Springer Optimization and Its Applications

Volume 139

Aims and Scope

Optimization has been expanding in all directions at an astonishing rate during the last few decades. New algorithmic and theoretical techniques have been developed, the diffusion into other disciplines has proceeded at a rapid pace, and our knowledge of all aspects of the field has grown even more profound. At the same time, one of the most striking trends in optimization is the constantly increasing emphasis on the interdisciplinary nature of the field. Optimization has been a basic tool in all areas of applied mathematics, engineering, medicine, economics and other sciences.

The series *Springer Optimization and Its Applications* publishes undergraduate and graduate textbooks, monographs and state-of-the-art expository works that focus on algorithms for solving optimization problems and also study applications involving such problems. Some of the topics covered include nonlinear optimization (convex and nonconvex), network flow problems, stochastic optimization, optimal control, discrete optimization, multi-objective programming, description of software packages, approximation techniques and heuristic approaches.

More information about this series at http://www.springer.com/series/7393

Boris Goldengorin
Editor

Optimization Problems in Graph Theory

In Honor of Gregory Z. Gutin's 60th Birthday

Springer

Editor
Boris Goldengorin
Department of Information Systems
and Decision Science
Merrick School of Business
University of Baltimore
Baltimore, MD, USA

ISSN 1931-6828 ISSN 1931-6836 (electronic)
Springer Optimization and Its Applications
ISBN 978-3-319-94829-4 ISBN 978-3-319-94830-0 (eBook)
https://doi.org/10.1007/978-3-319-94830-0

Library of Congress Control Number: 2018958502

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

This book is dedicated to Professor Gregory Z. Gutin on the occasion of his 60th birthday.

Preface

This book is a collection of papers related to the conference on 7 and 8 January 2017 organised by Simon Blackburn, Jason Crampton and Stefanie Gerke at Royal Holloway University of London on the occasion of Professor Gregory Z. Gutin's 60th birthday. The invited speakers Noga Alon, Jørgen Bang-Jensen, Fedor Fomin, Mark Jones, Daniel Karapetyan, Eunjung Kim, Michael Krivelevich, Igor Razgon, Saket Saurabh, Benny Sudakov, Stefan Szeider and Anders Yeo have contributed to the success of this conference with the following:

Programme

Saturday 7th January 2017, Horton Lecture Theatre 1

10.20–10.50	Coffee/tea break (McCrea 219)
10.50–11.00	Welcome
11.00–11.30	Noga Alon, Tel Aviv University, Israel. Universal tournaments.

Abstract Tournaments have been the subject of much of the work of Gutin. In the spirit of his work, I will discuss the problem, raised by Moon in the 1960s, of estimating the minimum possible number of vertices in a tournament that contains every k-vertex tournament as an induced subgraph. The main result is that this number is $(1 + o(1))2^{(k-1)/2}$, improving earlier estimates of several researchers. The proof combines combinatorial and probabilistic techniques with group theoretic tools.

11.35–12.05 Jørgen Bang-Jensen, University of Southern Denmark, Denmark. 2-partitions of digraphs.

Abstract We report on recent results with various co-authors on the complexity of deciding whether a given digraph D has a vertex partition into two digraphs D' and D'' such that these have prespecified properties. These could be minimum out-degree at least k, being strongly connected, acylic and lots of others. Among the results on which we report is a complete classification of the complexity for 120 natural such problems. This part is joint work with Havet and Cohen.

12.10–12.40 Anders Yeo, Singapore University of Technology and Design. Perfect forests in digraphs

Abstract A spanning subgraph F of a graph G is called perfect if F is a forest, the degree of each vertex in F is odd, and each tree of F is an induced subgraph of G. Alex Scott (Graphs and Combinatorics, 2001) proved that every connected graph G contains a perfect forest if and only if G has an even number of vertices. We consider four generalisations to directed graphs of the concept of a perfect forest. While the problem of existence of the most straightforward one is NP-hard, for the three others, this problem is polynomial time solvable. Moreover, every digraph with only one strong component contains a directed forest of each of these three generalisation types. One of our results extends Scott's theorem to digraphs in a nontrivial way.

12.40–14.30 Lunch break (McCrea 219)

14.30–15.00 Michael Krivelevich, Tel Aviv University, Israel. Long cycles in locally expanding graphs, with applications

Abstract We provide sufficient conditions for the existence of long cycles in locally expanding graphs. Time permitting, we will present applications of our conditions and techniques to Ramsey theory, random graphs and positional games.

15.05–15.35 Eunjung Kim, Paris Dauphine University. A polynomial kernel for distance-hereditary vertex deletion

Abstract A graph is distance-hereditary if, for any pair of vertices, their distance in every connected induced subgraph containing both vertices is the same as their distance in the original graph. Distance hereditary graphs are exactly the graphs with rank-width at most 1. The Distance-Hereditary Vertex Deletion problem asks, given a graph G on n vertices and an integer k, whether there is a set S of at most k vertices in G such that G^S is distance-hereditary. It was shown by Eiben, Ganian and Kwon (MFCS'16) that Distance-Hereditary Vertex Deletion can be solved in time $2^{O(k)}n^{O(1)}$, and they asked whether the problem admits a polynomial kernelisation. We show that this problem admits a polynomial kernel, answering this question positively. For this, we use a similar idea for obtaining an approximate solution for Chordal Vertex Deletion due to Jansen and Pilipczuk (SODA'17) to obtain an approximate solution with $O(k^4)$ vertices when the problem is a Yes-instance and use Mader's S-path theorem to hit all obstructions containing exactly one vertex of the approximate solution. Then, we exploit the structure of split decompositions of distance-hereditary graphs to reduce the total size. Using Mader's S-path theorem in the context of kernelisation might be of independent interest.

