Daniel Brosch

Curriculum Vitae

Personal Details

Date of birth November 18, 1996 Place of birth Leverkusen, Germany Citizenship German

PhD-Thesis

title Symmetry Reduction in Convex Optimization with Applications in Combinatorics

main supervisor Etienne de Klerk co-supervisor Monique Laurent summary We explore diffe

Imary We explore different approaches to and applications of symmetry reduction in convex optimization. Using tools from semidefinite programming, representation theory and algebraic combinatorics, we solve or bound hard problems coming from combinatorial optimization, energy minimization, queuing theory, and extremal combinatorics.

defended on October 19, 2022.

Employment

December 2022 — today	Postdoc Assistant , <i>Department of Mathematics,</i> <i>University of Klagenfurt</i> , Austria, Limited to 6 years
September 2022 — November 2022	Senior Scientist, Department of Mathematics, University of Klagenfurt, Austria
November 2018 — July 2022	PhD-student, Tilburg University, the Netherlands
January 2020 — March 2020	Researcher , <i>Centrum Wiskunde & Informatica</i> , Amsterdam, the Netherlands
October 2019 — December 2019	Researcher, Ortec, Zoetermeer, the Netherlands

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Education

- 2018 2022 PhD in Mathematics, *Tilburg University*, the Netherlands Under supervision of *Etienne de Klerk* and *Monique Laurent*, as early stage researcher of the Marie-Curie innovative training network MINOA.
- 2017 2018 Mathematics MSc, University of Cologne, cum laude Thesis: Semidefinite Bounds for Unequal Error Protection Codes, under supervision of Frank Vallentin.
- 2015 2017 **Mathematics BSc**, *University of Cologne, cum laude* Thesis: *The Banach-Tarski Paradox*, under supervision of *Alexander Lytchak*.
- 2012 2015 **Project**, *Schülerinnen und Schüler an der Universität*, University of Cologne

Project that allowed me to attend university early in parallel to high school.

2008 — 2015 Abitur, *Otto-Hahn-Gymnasium*, Monheim am Rhein Abitur in Mathematics, Physics, Latin, Philosophy

Personnel Development Courses

- 2024 Erfolgreich überzeugen, argumentieren und zielgerichtet Fragen stellen, *Klagenfurt*
- 2024 Konferenzen stressfrei planen, Klagenfurt
- 2024 Online-Lehre interaktiv(er) gestalten mit H5P, Klagenfurt
- 2024 Was ist eigentlich dieses Gendern? Und wie schaut es im Uni-Alltag aus? - Ein Kurzworkshop zu gender- und diversitätssensibler Sprache, *Klagenfurt*
- 2024 Wie aktiviere ich Studierende (online)? Einsatz von Tweedback, Klagenfurt
- 2023 Effective Presentation in Class and at Conferences, Klagenfurt
- 2020 **Complementary Skills Session on intellectual property rights**, *Tilburg*

Papers

Preprints

2024 Getting to the Root of the Problem: Sums of Squares for Infinite Trees, joint work with *Diane Puges*, https://arxiv.org/ abs/2404.12838

Trees can be considered dense objects when we only consider the leaves of the trees to be its vertices. This leads to a natural theory of limits of trees, first considered by Czabarga, Székely and Wagner, allowing us to ask questions of the form "How many copies of a small tree can an infinite tree contain?". We define the flag algebra of binary trees in this setting, and use it to recover all existing bounds on the inducilibities of trees with up to 10 leaves, and compute hundreds of completely new bounds. Finally, we compute first outer approximations of profiles of trees, which encode the possible simultaneous densities of multiple small trees in an infinite tree.

In Journals

- 2023 New lower bounds on crossing numbers of $K_{m,n}$ from semidefinite programming, *Mathematical Programming*, joint work with *Sven Polak*, https://doi.org/10.1007/s10107-023-02028-1 We develop tools based on representation theory to simplify SDP-based bounds for the crossing number of complete bipartite graphs, and improve bounds both in the finite case and in the limit. We also introduce a new, slightly weaker, but computationally more efficient bound for the crossing number of $K_{m,n}$, allowing us to compute bounds for bigger parameters mand n.
- 2021 Jordan symmetry reduction for conic optimization over the doubly nonnegative cone: theory and software, Optimization Methods and Software, joint work with Etienne de Klerk, https: //doi.org/10.1080/10556788.2021.2022146

We extend the Jordan Reduction method to the doubly nonnegative cone, and describe a Julia software package implementing it.

