

Lecture Notes in Computer Science

820

Edited by G. Goos and J. Hartmanis

Advisory Board: W. Brauer D. Gries J. Stoer



Serge Abiteboul Eli Shamir (Eds.)

Automata, Languages and Programming

21st International Colloquium, ICALP 94

Jerusalem, Israel, July 11-14, 1994

Proceedings



Springer-Verlag

Berlin Heidelberg New York

London Paris Tokyo

Hong Kong Barcelona

Budapest

Series Editors

Gerhard Goos
Universität Karlsruhe
Postfach 69 80
Vincenz-Priessnitz-Straße 1
D-76131 Karlsruhe, Germany

Juris Hartmanis
Cornell University
Department of Computer Science
4130 Upson Hall
Ithaca, NY 14853, USA

Volume Editors

Serge Abiteboul
INRIA-Rocquencourt, Domaine de Voluceau
B. P. 105, F-78153 Le Chesnay Cedex, France

Eli Shamir
The Hebrew University
Jerusalem 91904, Israel

CR Subject Classification (1991): F, D.1, E.1, E.3, G.2, I.3.5

ISBN 3-540-58201-0 Springer-Verlag Berlin Heidelberg New York
ISBN 0-387-58201-0 Springer-Verlag New York Berlin Heidelberg

CIP data applied for.

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer-Verlag. Violations are liable for prosecution under the German Copyright Law.

© Springer-Verlag Berlin Heidelberg 1994
Printed in Germany

Typesetting: Camera-ready by author
SPIN: 10128054 45/3140-543210 - Printed on acid-free paper

Foreword

The International Colloquium on Automata, Languages and Programming (ICALP) is an annual conference series sponsored by the European Association for Theoretical Computer Science (EATCS). It is intended to cover all important areas of theoretical computer science, such as: computability, automata, formal languages, term rewriting, analysis of algorithms, computational geometry, computational complexity, symbolic and algebraic computation, cryptography, data types and data structures, theory of databases and knowledge bases, semantics of programming languages, program specification, transformation and verification, foundations of logic programming, theory of logical design and layout, parallel and distributed computation, concurrency, artificial intelligence and robotics. ICALP 94 was held in Jerusalem, Israel, from July 11 to July 14, 1994. Previous colloquia were held in Lund (1993), in Wien (1992), Madrid (1991), Warwick (1990), Stresa (1989), Tampere (1988), Karlsruhe (1987), Rennes (1986), Nafplion (1985), Antwerp (1984), Barcelona (1983), Aarhus (1982), Haifa (1981), Amsterdam (1980), Graz (1979), Udine (1978), Turku (1977), Edinburg (1976), Saarbrücken (1974) and Paris (1972). ICALP 95 will be held in Hungary.

The number of papers submitted was 154. Each submitted paper was sent to at least four Programme Committee members, who were often assisted by their referees. The Programme Committee meeting took place at ENST in Paris on the 3rd and 4th of February 1994. This volume contains the 48 papers selected at the meeting plus the four invited papers. We would like to thank all the Programme Committee members and the referees who assisted them in their work. The list of referees is as complete as we can achieve and we apologize for any omissions and errors.

We would like to thank the members of the Organizing Committee, members and staff of the Computer Science Institute in Jerusalem, and the staff of INRIA-Rocquencourt for their contribution throughout the preparations.

We also gratefully acknowledge support from

Commission of the European Union

INRIA-Rocquencourt

Leibniz Center for Research in Computer Science, Hebrew University

The Israel Academy of Sciences and Humanities

The National Research Council of Israel

The Hebrew University

The Technion, Israel Institute of Technology

IBM Israel Ltd

Intel Electronics Ltd

May 1994

Serge Abiteboul
Eli Shamir

Invited Lecturers

P.C. Kanellakis, Providence
M. Hennessy, Brighton
P. Pudlák, Prague
E. Upfal, Rehovot and Almaden

Programme Committee

S. Abiteboul, Rocquencourt (co-chairman)
A. Apostolico, West Lafayette and Padova
E. Clarke, Pittsburgh
B. Courcelle, Bordeaux
J. de Bakker, Amsterdam
O. Grumberg, Haifa
J. Hromkovic, Paderborn
Z. Kedem, New York
A. Lingas, Lund
G. Mauri, Milano
U. Montanari, Pisa
M. Nielsen, Aarhus
F. Orejas, Barcelona
P. Orponen, Helsinki
H. Proding, Vienna
E. Shamir, Jerusalem (co-chairman)
W. Thomas, Kiel
J. Tiuryn, Warsaw
J. Tucker, Swansea
O. Watanabe, Tokyo
E. Welzl, Berlin

