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Mathematical Optimization Theory and Operations Research

19th International Conference, MOTOR 2020
Novosibirsk, Russia, July 6–10, 2020
Proceedings

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Preface

This volume contains the refereed proceedings of the 19th International Conference on Mathematical Optimization Theory and Operations Research (MOTOR 2020)[1] held on July 6–10, 2020, near Novosibirsk, Russia.

MOTOR 2020 was the second joint scientific event[2] unifying a number of well-known international and Russian conferences held in Ural, Siberia, and the Far East for a long time:

- The Baikal International Triennial School Seminar on Methods of Optimization and Their Applications (BITSS MOPT), established in 1969 by academician N. N. Moiseev, was the 17th event[3] in this series, held in 2017 in Buryatia
- The All-Russian Conference on Mathematical Programming and Applications (MPA), established in 1972 by academician I. I. Eremin, was the 15th conference[4] in this series, held in 2015 near Ekaterinburg
- The International Conference on Discrete Optimization and Operations Research (DOOR) was organized nine times since 1996, and the last event[5] was held in 2016 in Vladivostok
- The International Conference on Optimization Problems and Their Applications (OPTA) was organized regularly in Omsk since 1997, and the 7th event[6] was held in 2018

As per tradition, the main conference scope included, but was not limited to, mathematical programming, bi-level and global optimization, integer programming and combinatorial optimization, approximation algorithms with theoretical guarantees and approximation schemes, heuristics and meta-heuristics, game theory, optimization in machine learning and data analysis, and valuable practical applications in operations research and economics.

In response to the call for papers, MOTOR 2020 received 175 submissions. Out of 102 full papers considered for reviewing (73 abstracts and short communications were excluded because of formal reasons) only 31 papers were selected by the Program Committee (PC) for publication in this volume. Each submission was reviewed by at least three PC members or invited reviewers, experts in their fields, in order to supply

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[1] http://math.nsc.ru/conference/motor/2020/.

[2] http://motor2019.uran.ru.

[3] http://isem.irk.ru/conferences/mopt2017/en/index.html.

[4] http://mpa.imm.uran.ru/96/en.

[5] http://www.math.nsc.ru/conference/door/2016/.

[6] http://opta18.oscsbras.ru/en/.

detailed and helpful comments. In addition, the PC recommended to include 33 papers in the supplementary volume after their presentation and discussion during the conference and subsequent revision with respect to the reviewers' comments.

The conference featured nine invited lectures:

- Prof. Aida Abiad (Eindhoven University of Technology, The Netherlands, and Ghent University, Belgium), "Graph invariants and their application to the graph isomorphism problem"
- Prof. Evripidis Bampis (Sorbonne Université, France), "Multistage Optimization Problems"
- Prof. Bo Chen (University of Warwick, UK), "Capacity Auctions: VCG Mechanism vs. Submodularity"
- Prof. Sergei Chubanov (Bosch Research, Germany), "Convex geometry in the context of artificial intelligence"
- Prof. Igor Konnov (Kazan Federal University, Russia) "Equilibrium Formulations of Relative Optimization Problems"
- Prof. Alexander Kostochka (University of Illinois at Chicago, USA), "Long cycles in graph and hypergraphs"
- Prof. Panos Pardalos (University Florida, USA), "Inverse Combinatorial Optimization Problems"
- Prof. Soumyendu Raha (Indian Institute of Science, Bangalore, India) "Optimal complexity Matrix Multiplication like computation structures on network-on-chip architecture subject to conflicts of resource allocation constraints"
- Prof. Yakov Zinder (University of Technology Sydney, Australia), "Two-stage Scheduling Models with Limited Storage"

The following five tutorials were given by outstanding scientists:

- Prof. Alexander Grigoriev (Maastricht University, The Netherlands), "Evolution of sailor and surgical knots"
- Prof. Michael Khachay (Krasovsky Institute of Mathematics and Mechanics, Russia), "Metrics of a fixed doubling dimension: an efficient approximation of combinatorial problems"
- Prof. Vladimir Mazalov (Institute of Applied Mathematical Research, Russia), "Game Theory and Social Networks"
- Dr. Andrey Melnikov (Sobolev Institute of Mathematics, Russia), "Practice of using the Gurobi optimizer"
- Prof. Konstantin Vorontsov (Institute of Physics and Technology, Russia), "A survey of machine learning problems from optimization point of view".

