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Preface

This volume contains the papers presented at the 15th International Algorithms and Data Structures Symposium (WADS 2017), which was held from July 31 to August 2, 2017, in St. John's, Newfoundland, Canada. WADS, which alternates with the Scandinavian Symposium and Workshops on Algorithm Theory, SWAT, is a forum for researchers in the area of design and analysis of algorithms and data structures.

In response to the call for papers, 109 papers were submitted. From these submissions, the Program Committee selected 49 papers for presentation at WADS 2017, using a combination of online discussion in EasyChair and a one-day video conference. In addition, invited lectures were given by Pankaj Agarwal (Duke University), Michael Saks (Rutgers University), and Virginia Vassilevska Williams (MIT).

Special issues of papers selected from WADS 2017 are planned for two journals, *Algorithmica* and *Computational Geometry: Theory and Applications*.

We gratefully acknowledge the support of the WADS 2017 sponsors: Memorial University of Newfoundland, The Fields Institute for Research in Mathematical Sciences, Elsevier, and Springer.

July 2017

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Abstracts of Invited Lectures

Algorithms for Geometric Similarity: Recent Developments

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Abstract. A basic problem in classifying, or searching for similar objects, in a large set of geometric objects is computing similarity between two objects. There has been extensive work on computing geometric similarity between two objects. In many applications, it is not sufficient to return a single similarity score. Instead, a map between two objects that identifies shared structures is needed.

This talk discusses some recent work on computing maps between two or more objects. The talk consists of three parts. The first part focuses on computing maps between two weighted point sets, say, distributions. The second part is devoted to computing maps between a pair of trajectories. The third part will briefly discuss computing Gromov-Hausdorff distance between two metric spaces.

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How efficiently can easy dynamic programs be approximated?

Michael Saks

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Abstract. In many of the simplest examples of dynamic programming, inputs of size n are processed by constructing an $n \times n$ matrix, where each entry is obtained by a simple function of a few entries above and to the left. This yields a simple $O(n^2)$ algorithm for such problems. These algorithms naturally arise, for example, in evaluating various distance measures between two strings, such as LCS (longest common subsequence) distance, Edit Distance, Frechet Distance, and Dynamic Time Warping Distance, and the i,j entry of the matrix gives the desired measure between the length i prefix of the first string, and the length j prefix of the second. With few exceptions (such as the Longest Increasing Subsequence (LIS) problem where the quadratic time algorithm has been improved to $O(n\log(n))$), these quadratic time dynamic programming algorithms remain essentially the fastest exact algorithms (except for $n^{o(1)}$ factor improvements). This phenomenon has been the focus of much recent research in *fine grain complexity*, and it has been shown that for many such problems, reducing the running time to $O(n^{2-\varepsilon})$ would contradict the Strong Exponential Time Hypothesis (e.g., Bringmann [7], Abboud, Backurs and Williams [2], Backurs and Indyk [6] and Bringmann and Kunnermann [8].)

If we are willing to accept a good approximation (rather than the exact answer), then there is much less evidence that quadratic complexity is needed. Bringmann [7] proved that the Strong Exponential Hypothesis implies that truly subquadratic algorithms cannot achieve approximation factors arbitrarily close to 1. Abboud and Backurs [1] provided complexity theoretic evidence that truly subquadratic deterministic algorithms cannot achieve approximation factors arbitrarily close to 1 for edit distance and LCS-distance.

If we allow randomized algorithms, it is quite possible that problems such as edit distance and LCS distance have constant factor approximation algorithms that are significantly faster than quadratic. Andoni, Krauthgamer and Onak [4] gave a nearly linear time algorithm that achieves a polylogarithmic approximation to edit distance. For certain special cases of LCS-distance, arbitrarily good *additive* εn *error* approximation algorithms are known that are substantially faster than the best exact algorithms. For the LIS Problem, Saks and Seshadhri [11] (following the work of Ailon, Chazelle, Comandur and Liu [3] and Parnas, Ron and Rubinfeld [10]) developed such an additive approximation

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whose running time is only polylogarithmic in the length of the input. For the special case of LCS-distance between two permutations of $\{1,\ldots,n\}$ (Ulam Distance), Naumovitz, Saks and Seshadhri [9] (following earlier work of Andoni and Nguyen [5]) obtained such an additive approximation running in time $\tilde{O}(\sqrt{n})$.

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Fine-Grained Complexity of Problems in P

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Abstract. 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 their classical algorithms from 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 problem is already solvable in polynomial time. In recent years, a new theory has been developed, based on “fine-grained reductions” that focus on exact running times. Mimicking NP-hardness, the approach is to (1) select a key problem X that is conjectured to require essentially $t(n)$ time for some t, 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.

The main key problems used to base hardness on have been: the 3SUM problem, the CNF-SAT problem (based on the Strong Exponential Time Hypothesis (SETH)) and the All Pairs Shortest Paths Problem. Research on SETH-based lower bounds has flourished in particular in recent years showing that the classical algorithms are optimal for problems such as Approximate Diameter, Edit Distance, Frechet Distance, Longest Common Subsequence, many dynamic graph problems, etc.

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

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