15.35–16.10 Coffee/tea break (McCrea 219)

16.10–16.40 Benny Sudakov. Swiss Federal Institute of Technology, Switzerland. Rainbow cycles and trees in properly edge-colored complete graphs

Abstract A rainbow subgraph of a properly edge-colored complete graph is a subgraph all of whose edges have different colors. One reason to study such subgraphs arises from the canonical version of Ramsey's theorem, proved by Erdõs and Rado. Another motivation comes from problems in design theory. In this talk,

we discuss several old conjectures about finding spanning rainbow cycles and trees in properly edge-colored complete graphs and present some recent progress on these problems. Joint work with A. Pokrovskiy and in part with N. Alon.

16.45–17.15 Mark Jones, Royal Holloway, University of London. Enforcing information flow policies through chain and tree-based enforcement schemes

Abstract In an information flow policy, users have different access permissions based on their position in a hierarchy or partial order. In most enforcement schemes that use symmetric cryptographic primitives, each user is assigned a single secret and derives decryption keys using this secret and publicly available information. Recent work has challenged this approach by developing schemes, based on chain or tree partitions of the information flow policy, that do not require public information for key derivation, the trade-off being that a user may need to be assigned more than one secret. In this talk, we show how to construct chain and tree-based cryptographic enforcement schemes and give polynomial-time algorithms to find such enforcement schemes using the minimum number of secrets.

18.30 Dinner (Large Board Room, Founders) Only if you have reserved a seat!

Sunday 8th January 2018, McCrea 219

9.30–10.00 Fedor Fomin, University of Bergen, Norway. Finding detours is fixed-parameter tractable

Abstract We consider the following natural "above guarantee" parameterisation of the classical longest path problem: For given vertices s and t of a graph G and an integer k, the problem longest detour asks for an (s,t)-path in G that is at least k longer than a shortest (s,t)-path. Using insights into structural graph theory, we prove that Longest Detour is fixed-parameter tractable on undirected graphs and actually even admits a single-exponential algorithm, that is, one of running time $\exp(O(k))poly(n)$. This matches (up to the base of the exponential) the best algorithms for finding a path of length at least k. Joint work with Ivona Bezáková, Radu Curticapean and Holger Dell.

10.05–10.35 Stefan Szeider, Vienna University of Technology, Austria. Backdoors for constraint satisfaction

Abstract We will review some recent parameterised complexity results for the constraint satisfaction problem (CSP), considering parameters that arise from strong backdoor sets. A strong backdoor set of a CSP instance is a set of variables with the property that any instantiation of these variables moves the instance into a polynomial-time tractable class. We will focus on tractable classes defined by restricting the involved constraint relations. Joint work with R. Ganian, S. Gaspers, N. Misra, S. Ordyniak, M.S. Ramanujan and S. Živný.

10.35–11.00 Coffee/tea break (McCrea 237)

11.00–11.30 Saket Saurabh, University of Bergen, Norway. Gregory: The "tree" of knowledge

Abstract In this talk, I will document my association with Gregory via algorithms for finding trees with certain properties. This will include some old and some more modern developments in the area.

11.35–12.05 Igor Razgon, Birkbeck University of London, United Kingdom. Well quasi-orderability vs. clique-width

Abstract Well quasi-orderability is an important topic of structural graph theory. The famous result of Robertson and Seymour showing that the class of all graphs is well-quasi-ordered (WQO) by the graph minors relation inspired researchers to consider other order relations on graphs. One such relation is "induced subgraph". This relation is easy to show to be non-WQO; however, many hereditary graph classes are WQO. Up to some moment, all known WQO classes were of bounded clique-width, and this led researchers to a question whether this situation is true in general (i.e. whether a class of graphs that is WQO under the induced subgraph relation is of bounded clique-width). A wide belief was that it is indeed the case. V. Lozin, V. Zamaraev, and myself have demonstrated the first counterexample: a hereditary class of unbounded clique-width which is WQO by the induced subgraph relation. A preliminary version of our result appeared in WG15. In this talk, I will overview the result and state several interesting open problems.

12.10–12.40 Daniel Karapetyan, University of Essex, United Kingdom. Practically efficient algorithms for the workflow satisfiability problem and its optimisation version.

Abstract We consider an interesting satisfiability problem finding applications in access control. The problem is known to be fixed-parameter tractable (FPT), but existing algorithms are relatively inefficient in practice. Our new algorithm more than doubled the value of the parameter that could be practically tackled. The key idea of this new approach is also incorporated into a pseudo-Boolean formulation, with promising results. In the second part of the talk, we discuss single- and bi-objective optimisation extensions of the problem. While providing much greater modelling power, these extensions are still FPT, and our algorithms need only small modification to be used for them. Some conclusions of this research may be applicable to other FPT problems.

