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Zvi Lotker · Boaz Patt-Shamir (Eds.)

Structural Information and Communication Complexity

25th International Colloquium, SIROCCO 2018
Ma'ale HaHamisha, Israel, June 18–21, 2018
Revised Selected Papers

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Preface

This volume contains the papers presented at the 25th International Colloquium on Structural Information and Communication Complexity (SIROCCO 2018). This year was particularly special for SIROCCO, as it was the half-jubilee of SIROCCO. The conference and celebration were held during June 18–21, in Ma’ale HaHamisha, Israel.

This year we received 46 submissions in response to the call for papers. Each submission was reviewed by at least three reviewers; we had a total of 21 Program Committee members and 49 external reviewers. The Program Committee decided to accept 23 papers for regular presentations, and eight papers for brief announcements. All these papers are included in this volume.

In addition the conference program included five additional talks: four keynote talks, and one talk by the winner of the SIROCCO Prize for Innovation in Distributed Computing. The invited speakers were Kurt Melhorn, David Peleg, Claire Mathieu, and Seth Pettie. Additionally, there was a talk by Zvi Lotker, the recipient of the 2018 SIROCCO Prize for Innovation in Distributed Computing. Papers representing these talks are also included in this volume.

The Program Committee selected the following paper as the winner of the SIROCCO 2018 Best Student Paper Award: “Mixed Fault Tolerance in Server Assignment: Combining Reinforcement and Backup,” by Tal Navon and David Peleg. Selected papers will also appear in a special issue of the *Theoretical Computer Science* journal devoted to SIROCCO 2018.

We would like to thank all of the authors for their high-quality submissions and all of the speakers for their excellent talks. We are grateful to the Program Committee and all external reviewers for their efforts in putting together a great conference program, to the Steering Committee, chaired by Andrzej Pelc, for their help and support, and to everyone who was involved in the local organization for making it possible to have SIROCCO 2018 in lovely Israel. Thanks also to Michael Borokhovich for his work as the proceedings chair.

August 2018

Zvi Lotker
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Invited Talks (Abstracts)

The Distributed Lovász Local Lemma Problem

Seth Pettie

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Abstract. The Lovász Local Lemma (LLL) is a well known tool to prove the *existence* of a combinatorial object, by showing that a randomly chosen object satisfies some property with positive (but small) probability. The LLL has been applied in numerous areas, e.g., to compute graph colorings, packet-routing schedules, and satisfying assignments to CNF-SAT formulae. *Algorithmic* versions of the LLL can compute such objects efficiently, in polynomial time.

In this talk I will define the *Distributed LLL* problem and survey its role in algorithm design and complexity theory in the LOCAL model. Among the take-away messages from this talk are the following:

- The LLL is instrumental for designing fast algorithms for edge-coloring, defective coloring, frugal coloring, and other problems.
- There is an exponential gap between randomized and deterministic complexity in the LOCAL model, and the Distributed LLL is the foremost problem realizing this gap.
- The randomized Distributed LLL is *complete* for sublogarithmic randomized time. In particular, any sublogarithmic time algorithm for a locally checkable labeling problem can be automatically sped up to match the time of the Distributed LLL.
- The *deterministic* complexity of the Distributed LLL is inextricably linked to computing network decompositions deterministically. On the one hand, network decompositions are the basis of the fastest Distributed LLL algorithms. Conversely, a deterministic $\text{polylog}(n)$ LLL algorithm implies a deterministic $(\text{polylog}(n), \text{polylog}(n))$ -network decomposition algorithm. (The Distributed LLL is PSLOCAL-hard.)

