The Ackermann Award 2016

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Abstract

The Ackermann Award is the EACSL Outstanding Dissertation Award for Logic in Computer Science. It is presented during the annual conference of the EACSL (CSL'xx). This contribution reports on the 2016 edition of the award.

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Category Award Description

1 The Ackermann Award 2016

The twelfth Ackermann Award is presented at CSL'16 in Marseille, France. The 2016 Ackermann Award was open to PhD dissertations in topics specified by the CSL and LICS conferences, which were formally accepted as theses for the award of a PhD degree at a university or equivalent institution between 1 January 2014 and 31 December 2015. The Jury received fifteen nominations for the Ackermann Award 2016. The candidates came from a number of different countries across the world. The institutions at which the nominees obtained their doctorates represent nine countries in Europe, North America, the Middle East and Australia.

The topics covered a wide range of Logic and Computer Science as represented by the LICS and CSL Conferences. All submissions were of a very high standard and contained remarkable contributions to their particular fields. The Jury wishes to extend its congratulations to all 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 wide range of excellent candidates presented the jury with a difficult task. After an extensive discussion, one candidate stood out and the jury decided to award the **2016 Ackermann Award** to:

Nicolai Kraus from Germany, for his thesis
Truncation Levels in Homotopy Type Theory
approved by the University of Notthingham, UK, in 2015,
supervised by Thorsten Altenkirch.

Citation. Nicolai Kraus receives the *2016 Ackermann Award* of the European Association of Computer Science Logic (EACSL) for his thesis

Truncation Levels in Homotopy Type Theory.

* For the Jury of the EACSL Ackermann Award.

25th EACSL Annual Conference on Computer Science Logic (CSL 2016).
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His thesis makes fundamental contributions to the field of Homotopy Type Theory. In particular, he resolves an important open question on the truncation level of the nth univalent universe. He also obtains deep results on propositional truncation. In obtaining his results, he develops sophisticated mathematical and logical methods which are certain to play an important role in the further development of this field.

Background of the Thesis. Dependent type theory was introduced by the mathematician N.G. de Bruijn as a formalism particularly well-adapted to represent in automated mathematical reasoning. The following quote from D. Knuth is a good illustration of its originality:

> This reminds me of the very interesting language AUTOMATH, invented by Dijkstra's colleague (and next-door neighbor) N.G. de Bruijn. AUTOMATH is not a programming language, it is a language for expressing proofs of mathematical theorems. The interesting thing is that AUTOMATH works entirely by type declarations, without any need for traditional logic! I urge you to spend a couple of days looking at AUTOMATH, since it is the epitome of the concept of type.

This formalism extends *simple type theory* (A. Church 1940), allowing the representation of arbitrary structures, and exploiting systematically the idea of "propositions-as-types". It takes as primitive the notion of a *family of types* over a given type together with the operation of *dependent product* and *dependent sum*. Recently, a proof of the 4-colour Theorem (2004), and then a proof of the Feit-Thompson Theorem (2012), were formally expressed in a formal system based on type theory, showing that this approach scales to non-trivial results. These representations however were limited to *discrete* structures (finite graphs, or finite groups), and it was not entirely clear how to represent in this formal system more general structures, not necessarily discrete, and notions essential in some parts of contemporary mathematics and computer science, such as the notion of category. Connected to this, the *identity type*, introduced by P. Martin-Löf in 1973, with an elimination rule which exploited fully the notion of dependent types, had a somewhat mysterious status. It was not clear in particular how to generalize to dependent types the *extensionality axiom*, which plays a fundamental role in set theory and in simple type theory. An answer to these questions was provided by the formulation of the *univalence axiom* (Voevodsky 2010), which can be seen as a general expression of the extensionality axiom. Voevodsky also introduced a natural stratification of types, according to the complexity of their associated identity types: first propositions (where any two objects are equal), then sets (where any equality type is a proposition), then groupoids (where any equality type is a set), 2-groupoid, *etc.* Following this description, one can view type theory as a *generalization* of set theory, where sets appears as types having a particularly simple notion of identity. Voevodsky also introduced a new modal operation on types, the *propositional truncation*. These discoveries have deeply transformed our understanding of type theory, and a special year (2012–13) was organized at the Institute of Advanced Study in Princeton to better analyse their implications. Some open problems were formulated during this meeting. One such problem was to understand if there is some connection between the intuitive notion of "size" of a type and the complexity of its equality. More precisely, Martin-Löf had introduced in type theory "larger and larger" universes $U_0,\ U_1,\ U_2,\ldots$ Is it the case that the corresponding equality type also becomes more and more complex? It is for instance easy to show from the univalence axiom that U_0 itself cannot be a set, but must at least be a groupoid. With more effort, one can show that U_1 is not a groupoid, but at least a 2-groupoid. Can one show in general that U_n is not an n-groupoid? This question is already a challenge for $n = 2$.

