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Alexander S. Kulikov · Gerhard J. Woeginger (Eds.)

Computer Science – Theory and Applications

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Preface

This volume contains the 28 papers presented at CSR 2016, the 11th International Computer Science Symposium in Russia, held during June 9–13, 2016, in St. Petersburg, Russia. The symposium was organized by the Steklov Mathematical Institute at St. Petersburg of the Russian Academy of Sciences (PDMI). The first CSR took place in 2006 in St. Petersburg, and this was then followed by meetings in Ekaterinburg (2007), Moscow (2008), Novosibirsk (2009), Kazan (2010), St. Petersburg (2011), Nizhny Novgorod (2012), Ekaterinburg (2013), Moscow (2014), and Listvyanka (2015). CSR covers a wide range of areas in theoretical computer science and its applications.

The opening lecture at CSR 2016 was given by Christos Papadimitriou (Berkeley). Four other invited plenary lectures were given by Herbert Edelsbrunner (IST Austria), Vladimir Kolmogorov (IST Austria), Orna Kupferman (Hebrew University), and Virginia Vassilevska Williams (Stanford).

We received 71 submissions in total, and out of these the Program Committee selected 28 papers for presentation at the symposium and for publication in the proceedings. Each submission was reviewed by at least three Program Committee members. We expect the full versions of the papers contained in this volume to be submitted for publication in refereed journals. The Program Committee also selected the winners of the two Yandex Best Paper Awards.

Best Paper Award: Meena Mahajan and Nitin Saurabh, "Some Complete and Intermediate Polynomials in Algebraic Complexity Theory"
Best Student Paper Award: Alexander Kozachinskiy, "On Slepian–Wolf Theorem with Interaction"

Many people and organizations contributed to the smooth running and the success of CSR 2016. In particular our thanks go to:

- All authors who submitted their current research to CSR
- Our reviewers and subreferees whose expertise flowed into the decision process
- The members of the Program Committee, who graciously gave their time and energy
- The members of the local Organizing Committee, who made the conference possible
- The EasyChair conference management system for hosting the evaluation process
- Yandex
- The Government of the Russian Federation (Grant 14.Z50.31.0030)
- The Steklov Mathematical Institute at St. Petersburg of the Russian Academy of Sciences
- The European Association for Theoretical Computer Science (EATCS)
- Monomax Congresses and Incentives

June 2016

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Abstracts of Invited Talks

Topological Data Analysis with Bregman Divergences

Herbert Edelsbrunner
(joint work with Hubert Wagner)

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Given a finite set in a metric space, the topological analysis assesses its multi-scale connectivity quantified in terms of a 1-parameter family of homology groups. Going beyond Euclidean distance and really beyond metrics, we show that the basic tools of topological data analysis also apply when we measure distance with Bregman divergences. While these violate two of the three axioms of a metric, they have been found more effective for high-dimensional data. Examples are the Kullback–Leibler divergence, which is commonly used for text and images, and the Itakura–Saito divergence, which is popular for speech and sound.

Complexity Classifications of Valued Constraint Satisfaction Problems

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Classifying complexity of different classes of optimization problems is an important research direction in Theoretical Computer Science. One prominent framework is Valued Constraint Satisfaction Problems (VCSPs) in which the class is parameterized by a "language" Γ, i.e. a set of cost functions over a fixed discrete domain D. A instance of VCSP(Γ) is an arbitrary sum of functions from Gamma (possibly with overlapping variables), and the goal is to minimize the sum. The complexity of VCSP (Γ) depends on how "rich" the set Γ is. If, for example, Γ contains only submodular functions then any instance in VCSP(Γ) can be solved in polynomial time. If, on the other hand, Γ contains e.g. the "not-equal" relation then VCSP(Γ) can express the $|D|$-coloring problem and thus is NP-hard when $|D| > 2$.

I will show that establishing complexity classification for plain CSPs (i.e. when functions in Γ only take values in $\{0, \infty\}$) would immediately give the classification for general VCSPs. The key algorithmic tool that we use is a certain LP relaxation of the problem combined with the assumed algorithm for plain CSPs.

In the second part of the talk I will consider a version where we additionally restrict the structure of the instance to be *planar*. More specifically, I will describe a generalization of the Edmonds's blossom-shrinking algorithm from "perfect matching" constraints to arbitrary "even Δ-matroid" constraints. As a consequence of this, we settle the complexity classification of planar Boolean CSPs started by Dvořák and Kupec.

