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Rusins Freivalds (Eds.)

Algorithm Theory – SWAT 2006

10th Scandinavian Workshop on Algorithm Theory
Riga, Latvia, July 2006
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Preface

This volume contains the papers presented at SWAT 2006, the 10th Scandinavian Workshop on Algorithm Theory. The workshop, which is really a full-fledged international conference, is intended as a forum for researchers in the area of design and analysis of algorithms and data structures. Since 1988 SWAT has been held biennially in the five Nordic countries; it has a loose association with WADS (Workshop on Algorithms and Data Structures) that is held in odd-numbered years in North America. This 10th SWAT was held in the neighboring Baltic region. More precisely, it was held on July 6-8, 2006, at the Institute of Mathematics and Computer Science in the University of Latvia in Riga.

The call for papers invited contributions in all areas of algorithms and data structures, including approximation algorithms, computational biology, computational geometry, distributed algorithms, external-memory algorithms, graph algorithms, online algorithms, optimization algorithms, parallel algorithms, randomized algorithms, string algorithms and algorithmic game theory. A total of 154 papers were submitted, out of which the Program Committee selected 36 for presentation at the workshop. In addition, invited lectures were given by Kazuo Iwama (Kyoto University), Raimund Seidel (Universität des Saarlandes) and Robert E. Tarjan (Princeton University).

We would like to thank all the people who contributed to making SWAT 2006 a success. In particular, we thank the Program Committee and all of our many colleagues who helped the committee evaluate the submissions. We also thank Gerth S. Brodal for his invaluable help with the submission process and the Program Committee software.

May 2006 Lars Arge and Rusins Freivalds

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Invited Papers

Contributed Papers

Top-Down Analysis of Path Compression: Deriving the Inverse-Ackermann Bound Naturally (and Easily)

Raimund Seidel

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Path compression is used in a number of algorithms, most notably in various very natural solutions to the so-called Union-Find problem. This problem is basic and important enough to be covered in most introductory courses and textbooks on algorithms and data structures. However the performance analysis of the solutions is more often than not at best incomplete if not omitted altogether. Already the definition of the function α, the interesting constituent of the time bound, as a quasi inverse of the Ackermann function is complicated and not easy to understand.

All the previous analyses of path compression proceed in a bottom-up fashion, employing rather intricate charging schemes, sometimes cloaked in the language of potential functions for amortized analysis, and they need to introduce the Ackermann function beforehand in order to be properly formulated.

I will present a new [1], rather easy way of analyzing the running times of union-find algorithms. It is based on a relatively simple top-down approach and naturally leads by itself to this famous "Inverse Ackermann" function without ever having to talk about the Ackermann function itself.

I will discuss how this top-down approach can also be made to work for related procedures such as path compaction. Finally I will consider the case of moderately sized instances and will derive some explicit, rather small upper bounds on the number of pointer changes.

Reference

1. Seidel, R., Sharir, M.: Top-Down Analysis of Path Compression. SIAM J. Comput. **34** (2005) 515–525.

L. Arge and R. Freivalds (Eds.): SWAT 2006, LNCS 4059, p. 1, 2006.

Results and Problems on Self-adjusting Search Trees and Related Data Structures

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The splay tree is a form of self-adjusting search tree invented almost 25 years ago. Splay trees are remarkably efficient in both theory and practice, but many questions concerning splay trees and related data structures remain open. Foremost among these is the dynamic optimality conjecture, which states that the amortized efficiency of splay trees is optimum to within a constant factor among all kinds of binary search trees. That is, are splay trees constant-competitive? A broader question is whether there is any form of binary search tree that is constant-competitive. Recently, three different groups of researchers have devised kinds of search trees that are loglog-competitive, improving on the log-competitiveness of balanced trees. At least one of these data structures, the multisplay tree, has many if not all of the nice asymptotic properties of splay trees (even though it is more complicated than splay trees). We review this recent work and look at remaining open problems, of which there are many, including resolving the question of whether splay trees themselves are loglog-competitive.

We also look at a more complicated class of data structures that maintain information about a dynamic collection of disjoint trees. We review various versions of the dynamic trees problem, describe efficient solutions (both worst-case and amortized), and list open problems.