We thank the authors for their submissions, members of the PC, and external reviewers for their efforts in providing exhaustive reviews. We thank our sponsors and partners: Mathematical Center in Akademgorodok, Russian Foundation for Basic Research, Sobolev Institute of Mathematics, Novosibirsk State University, Krasovsky Institute of Mathematics and Mechanics, Higher School of Economics, and Melentiev

Energy Systems Institute. We are grateful to Alfred Hofmann, Aliaksandr Birukou, Anna Kramer, and colleagues from Springer LNCS and CCIS editorial boards for their kind and helpful support.

July 2020

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Abstracts of Invited Talks

On Graph Invariants and Their Application to the Graph Isomorphism Problem

Aida Abiad

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Abstract. Graphs invariants have proven to be one of the most important and fruitful concepts in modern Combinatorics and Theoretical Computer Science. Besides being a fascinating study subject for their own sake, they play an important role in the famous graph isomorphism problem. Their success serves as a natural motivation for the following natural question: what are the graph properties that can be deduced from a certain graph invariant? In this talk we will give an overview and will report on recent results concerning two graph invariants: the status sequence of a graph and the graph spectrum.

Keywords: Graph isomorphism problem · Graph invariant · Graph spectrum

Multistage Optimization Problems

Evripidis Bampis

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Abstract. Many systems have to be maintained while the underlying constraints, costs and/or profits change over time. Although the state of a system may evolve during time, a non-negligible transition cost is incurred for transitioning from one state to another. In order to model such situations, Gupta et al. (ICALP 2014) and Eisenstat et al. (ICALP 2014) introduced a multistage model where the input is a sequence of instances (one for each time step), and the goal is to find a sequence of solutions (one for each time step) that are both (i) near optimal for each time step and (ii) as stable as possible. In this talk, we will give a survey of recent results in algorithmic multistage optimization, both in the offline and the online contexts and we will discuss connections with other models taking into account the evolution of data during time.

Keywords: Multistage optimization · Approximation algorithms · Online algorithms

Capacity Auctions: VCG Mechanism vs. Submodularity

Bo Chen

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Abstract. We study a form of capacity mechanism that combines capacity and supply auctions. We characterize how participants bid in this auction and show that, on a pay-as-bid basis, an equilibrium behavior gives Vickrey-Clarke-Groves (VCG) profits and achieves efficient outcomes when there is submodularity, which is in stark contrast with what in the existing literature—at equilibrium VCG payments achieve truthful bids and efficiency. We also provide some necessary and sufficient conditions for submodularity.

Keywords: Capacity mechanism · Supply auction · Submodularity

Convex Geometry in the Context of Artificial Intelligence

Sergei Chubanov

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Abstract. Applications of convex optimization in machine learning include support vector machines, polyhedral classifiers, deduction of disjunctive and conjunctive normal forms, time-series clustering, image segmentation, different models based on information theory, e.g., those involving Shannon entropy and Kullback-Leibler divergence. Virtually the whole spectrum of standard methods of convex optimization such as the gradient descent, the Frank-Wolfe algorithm, and interior-point methods is used for training deep neural networks. At the same time, some new results in the area of linear programming and convex optimization indicate that there are methodologies beyond the classical approaches which can lead to substantially more efficient machine learning algorithms and better interpretable machine learning models. So in this lecture we will address recent developments in convex optimization and convex analysis, in particular in the context of machine learning.

Keywords: Machine learning · Polyhedral theory · Information theory

Equilibrium Formulations of Relative Optimization Problems

Igor Konnov

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Abstract: We consider relative or subjective optimization problems where the goal function and feasible set are dependent of the current state of the system under consideration. We propose equilibrium formulations of the corresponding problems that lead to general (quasi-)equilibrium problems. We propose to apply a regularized version of the penalty method for the general quasi-equilibrium problem, which enables us to establish existence results under weak coercivity conditions and replace the quasi-equilibrium problem with a sequence of the usual equilibrium problems. We describe several examples of applications and show that the subjective approach can be extended to non-cooperative game problems.