Keywords: LOCAL model · Probabilistic method · Graph coloring
Lovász local lemma

On Fair Division for Indivisible Goods

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We consider the task of dividing indivisible goods among a set of n agents in a fair manner. More precisely, we consider the following scenario. We have m distinct goods. Goods are available in several copies or items; there are k_j items of good j . The agents have decreasing utilities for the different items of a good, i.e., for all i and j

$$u_{i,j,1} \geq u_{i,j,2} \geq \dots \geq u_{i,j,k_j}.$$

An allocation assigns the items to the agents. For an allocation x , x_i denotes the multi-set of items assigned to agent i , and $m(j, x_i)$ denotes the multiplicity of j in x_i . The total utility of bundle x_i under valuation u_i is given by

$$u_i(x_i) := \sum_j \sum_{1 \leq \ell \leq m(j, x_i)} u_{i,j,\ell}.$$

Each agent has a utility cap c_i . The utility of bundle x_i for agent i is defined as

$$\bar{u}_i(x_i) = \min(c_i, u_i(x_i)).$$

Our notion of fairness is *Nash social welfare* (NSW) [Nas50], i.e., the goal is to maximize the geometric mean

$$\text{NSW}(x) = \left(\prod_{1 \leq i \leq n} \bar{u}_i(x_i) \right)^{1/n}$$

of the capped utilities. All utilities and caps are assumed to be integers.

The problem has a long history. For divisible goods, maximizing Nash Social Welfare (NSW) for any set of valuation functions can be expressed via an Eisenberg-Gale program [EG59]. For *additive valuations* ($c_i = \infty$ for each agent i and $k_j = 1$ for each good j) this program is equivalent to a Fisher market with identical budgets and maximizing NSW is achieved via the well-known fairness notion of competitive equilibrium with equal incomes (CEEI) [Mou03].

For indivisible goods, the problem is NP-complete [NNRR14] and APX-hard [Lee17]. Several constant-factor approximation algorithms are known for the case of additive valuations. They use different approaches.

The first one was pioneered by Cole and Gkatzelis [CG15] and uses spending-restricted Fisher markets. Each agent comes with one unit of money to the market. Spending is restricted in the sense that no seller wants to earn more than one unit of money. If the price p of a good is higher than one in equilibrium, only a fraction $1/p$ of the good is sold. Cole and Gkatzelis showed how to compute a spending restricted equilibrium in polynomial time and how to round its allocation to an integral

allocation with good NSW. In the original paper they obtained an approximation ratio of $2e^{1/e} \approx 2.889$. Subsequent work [CDG+17] improved the ratio to 2.

The second approach is via stable polynomials. Anari et al. [AGSS17] obtained an approximation factor of e .

The third approach is via integral allocations that are Pareto-optimal and envy-free up to one good introduced by Barman et al. [BMV17]. Let x_i be the set of goods that are allocated to agent i . An allocation is envy-free up to one good if for any two agents i and k , there is a good j such that $u_i(x_k - j) \leq u_i(x_i)$, i.e., after removal of one good from k 's bundle its value for i is no larger than the value of i 's bundle for i . Caragiannis et al. [CKM+16] have shown that an allocation maximizing NSW is Pareto-optimal and envy-free up to one good. Barman et al. [BMV17] studied allocations that are Pareto-optimal and almost envy-free up to one good (ε -EF1), i.e., $u_i(x_k - g) \leq (1 + \varepsilon)u_i(x_i)$, where ε is an approximation parameter. They showed that a Pareto-optimal and ε -EF1 allocation approximates NSW up to a factor $e^{1/e} + \varepsilon \approx 1.445 + \varepsilon$. They also showed how to compute such an allocation in polynomial time.

There are also constant-factor approximation algorithms beyond additive utilities.

Garg et al. [GHM18] studied budget-additive utilities ($k_j = 1$ for all goods j and arbitrary c_i). They showed how to generalize the Fisher market approach and obtained an $2e^{1/2e} \approx 2.404$ -approximation.

Anari et al. [AMGV18] investigated multi-item concave utilities ($c_i = \infty$ for all i and k_j arbitrary). They generalized the Fisher market and the stable polynomial approach and obtained approximation factors of 2 and e^2 , respectively.

In [CCG+18] is shown that the envy-free allocation approach can handle both generalizations combined and yields an approximation ratio of $e^{1/e} + \varepsilon \approx 1.445 + \varepsilon$. The approach via envy-freeness does not only yield better approximation ratios, it is also easier to state and to analyse.

