Maciej Liśkiewicz
Rüdiger Reischuk (Eds.)

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15th International Symposium, FCT 2005
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Preface

This volume is dedicated to the 15th Symposium on Fundamentals of Computation Theory FCT 2005, held in Lübeck, Germany, on August 17–20, 2005.

The FCT symposium was established in 1977 as a biennial event for researchers interested in all aspects of theoretical computer science, in particular in algorithms, complexity, and formal and logical methods. The previous FCT conferences were held in the following places: Poznań (Poland, 1977), Wendisch-Rietz (Germany, 1979), Szeged (Hungary, 1981), Borgholm (Sweden, 1983), Cottbus (Germany, 1985), Kazan (Russia, 1987), Szeged (Hungary, 1989), Gosen-Berlin (Germany, 1991), Szeged (Hungary, 1993), Dresden (Germany, 1995), Kraków (Poland, 1997), Iasi (Romania, 1999), Riga (Latvia, 2001) and Malmö (Sweden, 2003). The FCT conference series is coordinated by a steering committee. Its current members are B. Chlebus (Denver/Warsaw), Z. Esik (Szeged), M. Karpinski (Bonn), A. Lingas (Lund), M. Santha (Paris), E. Upfal (Providence) and I. Wegener (Dortmund).

The call for papers for FCT 2005 sought contributions on original research in all aspects of theoretical computer science including *design and analysis of algorithms, abstract data types, approximation algorithms, automata and formal languages, categorical and topological approaches, circuits, computational and structural complexity, circuit and proof theory, computational biology, computational geometry, computer systems theory, concurrency theory, cryptography, domain theory, distributed algorithms and computation, molecular computation, quantum computation and information, granular computation, probabilistic computation, learning theory, rewriting, semantics, logic in computer science, specification, transformation and verification, and algebraic aspects of computer science.* A total of 105 papers were submitted – most of them focusing on fundamental questions in these areas of computing. Thanks to all the authors who gave the program committee the chance to select 46 top papers for presentation at the conference. An extended abstract of these results can be found in these proceedings.

Our thanks go to the 15 members of the program committee that took their duty very seriously. Each submitted paper was carefully reviewed by at least five members – some with the help of subreferees. The Easy-Chair evaluation system turned out to be of great help in our electronic discussion and decision process – many thanks to Andrei Voronkov for developing such a useful and professional tool.

In addition to the presentation of the accepted papers, invited lectures on current research topics in theoretical computer science were given by Martin Dyer (Leeds), Martin Grohe (Berlin), and Daniel Spielman (Cambridge, MA).

We are grateful to the German Science Foundation (DFG) and the *Gesellschaft der Freunde und Förderer der Universität zu Lübeck* for their financial

support, and all members of the Institute for Theoretical Computer Science (ITCS) of the University of Lübeck for their help in preparing and running this conference.

August 2005

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The Complexity of Querying External Memory and Streaming Data

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Abstract. We review a recently introduced computation model for streaming and external memory data. An important feature of this model is that it distinguishes between *sequentially reading (streaming)* data from external memory (through main memory) and *randomly accessing* external memory data at specific memory locations; it is well-known that the latter is much more expensive in practice. We explain how a number of lower bound results are obtained in this model and how they can be applied for proving lower bounds for XML query processing.

1 Introduction

Modern computers rely on a hierarchy of storage media from tapes and disks at the bottom through what is usually called random-access memory or main memory up to various levels of (even on-CPU) memory caches at the top. The storage media at the bottom of this hierarchy are the slowest and least expensive and those at the top the fastest and dearest. The need for this *memory hierarchy* is dictated by the ever-growing amounts of data that have to be managed and processed by computers. Currently, the most pronounced performance and price gap in this hierarchy is between (random access) main memory and the next-lower level in the memory hierarchy, usually magnetic disks, which have to rely on mechanical, physically moving parts. One often refers to the upper layers above this gap by *internal memory* and the lower layers of the memory hierarchy by *external memory*. The technological reality is such that the time for accessing a given bit of information in external memory is five to six orders of magnitude greater than the time required to access a bit in internal memory.

Current external storage technology (disks and tapes) renders algorithms that can read and write their data to and from external memory in few *sequential scans* much faster than algorithms that require many random data accesses. Indeed, the time required to move a read/write head to a certain position of a disk or tape – a slow mechanical operation – is by orders of magnitude greater than actually reading a considerable amount of data stored in sequence once the read/write head has been placed at the starting position of the data in question.

Managing and processing huge amounts of data has been traditionally the domain of database research. It is generally assumed that databases have to

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