetting processes with desirable properties. An example of such a wetting process is the doctor blading, which is a sub process of printing or coating. The results of this optimizations should be particularly valuable for the future selection of generic experimental setups and will make available quantities which are difficult to measure experimentally. Moreover, some theoretical investigations are in focus. Based on L_p-maximal regularity of the underlying linear twophase problem we showed the differentiability of the control-to-state-mapping, arising from resulting optimal control problems, with respect to initial and distributed controls for appropriate spaces [1].

Partner: Collaborative Research Centre (SFB) 1194: "Interaction of Transport and Wetting Processes"; speaker Prof. Dr.-Ing. Peter Stephan (Department of Mechanical Engineering, TU Darmstadt)

Support: German Research Foundation (DFG)

Contact: E. Diehl, S. Ulbrich

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Project: Robust optimization and evaluation of the energy and logistics networks in Clean Circles (Subproject of Clean Circles)

The main benefit of an iron-based cycle for a CO_2-neutral energy storage is the capability to relatively easily and cheaply store and transport energy compared to other chemical energy carriers like hydrogen. This enables decoupling the location of energy generation and its consumption as well as energy storage. Hence, we can expand considerations for a climate-neutral energy supply of Germany to international locations with multiple renewable energy sources. For evaluating the resulting circular model under differing criteria, the development and optimization of a corresponding material cycle with attached energy consumption and generation models are necessary. Due to the dependencies of the logistic network on its energy components, the further development of solvers for nonlinear mixed integer problems is needed for robust and optimal decisions regarding choices of technologies, locations and components of the overall system. In addition to that, the development of appropriate methods for sensitivity analysis of such problems is required for evaluating iron as an energy carrier. Different economical, process-related and political uncertainties as well as multiple (conflicting) criteria are also considered for the overall evaluation of the concept.

Partner: Cluster Project: “Clean Circles”; speaker Prof. Dr.-Ing. Andreas Dreizler and Prof. Dr.-Ing. Christian Hasse (Department of Mechanical Engineering, TU Darmstadt)

Support: HMWK

Contact: E. Jansen, M. E. Pfetsch

Project: Design Optimisation of Electric Machines under Uncertainty and Optimal Design of Experiments for Parameter Identification (Subproject D03 of TRR361)

In this project the design (shape and topology) of electric machines under uncertainties is optimised. Electric machines are described with sufficient accuracy by the magnetostatic approximation of Maxwell´s equations, which yields for a Permanent Magnet Synchronous Machine (PMSM) to an elliptic partial differential equation (PDE). Also production tolerances, material variations, usage scenarios and other influences have to be taken into account during the optimisation, because they lead to uncertainty in the shape or topology optimisation of electric machines.

The optimised design should be robust with respect to the considered uncertainties either in a worst case sense (robust optimisation) or in a stochastic sense while providing similar performance as the nominal optimum. The development of efficient methods for complex shape or topology optimisation under uncertainty is challenging. Such problems are a bilevel optimisation problem with PDE-contraints which are contained of an inner maximization problem and difficult to treat numerically.

To obtain tractability of the problem an approximation (linear, quadratic, reduced order model) of the problem is necessary.

Moreover, in order to determine material properties, e.g., local magnetic properties, accurately and to quantify their uncertainty, advanced methods for optimal experimental design governed by PDEs are required.

Partner: Collaborative Research Centre - TRR361/F90: CREATOR - Computational Electric Machine Laboratory

Support: DFG

Contact: T. Komann, S. Ulbrich

Project: Online optimization of potential-based flow networks (Subproject A09 of Transregio/SFB 154, phase 3)

The goal of this project is to address temporal uncertainties arising in the planning and operation of potential-based flow networks, and gas networks in particular, in terms of combinatorial online optimization. Long-term decisions need to be made to address the development of new infrastructures and the systematic expansion of networks, while short-term decisions are required to react to fluctuations in demand. The former setting arises, for example, in the development of upcoming hydrogen networks, where demands and production capacities are still very much uncertain. The latter fluctuations play an important role, for example, when coupling gas networks to renewable energy sources which highly depend on seasonal and weather changes, affecting other forms of backup energy generation and storage. We plan to approach these temporal uncertainties from a combinatorial perspective of online optimization, i.e., we ask for algorithms that need to make irrevocable decisions as the input is revealed over time without knowledge of future data. The key objectives in this context are to (a) devise suitable approaches for algorithmically handling these uncertainties, and to (b) evaluate the performance of these algorithms both in theory and practice. The first part of the project focuses on long-term uncertainties in the framework of incremental optimization, and the second part of the project then expands to more dynamic online settings, capturing short- and medium-term uncertainties.

Partner: Prof. Dr. Max Klimm (TU Berlin); Transregio/SFB 154: "Mathematical Modelling, Simulation and Optimization on the Example of Gas Networks"; speaker Prof. Dr. Frauke Liers (Department of Data Science, Universität Erlangen-Nürnberg)

Support: DFG

Contact: A. Lutz, Y. Disser

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Project: Mathematical optimization in robust product design (Subproject A3 of Collaborative Research Centre (SFB) 805)

The objectives of this subproject are the optimal design of load-carrying systems under uncertainty based on complex finite-element methods for system components and the determination of optimal excitations and sensor positions such that model uncertainty during production and usage can be identified reliably. The first goal is achieved by the development and application of novel mathematical methods for the robust optimization of geometry, topology and for actuator placement. For an efficient numerical treatment, first- and second-order approximations with respect to the uncertain parameters were used and reduced-order models with a-posteriori error control were implemented [1]. In order to detect model uncertainty after production or during usage, we developed a novel algorithm [2]. Therein, parameter estimation problems are solved in real time to estimate specific model parameters based on collected sensor data. In order to keep the estimation variance low, methods of optimal experiment design are applied that determine optimal sensor positions as well as optimal excitation positions and signals. A hypothesis test with the estimated parameters which are obtained from different test sets is constructed to quantify the quality of the employed model and the risk of its rejection.

Partner: Collaborative Research Centre (SFB) 805: "Control of Uncertainty in Load-Carrying Structures in Mechanical Engineering"; speaker Prof. Dr.-Ing. Peter Pelz (Department of Mechanical Engineering, TU Darmstadt)

Support: DFG

Contact: A. Matei, S. Ulbrich

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Project: Exploiting structure in compressed sensing using side constraints – From analysis to system design (EXPRESS II)

The key objective in EXPRESS II is to design, configure, and dimension hybrid analog/digital data acquisition systems for sparse signal recovery under structure. We consider exploiting prior knowledge of particular structure in the array geometry (e.g., uniform-linear arrays, shift-invariant arrays, etc.), the source signals (e.g., signal constellations, constant modulus, etc.), and the temporal signature of the signals (e.g., block-, row-, or rank-sparsity) in the hybrid system. This requires theoretical results regarding sparse signal recoverability exploiting the available structure as well as formulating and solving the corresponding optimization criteria. As a particularly interesting structure we have considered recovery of integral source signals with and without additional bounds. This structure can be exploited by using ℓ_1-minimization with an additional integrality constraint and possibly variable bounds. The results of the project are summarized in [1] and the dissertation [2].

Partner: DFG Priority Programme (SPP) 1798: "Compressed Sensing in Information Processing"; speakers Prof. Dr. Gitta Kutyniok (Department of Mathematics, LMU Munich) and Prof. Dr. Holger Rauhut (Chair for Mathematics of Information Processing, RWTH Aachen)

Support: DFG

Contact: F. Matter, M. E. Pfetsch

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Project: `polymake/polyDB`

The mathematical software system `polymake` provides a wide range of functions for convex polytopes, simplicial complexes, polyhedral cones and fans, lattice polytopes, toric geometry

and tropical geometry. While the system exists for more than 20 years it was continuously developed and expanded. The focus of the development in the last years was on interaction with other software systems that complement methods and computations offered by `polymake`, among them `GAP` and `Singular`, and their application to extend the capabilities of `polymake`. A combined access is now implemented within the computer algabra system `OSCAR` (oscar.computeralgebra.de). `polymake` offers an interface similar to many computer algebra systems. However, on the technical level polymake differs from most mathematical software systems: rule based computations, a flexible object hierarchy and an extendible dual Perl/C++ interface are the most important characteristics. Recent development also allows access to `polymake` via Jupyter notebooks and via a common Julia based interactive shell with `GAP` and `Singular`.
The database `polyDB` (polyDB.org) collects research data in the areas of discrete, combinatorial and tropical geometry. It aims to provide a free, simple, and structured access to available research data in these fields with links to relvant literature and sources. The data is accessible via the web page, interfaces from polymake and OSCAR, and a REST API for integration into other software projects.
polymake is an open source software project. The current version 4.9 can be downloaded from polymake.org.

Partner: Michael Joswig (TU Berlin); Ewgenij Gawrilow (TomTom N.V.), The `polymake` team

Contact: A. Paffenholz

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Project: Optimization and control (Subproject AP C of PASIROM)

This project is a subproject of PASIROM, which builds upon the achievements of SIMUROM, its predecessing project. As in SIMUROM, the modeling, simulation and optimization of electromechanical energy converters is investigated. In the subproject we particularly focus on the robust shape optimization of an asynchronous induction machine, which can be modeled by a coupled system of partial differential algebraic equations. In our robust optimization approach we treat uncertainties due to imperfect manufacturing and therefore geometric imprecision. We use the worst case approach to treat the uncertainties and approximate the robust counterpart by Taylor expansions of different degrees to get a numerically convenient problem. To reduce computational effort we apply a model order reduction technique in the form of the proper orthogonal decomposition method. As we consider linear and nonlinear material properties, we use the discrete empirical interpolation method to efficiently evaluate the nonlinear terms.

Partner: Sebastian Schöps (TU Darmstadt); Stephanie Friedhoff (Universität Wuppertal); Michael Hinze (Universität Hamburg); Stefan Kurz, Oliver Rain (Robert Bosch GmbH); Enno Lange, Stefan Reitzinger (CST - Computer Simulation Technology AG)

Support: Federal Ministry of Education and Research (BMBF)

Contact: B. Polenz, S. Ulbrich

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Project: Mathematical optimization of heating networks (Subproject of EnEff:Wärme – MeFlexWärme)

The decarbonization of heat generation plays a major role for limiting climate change. The project EnEff:Wärme – MeFlexWärme: "Methods for flexible heating networks of the future" is concerned with the flexibility of heating networks to enable decarbonization of heat generation. The heat generation from electrical energy (power-to-heat) can provide a major contribution to maintaining low-CO_2 heat and offer an alternative for electricity storing. To enable a flexible balance between heat generators, storage tanks and consumers, appropriate network expansions are significant. The project is executed together with an interdisciplinary group of TU Darmstadt as well as industrial partners and is focused on research in the areas of network transparency, flexibility and mathematical optimization of heating networks.

As part of the project we consider the modeling and globally optimal solving of heating networks to make heating networks flexible. The globally optimal solution determines the control of pumps and heatings in the network to regulate the state variables massflow, pressure and temperature. Boundary conditions are the consumed heat power as well as network related variable bounds. The development of the state variables over the network is determined by nonlinear equations with discrete decisions. The goal is to enable good solvability of the Mixed-Integer Nonlinear Problem (MINLP) with the high accuracy. To achieve this, we consider convex relaxations and approximations of the model equations as well as network specific properties. The research is validated with real network data and the results are integrated in the other research areas.

Partner: Entega AG; Siemens AG; speaker Prof. Dr. Florian Steinke (TU Darmstadt)

Support: BMWK

Contact: L. Rehlich, M. E. Pfetsch, S. Ulbrich

Project: Resilient design (Subproject A9 of Collaborative Research Centre (SFB) 805)

In this subproject, optimization methods for the optimal design of technical systems under uncertainty were developed. The goal was to find an optimal combination of different components constituting a resilient system structure, i.e., a structure which can tolerate failing components. To evaluate and optimize resilience, the concept of k-reliability is used. If a system is k-reliable, k of its components can fail and it still fulfills a previously defined minimum function. If one takes this property into account, the corresponding mathematical optimization model has multiple levels, since an emergency function must be guaranteed for each combination of a previously specified maximum number k of failed components. In [2], a generic approach to optimally design resilient systems is developed, based on a nested Benders algorithm and general underlying mixed-integer nonlinear optimization models. Moreover, the outcomes of this project are summarized in the dissertations [3] and [1].

Partner: Collaborative Research Centre (SFB) 805: "Control of Uncertainty in Load-Carrying Structures in Mechanical Engineering"; speaker Prof. Dr.-Ing. Peter Pelz (Department of Mechanical Engineering, TU Darmstadt); Lena C. Altherr (Faculty of Energy, Buildings, Environment, Münster University of Applied Sciences), Philipp Leise (Department of Mechanical Engineering, TU Darmstadt)

Support: DFG

Contact: A. Schmitt, M. E. Pfetsch

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Project: Optimal control of Navier-Stokes with combustion

Based on the work of the SFB 568 subproject D5 we continue to develop efficient methods for the optimization of combustion chambers containing turbulent fluid flow and combustion processes, which are modeled by partial differential equations.
The employed optimization methods rely on adjoints and derivative information, calculated by automatic differentiation [1]. The implementation uses the parallel multi-grid flow solver "Fastest", which incorporates recent simplified combustion models such as the flamelet-generated-manifold (FGM) method.

Partner: Darmstadt Graduate School of Excellence Energy Science and Engineering (GSC 1070); speakers Prof. Dr. Wolfram Jaegermann and Prof. Dr. Johannes Janicka (TU Darmstadt)

Support: DFG

Contact: C. Sehrt, S. Ulbrich

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Project: Competitive analysis for incremental maximization

Incremental Maximization deals with the problem of incrementally building a solution set without knowing the maximum feasible size of the set. Thus, the solution has to be competitive for every size while it is built. Problems like this arise when incrementally developing communication, production, storage, and other infrastructures. In [**?**], under very mild assumptions, a lower bound of ~ 2.18 and an upper bound of $1 + \varphi$ were presented, where $\varphi \approx 1.618$ is the golden ratio, was proven for the competitive ratio. Furthermore, in this paper, the property of

α-augmentability was introduced. It was proven that, for α-augmentable, monotone objectives, the solution produced by the greedy algorithm is $\alpha\frac{e^\alpha}{e^\alpha-1}$-competitive and that this competitive ratio is tight for $\alpha \in \{1,2\}$ and for $\alpha \to \infty$.
As a first contribution, we introduced γ-α-augmentability as a relaxation of α-augmentability [**?**]. We proved a tight bound of $\frac{\alpha}{\gamma}\frac{e^\alpha}{e^\alpha-1}$ on the competitive ratio of the greedy algorithm for γ-α-augmentable, monotone objective functions, and we were able to extend our lower bound construction to α-augmentable objectives to show that the known upper bound of $\alpha\frac{e^\alpha}{e^\alpha-1}$ is tight for all $\alpha > 0$. In an effort to reduce the gap between 2.18 and 2.618, we introduced a continuization technique to analyze incremental maximization, and used it to increase the lower bound of 2.18 to 2.24. We investigated randomized algorithms for incremental maximization and were able to show a lower bound of 1.447 for all randomized algorithms and an upper bound of 1.772 by providing a randomized algorithm that achieves this competitive ratio.

Support: DFG

Contact: D. Weckbecker, Y. Disser

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Project: Optimizing fracture propagation using a phase-field approach (Project P17 in Phase 1 of SPP 1962)

We consider the numerical approximation and solution of control problems governed by a quasi-static brittle fracture propagation model. As a central modeling component, a phase-field formulation for the fracture formation and propagation is considered.
The fracture propagation problem itself can be formulated as a minimization problem with inequality constraints, imposed by multiple relevant side conditions, such as irreversibility of the fracture-growth or non-selfpenetration of the material across the fracture surface. These lead to variational inequalities as first order necessary conditions. Consequently, optimization problems for the control of the fracture process give rise to a mathematical program with complementarity constraints (MPCC) in function spaces.
Within this project, we intend to analyze the resulting MPCC with respect to its necessary and sufficient optimality conditions by means of a regularization of the lower-level problem and passage to the limit with respect to the regularization parameter. Moreover, we will consider SQP-type algorithms for the solution of this MPCC in function space and investigate its properties. Additionally, we will consider the discretization by finite elements and show the convergence of the discrete approximations to the continuous limit.
The simultaneous consideration of the inexactness due to discretization and regularization error will allow us to construct and analyze an efficient inexact SQP-type solver for the MPCC under consideration.

Partner: Ira Neitzel (Universität Bonn), Thomas Wick (Universität Hannover), Christoph Ortner (University of Warwick), DFG Priority Programme (SPP) 1962: "Non-smooth and

Complementarity-based Distributed Parameter Systems: Simulation and Hierarchical Optimization"; speaker Prof. Dr. Michael Hintermüller (HU Berlin / WIAS Berlin)

Support: DFG

Contact: M. Mohammadi, W. Wollner

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Project: Optimizing fracture propagation using a phase-field approach (Project P15 in Phase 2 of SPP 1962)

We consider the numerical approximation and solution of control problems governed by a quasi-static brittle fracture propagation model. As a central modeling component, a phase-field formulation for the fracture formation and propagation is considered.

The fracture propagation problem itself can be formulated as a minimization problem with inequality constraints, imposed by multiple relevant side conditions, such as irreversibility of the fracture-growth or non-selfpenetration of the material across the fracture surface. These lead to variational inequalities as first order necessary conditions. Consequently, optimization problems for the control of the fracture process give rise to a mathematical program with complementarity constraints (MPCC) in function spaces.

Within this project, we intend to focus on mathematical challenges, that are also motivated by applications, such as control of the coefficients of the variational inequality, or nonsmooth and/or nonconvex cost functionals in the outer optimization, such as, e.g., maximizing the released energy of the fracture. We will develop first and second order optimality conditions for the resulting MPCC as well as other obstacle-like formulations. Additionally, we will consider the discretization by finite elements and show the convergence of the discrete approximations to the continuous limit. These findings will be substantiated with prototype numerical tests.

Partner: Ira Neitzel (Universität Bonn), Thomas Wick (Universität Hannover), DFG Priority Programme (SPP) 1962: "Non-smooth and Complementarity-based Distributed Parameter Systems: Simulation and Hierarchical Optimization"; speaker Prof. Dr. Michael Hintermüller (HU Berlin / WIAS Berlin)

Support: DFG

Contact: N. Simon, W. Wollner

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Project: Structure preserving adaptive enriched Galerkin methods for pressure-driven 3D fracture phase-field models (Project in SPP 1748)

This project is focused on numerically stable treatment of incompressible and quasi-incompressible materials within a quasi-static fracture growth problem. At a given time-step the discretization of the incompressible material by standard mixed methods will introduce an error of the displacement depending on the pressure; a situation that is highly problematic in hydraulic equilibria where the pressure error can be large despite the fact that the displacement is easy to calculate. Therefore, a pressure-robust discretization technique for incompressible quasi static damage evolutions has been investigated to overcome the above mentioned problem. A pressure-robust technique of interpolating discrete divergence free functions to divergence free functions has been implemented in deal.II and DOpE lib libraries for stationary stokes and linear elasticity problems. The extension to the quasi-incompressible case is currently under investigation.

Partner: Katrin Mang, Thomas Wick (Universität Hannover), Mirjam Walloth (TU Darmstadt), DFG Priority Programme (SPP) 1748: "Reliable Simulation Techniques in Solid Mechanics. Development of Non-standard Discretization Methods, Mechanical and Mathematical Analysis"; speaker Prof. Dr. Jörg Schröder (Universität Duisburg-Essen)

Support: DFG

Contact: S. Basava, W. Wollner

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Project: Eigenvalue optimization with respect to shape variations in electro-magnetic systems

The goal of particle accelerators cavities is to transfer energy to a charged particle beam by applying an electric field. To achieve accurate simulation results an exact representation of the geometry of electro-magnetic devices is crucial because even small changes can have a

non-negligible effect on the final performance. The field distribution and its frequency in a radio-frequency (RF) cavity are governed by the Maxwell's eigenvalue problem.
Within this project, we consider the optimization of these eigenvalues by means of shape optimization. To this end, we utilize a mixed formulation by (Kikuchi (1987)) and a discretization by means of Nédelec elements. The shape optimization is based on the method of mappings, where a Piola transformation is utilized to assert conformity of the mapped spaces. The derivation of derivatives is based on adjoint calculus for the constraining Maxwell eigenvalue problem.

Partner: Prof. Dr. Sebastian Schöps (TU Darmstadt)

Contact: C. Herter, W. Wollner

References

[1] C. Herter, S. Schöos, and W. Wollner. Eigenvalue optimization with respect to shape-variations in electromagnetic cavities. In *PAMM*, volume 22, 2023.

1.8 Stochastics

Research in the stochastics group is split into a probability theory part (Aurzada, Betz) and a part on mathematical statistics (Kohler, Wichelhaus).
In the mathematical statistics part, we work on curve estimation. The particular focus here is on the derivation of a statistical theory for deep learning. Furthermore, we study nonparametric estimation problems for stochastic networks. The major research topics studied by the probability group are statistical mechanics, interacting particle systems, stochastic processes, and problems from applied probability. The particular problems considered are from the following areas: spacial random permutations, probabilistic methods in quantum theory, the theory of Bose-Einstein condensation, exit problems for stochastic processes and their relation to functional analysis, fractional processes, insurance mathematics, and limit theorems for spatial models.
The members of the research group stochastics are involved in joint projects with colleagues working in probability and statistics as well as colleagues in sciences where probability and statistics are applied to, such as econometrics, engineering, telecommunication, physics, and psychology. Furthermore, we carry out research projects in applied stochastics with industrial partners.

Members of the research group
Professors and Permament Staff

Frank Aurzada, Volker Betz, Michael Kohler

Postdocs

Cornelia Wichelhaus

Research Associates

Selina Drews, Max Helmer, Andreas Klippel, Lukas Roth, Dominic T. Schickentanz, Benjamin Walter

Secretary

Alexandra Frohn

Project: Persistence probabilities

Persistence probabilities concern the question that a stochastic process remains below a fixed boundary for a long time. This is a classical question in probability that was studied extensively for random walks and Lévy processes. It has various connections to other fields, most notably to statistical physics and insurance. In physics, the rate of decay of the persistence probability is perceived as a measure for the return time of a complicated physical system to an equilibrium state. In insurance, one asks for the probability of (non)ruin of an asset, which is clearly the probability that a stochastic process remains above a fixed boundary. In this project, we study persistence probabilities of fractional processes [1, 2, 3] and of Markov chains [4].

Support: German Research Association (DFG), AU370/5.

Partner: Sumit Mukherjee (Columbia University), Ercan Sönmez (Klagenfurt), Ofer Zeitouni (Weizman Institute)

Contact: Frank Aurzada

References

[1] F. Aurzada and M. Kilian. Asymptotics of the persistence exponent of integrated fractional Brownian motion and fractionally integrated Brownian motion. *Theory Probab. Appl.*, 67(1):77–88, 2022. Translation of Teor. Veroyatn. Primen. 6(7) (2022), 100–114.

[2] F. Aurzada, M. Kilian, and E. Sönmez. Persistence probabilities of mixed FBM and other mixed processes. *J. Phys. A*, 55(30):Paper No. 305003, 17, 2022.

[3] F. Aurzada and S. Mukherjee. Persistence probabilities of weighted sums of stationary Gaussian sequences. Preprint, 2022.

[4] F. Aurzada, S. Mukherjee, and O. Zeitouni. Persistence exponents in Markov chains. *Ann. Inst. Henri Poincaré Probab. Stat.*, 57(3):1411–1441, 2021.

Project: Chains of interacting Brownian particles

We investigate the behaviour of a finite chain of Brownian particles, interacting through a pairwise potential, with one end of the chain fixed and the other end pulled away at slow speed, in the limit of slow speed and small Brownian noise. We study the instant when the chain “breaks,” that is, the distance between two neighboring particles becomes larger than a certain limit. There are three different regimes depending on the relation between the speed of pulling and the Brownian noise. We prove weak limit theorems for the break time and the break position for each regime, [1, 2, 3].

Support: German Research Association (DFG), AU370/7.

Partner: Mikhail Lifshits (St. Petersburg)

Contact: Frank Aurzada, Volker Betz

References

[1] F. Aurzada, V. Betz, and M. Lifshits. Breaking a chain of interacting Brownian particles. *Ann. Appl. Probab.*, 31(6):2585–2611, 2021.

[2] F. Aurzada, V. Betz, and M. Lifshits. Breaking a chain of interacting Brownian particles: a Gumbel limit theorem. *Theory Probab. Appl.*, 66(2):184–208, 2021. Translation of Teor. Veroyatn. Primen. 6(6) (2021), 231–260.

[3] F. Aurzada, V. Betz, and M. Lifshits. Universal break law for a class of models of polymer rupture. *J. Phys. A*, 54(30):Paper No. 305204, 28, 2021.

Project: Applied probability problems

We investigate several problems related to applied probability models and their applications to engineering problems.
In a joint project with colleagues from the group of Prof. Klein (FB ETIT), we deal with a wireless communication network and try to optimize the age-of-information at a specific node of the network. For this purpose, a specifically adapted reinforcement learning algorithm is developed and proved to be optimal in a certain class, [1].
Further, in a cooperation with colleagues from the Institute for Systems Theory and Automatic Control at the University of Stuttgart, we studied a distributed system (e.g. sensors) that regularly need to update the current status. Here, the different performance of an event-triggered algorithm vs. a time-triggered algorithm are investigated, [2].

Partner: Wanja de Sombre, Andrea Ortiz, Anja Klein (FB ETIT, TU Darmstadt), David Meister, Frank Allgöwer (Universität Stuttgart), Mikhail Lifshits (St. Petersburg)

Support: German Research Association (DFG), AU370/7.

Contact: Frank Aurzada

References

[1] W. de Sombre, A. Ortiz, F. Aurzada, and A. Klein. Minimization of age of information using threshold-based and risk-sensitive approaches. Preprint, 2022.

[2] D. Meister, F. Aurzada, M. Lifshits, and F. Allgöwer. Analysis of time- versus event-triggered consensus for a single-integrator multi-agent system. Preprint, 2022.

Project: Brownian motion conditioned to spend limited time outside intervals

We investigate a standard Brownian motion which is conditioned to spend limited time outside the interval $(-\infty, 0]$. As this event has zero probability, a limiting procedure has to be applied. This is published in [1].
The corresponding question where Brownian motion is conditioned to spend limited time outside $[-1, 1]$ is work in progress.

Partner: Martin Kolb (Universität Paderborn)

Contact: Frank Aurzada, Dominic Schickentanz

References

[1] F. Aurzada and D. T. Schickentanz. Brownian motion conditioned to spend limited time below a barrier. *Stochastic Process. Appl.*, 146:360–381, 2022.

Project: Spatial random permutations and Bose-Einstein condensation

The theoretical understanding of the quantum phenomenon of Bose-Einstein condensation is one of the great unsolved problems of theoretical physics. It is well known that the quantum mechanical problem can be translated into a probabilistic one by using the Feynman-Kac formula. The result is a system of interacting spatial permutations, and the question to be answered is about a phase transition in the typical length of cycles, with the order parameter being the typical distance of two spatial points that will be mapped into each other by the permutation. Even though an understanding of the full probabilistic model is currently out of reach, there are various simplifications that should exhibit typical properties of the full model and are interesting in their own right. Moreover, these simpler models touch on many other current topics of statistical mechanics, such as motion by mean curvature, percolation or Schramm-Löwner evolution. The work in the research group is focused on understanding various of these aspects in simple cases, using both analytical and numerical methods.

Partner: D. Ueltschi (University of Warwick); Lorenzo Taggi (WIAS Berlin); Peter Mörters (Universität Köln); Steffen Dereich (Universität Münster)

Contact: V. Betz

References

[1] V. Betz, S. Dereich, and P. Mörters. The shape of the emerging condensate in effective models of condensation. *Annales Henri Poincare*, pages 1869–1889, 2018.

[2] V. Betz, J. Mühlbauer, H. Schäfer, and D. Zeindler. Precise asymptotics of longest cycles in random permutations without macroscopic cycles. *Bernoulli*, 27.3, 2021.

[3] V. Betz and H. Schäfer. The number of cycles in random permutations without long cycles is asymptotically gaussian. *ALEA*, 14:427–444, 2017.

[4] V. Betz, H. Schäfer, and L. Taggi. Interacting self-avoiding polygons. *Ann. Inst. H. Poincaré Probab. Statist.*, 56:1321–1335, 2020.

[5] V. Betz, H. Schäfer, and D. Zeindler. Random permutations without macroscopic cycles. *Ann. Appl. Probab.*, 30:1484–1505, 2020.

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[7] V. Betz and D. Ueltschi. Spatial random permutations and poisson-dirichlet law of cycle lengths. *Electronic Journal of Probability*, 16:41, 2011.

[8] V. Betz and D. Ueltschi. Spatial random permutations with small cycle weights. *Probab. Th. Rel. Fields*, 149:191–222, 2011.

[9] V. Betz, D. Ueltschi, and Y. Velenik. Random permutations with cycle weights. *Ann. Appl. Probab.*, 21:312–331, 2011.

Project: Loop models and quantum systems

Quantum many body systems can be described by so-called loop models. These are percolation type models that, however, have much stronger correlations than usual and are thus very hard to analyse. On certain graphs (like trees) there has been some progress. We investigate different types of loop models using probabilistic techniques.

Partner: Benjamin Lees (Bristol), Daneil Ueltschi (Warwick)

Contact: V. Betz

References

[1] V. Betz, J. Ehlert, and B. Lees. Phase transition for loop representations of quantum spin systems on trees. *Journal of Mathematical Physics*, 59:113302, 2018.

[2] V. Betz, J. Ehlert, B. Lees, and L. Roth. Sharp phase transition for random loop models on trees. *preprint*, 2020.

Project: The polaron path measure

The polaron is an important model for matter interacting with quantized fields. In its probabilistic version, it leads to a path measure with a self-attracting interaction. We have made substantial progress towards clarifying the behaviour of the effective mass of the polaron at large coupling.

Partner: Steffen Polzer (Geneva)

Contact: V. Betz

References

[1] V. Betz and S. Polzer. Effective mass of the polaron: a lower bound. *Communications in Mathematical Physics*, online first:1–19, 2022.

[2] V. Betz and S. Polzer. A functional central limit theorem for polaron path measures. *Communications on Pure and Applied Mathematics*, 75 (11):2345–2392, 2022.

Project: Chains of interacting Brownian particles

We investigate the behaviour of chains of interacting brownian particles under strain, and the place and time of their rupture. These chains model polymers that are stretched. We look for asymptotic expressions for the above mentioned quantities in terms of probabilities and probability distributions.

Partner: Frank Aurzada (Darmstadt), Mikhail Lifshits (St. Petersburg)

Contact: V. Betz, F. Aurzada

References

[1] F. Aurzada, V. Betz, and M. Lifshits. Breaking a chain of interacting brownian particles. *Ann. Appl. Probab.*, 31 (6):2585–2611, 2021.

[2] F. Aurzada, V. Betz, and M. Lifshits. Breaking a chain of interacting brownian particles: a gumbel limit theorem. *Theory of Probability and Its Applications*, 66 (2):184–208, 2021.

[3] F. Aurzada, V. Betz, and M. Lifshits. Universal break law for a class of models of polymer rupture. *Journal of Physics A: Mathematical and Theoretical*, 54 (30):305204, 2021.

Project: Regularized over-parametrized neural networks learned by gradient descent can generalize well

Estimation of univariate regression functions by a neural network with one hidden layer is considered, where the weight vector is determined by applying gradient descent to a regularized empirical L_2 risk. Here the number of hidden neurons is allowed to be much larger than the sample size. The aim of this project is to show that the estimate nevertheless generalizes well in case that the Fourier transform of the regression function decays suitably fast, and that in this case over-parametrization leads to a particular good rate of convergence.

Partner: A. Krzyżak (Concordia University, Montreal)

Support: Humbold Foundation

Contact: M. Kohler

References

[1] M. Kohler and A. Krzyżak. Over-parametrized neural networks learned by gradient descent can generalize especially well. Preprint, TU Darmstadt, 2021.

Project: Analysis of the error of over-parametrized deep neural network estimates learned by gradient descent

The aim of this project is to understand why deep neural network estimates learned by gradient descent achieve good results in applications although they are over-parametrized. In order to understand this we have to analyze simultaneously approximation, generalization and optimization for deep neural networks. Using weight bounds for deep neural network learned by gradient descent we analyze the generalization error via metric entropy bounds, at the same time we use a proper topology and initialization of the network to control the approximation error. Results concerning universal consistency and rate of convergence of the corresponding estimates are derived.

Partner: A. Krzyżak (Concordia University, Montreal)

Contact: M. Kohler, S. Drews

References

[1] M. Kohler and S. Drews. On the universal consistency of an over-parametrized deep neural network estimate learned by gradient descent. Preprint, TU Darmstadt, 2022.

