The Ackermann Award 2012

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1,2,3 Members of EACSL Jury of the Ackermann Award*

The eighth Ackermann Award is presented at this CSL'12, held in Fontainebleau, France. This is the sixth year in which the EACSL Ackermann Award is generously sponsored. Our sponsor for the period 2011–2013 is the Kurt Gödel Society. Besides providing financial support for the Ackermann Award, the KGS also committed itself to inviting recipients of the Award for a special lecture to be given in Vienna.

Eligible for the 2012 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. 2010 and 31.12. 2011. The Jury received 7 nominations for the Ackermann Award 2012. The candidates came from 7 different nationalities from Europe, Australia, and South America, and received their PhDs in 6 different countries in Europe (2 in UK). Only two candidates received the PhD in the country of their origin.

All the submissions were of very high standard and contained remarkable results in their particular domain. The Jury wishes to congratulate all the nominated candidates for their outstanding work. The Jury encourages them to continue their scientific careers, and hopes to see more of their work in the future.

The jury decided finally, to give for the year 2012 two awards, one for work in *lambda calculus*, and one for work in *automata theory*. The **2012 Ackermann Award** winners are, in alphabetical order

- Andrew Polonsky from Ukraine, for his thesis
  Proofs, Types and Lambda Calculus
  issued by University of Bergen, Norway, in 2011,
  supervised by Marc Bezem,
- Szymon Toruńczyk from Poland, for his thesis
  Languages of profinite words and the limitedeness problem
  issued by University of Warsaw, Poland, in 2011,
  supervised by Mikołaj Bojańczyk.

Andrew Polonsky

Citation. Andrew Polonsky receives the *2012 Ackermann Award* of the European Association of Computer Science Logic (EACSL) for his thesis

Proofs, Types and Lambda Calculus.

His thesis brings a number of valuable results in λ-calculus. In particular, it solves in a negative way the range property problem for the theory $\mathcal{H}$, stated by Barendregt in 1976.

Background of the Thesis. The λ-calculus, introduced by Church in the 1930s, is the first mathematical model of effectively computable functions and it was for this model that Church's Thesis was originally formulated. This is surprising if one considers the fact that λ-terms were first introduced to represent logical formulae, and this tight connection between logic and computations gives to λ-calculus a special status in computer science.

* We would like to thank H. Barendregt, J.-E. Pin, and R. Statman for their help in preparing the citations.

One important issue has been when two λ-terms should be identified, since this corresponds to the issue of when two algorithms can be considered to be the same. This question has given rise to a rich lattice of lambda theories. The first notion of equality is β-conversion, for which the confluence result known as the Church-Rosser property was first formulated. Church himself believed that meaningless computations in the λ-calculus are represented by terms without normal forms, and so that all these terms should be identified. For the type-free λ-calculus however this approach has a number of disadvantages and it became clear in the 1970s, through the work of Scott, Wadsworth, Barendregt and others, that a more appropriate notion to capture non-terminating computations was that of terms without a head normal form, known as *unsolvable terms*. Barendregt defined the theory $\mathcal{H}$ as the least equational theory extending β-conversion and equating all unsolvable terms. This theory $\mathcal{H}$ has a number of interesting properties and occupies an important place in the lattice of different ways of identifying λ-terms.

To deeper analyze these various theories, Barendregt formulated the *range property*. This is a kind of zero-one law: it states that for any closed λ-term F the collection of all closed applications $F\ M$ has, modulo the given theory, either exactly one or infinitely many elements. This expresses the fact that a given term cannot classify the λ-terms into finitely many sets with given properties. The first instance of this property, for β-conversion, was conjectured in a classical paper of Böhm (1968). This conjecture was proved later by Barendregt and Myhill, as a consequence of Scott's Theorem that a non trivial set of λ-terms closed under β-conversion cannot be recursive. It was then realized that most lambda theories ($\lambda\beta\eta$, the theory of models D_∞,the Böhm-tree model, and many others) satisfy the range property. In 1976, Barendregt conjectured the range property for the theory $\mathcal{H}$. In his classic monograph *The lambda calculus, its syntax and semantics*, North-Holland 1984, Barendregt collected several arguments in favour of this conjecture. The main one is that a putative counter-example would have non-computable properties, and hence cannot be represented by a λ-term. Since then, several strong researchers have been trying to settle the range property for $\mathcal{H}$. Indeed Statman and Intrigila were recently able to show that the corresponding conjecture holds for combinatory logic.

