The Ackermann Award 2008

J.A. Makowsky and D. Niwinski

Members of EACSL Jury for the Ackermann Award*

The fourth **Ackermann Award** is presented at this CSL'08. This is the second year in which the EACSL Ackermann Award is generously sponsored. Our sponsor for the remaining two years is the worlds leading provider of personal peripherals, Logitech S.A., situated in Romanel, Switzerland[1].

Eligible for the 2008 **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. 2006 and 31.12. 2007. The Jury received 13 nominations for the **Ackermann Award 2008**. The candidates came from 8 different nationalities from Europe, Russia and India, and received their PhDs in 8 different 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. In the past the Jury reached a consensus to give more than one award. This time, in spite of the extreme high quality of the nominated theses, the Jury decided finally, to give for the year 2008 **only one** award. The 2008 **Ackermann Award** winner is

Krishnendu Chatterjee

for his thesis *Stochastic ω-Regular Games* issued by the University of California at Berkeley, supervised by Prof. Thomas A. Henzinger.

The Jury wishes to congratulate the recipient of the Ackermann Award for his outstanding work and wishes him a successful continuation of his career.

The Jury wishes also to congratulate all the remaining 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.

* We would like to thank T. Henzinger and L. de Alfaro for their help in preparing the citations.

[1] We would like to thank Daniel Borel, Co-founder and Chairman of the Board of Logitech S.A, for his generous support of the Ackermann Award for the years 2007-2009. For a history of the company, founded in 1981 in Switzerland, consult `http://www.logitech.com`.

Krishnendu Chatterjee

Citation. Krishnendu Chatterjee receives the *2008 Ackermann Award* of the European Association of Computer Science Logic (EACSL) for his thesis

Stochastic ω-Regular Games.

The thesis greatly advances the algorithmics of repeated games, and indicates that the new degrees of freedom, such as stochastic and concurrent moves, need not increase the computational complexity. The results reveal the algorithmic aspect of determinacy of repeated games and enhance the scope of formal methods in verification of reactive systems, where repeated games form one of leading paradigms.

Background of the thesis. Since the pioneering work of Zermelo on determinacy of chess, determinacy of games has been recognized as an interesting mathematical problem. It cannot be taken for granted, even for perfect information games, if the players take liberty to play *ad infinitum* (as noted by Gale and Stewart in 1953). But the fundamental result of Martin (1975) establishes the determinacy of all turn-based perfect information games with Borel winning objectives.

While determinacy assures the existence of a winning strategy for one of the players, the algorithmic solution of a game consists in determining the winner effectively, and computing the strategy. The usefulness of determinacy of infinite games in the design of decision procedures was discovered by Büchi, and then by Gurevich and Harrington (and, independently, A.A.Muchnik) in their celebrated simplified proofs of the Rabin Tree Theorem (in 1982). The algorithmic approach also revealed the role of players' *memory* in the determinacy results, which can be actually finite for games with ω-regular objectives, and is not needed at all for the (essentially equivalent) parity games. The subsequent development of the mathematical theory of verification, synthesis, and control of reactive systems (especially by E.A.Emerson and his collaborators) showed that, in spite of a large variety of possible logical formalisms, the algorithmic content of the main verification problem – model checking – can be reduced to solving some conceptually simple (though infinite) repeated games on graphs, like parity games. In these games the players, in turns, choose which edge of the graph to follow, so that a play of the game forms an infinite path in the graph, which is winning for one of the players depending on the winning objective. Indeed, it is natural to formulate the verification problems directly within a game framework, e.g., as a game of a system versus environment, or a a controller versus a non-deterministic system under its control.

Now the game framework also opens paths to extensions of the model, less apparent in logical setting, but for long present in the main stream of the game theory. These are, in particular, games with quantitative rather than qualitative objectives (like mean-payoff games), games with simultaneous rather than turn-based moves (so-called concurrent games), or games where the players select probability distributions over successor states (so-called stochastic games).

While the determinacy of the one-shot concurrent stochastic games is given by the classical von Neumann Minimax Theorem (of 1928), its powerful repeated game extension, the determinacy of Blackwell games, has been established by D.A.Martin only quite recently (1998). What is more, one can also consider a more general case, where the players' objectives are not antagonistic, and the role of determinacy is taken by the central concept of the game theory – the Nash equilibrium.

All these features can make sense in a number of verification scenarios, which makes the aforementioned game models attractive for computer science. They are however inherently complex mathematically, in particular the very concept of winning has to be refined, according to if we search for (almost) sure winning, or for maximizing the winning probability (quantitative analysis). One could expect that the computational complexity of the decision problems of the new games is also prohibitive. By the time when Krishnendu Chatterjee started his research, only few results were known for some special cases (the work by Condon, Zwick and Paterson, Jurdziński on turn-based stochastic games, and Secchi and Sudderth on concurrent games with boolean safety objectives). His subsequent work had to change the picture essentially.