[2] M. Kohler and A. Krzyżak. Analysis of the rate of convergence of an over-parametrized deep neural network estimate learned by gradient descent. Preprint, TU Darmstadt, 2022.

Project: Analysis of convolutional neural network image classifiers in a rotationally symmetric model

The aim of this project is to understand theoretically why convolutionary neural networks are able to achieve good results in image classification problems. To achieve this goal, convolutional neural network image classifiers are defined and the rate of convergence of the misclassification risk of the estimates towards the optimal misclassification risk is analyzed. Here we consider images as random variables with values in some functional space, where we only observe discrete samples as function values on some finite grid. Under suitable structural and smoothness assumptions on the functional a posteriori probability, which includes some kind of symmetry against rotation of subparts of the input image, it is shown that least squares plug-in classifiers based on convolutional neural networks are able to circumvent the curse of dimensionality in binary image classification if we neglect a resolution-dependent error term. The finite sample size behavior of the classifier is analyzed by applying it to simulated and real data.

Support: DFG

Contact: M. Kohler, B. Walter

References

[1] M. Kohler and B. Walter. Analysis of convolutional neural network image classifiers in a rotational symmetric model. Preprint, TU Darmstadt, 2022.

Project: Analysis of the rate of convergence of an over-parametrized convolutional neural network image classifier learned by gradient descent

Image classification based on over-parametrized convolutional neural networks with a global average-pooling layer is considered. The weights of the network are learned by gradient descent. A bound on the rate of convergence of the difference between the misclassification risk of the newly introduced convolutional neural network estimate and the minimal possible value is derived.

Partner: A. Krzyżak (Concordia University, Montreal)

Contact: M. Kohler, B. Walter

References

[1] M. Kohler, A. Krzyżak, and B. Walter. Analysis of the rate of convergence of an over-parametrized convolutional neural network image classifier learned by gradient descent. Preprint, TU Darmstadt, 2021.

Project: Rate of convergence of a classifier based on a Transformer encode

In this project we study the problem of pattern recognition based on a high-dimensional predictor. A classifier is defined which is based on a Transformer encoder. The rate of convergence of the misclassification probability of the classifier towards the optimal misclassification probability is analyzed. It is shown that this classifier is able to circumvent the curse of dimensionality provided the a posteriori probability satisfies a suitable hierarchical composition model. Furthermore, the difference between the Transformer classifiers theoretically analyzed in this project and the ones used in practice today is illustrated by means of classification problems in natural language processing.

Partner: Iryna Gurevych (TU Darmstadt), Gözde Gül Şahin (TU Darmstadt)

Contact: M. Kohler

References

[1] I. Gurevych, M. Kohler, and G. Sahin. On the rate of convergence of a classifier based on a transformer encoder. *IEEE Transactions on Information Theory*, 68:8139–8155, 2022.

2 Collaborative Research Projects and Cooperations

The department is involved in a number of interdisciplinary research projects including excellence projects, collaborative research centres and priority programs. This section gives a brief overview of these activities.

2.1 Collaborative Research Centre SFB 805

The Collaborative Research Centre SFB 805 “Control of Uncertainty in Load-Carrying Structures in Mechanical Engineering” was established in January 2009. The third funding period started in January 2017 and ended in March 2021. The main objective is the development of methods and techniques to control uncertainties in the development, production and usage of load-carrying structures to significantly enhance their safety, reliability and economic efficiency. While uncertainty cannot be avoided or eliminated, its influence during the product lifecycle – from material properties to production and usage – can be controlled and hence minimized. Especially in the area of light-weight construction, the trade-off between low weight and low production cost on one hand and adequate load-bearing capacity on the other hand makes the influence of uncertainties critical. Hence, the control of uncertainty is of significant importance and is therefore a focus of the research to be conducted by the SFB 805.

The control of uncertainty through the entire process chain of development, production and usage necessitates a close interdisciplinary cooperation of engineers, mathematicians and legal experts. The mathematical research assesses the influence and effects of uncertainty and its interdependencies. It then derives optimal solution strategies for processes with minimal uncertainty and optimal design concepts for load-carrying systems from this.

The Department of Mathematics is involved in four projects of the SFB 805 (with P.I.s Kohler, Pfetsch, Ulbrich). To deal with uncertainty, the tool of robust optimization is applied, where complex products are optimized while controlling inherent uncertainty already in the product development phase. Uncertainty may occur because of uncertain loadings, uncertain material properties or unknown user behavior. A further source of uncertainty are models that do not adequately describe reality. To detect such model uncertainty, mathematical methods like optimal design of experiments and parameter identification are applied. Furthermore, the SFB 805 examines the use of active elements to react on uncertainty in a load-carrying system. The question of optimal placement of active elements in the structure is a challenging nonlinear mixed-integer optimization problem. Another focus lies in the optimal design of resilient technical systems, which are able to tolerate component failures. Additionally an attempt is made to control stochastic uncertainty at the planning stage of a product. Therefore knowledge of the effects of unavoidable occurring (random) fluctuations in the production or usage are required. Based on suitable models of the underlying process, methods of nonparametric regression were and will be developed to do this in an efficient way.

The homepage of the SFB 805 is reachable at `www.sfb805.tu-darmstadt.de`.

2.2 Collaborative Research Centre SFB 1194

The Collaborative Research Centre SFB 1194 "Interaction between Transport and Wetting Processes", established in July 2016, involves researchers from the TU Darmstadt and the Max Planck Institute for Polymer Research Mainz. Their common goal is the fundamental analysis of the interaction between transport and wetting processes. The SFB focuses particularly on the interactions between wetting and transport processes when, parallel to momentum transport, also heat and mass transport occur, complex fluids are involved or complex surfaces are examined. Although the physical phenomena take place only in a range of nanometres or micrometres, they often determine the efficiency of the overall process and the resulting product quality. Therefore, fundamental processes and phenomena are examined over a wide range of length scales (nano-micro-macro) and the transfer of basic research to applications is an integral part of the research program.

The SFB comprises 21 projects in the current second funding period, grouped into three research areas: A – Generic Experiments, B – Modeling and Simulation and C – New and Improved Applications. The Department of Mathematics is involved in three projects of SFB

1194 (Bothe, Ulbrich), which are allocated to research area B.
Research area B includes developments of mathematical models and numerical simulation techniques that describe the interaction of wetting processes with momentum, heat and mass transport, using physics based approaches. These models and simulations are closely linked and validated with the generic experiments performed in research area A. Once validated, these models and simulations are not subjected to the same parameter constraints as the generic experiments, e.g. with respect to resolution or parameter space; hence they contribute essential information to the overall understanding of the phenomena. Based on sensitivity as well as adjoint based derivative computations parameter identification, derivative-based optimization and optimal experimental design are performed. This leads to suggestions for improved designs and process control for specific applications, such as in printing or heat transfer devices. Throughout the future funding periods of the SFB the complexity of the fluids and surfaces being examined will increase.

2.3 Collaborative Research Centre Transregio TRR 146

Multiscale modeling is a central topic in theoretical condensed matter physics and materials science. One prominent class of materials, whose properties can rarely be understood on one length scale and one time scale alone, is soft matter. The properties of soft materials are determined by an intricate interplay of energy and entropy, and minute changes of molecular interactions may lead to massive changes of macroscopic system properties.
In a joint effort of physicists, chemists, applied mathematicians, and computer scientists, the Collaborative Research Center TRR 146 investigates some of the most pressing problems in multiscale modeling, viz.

- Dynamics: In the past, multiscale coarse-graining approaches have to a large extent focused on static equilibrium properties. However, a thorough understanding of the coarse-grained dynamical system properties is necessary if one wants to apply multiscale concepts to the study of transport and nonequilibrium processes.
- Coarse-graining and mixed resolution: In many applications, selected small (e.g., functional) regions of a material must be treated in great detail, whereas the large bulk can be modeled at a coarse-grained level. Simulation schemes are desirable, where fine-grained and coarse-grained regions can dynamically be assigned to the current state of the system. In this context, we also re-analyze fundamental aspects of coarse-graining from a mathematical point of view.
- Bridging the particle-continuum gap: So far, only few successful attempts have been made to combine particle models of soft matter with continuum models in a nontrivial fashion. Multiscale schemes for particle models have mostly been developed in the soft matter community, whereas schemes for treating continuum models with variable resolution are developed in the applied mathematics community. In the CRC-TR, we bring these two communities together to advance the field as a whole.

Problems addressed in the TRR 146 require a massive interdisciplinary effort at the level of fundamental science and algorithmic development. The TRR 146 brings together scientists with a complementary expertise in a wide range of modeling methods. Also one professor of the Department of Mathematics (Egger) is under the group of principal investigators.

2.4 Collaborative Research Centre Transregio TRR 154

The Collaborative Research Centre Transregio TRR 154 "Mathematical Modelling, Simulation and Optimization Using the Example of Gas Networks" was established in 2014 and is now in its third funding period.

The energy transition ("Energiewende") in Germany and its success are currently – more than ever – in the focus of public interest. This transition is of central significance to society, politics, and science, since Germany, like many other industrial nations, finds itself in a situation of dramatically increased dependence on a reliable, secure, and affordable energy supply. At the same time, the request for clean, environment and climate-friendly energy generation is as large as never before. Originally, natural gas was planned to bridge the transition in the next decades, since it was readily accessible, tradable, and storable. However, the pressure to accelerate the transition is increasing. Moreover, hydrogen as an alternative energy carrier is gaining importance and can be transported through pipelines. Although its physical behavior can be treated using similar mathematical equations as for natural gas, there are several issues that require attention, especially if hydrogen is mixed with natural gas.

The aim of the TRR 154 is to offer answers to these challenges by using methods of mathematical modelling, simulation, and optimization and, in turn, to provide solutions of increased quality. Novel mathematical findings are required in different areas such as mathematical modelling, numerical analysis, simulation and integer, continuous, and stochastic optimization as well as equilibrium problems in order to achieve this aim. As examples, we mention the modelling and analysis of complex networks of hyperbolic balance equations including switches and the development of a mixed-integer optimization theory together with its algorithmic realisation for such networks including the handling of data uncertainty. Furthermore, efficient hierarchical numerical approximation techniques for the resulting algebraically coupled PDEs need to be developed and a sophisticated error control, taking the interaction with the mixed-integer optimization algorithms into account, is required.

The Department of Mathematics at TU Darmstadt has been involved in the collaborative research centre Transregio TRR 154 with Professors Disser, Giesselmann, Egger, Lang, Pfetsch, Schwartz and Ulbrich. Furthermore, groups at Universität Erlangen-Nürnberg (speaker), HU Berlin, TU Berlin, Universität Duisburg-Essen, and Weierstraß-Institut für Angewandte Analysis und Stochastik (WIAS) are part of TRR 154.

The homepage of TRR 154 is reachable at `trr154.fau.de`.

2.5 Collaborative Research Centre Transregio TRR 326

The CRC/Transregio 326 *Geometry and Arithmetic of Uniformized Structures (GAUS)* was established by the DFG (German Research Foundation) in July 2021. It is based at the Universities of Darmstadt, Frankfurt, and Heidelberg, with collaborating partners in Mainz and Münster. The speaker is Jakob Stix (Frankfurt), and co-speakers are Alexander Schmidt (Heidelberg) and Jan Bruinier (Darmstadt). In addition, Torsten Wedhorn (Darmstadt) serves as the speaker of the integrated Research Training Group.

The concept of uniformization is ubiquitous in mathematics. It serves as a tool to replace a complicated geometric object by a simpler one without altering the local structure. The original mathematical complexity is now encoded in a suitable symmetry group. This translation into another language opens up new perspectives for the study of the original mathematical objects. A very active and successful area of research uses this rich framework to study the geometry and arithmetic of algebraic varieties.

Important features in the concept of uniformized spaces include the following: automorphic forms arise as functions respecting these symmetry groups. Galois representations, which are fundamental in all branches of modern number theory, encode arithmetic symmetries. The tower of all covering spaces between the original object and its uniformization reflects the 'paths' of the space under consideration and ultimately leads to topological and cohomological invariants that are often of a non-abelian nature. Frobenius symmetry enhances geometry in the parallel universe of positive characteristic in an unexpected manner. Celebrated new results by Fields medalist Peter Scholze provide a bridge from the classical setting to the realm of positive characteristic, thus allowing the application of Frobenius symmetry even to classical questions in the framework of uniformization.

The core areas of the CRC/TRR are:
(A) Moduli spaces and automorphic forms,
(B) Galois representations and étale invariants,
(C) Cohomological structures and degeneration in positive characteristic.

Research in these areas is divided in 22 projects which are lead by 18 PIs with the support of about 30 (post-) doctoral researchers funded by the DFG and a similar number of associated (post-) doctoral researchers funded by the host institutions.

2.6 Collaborative Research Centre Transregio TRR 361

The Collaborative Research Centre Transregio TRR 361/F90 "CREATOR - Computational Electric Machine Laboratory: Thermal Modelling, Transient Analysis, Geometry Handling and Robust Design" was established in 2022.
Electric machines have played a major role in energy conversion already for decades. Modern power electronics have brought major improvements and together with the advent of new materials and manufacturing techniques unprecedented opportunities for future innovation exist. Backed by advances in design optimisation and control, novel drive systems provide huge potential to further increase energy conversion efficiency, and thereby contributing to meeting climate goals.
While current drive systems are operated in different environments and at variable speeds, current design procedures usually start with an expert's choice for a particular machine type and topology. Dimensioning is then based on a limited number of parameters and well-chosen operation modes, typically at constant speed or torque. Thereby considerable opportunities for optimisation are missed. Only a paradigm shift towards a fundamentally new integrated simulation and design approach will allow the potential of modern electric drives to be fully exploited. From the outset, this approach must consider all relevant aspects of a machine, e.g. shape and topology, time-dependent operating cycles, complex material behaviour, uncertainties and robustness, new cooling techniques to push thermal limits, noise and vibrations and various key performance indicators. The modelling, simulation and optimisation of such a complex system pose an extreme computational engineering challenge.

This Collaborative Research Centre (CRC) will lay the foundations for the next generation electro-thermal machine design to overcome the challenges of modelling, simulation and optimisation in these multiscale and multiphysical systems. In particular, we address (i) modelling of nonlinear material behaviour, e.g. hysteresis, losses and novel cooling strategies, (ii) simulation of coupled electronic-electromagnetic-mechanical-thermal multiscale dynamical systems, (iii) flexible geometry handling, involving rotating geometry and geometric design, (iv) multiobjective shape and topology optimisation, sensitivity analysis and uncertainty quantification. The innovations in these areas will boost the predictive power of machine models. They will allow design engineers to take full advantage of the recent achievements in the conception of next-generation electric machines.
For this, the CRC is organised in four scientific Project Areas, as well as an area of central projects for research training, research data management and project management. The four scientific areas are classified into electromagnetism, fluid mechanics, numerics and optimisation. All projects are interwoven, with the regular exchange of results, including models and algorithms. Validation is ensured by integrated measurements. The different multiphysical and multiscale aspects are tackled in a holistic approach with a project plan designed to fully address the interdisciplinary character of the task.
The Department of Mathematics at TU Darmstadt has been involved in the collaborative research centre Transregio TRR 361 with Professor Ulbrich. Furthermore, the Departments of Electrical Engineering and Information Technology, Mechanical Engineering and Materials Science at TU Darmstadt as well as groups at TU Graz and Johannes Kepler University (JKU) Linz are part of the TRR361.

2.7 Graduate School of Computational Engineering

Computational Engineering (CE) denotes computer based modeling, analysis, simulation, and optimization. It is a cost-effective, efficient and complementary approach to study engineering applications and to engineer new technical solutions when experimental investigations are too complex, risky, or costly. CE enables the creation of scalable models to support research, development, design, construction, evaluation, production, and operation of engineering applications which address key issues in future technology developments for the economy and society in areas such as energy, health, safety, and mobility. However, such engineering applications are becoming increasingly complex. Consequently, the theory and methodologies required to investigate corresponding systems become challenging.
With the Graduate School of Computational Engineering, TU Darmstadt was able to further strengthen its role in CE. The school enables highly talented PhD students to develop their scientific skills in a focused way, and to cooperate under optimal conditions in a highly stimulating interdisciplinary environment based on the interaction of Computer Science, Mathematics, and Engineering Sciences. Partnerships with well established research organizations as well as cooperation with industry increase the impact of the Graduate School. Building on the well established interdepartmental expertise at TU Darmstadt, the Graduate School focusses on the following key research areas: modeling and simulation of coupled multi-physics problems, simulation based optimization, and hierarchical multi-scale modeling and simulation. The research efforts in the above fields are accompanied by corresponding developments of methods of visualization, simulated reality, high-performance computing, verification and validation, as well as software engineering and lifecycle research. The PhD

students work together within research foci comprising one or more of the above topics. The joint research on specially defined use cases will further strengthen the interdisciplinary skills and cooperation.
Seven professors of the Department of Mathematics are Principal Investigators within the Graduate School Computational Engineering (Aurzada, Bothe, Disser, Giesselmann, Lang, Pfetsch, Ulbrich) with expertise in Probability Theory and Stochastic Analysis, Mathematical Modeling and Analysis, Numerical Analysis and Scientific Computing, Numerics of Partial Differential Equations, Discrete Optimization, and Nonlinear Optimization and Optimal Control. Dr.-Ing. Marschall is Research Group Leader with scientific focus on Two-Phase and Interfacial Flows. Together they supervise more than 11 interdisciplinary PhD projects within the Graduate School in close cooperation with a co-supervisor from Engineering or Computer Science. Former members of the Graduate School who contributed during 2021-2022 are Profs. Egger, Schwartz and Wollner.

2.8 Graduate School of Energy Science and Engineering

The mission of the Darmstadt Graduate School of Energy Science and Engineering is to educate tomorrow's leading Energy Engineers in a multidisciplinary field of expertise needed to identify and master the most demanding scientific, engineering, economic and social challenges in an interdisciplinary approach. The main challenge is viewed to be a continuous transition from the carbon-based, non-renewable primary energy sources of today to renewable and environmentally friendly energy resources of tomorrow.
The optimal strategy to meet this challenge is on the one hand to improve conventional energy technologies and render them progressively more efficient, to meet the ever more stringent demands on pollutant emissions, and on the other hand to simultaneously develop innovative, advanced renewable energy technologies, which must be brought to a competitive technological readiness level and provide safe, reliable and cost-effective solutions.
Two professors of the Department of Mathematics are Principal Investigators within the Graduate School Energy Science and Engineering (Lang, Ulbrich) with expertise in Numerical Analysis, Nonlinear Optimization and Optimal Control.

2.9 Priority Programme SPP 1962

Many of the most challenging problems in the applied sciences involve non-differentiable structures as well as partial differential operators, thus leading to non-smooth distributed parameter systems. Those systems are investigated by the DFG Priority Programme 1962 "Non-smooth and Complementarity-based Distributed Parameter Systems: Simulation and Hierarchical Optimization". The non-smoothness considered in this DFG-Priority Programme typically arises (i) directly in the problem formulation, (ii) through inequality constraints, nonlinear complementarity or switching systems, or (iii) as a result of competition and hierarchy.
In fact, very challenging applications for (i) come from frictional contact problems, or non-smooth constitutive laws associated with physical processes such as Bean's critical state model for the magnetization of superconductors, which leads to a quasi-variational inequality (QVI) problem; for (ii) are related to non-penetration conditions in contact problems, variational

inequality problems, or inequality constraints in optimization problems which, upon proper re-formulation lead to complementarity problems and further, by means of non-linear complementarity problem (NCP) functions, to non-smooth systems similar to (i); and for (iii) come from multi-objective control systems or leader-follower principles, as they can be found in optimal system design in robotics and biomechanics. Modeling "competition" often leads to generalized Nash equilibrium problems (GNEPs) or partial differential games. Moreover, modeling "hierarchy" results in mathematical programs with equilibrium constraints (MPECs), a class of optimization problems with degenerate, non-smooth constraints. All of these problems are highly nonlinear, lead to QVIs, and represent rather novel mathematical structures in applications based on partial differential operators. In these and related applications, the transition from smoothing or simulation-based approaches to genuinely non-smooth techniques or to multi-objective respectively hierarchical optimization is crucial.

The SPP1962 is coordinated by Michael Hintermüller (HU Berlin/WIAS Berlin). The first funding period started in 2016 and ran until 2019, comprising 23 scientific projects. The current second funding period started in 2019, comprising 22 scientific projects.

The Department of Mathematics participated in the SPP1962 with three projects (Schwartz, Ulbrich, Wollner) during the first funding period and now participates with two projects (Ulbrich, Wollner) during the second funding period.

2.10 Priority Programme SPP 2026

The DFG-priority programme 2026 "Geometry at infinity" combines research in differential geometry, geometric topology, and global analysis. Crossing and transcending the frontiers of these disciplines it is concerned with convergence and limits in geometric-topological settings and with asymptotic properties of objects of infinite size. The overall theme can roughly be divided into the three cross-sectional topics convergence, compactifications, and rigidity.

Examples of convergence arise in Gromov-Hausdorff limits and geometric evolution equations. The behaviour of geometric, topological and analytic invariants under limits is of fundamental interest. Often limit spaces are non-smooth so that it is desirable to generalize notions like curvature or spectral invariants appropriately. Limits can also be used to construct asymptotic invariants in geometry and topology such as simplicial volume or L^2-invariants. Compactifications reflect asymptotic properties of geometric objects under suitable curvature conditions.

Methods from topology, differential geometry, operator algebras and probability play a role in this priority programme. Important issues are boundary value problems for Laplace or Dirac type operators, both in the Riemannian and Lorentzian setting, as well as spectral geometry and Brownian motion on non-compact manifolds. Besides continuous deformations rigidity is essential for many classification problems in geometry and topology. It appears in geometric contexts, typically in the presence of negative curvature, and in topological and even algebraic settings. Rigidity also underlies isomorphism conjectures relating analytic, geometric and homological invariants of infinite groups and more general coarse spaces. The priority programme supports individual research projects and coordinated research activities.

The SPP 2026 has two funding periods, 2017-2020 (33 funded projects) and 2020-2023 (46 funded projects).

The coordinator of the SPP 2026 is Prof. Dr. Bernhard Hanke from the Universität Augsburg.

At the TU Darmstadt, Elena Mäder-Baumdicker participates in the SPP 2026 with projects in both funding periods.

2.11 Cluster Clean Circles

Iron has enormous potential to boost the energy transition. The project Clean Circles teams up scientists from multiple disciplines to explore how the metal and its oxides can be used in a cycle as carbon-free chemical energy carrier to store wind and solar power.
The center of the project is formed by an innovative energy cycle as an important contribution to the energy transition. Electric energy from renewable sources is accumulated in iron and thus becomes storable and transportable with a high energy density. This can be done directly by electrochemical reduction or by using green hydrogen in a thermochemical reduction. The chemical energy is released again with high power densities via high-temperature thermochemical oxidation and reconverted into electricty in thermal power stations. This forms a carbon-free energy carrier. Well packed, iron can be stored for long periods of time and is non-toxic. This makes iron an ideal chemical energy carrier to guarantee the supply by controllable power station capacities.
Clean Circles is funded by the Hessian Cluster Initiative (2021–2025). PIs at the Department of Mathematics include Dieter Bothe, Marc Pfetsch, Stefan Ulbrich. The key aspects of the corresponding projects are a model hierarchy that enables an analysis and optimization of the Clean Circles processes. Together with partners from political science and economics, the goal is to arrive at a holistic analysis of socio-economic factors around such a project. The Clean Circles web pages is available at `https://www.tu-darmstadt.de/clean-circles/about_cc/index.en.jsp`.

2.12 Research Unit Symmetry, Geometry, and Arithmetic

The DFG Research Unit 1920 “Symmetry, Geometry and Arithmetic” examines current issues in modern arithmetic. An important and key theme is the investigation of absolute Galois groups and their generalizations. These elegantly code arithmetic information which can be extracted through the study of these groups and their representations. The researchers, who are based in Heidelberg and Darmstadt, are hoping that by dovetailing motivic homotopy theory, deformation theory, Iwasawa theory, the theory of automorphic forms and L-functions, they will be able to draw interesting conclusions from new insight into one of these areas which they can apply to the others, in a contemporary vision and modern understanding of basic mathematical research.
As a principal investigator Jan Bruinier is part of this research unit with a project centered around special cycles on the moduli space of abelian surfaces and their connections with L-functions. The spokesperson is Alexander Schmidt from the Universität Heidelberg.

2.13 LOEWE Research Unit USAG: Uniformized Structures in Arithmetic and Geometry

The LOEWE research unit *Uniformized Structures in Arithmetic and Geometry (USAG)* aims at joining the broad expertise of TU Darmstadt and GU Frankfurt in the fields of number theory and arithmetic/algebraic geometry. The speaker is Jan Bruinier (Darmstadt), and the co-speaker is Martin Möller (Frankfurt).

The concept of uniformization, which goes back to famous works by Riemann and Klein from the 19th century, allows to replace a complicated geometric space with a much simpler one without changing the local structure. The complexity is then described with inner symmetries of the simpler space. This basic idea has proven to be very effective. The aim of the LOEWE research unit is to gain new insights into current arithmetic and geometric classification problems by combining different techniques of uniformization.

Our research program focuses on the following three research areas:
(A) Special Subvarieties,
(B) Automorphic Forms, and
(C) Variation of Geometry.

In research area A we explore Orthogonal Shimura Varieties and the Kudla Conjecture, in research area B we investigate Borcherds-Products as well as Vertex Algebras, and in research area C we study the Uniformization of Spherical Varieties, the Anabelian Section Conjecture, as well as Tropical Moduli Spaces. The research areas A, B, and C are mutually interconnected and techniques of uniformization are crucial in our research approaches.

3 Scientific and Industrial Cooperations

In the following we list all scientific and industrial projects by names of the researcher of our department in alphabetical order, by names of partners in universities and industry, and the title of the project.

Frank Aurzada

- Prof. Dr. F. Allgöwer (Universität Stuttgart): joint publications.
- Prof. Dr. A. Klein (TU Darmstadt, FB ETIT): joint publication.
- Prof. Dr. M. Kolb (Universität Paderborn): publication in preparation.
- Prof. Dr. M.A. Lifshits (St. Petersburg State University): joint publications.
- D. Meister (Universität Stuttgart): joint publications.
- Prof. Dr. S. Mukherjee (Columbia University): joint publications.
- Dr. A. Ortiz (TU Darmstadt, FB ETIT): joint publication.
- Dr. E. Sönmez (Universität Klagenfurt): joint publication.
- W. de Sombre (TU Darmstadt, FB ETIT): joint publication.
- Prof. Dr. O. Zeitouni (Weizmann Institute): joint publication.

Volker Betz

- Dr. Daniel Ueltschi (University of Warwick): Spatial random permutations and Bose-Einstein condensation.
- Prof. Erwin Bolthausen (University of Zurich): Enhanced binding via path integrals.
- Dr. Benjamin Goddard (University of Edinburgh): Nonadiabatic Transition through Born-Oppenheimer surfaces.
- Dr. Dirk Zeindler (University of Lancaster): Cycle counts in random permutations.
- Prof. Lorenzo Taggi (Sapienza University of Rome): Spatial Random Permutations.
- Dr. Benjamin Lees (University of Leeds): Loop models.

Dieter Bothe

- Freudenberg New Technologies SE & Co. KG: Simulation of viscoelastic flows with OpenFOAM.
- Prof. Dr. Günter Brenn (TU Graz): Numerical and experimental analysis of bubbles rising in viscoelastic liquids.
- Prof. Dr. Wolfgang Dreyer (WIAS Berlin): Continuum thermodynamics of fluid mixtures.
- Prof. Dr. Pierre-Étienne Druet (WIAS Berlin): Modeling and analysis of fluid mixtures.
- Dr. Matthias Köhne (Universität Düsseldorf): Analysis of dynamic contact lines.
- Prof. Dr. Michel Pierre (ENS Rennes): Modeling and analysis of reaction-diffusion systems.
- Prof. Dr. Michael Schlüter (Institut für Mehrphasenströmung, TU Hamburg-Harburg): Numerical and experimental analysis of reactive mass transfer at bubbles.
- Dr. Kathrin Schulte (Universität Stuttgart): Direct Numerical Simulation of binary droplet collisions.
- Prof. Dr. Akio Tomiyama (Kobe University): Mass transfer under surfactant influence.

Jan H. Bruinier

- Prof. Dr. B. Howard (Boston College) and Prof. Dr. T. Yang (University of Wisconsin at Madison): Arithmetic intersection theory on Shimura varieties.
- Prof. Dr. J. Funke (University of Durham) and Prof. Dr. O. Imamoglu (ETH Zürich): Regularized theta liftings and periods of modular functions.
- Dr. Markus Schwagenscheidt (ETH Zürich): Automorphic products.
- Prof. Dr. S. Kudla (University of Toronto) and Siddarth Sankaran (University of Manitoba): Green currents and Whittaker functions.

– Prof. Dr. T. Yang (University of Wisconsin) and Stephan Ehlen (Universität Köln): Higher automorphic Green functions.

Yann Disser

– Dr. Jérémie Chalopin (Aix-Marseille University): Graph exploration and delivery.

– Prof. Dr. Simon Emde (Universität Jena): Point-to-point delivery.

– Dr. Andreas Feldmann (University of Sheffield): Fixed parameter tractability.

– Prof. Dr. Max Klimm (TU Berlin): Incremental optimization.

– Prof. Dr. Jochen Könemann (University of Waterloo, Canada): Highway dimension.

– Prof. Dr. Matúš Mihalák (Maastricht University): Graph exploration and delivery.

– Prof. Dr. Michał Pilipczuk (University of Warsaw): Dynamic parameterized algorithms.

– Prof. Dr. Kevin Schewior (University of Southern Denmark): Online Dial-a-Ride.

– Prof. Dr. Leen Stougie (CWI Amsterdam): Online Dial-a-Ride.

– Dr. Anna Zych-Pawlewicz (University of Warsaw): Fixed parameter tractability.

Moritz Egert

– Andrew Morris (University of Birmingham) and Pascal Auscher (Paris-Saclay University): Eliminating symmetry and permitting singularity in periodic homogenization.

– Pascal Auscher (Paris-Saclay University): Boundary value problems for p-elliptic operators.

– Simon Bortz (University of Alabama) and Olli Saari (Polytechnic University of Catalonia): Optimal Green function estimates in elliptic and parabolic problems.

– Simone Ciani (University of Bologna): Kernel estimates vs. elliptic regularity.

Herbert Egger

– Prof. Dr. Matthias Schlottbom (University of Twente, The Netherlands), Prof. Dr. Jürgen Dölz (Universität Bonn): Model reduction for inverse problems.

– Dr. Aaron Brunk, Prof. Dr. Maria Lukacova (Universität Mainz): Spinodal decomposition of polymer solvent systems.

– Dr. Mania Sabouri (Universität Kassel): High-order methods for poroelasticity.

– Prof. Dr. Jürgen Dölz (Universität Bonn): Convolution quadrature methods.

– Ass.-Prof. Dr. Idoia Cortes Garcia (TU Eindhoven, The Netherlands): Simulation of electric circuits.

- Melina Merkel (TU Darmstadt), Prof. Dr. Sebastian Schöps (TU Darmstadt): Electric machine simulation.
- Prof. Dr. Bai-Xian Xu (TU Darmstadt): Analysis and simulation of additive manufacturing processes.
- Prof. C. Tropea (TU Darmstadt), Prof. J. Hennig, Dr. A. Krafft (UK Freiburg): MRI-based Wall Shear Stress Quantification.

Anton Freund

- Dr. J. Aguilera (TU Wien and Ghent University): Generalized Goodstein principles.
- Dr. F. Pakhomov (Steklov Mathematical Institute Moscow and Ghent University): Slow consistency.
- Prof. Dr. M. Rathjen (University of Leeds): Normal functions in reverse mathematics, Uniform Kruskal theorem, Generalized Goodstein principles.
- Prof. Dr. A. Weiermann (Ghent University): Uniform Kruskal theorem, Generalized Goodstein principles.

Mathis Fricke

- Prof. Stephane Zaleski (Sorbonne University, Paris): Numerical simulation of dynamic wetting using the Volume-of-Fluid method.
- Prof. Joel De Coninck (Free University of Brussels): Fundamental mathematical modeling of dynamic wetting.
- Prof. Kohei Soga (Keio University, Tokyo): Level Set Transport Equations.
- Dr. Mathis Köhne (Universität Düsseldorf): Kinematics of moving interfaces and contact lines.