Polonsky's Thesis. The main result of Polonsky's thesis is a surprising negative solution to the range property of the lambda theory $\mathcal{H}$. This failure of the range property indicates a subtle unexpected difference between the theory $\mathcal{H}$ and most other lambda theories. For this, Polonksy defines a lambda term, having modulo $\mathcal{H}$ a range of cardinality 2. This uses previous works by Statman and Barendregt who outlined what kind of construction was needed in order to get such a counterexample. The required behaviour of such lambda term was however so complex that this was then used as a positive argument in favour of the conjecture. This construction is carried out in Polonsky's thesis as the "devil's tunnel". The exact details are quite ingenious and the devil's tunnel construction produces a recursively enumerable Böhm tree with a unique infinite path which is not recursively enumerable. This path is constructed by a Putnam-Gold-like trial and error procedure. All this is very elegantly presented in the thesis. The solution of the range problem for $\mathcal{H}$ can be considered to be one of the strong achievements in the field of λ-calculus. It is in some way reminiscent of Plotkin (1974) fundamental and unexpected discovery of the failure of ω-completeness of λ-calculus (exhibiting two closed terms F and Z such that $F\ M =_\beta Z$ for any closed term M and $F\ x \neq_\beta Z$).

Polonsky's thesis contains several other significant results. Smullyan (1994) had given an interesting axiomatization of enumerators, but left three open problems having to do with the independence of the given axiomatic system. Polonsky solved these by characterizing when an enumerator is "standard". He did this again by using results of computability theory, making clever use of non-computable functions. Another elegant result of Polonsky characterizes when an untyped lambda term can be typed in a type algebra. This contribution is already incorporated in the recent book *Lambda calculus with types* by Barendregt, Cambridge University Press (to appear in 2013). The first part of the thesis contains an interesting analysis of the connection between coherent logic and general first-order logic.

The thesis is of high level of original creativity. Not only are strong results presented, but Polonsky also shows creativity stating open problems, which undoubtedly are fruitful for future research.

Biographical Sketch. Andrew Polonsky was born on 9 June 1984 in Ukraine. In 2002-2005 he studied Mathematics in the University of Storss, Connecticut, U.S. In 2006-2007 he attend a Master Class in Logic at the Mathematical Research Institute of Utrecht, The Netherlands. Between 2007 and 2010 he was a PhD student at the University of Bergen, Norway, under the supervision of Marc Bezem. In 2011-2012 he has been a postdoc at the University of Amsterdam, The Netherlands, and is now a postdoc at the Radboud University Nijmegen, The Netherlands.

Szymon Toruńczyk

Citation. Szymon Toruńczyk receives the *2012 Ackermann Award* of the European Association of Computer Science Logic (EACSL) for his thesis

Languages of profinite words and the limitedeness problem.

His thesis builds a new framework to study limitedeness problems of finite automata, based on the topology of profinite words.

Background of the Thesis. Research currents in computer science are often driven by decidability questions. Even when a problem is solved, it often stimulates theoretical work explaining the solution. Toruńczyk's thesis is related to two decidability questions: the limitedeness problem for distance automata originally solved by Hashigushi in 1982, and the still unsolved decidability status of the logic MSO + B. The actual motivation arose from a connection between the two problems.

In 2004, Mikołaj Bojańczyk raised the question whether the decidability of some instances of the finite model property can be strengthened to decidability of a suitable logic. He proposed an extension of the monadic second order logic by a quantifier $BX\,\varphi(X)$, expressing the existence of a finite bound on the cardinality of sets X satisfying φ. The decidability status of the new logic remains unknown. In particular, the MSO + B theory of $\langle \omega, \leq \rangle$ is a plausible extension of Büchi's arithmetic S1S, but its decidability remains open. Approaching the problem, Bojańczyk and Thomas Colcombet captured a fragment of this theory by automata with blind counters, which can be incremented and reset, but not read. The technical core of their proof is a duality result claiming that two variants of the model, called ωB and ωS-automata respectively, actually complemented each other. It was only afterwards that the authors realized that some of their ideas occurred previously in research on the *star height* problem.