Kraus' Thesis. A first impressive contribution (joint with Christian Sattler) of this thesis is to present a solution to this open problem, at any level n. Furthermore, this result is completely formalized in the interactive proof system Agda. This argument relies on an elegant general principle: the *Local-Global Looping Principle*, which states that an $(n+2)$-loop in the universe with base point X is the same as a family of $(n+1)$-loops in X.

The second contribution consists in a deep analysis of the operation of propositional truncation. By definition, we know that, if the type B is a proposition, a map from the propositional truncation of a type A to the type B corresponds exactly to a map from A to B. A natural question is: what happens if B has a more complex notion of equality, for instance if B is a set? How to give then a map from the propositional truncation of A to the type B? For analysing this question, Nicolai Kraus introduces the notion of a *weakly constant* map, i.e. a map such that the images of any two points in the domain are equal in the codomain. This notion is subtle when the equality in the codomain is complex. A general result about this notion is the *Fixed Point Lemma* (also now known as *Kraus' Lemma*) which states that the type of fixed-points of a weakly constant endomap is always a proposition. Nicolai Kraus presents then a general characterization of maps from the propositional truncation of a type, without any restriction on the complexity of the codomain.

This thesis contains several other surprising results. Here we highlight two of them. The first is that one can show that the propositional truncation of the sum of two propositions has the universal property of the *join* operation (an important operation in homotopy theory). The second is that it is possible to build a type that has exactly one non-trivial homotopy group on level n, and this, *only* using the univalence axiom. This type can be seen as an approximation of an Eilenberg-Mac Lane space, also important in homotopy theory.

The thesis is coherently written, in a fluent, lucid and scholarly manner. It gives a lucid account of a number of deep, original and technically non-trivial contributions to the field of dependent type theory, answering difficult open questions and formulating new techniques and notions which will play an important role in its future development.

Biographical Sketch. Nicolai Kraus completed his early education in Bavaria, being a representative for the German Mathematics Olympiad in ever year in the period 2002–07. He pursued his undergraduate education at the Ludwig Maximilains University in Munich obtaining a Bachelor's degree in Mathematics in 2010 and a second Bachelor's in Computer Science in 2011. He then pursued a PhD at the University of Nottingham in England under the supervision of Thorsten Altenkirch. Since 2015 he is is post-doctoral Research Fellow at Nottingham.

2 Jury

The Jury for the **Ackermann Award 2016** consisted of eight members, two of them *ex officio*, namely, the president and the vice-president of EACSL. In addition, the jury also included a representative of SigLog (the ACM Special Interest Group on Logic and Computation).

The members of the jury were:

- Thierry Coquand (Chalmers University of Gothenburg),
- Anuj Dawar (University of Cambridge), the president of EACSL,
- Orna Kupferman (Hebrew University of Jerusalem),
- Daniel Leivant (Indiana University, Bloomington),
- Dale Miller (INRIA Saclay), SigLog representative,

- Luke Ong (University of Oxford),
- Jean-Éric Pin (CNRS and Université Paris 7),
- Simona Ronchi Della Rocca (University of Torino), the vice-president of EACSL.

3 Previous winners

Previous winners of the Ackermann Award were

2005, Oxford:
Mikołaj Bojańczyk from Poland,
Konstantin Korovin from Russia, and
Nathan Segerlind from the USA.

2006, Szeged:
Balder ten Cate from The Netherlands, and
Stefan Milius from Germany.

2007, Lausanne:
Dietmar Berwanger from Germany and Romania,
Stéphane Lengrand from France, and
Ting Zhang from the People's Republic of China.

2008, Bertinoro:
Krishnendu Chatterjee from India.

2009, Coimbra:
Jakob Nordström from Sweden.

2010, Brno:
no award given.

2011, Bergen:
Benjamin Rossman from USA.

2012, Fontainebleau:
Andrew Polonsky from Ukraine, and
Szymon Toruńczyk from Poland.

2013, Turin:
Matteo Mio from Italy.

2014, Vienna:
Michael Elberfeld from Germany.

2015, Berlin:
Hugo Férée from France, and
Mickael Randour from Belgium

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