

Curriculum Vitae

Thierry CACHAT

Laboratoire d'Informatique Algorithmique : Fondements et Applications
University Paris Diderot – Paris 7

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1 Résumé

Name: Thierry CACHAT

Current position: Assistant professor of computer science

URL: <http://www.liafa.jussieu.fr/~txc/>

Date of birth: 6th June 1975

Nationality: French

Work experience

2004– ... Assistant professor of computer science at University PARIS 7, France, researcher at LIAFA: Laboratoire d’Informatique Algorithmique : Fondements et Applications. (tenure position “Maître de Conférence”)

2003–2004 Teaching assistant at computer science department of École Normale Supérieure de CACHAN, France, researcher at LSV: Laboratoire Spécification et Vérification. (One year position “ATER: attaché temporaire d’enseignement et de recherche”)

2000–2003 Teaching assistant in Wolfgang THOMAS’ group Informatik VII “Logic and Theory of Discrete Systems”, University of AACHEN, Germany. (fixed term position “wissenschaftlicher Angestellter”, also known as “wissenschaftlicher Assistent”)

Education

2000–2003 PhD in computer science at University of AACHEN, Germany. Defended on 18th December 2003, “Games on Pushdown Graphs and Extensions”. Reviewers: Wolfgang THOMAS (supervisor) and Didier CAUCAL. Examiners: Manfred NAGL and Peter ROSSMANITH.

PhD in computer science at University of RENNES 1, France. Defended on 19th March 2004: “Jeux sur des graphes d’automates à pile et leurs extensions”. Reviewers: Damian NIWIŃSKI and Igor WALUKIEWICZ. Examiners: Didier CAUCAL, Antoine PETIT, Jean-Claude RAOULT and Wolfgang THOMAS.

1999–2000 Master of Research in computer science at University RENNES 1 with first-class honors, ranked 1st (DEA: “Diplôme d’Études Approfondies”). Internship at IRISA, supervised by Didier CAUCAL: regularity of the product of regular sets of integers. 1st February to 30th June 2000.

1998–1999 Passed the French competitive examination “agrégation” in mathematics. Master of Research “Logics and foundations of mathematics” at University PARIS 7 (finished in 2000).

1997–1998 Admission in École Normale Supérieure de CACHAN (competitive examination).

1995–1997 Study of Mathematics at University GRENOBLE 1 “Licence” and “maîtrise” obtained with first-class honors. Two month internship at the University of Konstanz, Germany.

1993–1995 Undergraduate study of Mathematics and Physics at lycée Clemenceau, NANTES, in highly selective preparatory classes. Admission obtained in engineering schools “École Centrale de Paris” and “ENSIMAG” (competitive examination).

1993 End of high school study: “baccalauréat” diploma with honors at MONTÉLIMAR, Drôme, France.

Visits

18th to 28th December 2006 at *Institute for Information Transmission Problems (IITP) of the Russian Academy of Sciences*, Moscow, in the framework of a CNRS-RAS project between IITP and LIAFA.

Languages

French: mother tongue,
English: read, written and spoken fluently,
German: read, written and spoken fluently.

Programming

C, HTML, Java, L^AT_EX, Maple, Pascal, PHP, Visual Basic.

2 Publications

For each conference appears in parenthesis the total number of accepted and submitted papers, when it is known. All publications are available on