2021 Optimizing hypergraph-based polynomials modeling joboccupancy in queueing with redundancy scheduling, *SIAM Journal on Optimization*, joint work with *Monique Laurent* and *Andries Steenkamp*, https://doi.org/10.1137/20M1369592 We show that a family of highly symmetric polynomials is convex, thus (partially) solving a problem coming from queueing with redundancy scheduling. To do this, we exploit the symmetries of the Hessians of the polynomials algebraically.

University of Klagenfurt, Department of Mathematics, room N.2.26 Universitätsstraße 65–67, 9020 Klagenfurt am Wörthersee, Austria ⊠ daniel.brosch@aau.at • S danielbrosch.com 2020 Minimum energy configurations on a toric lattice as a quadratic assignment problem, *Discrete Optimization*, joint work with *Etienne de Klerk*, https://doi.org/10.1016/j.disopt.2020.100612 We bound the potential energy of charged particles on an infinite, periodic grid from below, using semidefinite programming and symmetry reduction based on the Jordan Reduction method.

Work in progress

2020- The symmetries of the gluing algebra of graphs

We exploit the symmetries of the SOS and moment hierarchies fully for the class of S_n -invariant polynomials over the *k*-subset-hybercube. This leads to computationally more efficient hierarchies equivalent to Razborov's Flag-SOS hierarchies, and extends their use case to finite and degenerate problems.

- 2021– An efficient decomposition algorithm for quotients of permutation modules
- 2021– Combinatoric derivations: characterizing local and global minimizers in extremal combinatorics
- 2022– Möbius-transform based bounds for error correcting codes, joint work with *Sven Polak*
- 2022– Generalizing the mixing method, joint work with Jan Schwiddessen and Angelika Wiegele
- 2023– **Improved bounds for the Grothendieck constants**, joint work with Nando Leijenhorst, Fernando Oliveira, Frank Vallentin, Angelika Wiegele
- 2023- The graph profile of even cycles, joint work with Greg Blekherman
- 2023– Lattice paths with moving boundaries, joint work with Sarah Selkirk and Andrei Asinowski
- 2024– Lower and Upper Bounds for Small Canonical and Ordered Ramsey Numbers, joint work with *Bernard Lidický*, *Sydney Miyasaki* and *Diane Puges*

Academic Service

Reviews for Journals, Mathematical Programming, Electronic Journal of Combinatorics, Journal of Optimization Theory and Applications Reviews for Conferences, IPCO

Sessions Organized, EUROPT

University of Klagenfurt, Department of Mathematics, room N.2.26 Universitätsstraße 65–67, 9020 Klagenfurt am Wörthersee, Austria ⊠ daniel.brosch@aau.at • � danielbrosch.com Software

2021– FlagSOS.jl

Extendable Julia package for solving fully symmetry-reduced Flag-SOS problems for a variety of combinatorial objects. Available at https://github.com/DanielBrosch/FlagSOS.jl

2021 SDPSymmetryReduction.jl

Julia package for automatic symmetry reduction of SDPs using the Jordan Reduction method. Available at https://github.com/DanielBrosch/SDPSymmetryReduction.jl

Programming Knowledge

Well familiar with Julia, C/C++, Python, Java and Matlab. Some experience with SageMath, Javascript and C#.

Supervision

PhD students

2022– Jan Schwiddessen, Semidefinite Programming for Integer Quadratic Problems, Klagenfurt

Master students

- 2024– Johannes Schmucker, Symmetric Term Sparsity, Klagenfurt
- 2024– **Fatma Bousbiat**, *Linear Programming for Distance Avoiding Sets*, Klagenfurt

Funding

- 2023 Young Scientist Mentoring, University of Klagenfurt, 3100€ Grant for high-performing early career researchers (competitive selection procedure) to visit or invite their mentor. Mentor: Greg Blekherman, Georgia Tech
- 2021 **Talent Grant**, *Tilburg University* Internal grant for a 9-month contract extension during my PhD (competitive selection procedure).

