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Novosibirsk, Russia, July 1–5, 2019
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Preface

The 14th International Computer Science Symposium in Russia (CSR 2019) was held during July 1–5, 2019, in Novosibirsk, Russian Federation. It was organized by Novosibirsk State University, Ershov Institute of Informatics Systems, and Sobolev Institute of Mathematics. This was the 14th edition of the annual series of meetings; previous editions were held in St. Petersburg (2006), Ekaterinburg (2007), Moscow (2008), Novosibirsk (2009), Kazan (2010), St. Petersburg (2011), Nizhny Novgorod (2012), Ekaterinburg (2013), Moscow (2014), Listvyanka (2015), St. Petersburg (2016), Kazan (2017), and Moscow (2018). The symposium covers a broad range of topics in theoretical computer science, ranging from fundamental to application-related.

This year, CSR was organized as a part of the Computer Science Summer in Russia and was held in parallel with the A.P. Ershov Informatics Conference (PSI conference series). The distinguished CSR keynote lecture was given by Andrew Yao. The lecture was delivered at a joint CSR-PSI distinguished lecture session, along with the lecture of Moshe Vardi, a keynote speaker of PSI, attended by CSR participants as well.

The seven other CSR invited plenary speakers were Michael Fellows (University of Bergen, Norway), Eric Fusy (École Polytechnique, France), Giuseppe Italiano (LUISS University, Italy), Meena Mahajan (Institute of Mathematical Sciences, India), Petros Petrosyan (Yerevan State University, Armenia), David Woodruff (Carnegie Mellon University, USA), and Dmitry Zhuk (Moscow State University, Russia). The Program Committee included 24 scientists and was chaired by Gregory Kucherov (CNRS and University of Paris-Est Marne-la-Vallée).

This volume contains the accepted papers as well as abstracts of invited lectures. We received 71 submissions in total. Each paper was reviewed by at least three Program Committee (PC) members. As a result, the PC selected 31 papers for presentation at the symposium and publication in these proceedings. The reviewing process was run using the EasyChair conference system.

The PC also selected two papers to receive the Best Paper Award and the Best Student Paper Award. These awards were sponsored by Yandex and Springer. The winners were:

– Best Paper Award: Ludmila Glinskih and Dmitry Itsykson, "On Tseitin Formulas, Read-Once Branching Programs and Treewidth"
– Best Student Paper Award: Jan-Hendrik Lorenz, "On the Complexity of Restarting"

We would like to thank many people and organizations that contributed to the organization of CSR 2019. In particular, our thanks go to:

– All invited speakers for accepting to give a talk at the conference
– The PC members, who graciously gave their time and energy
– All reviewers and additional reviewers for their expertise
– The members of the local Organizing Committee: Denis Ponomaryov (Ershov Institute of Informatics Systems), Oxana Tsidulko (Sobolev Institute

of Mathematics, Novosibirsk, Russia), Pavel Emelyanov (Novosibirsk State University), and Anastasia Karpenko (Novosibirsk State University).
– Our sponsors: Springer, the European Association for Theoretical Computer Science, Yandex, and UMA.TECH.

April 2019

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Abstract of Invited Talks

Two Heresies

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The advent of parameterization has allowed two important heresies concerning how we model and analyze computational complexity to be articulated. The first concerns the handling of real numbers. The second concerns decision problems and how these interface with scientific methodology. The talk will survey the basics of parameterized complexity and how these heresies naturally follow, and some recent results that illustrate them.

Schnyder Woods and the Combinatorics of Triangulations in Genus 0 and 1

Eric Fusy

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Schnyder woods are combinatorial structures on planar triangulations (maximal planar graphs embedded on the sphere) that can be formulated as certain partitions of the edges into three spanning trees. These structures have originally been introduced by Schnyder in 1989 to give a new planarity criterion for graphs in terms of the order dimension of their incidence posets. Since then, they have found many algorithmic applications, for instance in graph drawing, succinct encoding of meshes, efficient routing in planar networks, geometric spanners, random generation of planar graphs, etc.

