Jens Vygen

Academic career

1992	Diploma, University of Bonn
1992 - 2003	Various Assistant Positions, University of Bonn
1995 - 2003	Stays at Budapest (Hungary), Institute for Mathematics and its Applications Minneapolis (MN, USA), IBM Research, and Yale (CT, USA)
1997	Dr. rer. nat., University of Bonn
2001	Habilitation, University of Bonn
Since 2003	Professor (C4/W3), Chair of Discrete Mathematics, University of Bonn
2011 - 2012	Visiting Professor, University of Grenoble, France
2019 - 2020	Visiting Professor, ENS Paris and ETH Zurich

Honours

2016	Faculty Teaching Award
2018	Best Paper Award of the ACM-SIAM Symposium on Discrete Algorithms

Invited Lectures

2009	23rd European Conference on Operations Research, keynote lecture, Bonn
2012	Third Cargese Workshop on Combinatorial Optimization, distinguished lecture series, France
2016	DIAMOND symposium, Veenendaal, Netherlands
2016	FIM workshop on combinatorial optimization, Zürich, Switzerland
2018	Workshop on the traveling salesman problem, Banff, Canada
2018	Workshop on combinatorial optimization, Oberwolfach

Research Projects and Activities

Large-scale cooperation on “Combinatorial optimization in chip design” with IBM
Management, jointly with Bernhard Korte
Cooperation “Combinatorial Optimization for Applications in Pickup and Delivery Services” with
Deutsche Post/DHL
Director
HIM Trimester on Combinatorial Optimization
Organizer, 2015
Oberwolfach Workshop on Combinatorial Optimization
Organizer, 2011
Long-term research project “Discrete Mathematics and Applications” of the North Rhine-Westphalian
Academy of Sciences, Humanities and the Arts, Düsseldorf
Director, 2004 - 2012
DFG Cluster of Excellence “Hausdorff Center for Mathematics”
Principal Investigator
Research Area KL
Leader

Research profile

My research is in combinatorial optimization [1] and its applications. Recently, we made significant progress in improving approximation ratios for the famous traveling salesman problem, yielding the best known ratios for graph-TSP [7], the s-t-path TSP [5, 6, 2] and several related problems, including finding a smallest 2-edge- or 2-vertex-connected subgraph. To this end, we introduced several new techniques to this area, such as optimized ear-decompositons [7], forest representations of hypergraphs [7], local parity correction [7], reassembling trees [5], and a global decomposition theorem [6], and recursive dynamic programming [2]. Another classical combinatorial optimization problems which I worked on recently is the Steiner tree problem. We found the theoretically [9] and the practically [4] fastest algorithm in many cases. Steiner trees are also key objects in chip design, but here they must be packed in a huge graph subject to timing constraints and other aspects. We devised the fastest known algorithm (in theory and practice) for the very general min-max resource sharing problem (which includes, for instance, a better algorithm for multicommodity flows) [10] and applied it in a new way to optimize global routing with timing constraints [3], yielding the first such algorithm with a provable guarantee. This is a key element of BonnRoute [8], an algorithm that is part of the BonnTools and has been used for the design of thousands of complex chips. The constant need for new and very efficient algorithms to solve very hard practical problems inspires the development of combinatorial optimization. The interplay between fundamental theory, efficient algorithms, and industrial practice is extremely interesting.

The recently developed new techniques for the traveling salesman problem are definitely not yet fully exploited. In the future, we hope to improve further approximation ratios of the TSP and its variants, hopefully including Christofides' 3/2 approximation ratio from 1976 and making progress on the famous 4/3 conjecture. Simplifying and improving the recent constant-factor approximation for the asymmetric TSP is another goal. Also the s-t-path TSP is not yet fully understood, although great progress has been made. The only important case where the integrality ratio is known today is the graph s-t-path TSP, but even there it might be possible to improve the approximation ratio below this threshold. We also plan to extend the approximation algorithm to more general practical settings, including ones with several vehicles. Other fundamental problems in combinatorial optimization, in particular network design problems, are also challenging and not fully understood yet. On the application side, after having integrated timing optimization and routing for the first time, we plan to extend our model to include buffering and hopefully also placement, in order to obtain a general model for chip design that allows global optimization in a single step. In the theoretical foundation of timing optimization, but also in project scheduling, the discrete time-cost tradeoff problem plays a key role. We would like to understand why essentially no approximation algorithm is known for this problem, and hopefully find one.