Organizing Committee

R. Cohen
N. Lindenstrauss
N. Nisan
E. Shamir
E. Wigderson (chairperson)

List of Referees

| | | | |
|----------------------|--------------------|------------------|----------------|
| Aizawa K. | Alberts D. | Alt H. | Andersson A. |
| Arge L. | Arnborg S. | Arnold A. | Aspvall B. |
| Attiya H. | Aumann Y. | Bétréma J. | Baaz M. |
| Baeten J.C.M. | Beeri C. | Bellia M. | Ben-David S. |
| Ben-Or M. | Bernholtz O. | Berry D.M. | Bertoni A. |
| Best E. | Bilardi G. | Birget J.C. | Blaaberg B. |
| Blum N. | Bodlaender H.L. | Bonizzoni P. | Bonsangue M.M. |
| Boppana R.B. | Borodin A. | Bosscher D.J.B. | Bouali A. |
| Brandenburg F.J. | Brauner T. | Brodal G. | Broggi A. |
| Brookes S. | Bruschi D. | Carlsson S. | Carpri A. |
| Carrère F. | Case J. | Chambre P. | Chao K.-M. |
| Chen J. | Cheng A. | Chlebus B.S. | Chom U. |
| Codenotti B. | Crespi-Reghizzi S. | Damgaard I.B. | Dams D. |
| Dassow J. | Davis E. | de Boer F.S. | de Bruin A. |
| De Francesco N. | De Nicola R. | de Vink E.P. | de Vrijer R.C. |
| Degano P. | Dessmark A. | Dichterman E. | Diekert V. |
| Dietzfelbinger M. | Drewes F. | Drysdale S. | Dumas P. |
| Đuriš P. | Ehrenfeucht A. | Engberg U. | Engelfriet J. |
| Esparza J. | Etzion T. | Fernau H. | Ferrari G. |
| Fessler S. | Feuerstein E. | Flajolet P. | Floren P. |
| Fokkink W.J. | Fransen G.S. | Fuchs U. | Gärtner B. |
| Gabarro J. | Gabbrielli M. | Ganzinger H. | Gerth R. |
| Giancarlo R. | Goerdts A. | Goldwurm M. | Gorrieri R. |
| Grant P.W. | Grumbach S. | Guerra C. | Hagerup T. |
| Halldórsson M. | Hamaguchi K. | Hariharan R. | Harju T. |
| Hastad J. | Heering J. | Hermenegildo M. | Hermida C. |
| Hillebrand G. | Hoffmann C. | Hoffmann F. | Honkala J. |
| Hoogeboom H.J. | Hooman J.J.M. | Huang S.-C. | Husfeldt T. |
| Huttel H. | Inverardi P. | Itai A. | Italiano G.F. |
| Itoh T. | Jacobs B.P.F. | Janssens D. | Jantzen M. |
| Jaromczyk J. | Jennings E. | Jha S. | Johansson H. |
| Kärkkäinen J. | Kakugawa H. | Kaminski M. | Karhumäki J. |
| Karlsson R. | Katz S. | Kelemenová A. | Klarlund N. |
| Klasing R. | Klawe M. | Kleijn J. | Kok J.N. |
| Korec I. | Kröger F. | Kreowski H.J. | Kriegel K. |
| Krznaric D. | Kucherov G. | Kuich W. | Lagergren J. |
| Landau G.M. | Lange J.-J. | Larsen K.G. | Lautemann C. |
| Le Saec B. | Lepistö A. | Lescanne P. | Lescow H. |
| Levcopoulos C. | Linial N. | Mäkelä M. | Métivier Y. |
| Majster-Cederbaum M. | Maggiolo A. | Makowsky J. | Maluszynski J. |
| Manca V. | Mandrioli D. | Mannila H. | Marini D. |
| Marrero W. | Marti-Oliet N. | Martini S. | Massazza P. |
| Matsumoto T. | Mayoh B.H. | McConnell B.R.J. | McConnell R.M. |
| Meinke K. | Middeldorp A. | Mignosi F. | Millo R. De |

