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Preface

DISC, the International Symposium on Distributed Computing, is an international forum on the theory, design, analysis, implementation, and application of distributed systems and networks. DISC is organized in cooperation with the European Association for Theoretical Computer Science (EATCS).

This volume contains the papers presented at DISC 2016, the 30th International Symposium on Distributed Computing, held during September 27–29, 2016, in Paris, France. The volume includes the citation for the 2016 Edsger W. Dijkstra Prize in Distributed Computing, jointly sponsored by DISC and PODC (the ACM Symposium on Principles of Distributed Computing), which was presented at PODC 2016 in Chicago and split between Noga Alon, Laszlo Babai, and Alon Itai; and Michael Luby for their two seminal papers both published in 1986: “A Fast and Simple Randomized Parallel Algorithm for the Maximal Independent Set Problem” and “A Simple Parallel Algorithm for the Maximal Independent Set Problem”. The volume also includes the citation for the 2016 Doctoral Dissertation Award, also jointly sponsored by DISC and PODC, which was presented at DISC 2016 in Paris. This year the award was split between Hsin-Hao Su, who completed his dissertation “Algorithms for Fundamental Problems in Computer Networks” in July 2015, under the supervision of Seth Pettie at the University of Michigan, and Shahar Timnat, who completed his dissertation “Practical Parallel Data Structures” in July 2015, under the supervision of Erez Petrank at Technion.

In total, 132 regular papers and 13 brief announcements were submitted and peer reviewed. The Program Committee selected 32 contributions out of the 132 submissions for regular presentations at the symposium. Each presentation was accompanied by a paper of up to 14 pages in this volume. Every submission was read and evaluated by at least three members of the Program Committee (PC). The PC was assisted by 148 external reviewers. Following a 10-day discussion period, the PC held a physical meeting in Paris, France, on July 4, 2016, with some of the PC members participating by conference call. Revised and expanded versions of several selected papers will be considered for publication in a special issue of the journal Distributed Computing. Four of the regular submissions that were rejected, but generated substantial interest among the members of the PC, were invited to be published as brief announcements. In total, 10 brief announcements were accepted for a short presentation and accompanied by a 3-page publication presented in the back-matter pages of this volume. Each brief announcement summarizes ongoing work or recent results, and it can be expected that these results will appear as full papers in later conferences or journals.

The Best Paper Award for DISC 2016 was presented to Dan Hefetz, Fabian Khun, Yannic Maus, and Angelika Steger for their paper “A Polynomial Lower Bound for Distributed Graph Coloring in a Weak LOCAL Model”. This year three papers have been nominated for the Best Student Paper Award. It will be awarded after a vote on the student talk at the conference during a special session. The nominated students are

Amir Abboud and Seri Khoury for their paper “Near-Linear Lower Bounds for Distributed Distance Computations, Even in Sparse Networks” (co-authored by Keren Censor-Hillel), Ohad Ben-Baruch for his paper “Lower Bound on the Step Complexity of Anonymous Binary Consensus” (co-authored by Hagit Attiya and Danny Hendler), and Lili Su for the paper “Non-Bayesian Learning in the Presence of Byzantine Agents” (co-authored by Nitin H. Vaidya).

The program featured three invited lectures, presented by Javier Esparza (Technische Universität München), Serge Abitboul (Inria & ENS Cachan), and Graham Cormode (University of Warwick). An abstract of each invited lecture is included in the front-matter pages of the proceedings. Three workshops were co-located with the DISC symposium this year. The 5th Workshop on Advances on Distributed Graph Algorithms (ADGA) chaired by Danupon Nanongkai, the 6th Research Meeting on Distributed Computing by Mobile Robots (MAC) co-chaired by Paola Flocchini and Maria Potop-Butucaru, and the 1st Workshop on Dynamic Graph in Distributed Computing (DGDC) co-chaired by Arnaud Casteight and Swan Dubois. The workshops AGDA and MAC were held on September 26, and DGDC on September 30.