Editorships

- Operations Research Letters (2002 - 2015)
- Discrete Optimization (2003 - 2017)
- Mathematical Programming (Series A) (2004 - 2016)
- ACM Transactions on Design Automation of Electronic Systems (2013 - 2016)
- Mathematics of Operations Research (area editor for discrete optimization, since 2015)
- INFORMS Journal on Computing (2016 - 2019)
- Mathematical Programming A: (Co-Editor, since 2019)

Program committee member of IPCO (2002, 2011, 2014), ICCAD (2002, 2005), ESA (2003), DATE (2004, 2005, 2008), ISPD (2006), DAC (2009), ISAAC (2011), ICALP (2020) and other international conferences

Research Area KL Most of my research is devoted to combinatorial optimization [1] in a quite broad sense, and to efficient algorithms for chip design. The interplay between theory and practice is particularly fruitful.

With Müller and Radke we designed and analyzed combinatorial fully polynomial approximation schemes for the (block-angular) min-max resource sharing problem [10]. Our algorithm is at the same time much faster and significantly more general than all previous ones. It is even faster in the linear special case, which includes the well-known multi-commodity flow problem. Our implementation solves huge instances almost optimally. Recently, we managed to incorporate timing constraints [3].

Another research topic of mine is approximation algorithms. For example, I improved the best known approximation ratio for various problems, including the graph-TSP [7], the s-t-path TSP

[5, 6, 2], smallest 2-edge- and 2-vertex-connected subgraphs, d-dimensional arrangement, universal facility location, and sink clustering. Our new exact algorithms for the classical Steiner tree problem in graphs [9, 4] are faster than all previous ones in many cases.
We also continued our work on the mathematics of chip design. We advanced the state of the art in placement, repeater tree design, and routing [3, 8].
Our BonnTools are being used in industry for the design of next-generation computer chips, which are the most complex structures that mankind has ever designed.

Supervised theses

Master theses: 20
Diplom theses: 48
PhD theses: 25

References

[1] Bernhard Korte and Jens Vygen. *Combinatorial Optimization: Theory and Algorithms*. Springer, 6th edition, 2018.

[2] Vera Traub and Jens Vygen. Approaching 3/2 for the s-t-path tsp. In *Proceedings of the 29th Annual ACM-SIAM Symposium on Discrete Algorithms (SODA)*, pages 1854–1864, 2018. (Best Paper Award).

[3] Stephan Held, Dirk Müller, Daniel Rotter, Rudolf Scheifele, Vera Traub, and Jens Vygen. Global routing with timing constraints. *IEEE Trans. on CAD of Integrated Circuits and Systems*, 37:406–419, 2018.

[4] Stefan Hougardy, Jannik Silvanus, and Jens Vygen. Dijkstra meets steiner: a fast exact goal-oriented steiner tree algorithm. *Math. Program. Comput.*, 9(2):135–202, 2017.

[5] Jens Vygen. Reassembling trees for the traveling salesman. *SIAM J. Discrete Math.*, 30(2):875–894, 2016.

[6] Corinna Gottschalk and Jens Vygen. Better s-t-tours by gao trees. In *Integer programming and combinatorial optimization*, volume 9682 of *Lecture Notes in Comput. Sci.*, pages 126–137. Springer, [Cham], 2016.

[7] András Sebő and Jens Vygen. Shorter tours by nicer ears: 7/5-approximation for the graph-tsp, 3/2 for the path version, and 4/3 for two-edge-connected subgraphs. *Combinatorica*, 34(5):597–629, 2014.

[8] Michael Gester, Dirk Müller, Tim Nieberg, Christian Panten, Christian Schulte, and Jens Vygen. Bonnroute: Algorithms and data structures for fast and good vlsi routing. *ACM Trans. Des. Autom. Electron. Syst.*, 18(2):32:1–32:24, 2013.

[9] Jens Vygen. Faster algorithm for optimum steiner trees. *Inform. Process. Lett.*, 111(21-22):1075–1079, 2011.

[10] Dirk Müller, Klaus Radke, and Jens Vygen. Faster min-max resource sharing in theory and practice. *Math. Program. Comput.*, 3(1):1–35, 2011.