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Developments in Language Theory

20th International Conference, DLT 2016 Montréal, Canada, July 25–28, 2016 Proceedings

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Preface

The DLT 2016 Conference was organized by the Laboratoire de Combinatoire et d'Informatique mathématique (LaCIM) during July 25–28, 2016. It was the 20th edition of a series initiated in 1993 by G. Rozenberg and A. Salomaa in Turku (Finland). These conferences took place every odd year in the first editions: Magdeburg, Germany (1995), Thessaloniki, Greece (1997), Aachen, Germany (1999), and Vienna, Austria (2001). Since then, the event was held in Europe on every odd year and outside Europe on every even year. The locations of DLT conferences since 2002 have been: Kyoto, Japan (2002), Szeged, Hungary (2003), Auckland, New Zealand (2004), Palermo, Italy (2005), Santa Barbara, California, USA (2006), Turku, Finland (2007), Kyoto, Japan (2008), Stuttgart, Germany (2009), London, Ontario, Canada (2010), Milan, Italy (2011), Taipei, Taiwan (2012), Marne-la-Vallée, France (2013), Ekaterinburg, Russia (2014), Liverpool (2015).

This series of International Conferences on Developments in Language Theory provides a forum for presenting current developments in formal languages and automata. Its scope is very general and includes, among others, the following topics and areas: combinatorial and algebraic properties of words and languages; grammars, acceptors and transducers for strings, trees, graphs, arrays; algebraic theories for automata and languages; codes; efficient text algorithms; symbolic dynamics; decision problems; relationships to complexity theory and logic; picture description and analysis; polyominoes and bidimensional patterns; cryptography; concurrency; cellular automata; bio-inspired computing; quantum computing.

This volume of *Lecture Notes in Computer Science* contains the papers that were presented at DLT 2016. There were 48 submissions and each of them was reviewed by at least three reviewers. The selection process was undertaken by the Program Committee with the help of generous reviewers who accepted to participate in the selection of 32 papers within a tight schedule. The present volume also includes the abstracts of the lectures given by four invited speakers

- Valérie Berthé: "Tree Sets: From Bifix Codes to Algebraic Word Combinatorics"
- Emilie Charlier: "Permutations and Shifts"
- Cédric Chauve: "Counting, Generating, and Sampling Tree Alignments"
- Janusz A. (John) Brzozowski: "Towards a Theory of Complexity for Regular Languages"

We warmly thank Valérie, Émilie, Cédric, and Janusz for delivering sound lectures intended for a large audience. We take this opportunity to thank all authors for their submissions and the anonymous reviewers who provided numerous and constructive reviews that led to the selection of high-standard contributions.

Special thanks are due to Alfred Hofmann and the *Lecture Notes in Computer Science* team at Springer for having granted us the opportunity to publish this special issue devoted to DLT 2016 and for their help during the final stages.

The organization of DLT 2016 benefited from the support of the Centre de Recherches Mathématiques (CRM) and the Canadian Research Chair in Algebra, Combinatorics and Computer Science. The reviewing process was facilitated by the EasyChair conference system created by Andrei Voronkov.

Finally, we were fortunate to have a number of collaborators who contributed to the success of the conference: the secretary Johanne Patoine, our postdoctoral fellows Mathieu Guay-Paquet and Nathan Williams, our students Mélodie Lapointe, Nadia Lafrenière, and Hugo Tremblay. Our warmest thanks for their invaluable assistance and contribution in the organization of the event.

June 2016

Srečko Brlek
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Abstracts of Invited Talks

Tree Sets: From Bifix Codes to Algebraic Word Combinatorics

Valérie Berthé

Université Paris-Diderot, Paris, France

Tree sets are languages defined with regard to a tree property: they are sets of factors of a family of infinite words that are defined in terms of the possible left and right extensions of their factors, with their extension graphs being trees. This class of words with linear factor complexity includes classical families such as Sturmian words, interval exchanges or else Arnoux-Rauzy words. We discuss here their combinatorial, ergodic and algebraic properties. This includes algebraic properties of their return words, and of maximal bifix codes defined with respect to their languages. This lecture is based on joint work with C. De Felice, V. Delecroix, F. Dolce, J. Leroy, D. Perrin, C. Reutenauer, G. Rindone.

Towards a Theory of Complexity for Regular Languages

Janusz A. (John) Brzozowski

University of Waterloo, Waterloo, Canada

The state complexity of a regular language is the number of states in a complete minimal deterministic finite automaton (DFA) recognizing the language. The state complexity of an operation on regular languages is the maximal state complexity of the result of the operation as a function of the state complexities of the operands. The state complexity of an operation gives a worst-case lower bound on the time and space complexity of the operation, and has been studied extensively for that reason. The first results on the state complexity of union, concatenation, Kleene star and four other less often used operations were stated without proof by Maslov in 1970, but this paper was unknown in the West for many years. In 1994, Yu, Zhuang and K. Salomaa studied the complexity of basic operations (union, intersection, concatenation, star and reversal) and provided complete proofs. Since then, many authors obtained numerous results for various subclasses of the class of regular languages, and for various operations. Moreover, other measures of complexity, including the size of the syntactic semi-group of a language, have been added. In this talk I will summarize the results obtained in the past few years in the area of complexity of regular languages and finite automata.

Permutations and Shifts

Émilie Charlier

Université de Liège, Liège, Belgique

The entropy of a symbolic dynamical system is usually defined in terms of the growth rate of the number of distinct allowed factors of length n. Bandt, Keller and Pompe showed that, for piecewise monotone interval maps, the entropy is also given by the number of permutations defined by consecutive elements in the trajectory of a point. This result was the starting point of several works of Elizalde where he investigates permutations in shift systems, notably in full shifts and in beta-shifts. The goal of this talk is to survey Elizalde's results. I will end by mentioning the case of negative beta-shifts, which has been simultaneously studied by Elizalde and Moore on the one hand, and by Steiner and myself on the other hand.

A full version is available at http://dlt2016.lacim.uqam.ca/en/files/charlier.pdf.

Counting, Generating and Sampling Tree Alignments

Cédric Chauve

Simon Fraser University, Burnaby, Canada

Pairwise alignment of ordered rooted trees is a natural extension of the classical pairwise sequence alignment, with applications in several fields, such as RNA secondary structure comparison for example. Motivated by this application, and the need to explore the space of possibly sub-optimal alignments, we introduce the notion of unambiguous tree alignment. We first take an enumerative combinatorics point of view and propose a decomposition scheme for unambiguous tree alignments, under the form of a context-free grammar, that leads to precise asymptotic enumerative results, by mean of basic analytic combinatorics. We then shift our focus to algorithmic questions, and show our grammar can be refined into a dynamic programming algorithm for sampling tree alignments under the Gibbs-Boltzmann probability distribution. We also provide some surprising average case complexity results on the tree alignment problem. This work, in collaboration with Yann Ponty and Julien Courtiel, illustrates the potential of considering algorithmic questions from the point of view of enumerating the solution space.

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