Alf Gerisch

- Prof. Dr. Mark A. J. Chaplain (University of St. Andrews, UK), Prof. Dr. Kevin J. Painter (Polytechnic University of Turin, Italy), Dr. Chiara Villa (Sorbonne University, Paris, France), Dr. Mariya Ptashnyk (Heriot-Watt University, Edinburgh, UK), Prof. Dr. Anja Voß-Böhme (HTW Dresden): Mechano-biological and non-local models of tissue development.
- Prof. Dr. Jens Lang (TU Darmstadt), Prof. Dr. Rüdiger Weiner, Dr. Helmut Podhaisky (Universität Halle-Wittenberg): Peer methods and their application in the Finite Element system KARDOS.
- Prof. Dr. Jonathan Sherratt (Heriot-Watt University, Edinburgh, UK): Mathematical modelling of wound healing.

- Prof. Dr. Ram Jiwari (IIT Roorkee, India): Radial basis function differential quadrature methods for time-dependent PDEs.

Jan Giesselmann

- SFB Transregio 154: Mathematische Modellierung, Simulation und Optimierung am Beispiel von Gasnetzwerken, Speaker: Prof. Dr. Alexander Martin (Universität Erlangen-Nürnberg).
- Prof. Dr. Martin Gugat (Universität Erlangen-Nürnberg): Boundary observers for hyperbolic balance laws.
- Prof. Dr. Christiane Helzel (Universität Düsseldorf): A posteriori error estimator for kinetic equations describing rod like particles.
- Prof. Dr. Sebastian Krumscheid (KIT, Karlsruhe): A posteriori error control for statistical solutions of barotropic Navier-Stokes equations.
- Dr. Sam G. Krupa (MPI Leipzig): A posteriori error estimates for discontinuous solutions to hyperbolic conservation laws.
- Prof. Dr. Sandra May (University Uppsala, Finland): A priori error estimates for finite volume schemes on cut-cell meshes.
- Prof. Dr. Min-Gi Lee (Kyungpook National University, Korea), Kiwoong Kwon (Kyungpook National University, Korea), Dr. Niklas Kolbe (RWTH Aachen): A posteriori error estimates for Keller-Segel models with linear and non-linear diffusion.
- Group of Prof. Dr. Maria Lukacova (Universität Mainz): Robust a posteriori error estimates for Allen-Cahn equations with non-constant mobility.
- Dr. Philipp Öffner (Universität Mainz): Dissipative solutions for the Navier-Stokes-Korteweg system and their numerical treatment.
- Dr. Aleksey Sikstel (Universität Köln): A posteriori error estimates for discontinuous solutions to hyperbolic conservation laws.

Lisanne Gossel

- Prof. Dr. C. Hasse (TU Darmstadt): Intense exchange in development of Chemical Reactor Network method, probably leading to future common publication.
- Prof. Dr. T. Faravelli, Prof. Dr. A. Stagni (Polytechnic University of Milan): Intense exchange in development of Chemical Reactor Network method, probably leading to future common publication.

Karsten Große-Brauckmann

- Dr. Jesse Ratzkin (Universität Würzburg): Degeneracy problems for minimal surfaces.

- Prof. Dr. Robert Kusner (University of Massachusetts at Amherst): Constant mean curvature surfaces.

Robert Haller

- Felix Ali Mehmeti (Polytechnic University of Hauts-de-France): The Klein-Gordon equations on a star-shaped network.
- Russell Brown (University of Kentucky, Lexington, KY, USA) and Patrick Tolksdorf (Universität Mainz): Extendability of functions with partially vanishing trace.
- Tom ter Elst (University of Auckland, New Zealand), Joachim Rehberg (WIAS Berlin) and Patrick Tolksdorf (Universität Mainz): Second order elliptic operators in divergence form with complex coefficients.
- Hannes Meinlschmidt (Universität Erlangen-Nürnberg) and Joachim Rehberg (WIAS Berlin): Elliptic operators with mixed boundary conditions.

Thibaud van den Hove

- Dr. Robert Cass (University of Michigan) and Prof. Dr. Jakob Scholbach (University of Padua): Integral motivic Satake equivalence.

Konstantin Jakob

- Dr. Andreas Hohl (Mathematics Institute of Jussieu-Paris Rive Gauche): Tannakian formalism, Stokes matrices and Fourier transform.
- Prof. Dr. Masoud Kamgarpour (University of Queensland): Point counting on twisted wild G-character varieties.
- Prof. Dr. Z. Yun (Massachusetts Institute of Technology): Microlocal criterion for rigid automorphic data.

Ulrich Kohlenbach

- Prof. Dr. Laurenţiu Leuştean (University of Bucharest): Linear rates of asymptotic regularity for the Tikhonov-Mann iteration in geodesic spaces.
- Prof. Dr. Genaro Lopéz-Acedo (University of Seville): The Lion-Man game in geodesic spaces.
- Prof. Dr. Adriana Nicolae (University of Cluj-Napoca): The Lion-Man game in geodesic spaces.
- Dr. Thomas Powell (University of Bath): Proof Mining in Nonlinear Analysis.

Michael Kohler

- Prof. Dr. Adam Krzyżak (Concordia University, Montreal): Statistical theory for deep neural networks.

- Prof. Dr. Harro Walk (Universität Stuttgart): Rate of convergence of neural network regression estimates learned by gradient descent.
- SFB 805 (TU Darmstadt): Efficient estimation of uncertainty of technical systems.

Katja Krüger

- Dr. Gerda Werth (Universität Paderborn): History of mathematics eduction at the beginning of the 20th century.
- Prof. Hans Dieter Rinkens (Universität Paderborn): Understanding of Euler's identity on the basis of elementary mathematical knowledge.
- Prof. Anselm Lambert (Universität des Saarlandes) and Prof. Jürgen Roth (Universität Koblenz Landau) and Dr. Philipp Ullmann (Universität Frankfurt) and Prof. Markus Vogel (PH Heidelberg) and Prof. Ysette Weiss-Pidstrygach (Universität Mainz): Oberseminar Südwest.

Burkhard Kümmerer

- Prof. Dr. R. Gohm (Aberystwyth): Quantum System Theory, Quantum Markov Processes.
- Prof. Dr. H. Maassen (Nijmegen): Quantum Probability.
- Hildrun-Bäzner-Zehender (Kepler-Gesellschaft e.V., Weil der Stadt): Johannes Kepler.
- Hermann Faber (Kepler-Gesellschaft e.V., Weil der Stadt): Johannes Kepler.
- Wolfgang Pleithner (Kepler-Gesellschaft e.V., Weil der Stadt): Johannes Kepler.
- Dr. Robert Löw (5th Institute of Physics, Universität Stuttgart): Johannes Kepler.
- Karin Otter (5th Institute of Physics, Universität Stuttgart): Johannes Kepler.

Jens Lang

- Dr. Pia Domschke (Frankfurt School of Finance & Management): Gas transport in networks.
- Prof. Dr. Martin Gugat (Universität Erlangen-Nürnberg): Probabilistic constrained optimization on flow networks.
- Prof. Dr. Ingo Sass (Deutsches Geoforschungszentrum Potsdam): Borehole heat exchanger.
- Prof. Dr. Bernhard A. Schmitt (Universität Marburg): Discrete adjoint implicit Peer methods.
- Prof. Dr. Rüdiger Weiner (Universität Halle-Wittenberg): IMEX-Peer methods.
- Prof. Dr. Weizhang Huang (University of Kansas, USA), Lennard Kamenski (WIAS Berlin): Anisotropic mesh methods.

Yingkun Li

- Prof. Tonghai Yang (UW Madison): CM value of higher Green functions.
- Dr. Markus Schwagenscheidt (ETH): Harmonic Maass forms.
- Prof. Shaul Zemel (Hebrew University of Jerusalem): Shintani lift of nearly holomorphic modular forms.
- Dr. Gabriele Bogo (TU Darmstadt): Expansions of theta lifts.
- Dr. Christina Röhrig (TU Darmstadt): Theta series and mock Maass forms.

Elena Mäder-Baumdicker

- Prof. Dr. Jonas Hirsch (Universität Leipzig): Analysis of Willmore surfaces and minimal surfaces.
- Prof. Dr. Rob Kusner (University of Massachusetts at Amherst): Morse theory of Willmore surfaces.
- Dr. Casey Kelleher (Princeton University): Fourth order geometric flows.
- Prof. Dr. Andrea Malchiodi (Scuola Normale Superiore of Pisa): Entropies of geometric flows.
- Dr. Ben Lambert (University of Leeds): Globally constrained flows.
- Prof. Dr. Julian Scheuer (Universität Frankfurt): Stability of bipolar minimal surfaces.
- Dr. Fabian Rupp (Universität Wien): Volume preserving Mean curvature flow and isoperimetric problems.

Tomislav Maric

- Laboratoire Interdisciplinaire des Sciences du Numerique (LISN, CNRS, Orsay, France): Unstructured Level Set / Front Tracking Method.
- Office National d'Etudes et de Recherches Aérospatiales (ONERA, Palaiseau, France): Unstructured Volume-of-Fluid method for two-phase flows with high density ratios.
- Professor Johan Roenby, Roskilde University, Roskilde, Denmark: Unstructured Volume-of-Fluid method.
- Professor Seungwon Shin, Hongik University, Seoul, Republic of Korea: Unstructured Level Set / Front Tracking Method.
- BOSCH Corporate Research: Microfluidics.

Holger Marschall

- Karlsruhe Institute of Technology (KIT), Institute of Catalysis Research and Technology (IKFT), Germany: Diffuse-Interface Phase-Field methods.
- BOSCH GmbH, Campus for Research and Advance Engineering, Renningen, Germany: Diffuse-Interface Phase-Field methods.
- Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research (IEK), Jülich, Germany: Coupled methods in electrochemical applications.
- Universität Bochum, Thermal Turbomachinery and Aero Engines: Filtering operators for the double-averaged equations of flows in porous media.

Marc Pfetsch

- Prof. Dr. Max Klimm (TU Berlin): Algorithms for Gas Transport Optimization.
- Prof. Dr. Martin Haardt (TU Ilmenau): Compressed Sensing in Signal processing.
- Dr. Christopher Hojny (Eindhoven University of Technology): Symmetry in Integer Programs.
- Dr. Pierre Le Bodic (Monash University, Australia): Estimating the Size of Branch-and-Bound Trees.
- Prof. Dr. Alexander Martin (Universität Erlangen-Nürnberg): Gas Transport Optimization.
- Prof. Dr. Sebastian Pokutta (Zuse Institut Berlin): Methods for Integer Programs.
- Prof. Dr. Marius Pesavento (TU Darmstadt): Mixed-Integer Programs in Signal Processing.
- Prof. Dr. Giovanni Rinaldi (IASI Rome): Separation of Oracle-Based Cutting Planes.
- Prof. Dr. Martin Skutella (TU Berlin): Algorithms for Gas Transport Optimization.
- Prof. Dr. Thorsten Theobald (Universität Frankfurt): Block Semidefinite Programs.

Pedro Pinto

- Prof. Dr. Laurenţiu Leuştean (University of Bucharest): On the generalization of asymptotic regularity results.
- Dr. Bruno Dinis (University of Évora): Proof mining and the development of novel strongly convergent splitting methods.

Ulrich Reif

- Prof. Dr. Andreas Weinmann (Hochschule Darmstadt): Geometric Hermite Subdivision.

- Dr. Ahmad Lutfi Amri Ramli (Universiti Sains Malaysia): Spline Methods for Road Design.
- Dr. Thomas Mejstrik (TU Wien): Determination of the Joint Spectral Radius.

Timo Richarz

- Prof. Dr. V. Pilloni (University of Paris-Saclay): Cotutelle-Vertrag, gemeinsame PhD Supervision.

Nils Scheithauer

- Prof. Dr. G. Höhn (Kansas State University, Manhattan): Vertex algebras and Lie algebras.
- Dr. S. Möller (Universität Hamburg): Automorphic forms and vertex algebras.

Pascal Schweitzer

- Prof. Dr. Martin Grohe (RWTH Aachen University): Descriptive complexity.
- Prof. Dr. Colva M. Roney-Dougal (University of St Andrews): Computation of normalizers in matrix groups.
- Prof. Dr. Max Horn: RPTU Kaiserslautern-Landau.Computational permutation group theory
- Prof. Dr. Christoph Garth: RPTU Kaiserslautern-Landau.Algorithm design and visualization
- Prof. Dr. Yota Otachi: Nagoya University.Algorithmic graph theory
- Prof. Dr. Brendan McKay: Australian National University.Canonization, generation, and isomorphisms

Christian Stinner

- Dr. Philippe Laurençot (Directeur de Recherches CNRS, University Savoy Mont Blanc): Chemotaxis models.
- Prof. Dr. Michael Winkler (Universität Paderborn): Chemotaxis models.

Tabea Tscherpel

- Prof. Dr. Lars Diening, Dr. Johannes Storn (Universität Bielefeld): Grading of adaptively generated triangulations and projection operators onto conforming finite element spaces.
- Prof. Dr. L. Ridgway Scott (University of Chicago, Emeritus, USA): Divergence-free finite element spaces.

- Dr. Alexei Gazca Orozco (Universität Freiburg), Dr. Erika Maringova (Institute of Science and Technology Austria): Numerical analysis for fluid models with complex boundary conditions.
- Dr. Martin Parisot (Inria, University of Bordeaux, France), Prof. Dr. Emmanuel Audusse (University Paris 13, France), Prof. Dr. Sebastian Noelle (RWTH Aachen): Numerical approximation of the Green–Naghdi equations.

Stefan Ulbrich

- Prof. Dr. Serge Gratton (INP ENSEEIHT Toulouse): Subspace Decomposition Methods for Optimization.
- Prof. Dr. Martin Gugat (Universität Erlangen-Nürnberg): Optimal Control of Hyperbolic Conservation Laws.
- Prof. Dr. Michael Hintermüller (WIAS Berlin): Optimal Control of Hyperbolic Conservation Laws.
- Prof. Dr. Michael Hinze (Universität Hamburg): Model Order Reduction in Optimization.
- Prof. Dr. Christian Kirches (TU Braunschweig): Mixed-Integer Optimal Control.
- Dr. Paul Manns (TU Braunschweig): Mixed-Integer Optimal Control.
- Prof. Dr. Michael Ulbrich (TU München): PDE- and VI-Constrained Optimization.

Torsten Wedhorn

- Dr. Paul Ziegler (TU München): Cycle classes on Shimura varieties.
- Prof. Dr. Eike Lau (Universität Bielefeld): Higher displays.
- Prof. Dr. Eva Viehmann (Universität Münster): Moduli of truncated shtukas.

Cornelia Wichelhaus

- Dr. Liron Ravner (Tel Aviv University): Statistical inference for fluid systems.

Winnifried Wollner

- Prof. Dr. Jörn Behrens (Universität Hamburg): Goal-Oriented Adaptivity for Hyperbolic PDEs.
- Prof. Dr. Sue Brenner (Louisianna State University): Discretization of Gradient Constrained Optimization Problems.
- Dr. Caroline Geiersbach (WIAS Berlin): Stochastic Optimization with PDE Constraints.
- Prof. Dr. Luca Heltai (SISSA, Trieste): Pressure-Robust Stokes Elements.
- Prof. Dr. Adrian Hirn (HS Esslingen): Optimization of Systems with p-Structure.

– Prof. Dr. Christian Kreuzer (TU Dortmund): Finite Element Approximation of PDE Constrained Optimization Problems.

– Prof. Dr. Ulrich Langer (Universität Linz): Numerical Methods for Phase-Field Fracture.

– Dr. Alexander Linke (WIAS, Berlin): Pressure-Robust Stokes Elements.

– Prof. Dr. Matthias Maier (Texas A& M): Eigenvalue Optimization for Maxwell's Equation.

– Dr. Hannes Meinlschmidt (RICAM Linz): Regularity of Elliptic Systems.

– Prof. Dr. Ira Neitzel (Universität Bonn): Optimizing Fracture Propagation Using a Phase-Field Approach.

– Prof. Dr. Thomas Richter (Universität Magdeburg): Numerical Methods for Time Periodic Problems.

– Prof. Dr. Andreas Veeser (University of Milan): Finite Element Approximation of PDE Constrained Optimization Problems.

– Prof. Dr. Thomas Wick (Universität Hannover): Optimizing Fracture Propagation Using a Phase-Field Approach.

4 Teaching

Teaching of mathematics in our department can be divided into three categories: teaching in mathematical degree programmes, specific teaching activities for future mathematics teachers (in secondary and vocational education), and teaching mathematics to students in the sciences and engineering subjects (often described as ‘service teaching’). Each of these teaching activities has its own characteristics in terms of mathematical content and style as well as in terms of specific regulations of corresponding degree schemes.

4.1 Degree Programmes in Mathematics

There are currently three mathematics programmes: the Bachelor programme in mathematics and the Master programme in mathematics (both taught in German) and the English-taught Master’s degree programme in mathematics. The following table shows the enrolement numbers over the last 8 years:

Students in Mathematics programmes
(Source: Data Warehouse (DW), 29.03.2023)

Programme	2015	2016	2017	2018	2019	2020	2021	2022
Bachelor	535	518	480	435	424	440	392	394
Master (incl. Engl. Master)	309	292	274	251	235	246	231	211
Teacher (secondary)	335	289	270	227	218	240	221	224
Teacher (vocational)	18	18	15	12	10	16	14	11

New enrolments
(Source: Data Warehouse (DW), 29.03.2023)

Programme	2015	2016	2017	2018	2019	2020	2021	2022
Bachelor	122	126	120	134	122	118	86	71
Master (incl. Engl. Master)	96	89	86	79	62	85	65	49
Teacher (secondary)	48	45	39	47	49	56	45	36
Teacher (vocational)	5	7	5	4	1	10	7	0

The main aspects in the design of the current programme structure could be described as both modern and conservative at the same time. A more detailed look at both programmes resolves this apparent contradiction. They combine proven and tested components of the Diplom programme with new aspects such as modularization and a credit point system. The new programme retains the idea that mathematics should be studied together with a minor, which is typically a subject in which mathematics is applied. The standard choice of a minor can be one of computer science, economics, physics, chemistry or, since 2018, mechanics. Further subjects are available upon application. If students choose the option “Mathematics with Economics” (available both for Bachelor and Master), their minor is a combination of economics and computer science.

The Bachelor programme has a duration of 6 semesters and finishes with a Bachelor thesis on a mathematical topic. A unique feature of our Bachelor programme are the optional bilingual courses. Both options “Mathematics” (with arbitrary minor) and “Mathematics with Economics” can be studied as a bilingual programme since 2009.
According to a survey during the orientation week in the winter semester 2017/18, about 33 % among the 118 Bachelor students interviewed expressed the intension of obtaining the bilingual certificate.

Graduates of the Bachelor programme have the option of taking up a job or continuing their studies in a Master programme. This can be the Master programme at our department, at a different university or even a Master programme in a different area based on their education in mathematics.

Our Master programme has a duration of 4 semesters. It is centred on two in-depth specializations or focus areas within mathematics or, alternatively, one focus area in mathematics and one in a cognate subject in which mathematics is applied (such as computer science, economics, physics, chemistry or, since 2018, mechanics). The mathematical specializations (Vertiefungsrichtungen) are offered by the research groups in the department. Beside the two focus areas (at 18 CP each), there is room for additional courses in mathematics, minors and general studies. The topic of the Master thesis is selected in one of the two focus areas; in the case of a combination with an extra-mathematical focus area, the topic of the Master thesis may be chosen from that other subject but has to be related to mathematics.

The structure of the English-taught Master´s degree programme mathematics is close to the German-taught Master´s programme. Deviating from the mandatory minor, the students can choose between taking a minor or additional mathematical courses on the master´s level. Since its implementation the application as well as the enrolment numbers in the M.Sc. Mathematics are slowly but continuously increasing. Also, with the academic year 2020/21 our Bachelor´s graduates begin to decide to continue their studies in the English-taught Master´s programme. Deviating from the mandatory minor, the students can choose between taking a minor or a third mathematical specialization.

The teaching programme for grammar schools has a duration of 9 semesters and can also be studied as a bilingual programme. Next to the mathematical part, students in this teaching programme study a second subject and take courses in pedagogy and education ("Grundwissenschaften"). The study programme closes with the first state examination ("Erstes Staatsexamen"). The Master of Education, the teaching programme for vocational schools, has a duration for 4 semesters and can only be studied by students who have graduated in a Bachelor of Education, or with a respective professional background or apprenticeship.

Graduates of the Bachelor programme
(Source: Data Warehouse (DW), 29.03.2023)

Programme	2016	2017	2018	2019	2020	2021
Total	73	83	78	60	78	69
Female students	24	26	32	15	21	20
Graduation within 3 years	20	25	26	19	29	12
Graduation within 4 years	48	61	55	39	56	37

Graduates of the Master programme (Source: Data Warehouse (DW), 29.03.2023)						
Programme	2016	2017	2018	2019	2020	2021
Total	89	83	67	79	65	61
Female students	25	35	22	29	20	22
Graduation within 2 years	32	11	13	18	10	13
Graduation within 3 years	72	57	55	62	56	51

Graduates in Education for Secondary Schools (Source: Data Warehouse (DW), 29.03.2023)						
Programme	2016	2017	2018	2019	2020	2021
Total	18	13	19	8	9	8
Female students	6	8	11	4	3	4
Graduation within 9 semesters	1	1	4	0	0	3
Graduation within 11 semesters	7	4	12	1	0	6

Graduates in Education for Vocational Colleges (Source: Data Warehouse (DW), 29.03.2023)						
Programme	2016	2017	2018	2019	2020	2021
Total	7	7	1	0	0	6
Female students	3	3	0	0	0	2
Graduation within 9 semesters	1	0	0	0	0	2
Graduation within 11 semesters	4	3	9	0	0	3

International exchange Many students choose to study at a university abroad for one or two terms, typically in their third year.
The department provides general information (online and through an annual information event) as well as individual advice for students who plan a period of time abroad and also maintains contacts with various popular destinations abroad. Students who return after their time abroad are encouraged to share their experiences through short summaries with informal advice on the departmental web pages.
Close cooperation between the students and the department facilitates the transfer of their credits from abroad into their study programme in Darmstadt. This helps to avoid negative effects on the overall duration of studies. Since 2019, incoming students are encouraged to take part in the department´s buddy programme. In this programme, students of the department voluntarily help incoming students getting settled in Darmstadt and support them during the exchange period (one semester max.). Close cooperation between the students and the department facilitates the transfer of their credits from abroad into their study programme in Darmstadt. This helps to avoid negative effects on the overall duration of studies. The numbers of the academic year 2019/20 represent the students that applied for a semester abroad and accepted their nomination. Due to the Covid-19 pandemic, almost all students cancelled their stay or had to cancel it due to cancellation by the partner universities.

Academic year 14/15	15/16	16/17	17/18	18/19	19/20	20/21	21/22
Erasmus outgoers 8	27	13	12	19	12	10	21
Further outgoers 7	12	7	7	3	5	1	3
Incomers 2	5	4	4	8	11	3	6

4.2 Teaching for Other Departments

Students in almost all study programmes of this university have to take at least one course in mathematics. The department teaches students in the engineering sciences (mechanical, electrical, civil engineering, material sciences), in computer science, the natural sciences (chemistry, physics, biology, geology), economics, the liberal arts, social sciences and in architecture.

Service teaching comprises courses of a variety of different formats. There are large lecture courses providing a solid foundation in mathematics covering subjects such as basic analysis (calculus), differential equations, numerical methods and stochastics. For instance, there is a four semester cycle for students of Electrical Engineering, with 4 hours of lectures and 2 hours of exercise groups per week. There are also smaller courses, concentrating on special areas in mathematics used in particular disciplines, as, for instance, our one-semester statistics courses for students in Biology or the social sciences. In an innovative format (Team Teaching), the course “Mathematik für Chemiker” is taught jointly by a mathematician and a chemist.

Service courses, no. participants, winter semester 2021/22 (Source: TUCaN, 29.03.2023)	
Höhere Mathematik I	112
Mathematik I für Bauwesen	485
Mathematik I für Elektrotechnik	601
Mathematik I für Informatik	1000
Mathematik I für Maschinenbau	673
Mathematik III für Bauwesen	523
Mathematik III für Elektrotechnik	645
Mathematik III für Maschinenbau	606
Mathematik für Chemie	123
Mathematik und Statistik für Biologie	234
Statistik I für Human- und Sozialwissenschaft	76
Statistik I für Wirtschaftsingenieurwesen	670
Statistik I für Cognitive Science	56
Mathematik als gemeinsame Sprache der Naturwissenschaften	71
Treffpunkt Mathematik (ET I, MB I, Inf I)	1433

Service courses, no. participants, summer semester 2021 (Source: TUCaN, 29.03.2023)	
Lineare Algebra II für Physikstudierende	228
Höhere Mathematik II	50
Mathematik II für Bauwesen	729
Mathematik II für Elektrotechnik	673
Mathematik II für Informatik	969
Mathematik II für Maschinenbau	823
Mathematik IV für Elektrotechnik, Mathematik III für Informatik	917
Numerische Mathematik für Maschinenbau	401
Aussagen- und Prädikatenlogik	655
Elementare PDGL: Klassische Methoden	104
Treffpunkt Mathematik (MB II, Inf II, ET II)	1150

It is one of the principles of this university that the department of mathematics is responsible for the teaching of mathematics across all subjects that require mathematics in their education. The importance of this aspect of our teaching activities is also borne out in the university's KIVA initiative, which among other aspects emphasises the critical role of mathematics education in the early phases of university studies in the sciences and engineering disciplines. Among our efforts to strengthen the basis for this mathematical education, the department has set up optional extra learning platforms under the name of "Treffpunkte Mathematik", which serve to give extra support to students in the large mainstream mathematics lecture courses. We also have established the "Lernzentrum Mathematik", a working space especially for students taking maths courses where more than seven hours a day research assistants (during the term) or advanced students (during the vacations) are available for assistance. One of the guiding ideas in these activities is the attempt to provide auxiliary training and to improve the motivation of students from those other subjects through problems that relate mathematics better with themes from the own subjects. Participation and student evaluations for these extras show this approach to be a success.

4.3 Characteristics in Teaching

As in previous years, the efforts of the department of mathematics were rewarded in the "CHE-Hochschul Ranking Mathematik" (Bachelor as well as Master). According to the results published in 2021, the department of mathematics again holds a good position among the universities in Germany. This success also reflects the emphasis on teaching methods at the department of mathematics. Our aim in teaching is to encourage and motivate students to actively pursue the understanding of the taught material. The learning of mathematics is an intellectual activity equally supported by classroom teaching, by individual work and study, and by team work, both with and without direct supervision.

Lectures present mathematical content and methods through personal presentation; the systematic development and exposition of the material in the lectures is intended to stimulate the students' mathematical intuition. Lectures are complemented by exercise groups, and by additional tutorials during the first year. The time ratio between classroom lectures and exercises is 2:1.

In exercise classes, students work on problems and topics from the lecture with the support of a tutor and they are encouraged to present and discuss solutions to homework problems. Students are also expected to work on weekly sets of homework problems and to submit their solutions to their tutors for marking in order to obtain feedback. The department has implemented a format for tutorials in the first year, which are provided as an additional learning platform besides exercise groups. Here teaching assistants hold classroom sessions devoted to the review of current material from the lecture classes, current and past problems from the exercises, further examples, basic problems and illustrations, or to filling gaps in students' basic understanding. Regarded as an optional extra rather than as a mandatory part of the course, these tutorials are offered on a weekly alternating basis for the two main first-year courses (Analysis and Linear Algebra). Overall, all these activities are meant to support learning and to give students ample opportunity to improve and to test their knowledge and understanding.
Exercise groups and homework activities also form an integral part of most of the more advanced lecture courses, including those at Master level. In the course of the re-accreditation in 2011/12, the department decided to strengthen the Master programme with its rich spectrum of focus areas to choose from, by giving firmer guarantees as to the concrete choices of specialization areas that would be available to any cohort of Master students in the upcoming three years. The department also committed itself to devote any extra teaching capacity that was freed through the termination of freshers' enrolment in the summer semester to a corresponding strengthening of the Master programme. Among other changes this has enabled us to allow for a larger number of teaching assistants to be employed in exercises for Master level courses. These measures are meant to make our Master programme even more competitive through its quality of teaching, greater reliability and impressive variety across a considerable breadth of research areas – both to retain our own Bachelor students and to attract new Master students from elsewhere. These strengthenings of the Master programme proved to be succesful by the accreditation in 2017/18 and have been continued accordingly.

Moreover, the department supports students in their learning experience by the following measures:

- the organisation of exercises and tutorials typically lies in the hands of experienced teaching assistants
- newly recruited tutors and student demonstrators undergo a dedicated training programme (which serves as an example of good practice in the context of the KIVA project, where similar ideas are being tested in other departments' teaching)
- exercise groups are limited to a size of 20 students in the first year and 25 students from the second year onwards
- we provide an open learning environment with small learning groups
- all teaching staff offer weekly consultation hours for individual help and support
- the department provides altogether 12 student rooms (open access and reserved) with about 160 places for students to meet in learning groups, to work on their thesis or to prepare for their final exams

- the Mathematics Learning Center (Lernzentrum Mathematik) is staffed during opening hours by an assistant, available to answer questions; in addition, textbooks and up-to-date material for the current courses are provided
- there are 32 places for reading and studying in the departmental library (towards the end of 2012, this departmental library was incorporated into the new central university library)
- the department has three open access computer labs (with a total of 43 Linux machines) and two reserved computer labs (with a total of 15 Linux machines)

4.4 E-Learning/E-Teaching in Academic Training

E-Learning is present in the Department of Mathematics in teaching and research. The Covid-19 pandemic gave our already established concepts in E-Learning and E-Teaching a massive boost. When the pandemic forced us all to work and study from home, lecturers came up with wide range of ideas to realise effective distance learning. Next to the below listed standards, a lot of lecturers are now using a lot more innovative concepts such as Flipped Classrooms and open-book-exams. Due to the efforts of the teaching and administrative staff, all lectures and examinations took place. We will use the experience from the challenges the Covid-19 pandemic provided and will continue to develop the E-Learning and E-Teaching concepts at the Department of Mathematics.

Overall standards and innovation of E-Learning and E-Teaching in the Department of Mathematics are:

- video capturing of almost all lectures during Covid-19
- the learning material and exercises of most of all math-courses are adaptably accessible for the students on the Moodle platform
- support for individual assessment (diagnostic tests, project TELPS)
- two online-lessons (task-diversity (MAVIE) and task-training) for teacher education, available in German as well as in English.
- In some research projects new websites and digital tools as test- or/and learning environments are developed, see projects MAKOS, CODI, BASICS Mathematik, Basics2go
- 4 - 5 half-year-online teacher training courses (in service) are running each semester. The course is taken by 60 - 80 teachers each year.
- the task-database `www.madaba.de` with more than 1000 interesting math tasks supports teachers to prepare learning environments for math-lessons in school (secondary level I and II)
- Project TU-WAS: Development of a web-based task STACK collection to support tutors in their work and students with individual feedback. The platform STACK was first used in mathematical courses in the engineering study programmes in winter semester 2020/21

Research and research-based development

In connection with the VEMINT project (cooperation between TU Darmstadt (Reif, Genc), University of Paderborn (Biehler) and University of Kassel (Eichler)) and TU Hannover (Hochmuth), some new E-Learning elements, e.g., for self-regulation in cooperation with psychologists (Dr. Bellhaeuser) and for training of basic school knowledge in mathematics with initial differentiation in a new group formation (Project MOODLE-PEERS), were developed for the preparatory math courses for beginner students. Since 2009, the preparatory course has been presented online via Moodle each winter semester for (as of winter semester 2020/21) almost all departments of TU Darmstadt. In winter semester 2020/21, 1800 students participated in the programme.

https://www.mathematik.tu-darmstadt.de/studium/studierende/orientierungsangebote_1/mathematik_vorkurs/mathematik_vorkurs_2.de.jsp

VEMINT project homepage:
https://www.vemint.de/.

MaViT: Mathematical Video Tutorials for Students of Engineering Sciences

Since the winter semester 2013/14 mathematical video tutorials have been produced to support students of Engineering Sciences to improve their mathematical basic skills single-handedly.
Especially within the service courses taken by students of other departments a large heterogeneity can be observed regarding previous knowledge as well as learning strategies. The videos are embedded into interactive digital learning environments that give graded hints on how to solve the problem if required and provide a collection of additional exercises with sample solutions. In addition assisted forums offer the possibility to ask and discuss questions regarding the respective content. Students can access the learning environments via Moodle. Based on the know how of the project MaViT the presentation of solutions to the given tasks from the data bank is filmed now. More than 50 videos are stored on a central server. In the data bank of tasks weblinks to the videos are integrated. The evaluation shows that students appreciate the offered material for being valuable support of their learning process. An other new feature to support Mathematics I for electrical engineers was a weekly diagnostic test via Moodle. The task format was multiple choice. Indeed, the effort is very high to the construction of such tests. The effort stands in no satisfactory relation with the interest of the students in the tests.