Keywords: Quasiequilibrium problems · Penalty method · Weak coercivity conditions

Long Cycles in Graph and Hypergraphs

Alexander Kostochka

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Abstract. Finding long cycles in graphs is an NP-hard problem. Cycles in hypergraphs can be defined in several natural ways. Since finding long cycles in hypergraphs is hard for all kinds of cycles, it makes sense to consider approximate algorithms and extremal problems on long cycles in hypergraphs. We discuss several such extremal problems, recent progress on them and possible algorithms based on the proofs.

Keywords: Long cycles · Approximate algorithm · NP-hard problem

Inverse Combinatorial Optimization Problems

Panos M. Pardalos

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Abstract: Given an optimization problem and a feasible solution to it, the corresponding inverse optimization problem is to find a minimal adjustment of the cost vector under some norm such that the given solution becomes optimum. Inverse optimization problems have been applied in diverse areas, ranging from geophysical sciences, traffic networks, communication networks, facility location problems, finance, electricity markets, and medical decision-making. It has been studied in various optimization frameworks including linear programming, combinatorial optimization, conic, integer and mixed-integer programming, variational inequalities, and countably infinite linear problems and robust optimization. In this talk, we mainly concentrate on inverse combinatorial optimization problems (ICOP). We will introduce some classes of ICOP as well as general methods to solve them. Some open problems are proposed. We also discuss some generalized inverse optimization problems. We introduce inverse optimization problems on spanning trees and mainly concentrate on the inverse max+sum spanning tree problems in which the original problem aims to minimize the sum of a maximum weight and a sum cost of a spanning tree.

Keywords: Inverse optimization problem · Spanning tree · Optimization framework

Optimal Complexity Matrix Multiplication Like Computation Structures on Network-on-Chip Architecture Subject to Conflicts of Resource Allocation Constraints

Soumyendu Raha

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Abstract. Massively parallel many-core coarse-grain reconfigurable system-on-chip (SoC) solutions are being increasingly deployed for solving compute intensive problems in an energy constrained environment. In this talk we will present how computational structures similar to matrix multiplication, as in all pairs shortest path algorithm, convolution neural networks, digital filtering, etc. can be optimally (in terms of power, performance, and resource utilization) constructed, and realized as efficient datapaths on a matrix of compute units refered to as Hypercells. Several of such Hypercells interconnected over a network-on-chip (NoC) make up the massively parallel many-core runtime reconfigurable SoC. Deadlock free data communication on the network-on-chip (NoC) is provisioned and scheduled in a way such that the optimality of the computation structures is preserved both at the level of individual Hypercells, and at the level of the overall many-core SoC.

Keywords: Matrix multiplication · Hypercells · System-on-chip

Two-Stage Scheduling Models with Limited Storage

Yakov Zinder

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Abstract. Publications on the two-stage scheduling systems such as two-machine flow shops, job shops and open shops, single machine with coupled tasks, and their various generalisations constitute a significant part of the scheduling literature. Many of these publications consider a limited storage (buffer) or an additional limited resource. The majority of publications on scheduling with a buffer consider the buffer as storage that limits the number of jobs that have completed their first operation and are waiting for the commencement of the second one. The majority of scheduling models with an additional resource assume that the resource is used only during the processing on a machine. Despite numerous possible applications that include, for example, supply chains, multimedia systems and data gathering networks, much less research has been done on the models where the resource (storage space, buffer) is allocated to a job from the start of its first operation till the end of its second operation and where the storage requirement varies from job to job. The talk presents a survey of recent publications on this type of scheduling problems, which includes NP-hardness proofs, particular cases amenable for polynomial-time algorithms, polynomial approximation schemes, and integer programming based algorithms, including for example Lagrangian relaxation.