This book's focus is on the recent research in modern optimisation problems on graphs and their computational complexities. Researchers, students and engineers will benefit from the original contributions and overviews included in this book. The book is of great interest to researchers in algorithmical graph theory and its applications to max-clique and stable set problems, computing the line index of balance in general graphs, branching in digraphs with many and few leaves, dominance certificates for combinatorial optimisation problems, improved upper bounds for 12 computationally difficult KG instances for the simple plant location problem, an algorithmic answer to the Ore-type version of Dirac's question on disjoint cycles formulated in 1963, efficient heuristics for solving optimal patrol problem on graph against random and strategic attackers, branch-and-cut-type algorithm for the network design problem with cut constraints, heuristic algorithm

for the sequencing problem in distributed manufacturing planning process as well as sharp Nordhaus-Gaddum-type lower bounds for proper connection numbers of graphs.

The book presents open problems in graph theory including applied optimisation problems on graphs and networks which have many applications in markets and data analysis, design of efficient algorithms and software for solving optimisation problems in industrial and systems engineering. Undergraduate, graduate and PhD students as well as theoreticians in computer science, big data analysis, applied mathematics, operations research, design of algorithms, artificial intelligence and software engineering will benefit from the state-of-the-art results in modern graph theory and its applications presented in this book.

Baltimore, MD, USA Boris Goldengorin
October 2018

Acknowledgements

I would like to acknowledge Simon Blackburn, Jason Crampton and Stefanie Gerke who have organised a great conference and supported my idea to publish this book. I am thankful to the reviewers for their comprehensive feedback on every submitted paper and their timely replies. They fundamentally improved the quality of submitted contributions and hence of this volume.

The project of this book was supported by Panos M. Pardalos. His careful editing contributed enormously to the production of this book.

Technical assistance with reformatting and compilations of several versions of this book by Arkopaul Sarkar (PhD candidate in the Industrial and Systems Engineering Department, Ohio University, Athens, OH, USA) is greatly appreciated. I would like to thank all my colleagues from the Department of Industrial and Sys-tems Engineering, the Russ College of Engineering and Technology, and Ohio University, Athens, OH, USA, especially the chair and Russ professor, Robert Judd for providing me with unlimited freedom in research activities and creative atmosphere to work within C. Paul Stocker visiting professor position.

The research and travel grant supported by the Chair of Department of Information Systems and Decision Science, Danielle Fowler, and granted by the Dean of Merrick School of Business, Murray Dalziel, University of Baltimore Maryland, USA is greatly appreciated.

The support of my wife, Ljana, and children, Mark, Vitaliy, Nicolai and Polina, stimulated to complete this book with the highest quality.

Contents

Dr. Gregory Gutin – Short Bio

Gregory Gutin received his MSc in mathematics in 1979 from Gomel State University, Belarus. He worked in high school and research institutes of Belarus from 1979 to 1990. He studied for PhD under Professor Noga Alon at the School of Mathematics, Tel Aviv University, Israel, and received his PhD (with distinction) in 1993. Between 1993 and 1996, he held visiting positions in the Department of Mathematics and Computer Science, Odense University, Denmark, and then became a lecturer in the Department of Mathematics, Brunel University, United Kingdom. Since 2000, Gregory has been professor of computer science, Department of Computer Science, Royal Holloway, University of London.

Gregory is recepient of the following prestigious scientific awards. In 1992, he received the Wolf Prize for PhD students scholarship for excellence. This is the most prestigious Israeli prize awarded to PhD students. The Wolf Foundation also grants the international Wolf Prize to senior researchers. The Wolf Foundation Prize Committee elects the candidates according to high-standard excellence criteria, regardless to the institution where the research is conducted.

In 1996, he received the Kirkman Medal of International Institute of Combinatorics and Applications to recognise outstanding achievements by members who are within 4 years past their PhD.

In 2014, he received Royal Society Wolfson Research Merit Award and the Best Paper Awards at SACMAT 2015 and 2016. In 2017, he became a member of Academia Europaea.

Currently, Gregory Gutin's h-index is 38 with 8400 citations including 3542 citations since 2013.

Professor Gutin's main research interests include graphs and combinatorics (theory, algorithms and applications), parameterised algorithmics and combinatorial optimisation. Dr. Gutin has more than 200 papers published or accepted for publication in refereed journals and conference proceedings. He published nine chapters/sections in books and two editions of the following monograph: J. Bang-Jensen and G. Gutin, *Digraphs: Theory, Algorithms and Applications*,

Springer-Verlag 2000 (1st Ed.) and 2009 (2nd Ed.). The 1st Edition was published in Chinese in 2009. He co-edited (with A.P. Punnen) the book *Traveling Salesman Problem and Its Variations*, Springer 2002. He was or is on the editorial board of the following journals: *Discrete Optimization, Order, Algorithmic Operations Research, Memetic Computing*.