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College Admissions in Practice

Claire Mathieu

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Abstract. The Gale-Shapley algorithm is the standard method in practice for stable marriage in large matching markets, but must be adapted to the constraints of each situation. We study the design of college admissions in a setting with the following features and constraints:

- Lack of trust in the platform: students worry that the rankings of students by schools will factor in their own ranking of schools
- Simplicity: the general public must be able to understand the method
- Transparency: the final result must not be given as a black box but come with an “explanation” that helps rebuild trust
- Quotas: schools have a legal obligation to respect certain quotas of student types. The types and quotas vary from school to school
- Housing: schools provide need-based housing to some of their students. Some students can only afford to attend if housing is provided. The offers must thus take into account both the students’ academic ranking and their ranking according to need.

I will present some preliminary work to address such issues, with an application to the French higher education admissions problem.

This is ongoing joint work with Hugo Gimbert.

Taking Turing to the Theater (Abstract of Award Lecture)

Zvi Lotker

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Abstract. Computer science has grown out of the seed of imitation. From von Neumann's machine to the famous Turing test, which sparked the field of AI, algorithms have always tried to imitate humans and nature. Examples of such "imitation algorithms" are simulated annealing which imitates thermodynamics, genetic algorithms which imitate biology, or deep learning which imitates human learning.

In this talk, I describe an algorithm which imitates human psychology. Specifically, I discuss M algorithms, which serve as a simple example of psychology-based imitation algorithms. The M algorithm is one of the simplest natural language processing (NLP) algorithms.

Respecting the long tradition of imitation algorithms, the M algorithm is simple yet powerful. Like other imitation algorithms, the M algorithm is able to efficiently solve difficult problems. The M algorithm pinpoints critical events in films, theater productions, and other scripts, revealing the rhythm of the texts.

At first glance, when trying to design an algorithm which pinpoints critical events of a text, it seems necessary for the algorithm to understand the complete text. Additionally, it would be expected that all layers of the narrative, background information, etc., would also be necessary. In short, it would be expected that the algorithm would imitate the human process of comprehending a text.

Surprisingly, the M algorithm utilizes the structure of the complete text itself without understanding even a *single* word, sentence, or character in order to discover critical events. The content of the narrative is not necessary for the algorithm to work. Other than an awareness of the illusion of time, borrowed from psychology, the M algorithm circumvents the human process of reading.

In the link below, we can see the computerized summary of several movies and relevant data. The M algorithm extracted the critical points on all those movies. As you can see these synopsis provides an "executive" summary of the movies. <https://zvilotker.myportfolio.com/psychological-alg>.

This talk is based on my upcoming book (in process).

Contents

Invited Talks and Brief Announcements

Realizability of Graph Specifications: Characterizations and Algorithms.	3
<i>Amotz Bar-Noy, Keerti Choudhary, David Peleg, and Dror Rawitz</i>	
A Self-Stabilizing Algorithm for Maximal Matching in Link-Register Model	14
<i>Johanne Cohen, George Manoussakis, Laurence Pilard, and Devan Sohler</i>	
Message-Efficient Self-stabilizing Transformer Using Snap-Stabilizing Quiescence Detection.	20
<i>Anaïs Durand and Shay Kutten</i>	
Constant-Space Self-stabilizing Token Distribution in Trees	25
<i>Yuichi Sudo, Ajoy K. Datta, Lawrence L. Larmore, and Toshimitsu Masuzawa</i>	
Distributed Counting Along Lossy Paths Without Feedback	30
<i>Vitalii Demianiuk, Sergey Gorinsky, Sergey Nikolenko, and Kirill Kogan</i>	
Make&Activate-Before-Break: Policy Preserving Seamless Routes Replacement in SDN.	34
<i>Yefim Dinitz, Shlomi Dolev, and Daniel Khankin</i>	
Brief Announcement: Fast Approximate Counting and Leader Election in Populations.	38
<i>Othon Michail, Paul G. Spirakis, and Michail Theofilatos</i>	
One-Max Constant-Probability Networks: Results and Future Work.	43
<i>Mark Korenblit</i>	
Reaching Distributed Equilibrium with Limited ID Space.	48
<i>Dor Bank, Moshe Sulamy, and Eyal Wasserman</i>	

Full Papers

Crash-Tolerant Consensus in Directed Graph Revisited (Extended Abstract) . . .	55
<i>Ashish Choudhury, Gayathri Garimella, Arpita Patra, Divya Ravi, and Pratik Sarkar</i>	

