Lecture Notes in Computer Science 9849

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Combinatorial Optimization

4th International Symposium, ISCO 2016
Vietri sul Mare, Italy, May 16–18, 2016
Revised Selected Papers

Springer

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ISSN 0302-9743 ISSN 1611-3349 (electronic)
Lecture Notes in Computer Science
ISBN 978-3-319-45586-0 ISBN 978-3-319-45587-7 (eBook)
DOI 10.1007/978-3-319-45587-7

Library of Congress Control Number: 2016949112

LNCS Sublibrary: SL1 – Theoretical Computer Science and General Issues

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG Switzerland

Preface

This volume contains the full-papers presented at ISCO 2016, the 4th International Symposium on Combinatorial Optimization, held in Vietri Sul Mare (Italy) during May 16–18, 2016. ISCO 2016 was followed by the Spring School on “Extended Formulations for Combinatorial Optimization” given by Volker Kaibel and Samuel Fiorni. ISCO is a biennial symposium. The first event was held in Hammamet, Tunisia, in March 2010, the second in Athens, Greece, in April 2012, and the third in Lisbon, Portugal, in March 2014. The symposium aims to bring together researchers from all the communities related to combinatorial optimization, including algorithms and complexity, mathematical programming, operations research, stochastic optimization, graphs, and combinatorics. It is intended to be a forum for presenting original research on all aspects of combinatorial optimization, ranging from mathematical foundations and theory of algorithms to computational studies and practical applications, and especially their intersections. In response to the call for papers, ISCO 2016 received 98 fullpaper submissions. Each submission was reviewed by at least three reviewers, with at least two of them belonging to the Program Committee (PC). The submissions were judged on their originality and technical quality and the PC had to discuss in length the reviews and make tough decisions. As a result, the PC selected 38 fullpapers to be presented at the symposium, giving an acceptance rate of 39 % (57 short papers were also selected from both regular and short submissions). Four eminent invited speakers, R. Ravi (Carnegie Mellon University), András Frank (Egerváry Research Group, Eövös University Budapest), Adam N. Letchford (Lancaster University), and Volker Kaibel (Otto-von-Guericke University, Magdeburg), gave talks at the symposium. The revised versions of the accepted full-papers, as well as the abstracts of the invited talks, are included in this volume. We would like to thank all the authors who submitted their work to ISCO 2016, and the PC members and external reviewers for their excellent work. We would also like to thank our invited speakers as well as the speakers of the Spring School for their exciting lectures. They all greatly contributed to the quality of the symposium. Finally, we would like to thank the Organizing Committee members for their dedicated work in preparing this conference, and we gratefully acknowledge our sponsoring institutions for their assistance and support.

July 2016

Raffaele Cerulli
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Abstracts

New Graph Optimization Problems in NP∩co-NP

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We show that the following three problems in graph theory belong to **NP**∩co-**NP**.

1. Wang and Kleitman (1972) characterized degree-sequences of simple k-connected undirected graphs. We solve the corresponding problem for digraphs.
2. Edmonds (1973) characterized digraphs admitting k disjoint spanning arborescences of given root, and his result could be extended to the case when there is no prescription for the localization of the roots. Here we exhibit a much more general result that characterizes digraphs admitting k disjoint branchings with specified sizes $\mu_1, \mu_2, \ldots, \mu_k$.
3. Ryser (1958) solved the maximum term rank problem which consisted of characterizing the row-sums and column-sums of (0, 1)-matrices with term-rank at least μ, or equivalently, characterize the degree-sequences of simple bipartite graphs with matching number at least μ. Recently, it turned out that the maximum term rank problem, though not particularly difficult, is not tractable with network flow or matroid techniques since the weighted version is **NP**-complete. Yet, we found a necessary and sufficient condition for the existence of a simple bipartite graph with matching number at least μ such that the degree of each node lies between specified lower and upper bounds.

As a major novelty, we show that these three apparently quite distant problems stem out from one common root: a general theorem on covering a supermodular function by a minimal *simple* digraph. Since the corresponding weighted optimization version includes **NP**-complete problems, the new results are certainly out of the range of classic general frameworks such as the one of submodular flows.

In the talk, I outline first the origin and the history of optimization problems concerning optimal coverings of supermodular functions and exhibit then the new developments giving rise to the characterizations indicated above. Finally, some open problems are sketched that are hopeful to be attacked successfully with the new approach.

Describing Integer Points in Polyhedra

Volker Kaibel

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Linear mixed integer models are fundamental in treating combinatorial problems via Mathematical Programming. In this lecture we are going to discuss the question how small such formulations one can obtain for different problems. It turns out that for several problems including, e.g., the traveling salesman problem and the spanning tree problem, the use of additional variables is essential for the design of polynomial sized integer programming formulations. In fact, we prove that their standard exponential size formulations are asymptotically minimal among the formulations based on incidence vectors only. We also treat bounds for general sets of 0/1-points and briey discuss the question for the role of rationality of coefficients in formulations.

Some Hard Combinatorial Optimization Problems from Mobile Wireless Communications

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In the past decade, a revolution in telecommunications has been taking place. There has been an inexorable trend towards mobile wireless communications, in which there are a large number of *portable devices* (such as smartphones) scattered across a geographical region. Each such region is divided into a number of so-called *cells*. Each cell contains a powerful transmitter called a *base station*. When they wish to send or receive data, the portable devices have to send requests to one or more nearby base stations.

It turns out that mobile wireless communications are a rich source of new and difficult combinatorial optimisation problems. These include strategic problems, such as where and when to locate new base stations, tactical problems, such as how much power to give to each base station, and operational problems, such as how to assign incoming user requests to the available frequency bands.

In this talk, we focus on operational problems associated with so-called *orthogonal frequency-division multiple access* (OFDMA) systems. In these systems, there are a large number of channels available, each of which can be allocated to at most one user. On the other hand, a user can be assigned to more than one channel. The rate at which data is transmitted over a given channel is a nonlinear function of the power allocated to that channel, the bandwidth of the channel, and the noise associated with the channel. So one faces the problem of simultaneously assigning channels to users and allocating the available power to the channels. This leads to several different combinatorial optimization problems, depending on the particular objective in question, the side-constraints imposed, and the time-horizon of interest.

We show that some of these joint channel assignment and power allocation problems can be tackled successfully via mixed-integer linear programming, especially if one uses clever pre-processing tricks, strong cutting planes, and symmetry-breaking techniques. On the other hand, some of the problems still present a formidable challenge.

Improved Approximations for Graph-TSP in Regular Graphs

R. Ravi

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A tour in a graph is a connected walk that visits every vertex at least once, and returns to the starting vertex. We describe improved approximation results for a tour with the minimum number of edges in regular graphs. En route we illustrate the main ideas used recently in designing improved approximation algorithms for graph TSP.

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