I will present some of these applications, with an emphasis on bijective enumeration, giving in particular combinatorial proofs of the beautiful formulas $s_n = \frac{6(2n)!(2n+2)!}{n!(n+1)!(n+2)!(n+3)!}$ for the total number of Schnyder woods on triangulations with $n+3$ vertices and $t_n = \frac{2(4n+1)!}{(n+1)!(3n+2)!}$ for the number of planar triangulations with $n+3$ vertices. I will also explain how the bijective approach can be extended to count triangulations on the torus.

Based on joint work with Dominique Poulalhon, Gilles Schaeffer, Olivier Bernardi, and Benjamin Lévêque.

2-Connectivity in Directed Graphs

Giuseppe F. Italiano

LUISS University, Rome, Italy

We survey some recent theoretical and experimental results on 2-edge and 2-vertex connectivity in directed graphs. Despite being complete analogs of the corresponding notions on undirected graphs, in digraphs 2-connectivity has a much richer and more complicated structure. For undirected graphs it has been known for over 40 years how to compute all bridges, articulation points, 2-edge- and 2-vertex-connected components in linear time, by simply using depth first search. In the case of digraphs, however, the very same problems have been much more challenging and have been tackled only recently.

QBF Proof Complexity: An Overview

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How do we prove that a false QBF is indeed false? A proof of which size is needed? The special case when all quantifiers are existential is the well-studied setting of propositional proof complexity. Expectedly, universal quantifiers change the game significantly. Several proof systems have been designed in the last couple of decades to handle QBFs. Lower bound paradigms from propositional proof complexity cannot always be extended—in most cases feasible interpolation and consequent transfer of circuit lower bounds works, but obtaining lower bounds on size by providing lower bounds on width fails dramatically in one of the simplest QBF proof systems. A central lower bound paradigm for QBFs (with no analogue in the propositional world) involves viewing the QBF as a 2-player game and considering the winning strategies of the player who can win. Lower bounds follow from the hardness of computing these strategies in restricted models. Thus circuit lower bounds and QBF proof lower bounds are intimately intertwined. Lower bounds also follow from a semantic cost measure on winning strategies.

This talk will provide a broad overview of some of these developments. A brief introduction to the topic can be found in [1].

Keywords: Proof complexity · Quantified Boolean formulas · Resolution · Lower bounds

Reference

1. Mahajan, M.: Lower bound techniques for QBF proof systems. In: STACS, LIPIcs, vol. 96, pp. 2:1–2:8. Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik (2018)

Interval Edge-Colorings of Graphs: Variations and Generalizations

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Abstract. An edge-coloring of a graph G with colors $1,\ldots,t$ is called an *interval t-coloring* if all colors are used and the colors of edges incident to each vertex of G are distinct and form an interval of integers. The concept of interval edge-coloring of graphs was introduced by Asratian and Kamalian more than 30 years ago and was motivated by the problems in scheduling theory. In the last 10 years different types of variations and generalizations of interval edge-colorings were studied. In this talk we will give a survey of the topic and present a recent progress in the study of interval edge-colorings and their various variations and generalizations.

Introduction

We use [33] for terminology and notation not defined here. We consider graphs that are finite, undirected, and have no loops or multiple edges and multigraphs that may contain multiple edges but no loops. Let $V(G)$ and $E(G)$ denote the sets of vertices and edges of a multigraph G, respectively. The degree of a vertex $v \in V(G)$ is denoted by $d_G(v)$ and the maximum degree of G by $\Delta(G)$.

A proper edge-coloring of a multigraph G is a mapping $\alpha : E(G) \to \mathbf{N}$ such that $\alpha(e) \neq \alpha(e')$ for every pair of adjacent edges e and e' in G. If α is a proper edge-coloring of G and $v \in V(G)$, then the *spectrum of a vertex* v, denoted by $S(v, \alpha)$, is the set of colors appearing on edges incident to v. If α is a proper edge-coloring of a multigraph G and $v \in V(G)$, then the smallest and largest colors of the spectrum $S(v, \alpha)$ are denoted by $\underline{S}(v, \alpha)$ and $\overline{S}(v, \alpha)$, respectively.