Research Visits

- 2024 **Iowa State University**, *Ames*, *USA*, 5 days Visited *Bernard Lidicky*
- 2024 **Georgia Tech**, *Atlanta, USA*, 1 month Visited *Greg Blekherman*

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- 2024 **University of Iowa**, *Iowa City, USA*, 2 days Visited *Kurt Anstreicher*
- 2023 Georgia Tech, Atlanta, USA, 10 days Visited Greg Blekherman

Teaching

University of Klagenfurt

- SS 25 Kombinatorische Strukturen Lecture and exercise classes
- WS 24 Diskrete Mathematik Lecture and exercise classes
- SS 24 Selected Topics in Optimization: Symmetries and Semidefinite Programming Lecture and exercise classes
- WS 23 Algebraische Strukturen Lecture and exercise classes
- WS 23 Lineare Algebra 1 Exercise classes
- WS 23 Computermathematik für das Lehramt
- WS 23 Preparatory Course for Mathematics
- SS 23 Lineare Algebra 2 Exercise classes
- SS 23 Linear Algebra for Engineers Exercise classes
- WS 22 Computermathematik für das Lehramt
- WS 22 Proseminar Diskrete Mathematik

Tilburg University

- SS 22 Linear Algebra for Data Science Tutorials
- WS 21 Linear Optimization Tutorials and computer labs

Administrative Activities

- 2024 Member of a hiring committee, Professorship optimization
- 2023 Member of a hiring committee, Postdoc optimization

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Outreach and PR

2024 Ferialpraktikum

High school students join us at university and work on projects together. I helped with the supervision.

2023–2024 Modellierungstage

Visited multiple schools in Kärnten for day-long workshops on various math related topics.

Talks

Invited Talks

March 14, 2024	MoPAT-24: Moments and Polynomials: Applications and Theory , Konstanz, Germany
	Combinatoric derivations in extremal graph theory and Sidorenko's conjecture.
February 22, 2024	Iowa State University , Ames, USA New lower bounds on crossing numbers of $K_{m,n}$.
February 20–21, 2024	Iowa State University , Ames, USA Mini Course: Symmetry reduction and semidefinite programming
February 13, 2024	GT Graph Theory/Combinatorics Seminar , Georgia Tech, Atlanta, USA
	Combinatoric Derivations in Extremal Graph Theory and Sidorenko's Conjecture.
February 9, 2024	Tippie College of Business , Iowa City, USA New lower bounds on crossing numbers of $K_{m,n}$.
November 13, 2023	Symmetry, Stability, and interactions with Computation , CIRM, Luminy, France
	Flag Sums of Squares for Sidorenko's Conjecture.
April 15, 2023	Meeting on Applied Algebraic Geometry (MAAG) 2023, Atlanta, USA
	The Flag Algebra of Rooted Binary Trees.
August 17, 2023	Mixed-integer Nonlinear Optimization: A Hatchery for Modern Mathematics, Oberwolfach, Germany Is the set of trees convex?
April 14 2023	Georgia Tech Graph Theory & Combinatorics Seminar Atlanta
April 11, 2020	USA
	New lower bounds on crossing numbers of $K_{m,n}$.
February 22, 2023	Semidefinite optimization approaches to classical and quantum combinatorial optimization, Cologne, Germany SDPs for Extremal Combinatorics.