<http://www.liafa.jussieu.fr/~txc/publi.html>

International conferences with program committee

- [Cac02a] Thierry Cachat. The power of one-letter rational languages. In *Proceedings of the 5th international conference Developments in Language Theory, DLT'01*, volume 2295 of *Lecture Notes in Computer Science*, pages 145–154. Springer, 2002. (24/64)
- [Cac02b] Thierry Cachat. Symbolic strategy synthesis for games on pushdown graphs. In *Proceedings of the 29th International Colloquium on Automata, Languages, and Programming, ICALP'02*, volume 2380 of *Lecture Notes in Computer Science*, pages 704–715. Springer, 2002. (83/269)
- [CDT02] Thierry Cachat, Jacques Duparc, and Wolfgang Thomas. Solving pushdown games with a Σ_3 winning condition. In *Proceedings of the 11th Annual Conference of the European Association for Computer Science Logic, CSL'02*, volume 2471 of *Lecture Notes in Computer Science*, pages 322–336. Springer, 2002. (37/111)
- [Cac03] Thierry Cachat. Higher order pushdown automata, the Caucal hierarchy of graphs and parity games. In *Proceedings of the 30th International Colloquium on Automata, Languages, and Programming, ICALP'03*, volume 2719 of *Lecture Notes in Computer Science*, pages 556–569. Springer, 2003. (84/212)
- [Cac06a] Thierry Cachat. Controller synthesis and ordinal automata. In *Proceedings of the 4th International Symposium Automated Technology for Verification and Analysis, ATVA'06*, volume 4218 of *Lecture Notes in Computer Science*, pages 215–228, Springer, 2006. (35/137)
- [Cac06b] Thierry Cachat. Tree automata make ordinal theory easy. In *Proceedings of the 26th International Conference Foundations of Software Technology and Theoretical Computer Science, FSTTCS'06*, volume 4337 of *Lecture Notes in Computer Science*, pages 286–297. Springer, 2006. (34/155)

International workshops with program committee

- [Cac02d] Thierry Cachat. Uniform solution of parity games on prefix-recognizable graphs. In *Proceedings of the 4th International Workshop on Verification of Infinite-State Systems, INFINITY'02*, volume 68 (6) of *Electronic Notes in Theoretical Computer Science*. Elsevier Science Publishers, 2002.
- [ACS⁺07] Eugene Asarin, Thierry Cachat, Alexander Seliverstov, Tayssir Touili, and Vassily A. Lyubetsky. Attenuation regulation as a term rewriting system. In *Proceedings of the Second International Conference on Algebraic Biology, AB'07*, volume 4545 of *Lecture Notes in Computer Science*, pages 81–94. Springer, 2007. (19/40)

Others

- [Cac02c] Thierry Cachat. Two-way tree automata solving pushdown games. In Erich Grädel, Wolfgang Thomas, and Thomas Wilke, editors, *Automata, Logics, and Infinite Games*, volume 2500 of *Lecture Notes in Computer Science*, pages 303–317. Springer, 2002.
- [ABC⁺05] Karine Altisen, Patricia Bouyer, Thierry Cachat, Franck Cassez, and Guillaume Gardey. Introduction au contrôle des systèmes temps-réel. In *Actes du 5ème Colloque sur la Modélisation des Systèmes Réactifs (MSR'05)*, pages 367–380, Autrans, France, October 2005. Hermès.
- [CW07] Thierry Cachat and Igor Walukiewicz. The complexity of games on higher order pushdown automata. Research report available at <http://hal.archives-ouvertes.fr/hal-00144226> and <http://fr.arxiv.org/abs/0705.0262>, May 2007.

3 Teaching

In Aachen (2000–2003) in German

Undergraduate Exercise class for “automata, languages and complexity”: introduction to finite automata, pushdown automata, language theory, Turing machines, calculability, complexity, for students of technology.

Co-supervision of students’ seminar “efficient algorithms”, based on the book by Cormen, Leiserson, Rivest: Introduction to Algorithms.

Co-supervision of students’ seminar “Pattern-Matching and applications to Bio-Informatics”, based on: J. Setubal and J. Meidanis, Introduction to Computational Molecular Biology, PWS Publishing Company, 1997; M. Crochemore and W. Rytter, Text Algorithms, Oxford University Press, 1994.

Co-supervision of software internship “platform for algorithms from automata theory”: graphical interface to draw automata and apply determinization and minimization algorithms.

Postgraduate Exercise class for “Automata theory and applications”: minimization, bisimulation, logic (LTL, FO), model checking, tree automata, XML documents, pushdown systems, communicating automata, Message Sequence Charts, hierarchical systems, Petri nets.

Exercise class for “Automata and reactive systems”: omega-automata, Staiger-Wagner, Büchi, Street, Rabin, Muller, two-player games: reachability, parity.

Co-supervision of students’ seminar “Automata theory and applications: specification and verification of infinite transitions systems”, based on different recent papers.