Based on joint work with Alexandr Kazda, Andrei Krokhin, Michal Rolínek, Johann Thapper and Stanislav Živný [1–3].

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On High-Quality Synthesis

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Abstract. In the synthesis problem, we are given a specification ψ over input and output signals, and we synthesize a system that realizes ψ: with every sequence of input signals, the system associates a sequence of output signals so that the generated computation satisfies ψ. The above classical formulation of the problem is Boolean. First, correctness is Boolean: a computation satisfies the specification ψ or does not satisfy it. Then, other important and interesting measures like the size of the synthesized system, its robustness, price, and so on, are ignored. The paper surveys recent efforts to address and formalize different aspects of quality of synthesized systems. We start with multi-valued specification formalisms, which refine the notion of correctness and enable the designer to specify quality, and continue to the quality measure of sensing: the detail in which the inputs should be read in order to generate a correct computation. The first part is based on the articles [1–3]. The second part is based on [4, 5].

The research leading to these results has received funding from the European Research Council under the European Union's Seventh Framework Programme (FP7/2007-2013)/ERC grant agreement no. 278410, and from The Israel Science Foundation (grant no. 1229/10).

Algorithm as a Scientific Weltanschauung

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The idea of the algorithm, present in the work of Euclid, Archimedes, and Al Khorizmi, and formalized by Alan Turing only eight decades ago, underlies much of the realm of science — physical, life, or social. Algorithmic processes are present in the great objects of scientific inquiry — the cell, the universe, the market, the brain — as well as in the models developed by scientists over the centuries for studying them. During the past quarter century this algorithmic point of view has helped make important progress in science, for example in statistical physics through the study of phase transitions in terms of the convergence of Markov chain Monte carlo algorithms, and in quantum mechanics through the lens of quantum computing.

In this talk I will recount a few more instances of this mode of research. Algorithmic considerations, as well as ideas from computational complexity, revealed a conceptual flaw in the solution concept of Nash equilibrium ubiquitous in economics. In the study of evolution, a new understanding of century-old questions has been achieved through purely algorithmic ideas. Finally, current work in theoretical neuroscience suggests that the algorithmic point of view may be invaluable in the central scientific question of our era, namely understanding how behavior and cognition emerge from the structure and activity of neurons and synapses.

Fine-Grained Algorithms and Complexity

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A central goal of algorithmic research is to determine how fast computational problems can be solved in the worst case. Theorems from complexity theory state that there are problems that, on inputs of size n, can be solved in $t(n)$ time but not in $t(n)^{1-\varepsilon}$ time for $\varepsilon > 0$. The main challenge is to determine where in this hierarchy various natural and important problems lie. Throughout the years, many ingenious algorithmic techniques have been developed and applied to obtain blazingly fast algorithms for many problems. Nevertheless, for many other central problems, the best known running times are essentially those of the classical algorithms devised for them in the 1950s and 1960s.

Unconditional lower bounds seem very difficult to obtain, and so practically all known time lower bounds are conditional. For years, the main tool for proving hardness of computational problems have been NP-hardness reductions, basing hardness on P$\neq$NP. However, when we care about the exact running time (as opposed to merely polynomial vs non-polynomial), NP-hardness is not applicable, especially if the running time is already polynomial. In recent years, a new theory has been developed, based on *"fine-grained reductions"* that focus on exact running times. The goal of these reductions is as follows. Suppose problem A is solvable in $a(n)$ time and problem B in $b(n)$ time, and no $a(n)^{1-\varepsilon}$ and $b(n)^{1-\varepsilon}$ algorithms are known for A and B respectively. The reductions are such that whenever A is fine-grained reducible to B (for $a(n)$ and $b(n)$), then a $b(n)^{1-\varepsilon}$ time algorithm for B (for any $\varepsilon > 0$) implies an $a(n)^{1-\varepsilon'}$ algorithm for A (for some $\varepsilon' > 0$). Now, mimicking NP-hardness, the approach is to (1) select a key problem X that is conjectured to require $t(n)^{1-o(1)}$ time, and (2) reduce X in a fine-grained way to many important problems. This approach has led to the discovery of many meaningful relationships between problems, and even sometimes to equivalence classes.

In this talk I will give an overview of the current progress in this area of study, and will highlight some new exciting developments.

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