The Ackermann Award 2005

E. Grädel, J. Makowsky, and A. Razborov

Members of EACSL Jury for the Ackermann Award

The Ackermann Award

At the annual conference of the EACSL, CSL'04, it was suggested to the newly elected president of EACSL to do something which will make the Annual Conference of EACSL even more attractive for young researchers in Logic and Computer Science. In response to this suggestion, the EACSL Board decided in November 2004 to launch the

Ackermann Award,
the EACSL Outstanding Dissertation Award
for Logic in Computer Science.

The **Ackermann Award** is presented to the recipients at the annual conference of the EACSL. The jury is entitled to give more than one award per year. The award consists of a diploma, an invitation to present the thesis at the CSL conference, the publication of the abstract of the thesis and the citation in the CSL proceedings, and travel support to attend the conference.

The first **Ackermann Award** is presented at this CSL'05. Eligible for the 2005 **Ackermann Award** were PhD dissertations in topics specified by the EACSL and LICS conferences, which were formally accepted as PhD theses at a university or equivalent institution between 1.1. 2003 and 31.12. 2004.

The jury for the **Ackermann Award** consists of seven members, three of them ex officio, namely the president and the vice-president of EACSL, and one member of the LICS organizing committee.

The current jury consists of

- S. Abramsky (Oxford, LICS Organizing Committee)
- B. Courcelle (Bordeaux)
- E. Grädel (Aachen)
- M. Hyland (Cambridge)
- J.A. Makowsky (Haifa, President of EACSL)
- D. Niwinski (Warsaw, Vice President of EACSL)
- A. Razborov (Moscow and Princeton)

Wilhelm Ackermann 1896-1962

Wilhelm Ackermann[1] was born on March 29, 1896, in Schoönebeck (Kreis Altena) in Westphalia, Germany, at the time belonging to Prussia. His first studies at the University of Göttingen, which were interrupted during the First World War, were devoted to mathematics, physics and philosophy. He obtained his PhD in 1924 under the guidance of David Hilbert. F From 1927 until 1961 he taught in secondary schools (Gymnasium). In 1953 he became a corresponding member of the Göttingen Academy of Sciences, and in the same year the university of Münster made him a honorary professor at the Faculty of Mathematics and Exact Sciences. He lectured until three days before hi death died on December 24, 1962.

His logic textbook, *Grundzuege der Theoretischen Logik* written together with David Hilbert and first published in 1928, was the most influential textbook in the formative years of mathematical logic. Its fourth edition was published in 1959. The book was translated into several languages.

Although W. Ackermann did not pursue an academic career, he nevertheless continued his research work and helped to shape mathematical logic as a tool of scientific investigations. He also played an important role in establishing mathematical logic as a discipline on post-war Germany. His work includes major contributions in the investigations

- in the consistency of arithmetic, set theory and other comprehensive mathematical systems;
- in various strengthenings of strict implication;
- in the complexity and the rate of growth of recursive functions;
- and in decision problems of predicate logic.

Every Computer Science student knows the Ackermann function, a recursive function (given by a simple recursive definition) which is provably not primitive recursive. But computer scientists are less aware of his other contributions. Goedel's completeness theorem proves the completeness of the system presented and proved sound by Hilbert and Ackermann. Ackermann was also the main contributor to the logical system known as the epsilon calculus, originally due to Hilbert. Finally, Ackermann solved the decision problem for $\exists^*\forall\exists^*$-formulas positively. As one of the pioneers of logic, he left his mark in shaping logic and the theory of computation. Several of his publications discussed topics which were later further developed in papers presented at the LICS and EACSL conferences.

[1] The following sources are used and sometimes quoted verbatim: An obituary, written in English by H. Hermes, appeared in the Notre Dame Journal of Formal Logic, vol. VIII, No 1-2, April 1967.
Links on the WEB: Biographic note written by W. Felscher
`http://www-gap.dcs.st-and.ac.uk/ ~history/Mathematicians/Ackermann.html`
and Biography base
`http://www.biographybase.com/biography/Ackermann_Wilhelm.html`

Report of the Jury

The jury received 15 nominations for the **Ackermann Award 2005**. The candidates came from 9 different nationalities and received their PhDs in 7 diferent countries in Europe and North America.