At École Normale Supérieure (ENS) de Cachan (2003–2004)

Postgraduate Computer class Excel / Visual Basic: introduction to Excel and algorithmic, for students of economics and management.

Computer class C++: introduction to algorithmic and programming, for students of technology.

Exercise class “static analysis”.

Exercise class “language theory”: regular and context-free languages, syntactic analysis.

Course “logic and automata”: Monadic Second Order Logic, infinite trees, Rabin’s Theorem.

At University Paris Diderot – Paris 7 (2004– . . .)

Undergraduate Course, exercise class and computer class “introduction to computer science and programming”: Java programming for first year students.

Exercise class and computer class “data structure”: Java programming with trees, linked lists, and static objects.

Exercise class “concepts in computer science”: call by value/address, recursion, stack, digitizing, compression.

Postgraduate Exercise class “grammar and analysis” / “language theory”: finite automata, regular expressions, pushdown automata, context-free grammar, syntactic analysis.

Exercise class “algorithmic theory”: sorting algorithms, complexity, trees, greedy algorithms, dynamic programming.

Exercise class “logic”: propositional logic, induction, proof systems, predicate logic.

Computer class “network programming”: Java/C programming of clients and serveurur, TCP, UDP.

Computer class and exercise class “circuits and architecture”: Boolean functions, gates, registers, adder, mini-processor, tool tkgate, assembly language LC-3 and SPARC.

Computer class and exercise class “Model Checking”: logic LTL, Binary Decision Diagram, tools CADP, UPPALL, SPIN.

Exercise class “static analysis”: fixed points, live variables, available expressions, ...

Course “game on pushdown graphs”/“rational graphs and infinite automata” for research master students.

4 Other tasks

In Aachen (2000–2003): updating some Web pages.

At LSV (2003–2004): updating some intern Web pages.

At LIAFA (2004– ...): helping for the organization of the conference Games’05, demonstration at science days 2006 and 2007: game theory for kids.

Script in PHP for “opération postes”: <http://postes.smai.emath.fr/echanges/Cycles/>.

5 PhD Thesis

Title: Games on Pushdown Graphs and Extensions / “Jeux sur des graphes d’automates à pile et leurs extensions”

Jury (RWTH Aachen, Germany):

reviewers: Wolfgang THOMAS (RWTH Aachen) and Didier CAUCAL (IRISA Rennes),

examiners: Manfred NAGL and Peter ROSSMANITH (RWTH Aachen).

Jury (Rennes 1, France):

reviewers: Damian NIWIŃSKI (Univ. Warsaw) and Igor WALUKIEWICZ (LaBRI Bordeaux),

examiners: Didier CAUCAL (IRISA Rennes), Antoine PETIT (ENS Cachan), Jean-Claude RAOULT (Univ. Rennes 1) and Wolfgang THOMAS (RWTH Aachen).

Abstract:

Two player games are a standard model of reactive computation, where e.g. one player is the controller and the other is the environment. A game is won by a player if she has a winning strategy, *i.e.*, if she can win every play. Given a finite description of the game, our aim is to compute the winner and a winning strategy. For finite graphs these problems have been solved for a long time, although some complexity questions remain open.

We consider several classes of infinite graphs, from transition graphs of pushdown automata up to graphs of the Caucal hierarchy, and we investigate different winning conditions: reachability, recurrence (Büchi), parity, and a so called Σ_3 -condition.

Two kinds of techniques are developed: a symbolic approach based on finite automata recognizing infinite sets of configurations and a game simulation which reduces a given game into a simpler one and solves it. Different kinds of strategies are also constructed: either positional or based on pushdown stack memories.

6 Research

Regular Sets of Integers

During my research master (DEA: “Diplôme d’Études Approfondies”) I studied a combinatorial and algebraic question about regular (rational) languages. Given a regular language $L \subseteq A^*$, the question is whether its power, given by

$$\text{pow}(L) = \{u^k \mid u \in L, k \geq 0\} ,$$

is also regular (it is not always the case). The general problem is open since 1996 [Cal96, CN96], but in the case of a one-letter alphabet, I proposed a decision procedure [Cac02a]. Even in that restricted case, where one can consider sets of integers, the problem is not simple.

