THEORETICAL COMPUTER SCIENCE

The research performed in the Department of Foundations of Computer Science lies in the intersection of algebra, logic and computer science. The main themes are automata and formal languages, tree automata and term rewriting, weighted tree automata, logics on words and trees, finite model theory, fixed point operators in computer science, and axiomatic questions.

I. FIXED POINTS IN COMPUTER SCIENCE

We studied categorical models that give rise to solutions of recursion schemes [1, 3], the expressive power of recursion schemes [2, 4, 5], and complete descriptions of the equational properties of fixed point operations [11]. The papers [9, 10] provide applications of fixed point theory to fuzzy languages and weighted tree automata.

II. TREE AUTOMATA, TERM REWRITING AND LOGICS ON WORDS AND TREES

We studied logical aspects of automata and tree automata. In the papers [12–18, 20–22], we gave algebraic and game theoretic characterizations of various logics on words and trees, including linear and branching time temporal logics, and extensions of first-order logic by Lindström quantifiers. In [19], we gave a complete axiomatization of regular tree languages.

In [38, 39], we investigated macro pebble tree transducers. We showed that three different versions of the circularity problem for pebble macro tree transducers are decidable. Moreover, we proved several composition and decomposition results and showed that the type checking problem for pebble macro tree transducers is decidable.

In [46], we showed that there are finitely many descendants of any recognizable tree language L for all linear monadic term rewrite systems, and we gave these descendants through finitely many linear monadic term rewrite systems. In [47], we considered the ranked alphabet consisting of a binary symbol. Then we gave a rewrite system R effectively preserving recognizability on any ranked alphabet obtained by adding finitely many nullary symbols, and losing recognizability on the ranked alphabet obtained by adding one unary and one nullary symbol. In [48], we showed that some basic properties of murg term rewrite systems are undecidable. In [49], we compared the computing powers of a given deterministic bottom-up tree transducer and a given ground term rewrite system. In [50], we gave a weak quasi-decision procedure for deciding whether the range of a bottom-up tree transducer is recognizable, and in [51] we showed that it is decidable for any extended ground term rewrite system R whether there is an equivalent ground term rewrite system S.

III. WEIGHTED AUTOMATA AND SEMIRINGS

In the papers [6–8, 23–28], we carried out research on the axiomatic foundation of weighted automata. We identified several structures for this purpose such as Conway and iteration semirings [6–8, 27, 28], Conway and iteration semiring-semimodule pairs [25, 26]. We derived several key results of the theory of automata in the axiomatic settings.

IV. WEIGHTED TREE AUTOMATA AND TREE TRANSDUCERS

In [29], we used simulation to characterize equivalence of weighted tree automata. In [34], we gave a summary on several important results for weighted tree automata and weighted tree transducers. In [35], we characterized the syntactic $K\Sigma$-algebras of recognizable tree series and showed that all subdirectly irreducible $K\Sigma$-algebras are syntactic. In [36], we proved that a tree series is recognizable by a tree automaton over a multioperator monoid iff it appears as the composition of a relabeling tree transformation, a recognizable tree language, and a tree series computed by a one-state weighted tree automaton of the same type. In [37], we presented a KLEENE theorem on the equivalence of recognizability and rationality for tree series over distributive multioperator monoids. In [40], we proved that tree series recognizable by weighted tree walking automata over a commutative semiring K form a strict subclass of the class of recognizable tree series over K.

V. HIGHER DIMENSIONAL AUTOMATA

In the papers [42, 44, 45], we studied languages of higher dimensional words (elements of free algebras with several independent associative operations) and their acceptors, called parenthesizing automata.

VI. OTHER

In [30], we gave estimations of the state complexity of several operations on finite automata, such as operations induced by boolean functions. In [31–33], we opened a new direction in the study of infinitary languages by introducing context-free grammars generating languages of countable words.