TU-WAS: Web-based task collection with STACK

As part of the project "Digitally Supported Teaching and Learning in Hesse", the state of Hesse is funding the development of innovative, digitally supported teaching and learning projects at TU Darmstadt. The TU-WAS project is aimed at mathematics courses in first-year engineering study programs. Classroom teaching is to be supplemented by the use of digital tasks in order to provide students with differentiated and individual support by means of a digital task arrangement. As part of the project, a web-based collection of tasks to support

teaching is being developed in cooperation with the University Didactics Office (Reif, Celik, Genc, Metzler, Hoppe). The project was launched in 2019 and the platform was used for the first time in the winter semester 2020/21. In the long term, STACK should also be applicable for e-examinations.
https://www.mathematik.tu-darmstadt.de/geometrie-und-approximation/arbeitsgruppe_geometrie_und_approximation/projekte/digitales_lehren_und_lernen/index.de.jsp

4.5 Career-related Activities

In the series of lectures "Heute Mathe, morgen ...?" mathematicians present their current area of work, their vita and their employer. The main purpose is to give students a more personal insight into jobs for mathematicians outside the university than can be given by a job fair. A further intention is to give female students an easy opportunity to ask gender-specific questions and to present role models to the students.

19/01/2021 Dr. Sonja Mars (Gurobi),

02/02/2021 Tobias Bauer, Daniel Stühn (Willis Towers Watson),

04/05/2021 Christopher Brozek (Finanzguru),

18/05/2021 Simon Hampe (iteratec Gmbh),

01/06/2021 Christoph Klockewitz (m|rig GmbH),

15/06/2021 Adrian Gabel (Pricewaterhouse Coopers),

29/06/2021 Lukas Kottmann (xpact Consulting AG),

09/11/2021 Marlene Schaffland-Utz (Bearing Point),

23/11/2021 Norbert Sommer (Accenture Strategy & Consulting),

07/12/2021 Julia Brechtel (IT-Seal GmbH),

18/01/2022 Kenan Sancar (DACHPC),

01/02/2022 Fabian Völz (d-fine),

15/02/2022 Tobias Kanski (Cylad),

03/05/2022 Michael Moos, Jan Schröder (Fraunhofer-Institut für Techno- und Wirtschaftsmathematik),

17/05/2022 Matthias Deutschen (Oliver Wyman),

31/05/2022 Clara Funke (BCG Gamma),

21/06/2022 Jutta Hübner (ESA),

05/07/2022 Clara Spahn (DICOS),

12/07/2022 Anna Siffert (Universität Münster),

01/11/2022 Alexandra Bonin, Axinja Ambach (andrena objects ag),

15/11/2022 Meike Steinert, Stefan Wingenbach, Nick Kleinmanns (Lucht Probst Associates),

29/11/2022 Tobias Erdweg (Fintegral Deutschland AG),

13/12/2022 Luis Kaiser (HBA-Consulting AG),

5 Publications

5.1 Co-Editors of Publications

5.1.1 Editors of Journals

Dieter Bothe

- *International Journal of Multiphase Flows* (Editorial Advisory Board)
- *Nonlinear Analysis: Real World Applications* (Editorial Board)

Jan H. Bruinier

- *Forum Mathematicum* (Managing Editor)
- *Research in Number Theory* (Associate Editor)
- *Annali dell'Università di Ferrara* (Associate Editor)

Alf Gerisch

- *PLOS ONE* (Academic Editor)

Jan Giesselmann

- *Applied Numerical Mathematics* (Editor)

Matthias Hieber

- *Differential Integral Equations* (Editor-in-Chief)
- *Journal of Mathematical Fluid Dynamics* (Associate Editor)
- *Advances in Differential Equations* (Associate Editor)
- *Evolution Equations and Control Theory* (Associate Editor)
- *Springer Lecture Notes in Mathematical Fluid Dynamics* (Associate Editor)

Ulrich Kohlenbach

- *Annals of Pure and Applied Logic* (Coordinating Editor)
- *Computability* (Member of Editorial Board)
- *Journal of Mathematical Logic* (Advisory Editor)
- *Logical Methods in Computer Science* (Member of Editorial Board)

Michael Kohler

- *AStA Advances in Statistical Analysis* (Associate Editor)

Katja Krüger

- *Stochastik in der Schule* (Associate Editor)

Jens Lang

- *Applied Numerical Mathematics* (Editor)

Martin Otto

- *ASL Lecture Notes in Logic (book series)* (Editor)

Marc Pfetsch

- *Operations Research Letters* (Area Editor)
- *Mathematical Programming Computation* (Associate and Technical Editor)
- *INFORMS Journal on Computing* (Associate Editor)

Ulrich Reif

- *Journal of Approximation Theory* (Associate Editor)
- *Computer Aided Geometric Design* (Associate Editor)

Werner Schindler

- *Journal of Cryptographic Engineering* (Associate Editor)

Pascal Schweitzer

- *SIAM Journal on Discrete Mathematics* (Associate Editor)

Thomas Streicher

- *Applied Categorical Structures* (Associate Editor)
- *Mathematical Structures in Computer Science* (Associate Editor)

Stefan Ulbrich

- *Journal of Optimization Theory and Applications* (Associate Editor)
- *Optimization Methods and Software* (Editor in Chief)
- *Advances in Continuous and Discrete Models: Theory and Applications* (Associate Editor)
- *Asymptotic Analysis* (Associate Editor)
- *ESAIM: Control, Optimisation and Calculus of Variations* (Associate Editor)
- *SIAM Book Series: MOS-SIAM Series on Optimization* (Associate Editor)

Cornelia Wichelhaus

- *Journal Queueing Systems* (Associate Editor)

Winnifried Wollner

- *International Journal of Applied and Computational Mathematics* (Associate Editor)

5.1.2 Editors of Proceedings

5.1.3 Editors of a Festschrift

Burkhard Kümmerer

– *himmelwärts – 450 Jahre Johannes Kepler, 2022* (jointly with jointly with Hildrun Bäzner-Zehender, Hermann Faber, Wolfgang Pleithner (Kepler-Gesellschaft e.V.), Robert Löw, Karin Otter (Universität Stuttgart))

5.2 Monographs and Books

[1] P. Auscher and M. Egert. *Boundary value problems and Hardy spaces for elliptic systems with block structure*. Birkhäuser, 2023.

[2] K. Goschin. *Optimal Design of an Energy Network Involving Renewable Energies for a Settlement*. Dr. Hut Verlag, 2021.

[3] M. Hintermüller, R. Herzog, C. Kanzow, M. Ulbrich, and S. Ulbrich, editors. *Non-smooth and complementarity-based distributed parameter systems—simulation and hierarchical optimization*, volume 172 of *International Series of Numerical Mathematics*. Birkhäuser/Springer, Cham, [2022] ©2022.

[4] A. Matei. *Optimum Experimental Design with PDE Constraints for Identification of Model Uncertainty in Load-bearing Systems*. Dr. Hut Verlag, 2022.

[5] F. Matter. *Sparse Recovery Under Side Constraints Using Null Space Properties*. Dissertation, TU Darmstadt, 2022.

[6] P. F. Pelz, P. Groche, M. E. Pfetsch, and M. Schäffner, editors. *Mastering Uncertainty in Mechanical Engineering*. Springer, 2021.

[7] A.-T. Rauls. *Generalized Derivatives for Solution Operators of Variational Inequalities of Obstacle Type*. Dr. Hut Verlag, 2021.

[8] P. Schäfer Aguilar. *Numerical approximation of optimal control problems for hyperbolic conservation laws*. Dr. Hut Verlag, 2021.

[9] S. Schindler-Tschirner and W. Schindler. *Mathematische Geschichten III - Eulerscher Polyedersatz, Schubfachprinzip und Beweise. Für begabte Schülerinnen und Schüler in der Unterstufe*. Springer Spektrum, 2021.

[10] S. Schindler-Tschirner and W. Schindler. *Mathematische Geschichten IV - Euklidischer Algorithmus, Modulo-Rechnung und Beweise. Für begabte Schülerinnen und Schüler in der Unterstufe*. Springer Spektrum, 2021.

[11] S. Schindler-Tschirner and W. Schindler. *Mathematische Geschichten V - Binome, Ungleichungen und Beweise. Für begabte Schülerinnen und Schüler in der Mittelstufe*. Springer Spektrum, 2022.

[12] S. Schindler-Tschirner and W. Schindler. *Mathematische Geschichten VI - Kombinatorik, Polynome und Beweise. Für begabte Schülerinnen und Schüler in der Mittelstufe*. Springer Spektrum, 2022.

[13] A. Schmitt. *Interdiction Problems in Mixed-Integer Nonlinear Programming*. Dissertation, TU Darmstadt, 2022.

[14] A. Walter. *Optimal Control of Nonlinear Elastoplasticity Problems with Model Order Reduction*. Dr. Hut Verlag, 2021.

5.3 Publications in Journals and Proceedings

5.3.1 Journals

[1] J. Aguilera, A. Freund, M. Rathjen, and A. Weiermann. Ackermann and goodstein go functorial. *Pacific Journal of Mathematics*, 313(2):251–291, 2021.

[2] J. Aguilera, A. Freund, M. Rathjen, and A. Weiermann. Boundedness theorems for flowers and sharps. *Proceedings of the AMS*, 150(9):3973–3988, 2022.

[3] M. Arnold, H. Podhaisky, R. Weiner, E. Celledoni, J. Frank, and J. Lang. Numerical solution of differential and differential-algebraic equations. Selected papers from NUMDIFF-15 [Preface]. *J. Comput. Appl. Math.*, 387:112611, 2021.

[4] B. Augner and D. Bothe. Analysis of some heterogeneous catalysis models with fast sorption and fast surface chemistry. *Journal of Evolution Equations*, 21:3521–3552, 2021.

[5] F. Aurzada, V. Betz, and M. Lifshits. Breaking a chain of interacting Brownian particles. *Ann. Appl. Probab.*, 31(6):2585–2611, 2021.

[6] F. Aurzada, V. Betz, and M. Lifshits. Breaking a chain of interacting Brownian particles: a Gumbel limit theorem. *Theory Probab. Appl.*, 66(2):184–208, 2021. Translation of Teor. Veroyatn. Primen. 6(6) (2021), 231–260.

[7] F. Aurzada, V. Betz, and M. Lifshits. Universal break law for a class of models of polymer rupture. *J. Phys. A*, 54(30):Paper No. 305204, 28, 2021.

[8] F. Aurzada and M. Kilian. Asymptotics of the persistence exponent of integrated fractional Brownian motion and fractionally integrated Brownian motion. *Theory Probab. Appl.*, 67(1):77–88, 2022. Translation of Teor. Veroyatn. Primen. 6(7) (2022), 100–114.

[9] F. Aurzada, M. Kilian, and E. Sönmez. Persistence probabilities of mixed FBM and other mixed processes. *J. Phys. A*, 55(30):Paper No. 305003, 17, 2022.

[10] F. Aurzada, S. Mukherjee, and O. Zeitouni. Persistence exponents in Markov chains. *Ann. Inst. Henri Poincaré Probab. Stat.*, 57(3):1411–1441, 2021.

[11] F. Aurzada and D. T. Schickentanz. Brownian motion conditioned to spend limited time below a barrier. *Stochastic Process. Appl.*, 146:360–381, 2022.

[12] P. Auscher and M. Egert. Hardy spaces for boundary value problems of elliptic systems with block structure. *J. Geom. Anal.*, 31:9182–9198, 2021.

[13] M. Bagheri, B. Stumpf, I. V. Roisman, A. Dadvand, M. Wörner, and H. Marschall. A unified finite volume framework for phase-field simulations of an arbitrary number of fluid phases. *The Canadian Journal of Chemical Engineering*, 100(9):2291–2308, 2022.

[14] M. Bagheri, B. Stumpf, I. V. Roisman, C. Tropea, J. Hussong, M. Wörner, and H. Marschall. Interfacial relaxation–crucial for phase-field methods to capture low to high energy drop-film impacts. *International Journal of Heat and Fluid Flow*, 94:108943, 2022.

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5.5 Reviewing and Refereeing

Markus Anders: ACM Transactions on Computation Theory (TOCT)

Björn Augner: Mathematical Reviews; 25$^{\text{th}}$ International Symposium on Mathematical Theory of Networks and Systems, 60$^{\text{th}}$ IEEE Conference on Decision and Control (CDC), IEEE Transactions on Automatic Control, 21$^{\text{st}}$ IFAC World Congress 2020 (IFAC 2020), Journal of Dynamical and Control Systems, MICNON 2021, Nonlinear Analysis: Real World Applications, SIAM Journal on Control and Optimization

Frank Aurzada: Mathematical Reviews; Advances in Applied Mathematics, Annals of Applied Probability, Annales de l'Institut Henri Poincaré - Probabilités et Statistiques, Bernoulli, Communications in Mathematical Physics, Communications on Pure and Applied Mathematics, Electronic Communiations in Probability, Electronic Journal of Probability, Journal of Physics A, Journal of Statistical Physics, Journal of Theoretical Probability

Dieter Bothe: Reviews; Chemical Engineering Science, Communications in Partial Differential Equations, European Physical Journal Special Topics, Journal of Fluid Mechanics, Journal of Mathematical Analysis and Applications, International Journal of Heat and Mass Transfer, Physical Review Letters

Jendrik Brachter: Journal of Algebraic Combinatorics (JACO), Journal on Discrete Mathematics (SIDMA), International Colloquium on Automata, Languages, and Programming (ICALP)

Jan H. Bruinier: Invent. Math., Ann. of Math., Acta Math., Journal of the AMS, Math. Ann., Duke Math. Journal, Crelle, Advances in Mathematics, Compositio Mathematica, etc.

Yann Disser: CIAC 2023, Discrete Optimization, ICALP 2021, IPCO 2023, Journal of Scheduling, Mathematical Programming, MFCS 2022, SODA 2021, SODA 2022, STACS 2022, STOC 2023, SWAT 2022, Theoretical Computer Science, Transactions on Algorithms

Moritz Egert: Journal of Differential Equations, Journal of Evolution Equations, Journal of Functional Analysis, Journal of the EMS, Transactions of AMS, Publicacions Mathèmatiques, Communications on Pure and Applied Analysis, Revista Mathématica Iberoamericana, Forum Mathematicum

Herbert Egger: Mathematical Reviews; Applied Mathematics and Computer Science, Applied Numerical Mathematics, Applied Mathematics and Computation, Computational and Applied Mathematics with Applications, BIT Numerical Mathematics, Computational and Applied Mathematics, Computers and Mathematics with Applications, ESAIM: Control Optimisation and Calculus of Variations, ESAIM:Mathematical Modelling and Numerical Analysis, Inverse Problems, Journal Applied Mathematics and Computing, Journal Inverse and Ill-posed Problems, Journal Mathematical Analysis and Applications, Mathematical and Computational Applications, Mathematical Methods in the Applied Sciences, Numerische Mathematik, SIAM Journal on Numerical Analysis, SIAM Journal on Scientific Computing

Kord Eickmeyer: Logical Methods in Computer Science, Journal of Logic and Computation, European Journal of Combinatorics, Theoretical Computer Science, Discrete Mathematics

Mathis Fricke: Journal of Computational Physics, Physics of Fluids, Computers & Fluids; International Journal of Heat and Mass Transfer, The European Physical Journal

Alf Gerisch: Journal of Biomechanics, Journal of Computational and Applied Mathematics, IMA Journal of Applied Mathematics, Journal of Theoretical Biology, Mathematical Biosciences and Engineering, The Fund for Scientific Research (FNRS, Belgium)

Jan Giesselmann: Zentralblatt; Mathematics of Computation, Journal of Scientific Computing, Differential Integral Equations, Discrete Continuous Dynamical Systems-S, Mathematical Methods in the Applied Sciences, Applied Numerical Mathematics, SIAM/ASA Journal on Uncertainty Quantification, Journal of Applied Mathematics and Computing, SIAM Journal on Mathematical Analysis, SIAM Journal on Control and Optimization, IMA Journal of Numerical Analysis, Nonlinear Analysis Real World Applications, Communications in Optimization Theory, Science Advances, ZAMP

Robert Haller: Nonlinear Analysis: Real World Applications

Christian Herrmann: International Journal of Algebra and Computation

Konstantin Jakob: Zentralblatt; Advances in Mathematics, Trans. Amer. Math. Soc.

Ulrich Kohlenbach: Journal of Fixed Point Theory and Applications, Mathematics of Computation, Philosophia Mathematica, Studia Logica, The Journal of Symbolic Logic

Michael Kohler: Annals of Statistics, Bernoulli, IEEE Transcations on Information Theory

Katja Krüger: Stochastik in der Schule; mathematica didactica

Burkhard Kümmerer: Journal of Functional Analysis, Communications in Mathematical Physics, Journal of Operator Theory, Journal of Statistical Physics, Journal of Mathematical Analysis and Applications, Journal of Mathematical Physics

Jens Lang: Applied Numerical Mathematics, Combustion Theory and Modelling, Journal of Physics A: Mathematical and General, Inverse Problems, Computing and Visualization in Science, International Journal of Hyperthermia, International Journal for Numerical Methods in Fluids, Transactions on Mathematical Software, Journal of Computational Physics, Computational and Applied Mathematics, IMA Journal of Numerical Analysis, Mathematics of Computation, SIAM Journal Numerical Analysis, SIAM Journal Scientific Computing, BIT

Yingkun Li: Transaction AMS, Pure and Applied Math Quarterly, Pacific Journal of Math, Results in Mathematics, Duke Math Journal

Elena Mäder-Baumdicker: Advances in Differential Equations, Analysis and PDE, Communications in Analysis and Geometry

Tomislav Maric: Journal of Computational Physics, Computers & Fluids

Holger Marschall: Reviews; Applied Mathematical Modelling, Chemical Engineering Science, Flow Turbulence and Combustion, International Journal of Multiphase Flow, International Journal of Spray and Combustion Dynamics, International Journal for Numerical Methods in Fluids, Journal of Computational and Applied Mathematics, Journal of Computational Physics, Journal of Computational Science

Martin Otto: Bulletin of Symbolic Logic (BSL), Archive for Mathematical Logic, Mathematical Logic Quarterly (MLQ), Annals of Mathematical Logic

Andreas Paffenholz: Graphs and Combinatorics, International Journal of Computational Geometry and Applications, Information Processing Letters, Discrete Mathematics

Marc Pfetsch: Italian National Agency for the Evaluation of Universities and Research Institutes (ANVUR); Annals of Operations Research, Computers and Operations Research, Discrete & Computational Geometry, Discrete Optimization, ESA 2021, ICUME 2021, IEEE Transactions on Power Systems, INFORMS Journal on Computing, IPCO 2023, Journal of Mathematical Imaging and Vision, Journal of Optimization Theory and Applications, Mathematical Methods of Operations Research, Mathematical Programming, Networks, Optimization and Engineering, OR Letters

Pedro Pinto: Optimization, Fixed Point Theory and Algorithms for Sciences and Engineering, Journal of King Saud University – Science, MDPI Axioms, MDPI Mathematics.

Anne Therese Rauls: Optimization Methods and Software

Ulrich Reif: Journal of Approximation Theory, Computer Aided Geometric Design, Graphical Models, Journal of Numerical Mathematics, Advances in Computational Mathematics, Constructive Approximation, Linear Algebra and Applications

Steffen Roch: Mathematical Reviews; Results in Mathematics

Nils Scheithauer: Advances in Mathematics, Algebra and Number Theory, Annales scientifiques de l'Ecole normale superieure, Communications in Mathematical Physics, Compositio Mathematica, Journal of the EMS, Journal für die reine und angewandte Mathematik, Transactions of the AMS

Werner Schindler: Journal of Cryptology

Kersten Schmidt: European Journal of Applied Mathematics, Journal of Computational and Applied Mathematics, SIAM Journal for Applied Mathematics

Pascal Schweitzer: European Conference on Combinatorics, Graph Theory and Applications (EUROCOMB), International Colloquium on Automata, Languages and Programming (ICALP), International Symposium on Parameterized and Exact Computation (IPEC), International Symposium on Algorithms and Computation (ISAAC), Mathematical Foundations of Computer Science (MFCS), Computational Complexity Conference (CCC), Computing and Combinatorics Conference (COCOON), Computer Science Logic (CSL), Discrete Mathematics Days (DMD), Journal of Chemical Information and Modeling, Symposium on Theory of Computing (STOC), Workshop on Graph-Theoretic Concepts in Computer Science (WG)

Christian Stinner: Mathematical Reviews, Zentralblatt; Analysis, Differential and Integral Equations, Discrete and Continuous Dynamical Systems Series B, Evolution Equations and Control Theory, Taiwanese Journal of Mathematics, Zeitschrift für Angewandte Mathematik und Mechanik

Thomas Streicher: Mathematical Reviews; Annals of Pure and Applied Logic, Journal of Pure and Applied Algebra, Logical Methods in Computer Sciencel, Mathematical Structures in Computer Science

Tabea Tscherpel: IMA Journal of Numerical Analysis, Numerische Mathematik

Stefan Ulbrich: Alexander von Humboldt-Stiftung, Deutsche Forschungsgemeinschaft; Computational Optimization and Applications, Journal of Scientific Computing, Mathematical Programming, Optimization Methods and Software, SIAM Journal on Control and Optimization, SIAM Journal on Optimization,

Cornelia Wichelhaus: AStA Advances in Statistical Analysis, Mathematics and Computers in Simulation, Queueing Systems, Scandinavian Actuarial Journal

Winnifried Wollner: Mathematical Reviews, Zentralblatt MATH ; Applied Numerical Mathematics, Computational Methods in Applied Mathematics, Computer Methods in Applied Mechanics and Engineering, Computational Optimization and Applications, East Asian Journal on Applied Mathematics, Journal of Computational and Applied Mathematics, International Journal of Numerical Analysis and Modeling, Journal of Scientific Computing, Journal of Optimization Theory and Applications, Mathematics of Operations Research, Numerical Mathematics: Theory Methods and Applications

5.6 Software

dejavu: *Graph automorphism and isomorphism solver*
Parallel, random solver solving the graph automorphism and the graph isomorphism problem. For more information, see `https://github.com/markusa4/dejavu`

Contributor at TU Darmstadt: Markus Anders

GaussPar: *Parallel Gaussian elimination in GAP/HPC-GAP*
GaussPar is a software package written for the computer algebra system GAP and its high performance computing version HPC-GAP. It provides an implementation of a parallel Gaussian elimination algorithm over finite fields. For more information, see `https://lbfm-rwth.github.io/GaussParallel/`

Contributor at TU Darmstadt: Jendrik Brachter

sassy: *Preprocessor for the graph automorphism problem*
Preprocessor for the graph automorphism problem reducing large and sparse graphs. For more information, see `https://github.com/markusa4/sassy`

Contributor at TU Darmstadt: Markus Anders

GaussPar: *Parallel Gaussian elimination in GAP/HPC-GAP*
GaussPar is a software package written for the computer algebra system GAP and its high performance computing version HPC-GAP. It provides an implementation of a parallel Gaussian elimination algorithm over finite fields. For more information, see `https://lbfm-rwth.github.io/GaussParallel/`

Contributor at TU Darmstadt: Jendrik Brachter

FastCOIN: *Fast adaptive stochastic COllocation INfrastructure*
FastCOIN is a software package that implements an adaptive, anisotropic stochastic collocation approach on sparse grids for the quantification of uncertainty in PDEs or other models with random parameters described by finitely many random variables. This includes, in particular, finite-dimensional parametrizations of correlated random fields. Similar to a Monte Carlo simulation, this approach decouples and, hence, parallelizes the stochastic problem into a set of deterministic problems. FastCOIN is able to resolve a stochastic parameter space of dimensions up to $20 - 50$.

Contributor at TU Darmstadt: Jens Lang, Alf Gerisch, and formerly Sebastian Ullmann (now at Dassault Systèmes) and Bettina Schieche (now at Münchener Hyp)

KARDOS: *Solving time-dependent partial differential equations*
KARDOS is a software package to solve partial differential equations in one, two and three space dimension adaptively in space and time. Linearly implicit one-step methods of Rosenbrock type or two-step PEER-methods are coupled with standard Finite Elements of various orders. Extensions that we are working on include: incorporation of uncertainty quantification, optimisation and phase-field simulation.

Contributor at TU Darmstadt: Jens Lang, Alf Gerisch

geophase: *Unstructured Volume-of-Fluid Method*
Piecewise-linear reconstruction of fluid interfaces on unstructured meshes `https://git.rwth-aachen.de/leia/geophase`

Contributor at TU Darmstadt: Tomislav Maric

lent: *Unstructured Level Set / Front Tracking Method*
OpenFOAM implementation of the unstructured Level Set / Front Tracking method for simulating incompressible two-phase flows `https://gitlab.com/leia-methods/lent`

Contributor at TU Darmstadt: Tomislav Maric

argo: *Unstructured Volume-of-Fluid Method*
OpenFOAM implementation of the unstructured Volume-of-Fluid method: initializing volume fractions from triangulated surfaces, handling high density ratios, curvature approximation `https://gitlab.com/leia-methods/argo`

Contributor at TU Darmstadt: Tomislav Maric

SCIP: *Software for Solving Constraint Integer Programs*
SCIP is a framework for solving constraint integer programs and performing branch-cut-and-price. It allows total control of the solution process and the access of detailed information. SCIP is also currently one of the fastest non-commercial mixed integer programming (MIP) solvers. It is developed together with the Zuse-Institut Berlin and Universität Erlangen-Nürnberg and distributed under the Apache 2.0 license.
For more information, see `https://scipopt.zib.de`.

Contributor at TU Darmstadt: Marc E. Pfetsch

SCIP-SDP: *A mixed integer semidefinite programming plugin for SCIP*
SCIP-SDP is a plugin for SCIP to solve mixed integer semidefinite programs (MISDPs). It combines the branch-and-bound framework of SCIP with interior-point SDP-solvers to solve MISDPs using either a nonlinear branch-and-bound approach or an LP-based cutting-plane approach. It extends SCIP by several heuristics, propagators, file readers and the handling of SDP-constraints. It is distributed under the Apache 2.0 license.
For more information, see `http://www.opt.tu-darmstadt.de/scipsdp/`.

Contributor at TU Darmstadt: Frederic Matter, Marc E. Pfetsch

CONCEPTS: *High-order and generalized finite element library*

The numerical C++ library provides finite element methods of higher order, generalized finite element methods and boundary element methods in common object-oriented structures. We developed hp-adaptive finite element methods on curved quadrilateral and hexahedredal meshes with locally varying and anisotropic polynomial orders for Poisson and Helmholtz problems, problems in electromagnetics, quantum physics, viscous acoustics (based on Navier-Stokes equations), elasticity and coupling of those models. The matrices can be assembled and linear systems can be solved in parallel where we also give access to external direct solvers. There is a number of time integration schemes for dynamical modelling. CONCEPTS has got a large class documentation and various tutorials are available.
For more information, see `https://dowiki.mathematik.tu-darmstadt.de/numa/Concepts`

Contributor at TU Darmstadt: Kersten Schmidt, Adrien Semin, Vsevolod Shashkov

donlp2: *Solving general smooth nonlinear optimization problems, last version January 2015*

donlp2 is a software for the solution of general nonlinear programming problems. Different versions exist concerning the programming language (strict f77, f90, C99), the user interface and some options (for example elimination of redundant linear equality constraints and an interface known as "reverse communication"). donlp2 is free for research, whereas commercial use requires licensing by TU Darmstadt.

Contributor at TU Darmstadt: Peter Spellucci

numawww: *Interactive computing exercises for numerical methods and continuous optimization*

Numawww is a cgi/html-based computing device for general numerical methods and methods of continuous optimization. It may be used for exercises during a numerical methods course, as a self teaching aid or even as a small scale computing device, requiring minimal knowledge of programming. It is accessible from anywhere in the world and indeed users from about 80 countries are visiting it. Any application comes with predefined test cases which can be used without programming knowledge at all. Presently only the English version receives further development, but the German version will be maintained. This English version has been extended by new iterated quadrature formulas and an improved download of results. For more information, see `numawww.mathematik.tu-darmstadt.de`

Contributor at TU Darmstadt: Peter Spellucci

DOpElib: *Differential Equations and Optimization Environment*

DOpElib is a software library for the solution of optimization problems subject to partial differential equations.
For more information, see `www.dopelib.net`

Contributor at TU Darmstadt: Mirjam Walloth, Winnifried Wollner

6 Theses

6.1 Habilitations

2022

Sanders, Sam, *Some contributions to higher-order Reverse Mathematics* (Ulrich Kohlenbach)

6.2 PhD Dissertations

2021

Apel, Insa Maria, *Zum Einfluss von Kenntnisqualitäten auf Beweisprozesse am Beginn eines Mathematikstudiums aus tätigkeitstheoretischer Perspektive – Exemplarische Untersuchung am Beispiel der ϵ-δ-Definition von Stetigkeit –* (Regina Bruder)

Bechtel, Sebastian, *On mixed boundary conditions, function spaces, and Kato's square root property* (Robert Haller)

Becker, Jan, *Equilibrium Problems with Equilibrium Constraints in Banach Spaces: Stationarity Concepts, Applications and Algorithms* (Alexandra Schwartz)

Braun, Alina, *In Theory and Practice - On the Rate of Convergence of Implementable Neural Network Regression Estimates* (Michael Kohler)

Böttcher, Anke, *Study of an alternative phase field model for low interfacial energy in elastic solids* (Harald Garcke, Dieter Bothe)

Driscoll-Spittler, Thomas, *Reflective modular forms and vertex operator algebras* (Nils Scheithauer)

Ehlert, Johannes, *The Random Loop Model on Trees* (Volker Betz)

Goschin, Kristina, *Optimal Design of an Energy Network Involving Renewable Energies for a Settlement* (Stefan Ulbrich)

Kettner, Marvin, *Persistence exponents via perturbation theory:* (Frank Aurzada)

Kiefer, Paul, *Orthogonal Eisenstein Series of Singular Weight* (Jan Hendrik Bruinier)

Majumder, Priyanka, *Bounds for Canonical Green's Functions of Cofinite Fuchsian Groups at Cusps* (Anna-Maria von Pippich)

Nowak, Daniel, *Nonconvex Nash Games - Solution Concepts and Algorithms* (Alexandra Schwartz)

Rauls, Anne-Therese, *Generalized Derivatives for Solution Operators of Variational Inequalities of Obstacle Type* (Stefan Ulbrich)

Rössler, Maximilian, *Towards a Dimension Formula for Automorphic Forms on O($II_{2,10}$)* (Robert Haller)

Schäfer-Aguilar, Paloma, *Numerical approximation of optimal control problems for hyperbolic conservation laws* (Stefan Ulbrich)

Schmidt, Andreas, *The Navier-Stokes Equations with Elastic Boundary and Boundary Conditions of Friction Type* (Reinhard Farwig)

Schneider, Moritz, *Super-convergent Implicit-Explicit Peer Methods* (Jens Lang)

Steinbach, Philipp, *Modeling, Simulation and Quantification of Drilling-Related Geometric Uncertainty for Borehole Heat Exchanger Arrays* (Jens Lang)

Walter, Anna, *Optimal Control of Nonlinear Elastoplasticity Problems with Model Order Reduction* (Stefan Ulbrich)

Weinberger, Jonathan, *A Synthetic Perspective on (∞-,1)-Category Theory* (Thomas Streicher)

2022

Bieker, Patrick, *Integral Models of Moduli Spaces of Shtukas with Deep Level Structures* (Timo Richarz)

Buck, Johannes, *Green functions and arithmetic generating series on Hilbert modular surfaces* (Jan Hendrik Bruinier)

Joshi, Hrishikesh, *Mesh and model adaptation for hyperbolic balance laws* (Jan Giesselmann)

Kilian, Martin, *Persistence problems for fractional processes* (Frank Aurzada)

Lang, Sandra, *A Geometric Approach to the Projective Tensor Norm* (Burkhard Kümmerer)

Matei, Alexander, *Optimum Experimental Design with PDE Constraints for Identification of Model Uncertainty in Load-bearing Systems* (Stefan Ulbrich)

Matter, Frederic, *Sparse Recovery Under Side Constraints Using Null Space Properties* (Marc Pfetsch)

Radu, Bogdan, *Finite Element Mass Lumping for H(div) and H(curl)* (Herbert Egger)

Schmitt, Andreas, *Mixed-Integer Nonlinear Programming for Resilient Water Network Design* (Marc Pfetsch)

Strauch, Elisa, *Adaptive Multi-Level Monte Carlo and Stochastic Collocation Methods for Hyperbolic Partial Differential Equations with Random Data on Networks* (Jens Lang)

Teschner, Gabriel, *Data Driven Estimation of Wall Shear Stress from Magnetic Resonance Imaging* (Herbert Egger)

Tolle, Tobias, *An unstructured Finite-Volume Level Set/Front Tracking method for capillary flows* (Tomislav Marić)

Yaylali, Can, *Derived F-zips* (Torsten Wedhorn)

6.3 Master Theses

2021

Alban, Alexander, *Fractional Brownian Motion as the Scaling Limit of a Pólya Urn Process* (Frank Aurzada)