Games on Infinite Graphs

During my PhD I was studying different games on infinite graphs, motivated by verification problems. In the framework of reactive systems two entities, a controller and an environment, interact. The goal of the controller is to answer to every action of the environment in such a way that the resulting process satisfies some conditions like “no accident occurs”, “something is produced”, ... Formally it is useful to see such systems as two player games, where one player is the controller and the other is the environment. The controller wins the game if and only if the desired condition is fulfilled.

I have considered a situation where the problem is already modeled as a two player games, and have restricted myself to:

- turn based games: players move in turn,
- with complete information: both players know exactly the current state of the game, and the past,
- without random.

(Chess fulfills these conditions, lots of card game use random and incomplete information, rock-scissors-paper is not turn based, ...) We are interested in infinite games: a play is an infinite sequence (indexed by ω).

Our goal is to determine whether the controller can win against every behavior of the environment and to implement —if possible— a winning strategy for the controller. In the case of finite graphs these problems are known for long, even if some questions about complexity and algorithmic effectiveness remain open. I concentrated on some classes of infinite graphs. These graphs are needed to model programs with unbounded variables or recursive procedure calls.

Two kinds of techniques were developed: a symbolic approach based on finite automata recognizing infinite sets of configurations and a *game-simulation* allowing to reduce a given game to a simpler game and then solve it.

Symbolic Method for games To cope with transition graphs of pushdown automata, that are in general infinite, the symbolic approach uses finite automata representing (infinite) sets of configurations. A configuration is here a word pw where p is a control state and w is a stack content (a word over the stack alphabet). Algorithms are known for reachability and model-checking of pushdown transition graphs [BEM97, EHRS00a]. We have extended them to compute also winning strategies under two forms: positional strategies and pushdown strategies [Cac02b]. This lifts model-checking results to the level of program synthesis

We then considered *pushdown games* (games on pushdown graphs) with a Büchi winning condition: Player 0 wins if and only if the goal set is visited infinitely often. Again winning strategies can be computed [Cac02b]. Finally we have studied a new winning condition of type Σ_3 : Player 0 wins if and only if there exists a configuration that is visited infinitely often. As the graph is infinite, the quantification on “a configuration” do not boils down to a Büchi condition. It allows also to solve the “stack explosion” problem: does the program need an unbounded stack? Our solution is based on an extension of the algorithm for the Büchi condition, and can be considered as a new decidability result [CDT02].

Game-simulation Different versions of game-simulation exist in mathematics for long, but they are not always used in a computable way. The idea is to reduce a given game to a simpler game that one can solve and to deduce from it the winner and a winning strategy in the original game. Such methods have already been used [Wal01] to solve parity games on pushdown graphs via a reduction to games on (exponentially larger) finite graphs. To cope with the infinity of reachable stack contents, we ask one of the player to guess and announce what will happen later if the current top symbol is popped from the stack. We have used this reduction and we have given a new proof, more direct and intuitive. Moreover, using the reduced game on a finite graph, we have explicitly constructed a pushdown strategy for the initial game [Cac02d]. So long the analysis was done only from a particular initial configuration (with an empty stack). We have extended it to an arbitrary initial configuration, giving a uniform solution, and showing that the winning region of a player is a regular set of configurations. The winning region is here the set of configurations from which a player is guaranteed to win (if he plays correctly).

The results from [Var98, KV00] can also be seen as a game-simulation. Technically the main point is the transformation from two-way tree automata to one-way tree automata [Cac02c]. Determining the existence of an accepting run is equivalent to determining the winner of a particular game, where one player tries to prove the existence of such a run, and the other tries to avoid it. We have extended this reduction to the case of trees with unbounded or infinite arity. This allowed us to solve parity games on the infinite Caucal hierarchy and parity games on higher order pushdown automata (stack of stacks, ...) [Cac03]. As a byproduct one gets a better complexity bound for the decision procedure of the monadic second order logic on these graphs. Later we proved that the complexity of this construction is optimal [CW07].

I was member of the “Game” project of the European Union, *Games and Automata for Synthesis and Validation*, involving Aachen University, University of Bordeaux I, University of Edinburgh, University of Paris 7, Rice University, Uppsala University, Vienna University of Technology, Warsaw University, see <http://www.games.rwth-aachen.de/>.