The iterated shuffle is a frequently used operation to describe sequential execution histories of concurrent processes. In [43], necessary and sufficient conditions have been derived for regularity and context-freeness of the iterated shuffle of languages belonging to several simple classes of regular languages.

In [41], we gave new upper bounds for the length of the shortest i-directing word of an i-directable nondeterministic automaton for $i = 1, 2, 3$. For $i = 1, 2$ our bounds are asymptotically tight. These questions, introduced by Burkhardt in 1976, are motivated by the well-known Černý conjecture which is still open since 1964.

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OTHER ACTIVITIES

I. EDITED BOOKS

In the period 2006–2009, the members of the Department of Foundations of Computer Science edited or co-edited the following books and special journal issues.

1. A. Bertoni, Z. Ésik, J. Karhumäki, Eds.: The art of rationality. In honour of Professor Christian Choffrut on the occasion of his 60th birthday. *Theoretical Computer Science*, 356(2006), no. 1–2, 262 pages.
2. Z. Ésik, Ed.: Automata and Formal Languages 2005, Special issue of *Acta Cybernetica*, Volume 17, No.4, 2006, 663–841.
3. Z. Ésik, Ed.: Automata and Formal Languages 2005, Special Issue, *Theoretical Computer Science*, Volume 366, Number 3, 2006, 181–315.
4. Z. Ésik, C. Martin-Vide, V. Mitrana, Eds.: Recent Advances in Formal Languages and Applications, Studies in Computational Intelligence 25, Springer-Verlag, 2006, VIII + 373 pages.
5. Z. Ésik, Ed.: Computer Science Logic 2006, proceedings, LNCS 4207, Springer-Verlag, 2006, XII + 626 pages.
6. E. Csuhaj-Varjú, Z. Ésik, Eds.: Fundamentals of Computation Theory 2007, LNCS 4639, Springer, 2007.
7. E. Csuhaj-Varjú, Z. Ésik, Eds.: Automata and Formal Languages, proceedings of the 2008 conference, Balatonfüred, Computer and Automation Institute, Hungarian Academy of Science, 2008.
8. Z. Ésik, R. Ramanujam, Eds.: Selected Papers of the Conference "Computer Science Logic 2006" Szeged, Hungary, 2006 *Logical Methods in Computer Science*, 2009.
9. E. Csuhaj-Varjú, Z. Ésik, Eds.: Automata and Formal Languages, *Acta Cybernetica*, Vol. 19, No. 2, 441–565, 2009.
10. Z. Ésik, Z. Fülöp, Eds.: Automata, Formal Languages, and Related Topics, Dedicated to Ferenc Gécseg on the occasion of his 70th birthday, University of Szeged, 2009.
11. E. Csuhaj-Varjú, Z. Ésik, Eds.: Fundamentals of Computation Theory. Special issue devoted to papers presented at FCT 07, *Theoretical Computer Science*, Volume 411(2010), Issues 4–5.
12. E. Csuhaj-Varjú, Z. Ésik, Eds.: Automata and Formal Languages, special issue devoted to AFL 2008, *Int. J. Foundations of Computer Science*, to appear in 2010.

II. ORGANIZED CONFERENCES

In the period 2006-2009, the Department of Foundations of Computer Science has organized the following conferences and workshops:

1. Annual Conference of the European Association for Computer Science Logic, **CSL'06**, Szeged, Hungary, September 25–29, 2006.
2. Logic and Combinatorics, Satellite Workshop of CSL'06, Szeged, Hungary, September 23–24, 2006.
3. Algebraic Theory of Automata and Logic, Satellite Workshop of CSL'06, Szeged, Hungary, September 30 and October 1, 2006.
4. 16th International Symposium on Fundamentals of Computation Theory, **FCT'07**, Budapest, Hungary, August 27–30, 2007.

5. 12th International Conference on Automata and Formal Languages, **AFL'08**, Balatonfüred, Hungary, May 27–30, 2008.