Avenarius, Alexander Friedrich Wilhelm, *Fahrplanoptimierung für eine vorgegebene Gesamtverspätungszeit* (Marc Pfetsch)

Beck, Robin Alexander, *Compressed Sensing with Artificial Neural Networks* (Marc Pfetsch)

Biermann, Jens Peter, *An Optimal Control Problem for the p-Laplace Equation* (Winnifried Wollner)

Borkowski, Markus, *The Hodge-Laplace Equation on the Sphere* (Stefan Kurz, Herbert Egger)

Brandt, Felix Christopher Helmut Ludwig, *Analysis of the Hibler Sea Ice Model* (Robert Haller)

Buch, Bilke, *Schätzung einer Regressionsfunktion durch sehr tiefe bzw. sehr breite neuronale Netze* (Michael Kohler)

Cakaj, Rinor, *Exact Rule Learning via Boolean Compressed Sensing* (Marc Pfetsch)

Calo, Luca Domenico Mirko, *Compatibility of inverse operators between interpolation spaces* (Robert Haller)

Corbean, Elisa, *Sparse Sum of Squares Relaxation for Global Optimization for Heat Networks* (Stefan Ulbrich)

de Witte, Dominik Samuel, *Lévy Proceses in Insurance Risk Models* (Frank Aurzada)

Deutschen, Matthias, *Identification of Model Uncertainty via Optimal Design of Experiments by a Bayesian Approach* (Stefan Ulbrich)

Doat, Joel Andre, *Reyes' Topos of Reference and Modality from a Fibrational Perspective* (Thomas Streicher)

Drews, Selina, "*Ein Beitrag zur statistischen Theorie der gefalteten neuronalen Netze in der Bildklassifizierung* (Michael Kohler)

Euschen, Christopher Ralph, *Realoptionen im Immobilienmarkt: Eine Anwendbarkeitsanalyse im Bereich Immobilientoken* (Andreas Pfnür, Cornelia Wichelhaus)

Franck, Sascha Josef, *Konvergenz aufsteigender Folgen von nicht abschließbaren sektoriellen Formen* (Robert Haller)

Funke, Clara, *Using Classical Mathematical Finance to Model Interest Rates for Cryptocurrencies* (Frank Aurzada)

Gabriel, Dennis, *Globale Optimierung gemischt-ganzzahliger Netzwerkprobleme mit DGL Beschränkungen am Beispiel von Fernwärmenetzwerken* (Stefan Ulbrich)

Ganeshkumar, Akilavan, *Schätzung von Regressionsfunktionen auf Mannigfaltigkeiten* (Michael Kohler)

Gegelia, Nutsa, *Complex multiplication and applications* (Yingkun Li)

Gerlach, Dominique Nadine, *Restricted information in online Dial-A-Ride* (Yann Disser)

Göbel, Tim Mathias, *Viscosity Solutions for a diffusive Hamilton-Jacobi equation* (apl. Christian Stinner)

Güthge, Anton Basil Kato, *Pushforward with Compact Support of Solid Modules for Affine Complete Intersections* (Torsten Burkhard Wedhorn)

Gußmann, Lars, *An ILP model for coordinated motion planning* (Marc Pfetsch)

Herr, Lennart, *Ein nichtglattes Trust-Region Verfahren für lokale Lipschitz-Funktionen mit Anwendung auf das Hindernisproblem* (Winnifried Wollner)

Höbere, Resul, *Robuste Portfolio Optimierung mit ganzzahligen Nebenbedingungen* (Stefan Ulbrich)

Hüttl, Fedor, *Entwicklung eines E-Learningmoduls zur OOM für die Ausbildung und berufliche Weiterbildung von Mechatronikerinnen und Mechatronikern* (Guido Rößling)

Ihrig, Anna-Lisa, *ABC-Flächen mit einspringenden Ecken* (Ulrich Reif)

Jansen, Erik, *Physics-Informed Neural Networks- Applied to Temperature Models via Parameter Identification* (Stefan Ulbrich)

Jegatheeswaran, Prabashan, *Calderón-Zygmond-Theorie für nicht-Integraloperatoren* (Robert Haller)

Kanski, Tobias, *Stochastic Gradient Methods for Nonconvex PDE Constrained Optimization* (Winnifried Wollner)

Keinrath, Julian, *Estimating multivariate Regression Functions via deep neural Networks* (Michael Kohler)

Klein, Lisa Christel, *A stochastic proximal gradient algorithm and its application to non-convex PDE constrained optimization problems* (Winnifried Wollner)

Klippel, Andreas, *Existence of phase transitions using reflection positivity* (Volker Martin Betz)

Krach, Jennifer, *Natural Colored Hair - Zwischen 'Natürlichkeit' und 'Artifizialität'* (Alexandra Karentzos)

Kreh, Clarissa, *Zur Konvergenzgeschwindigkeit von neuronale Netze Schätzern mit einer verdeckten Schicht* (Michael Kohler)

Kukla, Stephanie, *Schädigungsidentifikation mit nicht-glatten Zielfunktionen* (Winnifried Wollner)

Lind, Jenny Ida, *Übertragung allgemeiner Ansätze in der inkrementellen Optimierung* (Yann Disser)

Mäder, Jan Philipp, *Stochastic Gradient Method and Inverse Problems* (Winnifried Wollner)

Mair, Catrin, *Animated condensed sets and their homotopy groups* (Torsten Burkhard Wedhorn)

Mc Cracken, Gabriel Simon, *Nonlinear Evolutionary Inclusions* (Robert Haller)

Meißner, Silke Anne, *Order and Tournament Expansions of Homogeneous Structures* (Martin Otto)

Moral Garcia del Cerro, Maria, *Generative Adversarial Networks: Mathematical Motivation and Outlook* (Alexandra Schwartz)

Morasch, Jakob Mathias, *Integer Programming Boosting for Classification* (Marc Pfetsch)

Müller, Manuel Karl-Heinz, *Invariants of the weil representation of $SL_2(\mathbb{Z})$ on discriminant forms of odd order* (Nils Scheithauer)

Müller, Sven-Andre, *Perfect complexes over quotient rings* (Torsten Burkhard Wedhorn)

Neuberger, Laura, *Exploiting low local dimensionality of regression functions with deep ReLU neural networks* (Michael Kohler)

Neuthard, Tobias Joachim, *Lösen gemischt-ganzzahliger PDE-beschränkter Probleme mit Hilfe eines inexakten Branch-and-Bound Verfahrens* (Winnifried Wollner)

Niehof, Christian, *Konstruktion einer Thetareihe als Anhebung* (Nils Scheithauer)

Nützenadel, Anna Christiane, *ABC-Flächen minimaler Willmore-Energie* (Ulrich Reif)

Özalp, Elise, *Physics Informed Deep Learning for Partial Differential Equations* (Jens Lang)

Pritzel, Kristin, *Zur Konvergenzrate von faltenden neuronalen Netzen in der Bildklassifikation* (Michael Kohler)

Racky, Maximilian Joachim, *The Modularity Theorem for Elliptic Curves with Complex Multiplication* (Yingkun Li)

Rosswinkel, Benjamin, *Condensed complete locally convex topological R-vector spaces* (Torsten Burkhard Wedhorn)

Schwaab, Carolin, *Ein Benders-Dekompositionsansatz für Korrelationsclustering* (Marc Pfetsch)

Schwartz, Daniel, *Optimierung eines MINLP-Modells zum Design und Betrieb von Nahwärmenetzen* (Stefan Ulbrich)

Sollbach, Raphael Benedikt, *Regressionsschätzung durch vollständig verbundene tiefe neurale Netze* (Michael Kohler)

Solms, Felix Mathias, *Implementing a Sink Game Solver* (Yann Disser)

Steinhardt, Marcel Maximilian, *Numerical Approximation of Optimal Control Problems for Networks of Conservation Laws* (Stefan Ulbrich)

Steiof, Yannick, *Stochastische Netzwerke mit Lagerhaltung sowie positiven und negativen Kunden* (Cornelia Wichelhaus)

Terpstra, Maria, *Density Estimation in a Simulation Model* (Michael Kohler)

Ücüncü, Semih, *Feynman-Kac-Formeln und Martingalprobleme* (Frank Aurzada)

Ullmann, Alexander, *Analysen zur Leistungsentwicklung im Vorkursprojekt VEMINT* (Anerkennung aus dem Studiengang LaG vor 2005)

Vetter, Sukie-Christin, *Polare Minimalflächen in der 3-Sphäre* (Karsten Große-Brauckmann)

Volk, Laura, *Minimale Konvexe Partitionen* (Marc Pfetsch)

Weigle, Daniel Peter, *Eine Quizduelladaption für den Mathematikunterricht* (Regina Bruder)

Wilde, Julian, *Relativ robuste Portfolio Optimierung, ein Vergleich zweier Ansätze* (Stefan Ulbrich)

Wilhelm, Janik, *Product expansions at 1-dimensional cusps and Schellekens' list* (Nils Scheithauer)

Wilka, Hendrik, *Numerische Realisierung der Karhunen-Loève-Entwicklung in 3D mit H-Matrizen* (Jens Lang)

Zaiser, Moritz Leon, *Bayessche inverse Probleme und die Anwendung auf lokale Volatilitätsflächen* (Winnifried Wollner)

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Agamia, Josef, *A Robust Optimization Approach to train Artificial Neural Networks for improved Image Classification* (Stefan Ulbrich)

Anthes, Christopher, *Maximaler Eigenwert von Wishart-Matrizen* (Frank Aurzada)

Ball, Fabian Balthasar, *Empirische Untersuchung eines digitalisierten Unterrichtsmodells auf Grundlage von getrackten Datensätzen sowie der Analyse von individuellen Lernverläufen innerhalb der virtuellen Lernumgebung* (Ralf Tenberg)

Benedikt, Barbara Jiabao, *Meet-in-the-Middle Attack on Ternary Learning-with-Error Keys with $O(n)$ Qubits* (Marc Fischlin)

Böhnlein, Tim, *p-Ellipticity and Perturbed Divergence Form Operators* (Moritz Egert)

Borchers, Felix Paul Daniel, *Konvergenzresultate und Anwendungen des Hopfield-Modells* (Volker Martin Betz)

Breitkopf, Jannik, *Multilevel Optimization Methods for Training Neural Networks* (Stefan Ulbrich)

de Sombre, Wanja, *Safe Reinforcement Learning - Methods and Application in Point to Point Wireless Communication* (Frank Aurzada)

Dieringer, Nicolette Ada Sabrina, *Bildklassifikation mit faltenden tiefen neuronalen Netzen* (Michael Kohler)

Endres, Luca Marco, *Zur Konvergenzrate eines durch Minimierung der Kreuzentropie gelernten Klassifikators basierend auf einem Transformer Encoder* (Michael Kohler)

Folger, Lea, *Analysis of Convolutional Neural Network Image Classifiers in a Rotationally Symmetric Model* (Michael Kohler)

Göbel, Michelle, *Quantum Graphs and Bigalois Extensions* ()

Görlich, Kai Jasper, *An Efficient Semismooth Newton-type Augmented Lagrangian Method for Lasso-type Problems* (Stefan Ulbrich)

Gronemeyer, Sven, *Local well-posedness in a tumor invasion model* (Christian Stinner)

Gunkel, Jonas, *On the Optimal Rate of Convergence in Estimation of Multivariate Regression Functions by Neural Networks* (Michael Kohler)

Halbey, Jannis, *Trust Region Policy Optimization and related methods* (Stefan Ulbrich)

Harder, Christian Lennart, *Context matters - Local vs. Global Initialization Approaches for Deep Medical Image Classification* (Anirban Mukhopadhyay)

Helmer, Max Peter, *Heavy-Tailed Random Matrices* (Frank Aurzada)

Helm, Falko Frederik Herbert Martin, *On the rate of convergence of a classifier based on a Transformer encoder* (Michael Kohler)

Herbert, Eric Louis, *Image classification using deep convolutional neural networks with cross-entropy loss* (Michael Kohler)

Jabi, Antonia, *Komplexitätseffiziente Algorithmen für die Durchmesserberechnung in medizinischen Bilddaten* (Stefan Ulbrich)

Jany, Jeremy Anton, *Facial reduction on binary semidefinite programs* (Marc Pfetsch)

Jiang, Haolin, *The Polynuclear Growth Model as an Example of Integrable Probability* (Volker Martin Betz)

Jordan, Felix, *Families of Characters of Quasiconvergent Subalgebras of l^∞* (Steffen Roch)

Kappesser, Maximilian Christoph Batho, *Reduced Basis Approximation Applied to Eigenvalue Tracking* (Sebastian Schöps)

Karg, Jonas, *Globul solutions to a chemotaxis-Navier-Stokes system* (Christian Stinner)

Kähm, Olga, *Low-resolution Iris Recognition via Knowledge Distillation* (Arjan Kuijper)

Klopp, Adrian, *Efficient usage of Attention in U-Nets for medical image segmentation* (Anirban Mukhopadhyay)

Knutsen, Laura Kathrina, *Schwache (1,1)-Abschätzung für Schrödinger-Gruppen* (Robert Haller)

Komann, Theodor, *Initial Boundary Value Problems für eine skalare hyperbolische Erhaltungsgleichung mit Knotenbedingung* (Stefan Ulbrich)

Kuhr, Christopher, *Arc descent for constructible adic sheaves* (Timo Richarz)

Lang, Christopher Matthias, *Fundamentalgruppen abelscher Schemata* (Torsten Burkhard Wedhorn)

Langhammer, Carmen Tamina Anna, *Stochastic Optimization of Multi-Stage Supply-Chain Problems under Demand Uncertainty* (Winnifried Wollner)

Langrock, Michaela Carolin, *Obere und untere Schranken zur Konvergenzgeschwindigkeit einschichtiger neuronale Netze* (Michael Kohler)

Latocha, Simon Jan, *Comparing Bounding Methods for Solutions of Ordinary Differential Equations* (Stefan Ulbrich)

Leichthammer, Lorenz Carl, *Evaluating Planning-based Machine Learning Algorithms for Scheduling Railway Operations* (Kristian Kersting)

Leotta, Fabio, *Locally parabolic interface reconstruction from volume fractions on unstructured polyhedral meshes* (Dieter Bothe)

Ludwig, Olivia Marie, *Estimation of a Regression Function by Shallow Neural Networks with Random Inner Weights* (Michael Kohler)

Mahncke, Swantje, *Wide Neural Networks for Category Learning* (Anerkennung)

Martin, Julian Lucas, *Klassifikation von Bildern durch faltende neuronale Netze in einem rotationssymmetrischen Modell* (Michael Kohler)

Müller, Benedikt Elmar, *Drinfeld's Lemma for Schemes* (Timo Richarz)

Möll, Ricardo, *Global Existence for a Go-or-Grow Tumor Invasion Model with Therapy* (Christian Stinner)

Moritz, Jan, *Klassifikation von Bildern durch faltende neuronale Netze in einem stochastischen Modell mit Pooling* (Michael Kohler)

Mosis, Nils, *Lower Bounds for Simplex Pivot Rules via Markov Decision Processes* (Yann Disser)

Nowak, Patrick, *Schätzung einer Regressionsfunktion durch mittels Gradientenabstieg mit fester bzw. variabler Schrittweite gelernter neuronaler Netze* (Michael Kohler)

Olbert, Yannik, *Entscheidungsregionen von künstlichen neuronalen Netzen mit ReLU-Aktivierungsfunktion* (Marc Pfetsch)

Pfaff, Sven, *Oberflächenhomogenisierung und Analysis einer Finite-Elemente-Methode* (Kersten Schmidt)

Pfeiffer, Isabell, *Eine Lösung für das "Integrated Time Tabling and Vehicle Scheduling" Problem* (Marc Pfetsch)

Pischke, Nicholas, *Logical metatheorems for set-valued operators and their use in the analysis of Moudafi's algorithm for the difference of two monotone operators in Hilbert space* (Ulrich Kohlenbach)

Potrikus, Pia, *Rekonstruktion von Lösungsvektoren unter l^0 und l^1 Miminierung für den Analysis Fall* (Marc Pfetsch)

Prokopetz, Johanna, *Berufliche Bildung und Akademische Bildung in Kanada und Deutschland – Ein Vergleich bezogen auf die Gleichwertigkeit beruflicher und akademischer Bildung* (Birgit Ziegler)

Raßmann, Simon Vincent, *Computational complexity of the Weisfeiler-Leman dimension* (Pascal Schweitzer)

Rückert, Katharina, *Generation of human embryo data using GANs* (Marc Pfetsch)

Rühl, Nico Adriaan, *Gradientenbestimmung für ein Optimierungsproblem unter Unsicherheiten* (Winnifried Wollner)

Ritter, Nadine Marlise, *On the estimation of a regression function defined on a manifold by neural networks* (Michael Kohler)

Roth, Christian Marius, *Optimierung der globalen Leistungsbilanz von Piezielektret Energy Harvestern durch die Ausführung als vibroakustisches Metamaterial* (Winnifried Wollner)

Scherf, Robert Ralf, *Zur Konvergenzrate von tiefen rekurrenten neuronalen Netzeschätzern* (Michael Kohler)

Schneidereit, Jan Felix, *Unendlichdimensionale stochastische Differentialgleichungen im Heath-Jarrow-Morton-Modell mit Lévy-Noise-Prozess und stochastische Integration in Hilberträumen* (Volker Martin Betz)

Schütz, Marcel, *Kripke-Joyal semantics for IZF w.r.t. Grothendieck toposes* (Thomas Streicher)

Schuchter, Jan, *Analyse der Codierung des Inputs bei einem Transformer-Netzwerk* (Michael Kohler)

Strobel-Hofmann, Christina, *Robuste Optimierung unter begrenzten Ressourcen – Ein anpassbares Projektterminierungsproblem unter unsicheren Vorgangszeiten für die Fertigungsplanung im Schiffbau* (Marc Pfetsch)

Szczuka, Svenja, *Minimum Partition into Plane Subgraphs* (Marc Pfetsch)

Tibke, Jonas Michael, *On C*-algebras of operator sequences and their K-groups* (Steffen Roch)

Tümmler, Marcel Marc Kevin, *Portfolio Optimization under Distributional Uncertainty and Integer Constraints with a Relative Robust C-VaR Approach* (Stefan Ulbrich)

Trieb, Mirjam, *The structure of hypergraph C*-algebras* (Steffen Roch)

Törner, Nils, *Zur Konvergenzrate von einschichtigen Neuronale-Netze-Regressionsschätzern* (Michael Kohler)

Volkert, Nathalie, *The Marchenko-Pastur theorem* (Frank Aurzada)

Weißmüller, Yanik Noah, *On the Estimation of a Regression Function by Over-Parametrized Neural Networks* (Michael Kohler)

Wigandt, Arthur, *Private Function Evaluation for Multi-Input Gates* (Thomas Schneider)

Youmbi NKomegni, Audrey Laetitia, *Schätzung einer Regressionsfunktion durch tiefe neuronale Netz mit ReLu -Aktivierungsfunktion* (Michael Kohler)

Zöchling, Tarek Manuel, *Maximale Regularität des Stokes Operator with Neumann Randbedingung* (Matthias Hieber)

6.4 Staatsexamen Theses

2021

Bettac, Lea, *Erstellung von Lernvideos zum Hypothesentesten für den Stochastikunterricht in der Sek II – Erprobung eines Zugangs über die P-Wert Methode* (Katja Krüger)

Darmstädter, Vera, *Entwicklung eines Unterrichtskonzeptes zum Themengebiet Stöchiometrie auf der Grundlage einer mathematikdidaktischen Analyse* (Katja Krüger)

Eckert, Tobias, *Mathematikunterricht mit Serious Games – ein kriteriengeleitetes jSpielkonzept* (Regina Bruder)

Kurz, Tobias, *Entwicklung digitaler Kopfübungen für die Klassenstufen 7/8* (Regina Bruder)

Steffler, Marvin, *Entwicklung einer digitalen Selbstlernumgebung als Zugang zur Taylorapproximation* (Katja Krüger)

Thomas, Esther, *Geometrische Denkaufgaben - Eine Untersuchung gemeinsamer Lösungsprozesse von Schüler*innen* (Katja Krüger) von Monkiewitsch, Till, *Analyse und Erprobung stochastischer Problemlöseaufgaben in der Begabtenförderung* (Katja Krüger)

2022

Bastians, Alexander, *Wetterdaten unter der Lupe – Erstellung einer Online-Lernumgebung zu Gebietsmitteln in Niederschlagsdaten* (Katja Krüger)

Deiler, Ronja, *Analyse, Weiterentwicklung und Erprobung von Fördermateriealien zur Bruchrechnung vor dem Hintergrund von Störungen im Lernprozess* (Katja Krüger)

Eilers, Judith, *Weiterentwicklung des Selbstlernmoduls Stochastische Simulationen im Seminar 'Aufgabenpraktikum online'* (Katja Krüger)

Lundt, Sarah, *Entwicklung eines Förderkurses für Schüler*innen mit starken Lernrückständen zum Sichern von geometrischen Grundwissen- und -können der Jahrgangsstufen 5-7* (Katja Krüger)

Rosemann, Lukas, *Nutzung des Prozentstreifens in einem Förderkurs für Schüler*innen mit starken Lernrückständen* (Katja Krüger)

6.5 Bachelor Theses

2021

Alisan, Adnan-Mustafa, *Eigenräume von Atkin-Lehner Involutionen* (Nils Scheithauer)

Alker, Jonas, *Algorithmen für nichtlineare und stochastische, ressourcenbeschränkte kürzeste Wege* (Marc Pfetsch)

Asmußen, Martin Jürgen, *Explizite Extrapolationsverfahren für Gewöhnliche Differentialgleichungen: Theorie und Anwendung* (Jens Lang)

Aumann, Leonie Sophie, *Problems and opportunities of infection chain tracking in consideration of COVID-19* (Martin Kiehl)

Becker, Patrick, *Eine Einführung in die nichtparametrische Regressionsschätzung* (Michael Kohler)

Böhnlein, Tim, *The Real Interpolation Method and its Applications to Fractional Powers of Positive Self-adjoint Operators* (Robert Haller)

Botz, Alexander, *Die Hausdorff-Dimension und ihre Alternativen* (Robert Haller)

Debes, Pascal, *Estimation of a nonparametric regression function with kernels* (Michael Kohler)

Drachenberg, Regina, *Zur Anwendung der nichtparametrischen Regression in der Finanzmathematik* (Michael Kohler)

Earley, Emma Louisa, *Online Matching with Delays* (Yann Disser)

Fatih, Souheil, *Geometrie ebener Kurven* (Karsten Große-Brauckmann)

Foltz, Jonathan, *Stochastisch proximales Gradientenverfahren zur Minimierung nichtkonvexer Funktionen in Hilberträumen* (Winnifried Wollner)

Herde, Thomas, *Berechnung eines maximalen Flusses mit Hilfe von elektrischen Flüssen* (Yann Disser)

Hertzner, Florian Walter Josef, *The Russo-Dye theorem* (Apl. Steffen Roch)

Jäger, Annika Christina, *Aspects of Algebraic Geometry on non-commutative rings* (Torsten Burkhard Wedhorn)

Kallendorf, Daniel, *Bayes-Schätzer der Transfer-Entropie* (Norbert Pietralla)

Klaft, Jan Cedric, *Anwendung von statistischen Testverfahren in der Schadenversicherungsmathematik* (Michael Kohler)

Kleinfeller, Marcel, *Funktionalkalküle* (Matthias Hieber)

Kopp, Erik Georg, *Parameteroptimierung chemischer Reaktionssysteme unter Beschränkungen* (Martin Kiehl)

Kosmala, Benjamin Wolfgang, *Lösungstheorie dispersiver Gleichungen und Anwendung auf die Wellengleichung mit kubischer Nichtlinearität* (Robert Haller)

Kowalik, Cedrik Peter, *Klassifikation der reellen Formen der exzeptionellen Lie-Algebren* (Nils Scheithauer)

Kraft, Mino Nicola, *Nicht-kommutative Von-Neumann-Algebren* (Robert Haller)

Kramer, Daniel, *A globally stabilised sequential quadratic programming method* (Winnifried Wollner)

Köstner, Noah Pascal, *C^∞-rings and manifolds* (Torsten Burkhard Wedhorn)

Langrock, Michaela Carolin, *Einführung in die Lebensversicherungsmathematik* (Michael Kohler)

Lehmann, Tom, *On Neighbourhood Diversity in Interpretations of Nowhere Dense Graph Classes* (Kord Eickmeyer)

Ludwig, Olivia Marie, *Essential modeling aspects and parameters for the long term prognosis of epidemical diseases like COVID19* (Martin Kiehl)

Mehlig, Jennifer, *Universelle Konsistenz des Nächste-Nachbar-Schätzers* (Michael Kohler)

Müller, Daniel Erhard, *Erweiterungen und Vervollständigen von Dedekindringen* (Torsten Burkhard Wedhorn)

Mosis, Nils, *The connection between policy iteration and the Simplex algorithm* (Yann Disser)

Mörbitz, Marcel, *Zur universellen Konsistenz in der nichtparametrischen Regression* (Michael Kohler)

März, Lars Steffen, *Convergence of Stochastic First-Order Methods for Composite Optimization* (Winnifried Wollner)

Neumann, Zarah, *Der Satz von Hattendorff in der Lebensversicherungsmathematik* (Michael Kohler)

Nguyen, Gia-Lam Kevin, *Deep Learning and classification of handwritten digits* (Winnifried Wollner)

Nguyen, Huyen Tran, *The Berry-Esseen Theorem and Edgeworth Expansion* (Frank Aurzada)

Nießner, Rafael, *Expressive Completeness of Modal Team Logic* (Martin Otto)

Piesold, Janine Patricia, *Theorem of Lebesgue-Radon-Nikodym in Ergodic Theory* (Robert Haller)

Pischke, Nicholas, *Quantitative proof-theoretic analysis of a subgradient-type method for equilibrium problems* (Ulrich Kohlenbach)

Rahm, Frederic, *Schätzung der mittleren Schadenhöhen in der Schadensversicherungsmathematik* (Michael Kohler)

Rauberger, Johanna Barbara Tina, *Der Satz von Tait-Kneser* (Ulrich Reif)

Reuter, Stefan-Dehu, *Bewertung Amerikanischer Optionen mithilfe von neuronalen Netzen* (Michael Kohler)

Salzmann, Juri, *Bi-Arboreszenzen* (Marc Pfetsch)

Scharpf, Max, *Bewertung Amerikanischer Optionen mit Hilfe von durch Backpropagation gelernten Neuronalen Netzen* (Michael Kohler)

Scheld, Corinne, *Zur Dichtheit von neuronalen Netzen mit ReLU-Aktivierungsfunktion in der Menge der stetigen Funktionen* (Michael Kohler)

Schiller, Nadine, *Beweis des Jacobischen Vierquadratesatzes mit Hilfe der Zetafunktion der Hurwitz-Quaternionen* (Anna-Maria von Pippich)

Schneider, Tarkan Jan, *Grothendieck's version of Galois theory* (Torsten Burkhard Wedhorn)

Seibel, Timon Philipp, *Fast Iterative Solution Methods for the Radiative Transfer Equation* (Herbert Egger)

Steblin, Daniel, *Über ein Simulated Annealing-basiertes Eröffnungsverfahren zur Lösung des Traveling Salesman Problems* (Volker Martin Betz)

Steubing, Nathalie Jennifer, *Innere-Punkte-Verfahren für SOCPs und ihre Anwendung auf Probleme mit hyperbolischen Restriktionen* (Stefan Ulbrich)

Strauch, Linus, *Zur Dichtheit von tiefen neuronalen Netzen mit ReLU-Aktivierungsfunktion in der Menge der stetigen Funktionen* (Michael Kohler)

Tschendel, Lara, *ruled surfaces and tangent developables* (Karsten Große-Brauckmann)

Volk, Lena, *A Zero-One Law for the Density of Regular Languages* (Kord Eickmeyer)

Weber, Lea Teresa, *Generative Netzwerke* (Marc Pfetsch)

Weißmüller, Yanik Noah, *Differential Games and their Application in the Modelling of Bitcoin* (Alexandra Schwartz)

Wieczorek, Tobias Jan, *The Monoid Resource Constrained Shortest Path Problem* (Marc Pfetsch)

Yavuz, Ozan-Evren, *A Relatively Robust CVaR-Approach for Portfolio Optimization under Distributional Uncertainty* (Stefan Ulbrich)

Zavala Hoffmann, Sebastian, *Zur Trarifkalkulation in der Schadenversicherungsmathematik* (Michael Kohler)

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Becker, Benjamin, *Real and Complex interpolation spaces* (Matthias Hieber)

Bierer, Dominik Nathanael, *Topic Modeling Using Latent Dirichlet Allocation* (Marc Pfetsch)

Binder, Patrick, *Approximationseigenschaften von Splines* (Jens Lang)

Bingemer, Janek, *Robuste (relative) Regret kombinatorische Optimierung* (Marc Pfetsch)

Braun, Karolina, *Syntactic treatment of Herbrand normal forms with equality* (Ulrich Kohlenbach)

Börner, Pascal, *Analysis of the Wait-or-Ignore algorithm for the open online Dial-a-Ride problem* (Yann Disser)

Cao, Xinyu, *Schätzung einer Regressionsfunktion durch tiefe neuronale Netze* (Michael Kohler)

Chaumet, Aidan Raoul, *Relative Energy Stability Estimates for the Euler-Poisson System* (Jan Giesselmann)

Companys Franzke, Margarida Elisabeth, *Random batch Methoden für wechselwirkende Teilchen* (Jan Giesselmann)

Dietz, Jeremy, *The sharp phase transition in Bernoullli percolation and the Ising model* (Volker Martin Betz)

Eisenbach, Sam, *Linear fraktionale Galton-Watson Prozesse in einer zufälligen Umgebung* (Frank Aurzada)

Gabor, Vanessa Martha, *Stochastische Modellierung und Numerische Simulation der COVID-19 Pandemie* (Jens Lang)

Geisler, Michelle, *Approximation by Deep Neural Networks* (Winnifried Wollner)

Gärtner, Nikolas Leander, *On the Raikov completion of topological groups* (Torsten Burkhard Wedhorn)

Herrmann, Anton Max, *Twin-width and FO model checking on ordered structures* (Kord Eickmeyer)

Hoffmann, Marc, *Convergence of Moment Approximations of Linear Kinetic Equations describing semiconductors* (Jan Giesselmann)

Ihde, Finn Viktor, *Ein relativ robuster CVaR Ansatz zur Wahl von Handelsstrategien in einem Markt mit ungewisser Entwicklung* (Stefan Ulbrich)

Jarms, Marlin Lennart, *Elementarteilersatz über Dedekindringe* (Torsten Burkhard Wedhorn)

Kasiman, Alexander, *Complex Interpolation* (Moritz Egert)

Klemet, Konstanze, *Sample based Quasi-Newton Methods for Machine Learning* (Stefan Ulbrich)

Klostermann, Jan Lasse, *Multicommodity flows in symmetric digraphs* (Marc Pfetsch)

Kramer, Julia Selua, *Das eingeschränkte, verlässliche Kürzeste-Wege-Problem in stochastischen zeitabhängigen Netzwerken* (Marc Pfetsch)

Krüpper, Hans Ruben Konstantin, *Die Hopf-Faserung* (Karsten Große-Brauckmann)

Lüder, Sarah Marie, *Density of omega-regular languages* (Kord Eickmeyer)

Lee, Sang Hyeon, *Estimation of a Regression Function using Deep Neural Network* (Michael Kohler)

Legenbauer, Max, *Maximale Entropie von Wahrscheinlichkeitsverteilungen* (Frank Aurzada)

Mayer, Ben Marian, *Universally generizing and flat morphisms* (Torsten Burkhard Wedhorn)

Michel, Moritz, *Phase-type Verteilungen und ihre Anwendung in der Risikotheorie* (Frank Aurzada)

Müller, Sabine, *Der Lebensraum einer Brownschen Herde* (Frank Aurzada)

Ouro-Koura, El Assad, *Zur mathematischen Modellierung des kapillaren Anstiegs - Dissipative Mechanismen und nicht-lineare Oszillationen* (Dieter Bothe)

Passon, Jan Karol, *Prokhorov's Theorem* (Frank Aurzada)

Petzler, Hendrik Uwe, *Adic spaces attached to rings* (Torsten Burkhard Wedhorn)

Rakowski, Max Gerd, *Spheres which are Lie groups* (Nils Scheithauer)

Rauch, Tim Alexander, *Using Linear Programs for competitive analysis of the online Travelling Salesman Problem* (Yann Disser)

Rothermel, Mark Stephan, *Latent Space Optimization: Solving Discrete, High-dimensional and Expensive Problems via the Latent Space of Deep Generative Models* (Marc Pfetsch)

Schewe, Olga Sabeth, "*Elastische Kurven im Raum und auf der 2-Sphäre* (Karsten Große-Brauckmann)