Chatterjee's thesis. Krishnendu Chatterjee has established a number of strong algorithmic results, proving the optimal or nearly optimal upper bounds for most of the games mentioned above, thus solving a long list of open problems. A general message of all these results is that enhancing the game model by concurrent and stochastic elements is much more feasible than it could appear at the first sight. This greatly improves our algorithmic understanding of games, and opens new perspectives for a variety of formal methods based on game scenarios. The main contributions are as follows.

- For turn-based stochastic games the author provides algorithms for both qualitative and quantitative analysis, which yield a PSPACE upper bound for games with Muller objective, and NP (resp. co-NP) upper bounds for games with Rabin and Streett objectives, respectively. This implies an NP $\cap$ co-NP upper bound for games with parity objective, which coincides with the best known upper bound in deterministic case. The previous upper bounds known for stochastic games, due to de Alfaro and Majumdar, were 2EXPTIME for parity games, and 3EXPTIME for the remaining games. The author also optimizes the amount of memory needed in optimal strategies, and designs a strategy improvement algorithm for turn-based Rabin and Streett games.

- For concurrent stochastic games, the author shows that the quantitative analysis can be achieved in PSPACE for games with parity objective, and in EXPSPACE for Muller, Rabin, and Streett objectives. The previous upper bounds here were 3EXPTIME and 4EXPTIME, respectively (again, due to de Alfaro and Majumdar). This impressive result, showing that a big advance in expressive power can be achieved with a relatively small complexity overhead, is obtained by a deep mathematical and game-theoretic insight.

- The author gives an elementary and combinatorial proof of existence of memoryless ε-optimal strategies in concurrent games with reachability objectives, for all $\varepsilon > 0$. The previous proof (in a monograph of Filek and Vrieze) used advanced results from analysis. The proof technique originally developed here also yields a strategy improvement algorithm for concurrent reachability games.

- The author makes a fundamental contribution to the theory of repeated games, by giving an EXPTIME algorithm for solving concurrent games with limit-average objective. This is a first algorithmic result in the analysis of these games, extensively studied in game theory for decades. The result also yields a PSPACE upper bound for solving concurrent games with discounted reward objectives.

- The author develops a game-theoretic model for an interaction between processes or components of a system, whose goals are not strictly conflicting, but rather conditionally competitive. This is a turn-based deterministic game with an ω-regular objective for each player. An essential conceptual contribution consists in an idea of a *secure* equilibrium, which is a special case of a Nash equilibrium, in which no player can lower the other player's payoff, without lowering her own payoff as well. The author establishes the existence and uniqueness of such equilibria, presents an algorithm to compute them, and demonstrates their applications in the modular verification of systems.

The results of the thesis were published in numerous papers, presented to conferences CSL, CONCUR, SODA, ICALP, QEST, LICS, FSTTCS, and TACAS, as well as in journals: *Theoretical Computer Science* and *International Journal of Game Theory*. Some of these papers were co-authored; the list of co-authors includes L. de Alfaro, T.A.Henzinger, M.Jurdziński, and R.Majumdar.

Biographic Sketch. Krishnendu Chatterjee was born in 1978 and received his B.Tech. degree in Computer Science and Engineering from the Indian Institute of Technology, Kharagpur, India, in 2001. He is the recipient of various excellent student awards, among them the *President of India Gold Medal* in 2001. He received his M.Sc. degree in Computer Science from the University of California, Berkeley, in 2004. He wrote his Ph.D. thesis under the supervision of professor Thomas A. Henzinger, and obtained the Ph.D. degree in Computer Science from the University of California in Berkeley in 2007. He is currently a post-doctoral researcher at the University of California in Santa Cruz.

The Ackermann Award

The EACSL Board decided in November 2004 to launch the EACSL Outstanding Dissertation Award for Logic in Computer Science, the **Ackermann Award**, The award[2]. is named after the eminent logician Wilhelm Ackermann (1896-1962), mostly known for the Ackermann function, a landmark contribution in early complexity theory and the study of the rate of growth of recursive functions, and for his coauthorship with D. Hilbert of the classic *Grundzüge der Theoretischen Logik*, first published in 1928. Translated early into several languages, this monograph was the most influential book in the formative years of mathematical logic. In fact, Gödel's completeness theorem proves the completeness of the system presented and proved sound by Hilbert and Ackermann. As one of the pioneers of logic, W. Ackermann left his mark in shaping logic and the theory of computation.

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 Jury for the **Ackermann Award** consists 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 current jury consists of J. van Benthem (Amsterdam), B. Courcelle (Bordeaux), M. Grohe (Berlin), M. Hyland (Cambridge), J.A. Makowsky (Haifa, President of EACSL), D. Niwinski (Warsaw, Vice President of EACSL), G. Plotkin (Edinburgh, LICS Organizing Committee) and A. Razborov (Moscow and Princeton).

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

Detailed reports on their work appeared in the CSL'05, CSL'06 and CSL'07 proceedings, and are also available via the EACSL homepage.

[2] Details concerning the Ackermann Award and a biographic sketch of W. Ackermann was published in the CSL'05 proceedings and can also be found at `http://www.dimi.uniud.it/eacsl/award.html`.