The topics covered the full range of Logic and Computer Science as represented by the LICS and CSL Conferences. All the submissions were of very high standard and contained outstanding results in their particular domain. The jury decided finally, to give for the year 2005 three awards, one for work on tree-automata and their applications to model checking and verification, one for work on logical and algorithmic properties of Knuth-Bendix orderings and their application to automated reasoning, and one for work on lower bounds for the complexity of propositional proof systems and their applications to complexity theory.

The jury considers the awarding of three awards truly exceptional, due to the outstanding quality of all three winners, and plans in the future to give at most two awards per year.

The 2005 **Ackermann Award** winners are, in alphabetical order,

- Mikołaj Bojańczyk from Poland, for his thesis
  Decidable Properties of Tree Languages,
  issued from Warsaw University, Warsaw, Poland in 2004
  (Supervisor: I. Walukiewicz, Bordeaux)

- Konstantin Korovin from Russia, for his thesis
  Knuth-Bendix orders in automated deduction and term rewriting,
  issued by the University of Manchester, England, in 2003
  (Supervisor: A. Voronkov)

- Nathan Segerlind from the USA, for his thesis
  New Separations in Propositional Proof Complexity,
  issued by the University of California at San Diego, California, USA, in 2003
  (Supervisors: S. Buss and R. Impagliazzo)

The 2005 Ackermann Award Winners

Mikołaj Bojańczyk

Citation. Mikołaj Bojańczyk receives the 2005 Ackermann Award of the European Association of Computer Science Logic (EACSL) for his thesis

Decidable Properties of Tree Languages

in which he substantially advanced our understanding of the definability and decidability properties of theories of finite and infinite trees.

Background of the thesis. The automata theoretic and logical study of tree properties has two branches, depending on whether one considers finite or infinite trees. Despite their common origin in the analysis of monadic second-order logic (MSO) over trees in the fundamental papers by Doner, Thatcher/Wright, Rabin, and others, the two research directions have developed in different ways and with different domains of application.

A motivating challenge for the the first part of Bojańcyk's thesis is to find an analogue of Schützenberger's Theorem for trees. More generally, the goal is to decide whether a given regular tree language belongs to some fixed definability class of trees. This is a very ambitious goal. Indeed, while this kind of definability problems are well-understood for words, and despite the fact that the theory of tree languages and tree automata is a bustling field, with close ties to verification and model checking, the question of deciding, or even characterising first-order definability of tree languages has not seen any progress for many years – not for lack of interest, but because previous efforts by doctoral students and experienced researchers alike in the 1990s had been inconclusive. A possible explanation for this is that in the case of words, these questions are tackled through an algebraic approach. In the case of trees, the algebraic approach is much more difficult and much less developed.

The motivating challenges for the second part of Bojańcyk's thesis are extensions of Rabin's Theorem on the decidability of the monadic theory of the infinite binary tree and their applications to program logics and games.

Bojańczyk's thesis. The thesis *Decidable Properties of Tree Languages* by M. Bojańczyk represents an important advance in the classification theory of regular sets of finite trees, and secondly it introduces an intriguing extension of MSO-logic over infinite trees with interesting applications in programming logics.

The first part deepens our understanding of various logics over finite trees, in particular first-order logic (including the partial tree ordering $<$ in the signature) and chain logic (where second-order variables only range over sets that are linearly ordered by $<$). Other systems are temporal logics like CTL* or fragments thereof. After about twenty years of little progress, the results of the thesis provide an important step forward in the aim of fixing syntactic invariants that allow to decide for a given MSO-property whether it is expressible in such a fragment. Bojańczyk develops a new machinery to study these questions:

- A new class of "path-oriented" tree automata is introduced, called word sum automata, and shown to capture the Boolean closure of deterministic tree languages (accepted by deterministic top-down tree automata).
- A cascade product construction is developed for word sum automata and shown to capture chain logic over trees (while the aperiodic version captures first-order logic).
- The cascade length is shown to capture the quantifier nesting of CTL*-formulae, giving an elegant new proof of the strictness of the corresponding hierarchy.
- A very interesting effective property of tree languages (and tree automata), called confusion, is worked out which has the potential to characterize those regular tree properties that cannot be defined in chain logic.