Keywords: Scheduling with limited storage · Approximation algorithms · NP-hard problem

Abstracts of Tutorials

Evolution of Sailor and Surgical Knots

Alexander Grigoriev

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Abstract. This is a survey of recent developments in the computational knot theory. We start with retrospective of well-known results and techniques bringing topological knot theory and graph theory together: knots equivalence, Reidemeister moves, knot diagrams and knot polynomials. Then, we briefly address the complexity of the unknotting problem. We illustrate the difficulty of unknotting on small and insightful examples of knots. The easy unknotting cases, e.g., knot diagrams of treewidth 2, are addressed in details. We wrap up the tutorial posing numerous open questions and introducing new research directions.

Keywords: Knot theory · Unknotting problem · Graph theory

Metrics of a Fixed Doubling Dimension: An Efficient Approximation of Combinatorial Problems

Mikhail Khachay

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Abstract. For decades, for many well-known combinatorial optimization problems, the approximability results in the class of algorithms with theoretical performance guarantees have had the quite similar nature. For instance, the classic Traveling Salesman Problem (TSP) is strongly NP-hard both in general and even in very specific settings, e.g. in the Euclidean plane. The problem is hardly approximable in general setting, it is APX-complete for an arbitrary metric, whilst, the problem admits polynomial time approximation schemes (PTAS) in the Euclidean space of an arbitrary fixed dimension. Recent results in the field of the analysis of finite metric spaces shed a light to the design of approximation schemes for a wide family of metric settings of these problems. In this tutorial, we give a short overview of such an approach leading to the PTAS for the metric TSP in metric space of any fixed doubling dimension.

Keywords: Metric combinatorial problem · APX-completness · PTAS

Game Theory and Social Networks

Vladimir V. Mazalov

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Abstract. Social networks represent a new phenomenon of our life. The growing popularity of social networks in the Web dates back to 1995 when American portal Classmates.com was launched. This project facilitated the soon appearance of online social networks (SixDegrees, LiveJournal, LinkedIn, MySpace, Facebook, Twitter, YouTube, and others) in the early 2000s. In Russia, the most popular networks are VKontakte and Odnoklassniki. Social networks are visualized using social graphs. Graph theory provides main analysis tools for social networks. In particular, by calculating centrality measures for nodes and edges one may detect active participants (members) of a social network. We use for the analysis of social networks game-theoretic approach. We propose a new concept of the betweenness centrality for weighted graphs using the methods of cooperative game theory. The characteristic function is determined by special way for different coalitions (subsets of the graph). The betweenness centrality is determined as the Myerson value. The results of computer simulations for some examples of networks, in particular, for the popular social network "VKontakte", as well as the comparing with the PageRank method are presented. Then we apply game-theoretic methods for community detection in networks. Finally, for approaches based on potential games we suggest a very efficient computational scheme using Gibbs sampling.

Keywords: Online social networks · Cooperative game theory · Social graphs

Practice of Using the Gurobi Optimizer

Andrey Melnikov

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Abstract. The general-purpose optimization software has never been more powerful than today. It is universal, customizable, controllable, and enables a user with a variety of tools and features to get better solutions in a shorter time. In this tutorial, we will overview the ingredients of one of the fastest MIP solvers, the Gurobi optimizer, that are relevant in academic studies. The key topics would be the internal organization of the solver, its tuning when solving LPs and MIPs, the most newly added features, and other selected ones.

Keywords: Optimization models · Mixed-integer programming · Software

A Survey of Machine Learning Problems from Optimization Point of View

Konstantin Vorontsov

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Abstract. In recent years, machine learning problems have become increasingly diverse and even exotic. We can no longer say that machine learning is basically classification, clustering, regression, and density estimation from empirical data. New types of machine learning, such as transfer, self-supervised, adversarial, privileged, meta, one-shot, few-shot, positive-unlabeled, and others, are expanding the boundaries of AI applications. Despite their diversity, each of them remains an optimization problem for the sum of a large number of terms. In this tutorial, you will learn how to set the meaning of a machine learning task by changing the construction of the terms, whether it be a parametric model of data, loss function, or regularizer.

Keywords: Machine learning · AI applications · Optimization

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