Schindling, Georg Josef, *A Zero-One Law for MSO on Binary Trees* (Kord Eickmeyer)

Schneider, Leon, *The Unreasonable Effectiveness of Martingales* (Frank Aurzada)

Seeger, Jason Markus, *Continuity and Monotonicity of Solutions to Greedy Optimization Problems* (Marc Pfetsch)

Sommer, Jonas, *Fundamentallösungen für Differentialoperatoren mit konstanten Koeffizienten* (Robert Haller)

Stellwag, Emma, *The iteration number of the Weisfeiler-Leman algorithm for different dimensions* ()

Tillmann, Inga Maria, *Condensed sets as sheaves on the category of spectral spaces* (Torsten Burkhard Wedhorn)

Tripp, Paula, *Glättungsmethoden für semidefinite Optimierung* (Stefan Ulbrich)

Vasconcelos Afonso, Tiago, *Vergleich verschiedener Zielfunktionale bei der Lösung pant. Dgln mittels neuronalen Netzen* (Jan Giesselmann)

Wahl, Jonas Sebastian Jason, *Semidefinite Programme* (Winnifried Wollner)

Wang, Tobias, *Diskrete Galerkin für die chemische Mastergleichung mit Hilfe von Tensorzerlegungsmethoden* (Herbert De Gersem)

Weiß, Elisa, *Algorithmus zur Lösung des Steinerbaumproblems* (Marc Pfetsch)

Wilde, Felix Linus, *Sampled Quasi-Nenton Methods* (Stefan Ulbrich)

Worf, Virginia Cora, *Levyprozesse und unbegrenzt teilbare Verteilungen* (Frank Aurzada)

Xhaferi, Elio, *Robust topology optimization* (Winnifried Wollner)

Zientek, Nicole Catherine, *Nash vs. Kalai-Smorodinski: A Comparison of Solution Concepts in Cooperative Game Theory* (Alexandra Schwartz)

7 Presentations

7.1 Talks and Visits

7.1.1 Invited Talks and Addresses

Frank Aurzada

02/03/2021 *Breaking a chain of interacting Brownian particles*
Seminar talk, University of Paris XIII

18/05/2021 *Persistence probabilities via perturbation theory: autoregessive and moving average processes*
Seminar talk, Joint Israeli Probability Seminar

24/06/2021 *Persistence probabilities for fractional processes*
8th European Congress of Mathematics, Portorož, Slovenia, invited session talk

16/03/2022 *Brownian motion conditioned to spend limited lime below a barrier*
Workshop Branching and persistence, Saumur, France, invited talk

11/05/2022 *Brownian motion conditioned to spend limited time below a barrier*
Seminar talk, Universität Ulm

Volker Betz

21/02/2022 *Effective Mass of the Polaron: a lower bound*
Seminar, Warwick

14/03/2022 *Effective Mass of the Polaron: a lower bound*
Seminar, l'Aquila

23/08/2022 *Effective Mass of the Polaron: a lower bound*
Workshop, Venice

05/09/2022 *The random loop model on trees*
Seminar, Bristol

28/09/2022 *Effective Mass of the Polaron: a lower bound*
Conference, Köln

Dieter Bothe

29/04/2021 *Modeling and simulation of mass-transfer across fluid interfaces*
Centre de Mise en Forme des Matériaux (CEMEF), MINES ParisTech

20/05/2021 *Modeling and simulation of mass-transfer across fluid interfaces*
EFCE Spotlight talks: Recent developments and further demands in reactive gas liquid flows, EFCE Working Parties Multiphase Fluid Flow & Chemical Reaction Engineering-Complex Fluids Seminar Series, Journal of Non-Newtonian Fluid Mechanics Webinar

02/06/2021 *On the velocity jump discontinuity for single bubbles rising in a viscoelastic fluid*
Complex Fluids Seminar Series, Journal of Non-Newtonian Fluid Mechanics Webinar

14/09/2021 *On the velocity jump discontinuity for bubbles rising in a viscoelastic fluid*
Free Boundary Problems, Berlin

13/07/2022 *Numerical Simulation and Optimization of Wetting with OpenFOAM - A guided tour through the project area B "Modeling, Numerics and Optimization" of the CRC 1194*
17th OpenFOAM Workshop, Cambridge/UK

Jan H. Bruinier

28/06/2021 *CM values of higher automorphic Green functions*
Number theory seminar, Hebrew University, online

07/07/2021 *CM values of higher automorphic Green functions*
Conference *Theta Series: Representation Theory, Geometry, and Arithmetic*, The Fields Institute, Toronto, online

07/09/2021 *Arithmetic volumes of unitary Shimura varieties*
Conference *Arakelov Geometry*, Universität Regensburg, online

26/10/2021 *Arithmetic volumes of unitary Shimura varieties*
International Seminar on Automorphic Forms, online

23/05/2022 *Special cycles on toroidal compactifications of orthogonal Shimura varieties*
Number Theory Seminar, Universität Köln

17/07/2022 *Arithmetic volumes of unitary Shimura varieties*
Workshop *Modular forms and representation theory*, Manigod

22/07/2022 *Arithmetic volumes of unitary Shimura varieties*
Hong-Kong University Number Theory Days 2022, online

14/09/2022 *Arithmetic volumes of unitary Shimura varieties*
Conference *Elliptic curves and modular forms in arithmetic geometry*, University of Milano

09/12/2022 *Generating series of special cycles on orthogonal Shimura varieties*
Number Theory Seminar, ETH Zürich

Neelabja Chatterjee

27/03/2021 *Convergence Analysis of a numerical scheme for a general class of mean field equations*
Recent Advances in Applied Mathematics: Theory and Computations, Calcutta, India

Yann Disser

02/03/2021 *Undirected Graph Exploration*
TU Kaiserslautern

Moritz Egert

20/08/2021 *Functional Calculus, Kato Problem and Boundary Value Problems*
IWOTA 2020, Lancaster

13/09/2022 *4 Critical numbers for elliptic systems with block structure*
13th Euro-Maghrebian Workshop on Evolution Equations, Lancaster

16/11/2022 *4 Critical numbers for elliptic systems with block structure*
WIAS Berlin

20/04/2021 *Bondary value problems for elliptic systems with block structure*
University of Minnesota (online)

02/12/2021 *Kato Square Root Problem – a personal review*
TU Dresden

08/07/2021 *Dirichlet problem for elliptic systems with block structure*
Universität Bonn

24/03/2022 *The Kato problem on open subsets*
HIM, Bonn

Herbert Egger

14/07/2021 *An arbitrary order variational discretization for Maxwell´s equations in nonlinear media*
ICOSAHOM 2021, Vienna

27/09/2021 *MONA: A magnetic oriented nodal analysis*
DMV-ÖMG Annual Conference 2021 (online)

Anton Freund

05/07/2021 *A Uniform Picture of Gap Condition and Collapsing Functions*
Celebrating 90 Years of Gödel's Incompleteness Theorems, Tübingen (online)

19/08/2021 *Independence without computational strength*
Workshop on Gödel's Incompleteness Theorems, Wuhan (online)

14/09/2021 *Resemblance and Collapsing*
Workshop on 'New Frontiers in Proofs and Computation', IASM Hangzhou / Banff International Research Station (online)

23/11/2021 *Proof mining a nonlinear ergodic theorem for Banach spaces*
Seminar on 'Geometric Logic, Constructivisation, and Automated Theorem Proving', Schloss Dagstuhl – Leibniz Center for Informatics

15/01/2022 *Optimal proofs of Kruskal's theorem*
Celebration of Unesco World Logic Day, Lisbon (online)

30/05/2022 *On a uniform Kruskal-Friedman theorem*
Conference on ‘Proof and Computation’, Schlehdorf

28/06/2022 *The uniform Kruskal theorem: a bridge between finite combinatorics and abstract set existence*
Invited Plenary Talk at the ASL Logic Colloquium, Reykjavik

29/08/2022 *Proof mining nonexpansive operators in Banach spaces*
International Conference on Applied Proof Theory, Pescara

Alf Gerisch

30/09/2021 *Mechanical models of pattern formation in biological tissues: the role of the stress-strain constitutive model*
CMO/BIRS Workshop Modeling and Computational Approaches to Individual and Collective Cell Movement in Complex Environments (online)

19/09/2022 *On the simulation of models of cell migration involving myopic diffusion and cell-cell adhesion*
Minisymposium Mathematics for cell migration under the influence of the microenvironment: from single cells to populations, European Conference on Mathematical and Theoretical Biology (ECMTB 2022), Heidelberg

Jan Giesselmann

02/03/2021 *L^2 theory with shifts for a posteriori error analysis of finite volume schemes for hyperbolic conservation laws*
Workshop on Hyperbolic Balance Laws: modeling, analysis, numerics, Oberwolfach

14/02/2022 *A Posteriori Error Control of Numerical Schemes for Random Conservation Laws*
Conference on Mathematics of Wave Phenomena 2022, Karlsruhe

07/03/2022 *A Posteriori Error Estimates for 1D Systems of Hyperbolic Conservation Laws*
Perspectives on Multiphase Fluid Dynamics, Continuum Mechanics and Hyperbolic Balance Laws, CIRM, Luminy, France

14/03/2022 *On the Convergence of the Regularized Entropy-Based Moment Method for Kinetic Equations*
SIAM Conference on Analysis of Partial Differential Equations, Minisymposium Data-Driven Closures for Kinetic and Fluid Models, Berlin

19/05/2022 *Structure preserving finite element schemes for Euler Equations on Networks*
Meeting of WG 5 of COST Action Mat-Dyn-Net, Namur, Belgium

Matthias Hieber

12/07/2021 *The primitive equations and scaling invariant spaces*
Conference on PDE and applied Analysis, Bari, Italy

21/11/2021 *The bidomain equations with FitzHugh-Nagumo nonlinearities*
Conference on PDE, Analysis and Applications, Valenciennes, France

17/05/2022 *The primitive equations with stochastic forces*
Newton Institute, Cambridge, UK

01/07/2022 *Spectral theory and operator semigroups*
Workshop on Functional Analysis, Tübingen

21/07/2022 *The Keller-Segel system on non-smooth domains*
Conference on new challengs on operator semigroups, Oxford, UK

06/12/2022 *The Navier-Stokes equations in the anisotropic framework*
Conference on Multiphase flows, Waseda University, Tokyo, Japan

Konstantin Jakob

02/02/2022 *Geometric Langlands correspondence for Airy sheaves*
HU Berlinseminar talk

08/12/2022 *The Deligne-Simpson problem for isoclinic G-connections*
Universität Duisburg-Essenseminar talk

Ulrich Kohlenbach

09/03/2021 *Proof Theory: From the Foundations of Mathematics to Applications in Core Mathematics*
Invited lecture at Tianyuan Mathematical Center in Central China and the School of Philosophy of Wuhan University (online)

26/04/2021 *Proof Mining in Nonconvex Optimization*
Oberwolfach Workshop on Computability Theory, April 25 - May 1, 2021

10/06/2021 *Applications of Proof Theory to Core Mathematics: Recent Developments*
Logical Perspectives 2021, Moscow June 7-July 8 (online)

06/07/2021 *From Gödel's incompleteness theorems and foundational reductions to applications in core mathematics*
Celebrating 90 Years of Gödel's Incompleteness Theorems, Carl Friedrich von Weizäcker-Zentrum, Tübingen, July 5-9, 2021

26/11/2021 *Proof Mining in Nonconvex Optimization*
Dagstuhl Seminar on Geometric Logic, Constructivisation, and Automated Theorem Proving, November 21-26, 2021

05/04/2022 *The influence of the work of R.E. Bruck on the development of proof mining*
Nonlinear Functional Analysis and Its Applications in Memory of Professor Ronald E. Bruck, Technion, Haifa April 4-6 (online)

31/05/2022 *The Computational Content of Proofs: Applications in Optimization and Ergodic Theory*
Proof and Computation 2022, Schlehdorf Monastery, May 30 - June 2, 2022

08/06/2022 *The Computational Content of Proofs: Applications in Optimization and Ergodic Theory*
Proof Mining Seminar Bucharest (online)

02/09/2022 *Proof Theory of Rectangular Operators and the Brezis-Haraux Theorem*
Applied Proof Theory (APT'22), U Chieti-Pescara, August 29 - September 2, 2022

27/09/2022 *Information Flow in Proofs by Contradiction and Effective Learnability*
4th International Workshop on Cognition: Interdisciplinary Foundations, Models and Applications (CIFMA-2022), HU Berlin, 27. September 2022

Michael Kohler

23/03/2021 *The smoking gun: Statistical theory improves neural network estimates*
Workshop Mathematical Foundations of Machine Learning, Oberwolfach

31/05/2022 *Estimation of multivariate regression functions by overparametrized deep neural networks*
Workshop Statistical estimation and deep learning in UQ for PDEs, ESI Wien

Burkhard Kümmerer

25/02/2021 *Der Vernetzungsbereich*
MINTplus2: Systematischer und vernetzter Kompetenzaufbau in der Lehrerbildung im Umgang mit Digitalisierung und Heterogenität, TU Darmstadt

13/10/2021 *Johannes Kepler – Dem Bauplan Gottes auf der Spur*
Sindringen

07/09/2021 *Mathematics Unites – A Lecture Course on "Mathematics as the Common Language of Natural Sciences"*
LATSIS Symposium STEM 2021, ETH Zürich

11/02/2022 *Dem Bauplan Gottes auf der Spur – Auf Zeitreise zu Johannes Kepler*
On the occasion of the exhibition "'himmelwärts – 450 Jahre Johannes Kepler, Stuttgart

18/02/2022 *himmelwärts – 450 Jahre Johannes Kepler*
Curator guided tour, Stutgart, Haus der Wirtschaft

11/03/2022 *Dem Bauplan Gottes auf der Spur – Auf Zeitreise zu Johannes Kepler*
Opening lecture for the exhibition "himmelwärts - 450 Jahre Johannes Kepler, Regensburg

15/03/2022 *Dem Bauplan Gottes auf der Spur – Auf Zeitreise zu Johannes Kepler*
Stadtmuseum Tübingen

07/05/2022 *Dem Bauplan Gottes auf der Spur – Auf Zeitreise zu Johannes Kepler*
Keplergymnasium Tübingen

15/06/2022 *Johannes Kepler – Mathematiker zwischen Weltharmonie und neuzeitlicher Naturwissenschaft*
Ringvorlesung on the occasion of the 65th birthday of Alfred Nordmann, TU Darmstadt

05/07/2022 *Dem Bauplan Gottes auf der Spur – Auf Zeitreise zu Johannes Kepler*
Königin-Charlotte-Gymnasium, Stuttgart-Möhringen

Teresa Kunkel

30/09/2021 *A uniformly convergent mixed finite element method for isothermal gas transport in pipe networks*
DMV-ÖMG Annual Conference 2021 (online)

23/11/2022 *What is … ? Euler equations and their solution concepts*
What is … ? Seminar, TU Darmstadt

Jens Lang

12/01/2021 *A Fully Adaptive Multilevel Stochastic Collocation Strategy for Solving Elliptic PDEs with Random Data*
WCCM 2021 (online)

14/07/2022 *Mathematical Solutions for Individualized Medical Treatment*
School of Medicine, Departments of Orthopaedic Surgery & Bioengineering, University of Pennsylvania, USA

26/07/2022 *Adaptive Stochastic Collocation Methods for Uncertain Unsteady Gas Transport in Networks*
WCCM 2022 (online)

28/07/2022 *Implicit A-Stable Peer Triplets for ODE Constrained Optimal Control Problems*
SCICADE 2022, Reykjavik, Iceland

Yingkun Li

24/03/2021 *Span of restriction of Hilbert theta series*
Northern number theory seminar, University of Nottingham, UK

12/05/2022 *Algebraicity of higher Green functions at CM points, POSTECH-PMI number theory seminar, Postech, South Korea*

12/08/2022 *Span of restriction of Hilbert theta series, Modular forms in number theory and beyond, Universität Bielefeld, Germany*

27/10/2022 *Harmonic Maass forms associated to binary theta series, ENTR Workshop, TU Darmstadt, Germany*

Annette Lutz

06/12/2022 *Incremental Optimization of Potential Based Flows*
DISCOGA Seminar, TU Berlin

Elena Mäder-Baumdicker

07/14/2021 *The Morse Index of Willmore Spheres*
British Mathematical Colloquium (BMC) GLASGOW 2021, Analysis Session, online

29/04/2021 *How to deform a Willmore sphere*
Geometry and Topology Seminar of the University of Durham, online

04/11/2021 *Geometry of complete minimal surfaces and the Willmore Morse index of their inversion*
Conference: New trends in Geometric PDEs, Universität Münster, online participation

26/04/2022 *The area preserving curve shortening flow in a free boundary setting*
Geometric Analysis Seminar of the University of Tennessee (USA), online

28/05/2022 *Compactification of Minimal flowers and their Morse Index*
Talk in the Oberseminar Differentialgeometrie of the Leibniz Universität Hannover

07/06/2022 *Some news about the volume preserving mean curvature flow*
Conference: Special Riemannian Metrics and Curvature Functionals, Centro di Ricerca Matematica Ennio De Giorgi, Pisa

27/06/2022 *Turning the sphere inside out – An introduction to the min-max sphere eversion*
Conference: Young Women in Geometric Analysis, Bonn international graduate school of mathematics, Bonn

06/07/2022 *Non-local estimates for the volume preserving mean curvature flow and applications*
Conference: Mean curvature flow and related topics, Queen Mary University of London

16/08/2022 *Mathe an der TU DA – (viel) mehr als Rechnen*
TU9-ING-Week 2022 at the TU Darmstadt

10/11/2022 *Progress in the theory of the volume preserving Mean curvature flow*
KIT Geometric analysis seminar, Karlsruhe

23/11/2022 *Recent developments concerning the Volume Preserving Mean Curvature Flow*
Universität Münster

Tomislav Maric

02/08/2022 *Force-balance with an unstructured Finite Volume discretization of single-field two-phase Navier-Stokes Equations*
M^5 Mathematics of Multiphase, Multiscale, Multiphysics Models, Casa Matematica Oaxaca (CMO) and Banff International Research Station (BIRS)

Holger Marschall

08/12/2022 *Computational Multiphase Flow*
Group Seminar (Assoc. Prof. Outi Tammisola), Dept. of Engineering Mechanics, KTH Royal Institute of Technology, Sweden.

30/09/2021 *Introduction to OpenFOAM*
PhD Seminar of DFG-CRC 1194

29/07/2021 *Interfacial Multiphysics using an ALE Interface-Tracking Method*
16^{th} U.S. National Congress on Computational Mechanics, MS422: Novel Simulation Techniques for Deforming-Domain Problems, Virtual Event, USA.

24/03/2021 *Towards a Unified Diffuse Interface Phase-Field Framework for Multiphase Multi-component Fluid Flow*
5^{th} German OpenFOAM User meeting, Rostock, Germany.

Christopher Müller

03/02/2021 *What is ... ? A goal-oriented formulation?*
What is ... ? Seminar, TU Darmstadt

Manuel K.-H. Müller

01/11/2022 *The Invariants of the Weil representation of* $\mathrm{Sl}_2(\mathbb{Z})$
International Seminar on Automorphic Forms

Andreas Paffenholz

22/05/2022 *Big Data in Pure Mathematics 2022*
Brown University (online)

Marc Pfetsch

04/11/2022 *SCIP: Past, Present, Future*
SCIP 20 Workshop, Zuse Institute Berlin

23/11/2022 *Globally Optimal Neural Network Training*
SPP 2298 Meeting, Tutzing

03/11/2022 *Solving Mixed-Integer Semidefinite Programs*
Oberseminar, HU Berlin

28/01/2022 *Presolving for Mixed-Integer Semidefinite Problems*
DOT Talk, Online

Pedro Pinto

04/03/2021 *Unwinding of proofs*
FMI/IMAR Logic Seminar, Faculty of Mathematics and Computer Science, University of Bucharest, Romania

15/09/2021 *Quantitative results on variants of the proximal point algorithm*
New Frontiers in Proofs and Computations, Institute for Advanced Study in Mathematics, Hangzhou, China

10/01/2022 *Halpern and Mann iterative schemas: A path towards generalization*
Mathematical Logic Seminar (SLM), University of Lisbon, Portugal

27/01/2022 *Halpern and Mann iterative schemas: A path towards generalization*
LOS-IMAR Logic Seminar, Faculty of Mathematics and Computer Science, University of Bucharest, Romania

06/07/2022 *The alternating Halpern-Mann iteration*
LOS-ILDS Proof Mining Seminar, Faculty of Mathematics and Computer Science, University of Bucharest, Romania

02/09/2022 *Proof mining on PDE theory*
International Conference on Applied Proof Theory 2022 (APT22), D'Annunzio University of Chieti-Pescara, Pescara, Italy

28/10/2022 *Proof mining on PDE theory*
Mathematical Logic Seminar (SLM), University of Lisbon, Portugal

22/02/2023 *On Computational Properties of Cauchy Problems*
CIMA/DMat/PDout Seminar, University of Évora, Évora, Portugal

Nicholas Pischke

02/09/2022 *Proof Mining and Monotone Operator Theory*
International Conference on Applied Proof Theory, D'Annunzio University of Chieti-Pescara

29/06/2022 *Proof mining for maximally monotone set-valued operators*
Proof Mining Seminar, LOS-ILDS, Faculty of Mathematics and Computer Science, University of Bucharest

14/02/2022 *Bound extraction theorems for proofs involving monotone operators*
Seminar on Mathematical Logic, Faculty of Sciences, University of Lisbon

17/09/2021 *Quantitative results for differences of maximal monotone operators*
Workshop on "New Frontiers in Proofs and Computation", IASM Hangzhou / BIRS

Anne Therese Rauls

23/07/2021 *On the Characterization of Generalized Derivatives for the Solution Oator of the Bilateral Obstacle Problem*
SIAM Conference on Optimization (OP21), Virtual Conference

Ulrich Reif

11/11/2021 *Geometric Hermite Subdivision*
Conference ATMA 2021, Reggio Calabria

14/11/2021 *Subdivision*
Conference SMI 21 – Subdivision day, online

23/11/2021 *ABC-Surfaces*
LZI Workshop Geometric Modeling: Interoperability and New Challenges, Schloss Dagstuhl

01/12/2021 *Interpolation and Approximation with Multivariate Polynomials and Splines*
Workshop on Multivariate Approximation and Geometric Modeling, Moskau

16/06/2022 *Degenerate Surface Patches*
GRAPES Doctoral School, Lugano

29/09/2022 *On the Condition of Cubic and Quartic B-Splines*
Conference MAIA 2022, Kassel

07/12/2022 *IGA for fourth order problems*
Conference IGA 2022, Banff

Timo Richarz

07/04/2021 *The motivic Satake equivalence*
Harvard number theory seminar, online

20/04/2021 *Non-normality of Schubert varieties*
Algebraic Groups, Oberwolfach

06/05/2021 *A categorical Künneth formula for Weil sheaves*
RAMpAGe seminar, online

24/08/2021 *Categorical Künneth formula for Weil sheaves*
Automorphic Forms, Geometry and Arithmetic, Oberwolfach

22/09/2021 *Constructible sheaves on schemes*
Six Functor Formalism and Motivic Homotopy Theory, Milano

28/09/2021 *Motivic Satake equivalence*
Representation Theory's hidden motives, Münster

20/05/2022 *Zeta functions and Galois representations*
Mathematisches Kolloquium, Universität Düsseldorf

21/07/2022 *Motives in representation theory*
AMS-SMF-EMS joint meeting, Grenoble

17/11/2022 *Reductions of Shimura varieties*
Mathematisches Kolloquium, Universität Münster

Christina Röhrig

08/04/2022 *Siegel Theta Series For Quadratic Forms of Signature (n-1,1)*
Virtual Joint Mathematics Meeting

25/08/2022 *Indefinite Theta Series with (Spherical) Polynomials*
Conference Modular Forms in Number Theory and Beyond, Universität Bielefeld

Nils Scheithauer

27/05/2021 *Holomorphic vertex operator algebras of central charge 24*
New connections in number theory and physics, Isaac Newton Institute, Cambridge, England

13/05/2022 *On the classification of holomorphic vertex operator algebras of central charge 24*
Bert Schellekens Fest, Nikhef, Amsterdam, Netherlands

07/09/2022 *Deep holes in vertex operator algebras*
Seminar, Isaac Newton Institute, Cambridge, England

04/10/2022 *Reflective forms on orthogonal groups and their expansions at 1-dimensional cusps*
Representation Theory XVII, IUC, Dubrovnik, Croatia

Werner Schindler

28/04/2021 *Update of the AIS 20/31*
NIST, SP 800-90B Entropy Source Validation Workshop, online event

29/11/2022 *New AIS 20/31*
Brainpool workshop, online event

Pascal Schweitzer

08/06/2022 *The Theory of Practical Graph Isomorphism Solving*
82. GI Theorietag

04/07/2022 *Symmetry in discrete structures: graphs, groups, and algorithms*
Discrete Mathematics Days DMD 20/22

Thomas Streicher

19/11/2021 *Precohesive toposes over arbitrary base toposes*
Open House on Category Theory 2021, Mexico City (online)

30/09/2022 *Thomas E. : Friend and my* “Passepartout” *for French TCS B”*
IRIF Paris

Tabea Tscherpel

03/12/2022 *Sobolev stability of the L^2-projection mapping to finite element spaces*
Recent trends in mathematical modelling, Kácov, Czech Republic

Stefan Ulbrich

17/02/2021 *Characterization of Generalized Derivatives for the Solution Operator of the Bilateral Obstacle Problem and A Posteriori Error Estimators for FE-Approximations of the Subgradient*
Workshop Challenges in Optimization with Complex PDE-Systems, Oberwolfach

16/08/2022 *Convergence of sensitivity and adjoint schemes for optimal boundary control of discontinuous solutions of hyperbolic conservation laws*
GAMM Annual Meeting, Aachen

15/09/2022 *Convergence of adjoint schemes for optimal boundary control of discontinuous solutions of hyperbolic conservation laws*
DMV Annual Meeting 2022, Berlin

David Michael Weckbecker

29/01/2021 *Unified Greedy Approximability Beyond Submodular Maximization*
Kolloquium über Informatik, Universiät Köln

10/11/2021 *Fractionally Subadditive Maximization under an Incremental Knapsack Constraint*
DISCOGA Seminar, TU Berlin

Cornelia Wichelhaus

22/09/2021 *Statistical inference for unreliable queueing systems*
Workshop Data-driven Queueing Challenges

30/11/2022 *Statistical challenges for stochastic networks*
Antrittsvorlesung, Mathematisches Kolloquium TU Darmstadt

Winnifried Wollner

25/02/2021 *Coupling Stochastic Gradient Methods with Mesh Refinement for PDE Constrained Optimization under Uncertainty*
AACMME 2021, Online

08/09/2021 *Coupling Stochastic Gradient Methods with Mesh Refinement for PDE Constrained Optimization under Uncertainty*
Workshop on Modeling, Simulation & Optimization of Fluid Dynamic Applications, Groß Schwansee

01/10/2021 *Coupling Stochastic Gradient Methods with Mesh Refinement for PDE Constrained Optimization under Uncertainty*
BI.discrete21, Bielefeld

7.1.2 Contributed Talks

Paloma Schäfer Aguilar

21/07/2021 *Numerical approximation for optimal control problems of hyperbolic conservation laws*
SIAM Conference on Optimization (OP21), Virtual Conference

Heba Alkafri

13/07/2022 *A Unified Multi-physics Framework for Multi-region Coupling and its Application to ALE Interface-tracking*
17$^{\text{th}}$ OpenFOAM Workshop, Cambridge, UK

29/09/2022 *A Unified Multi-physics Framework for Multi-region Coupling and its Application to ALE Interface-tracking*
International Conference on Numerical Methods in Multiphase Flows - 4, Venice, Italy

Markus Anders

10/01/2021 *Engineering a Fast Probabilistic Isomorphism Test*
ALENEX 2021 (online)

14/07/2021 *Search Problems in Trees with Symmetries: Near Optimal Traversal Strategies for Individualization-Refinement Algorithms*
ICALP 2021 (online)

14/07/2021 *Comparative Design-Choice Analysis of Color Refinement Algorithms Beyond the Worst Case*
ICALP 2021 (online)

06/09/2021 *Parallel Computation of Combinatorial Symmetries*
ESA 2021 (online)

07/12/2021 *A Characterization of Individualization-Refinement Trees*
ISAAC 2021 (online)

02/08/2022 *SAT Preprocessors and Symmetry*
SAT 2022, Haifa, Israel

Muhammad Hassan Asghar

06/06/2022 *Simulating wetting of geometrically complex surfaces using the unstructured Volume-of-Fluid method*
The 8th European Congress on Computational Methods in Applied Sciences and Engineering, ECCOMAS Congress 2022, Oslo, Norway

17/08/2022 *Validation and verification of the plicRDF-isoAdvector unstructured Volume-of-Fluid (VOF) method for wetting problems*
92nd Annual Meeting of the German Association of Applied Mathematics and Mechanics, GAMM 2022, Aachen, Germany

30/09/2022 *Simulating wetting of geometrically complex surfaces using the plicRDF-isoAdvector unstructured Volume-of-Fluid method*
International Conference on Numerical Methods in Multiphase Flows 4, Venice, Italy

Björn Augner

17/03/2021 *The fast-sorption-fast-surface-reaction limit of a heterogeneous catalysis model.*
GAMM Annual Meeting 20202021, Kassel (online).

29/09/2021 *Analysis of some heterogeneous catalysis reaction-diffusion-sorption model.*
DMV-ÖMG Annual Meeting 2021, Passau (online).