These concepts and results are beautiful and represent real innovations. The results are then applied to characterize effectively the tree languages definable by three different fragments of CTL*, in which the temporal operators are restricted to EX, EF, respectively the use of both (but excluding the until" construct). The given characterizations are very attractive for the effective criteria they provide, and they are technical master-pieces for the corresponding completeness proofs.

The second part of the thesis addresses the search for proper extensions of Rabin's Theorem that the monadic theory of the infinite binary tree (S2S) is decidable. There are two approaches: to change the model (e.g., by considering certain infinite graphs instead of the binary tree), or to modify the means of quantification. The thesis follows the second path, rather neglected up to now in the literature.

Mikołaj Bojańczyk introduces an interesting new quantifier B which allows to sharpen the existence of finite sets by the requirement that their size has to be bounded. Two decidability results on the satisfiability question are shown: first for the closure of MSO-logic by B, the existential quantifier plus the connectives "or", "and", secondly for the MSO-formulas preceded by the dual U-quantifier. The proof offers the interesting idea of "quasi-regular" tree languages which are shown to be the appropriate basis for B-quantification. The central contribution of the chapter is the set-up of a subtle balance between expressiveness and decidability. This is very convincingly documented in three different applications: the finite satisfiability problem for the two-way μ-calculus, the bounded tree-width problem for graphs defined inside the full binary tree, and solving pushdown games with stack unboundedness conditions.

The thesis is written in a very concise and fresh style and conveys a spirit of original thought and intuitive clarity.

Biographic Sketch. Mikołaj Bojańczyk was born on 8th June, 1977. He studied computer science in Warsaw where he graduated in 2000 with a M.Sc. thesis on two-way alternating automata. For this thesis he obtained the second prize in a national competition of the Polish Informatics Society for best M.Sc. awards in Computer Science. Between 200 and 2004 he was a Phd student, also at Warsaw, under the supervision of Igor Walukiewicz. He is currently a post-doc researcher at University Paris 7.

His brilliant dissertation is not the only point of excellence in Bojańczyk's work. His results on tree-walking automata, jointly with Colcombet and completely independent of the dissertation, solved a long-standing open problem and got a best paper award at ICALP 2004.

Konstantin Korovin

Citation. Konstantion Korovin recieves the **2005 Ackermann Award** of the European Association of Computer Science Logic (EACSL) for his thesis

Knuth-Bendix orders in automated deduction and term rewriting.

In this thesis he has advanced single-handedly the theoretical and algorithmic foundations of Knuth-Bendix orderings, separating effectively the feasible applicabilty of Knuth-Bendix orderings from its less feasible aspects.

Background of the thesis. Automated deduction is an important branch of Computer science, which has applications in various areas including specification and verfication of software and hardware, synthesis of safe programs, database systems, computer algebra and others. One of the most popular methods used in automated deduction are resolution based-theorem proving, which can be implemented efficiently, yet is powerful enough for many applications. Incorporated in the resolution method are various unification algorithms and term rewrite techniques. Because of the practical importance of resolution, unification and term rewriting, intensive research has been devoted both to theoretical improvements as well as implementation issues. Among the main tools developed for termination proofs and improved implementation strategies are orderings on term algebras, and the use of ordering restrictions, which allow to cut down the search space.

There are two classes of orderings that are widely used in automated deduction: In the seminal 1970 paper by D. Knuth and P. Bendix *Simple word problems in universal algebra*, Knuth-Bendix Orderings (KBOs), were introduced. Knuth-Bendix orders have a hybrid nature. They are defined on weighted terms of term algebras, relying both on syntactic precedence and a numeric weight function, hence introducing a (non-trivial) combination of integers and terms. In 1979, N. Dershowitz introduced recursive path orderings (RPOs) for the same purpose. Recursive path orders are defined on term algebras, relying on syntactic precendence only, without weights. The literature is rich in variations of the concept of RPOs. A popular variant are the lexicographical path orderings (LPOs) introduced by Levy and Kamin in 1980. Both types of term orderings are are widely used in almost all currently implemented and widely used automated theorem provers. Knuth-Bendix orderings (KBOs) is the main family of orderings used in the theorem provers VAMPIR, E, Waldmeister, and SPASS.