- | | | | |
|-------------------|--------------------|------------------|------------------|
| Mishra B. | Moffat A. | Moran S. | Muthukrishnan S. |
| Naor S. | Nieuwenhuis R. | Nipkow T. | Nisan N. |
| Niwinski D. | Nurmi O. | Otto F. | Palopoli L. |
| Pardubská D. | Pedreschi D. | Perrin D. | Petersson O. |
| Pettorossi A. | Pevzner P.A. | Pfenning F. | Pietracaprina A. |
| Pighizzini G. | Pin J.E. | Pnueli A. | Pouse A. |
| Porat S. | Potthoff A. | Pucci G. | Pudlák P. |
| Rüthing O. | Radhakrishnan J. | Raspaud A. | Rauzy A. |
| Ravasio F. | Regnier M. | Reischuk P. | Restivo A. |
| Reynolds J.C. | Rodriguez Artalejo | Romani F. | Rossi F. |
| Rote G. | Rudolph L. | Rutten J.J.M.M. | Sénizergues G. |
| Sabadini N. | Safra S. | Saks M. | Salomaa A. |
| Schöning U. | Scheffler P. | Schindelbauer C. | Schmid U. |
| Schmidt E.M. | Scholl M. | Scott D.S. | Seidl H. |
| Shamir R. | Siegel M. | Simon I. | Sippu S. |
| Skyum S. | Soloviev S. | Spirakis P. | Statman R. |
| Steffen B. | Steinby M. | Stephenson K. | Stern J. |
| Stewart I.A. | Stoltenberg-Hansen | Storlind R. | Straubing H. |
| Subrahmanyam K.V. | Sugihara K. | Sutinen E. | Swiatek G. |
| Szpankowski W. | Szymacha T. | Šturf J. | Takahashi A. |
| Tarlecki A. | Teillaud M. | Thiele T. | Tofts C. |
| Tokuyama T. | Trichina E. | Tygar J.D. | Ukkonen E. |
| Upfal E. | Urzyczyn P. | Vaandrager F.W. | Valkema E. |
| van Breugel F. | Varricchio S. | Vianu V. | Vogel J. |
| Vrto I. | Wagner H. | Wagner D. | Wagner F. |
| Walukiewicz I. | Wanka R. | Wanke E. | Warnow T. |
| Weber A. | Weber G. | Wegener I. | Weihe K. |
| Weil P. | Wein J. | Wernan M. | Widmayer P. |
| Wiedermann J. | Wigdernan A. | Wigderson A. | Zhou X. |
| Zielonka W. | Zuckerman D. | Zvonkin A. | Zwick U. |

Table of Contents

Theory of Computation

| | |
|--|----|
| Unexpected Upper Bounds on the Complexity of Some Communication Games <i>P. Pudlák (Invited Speaker)</i> | 1 |
| Valuations and Unambiguity of Languages, with Applications to Fractal Geometry <i>H. Fernau, L. Staiger</i> | 11 |
| On The Computational Power of Probabilistic and Faulty Neural Networks <i>H.T. Siegelmann</i> | 23 |

Automata, Computation Models

| | |
|---|----|
| Deciding Properties of Integral Relational Automata <i>K. Čerāns</i> | 35 |
| On the Cost of Recomputing: Tight Bounds on Pebbling with Faults <i>Y. Aumann, J. Bar-Ilan, U. Feige</i> | 47 |
| On some Relations between Dynamical Systems and Transition Systems <i>E. Asarin, O. Maler</i> | 59 |
| Complexity Results for Multi-Pebble Automata and their Logics <i>N. Globerman, D. Harel</i> | 73 |

Expressive Power

| | |
|--|-----|
| An Analysis of the Core-ML Language: Expressive Power and Type Reconstruction <i>P.C. Kanellakis (Invited Speaker), G.G. Hillebrand, H.G. Mairson</i> | 83 |
| Expressiveness of Efficient Semi-Deterministic Choice Constructs <i>M. Gyssens, J. Van den Bussche, D. Van Gucht</i> | 106 |
| Tailoring Recursion for Complexity <i>E. Grädel, Y. Gurevich</i> | 118 |

Automata, Concurrency

| | |
|--|-----|
| Determinizing Asynchronous Automata <i>N. Klarlund, M. Mukund, M. Sohoni</i> | 130 |
| On the Complementation of Büchi Asynchronous Cellular Automata <i>A. Muscholl</i> | 142 |
| Distribution and Locality of Concurrent Systems <i>F. Corradini, R. De Nicola</i> | 154 |
| Liveness in Timed and Untimed Systems <i>R. Gawlick, R. Segala, J. Søgaard-Andersen, N. Lynch</i> | 166 |

Pattern Matching

| | |
|---|-----|
| Average-case Analysis of Pattern-Matching in Trees under the BST Probability Model <i>J.R. Sánchez-Couso, M.I. Fernández-Camacho</i> | 178 |
| On the Approximation of Shortest Common Supersequences and Longest Common Subsequences <i>T. Jiang, M. Li</i> | 191 |
| Optimal Parallel Algorithms for Prefix Matching <i>R. Hariharan, S. Muthukrishnan</i> | 203 |
| Optimal Two-Dimensional Compressed Matching <i>A. Amir, G. Benson, M. Farach</i> | 215 |

Data Structures

| | |
|--|-----|
| Maintaining Spanning Trees of Small Diameter <i>G.F. Italiano, R. Ramaswami</i> | 227 |
| Simple Fast Parallel Hashing <i>J. Gil, Y. Matias</i> | 239 |
| The Optimal Alphabetic Tree Problem Revisited <i>T.M. Przytycka, L.L. Larmore</i> | 251 |