A Distributed Algorithm for Finding Hamiltonian Cycles in Random Graphs in $O(\log n)$ Time	72
<i>Volker Turau</i>	
Simple and Local Independent Set Approximation.	88
<i>Ravi B. Boppana, Magnús M. Halldórsson, and Dror Rawitz</i>	
On the Strongest Message Adversary for Consensus in Directed Dynamic Networks	102
<i>Ulrich Schmid, Manfred Schwarz, and Kyrill Winkler</i>	
Symmetric Rendezvous with Advice: How to Rendezvous in a Disk	121
<i>Konstantinos Georgiou, Jay Griffiths, and Yuval Yakubov</i>	
Two Rounds Are Enough for Reconstructing Any Graph (Class) in the Congested Clique Model.	134
<i>Pedro Montealegre, Sebastian Perez-Salazar, Ivan Rapaport, and Ioan Todinca</i>	
Space-Efficient Uniform Deployment of Mobile Agents in Asynchronous Unidirectional Rings	149
<i>Masahiro Shibata, Hirotsugu Kakugawa, and Toshimitsu Masuzawa</i>	
Explorable Families of Graphs	165
<i>Andrzej Pelc</i>	
A Characterization of t -Resilient Colorless Task Anonymous Solvability	178
<i>Carole Delporte-Gallet, Hugues Fauconnier, Sergio Rajsbaum, and Nayuta Yanagisawa</i>	
Deterministic Distributed Ruling Sets of Line Graphs	193
<i>Fabian Kuhn, Yannic Maus, and Simon Weidner</i>	
Broadcast with Energy-Exchanging Mobile Agents Distributed on a Tree. . . .	209
<i>Jurek Czyzowicz, Krzysztof Diks, Jean Moussi, and Wojciech Rytter</i>	
A Deterministic Distributed 2-Approximation for Weighted Vertex Cover in $O(\log N \log \Delta / \log^2 \log \Delta)$ Rounds.	226
<i>Ran Ben-Basat, Guy Even, Ken-ichi Kawarabayashi, and Gregory Schwartzman</i>	
Online Service with Delay on a Line.	237
<i>Marcin Bienkowski, Artur Kraska, and Paweł Schmidt</i>	
Mixed Fault Tolerance in Server Assignment: Combining Reinforcement and Backup	249
<i>Tal Navon and David Peleg</i>	

Communication Complexity in Vertex Partition Whiteboard Model 264
Tomasz Jurdzinski, Krzysztof Lorys, and Krzysztof Nowicki

Time-Bounded Influence Diffusion with Incentives 280
*Gennaro Cordasco, Luisa Gargano, Joseph G. Peters,
Adele A. Rescigno, and Ugo Vaccaro*

Balanced Allocations and Global Clock in Population Protocols:
An Accurate Analysis 296
Yves Mocquard, Bruno Sericola, and Emmanuelle Anceaume

On Knowledge and Communication Complexity in Distributed Systems 312
Daniel Pflieger and Ulrich Schmid

Connectivity and Minimum Cut Approximation in the Broadcast
Congested Clique 331
Tomasz Jurdziński and Krzysztof Nowicki

Biased Clocks: A Novel Approach to Improve the Ability To Perform
Predicate Detection with $O(1)$ Clocks 345
Vidhya Tekken Valapil and Sandeep Kulkarni

Gathering in the Plane of Location-Aware Robots in the Presence of Spies. . . . 361
*Jurek Czyzowicz, Ryan Killick, Evangelos Kranakis, Danny Krizanc,
and Oscar Morale-Ponce*

Formalizing Compute-Aggregate Problems in Cloud Computing 377
*Pavel Chuprikov, Alex Davydow, Kirill Kogan, Sergey Nikolenko,
and Alexander Sirotkin*

Priority Evacuation from a Disk Using Mobile Robots (Extended Abstract) . . . 392
*Jurek Czyzowicz, Konstantinos Georgiou, Ryan Killick,
Evangelos Kranakis, Danny Krizanc, Lata Narayanan,
Jaroslav Opatrny, and Sunil Shende*

Author Index 409