The first order theory of RPOs was proven undecidable in 1992, by R. Treinen, and for LPOs in 1997. by H. Comon and R. Treinen. In 2000 P. Narendran and M. Rusinowitch showed that the first order theory of unary RPOs is decidable. They also showed that solving RPOs constraints is in NP in 1998. It was known to be NP-hard since 1984. There exists an extensive literature on RPOs and LPOs. For a survey and historic details we refer to the handbook article on Rewriting by N. Dershowitz and D.A. Plaisted in *Handbook of Automated Reasoning*, edited by A. Robinson and A. Voronkov, MIT Press and Elsevier, 2001.

Although there have been many results on the properties of all variants of recursive path orderings, virtually nothing was known about the KBOs, before the work of K. Korovin, which was published jointly with his supervisor A. Voronkov. It seems the main problem with proving results about KBOs is the (non-trivial) combination of integers and term algebras, as compared to pure combinatorics on term algebras in the case of RPOs and KBOs.

Korovin's thesis. Konstantin Korovins thesis deals with the algorithmic properties of Knuth-Bendix orders. In his thesis, he has constructed polynomial time algorithms for the fundamental problems of solving ordering constraints of single inequalities, of the orientabilty of systems of equalities and rewrite rules by KBOs, and for term comparison. He has given lower bounds for the complexity of these problems showing that orientability is P-time complete, and the problem of solving ordering constraints is NP-complete. The general first order decision problem for KBOs is widely believed to be solvable, but no proof of this fact has been found so far. Korovin has shown the decidability of first ordering constraints for unary signatures. The proofs of the main results display a high level of interdisciplinarity, with a blend of optimization theory, complexity theory, and a mastery of a multitude of techniques for establishing effective decision procedures.

Biographic Sketch. Konstantin Korovin was born on April 4, 1976 in Sarapul, Russia (Soviet Union). He received his secondary education at the Specialized Scientific Study Center for Physics, Mathematics, Chemistry and Biology in Novosibirsk in the period from 1992-93. At the age of 17 he entered Novosibirsk University and received both his undergraduate and graduate education there. In 1998 he completed his M.Sc. studies under the supervision of Prof. Andrei Morozov. The title of his M.Sc. thesis is *Compositions of permutations and algorithmic reducibilities.*

From 1999-2002 he was a Ph.D. student under the supervision of Prof. Andrei Voronkov, and received his Ph.D. in 2003 for his thesis *Knuth-Bendix orders in automated deduction and term rewriting.* For this thesis he already received the best Ph.D. Thesis Award of the University of Manchester.

He spent the years 2003 and 2004 as a researcher at the Max Planck Institute in Saarbrücken, Germany, working with Professor Harald Ganzinger, in the difficult period when Ganzinger was already very ill and until his untimely death. He wrote several important papers with Harald Ganzinger, but it was his sole responsibility to elaborate, develope and complete Ganzinger's ideas. After Ganzinger's death he returned to Manchester University where he works as a research associate.

Nathan Segerlind

Citation. Nathan Segerlind recieves the **2005 Ackermann Award** of the European Association of Computer Science Logic (EACSL) for his thesis

New Separations in Propositional Proof Complexity.

His thesis extends switching lemmas, one of the most primary tools in the area, in a very unexpected way. This has allowed Segerlind to solve a host of difficult open problems in propositional proof complexity and, in particular, to take in a single step the proof system $Res(k)$ from an almost complete mystery to being almost completely understood.

Background of the thesis. The central question of propositional proof complexity can be formulated in a deceivingly simple way. Given a (sound and complete) proof system P for propositional logic and a tautology ϕ, what is the "simplest" (in most cases meaning the shortest) P-proof of ϕ? Partly due to the universal nature of the notion of a propositional tautology, this is an interdisciplinary area on the border between (and with motivations from) mathematical logic, theory of computing, automated theorem proving, cryptography, algebra and combinatorics among other.

Largely influenced by the automated theorem proving (Davis, Putnam (1960), Davis, Longemann, Loveland (1962), Robinson (1965)), the most widely studied proof system in the area is (propositional) Resolution. After considerable efforts by many researchers beginning with the seminal paper by Tseitin (1968), the resolution proof system is by now fairly well understood. We have rather general, industrial methods to analyze the complexity of resolution proofs (like the width-size relation by Ben-Sasson, Wigderson (1999)), as well as concrete results concerning virtually all combinatorial principles normally used as "benchmarks" in the whole area (Haken (1985), Urquhart (1987), Chvátal, Szemerédi (1988), Raz (2001), Razborov (2001)).