Milad Bagheri

12/01/2021 *Phase-Field simulation of drop impact on a liquid film: the critical role of interfacial mixing energy*
14th Virtual Congress WCCM & ECCOMAS 2020 (online)

09/03/2021 *Computational analysis of crown formation during drop impact onto a liquid film with experimental validation*
ProcessNet Fachgruppensitzung CFD & MPH (online)

11/06/2021 *Development and validation of a phase-field method for an arbitrary number of immiscible incompressible fluids*
The 16th OpenFOAM Workshop (online)

18/03/2022 *Simulating an arbitrary number of immiscible fluids using a phase-field method: development and validation*
Jahrestreffen der ProcessNet-Fachgruppen "Computational Fluid Dynamics, Mischvorgänge, Agglomerations- und Schüttguttechnik", Leipzig, Germany

14/07/2022 *A unified finite volume framework for phase-field simulations of arbitrary number of immiscible incompressible fluids*
The 17th OpenFOAM Workshop (online)

29/09/2022 *Drop impact onto a thin liquid film: extension from two to three phase scenarios using phase-field method*
4th International Conference on Numerical Methods in Multiphase Flows, Venice, Italy

Francisco Bodziony

07/06/2021 *Do Liquid Drops Roll or Slide on Inclined Surfaces? - Detailed Analysis using a Diffuse-InterfacePhase-Field Method*
The 16thOpenFOAM Workshop, Dublin, Ireland

16/08/2021 *Numerical study of droplets in fibers - spreading and motion on fiber strands.*
5th International Conference on Droplets, Darmstadt, Germany

14/07/2022 *An Hybrid-Atomistic-Continuum (HAC) Approach for Co-Simulation of Multiscale Wetting Processes.*
The 17th OpenFOAM Workshop, Cambridge, United Kingdom

29/09/2022 *Investigation of Droplet Motion on Chemically Heterogeneous Surfaces using a Phase-Field Approach.*
International Conference on Numerical Methods in Multiphase Flows 4, Venice, Italy

Niloufar Bordbar

12/07/2022 *Towards Direct Numerical Simulation of Bubble Formation and Dynamics in Water Electrolysis using a Phase-Field Method (poster)*
The 17th OpenFOAM Workshop

30/09/2022 *Towards Direct Numerical Simulation of Bubble Formation and Dynamics in Water Electrolysis using a Phase-Field Method (poster)*
4th International Conference on Numerical Methods in Multiphase Flows, Venice, Italy

28/11/2022 *Detailed Numerical Simulation of Bubble Formation and Dynamics in Water Electrolysis (poster)*
4th Wasserstoff-Stammtisch, Darmstadt, Germany

Dieter Bothe

17/03/2021 *Modeling and simulation of mass-transfer across fluid interfaces*
GAMM 91th Annual Meeting, Kassel

19/05/2021 *Sharp-interface modeling and numerical simulation of mass transfer at rising bubbles*
Minisymposium Multiphase Flow and Dynamics of Interfaces: Analysis & Numerics
SIAM-Material Science 21

26/09/2022 *On the local influence of surface active agents on mass transfer from gas bubbles*
4th International Symposium on Multiscale Multiphase Process Engineering (MMPE), Berlin

Jendrik Brachter

16/12/2021 *Weisfeiler-Leman Algorithms on Finite Groups*
Seminar on Discrete Algebraic Structures, Novosibirsk, Russland

07/09/2022 *A Systematic Study of Isomorphism Invariants of Finite Groups via the Weisfeiler-Leman Dimension*
European Symposium on Algorithms (ESA 2022), Potsdam, Deutschland

03/11/2022 *Approaching the group isomorphism problem via the Weisfeiler-Leman algorithm*
CIRCA Seminar, St Andrews, UK

Aidan Chaumet

24/05/2022 *Relative Energy Stability Estimates for the Euler-Poisson System*
Seminar der AG Numerik, TU Darmstadt

Elisabeth Andrea Gertrud Diehl

11/06/2021 *Simulation based Optimization of Wetting Phenomena*
Collaborative Research Centre 1194 PhD Colloquium, TU Darmstadt

22/07/2021 *Simulation based Optimization of Multiphase Flow*
SIAM Conference on Optimization (OP21), Virtual Conference

04/05/2022 *Sensitivity Approach for the Simulation based Optimization of Multiphase Flow with a dynamic Contact Line*
French-German-Portuguese Conference on Optimization (FGP), Porto, Portugal

01/07/2022 *Simulation based Optimization of Wetting Phenomena*
Collaborative Research Centre 1194 PhD Colloquium, TU Darmstadt

16/08/2022 *Optimization of Wetting Phenomena with Application to the Doctor Blading Process in Gravure Printing*
Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Aachen

11/11/2022 *Simulation based Optimization of Wetting Phenomena*
Optimization Seminar, TU Darmstadt

Herbert Egger

13/04/2021 *Hansjörg-Wacker Memorial Prize Laudatio*
ECMI Conference, Wuppertal

Franziska Eickmann

24/11/2022 *Mathematical modeling and numerical simulation of bedload sediment transport in shallow flows*
Seminar der AG Numerik, TU Darmstadt

Kord Eickmeyer

01/10/2021 *Logics with Invariantly Used Relations*
Workshop "Sparsity in Algorithms, Combinatorics, and Logics", Schloss Dagstuhl

Mohammed Elwardi Fadeli

08/12/2021 *Towards dynamically load-balanced reactive CFD using OpenFOAM*
NHR4CES - SDL Energy conversion annual meeting (online)

20/06/2022 *A unified framework for load-balanced adaptive mesh refinement in polyhedral meshes to solve reactive flows*
NHR4CES annual community meeting (online)

02/06/2022 *Parallelization in OpenFOAM for HPC deployment*
Working Group OpenFOAM within the DFG CRC 1194 (online)

13/07/2022 *Load-Balanced Multi-Criteria Adaptive Mesh Refinement on Polyhedral Meshes*
The 17th OpenFOAM Workshop (online)

18/10/2022 *A short workshop on Parallelization in OpenFOAM for HPC Deployment*
NHR4CES community trainings (online)

Anton Freund

28/09/2021 *Patterns of resemblance – between proof theory and set theory*
DMV-ÖMG Jahrestagung, Passau (online)

Mathis Fricke

11/01/2021 *Error analysis for the height function method in Volume-of-Fluid simulations*
WCCM, Paris

22/03/2021 *Breakup Dynamics of Capillary Bridges on Hydrophobic Stripes*
DPG Tagung, Online

16/08/2021 *Boundary conditions for dynamic wetting - A mathematical analysis*
Droplets Conference, Darmstadt

07/06/2022 *A reformulation of the level set equation with built-in redistancing*
Eccomas Conference, Oslo

17/08/2022 *New perspectives on capillary rise from complexity reduced models*
GAMM Annual Meeting, Aachen

22/09/2022 *A Reformulation of the Level Set Equation with Built-in Redistancing*
GACM Colloquium on Computational Mechanics, Essen

28/09/2022 *On the numerical approximation and transport of the mean curvature in Volume-of-Fluid methods*
ICNMMF Conference, Venice

22/11/2022 *Volume-of-Fluid based simulation of the withdrawing tape problem using a novel implementation of the generalized Navier boundary condition*
APS Fluid Dynamics Meeting, Indianapolis

04/04/2023 *New perspectives on capillary rise from complexity reduced models*
11th International Conference on Multiphase Flow, Kobe

Jan Giesselmann

24/06/2022 *Weak-strong stability for wave-maps*
Conference on Hyperbolic Problems, Malaga, Spain

24/08/2022 *Euler equations on networks: Parabolic limit and asymptotic preserving numerics*
BENASQUE IX Partial differential equations, optimal design and numerics, Benasque, Spain

26/08/2022 *Observer based data assimiliation for transient models of gas transport*
BENASQUE IX Partial differential equations, optimal design and numerics, Benasque, Spain

Isabel Jacob

22/07/2021 *A Recursive Multilevel Algorithm for Deep Learning*
SIAM Conference on Optimization (OP21), Virtual Conference

03/05/2022 *A Recursive Multilevel Algorithm for Deep Learning*
French-German-Portuguese Conference on Optimization (FGP), Porto, Portugal

01/07/2022 *A Recursive Multilevel Algorithm for Deep Learning*
Optimization Seminar, TU Darmstadt

16/08/2022 *A Recursive Multilevel Algorithm for Deep Learning*
Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Aachen

Erik Jansen

20/01/2023 *Optimization of Energy Networks and Sensitivity Analysis of Integer Programs*
Optimization Seminar, TU Darmstadt

Eda Kaja

10/12/2022 *Classification of Non-Solvable Groups whose Power Graph is a Cograph*
Nikolaus Conference 2022, Aachen, Germany

Theodor Komann

18/11/2022 *Robust Shape Optimization with IGA on Electrical Machines*
Optimization Seminar, TU Darmstadt

Teresa Kunkel

13/09/2021 *Robust error analysis of a mixed finite element method for friction dominated, low Mach gas transport*
15th Hirschegg Workshop on Conservation Laws, Hirschegg

22/06/2022 *Observer-based data assimilation for isothermal gas transport using distributed measurements*
Conference on Hyperbolic Problems, Malaga, Spain

11/07/2022 *Observer-based data assimilation for isothermal gas transport using distributed measurements*
Equadiff 15, Brno, Czech Republic

Jun Liu

12/07/2022 *A Numerically Consistent Unstructured Volume-Of-Fluid Discretization for the Two-Phase Momentum Convection with High-Density Ratios*
The 17th OpenFOAM Workshop, Cambridge, England

03/03/2023 *A numerically consistent unstructured Volume-of-Fluid discretization for the two-phase momentum convection with high density-ratios*
SIAM Conference on Computational Science and Engineering (CSE23), Amsterdam, The Netherlands

Annette Lutz

25/11/2022 *Incremental Optimization of Potential Based Flows*
Optimization Seminar, TU Darmstadt

Elena Mäder-Baumdicker

11/03/2021 *The Morse Index of Willmore Spheres*
Seminar of the AG Numerical Analysis and Scientific Computing, TU Darmstadt

20/11/2021 *Asymptotics of singularities and deformations*
Kickoff-Meeting of the SPP 2026, Nürnberg

14/03/2022 *Der volumenerhaltende mittlere Krümmungsfluss und Alexandrov-Immersionen*
Retreat of the AG Geometry and Approximation, Höchst

Tomislav Maric

29/09/2022 *An unstructured collocated finite-volume Level Set method with a geometrical phase indicator*
International Conference for Numerical Methods in Multiphase Flows ICNMMF-IV, Venice, Italy

12/07/2022 *A numerically consistent unstructured Volume-of-Fluid discretization for the two-phase momentum convection with high density ratios*
OpenFOAM Workshop, Cambridge, U.K.

09/06/2022 *Regularizing curvature for the unstructured Volume of Fluid method*
ECCOMAS, Oslo, Norway

20/03/2022 *Software design patterns in research software with examples from OpenFOAM*
IDEAS ECP Webinar (online)

16/09/2021 *Continous Integration for Research Software*
HiPerCH 13, Darmstadt

02/08/2021 *A collocated Finite Volume unstructured Level Set / Front Tracking method for high density ratios*
Droplets 2021, Darmstadt

07/07/2021 *Increasing the quality of scientific software*
IDEAS ECP Webinar (online)

Holger Marschall

02/05/2022 *Computational Multiphase Flow*
Retreat of the Graduate School of Excellence Computational Engineering, Grasellenbach, Germany

08/12/2021 *OpenFOAM Governance: Dissemination of NHR4CES OpenFOAM Developments*
Kick-off Meeting NHR4CES Simulation and Data Lab *Energy Conversion*, National High Performance Computing Center for Computational Engineering Science, Darmstadt, Germany

01/03/2021 *Towards Predictive Simulations of Droplets and Bubbles*
Research Colloquium of the Graduate School of Excellence Computational Engineering, Darmstadt, Germany

Alexander Matei

14/04/2021 *Identification of Model Uncertainty via Optimal Design of Experiments Applied to a Mechanical Press*
European Consortium for Mathematics in Industry Conference 2021 (ECMI), Virtual Conference

07/06/2021 *Detection of Model Uncertainty in the Dynamic Linear-Elastic Model of Vibrations in a Truss*
4th International Conference on Uncertainty in Mechanical Engineering

22/07/2021 *Detection of Model Uncertainty in the Dynamic Linear-Elastic Model of Vibrations in a Truss*
SIAM Conference on Optimization (OP21), Virtual Conference

Frederic Matter

12/07/2021 *A computational study of solution approaches for computing the Restricted Isometry Property using a mixed-integer SDP*
EURO 2021

Manuel K.-H. Müller

26/10/2022 *The Invariants of the Weil representation of* $\mathrm{Sl}_2(\mathbb{Z})$
ENTR-Workshop, Darmstadt

Nora Philippi

03/03/2021 *Relative energy estimates, asymptotic stability and structure preserving discretization for isentropic flow in gas networks*
Trends in Mathematical Modelling, Simulation and Optimisation: Theory and Applications (online)

29/09/2021 *Singular perturbation of transport problems on pipe networks*
DMV-ÖMG Annual Conference 2021 (online)

29/10/2021 *Relative energy estimates, asymptotic stability and structure preserving discretization for isentropic flow in gas networks*
Research seminar, HU Berlin

20/06/2022 *An asymptotic preserving discretization scheme for gas transport in pipe networks*
Conference on Hyperbolic Problems, Malaga, Spain

14/07/2022 *A structure and asymptotic preserving discretization scheme for gas transport in pipe networks*
Equadiff 15, Brno, Czech Republic

17/08/2022 *An asymptotic preserving hybrid discontinuous Galerkin method for singularly perturbed convection-diffusion problems on networks*
GAMM Annual meeting, Aachen

Pedro Pinto

26/07/2021 *Quantitative translations for viscosity approximation methods*
Eighteenth International Conference on Computability and Complexity in Analysis, Universität der Bundeswehr München, Germany

01/07/2022 *The Halpern-Mann iteration in UCW-hyperbolic spaces*
Days in Logic 2022, University of Algarve, Faro, Portugal

26/09/2022 *A generalization via proof mining methods*
Colloquium Logicum 2022, Universität Konstanz, Konstanz, Germany

Bjoern Polenz

13/04/2021 *Robust shape optimization using quadratic models and model order reduction for electric motors*
European Consortium for Mathematics in Industry Conference 2021 (ECMI), Virtual Conference

25/06/2021 *Robust shape optimization of an induction motor using reduced order models*
Optimization Seminar, TU Darmstadt

21/07/2021 *Robust Shape Optimization of an Electric Motor with Reduced Order Models*
SIAM Conference on Optimization (OP21), Virtual Conference

04/05/2022 *Nonlinear robust shape optimization using second-order approximations and model order reduction for electric motors*
French-German-Portuguese Conference on Optimization (FGP), Porto, Portugal

17/08/2022 *Robust shape optimization of electric motors using second-order approximations and model order reduction*
Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Aachen

Suraj Raju

07/06/2021 *Investigation of wetting under the influence of transport phenomenon using an ALE method*
The 16th OpenFOAM Workshop (Online), Dublin, Ireland

06/06/2022 *The impact of slip for regime transitions in capillary rise*
The 8th European Congress on Computational Methods in Applied Sciences and Engineering, ECCOMAS Congress 2022, Oslo, Norway

14/07/2022 *Investigation of oscillatory dynamics in capillary rise using an ALE method*
The 17th OpenFOAM Workshop, Cambridge, United Kingdom

16/08/2022 *Contact line advection using a finite volume ALE interface tracking method*
92nd Annual Meeting of the German Association of Applied Mathematics and Mechanics, GAMM 2022, Aachen, Germany

Simon Raßmann

10/06/2022 *Finding the number of variables needed to identify graphs*
Logic Postgraduate Seminar, TU Darmstadt

22/07/2022 *What are Constraint Satisfaction Problems?*
"What is ...?"-seminar, TU Darmstadt

18/11/2022 *Approximating the Weisfeiler-Leman dimension of graphs with bounded abelian colours*
Logic Postgraduate Seminar, TU Darmstadt

Lea Rehlich

12/02/2021 *Mixed-Integer Nonlinear Optimization of Heating Networks*
Optimization Seminar, TU Darmstadt

04/05/2022 *Mixed-Integer Nonlinear Optimization of Heating Networks*
French-German-Portuguese Conference on Optimization (FGP), Porto, Portugal

19/08/2022 *Mixed-Integer Nonlinear Optimization of Heating Networks*
Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Aachen

Christina Röhrig

22/06/2022 *False Theta Series*
ENTR (Early Number Theory Researchers Seminar) Seminar, Online

28/10/2022 *Mock Maass Theta Functions*
ENTR Workshop, TU Darmstadt

Werner Schindler

15/09/2022 *Comparison of Functionality Classes AIS 20/31 and Constructions of SP 800 90*
ICMC 2022, Arlington

15/09/2022 *An update on AIS 20/31*
ICMC 2022, Arlington

Kersten Schmidt

13/11/2021 *Acoustic impedance conditions and the Helmholtz equation*
SAM Alumni Reunion & Science Slam, ETH Zürich

28/07/2022 *Adapted contour integration for nonlinear eigenvalue problems in wave-guide coupled resonators*
15th International Conference on Mathematical and Numerical Aspects of Wave Propagation, Paris, France

18/08/2022 *Adapted contour integration for nonlinear eigenvalue problems in wave-guide coupled resonators*
93rd Annual Meeting of the International Association of Applied Mathematics and Mechanics, Aachen

Andreas Schmitt

08/03/2021 *Optimal design of resilient systems*
Technical Operations Research Workshop, Siegen, 2021

01/09/2021 *Optimization of wear related material costs of a hydrostatic transmission system via MINLP*
International Conference on Operations Research, Bern

Pascal Schweitzer

02/03/2021 *Deep Weisfeiler-Leman for graphs and other structures*
The 4th Workshop on Algebraic Graph Theory and its Applications (online)

17/08/2021 *Weisfeiler-Leman and Group Isomorphism*
Oberwolfach

16/02/2021 *Automorphism groups of graphs of bounded Hadwiger number*
Forschungsseminar Diskrete Mathematik, Universität Hamburg

29/03/2022 *Universal graph neural networks via random data augmentations using graph isomorphism tools*
Dagstuhl

10/11/2022 *Symmetry in discrete structures: graphs, groups, and algorithms*
Seminar Algebra-Geometrie-Kombinatorik

05/08/2022 *Choiceless Polynomial Time with Witnessed Symmetric Choice*
Logic in Computer Science, LICS 2022

24/11/2022 *The Graph Isomorphism Problem: a journey through theory-practice synergies*
Max-Planck-Institut für Informatik

05/12/2022 *Algorithms and Symmetry: interplays between theory and practice*
RWTH Aachen

Constantin Seebach

09/09/2022 *Algorithms and Hardness for Non-Pool-Based Line Planning*
ATMOS, Potsdam, Germany

Vsevolod Shashkov

10/07/2022 *MONA - A magnetic oriented nodal analysis for electric circuits*
SCEE 2022, Amsterdam, Netherlands

15/05/2022 *MONA - A magnetic oriented nodal analysis for electric circuits*
JKU Linz

Aleksey Sikstel

25/05/2022 *A local a-posteriori error estimator for systems of hyperbolic conservation laws*
SHARK-FV Conference, Minho, Portugal

23/06/2022 *A local a-posteriori error estimator for systems of hyperbolic conservation laws*
Conference on Hyperbolic Problems, Malaga, Spain

Nicolai Simon

15/01/2021 *An Introduction to the Optimization of Fracture Propagation Problems*
Optimization Seminar, TU Darmstadt

Marcel Maximilian Steinhardt

25/03/2021 *Project P21: Theory and Solution Methods for Generalized Nash Equilibrium Problems Governed by Networks of Nonlinear Hyperbolic Conservation Laws*
SPP 1962 Annual Meeting 2021, Virtual Meeting

16/08/2022 *A Variational Calculus for Optimal Control of Networks of Scalar Conservation Laws*
Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Aachen

25/10/2022 *Project P21: Theory and Solution Methods for Generalized Nash Equilibrium Problems Governed by Networks of Nonlinear Hyperbolic Conservation Laws*
SPP 1962 Annual Meeting 2022, Berlin

Elisa Strauch

19/04/2021 *Stochastic Collocation Method for Hyperbolic PDEs with Random Data*
CE Research Colloquium, TU Darmstadt

Erik Laurin Strelow

01/02/2021 *Physics informed neural networks for gas networks*
CE Research Colloquium, TU Darmstadt

David Michael Weckbecker

22/01/2021 *Unified Greedy Approximability Beyond Submodular Maximization*
Optimization Seminar, TU Darmstadt

10/09/2021 *Fractionally Subadditive Maximization under an Incremental Knapsack Constraint*
Workshop on Approximation and Online Algorithms (WAOA), Virtual Conference

26/11/2021 *Fractionally Subadditive Maximization under an Incremental Knapsack Constraint*
Optimization Seminar, TU Darmstadt

18/05/2022 *Unified Greedy Approximability Beyond Submodular Maximization*
International Symposium on Combinatorial Optimiziation (ISCO), Virtual Conference

09/09/2022 *An Improved Algorithm for Open Online Dial-a-Ride*
Workshop on Approximation and Online Algorithms (WAOA), Potsdam

Winnifried Wollner

17/03/2021 *Coupling Stochastic Gradient Methods with Mesh Refinement for PDE Constrained Optimization under Uncertainty*
Gamm Annual Meeting 2020/2021, Kassel

15/03/2021 *Approximation of Infinite Dimensional Optimization Problems*
CE-Research Colloquium, Darmstadt

7.1.3 Visits

Jendrik Brachter, University of St Andrews, October 2022 – December 2022

Yann Disser, University of Warsaw, Poland, March 2022

Yann Disser, TU Berlin, November 2021

Júlia Baligács, TU Dortmund, June 2022

Mathis Fricke, Sorbonne University, Paris, October 2021, April 2022, January 2023

Mathis Fricke, New Jersey Institute of Technology, May 2022

Jan Giesselmann, TU Berlin, September 2021

Jan Giesselmann, Institute for Advanced Study, Princeton, USA, February 2022

Lisanne Gossel, CRECK Modeling Group, Polytechnic University of Milan, October 2022

Matthias Hieber, University Bari, Italy, July 2021

Matthias Hieber, University Valenciennes, France, November 2021

Matthias Hieber, CIRM, Luminy, France, February 2022

Matthias Hieber, CIRM, Luminy, France, April 2022

Matthias Hieber, Newton Institute, Cambridge, UK, May 2022

Matthias Hieber, Universität Tübingen, July 2022

Matthias Hieber, University of Oxford, July 2022

Matthias Hieber, MFO, Oberwolfach, November 2022

Matthias Hieber, Waseda University, Tokyo, Japan, December 2022

Teresa Kunkel, Universität Erlangen-Nürnberg, November 2021 and October 2022

Jens Lang, University of Pennsylvania, School of Medicine, USA, July 2022

Annette Lutz, TU Berlin, December 2022

Elena Mäder-Baumdicker, Universität Hannover, May 2022

Elena Mäder-Baumdicker, Centro di Ricerca Matematica Ennio De Giorgi, Pisa, June 2022

Elena Mäder-Baumdicker, Universität Bonn, June 2022

Elena Mäder-Baumdicker, Queen Mary University of London, July 2022

Elena Mäder-Baumdicker, Karlruher Institut für Technologie, November 2022

Elena Mäder-Baumdicker, Universität Münster, November 2022

Tomislav Maric, University of Zagreb, June - July 2022

Ulrich Reif, TU Wien, October 2021

Nils Scheithauer, Nikhef, Amsterdam, Netherlands, May 2022

Nils Scheithauer, Isaac Newton Institute, Cambridge, England, September 2022

Nils Scheithauer, IUC, Dubrovnik, Croatia, October 2022

Nils Scheithauer, Universität Erlangen-Nürnberg, November 2022

David Michael Weckbecker, TU Berlin, November 2021

7.2 Organization and Program Commitees of Conferences and Workshops

Frank Aurzada

– Spring School "Random geometric graphs", March 28-April 1, 2022 (jointly with Volker Betz and Matthias Meiners (Gießen))

Jan H. Bruinier

– Workshop *Moduli spaces and modular forms* (jointly with G. van der Geer, V. Gritsenko), Mathematisches Forschungsinstitut Oberwolfach, 31.01.21–06.02.21

Moritz Egert

– Oberwolfach Seminar on Operator-Adapted Spaces in Harmonic Analysis and PDEs (jointly with Pascal Auscher and Dorothee Frey)

Anton Freund

- Proof Theory Virtual Seminar (co-organizer). Seminar series with up to 100 live participants and videos published on YouTube

Jan Giesselmann

- Member of Organizing Committee Meeting of Working Group 5 of COST Action Mat-Dyn-Net, Namur, Belgium, May 18–20 2022

Matthias Hieber

- Conference on Navier-Stokes, Darmstadt, June 21, 2021
- Research School on Keller-Segel-Fluid systems, CIRM, Luminy, France, February 21-25, 2022, (joinlty with S. Monniaux)
- Research School on Geophysical Flows, CIRM, Luminy, France, April 4-8, 2022, (joinlty with S. Monniaux)
- Conference on Liquid Crystals, CIRM, Luminy, France, April 25-29, 2022, (joinlty with S. Monniaux)
- Conference on Nonlinear PDEs in Fluid Dynamics, CIRM, Luminy, France, May 9-13, 2022, (joinlty with S. Monniaux)
- Workshop on Geophysical Flows, Oberwolfach, November 14-18, 2022, (jointly with Y. Giga, P. Korn, E. Titi)

Ulrich Kohlenbach

- Organizer of Workshop 'Frontiers in Proofs and Computations', Institute for Advanced Study in Mathematics, Hangzhou, China, Sep. 12-17, 2021. (jointly with Matthias Baaz, Yong Cheng, Michael Rathjen)
- Member of PC of CCA 2022, Glenside, PA (USA)
- Organizer Oberwolfach Workshop on 'Mathematical Logic', Nov. 12-18, 2023 (jointly with Sam Buss, Rosalie Iemhoff, Michael Rathjen)

Michael Kohler

- Section on "Uncertainty Quantification" at the ICUME 2021, Darmstadt
- Section on "A statistical view of neural networks" at the IMS meeting 2022 in London

Burkhard Kümmerer

- Exhibition: himmelwärts – 450 Jahre Johannes Kepler, 14.02.22-26.02.22, Haus der Wirtschaft, Stuttgart and 11.03.22-08.05.22, Historisches Museum Regensburg (jointly with Hildrun-Bäzner-Zehender, Hermann Faber, Wolfgang Pleithner (Kepler-Gesellschaft e.V., Weil der Stadt), Dr. Robert Löw, Karin Otter (5th Institute of Physics, University of Stuttgart)

Jens Lang

- International Conference: Numerical Solution of Differential and Differential-Algebraic Equations (NUMDIFF-16) (jointly with Martin Arnold (Halle), Elena Celledoni (Trondheim), Jason Frank (Utrecht), Maren Hantke (Halle), Raphael Kruse (Halle), and Helmut Podhaisky (Halle)), Sep 6–10, 2021, Martin Luther University of Halle-Wittenberg, Halle/Saale
- Minisymposium: Certification of Computer Simulations and Model Adaptation (jointly with Ludovic Chamoin (Paris-Saclay), Serge Prudhomme (Montreal) and Juan José Rodenas (Valencia)) at 14th World Congress on Computational Mechanics (WCCM), Jan 11–15, 2021, Online
- Minisymposium: Certification of Computer Simulations and Model Adaptation (jointly with Ludovic Chamoin (Paris-Saclay), Serge Prudhomme (Montreal), Juan José Rodenas (Valencia), and Fredrick Larsson (Göteborg)) at 15th World Congress on Computational Mechanics (WCCM), Jul 31 – Aug 5, 2022, Online
- Workshop: Adaptive Moving and Anisotropic Meshes for the Numerical Approximation of PDEs (jointly with Chris Budd (Bath), Weizhang Huang (Kansas), and Simona Perotto (Milano)), May 9–13, 2022, ICMS Edinburgh

Elena Mäder-Baumdicker

- “Geometric PDEs in Freiburg: A conference in honor of the 60th Birthday of Ernst Kuwert” conference (jointly with Tobias Lamm and Guofang Wang), 29.11.21 to 03.12.21, Albert-Ludwigs-Universität Freiburg

Tomislav Maric

- 2022, GACM, Minisymposium on Direct Numerical Simulations of multiphase flows
- 2021, SC21, Birds-of-Feather - Software Engineering and Reuse in Modeling, Simulation, and Data Analytics for Science and Engineering

Marc Pfetsch

- SCIP 20 Workshop (jointly with Ambros Gleixner, Sebastian Pokutta, Franziska Schlösser, Zuse Institute Berlin)
- ISCO 2022 (program commitee)
- Operations Research Conference, Karlsruhe 2022 (stream “Discrete and Combinatorial Optimization”, together with Britta Peis)

Timo Richarz

- Ruth Moufang Lectures (jointly with Otmar Venjakob and Martin Ulirsch)
- Workshop on Geometric Satake (jointly with Arnaud Mayeux and Simon Riche)
- Women in Arithmetic Geometry (jointly with Katharina Hübner and Holly Krieger)

- Arithmetic Algebraic Geometry (jointly with Ulrich Görtz and Torsten Wedhorn)

Nils Scheithauer

- Conference on vertex algebras and related topics, September 20-24, 2021, Darmstadt (organized by Tomoyuki Arakawa, Peter Fiebig, Nils Scheithauer and Katrin Wendland)
- 14th Seminar on Conformal Field Theory, November 25, 2022, Erlangen (organized by Peter Fiebig, Nils Scheithauer and Katrin Wendland)

Pascal Schweitzer

- Program committee member of the 16th International Symposium on Parameterized and Exact Computation (IPEC 2021)

Winnifried Wollner

- Workshop „WAND 2022 - Workshop on Adaptive Methods and Novel Discretization Techniques in Continuum Mechanics", July 13–15, Salzburg, Austria

8 Workshops and Visitors at the Department

8.1 The Colloquium

Winter term 2020

13/01/2021 Prof. Dr. Lorenzo Taggi (University of Rome – La Sapienza), *Bose-Einstein Condensation and Random Loops* (Online event)

20/01/2021 Prof. Dr. Jose Iovino (University of Texas at San Antonio), *Self-improving convergence theorems* (Online event)

27/01/2021 Prof. Dr. Thomas Surowiec (Universität Marburg), *Risk-Averse Optimization of Random Elliptic Partial Differential Equations: Modeling, Theory and Numerical Solution* (Online event)

03/02/2021 Prof. Dr. Serge Prudhomme (Polytechnique Montréal), *Goal-oriented formulations for finite element approximations and reduced-order models* (Online event)

10/02/2021 Prof. Dr. Gerd Laures (Universität Bochum), *Codes, lattice algebras and string groups from the topological viewpoint* (Online event)

Summer term 2021

28/04/2021 Prof. Dr. Felix Schulze (University of Warwick), *Mean curvature flow with generic initial data* (Online event)

05/05/2021 Prof. Dr. Ana Caraiani (Imperial College London), *Reciprocity laws for torsion classes* (Online event)

19/05/2021 Prof. Dr. Carola-Bibiane Schönlieb (Cambridge University), *From differential equations to deep learning for image analysis* (Online event)

02/06/2021 Prof. Dr. Jennifer K. Ryan (Colorado School of Mines), *Designing effective, efficient, and flexible convolution kernels* (Online event)

16/06/2021 Prof. Dr. Bálint Farkas (Universität Wuppertal), *Eine Begegnung von Funktionalanalysis und Zahlentheorie* (Online event)

30/06/2021 Prof. Dr. Allesandra Cipriani (TU Delft), *Some random interfaces in statistical mechanics* (Online event)

14/07/2021 Prof. Dr. Rico Zenklusen (ETH Zürich), *Matroids: A Powerful Abstraction for Optimization* (Online event)

Winter term 2021

27/10/2021 Prof. Dr. Matthias Heinkenschloss (Rice University), *Risk-averse PDE-constrained optimization* (Online event)

10/11/2021 Prof. Dr. Mark Ainsworth (Brown University), *Fractional order modelling of crystalline structures* (Online event)

08/12/2021 Prof. Dr. Linda Westrick (Pennsylvania State University), *Luzin's (N) and randomness reflection* (Online event)

12/01/2022 Prof. Dr. Ohad Noy Feldheim (Hebrew University of Jerusalem), *The power of choices in reducing inequality* (Online event)

19/01/2022 PD Dr. Hao Chen (Universität Göttingen), *Triply Periodic Minimal Surfaces* (Online event)

26/01/2022 Prof. Dr. Jessica Fintzen (University of Cambridge), *Representations of p-adic groups* (Online event)

09/02/2022 Prof. Dr. Pascal Schweitzer (TU Darmstadt), *Symmetrie in diskreten Strukturen: Graphen, Gruppen und Algorithmen* (Online event)

Summer term 2022

27/04/2022 Prof. Dr. Anton Freund (TU Darmstadt), *Fast algorithms and the higher infinite - two sides of Kruskal's theorem*

11/05/2022 Prof. Dr. Guido Kanschat (Universität Heidelberg), *Hybridized Discontinuous Galerkin Methods on Hypergraphs*

18/05/2022 Prof. Dr. Paul Walton (University of York, UK), *Gender equality in an academic department: how to do it*

25/05/2022 Dr. Sam Sanders (Universität Bochum), *On the past and present of computation in logic and mathematics*

01/06/2022 Prof. Dr. Simone Göttlich (Universität Mannheim), *A multi-scale model hierarchy for material flow problems*

08/06/2022 Prof. Dr. Katja Krüger (TU Darmstadt), *100 Jahre Mathematikunterricht für Mädchen - Hürden und Fortschritte auf dem Weg zur Chancengleichheit*

15/06/2022 Prof. Dr. Moritz Egert (TU Darmstadt), *Poisson extensions - from your Complex Analysis Textbook to open problems in Harmonic Analysis*

22/06/2022 Prof. Dr. Naomi Feldheim (Bar-Ilan University, Israel), *Zeroes of Gaussian Stationary Functions*

06/07/2022 Prof. Dr. Martin Kiehl (TU Darmstadt), *Wie begeistert man hochbegabte Schüler für ein Studium der Mathematik*

Winter term 2022

19/10/2022 Prof. Dr. Kohei Soga (Keio University, Japan), *Tonelli's calculus of variations and related topics*

26/10/2022 Festkolloquium für Prof. Dr. Karl H. Hofmann (TU Darmstadt), *Stefan Wolfgang Pickl: Real-Time Optimization in Lie Theory - The KHH Heuristics & Sidney Morris: Karl Heinrich Hofmann and the Structure of Compact Groups and Pro-Lie Groups*

09/11/2022 Prof. Dr. Sarah Zerbes (ETH Zürich), *Euler systems and the Birch - Swinnerton-Dyer conjecture*

16/11/2022 Prof. Dr. Siegfried Rump (TU Hamburg), *Mathematisch korrekte Ergebnisse mittels Gleitkommaarithmetik*

23/11/2022 Prof. Dr. Eduard Feireisl (Academy of Sciences of the Czech Republic), *The Euler system in fluid mechanics: Good and bad news*

07/12/2022 Prof. Dr. Matthias Ludwig (Universität Frankfurt), *Mathematisches Modellieren bei digitalgestützten Mathematischen Wanderpfaden*

11/01/2023 Vorträge zu den Fieldsmedaillen 2022 (Universität Frankfurt & TU Darmstadt), *Prof. Dr. Martin Ulirsch: Die Geometrie der Matroide & Prof. Dr. Nils Scheithauer: Sphere packings*

18/01/2023 Prof. Dr. Sebastian Schöps (TU Darmstadt), *Isogeometric Methods for Computational Electromagnetics*

25/01/2023 Prof. Dr. Christian Bender (Universität des Saarlandes), *Sample average approximation and randomization*

01/02/2023 Prof. Dr. Melanie Rupflin (University of Oxford, UK), *Quantitative estimates for geometric variational problems*