We wish to thank the many contributors to DISC 2016: the authors of the submitted papers, the PC members, who performed a huge and difficult job, the three invited speakers, the conference general chair and local organizers led by Maria Potop-Butucaru for the great effort they put in, the logistics chair Lélia Blin, the sponsoring chair Petr Kuznetsov, the publicity chair Swan Dubois, the web chair Stéphane Rovedakis, the workshop organizers led by the workshop chair Colette Johnen, the Steering Committee for its guidance led by Shlomi Dolev.

DISC 2016 acknowledges the use of the EasyChair system for handling submissions, managing the review process, and producing the proceedings.

July 2016

Cyril Gavoille
David Ilcinkas

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The 2016 Edsger W. Dijkstra Prize in Distributed Computing

The Dijkstra Prize Committee has decided to grant the 2016 Edsger W. Dijkstra Prize in Distributed Computing jointly to Noga Alon, László Babai, Alon Itai, and Michael Luby, for the following two papers:

- "A Fast and Simple Randomized Parallel Algorithm for the Maximal Independent Set Problem" by Noga Alon, László Babai, and Alon Itai, published in *Journal of Algorithms*, 7(4):567–583, 1986
- "A Simple Parallel Algorithm for the Maximal Independent Set Problem" by Michael Luby, published in the *Proceedings of the* 17^{th} *Annual ACM Symposium on Theory of Computing (STOC)*, pp. 1–10, May 1985, and in *SIAM Journal on Computing*, 15(4):1036–1053, 1986

The Prize is awarded for outstanding papers on the principles of distributed computing, whose significance and impact on the theory and/or practice of distributed computing have been evident for at least a decade.

In these seminal works, the authors present, simultaneously and independently, an $O(\log n)$ time randomized distributed/parallel algorithm for the Maximal Independent Set (MIS) problem. MIS is regarded as a crown jewel of distributed symmetry breaking problems, and a central problem in the area of locality in distributed computing. The nominated papers provide a fascinatingly simple, elegant, and efficient randomized solution for this problem. While many variations exist, at their core, the algorithms are as simple as this:

> *Repeat until done: each node picks an* $O(\log n)$*-bit random number; strict local minima join the MIS, and get removed from the graph along with their neighbors.*

The algorithm has played a significant role in popularizing Distributed Computing to the broader Computer Science community. It is one of the most well-known distributed algorithms, and perhaps the one covered most frequently in general algorithms courses and textbooks, especially those on randomized algorithms.

The algorithm leads to $O(\log n)$ time randomized distributed/parallel algorithms for many other basic symmetry breaking problems such as $(\Delta + 1)$-coloring, Maximal Matching, and Ruling Sets. The awarded papers were among the pioneers in demonstrating the striking power of randomization in Distributed Computing, and have received more than 1,000 citations. Interestingly, they were also among the first in observing the simple yet powerful fact that one can derandomize parallel/centralized algorithms that use only d-wise independent randomness for constant d. This fact is used in the papers to derive deterministic parallel MIS algorithms, and it is now viewed as one of the basic derandomization techniques.

Thanks to its simplicity, the algorithm and its variations have been in widespread use, in various settings, from wireless networks to biological systems where symmetry breaking is required. This algorithmic result has also given rise to a host of fundamental and rich theoretical questions. Although to this day many of the questions remain open and continue intriguing the researchers, the follow up work on these questions have advanced our understanding of locality considerably.

The E.W. Prize is sponsored jointly by the ACM Symposium on Principles of Distributed Computing (PODC) and the EATCS Symposium on Distributed Computing (DISC). The prize is presented annually, with the presentation taking place alternately at PODC and DISC. This year it will be presented at PODC to be held at Chicago, IL, USA, July 25–29, 2016.

The 2016 Dijkstra Prize Committee:

Shlomi Dolev	Ben-Gurion University of the Negev
Pierre Fraigniaud	CNRS and University Paris Diderot
Cyril Gavoille	University of Bordeaux (Chair)
Dahlia Malkhi	VMware Research
Andrzej Pelc	Université du Québec en Outaouais
David Peleg	Weizmann Institute

The 2016 Doctoral Dissertation Award in Distributed Computing

The Doctoral Dissertation Award Committee has awarded the 2016 Principles of Distributed Computing Doctoral Dissertation Award to Dr. Hsin-Hao Su and to Dr. Shahar Timnat:

- "Algorithms for Fundamental Problems in Computer Networks" by Dr. Hsin-Hao Su supervised by Professor Seth Pettie at University of Michigan, Ann Arbor.