An *interval t-coloring* of a multigraph G is a proper edge-coloring α of G with colors $1, \ldots, t$ such that all colors are used and for each $v \in V(G)$, the set $S(v, \alpha)$ is an interval of integers. The notion of interval colorings was introduced by Asratian and Kamalian [5] in 1987 and was motivated by the problem of finding compact school timetables, that is, timetables such that the lectures of each teacher and each class are scheduled at consecutive periods. This problem corresponds to the problem of finding an interval edge-coloring of a bipartite multigraph. There are graphs that do not have interval colorings (e.g. odd cycles, complete graphs of an odd order). For bipartite graphs, it is known that all subcubic graphs have interval colorings [15]. However, for every positive integer $\Delta \geq 11$, there exists a bipartite graph with maximum degree Δ that has no interval coloring [27]. Generally, it is an *NP*-complete problem to determine whether a bipartite graph has an interval coloring [31]. There are many papers devoted to this topic, in particular, surveys on the topic can be found in some books (see, for example, [4, 17, 22]).

In this talk we will discuss a recent progress in the study of interval edge-colorings and their various variations and generalizations.

Variations and Generalizations on Interval Edge-Colorings

One of the partial cases of an interval edge-coloring is a *sequential edge-coloring* which was considered in the early 1980s by Asratian [1] and Caro, Chonheim [9]. A *sequential t-coloring* of a multigraph G is a proper edge-coloring α of G with colors $1, \ldots, t$ such that all colors are used and for each $v \in V(G)$, $S(v, \alpha) = \{1, 2, \ldots, d_G(v)\}$. Sequential edge-colorings correspond to the problems of constructing a compact school timetable, when all groups and (or) teachers begin at the same time. This type of edge-coloring is also related to sum edge-colorings of graphs.

Let $G = (V, E)$ be a multigraph and $R \subseteq V$. An *interval (R, t)-coloring* of a multigraph G is a proper edge-coloring α of G with colors $1, \ldots, t$ such that all colors are used and for each $v \in R$, the set $S(v, \alpha)$ is an interval of integers. This type of interval colorings was the main subject of study in the doctoral thesis of Kamalian [18]. In the case of bipartite graphs with bipartition (X, Y), interval (R, t)-colorings with $R = X$ or $R = Y$ are also called *one-sided interval t-colorings*. Some new results on one-sided interval colorings of bipartite graphs were published in the last 5 years by Kamalian [20], Casselgren and Toft [11]. This type of coloring is of particular interest for graphs that do not have interval colorings.

In [26] it was given a generalization of interval edge-colorings of graphs, where the authors suggested the concept of *interval (t, k)-colorings* of graphs and studied the problem of the existence such colorings for some classes of graphs. Let k be a non-negative integer. An *interval (t, k)-coloring* of a graph G is a proper edge-coloring α of G with colors $1, \ldots, t$ such that all colors are used and the colors of edges incident to each vertex v satisfy the following condition:

$d_G(v) - 1 \leq \overline{S}(v, \alpha) - \underline{S}(v, \alpha) \leq d_G(v) + k - 1$.

The case $k = 1$ was also considered by some authors under the name "near-interval colorings". In particular, Casselgren and Toft [10] proved that some classes of bipartite graphs admit near-interval colorings. On the other hand, in [26] it was shown that there are bipartite graphs having no near-interval colorings. Recently, Petrosyan [25] proved that all graphs with maximum degree at most four admit near-interval colorings. On the other hand, he constructed bipartite graphs with maximum degree at least 18 that have no near-interval colorings.

Another important generalizations of interval edge-colorings are *cyclic interval colorings* which were introduced by de Werra and Solot [32] in 1991. A proper edge-coloring of a graph G with colors $1, 2, \ldots, t$ is called a *cyclic interval t-coloring* if for each vertex v of G the edges incident to v are colored by consecutive colors, under the condition that color 1 is considered as consecutive to color t. Cyclic interval colorings correspond to the problems of constructing a production schedule when the production cycle is repeated, tasks that are being processed at the beginning and at the end of the production cycle can be considered as non-preemptive. Generally, it is an *NP*-complete problem to determine whether a bipartite graph has a cyclic interval coloring [23]. There are many papers devoted to this topic [2, 10, 12, 19, 24, 29].