08/02/2023 Vorträge zu den Fieldsmedaillen 2022 (TU Darmstadt & TU Darmstadt), *Prof. Dr. Volker Betz: Phasenübergänge und mathematische statistische Mechanik & Prof. Dr. Jan Hendrik Bruinier: Die Struktur der Primzahlen*

8.2 Guest Talks at the Department

13/01/2021 Dr. Ilia Ponomarenko (Russian Academy of Sciences, St. Petersburg), *The isomorphism problem for graphs with given symmetries* (Pascal Schweitzer)

18/01/2021 Dr. Milana Pavic-Colic (University of Novi Sad), *Cauchy Problem and moment equations for the Boltzmann model describing polyatomic gas* (Jan Giesselmann)

22/01/2021 Prof. Dr. Mia Deijfen (Stockholm, Sweden), *Competing frogs on* Z^d (Frank Aurzada)

22/01/2021 Prof. Dr. Siva Athreya (Bengaluru, India), *Graphon dynamics from population genetics* (Frank Aurzada)

25/01/2021 Prof. Dr. Ansgar Jüngel (TU Vienna), *Structure-preserving finite-volume schemes for cross-diffusion systems* (Herbert Egger)

01/02/2021 Prof. Dr. Hana Mizerova (Comenius University in Bratislava and Czech Academy of Sciences), *Convergent finite volume scheme for compressible Euler equation* (Jan Giesselmann)

08/02/2021 Dr. Aleksey Sikstel (Universität Erlangen-Nürnberg), *Analysis and Numerical Methods for Coupled Hyperbolic Conservation Laws* (Jan Giesselmann)

21/04/2021 Dr. Stephan Gerster (RWTH Aachen), *Stochastic Galerkin Formulations for Hyperbolic Conservation Laws* (Jan Giesselmann)

04/05/2021 Daniel Schindler (Universität Potsdam), *Mathematical modeling and simulation of protrusion-driven cell dynamics* (Elena Mäder-Baumdicker)

05/05/2021 PD Dr. Stefan Takacs (JKU Linz), *Condition number bounds for IETI-DP methods that are explicit in h and p* (Herbert Egger)

02/06/2021 Dr. Clemens Hofreither (RICAM Linz), *Rational approximation in the context of fractional diffusion* (Herbert Egger)

09/06/2021 Prof. Dr. Tobias Breiten (TU Berlin), *Feedback control of nonlinear infinite-dimensional and port-Hamiltonian systems* (Jan Giesselmann)

15/06/2021 Dr. Fabian Rupp (Universität Wien), *A gradient flow approach to the Canham problem* (Elena Mäder-Baumdicker)

16/06/2021 Dr. Clemens Pechstein (Dassault Systèmes Austria GmbH), *A unified convergence theory for Robin-Schwarz methods – continuous and discrete, including crosspoints* (Herbert Egger)

30/06/2021 Aaron Brunk (JGU Mainz), *Wellposedness and numerical analysis for a viscoelastic phase separation model via energy and relative energy methods* (Herbert Egger)

07/07/2021 PD Dr. Peter Mewis (TU Darmstadt), *Strömungssimulation in Fließgewässer* (Jan Giesselmann)

21/09/2021 Dr. Sven Möller (RIMS Kyoto, Japan), *On the classification of holomorphic vertex operator superalgebras* (Nils Scheithauer)

22/09/2021 Prof. Dr. Christoph Schweigert (Universität Hamburg), *Rigidity in conformal field theory and (vertex) algebras beyond rigidity* (Nils Scheithauer)

23/09/2021 Prof. Dr. Anne Moreau (University Lille, France), *Nilpotent orbits arising from admissible affine vertex algebras* (Nils Scheithauer)

14/10/2021 Andrew Morris (University of Birmingham), *A first-order approach to solvability for singular Schrödinger equations* (Moritz Egert)

26/10/2021 Richard Löscher (TU Graz), *A General Approach to Mass Lumping Using Hilbert Complexes* (Herbert Egger)

09/11/2021 Dr. Piotr Minakowksi (OvGU Magdeburg), *Error Estimates for Neural Network Solutions of Partial Differential Equations* (Jan Giesselmann)

11/11/2021 Matthias Meiners (Universität Giessen), *Asymptotic fluctuations of supercritical general branching processes* (Volker Betz)

16/11/2021 Nicola De Nitti (Universität Erlangen-Nürnberg), *Control of advection-diffussion equations on networks and singular limits* (Herbert Egger)

19/11/2021 Prof. Dr. Vassilis Gregoriadis (University of Athens), *A characterization of Π^0_3-completeness* (Ulrich Kohlenbach)

25/11/2021 Chiranjib Mukherjee (Universität Münster), *Geometry of the Gaussian multiplicative chaos in the Wiener space* (Volker Betz)

06/12/2021 Ass. Prof. Carolina Urzua-Torres (TU Delft), *A New Approach to Space-Time Boundary Integral Equations for the Wave Equation* (Herbert Egger)

08/12/2021 Danny Vagnozzi (Unversity of Cambridge), *Weisfeiler and Leman meet Groebner* (Pascal Schweitzer)

14/12/2021 Prof. Dr. Francisco Torralbo (University of Granada), *Index of compact minimal submanifolds in the Berger spheres* (Elena Mäder-Baumdicker)

15/12/2021 Dr. Benjamin Bumpus (Unversity of Glasgow), *Spined Categories: generalising tree-width beyond graphs* (Pascal Schweitzer)

12/01/2022 Prof. Dr. Ohad Feldheim (Hebrew University Jerusalem, Isreal), *The power of choices in reducing inequality, Math. Kolloq.* (Frank Aurzada)

16/03/2022 Dr. Claudius Heyer (Universität Münster), *Model categories I* (Torsten Wedhorn)

16/03/2022 M.Sc. Luuk Stehouwer (Max-Planck-Institut für Mathematik ,Bonn), *Stable infinity categories II* (Torsten Wedhorn)

17/03/2022 Dr. Dmitry Kubrak (Max-Planck-Institut für Mathematik Bonn), *Animated Rings I* (Torsten Wedhorn)

17/03/2022 M.Sc. Manuel Hoff (Universität Duisburg-Essen), *Modules* (Torsten Wedhorn)

18/03/2022 Dr. Yifei Zhao (Universität Münster), *Animated Rings II* (Torsten Wedhorn)

06/05/2022 Dr. Diego Corro (Karlsruher Institut für Technologie), *Yamabe type problems and singular Riemannian foliations* (Elena Mäder-Baumdicker)

10/05/2022 Dr. Stephan Gerster (University of Como), *Feedback control for hyperbolic balance laws* (Jan Giesselmann)

13/05/2022 Prof. Dr. Michael Rapoport (Universität Bonn), *Integral models of local Shimura varieties* (Timo Richarz)

17/05/2022 Nadine Stahl (Universität Trier), *Efficient State Estimation using Reduced Order Models for Pipeline Networks* (Jan Giesselmann)

20/05/2022 Giovanni Solda (University of Ghent), *Multifunctions computing sequentially discontinuous multifunctions* (Anton Freund)

31/05/2022 Patrick Tolksdorf (Universität Mainz), *On off-diagonal behavior of the generalized Stokes operator* (Moritz Egert)

14/06/2022 Dr. Jim Magiera (Universität Stuttgart), *Components of a Molecular-Continuum Interface Solver for Liquid-Vapor Flow: Moving Mesh, Molecular Dynamics and Machine Learning* (Jan Giesselmann)

19/06/2022 Dr. Marlies Pirner (Universität Würzburg), *Hypocoercivity for a nonlinear generation-recombination model* (Jan Giesselmann)

22/06/2022 Dr. Gianmichele Di Matteo (Karlsruher Institut für Technologie), *CMC and isoperimetric small double bubbles in compact manifolds* (Elena Mäder-Baumdicker)

23/06/2022 Prof. Dr. Manuel Bodirsky (TU Dresden), *On the intersection of Datalog and Guarded Second-Order Logic* (Kord Eickmeyer)

23/06/2022 Prof. Manuel Bodirsky (TU Dresden), *On the intersection of Datalog and Guarded Second-Order Logic* (Kord Eickmeyer)

23/06/2022 Quirin Vogel (NYU Shanghai), *The limit of the Feynman representation for the Bose gas* (Volker Betz)

30/06/2022 Prof. Dr. Jacob Tsimerman (University of Toronto, Canada), *Heights on arbitrary Shimura Varieties and Tori* (Jan H. Bruinier)

01/07/2022 Dr. Paul van Hoften (Stanford University, USA), *Hecke orbits on Shimura varieties of Hodge type* (Timo Richarz)

11/07/2022 Dr. Yuhuan Yuan (Universität Mainz), *Convergence and error estimates of the Godunov Method for Multidimensional Compressible Euler Equations* (Jan Giesselmann)

12/07/2022 Sarah Kleest-Meißner (HU Berlin), *Discovering Event Queries from Traces using Subsequence-Queries with Wildcards and Gap-Size Constraints* (Kord Eickmeyer)

29/07/2022 Dr. Lucas Mann (Universität Münster), *Six Functors and Descent for Solid Sheaves on Discrete Adic Spaces* (Torsten Wedhorn)

29/07/2022 Prof. Dr. Naomi Feldheim (Bar-Ilan, Isreal), *Zeroes of Gaussian stationary functions, Math. Kolloq.* (Frank Aurzada)

03/10/2022 Dr. Johannes Anschütz (Universität Bonn), *C_p-semilinear Galois representations of p-adic fields via Cartier-Witt stacks* (Torsten Wedhorn)

03/10/2022 Prof. Dr. Ana Caraiani (Imperial College London, UK), *On the modularity of elliptic curves over imaginary quadratic fields* (Torsten Wedhorn)

03/10/2022 Prof. Dr. Michael Rapoport (Universität Bonn), *p-adic uniformization of Shimura curves* (Torsten Wedhorn)

03/10/2022 Prof. Dr. Xinwen Zhu (Stanford University, USA), *Isogenies of mod p CM abelian varieties via main theorem of complex multiplication* (Torsten Wedhorn)

04/10/2022 Prof. Dr. Arthur-César Le Bras (University of Strasbourg, France), *A Fourier transform for Banach-Colmez spaces* (Torsten Wedhorn)

04/10/2022 Prof. Dr. Jessica Fintzen (Universität Bonn), *Representations of p-adic groups* (Torsten Wedhorn)

04/10/2022 Prof. Dr. Laurent Fargues (Institut de Mathématiques de Jussieu, France), *Extension du domaine de la lutte* (Torsten Wedhorn)

04/10/2022 Prof. Dr. Peter Scholze (Universität Bonn), *Analytic Geometry* (Torsten Wedhorn)

05/10/2022 Prof. Dr. Sabrina Pauli (Universität Duisburg-Essen), *Arithmetic enrichments in enumerative geometry* (Torsten Wedhorn)

06/10/2022 Prof. Dr. George Pappas (Michigan State University, USA), *p-adic shtukas and integral models of Shimura varieties* (Torsten Wedhorn)

06/10/2022 Prof. Dr. Michael Temkin (The Hebrew University of Jerusalem, Israel), *Functorial resolution of singularities: comparison of the methods* (Torsten Wedhorn)

06/10/2022 Prof. Dr. Philipp Habegger (University of Basel, Switzerland), *Torsion Points on Families of Abelian Varieties* (Torsten Wedhorn)

06/10/2022 Prof. Dr. Toby Gee (Imperial College London, UK), *An introduction to the categorical p-adic Langlands program* (Torsten Wedhorn)

07/10/2022 Prof. Dr. Eugen Hellmann (Universität Münster), *On the K-theory of the stack of L-parameters for* GL_n (Torsten Wedhorn)

07/10/2022 Prof. Dr. Johannes Nicaise (University of Leuven, NL), *Irrationality of complete intersections* (Torsten Wedhorn)

07/10/2022 Prof. Dr. Vincent Pilloni (University Paris-Saclay, France), *Higher Hida theory* (Torsten Wedhorn)

12/10/2022 Ruiwen Dong (University of Oxford), *Algorithmic problems for finitely generated matrix semigroups* (Pascal Schweitzer)

25/10/2022 Lucas Maier (Universität Stuttgart), *Numerical Simulation of Multi-phase Flow in Porous Media with a Phase-field Model* (Jens Lang)

27/10/2022 Jonas Lenz (Universität Mainz), *Tent space maximal regularity for the Stokes operator on the half-space* (Moritz Egert)

02/11/2022 Svenja Griesbach (TU Darmstadt), *Improved Approximation Algorithms for the Expanding Search Problem* (Yann Disser)

03/11/2022 Alexandra Quitmann (WIAS Berlin), *Macroscopic loops in interacting random walk loop soups* (Volker Betz)

04/11/2022 Prof. Dr. Patrick Daniels (University of Michigan, USA), *Canonical integral models for Shimura varieties defined by tori* (Timo Richarz)

16/11/2022 Deniz Cagirici (Masaryk University, Brno, Czech Republic), *Isomorphism Problem for S_d- and T-graphs* (Pascal Schweitzer)

25/11/2022 Dr. Fabio Tanania (Universität München), *Isotropic motivic homotopy theory* (Timo Richarz)

01/12/2022 Dimitrios Tsagkarogiannis (University of L'Aquila), *Density functionals for inhomogeneous systems* (Volker Betz)

01/12/2022 Dr. Niklas Kolbe (RWTH Aachen), *New numerical and data-based approaches for networked scalar conservation laws* (Jan Giesselmann)

01/12/2022 Joachim Rehberg (WIAS Berlin), *On non-autonomous and quasilinear parabolic equations* (Moritz Egert)

01/12/2022 Olli Saari (Universität Bonn), *Construction of phase space localizing operators* (Moritz Egert)

02/12/2022 M.Sc. Arnab Kundu (University Paris-Saclay, France), *Torsors on valuation rings* (Timo Richarz)

02/12/2022 Prof. Alberto Marcone (University of Udine), *Some (extra)ordinary equivalences in reverse mathematics* (Anton Freund)

08/12/2022 Olli Saari (Universität Bonn), *Construction of phase space localizing operators* (Moritz Egert)

08/12/2022 Prof. Dr. Sebastian Krumscheid (KIT), *Multilevel Monte Carlo methods for forward Uncertainty Quantification* (Jan Giesselmann)

09/12/2022 Dr. Arnaud Etève (University Paris-Saclay, France), *Depth 0 local Langlands and cohomology of stacks of global chtoucas* (Timo Richarz)

12/12/2022 Dr. Ian Gleason (Berkeley University, USA), *Point-set topology methods in the theory of v-sheaves and diamonds* (Torsten Wedhorn)

14/12/2022 Prof. Dr. Emily Riehl (Johns Hopkins University), *How I became seduced by univalent foundations* (Thomas Streicher)

15/12/2022 Dr. Jörn Wichmann (Universität Bielefeld), *An averaged space-time discretization of the stochastic p-Laplace system* (Tabea Tscherpel)

15/12/2022 Sebastian Bechtel (TU Delft), *Non-autonomous maximal regularity using a mixed regularity condition in space and time* (Moritz Egert)

21/12/2022 Prof. Dr. Sarah Zerbes (ETH Zurich, Switzerland), *Euler systems and the Birch-Swinnerton-Dyer conjecture* (Yingkun Li)

8.3 Visitors at the Department

Prof. Dr. Naomi Feldheim (Bar-ilan University, Israel), June/July 2022.

Prof. Dr. Ohad Feldheim (Hebrew University, Israel), June/July 2022.

Prof. Dr. Kohei Soga (Keio University, Japan), April 2022.

Yash Kulkany (Sorbonne University), September 2022.

Prof. Dr. Kohei Soga (Keio University, Japan), September 2022.

Prof. Dr. Zeljko Tukovic (University of Zagreb), October 2022.

Prof. Dr. Joel De Coninck (Université de Mons), December 2022.

Prof. Dr. Max Klimm (TU Berlin), December 2022.

Martin Knaack (TU Berlin), August 2022.

Andrew Morris (University of Birmingham), October 2021.

Olli Saari (Universität Bonn), July 2022.

Prof. Dr. Manuel Bodirsky (TU Dresden), June 2022.

Kiwoong Kwon (Kyungpook National University, Korea), September to October 2022.

Prof. Dr. Sandra May (Uppsala University, Schweden), September 2022.

Dr. Joachim Rehberg (Weierstraß-Institut, Berlin), December 2022.

Prof. Dr. Adam Krzyżak (Concordia University, Montreal), September-October 2021.

Prof. Dr. Hans Maassen (University of Nijmegen), August 2021.

Prof. Dr. Hans Maassen (University of Nijmegen), October 2021.

Prof. Dr. Hans Maassen (University of Nijmegen), June 2022.

Prof. Dr. Hans Maassen (University of Nijmegen), October 2022.

Dr. Andrei Sipos (University of Bucharest), July 2021.

Dr. Emanuele Frittaion (University of Leeds), September 2020 to August 2022.

Prof. Shahram Saeidi (University of Kurdistan, Sanandaj), September 2022.

Prof. Dr. Jonas Hirsch (Universität Leipzig), September 2021.

Dr. Patrick Tolksdorf (Universität Mainz), April 2022.

Prof. Dr. Paul Walton (University of York), May 2022.

Dr. Gianmichele Di Matteo (Karlsruher Institut für Technologie), June 2022.

Prof. Dr. Zeljko Tukovic (University of Zagreb, Croatia), November 2021.

Dr. Thomas Mejstrik (TU Wien), March 2022.

Prof. Dr. Gerald Höhn (Kansas State University, USA), June 2021.

Dr. Sven Möller (RIMS Kyoto, Japan), September 2021.

Prof. Dr. Anne Moreau (University Lille, France), September 2021.

Prof. Dr. Christoph Schweigert (Universität Hamburg), September 2021.

Prof. Dr. Peter Fiebig (Universität Erlangen-Nürnberg), September 2021.

Prof. Dr. Katrin Wendland (Universität Freiburg), September 2021.

M.Sc. Charlotte Dombrowsky (Leiden University, NL), October 2021.

M.Sc. Rizacan Ciloglu (University of Zurich, Switzerland), November 2021.

M.Sc. Charlotte Dombrowsky (Leiden University, NL), December 2021.

Prof. Dr. Jens Funke (University of Durham, UK), December 2021.

Prof. Dr. Claudia Alfes-Neumann (Universität Bielefeld), March 2022.

Dr. Claudius Heyer (Universität Münster), March 2022.

M.Sc. Manuel Hoff (Universität Duisburg-Essen), March 2022.

Dr. Dmitry Kubrak (Max-Planck-Institut für Mathematik Bonn), March 2022.

Dr. Markus Schwagenscheidt (Universität Köln), March 2022.

M.Sc. Luuk Stehouwer (Max-Planck-Institut für Mathematik Bonn), March 2022.

Dr. Yifei Zhao (Universität Münster), March 2022.

Prof. Dr. Jens Funke (University of Durham, UK), April 2022.

Prof. Dr. Michael Rapoport (Universität Bonn), May 2022.

Dr. Sven Möller (Universität Hamburg), June 2022.

Prof. Dr. Jacob Tsimerman (University of Toronto, Canada), June 2022.

Dr. Pol van Hoften (Stanford University, USA), July 2022.

Dr. Lucas Mann (Universität Münster), July 2022.

Prof. Dr. Ulf Kühn (Universität Hamburg), September 2022.

Dr. Sven Möller (Universität Hamburg), September 2022.

Dr. Johannes Anschütz (Universität Bonn), October 2022.

Prof. Dr. Ana Caraiani (Imperial College London, UK), October 2022.

Prof. Dr. Laurent Fargues (Institut de Mathématiques de Jussieu, France), October 2022.

Prof. Dr. Jessica Fintzen (Universität Bonn), October 2022.

Prof. Dr. Toby Gee (Imperial College London, UK), October 2022.

Prof. Dr. Philipp Habegger (University of Basel, Switzerland), October 2022.

Prof. Dr. Eugen Hellmann (Universität Münster), October 2022.

Prof. Dr. Arthur-César Le Bras (University of Strasbourg, France), October 2022.

Prof. Dr. Johannes Nicaise (University of Leuven, NL), October 2022.

Prof. Dr. George Pappas (Michigan State University, USA), October 2022.

Prof. Dr. Sabrina Pauli (Universität Duisburg-Essen), October 2022.

Prof. Dr. Vincent Pilloni (University Paris-Saclay, France), October 2022.

Prof. Dr. Michael Rapoport (Universität Bonn), October 2022.

Prof. Dr. Peter Scholze (Max-Planck-Institut für Mathematik Bonn), October 2022.

Prof. Dr. Georg Tamme (Universität Mainz), October 2022.

Prof. Dr. Michael Temkin (The Hebrew University of Jerusalem, Israel), October 2022.

Prof. Dr. Xinwen Zhu (Stanford University, USA), October 2022.

Prof. Dr. Paul Ziegler (Universität München), October 2022.

Prof. Dr. Patrick Daniels (University of Michigan, USA), November 2022.

Dr. Fabio Tanania (Universität München), November 2022.

Dr. Arnaud Etève (University Paris-Saclay, France), December 2022.

Dr. Ian Gleason (UC Berkeley, USA), December 2022.

M.Sc. Arnab Kundu (University Paris-Saclay, France), December 2022.

M.Sc. Paul Siemon (Universität Bonn), December 2022.

Prof. Dr. Sarah Zerbes (ETH Zurich, Switzerland), December 2022.

Dr. Jörn Wichmann (Universität Bielefeld), December 2022.

8.4 Workshops and Conferences at the Department

- 5th International Conference on Droplets, 16.-18.08.2021 (organized by Dieter Bothe)
- Mathematische Modellierungswoche, October 17–22, 2021, Fuldatal (organized by Martin Kiehl, Jan Giesselmann (TU Darmstadt) and Tobias Braumann (Zentrum für Mathematik, Bensheim))
- Mathematische Modellierungswoche, October 23–28, 2022, Fuldatal (organized by Martin Kiehl, Jan Giesselmann (TU Darmstadt) and Tobias Braumann (Zentrum für Mathematik, Bensheim))
- Workshop "Topological Markov Chains, Road Coloured Graphs, and Asymptotic Completeness", 30.08.21 - 02.09.21 (organized by Burkhard Kümmerer)
- Session "Vernetzung" of "Tagung MINTplus2", 25.02.21 (organized by Burkhard Kümmerer)
- Early Number Theory Researchers Workshop, 26.-28.10.2022 (organized by Ingmar Metzler and Riccardo Zuffetti in cooperation with Giulia Cesana, Lars Kleinemeier, and Andreas Mono (Universität Köln))
- A Frankfurt-Darmstadt Afternoon on Optimization, 24.06.22 (organized by Thorsten Theobald, Universität Frankfurt; Marc E. Pfetsch, Stefan Ulbrich, TU Darmstadt)
- Atomization and Sprays, 17.-21. May 2021 (organized by Institute for Fluid Mechanics and Aerodynamics (SLA), TU Darmstadt)
- Conference on vertex algebras and related topics, September 20-24, 2021 (organized by Tomoyuki Arakawa, Peter Fiebig, Nils Scheithauer and Katrin Wendland)
- Higher algebra, March 16 to 18, 2022 (organized by Torsten Wedhorn and Can Yaylali)

9 Other scientific and organisational activities

9.1 Memberships in Scientific Boards and Committees

Frank Aurzada

- Treasurer of DMV-Fachgruppe Stochastik

Volker Betz

- Fellow in the EPSRC Peer Review College

Dieter Bothe

- Member of the German Mathematical Society (DMV)
- Member of DECHEMA (Society for Chemical Technology and Biotechnology)
- Advisory Board of ProcessNet technical committee on Computational Fluid Dynamics
- Advisory Board of ProcessNet technical committee on Multiphase Flows
- Member of GAMM section Partial Differential Equations

Jan H. Bruinier

- Associate Member of the Pohang Mathematics Institute (PMI), Postech, Pohang, Korea

Matthias Hieber

- Member Scientific Committee 'Minkowski Medal', DMV
- Gesellschaft für mathematische Forschung (GMF)

Martin Kiehl

- Vorsitzender des Aufsichtsrats, Zentrum für Mathematik, Bensheim

Ulrich Kohlenbach

- Council of the Association for Symbolic Logic (ASL)
- Advisory Board Member of Springer book series 'Theory and Applications of Computability Theory'
- Member of WoLLIC Steering Committee
- Member of LCC (Logic and Computational Complexity) Steering Committee
- Member of 'Wissenschaftliche Gesellschaft an der J.W.Goethe Universität Frankfurt'
- Honorary Member of the 'Institute for Logic and Data Science', Bucharest

Katja Krüger

– Member of the group 'Arbeitskreis Stochastik in der Schule' of the GDM

– Member of the Center of Teacher Education (ZfL) TU Darmstadt

Jens Lang

– Member of Board of Deans of the Graduate School Computational Engineering, TU Darmstadt, since 2008

– Member of Scientific Committee of the Conference on the Numerical Solution of Differential and Differential-Algebraic Equations to be held at the Martin-Luther University Halle-Wittenberg every three years

Holger Marschall

– Assigned Member of the DECHEMA ProcessNet Committee Computational Fluid Dynamics

– Chair of the Multiphase Technical Committee within the ESI OpenFOAM Governance structure

– Member of the OpenFOAM Workshop Committee

Marc Pfetsch

– Universitätsversammlung, TU Darmstadt

– HRZ AG, TU Darmstadt

– Forschungsrat der Rhein-Main Universitäten

– Committee for Applications and Interdisciplinary Relations of the European Mathematical Society

Steffen Roch

– Auswahlausschuss Bundeswettbewerb Mathematik

Stefan Ulbrich

– Member of the IFIP Technical Committee TC 7, WG 7.2 "Computational Techniques in Distributed Systems"

– Universitätsversammlung TU Darmstadt

– Senat TU Darmstadt

– Fachkollegium Mathematik, DFG

Winnifried Wollner

– Speaker of GAMM Activity Group on "Optimization with Partial Differential Equations"

– Senatsausschuss Lehre, TU Darmstadt

9.2 Awards and Offers

Awards

Markus Anders: Best student paper award SAT 22, "SAT Preprocessors and Symmetry"

Milad Bagheri: IEEE SciVis Contest 2022 Award - Second Place

Milad Bagheri: IEEE SciVis Contest 2022 Award - Best Cover Visualization

Jan Bruinier: Fellow of the American Mathematical Society

Jan Bruinier: Alexanderson Award of the American Institute of Mathematics (AIM), joint with B. Howard, S. Kudla, M. Rapoport, T. Yang

Moritz Egert (joint with Pascal Auscher): Ferran Sunyer i Balaguer Prize 2022

Matthias Hieber: Vice Director, Mathematisches Forschungsinstitut Oberwolfach (MFO)

Matthias Hieber: Jean-Morlet Chair, CIRM, Luminy, 2022

Burkhard Kümmerer for the "Vernetzungsbereich": "Hochschulwettbewerb MINTplus – plusMINT: Smart Qualifiziert" for the project "Das Ganze im Blick - vernetzt lehren" of the "Vernetzungsbereich" under the leadership of Burkhard Kümmerer

Moritz Lichter: Kleene Award for Best Student Paper LICS 2021, "Separating Rang Logic from Polynomial Time"

Moritz Lichter: Distinguished Paper at LICS 2021, "Separating Rang Logic from Polynomial Time"

Moritz Lichter, Pascal Schweitzer: Distinguished Paper at LICS 2022, "Choiceless Polynomial Time with Witnessed Symmetric Choice"

Nicholas Pischke: 'Datenlotsen-Preis 2022' - Award for excellent Master thesis

Nicholas Pischke: 'Preis für hervorragende wissenschaftliche Leistungen 2021, Freunde der Technischen Universität Darmstadt e.V.' - Award for excellent Bachelor thesis

Anne Therese Rauls: Ruth Moufang-Promotionspreis (Fachbereich Mathematik, TU Darmstadt), 2021

Anne Therese Rauls: Preis für hervorragende wissenschaftliche Leistungen (Vereinigung von Freunden der Technischen Universität zu Darmstadt e.V.), 20.05.22

Timo Richarz: ERC Starting Grant

Timo Richarz: LOEWE-Start-Professur

Offers of Appointments

Yann Disser: Professorship (W3) for Discrete Mathematics, Universität Kassel

Yann Disser: Professorship (W2) for Theoretical Computer Science, TU Kaiserslautern

Timo Richarz: Professur (W2tt) für Mathematik, LMU München

Timo Richarz: Professur (W2) für Reine Mathematik, Universität Mainz

Timo Richarz: Professur (W2) für Algebra und Zahlentheorie, Universität Wuppertal

Winnifried Wollner: Professorship (W3) for Optimization, Universität Hamburg

9.3 Secondary Schools and Public Relations

The department of mathematics is involved in various activities for schools, secondary school students, and public relations. In addition to providing printed information material, the department of mathematics presents itself to the public on its web pages. These were fundamentally revised in 2020 and provide useful information about all aspects of the study as well as an attractive insight into the department. The information is available in German and in English.

Math on Demand In April 2015, the mathematics department of TU Darmstadt launched the programme *Math on Demand* for mathematically interested secondary school students and mathematics teachers. The purpose of this programme is to stimulate their interest in mathematics beyond the traditional classroom. On demand, scientists from the mathematics department offer lectures or workshops, which are intended to illustrate the variety and importance of mathematics in everyday life, and to give a first insight in some recent developments in the tremendous opportunities for careers in mathematics and about the mathematics programme at TU Darmstadt.

The following is a list of further public relations activities.

Activities for secondary school students and prospective students

- Since 2020, th job and study information fair HoBIT, (Hochschul- und Berufsinformationstage) has been taking place in a new form. In January, members of the university inform about the different offers during podcast-like online discussions. Mathematics is represented by professors and students. In May, a significantly smaller fair takes place. The Department of Mathematics uses exhibits to convey the fascination of mathematics and provides information about studying in talks with about 100 pupils.

- Participation in the university fair "vocatium", a fair for school students who are interested in a university study programme (Offenbach and Mannheim)

- Several visits from schools, especially Leistungskurse (advanced courses in mathematics). The typical program consists of a mathematical lecture, information about the study and a meeting with students. Tours, for example of the ULB (Library) or the high-performance computer, are also organized on request.
- Due to the Covid-19 pandemic, student advisory for prospective students mostly was held online via Zoom by Dr. Seeberg in 2021.
- Activities for secondary school students and prospective students
  Tutoring courses in the scope of the Hessian programme "Löwenstark " for students of year 6 to 8. Topics covered are fractions, terms and variables, and geometry.
- Lecture titled "Mathematisches Problemlösen" in the context of the youth camp "Albert-Schweitzer-Uni" for 8-15-year-olds in Lindenfels by Jan Herzog in 2021.
- Annual organisation of the mathematical problem solving event "Knobelstraßen" for high school and university student by the working group on subject didactics in 2021 (online) and 2022 (in person). They take place annually shortly before Christmas. School groups that are unable to attend receive materials upon request.
- Annual Graduation Event: celebration with friends and family of the graduated students (organisation: Prof. Große-Brauckmann and staff) June 2022.

9.4 Student Body (Fachschaft)

Officially, the students at the Department of Mathematics are represented by the five people forming the "Fachschaftsrat". This board is elected once a year during the university elections. However, since there usually is more work to be done than five people can handle, there are many more students participating actively in the Students' Union. Moreover, some of them are members of university-wide committees such as the Senate or the University Assembly.
We, the Students' Union, regard ourselves as representatives inside and outside the mathematics department for all math students. As such, all students are invited to talk to us in order to tell us about problems or suggestions they might have. Furthermore, we organise a lot of orientation events for students and secondary school students throughout the year. Finally, a student's life does not only consist of attending lectures and exercises, so we additionally offer some extra-curricular activities.
As part of our activities we appoint the student representatives in the committees of the department. Some of us are members of the "Fachbereichsrat" (another important board consisting of professors, assistants and students, elected during the university elections) and its committees, like the committee for learning and studying, the library committee, and many more. The evaluation and quality control of teaching done at the department are two of our main objectives. We think it is essential to hear and consider students' opinions regarding these areas because they are the ones directly affected. We also support the improvement and development of courses and studying in general, a point which every student should be concerned about naturally. We are working on those subjects together with Students' Unions from other departments and with the university administration.
Concerning orientation events, we organise the orientation week for the first semester students, which takes place at the beginning of each semester. During the semester, there is an

orientation colloquium for the students in their first two years, which is meant to give them an impression of what the work in the research groups usually is about (meant to support the decision on a thesis subject). After finishing their first two years, students attend another orientation event, the "Introduction to Advanced Studies" (*Einführung ins Hauptstudium*), giving them more information about the research groups, the relevant regulations and much more.

Not all of these events take place in the mathematics department. University-wide orientation events for secondary school students are also part of our work. There, we cooperate with the student counsellors.

However, not all our activities concern purely study-related topics. The organisation of game evenings, music evenings, as well as the traditional Christmas party of the department are examples of what we do to help students socialize among themselves.

We hope that this rather brief introduction helps to give an impression of our work.

10 Contact

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