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Classic and Quantum Network Coding*

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Ahlswede, Cai, Li, and Yeung (IEEE Trans. Inform. Theory, 2000) showed that the fundamental law for network flow, the max-flow min-cut theorem, no longer applies for "digital information flow." The simple, nice example they gave is called the Butterfly network illustrated in Fig. 1. The capacity of each directed link is all one and there are two source-sink pairs s_1 to t_1 and s_2 to t_2. Notice that both paths have to use the single link from s_0 to t_0 and hence the total amount of (conventional commodity) flow in both paths is bounded by one, say, 1/2 for each. In the case of digital information flow, however, the protocol shown in Fig. 2 allows us to transmit two bits, x and y, simultaneously. Thus, we can effectively achieve larger channel capacity than can be achieved by simple routing. This is known as *network coding* since this seminal paper and has been quite popular as a mutual interest of theoretical computer science and information theory.

The natural question is whether such a capacity enhancement is also possible for *quantum* information, more specifically, whether we can transmit two qubits from s_1 to t_1 and s_2 to t_2 simultaneously, as with classical network coding. Note that there are (at least) two tricks in the classical case. One is the EX-OR (Exclusive-OR) operation at node s_0; one can see that the bit y is encoded by using x as a key which is sent directly from s_1 to t_2, and vise versa. The other is the exact copy of one-bit information at node t_0. Our answer to the question obviously depends on if we can find quantum counterparts for these key operations.

Neither seems easy: For the copy operation, there is the famous no-cloning theorem. Also, there is no obvious way of encoding a quantum state by a quantum state at s_0. Consider, for example, a simple extension of the classical operation at node s_0, i.e., a controlled unitary transform U as illustrated in Fig. 3. (Note that classical EX-OR is realized by setting $U = X$ "bit-flip.") Then, for any U, there is a quantum state $|\phi\rangle$ (actually an eigenvector of U) such that $|\phi\rangle$ and $U|\phi\rangle$ are identical (up to a global phase). Namely, if $|\psi_2\rangle = |\phi\rangle$, then the quantum state at the output of U is exactly the same for $|\psi_1\rangle = |0\rangle$ and $|\psi_1\rangle = |1\rangle$. This means their difference is completely lost at that position and hence is completely lost at t_1 also.

Nevertheless, we show that quantum network coding is possible if approximation is allowed. Our results for the Butterfly network include: (i) We can send any quantum state $|\psi_1\rangle$ from s_1 to t_1 and $|\psi_2\rangle$ from s_2 to t_2 simultaneously with a fidelity strictly greater than 1/2. (ii) If one of $|\psi_1\rangle$ and $|\psi_2\rangle$ is classical, then the

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fidelity can be improved to 2/3. (iii) Similar improvement is also possible if $|\psi_1\rangle$ and $|\psi_2\rangle$ are restricted to only a finite number of (previously known) states. (iv) Several impossibility results including the general upper bound of the fidelity are also given.

This is a joint work with Masahito Hayashi, Harumichi Nishimura, Rudy Raymond, and Shigeru Yamashita.

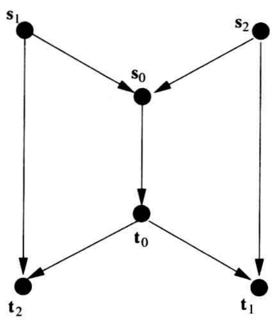

Fig. 1. Betterfly Network

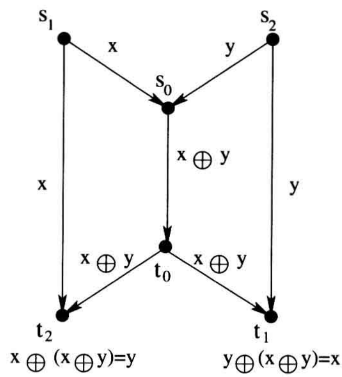

Fig. 2. Coding scheme

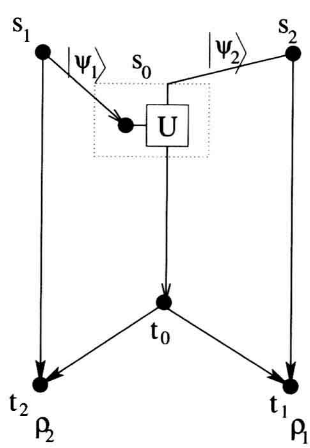

Fig. 3. Network using a controlled unitary operation