The Ackermann Award 2017

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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 2017 edition of the award.

1998 ACM Subject Classification F.3 Logics and Meanings of Programs, F.4 Mathematical Logic and Formal Languages

Keywords and phrases Ackermann Award, Computer Science, Logic

Digital Object Identifier 10.4230/LIPIcs.CSL.2017.1

Category Award Description

1 The Ackermann Award 2017

The thirteenth Ackermann Award is presented at CSL'17 in Stockholm, Sweden. The 2017 Ackermann Award was open to any PhD dissertation in the topics represented at the annual 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 2015 and 31 December 2016. The Jury received fourteen nominations for the Ackermann Award 2017. The candidates came from a number of different countries across the world. The institutions at which the nominees obtained their doctorates represent eleven different countries in Europe and North America.

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 unanimously decided to award the **2017 Ackermann Award** to:

> Amaury Pouly from France, for his thesis
> *Continuous Models of Computation: From Computability to Complexity*
> approved jointly by the École Polytechnique (France) and the Universidade do Algarve (Portugal), in 2015,
> supervised by Olivier Bournez and Daniel Graça.

* For the Jury of the EACSL Ackermann Award.

26th EACSL Annual Conference on Computer Science Logic (CSL 2017).
Editors: Valentin Goranko and Mads Dam; Article No. 1; pp. 1:1–1:4
Leibniz International Proceedings in Informatics
LIPICS Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

Citation. Amaury Pouly receives the *2017 Ackermann Award* of the European Association of Computer Science Logic (EACSL) for his thesis

Continuous Models of Computation: From Computability to Complexity.

His thesis offers a novel insight into computational complexity of analog devices, leading through deep and difficult landmark results to a strong corroboration of Church-Turing Thesis across digital and analog computation models, and of identifying feasibility with PTime across such models.

Background of the Thesis. Turing gave in 1936 a compelling analysis of digital computation devices, thereby providing intuitive evidence for the Church-Turing Thesis, that is the identification of digital computability with computability by Turing machines. This identification does not rule out, however, the existence of physical analog computation devices that are more powerful than Turing machines.

A mathematical model of analog computing was proposed in 1941 by Claude Shannon, dubbed the General Purpose Analog Computer (GPAC), and inspired by the Differential Analyzer a 1931 physical device built at MIT. Recent renewed interest in analog computing emanates from a general interest in novel models of computation, such as quantum and biological systems, as well as hybrid systems, where continuous computation plays a role.

Nonetheless, GPAC remains a solid paradigm for analog computing, because it is realistically implementable, is entirely continuous for both time and space, and can equivalently be described as the class of dynamical systems defined by differential equations, indeed by differential equations of a particularly simple form. While digital computers have replaced analog computers, the theoretical question of whether analog computers might be more powerful remains all the more pertinent with the advent of other models of computation, such as quantum and biological computers.

In recent years Graça and Bournez showed that GPACs are indeed equivalent to Turing machines: the two models compute the same real-valued functions. A key component of this equivalence is the characterization of GPAC by Costa and Graça (2003) in terms of polynomial differential equations. This corroborates the physical Church-Turing Thesis concerning computability. However, the real-life practicality of that equivalence hinges on the complexity of the mutual simulations. To resolve this issue, we need an appropriate notion of computational complexity for analog computing. Previous attempts to define such measures failed, primarily because time is not an appropriate complexity parameter for continuous computing: indeed, it can be re-scaled at will. The challenge is, therefore, to identify a complexity parameter that corresponds in analog computing to computation time in digital computing. This is the point of departure of Pouly's thesis.

Achievements. Identifying an appropriate complexity measure for GPACs required an important preliminary insight: the notions corresponding to time and to space are independent in continuous systems, as they can be traded for each other via scaling. This contrasts with discrete systems, where time bounds imply space bounds. An adequate complexity measure for GPACs must therefore refer to bounds of both quantities. Pouly's elegant solution was to adopt as a single complexity measure the length of the trajectory (computation) curve. That length is large if the system "blows up", consuming space, OR if it has a rapidly changing trajectory, consuming time. Either case represents computational hardness.

Pouly proceeds to define mutual simulations of GPACs and Turing machines that are polynomial with respect to computational complexity. This corroborates the physical

Church-Turing thesis at the practical level: no continuous physical device yields a super-polynomial speed-up over Turing machines.

The proof of that equivalence represents a highly complex and mature mathematical achievement, combining tools and insights from various disciplines, including classical analysis, numerical methods, dynamical systems theory, program verification, and computational complexity theory.

Extensions and Applications. Certain facets of Pouly's central proof are of substantial independent interest. Already in its initial phase, the proof includes an adaptive Taylor algorithm to solve polynomial initial-value differential equation problems over unbounded intervals, of polynomial computational complexity. Pouly also gives an implicit characterization of PTime for Turing machines in terms of differential equations, a result that earned him a Best Student Award at ICALP 2016. Moreover, the technology developed in the thesis opens the door to viewing differential equations as a computation model and as a general tool for implicit computational complexity. For example, following his thesis Pouly developed (with Bournez) a differential equation that maybe viewed as universal.

Broad Impact. We have been witnessing for some time the emergence of a broad array of computation models, related to various areas of databases, mathematics, physics, and biology. Unfortunately missing from this development are unifying concepts, themes, techniques, and results. Pouly's thesis is a remarkable contribution to the search of such unity. Surprisingly, it also provides new tools for both digital computing (such as implicit complexity via differential equations) and analog computing (efficient algorithms for differential equations).

Biographical Sketch. Amaury Pouly completed his early education in Lyon, France, obtaining a Bachelor's and Master's degree from the École Normale Supérieure de Lyon. His PhD work was jointly carried out in the LIX laboratory of the École Polytechnique (under the supervision of Olivier Bournez) and the University of Algarve in Portugal (under the supervision of Daniel Graça). Since completing his PhD in 2015, he has been working as a postdoctoral research assistant to Joel Ouaknine, first at Oxford and more recently at the Max Planck Institute in Saarbrücken.

2 Jury

The Jury for the **Ackermann Award 2017** 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:

- 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 Diderot),
- Simona Ronchi Della Rocca (University of Torino), the vice-president of EACSL.
- Thomas Schwentick (TU Dortmund University)

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

2016, Marseille:
Nicolai Kraus from Germany

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