  Dr. Hsin-Hao Su completed his dissertation "Algorithms for Fundamental Problems in Computer Networks" in July 2015, under the supervision of Professor Seth Pettie, at the University of Michigan, Ann Arbor.
  Hsin-Hao's thesis provides efficient algorithms for fundamental graph problems that arise in networks, in both sequential and distributed settings. Among the latter, the most prominent are his results concerning graph coloring. He showed that numerous existential results in graph theory can be viewed as distributed algorithms with a tiny probability of success (guaranteed by the Lovasz Local Lemma) and that a fast distributed algorithm for the constructive LLL could be used to amplify the success probability to nearly 1. Hsin-Hao presented a $O(\log n)$-time randomized algorithm for the LLL, and illustrated how it could be applied to graph coloring problems where the existence of the coloring is not obvious. Moser and Tardos observed that any LLL algorithm in their "resampling" framework requires $\Omega(\log n)$ time, so this result is optimal within a natural design space. Hsin-Hao used his LLL algorithm to establish an $O(\log n)$-time algorithm for $(4 + o(1))\Delta/\ln\Delta$-coloring triangle-free graphs. This result more than any other exhibits the technical virtuosity of Hsin-Hao: he discovered not only a great algorithm, but a new bound on the chromatic number of triangle-free graphs.
  Before Hsin-Hao's work many symmetry-breaking problems appeared to have similar complexity: $(\Delta + 1)$-coloring seemed similar to the Maximal Independent Set (MIS) problem and $(2\Delta - 1)$-edge coloring seemed similar to Maximal Matching. Hsin-Hao developed new tools for analyzing randomized coloring algorithms in locally sparse graphs, one consequence of which is that $(2\Delta - 1)$-edge coloring is provably easier than maximal matching.

- "Practical Parallel Data Structures" by Dr. Shahar Timnat supervised by Professor Erez Petrank at Technion.

  Dr. Shahar Timnat completed his dissertation "Practical Parallel Data Structures" in July 2015 under the supervision of Professor Erez Petrank at Technion.
  Shahar's dissertation provides an outstanding advance in our understanding of concurrent algorithms, including novel efficient practical algorithms and a theoretical study of their fundamental properties. The literature on highly-concurrent data structures focuses on lock-freedom, which guarantees

that some thread will eventually make progress, and wait-freedom, which guarantees that all threads will eventually make progress in spite of failures and delays of other threads. It was believed that the overhead and complexity required to achieve wait-freedom is too high for practical systems. Shahar's thesis changes this traditional belief by showing that lock-free algorithms can be made wait-free automatically and with a small performance penalty. His construction is realistic and practical.

Shahar provides a practical wait-free iterator, an original construct that no one knew how to do before. Another contribution is a novel and helpful analysis of the common "helping" pattern that is typically used for constructing wait-free algorithms. This analysis shows that there exist circumstances where some form of helping is required. Like many lower bounds, this has practical impact because it spares data structure designers from wasting their time trying on other approaches. Finally, the thesis proposes a simple transactional interface that is well-adapted both to architectures that provide hardware support for transactions, and to those that do not, yielding a way to design data structures that easily can be ported from one platform to another.

The 2016 Doctoral Dissertation Award Committee:

Yoram Moses Technion
Andrzej Pelc Université du Québec en Outaouais (Chair)
Paul Spirakis University of Liverpool

Invited Lectures

Verification of Population Protocols

Javier Esparza

Technische Universität München

Abstract. Population protocols (Angluin et al., PODC 2004) are a formal model of sensor networks consisting of identical mobile devices. When two devices come into the range of each other, they interact and change their states. Computations are infinite sequences of pairwise interactions where the interacting processes are picked by a fair scheduler. A population protocol is well specified if for every initial configuration C of devices and for every fair computation starting at C, all devices eventually agree on a consensus value that only depends on C. If a protocol is well-specified, then it is said to compute the predicate that assigns to each initial configuration its consensus value. The main two verification problems for population protocols are: Is a given protocol well-specified? Does a given protocol compute a given predicate?