An interesting variant of interval colorings is *improper interval colorings* which was suggested by Hudák, Kardoš, Madaras and Vrbjarová [16]. An edge-coloring of a graph G with colors $1, \ldots, t$ is called an *improper interval t-coloring* if for each vertex v of G the edges incident to v are colored by consecutive colors. Since each graph has such a coloring, so it is natural to study the maximum number of colors used in improper interval colorings of a graph. In [16], they derived some bounds on the parameter and determined the exact value of this parameter for some classes of graphs.

Finally, we would like to mention that by some authors were introduced and studied measures of closeness for a graph to be interval colorable. A first attempt to introduce such a measure was done by Giaro, Kubale and Małafiejski [13] in 1999. The *deficiency* of a graph is the minimum number of pendant edges whose attachment to the graph makes the resulting graph interval colorable. The authors obtained many interesting results. In particular, they showed that there are graphs whose deficiency approaches the number of vertices [14]. The last years many papers were published on this topic [6–8, 21, 28]. In [30], Petrosyan and Sargsyan suggested another measure of closeness for a graph to be interval colorable. The *resistance* of a graph is the minimum number of edges that should be removed from a given graph to obtain an interval colorable graph. The connection between the deficiency and the resistance of a graph should be useful for study interval colorings of graphs. Recently, Asratian, Casselgren and Petrosyan [3] introduced a new measure of closeness for a graph to be cyclically interval colorable. The *cyclic deficiency* is an analogue of deficiency for cyclic interval colorings. In particular, they proved that the difference between the deficiency and cyclic deficiency can be arbitrarily large.

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Sketching as a Tool for Numerical Linear Algebra

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In this tutorial, I'll give an overview of near optimal algorithms for regression, low rank approximation, and a variety of other problems. The results are based on the sketch and solve paradigm, which is a tool for quickly compressing a problem to a smaller version of itself, for which one can then run a slow algorithm on the smaller problem. These lead to the fastest known algorithms for fundamental machine learning and numerical linear algebra problems, which run in time proportional to the number of non-zero entries of the input. Time-permitting I'll discuss extensions to tensors, NP-hard variants of low rank approximation, and robust variants of the above problems.

Fintech and Its Scientific Drivers

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Abstract. FinTech can be seen as the meeting of minds between economics and computer science in the digital age. Among its major intellectual foundations are reliable distributed computing and cryptography from the side of computer science, and efficient mechanism design for financial activities from the side of economics. In this talk we discuss some recent work in auction and blockchain from this perspective. For example, is it true that more revenue can always be extracted from an auction where the bidders are more willing to pay than otherwise? Can more revenue be extracted when the bidders are more risk-tolerant than otherwise? We also present some new results on blockchain fees. These results help shed light on some structural questions in economics whose answers are non-obvious.

Keywords: Fintech · Distributed computing · Blockchain fees

A Proof of CSP Dichotomy Conjecture[1]

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Abstract. We prove the CSP Dichotomy conjecture, and therefore characterize the complexity of the Constraint Satisfaction Problem for all constraint languages on a finite set.

Keywords: Constraint satisfaction problem · Computational complexity · CSP Dichotomy conjecture

Many combinatorial problems (graph coloring, solving systems of equations, and so on) can be expressed as constraint satisfaction problems, where the *Constraint Satisfaction Problem (CSP)* is a problem of deciding whether there is an assignment to a set of variables subject to some specified constraints. This class of problems is known to be NP-complete in general, but certain restrictions on the constraint language (set of allowed constraints) can ensure tractability.

In 1998 Feder and Vardi [2] conjectured that for any constraint language CSP is either solvable in polynomial time, or NP-complete. Later this conjecture (known as CSP Dichotomy conjecture) was formulated in the following form: CSP over a constraint language Γ can be solved in polynomial time if Γ admits a weak near-unanimity polymorphism, and it is NP-complete otherwise. The hardness result has been known since 2001, but the other part remained open until 2017 when two different polynomial algorithms for the weak near-unanimity case were suggested [1, 3].

We present one of the two algorithms, which proves the CSP Dichotomy Conjecture.

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