Computation Complexity

| | |
|---|-----|
| On the Cutting Edge of Relativization: The Resource Bounded Injury Method <i>H. Buhrman, L. Torenuviet</i> | 263 |
| PSPACE-completeness of Certain Algorithmic Problems on the Subgroups of Free Groups <i>J.-C. Birget, S. Margolis, J. Meakin, P. Weil</i> | 274 |

Semantics, Logic and Verification I

| | |
|--|-----|
| Higher-Order Processes and Their Models <i>M. Hennessy (Invited Speaker)</i> | 286 |
| Efficient Local Correctness Checking for Single and Alternating Boolean Equation Systems <i>B. Vergauwen, J. Lewi</i> | 304 |
| Undecidable Verification Problems for Programs with Unreliable Channels <i>P.A. Abdulla, B. Jonsson</i> | 316 |
| Reasoning about Programs by Exploiting the Environment <i>L. Fix, F.B. Schneider</i> | 328 |

Semantics, Logic and Verification II

| | |
|---|-----|
| A Model of Intuitionistic Affine Logic from Stable Domain Theory <i>T. Br  uner</i> | 340 |
| Bistructures, Bidomains and Linear Logic <i>G. Plotkin, G. Winskel</i> | 352 |
| Equivalences for Fair Kripke Structures <i>A. Aziz, V. Singhal, F. Balarin, R.K. Brayton, A.L. Sangiovanni-Vincentelli</i> | 364 |
| Generalizing Finiteness Conditions of Labelled Transition Systems <i>F. van Breugel</i> | 376 |

Formal Languages

| | |
|--|-----|
| A Kleene Theorem for Recognizable Languages over Concurrency Monoids <i>M. Droste</i> | 388 |
| Least Solutions of Equations over \mathcal{N} <i>H. Seidl</i> | 400 |
| Fast Uniform Analysis of Coupled-Context-Free Languages <i>G. Hotz, G. Pitsch</i> | 412 |
| Polynomial Closure of Group Languages and Open Sets of the Hall Topology <i>J.-E. Pin</i> | 424 |

Term Rewriting Systems

| | |
|---|-----|
| Pumping, Cleaning and Symbolic Constraints Solving <i>A.-C. Caron, H. Comon, J.-L. Coquidé, M. Dauchet, F. Jacquemard</i> | 436 |
| Dynamically-Typed Computations for Order-Sorted Equational Presentations <i>C. Hintermeier, C. Kirchner, H. Kirchner</i> | 450 |
| Combining First Order Algebraic Rewriting Systems, Recursion and Extensional Lambda Calculi <i>R. Di Cosmo, D. Kesner</i> | 462 |

Algorithms and Communications

| | |
|---|-----|
| On the Theory of Interconnection Networks for Parallel Computers <i>E. Upfal</i> (Invited Speaker) | 473 |
| Multiway Cuts in Directed and Node Weighted Graphs <i>N. Garg, V.V. Vazirani, M. Yannakakis</i> | 487 |
| A Fast Randomized LOGSPACE Algorithm for Graph Connectivity <i>U. Feige</i> | 499 |
| Short Vertex Disjoint Paths and Multiconnectivity in Random Graphs: Reliable Network Computing <i>S. Nikolettseas, K. Palem, P. Spirakis, M. Yung</i> | 508 |

Graph Algorithms

| | |
|---|-----|
| The Size of an Intertwine <i>J. Lagergren</i> | 520 |
| Finding Even Cycles Even Faster <i>R. Yuster, U. Zwick</i> | 532 |
| Polynomial Time Analysis of Toroidal Periodic Graphs <i>F. Höfting, E. Wanke</i> | 544 |
| A Tight Lower Bound for Primitivity in k -Structures <i>P. Bonizzoni</i> | 556 |

Randomized Complexity

| | |
|--|-----|
| Randomness in Distribution Protocols <i>C. Blundo, A. De Santis, U. Vaccaro</i> | 568 |
| Lower Space Bounds for Randomized Computation <i>R. Freivalds, M. Karpinski</i> | 580 |
| The Average Case Complexity of the Parallel Prefix Problem <i>A. Jakoby, R. Reischuk, C. Schindelhauer, S. Weis</i> | 593 |

Various Algorithms

| | |
|---|-----|
| Prefix Codes: Equiprobable Words, Unequal Letter Costs <i>M.J. Golin, N. Young</i> | 605 |
| A Super-Logarithmic Lower Bound for Hypercubic Sorting Networks <i>C.G. Plaxton, T. Suel</i> | 618 |
| Efficient Strategies for Robot Navigation in Unknown Environment <i>A. Mei, Y. Igarashi</i> | 630 |
| Author Index | 643 |