While the class of predicates computable by population protocols was already established in 2007 (Angluin et al., Distributed Computing), the decidability of the verification problems remained open until 2015, when my colleagues and I finally managed to prove it (Esparza et al., CONCUR 2015, improved version to appear in Acta Informatica). In the talk I report on our results and discuss some new developments.

Personal Information Management Systems and Knowledge Integration

David Montoya[1], Thomas Pellissier Tanon[2], and Serge Abiteboul[3]

[1] Engie Ineo & ENS Cachan & Inria
[2] ENS Lyon
[3] INRIA & ENS Cachan

Abstract. Personal data is constantly collected, either voluntarily by users in emails, social media interactions, multimedia objects, calendar items, contacts, etc., or passively by various applications such as GPS of mobile devices, transactions, quantified self sensors, etc. The processing of personal data is complicated by the fact that such data is typically stored in silos with different terminologies/ontologies, formats and access protocoles. Users are more and more loosing control over their data; they are sometimes not even aware of the data collected about them and how it is used.

We discuss the new concept of Personal Information Management Systems (PIMS for short) that allows each user to be in a position to manage his/her personal information. Some applications are run directly by the PIMS, so are under direct control of the user. Others are in separate systems, that are willing to share with the PIMS the data they collect about that particular user. In that later case, the PIMS is a system for distributed data management. We argue that the time has come for PIMS even though the approach requires a sharp turn from previous models based on the monetisation of personal data. We consider research issues raised by PIMS, either new or that acquire a new avor in a PIMS context.

We also present works on the integration of users data from different sources (such as email messages, calendar, contacts, and location history) into a PIMS. The PIMS we consider is a Knowledge Base System based on Semantic Web standards, notably RDF and schema.org. Some of the knowledge is episodical (typically related to spatio-temporal events) and some is semantic (knowledge that holds irrelative to any such event). Of particular interest is the cross enrichment of these two kinds of knowledge based on the alignment of concepts, e.g., enrichment between a calendar and a geographical map using the location history. The goal is to enable users via the PIMS to query and perform analytics over their personal information within and across different dimensions.

Matching and Covering in Streaming Graphs

Graham Cormode

Department of Computer Science, University of Warwick, UK

Abstract. Problems related to (maximum) matchings and vertex covering in graph have a long history in Combinatorics and Computer Science. They arise in many contexts, from choosing which advertisements to display to online users, to characterizing properties of chemical compounds. Stable matchings have a suite of applications, from assigning students to universities, to arranging organ donations. These have been addressed in a variety of different computation models, from the traditional RAM model, to more recent sublinear (property testing) and external memory (MapReduce) models. Matching has also been studied for a number of classes of input graph: including general graphs, bipartite graphs, weighted graphs, and those with some sparsity structure.

We focus on the streaming case, where each edge is seen once only, and we are restricted to space sublinear in the size of the graph (ie., no. of its vertices). In this case, the objective is to find (approximately) the size of the matching. Even here, results for general graphs are either weak or make assumptions about the input or the stream order. In this talk, we describe work which seeks to improve the guarantees in various ways. First, we consider the case when we are given a promise on the size of the solution: the matching is of size at most k, say. This puts us in the realm of parameterized algorithms and kernelization, but with a streaming twist. We show that algorithms to find a maximal matching can have space which grows quadratically with k. Second, we consider restricting to graphs that have some measure of sparsity – bounded arboricity, or bounded degree. This aligns with reality, where most massive graphs have asymptotically fewer than $O(n^2)$ edges. In this case, we show algorithms whose space cost is polylogarithmic in the size of the input, multiplied by a constant that depends on the level of sparsity, in order to estimate the size of the maximum matching. The techniques used rely on ideas of sampling and sketching, developed to handle data which arrives as a stream of observations, coupled with analysis of the resulting randomized algorithms.

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