This celebrated automata-theoretic decision problem asks for the minimal nesting of the star operator needed to define a given regular language. The problem, raised by Lawrence C. Eggan in 1963, was solved positively by Kosaburo Hashiguchi only 25 years later. As a step toward the main solution, Hashiguchi solved in 1982 a related decision problem of limitedeness of distance automata. In the original setting, the problem concerns finite (non-deterministic) automata with non-negative costs over transitions, and asks if any acceptable word can be accepted with a cumulative cost within some finite bound. This can be generalized to other concepts of cost. The difficult techniques of Hashiguchi were further studied and developed in particular by Imre Simon and Hing Leung. An insightful new solution was given in 2005 by Daniel Kirsten, who reduced the star height question to the limitedeness problem of what he called distance desert automata. A surprising discovery made by Thomas Colcombet revealed that the ωB and ωS-automata introduced in the context of the logic MSO + B, were in fact the infinite computation variants of Kirsten's automata, and the aforementioned duality theorem yielded yet another path to the solution of the star height problem. Colcombet pursued this connection by cleaning away infinite computations, and concentrating on B and S-automata on finite words. He further developed a theory of cost functions, where the limitedeness problem appears as a special case of an equivalence between two functions. This theory constitutes a powerful quantitative generalization of the theory of regular languages, involving automata, algebra, and logic.

Toruńczyk's Thesis. Compared to the previous work, the thesis of Szymon Toruńczyk reveals a metric aspect of the limitedeness problem. It was first noticed by Hing Leung who in his alternative proof of Hashiguchi's result (from 1988) used a concept of limit, but it was not pursued very far. The reason perhaps is that a topological structure of finite words is not as apparent as it is in the case of ω-words, which can be just identified with reals. A topological structure of finite words is revealed however by their metric completion to *profinite* words, which moreover preserves the algebraic structure of semigroup. This is an alternative extension of the free monoid of finite words, just as the p-adic numbers form an extension of the rational field, which is alternative to reals. In his thesis, throughout a long series of results, Toruńczyk argues that the topological semigroup of profinite words constitutes a suitable framework to consider the limitedeness problem, cost functions, as well as the quantifier B.

The first main result is a self-contained proof of the decidability of the limitedeness problem for the (most general) case of B-automata, based on topological ideas. The results by Kirsten and Colcombet follow there from a more general, new result, on the structure of a certain profinite semigroup generalizing the tropical semiring considered by Simon and Leung.

The second main result consists of a multiple characterization of cost functions computable by B-automata (or S-automata) in terms of the associated sets of profinite words. It is a basic fact of the theory of profinite words that the completions of the ordinary regular languages form the family of *clopen* (closed and open) sets of profinite words. Toruńczyk makes the next step by showing that the profinite languages associated with B-automata (or S-automata) correspond to the *open* (resp. *closed*) sets with finite syntactic stabilization monoids. This yields a machine independent characterization of the cost functions of Colcombet. Another characterization is given in terms of logic, which is a profinite counterpart of the logic MSO + B. The decidability of the satisfiability problem for this logic remains open, but the author manages to show that satisfiability of propositional combinations of the formulas corresponding to cost functions is decidable.

Biographical Sketch. Szymon Toruńczyk was born in 1983. He obtained all his degrees from the University of Warsaw: B.S. degree in computer science in 2006, and M.Sc. degree in mathematics in 2006. He wrote his doctoral dissertation under the supervision of Mikołaj Bojańczyk and obtained the Ph.D. degree in computer science (with honors) in 2011. Throughout 2009-2011 he visited ENS Cachan, working under supervision of Luc Segoufin. He is currently an assistant professor at the Warsaw University.

Jury

The Jury for the **Ackermann Award 2012** consisted of eight members, three of them *ex officio*, namely the president and the vice-president of EACSL, and one member of the LICS organizing committee.

The members of the jury were

- Thierry Coquand (University of Gothenburg),
- Anuj Dawar (University of Cambridge), the vice-president of EACSL,
- Thomas A. Henzinger (IST Austria),
- Jean-Pierre Jouannaud (École Polytechnique, Paris),
- Daniel Leivant (Indiana University, Bloomington),
- Damian Niwiński (University of Warsaw), the president of EACSL,
- Luke Ong (University of Oxford), LICS representative,
- Wolfgang Thomas (RWTH, Aachen).

Previous winners

Previous winners of the Ackermann Award were

2005, Oxford
Mikołaj Bojańczyk,
Konstantin Korovin,
Nathan Segerlind,

2006, Szeged
Balder ten Cate,
Stefan Milius,

2007, Lausanne
Dietmar Berwanger,
Stéphane Lengrand,
Ting Zhang,

2008, Bertinoro
Krishnendu Chatterjee,

2009, Coimbra
Jakob Nordström,

2010, Brno
no award given,

2011, Bergen
Benjamin Rossman.

Detailed reports on their work appeared in the CSL proceedings, and are also available *via* the EACSL homepage.