Until the work represented by Segerlind's thesis, however, everything looked very different (meaning much more obscure) beyond Resolution. As a typical example, take one of the most influential results in the whole area, exponential lower bounds on the complexity of the *pigeon-hole principle* in the *constant-depth Frege proof system* (Beame, Impagliazzo, Krajíček, Pitassi, Pudlák, Woods (1992)) based on one of the most powerful tools in the area, *switching lemmas for random restrictions.* We do not know how to apply this method to many tautologies where it should have been applicable, and even when successful (like e.g. Beame, Riis (1998)), the switching lemmas and other techniques, already extremely complicated, have to be re-done almost from the scratch. The situation is very similar for the intermediate proof system $Res(k)$ that operates like Resolution but allows in clauses conjunctions of size $\leq k$ rather than just literals. This system is of great potential interest for automated proving (perhaps, of better interest than constant-depth Frege) since it is structured almost as well as Resolution but surprisingly can do more interesting things than the latter (Maciel, Pitassi, Woods (2000)).

Just to give an idea of the state of the art in the area, *random 3-CNF* is one of the most popular benchmark models both in theoretical and practical communities. They had been shown to be hard for Resolution by Chvátal and Szemerédi in 1988, but the same question was widely open for *any* reasonable extension of Resolution, including $Res(2)$.

Another important subject addressed in the thesis is *algebraic proof systems* (like Nullstellensatz and Polynomial Calculus) and hybrid systems combining logical and algebraic reasoning (constant-depth Frege with counting axioms or modular gates). By the time of Segerlind's work, purely algebraic proof systems and relations between them were in general understood much better than purely logical systems, but several important questions remained open.

Segerlind's thesis. In his thesis Segerlind proved important and nice results about the relative power of algebraic and mixed proof systems, both positive and negative, that had been open for a while. Among other things he showed that counting gates are more powerful than counting axioms (Chapter VI), but the counting axioms can efficiently simulate any Nullstellensatz proof (Chapter V). The most striking part of the thesis, however, concerns the systems $Res(k)$ for small values of k (Chapters III and IV).

The upshot of these latter results is very simple: we now understand the systems $Res(k)$ almost as well as Resolution itself. In his thesis Segerlind analyzed the complexity of the weak pigeon-hole principle and random w-CNFs (both are standard "tests for maturity") in these proof systems, and he also gave separation results between the systems $Res(k)$ and $Res(w)$ for some $w > k$. His techniques were already used in different situations by Razborov and Alekhnovich. So, it really looks like what he has found is a general, powerful and flexible method rather than ad hoc argument. All in all, Segerlind's work changed the situation with these prominent systems from a few scattered and weak results to a few important problems left open. And two features of this development look particularly striking.

The first is its speed. For Resolution it took decades to have reached the level of understanding that was reached here in a single step. Of course, this comparison is not quite fair since the general methodology gathered during these decades also played very essential role in Segerlind's work. But even with this disclaimer the speed with which it all happened was quite remarkable and totally unexpected.

The second surprise came in the form of proof methods. The novelty essentially consists in a new version of switching lemmas called in the thesis *switching with small restrictions*. And, in order to appreciate this, one should be fully aware to *which* extent this tool is basic in both computational complexity and proof complexity. Many researchers have been looking at these lemmas since the seminal work by Håstad (1986). They have been scrutinized and analyzed from every possible perspective and in all fine and technical details. The fact that Segerlind was able to say a substantially new word in an area so often re-visited by strongest researchers is also quite remarkable.

Biographic Sketch. Nathan Segerlind was born on December 31, 1973 in Marlette, Michigan. In 1992-1998 he studied Computer Science and Mathematics at Carnegie Mellon University, Pittsburg. Between 1998 and 2003 he was a PhD student at the University of California at San Diego, under joint supervision by Samuel Bass and Russell Impagliazzo. He spent the next year 2003-2004 as a postdoctoral member at the Institute for Advanced Study, Princeton. Currently he is continuing his post-doc research at the University of Washington, Seattle.