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December 1, 2022	Three days of computational methods for extremal discrete ge- ometry, Cologne, Germany New lower bounds on crossing numbers of $K_{m,n}$.
April 12, 2022	Workshop on Conic Linear Optimization for Computer-Assisted Proofs, Oberwolfach The Symmetries of Flag-Algebras.
April 1, 2022	Discrete Math Seminar , University of Massachusetts Amherst Symmetry reduced Flag-hierarchies.
January 2021	Oberseminar <i>Reelle Geometrie und Algebra</i> , Universität Konstanz More efficient and flexible flag algebras.
	Contributed Talks
July 25, 2024	ISMP 2024 , Montreal, Canada Combinatoric Derivations and Sidorenko's Conjecture.
June 6, 2024	Klagenfurt-Berlin Workshop on Multiple Perspectives in Optimiza- tion, Klagenfurt, Austria New lower bounds on crossing numbers of $K_{m,n}$.
May 22, 2024	ISCO 2024: International Symposium on Combinatorial Opti- mization , Tenerife, Spain Flag Sums of Squares for Sidorenko's Conjecture.
November 8, 2023	Doctoral Seminar , Klagenfurt, Austria Möbius Transform Based Bounds for Constant Weight Codes.
September 19, 2023	ÖMG Tagung 2023 , Graz, Austria Extremal Combinatorics in Julia.
August 25, 2023	Europt 2023 , Budapest, Hungary The flag algebra of rooted binary trees.
July 10, 2023	SIAM Conference on Applied Algebraic Geometry (AG23) , Eindhoven, the Netherlands Möbius Transform Based Bounds for Constant Weight Codes.
June 2, 2023	SIAM Conference on Optimization (OP23) , Seattle, USA Flag Sums of Squares for Sidorenko's Conjecture.
October 23, 2022	University of Klagenfurt , Klagenfurt, Austria Derivatives in Continuous Combinatorics.
July 26, 2022	ICCOPT , Betlehem, PA, USA Moebius-Transform Based Symmetry Reduction for Optimization in Binary Variables
March 23, 2022	Polynomial optimization reading group , CWI, Amsterdam Symmetry reduced Flag-hierarchies.
August 20, 2021	SIAM AG21 More efficient and flexible Flag-Algebras coming from polynomial optimiza- tion.
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July 20–23, 2021	SIAM OP21
	More efficient and flexible Flag-Algebras coming from polynomial optimiza- tion.
February 2021	Virtual OR seminar , Tilburg University More efficient and flexible Flag-Algebras.
January 2021	Shared seminar Cologne Oberseminar/CWI reading group More efficient and flexible Flag-Algebras.
February 26, 2020 and March 4, 2020	Polynomial optimization reading group , CWI, Amsterdam A two-part introduction to symmetry reduction for SDPs
August 7, 2019	ICCOPT , Berlin Minimum energy configurations on a toric lattice as a quadratic assignment problem.
	Conferences/Workshops/Summer Schools
July 21–26, 2024	ISMP 2024, Montreal, Canada
June 6–7, 2024	Klagenfurt-Berlin Workshop on Multiple Perspectives in Optimiza- tion, Klagenfurt, Austria
May 22–24, 2024	ISCO 2024: International Symposium on Combinatorial Opti- mization, Tenerife, Spain
March 11–14, 2024	MoPAT-24: Moments and Polynomials: Applications and Theory , Konstanz, Germany
November 13–17, 2023	Symmetry, Stability, and interactions with Computation , CIRM, Luminy, France
September 18–22, 2023	ÖMG Tagung 2023, Graz, Austria
August 23–25, 2023	Europt 2023, Budapest, Hungary
August 13–18, 2023	Mixed-integer Nonlinear Optimization: A Hatchery for Modern Mathematics, Oberwolfach, Germany
July 10–14, 2023	SIAM Conference on Applied Algebraic Geometry (AG23) , Eindhoven, the Netherlands
May 31–June 3, 2023	SIAM Conference on Optimization (OP23), Seattle, USA
April 15–16, 2023	Meeting on Applied Algebraic Geometry (MAAG) 2023, Atlanta, USA
February 22–23, 2023	Semidefinite optimization approaches to classical and quantum combinatorial optimization, Cologne
November 30–December 2	Three days of computational methods for extremal discrete ge- ometry, Cologne

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September 5–9, 2022	Final POEMA workshop, Paris
July 23–28, 2022	ICCOPT, Betlehem, PA, USA
June 7–9, 2022	Nordic Combinatorial Conference (NORCOM), Tromsø
April 10–15, 2022	Workshop on Conic Linear Optimization for Computer-Assisted Proofs, Oberwolfach
June 21–29, 2021	MINOA Doctoral School 2021, Online
April 16, 2021	General Julia training (POEMA), Online
March 4–5, 2021	Second MINOA ESR days, Online
March 1–3, 2021	Annual MINOA Conference 2021, Online
January—March 2021	POEMA 3 rd Workshop, Online
November 23–24, 2020	First MINOA ESR days, Online
October– December 2020	POEMA 2 nd Workshop, Online
May 27– September 16, 2020	POEMA Online Learning Weeks, Online
January 6–10, 2020	2 nd MINOA conference, Aussois, France
January 6–10, 2020	24 th Workshop on Combinatorial Optimization, Aussois, France
September 9– November 11, 2019	Interior Point Methods, LNMB PhD Course, Etienne de Klerk, Utrecht, the Netherlands
August 5–8, 2019	6 th International Conference on Continuous Optimization (IC-COPT), Berlin, Germany
June 24–28, 2019	1 st MINOA PhD school, <i>Mixed-Integer Nonlinear Optimization meets Data Science</i> , Ischia, Italy
January 14–16, 2019	1 st MINOA conference, Aussois, France
January 14–16, 2019	23 rd Workshop on Combinatorial Optimization, Aussois, France
January 7–11, 2019	44 th conference on the mathematics of operations research, Lun- teren, the Netherlands
November 19– February 18, 2019	Networks and Semidefinite Programming , <i>LNMB PhD Course</i> , Monique Laurent, Utrecht, the Netherlands
2019–2022	CWI reading group on polynomial optimization , <i>hosted by Monique Laurent and Sven Polak</i> , CWI, Amsterdam
2020-2022	Oberseminar, hosted by Frank Vallentin, Cologne

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