Control of Timed Systems / Imperfect Information

From October 2003 until November 2006 I participated in the research group “ACI Cortos”, *Control and Observation of Real-Time Open Systems*, involving the following laboratories: IRCCyN (Nantes), LSV (Cachan), VERIMAG (Grenoble), see <http://www.lsv.ens-cachan.fr/aci-cortos/index-en.html>. Since November 2006 I am a member of the ANR research group “DOTS” *Distributed Open and Timed Systems*, with IRCCyN (Nantes), IRISA (Rennes), LaBRI (Bordeaux), LAMSADE (Paris), LSV (Cachan), see <http://www.lsv.ens-cachan.fr/anr-dots/?l=en>. The framework of timed systems adds a new dimension to game and control problems: both players can move simultaneously and they act at times that are not known in advance [ABC⁺05].

One of my research interests is now concerned with games of imperfect information. The controller (in which we are interested) does not know exactly the current state of the game and has to make a decision according to the information he has. This can happen in particular in the context of partial observation, where the controller has only access to a part of the variables of the system, or when both players move simultaneously.

Ordinal automata recognize sequences of letters (words) indexed by ordinals. They allow to model physical systems with Zeno behavior. Demri and Nowak [DN05] have introduced a logic $LTL(\omega^k)$ to express properties of sequences of length ω^k , $k \geq 1$. But the goal is to construct a controller whose run is indexed by an usual ω -sequence. So the physical system evolves faster than the controller, and the controller can not fully observe every intermediate actions of the system. We have solved this control problem using a game of imperfect information [Cac06a].

Logical Theories of Ordinals

The decidability of Presburger logic (first order logic of integers with addition) can be proved using finite automata. By induction on the structure of the formula, one can construct an automaton recognizing the binary encoding of integers satisfying a formula, thanks to the closure properties of finite automata [Kla04]. We have extended this method to the decidability of the first order logic of ordinals of the form ω^{ω^i} with addition [Cac06b]. The idea is to code ordinals using binary trees and to use tree automata. This gives a simpler proof and a better complexity than previous results [Mau96].

Büchi has shown the decidability of the monadic second order logic of the integers, using automata now called Büchi automata, then he extended this result to ordinals using ordinal automata [Büc65]. Some attempts to improve the computational complexity of this result have lead to complicated coding [Mau96]. Using infinite binary trees it is easy to represent subsets of ordinals lower than ω^i and Rabin tree automata allow to give a new (simple) proof with a better complexity bound [Cac06b].

Modelling of RNA secondary structure

Now that the genome of many living organisms is (formally) known, one of the main biological question is to know how genes are expressed (and when, why, ...). For a DNA sequence to be expressed, a polymerase should first transcribe it into a corresponding RNA sequence, then a ribosome should translate the RNA into a sequence of amino acids. Inside bacteria (they have

no nucleus) both processes of transcription and translation happen simultaneously and the intermediate RNA sequence can be folded according to complementary bases. According to the CAR model, *Classical Attenuation Regulation* [LRSP06], the regulation of the expression of a gene is determined by this secondary structure, which has influence on the speed of the polymerase and can even remove it from the DNA sequence. In [ACS⁺07] we propose to use term rewriting to predict the probabilities of creation of these secondary structure in a more global way than the Monte-Carlo simulation from [LRSP06].

This project (Evolver) is supported by an agreement between CNRS, France, and Russian Academy of Science and is a collaboration between LIAFA (Paris) and IITP (Moscow).

References

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- [ACS⁺07] Eugene Asarin, Thierry Cachat, Alexander Seliverstov, Tayssir Touili, and Vassily A. Lyubetsky. Attenuation regulation as a term rewriting system. In Hirokazu Anai, Katsuhisa Horimoto, and Temur Kutsia, editors, *Proceedings of the Second International Conference on Algebraic Biology, AB'07*, volume 4545 of *Lecture Notes in Computer Science*, pages 81–94. Springer, 2007.
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- [Cac02a] Thierry Cachat. The power of one-letter rational languages. In *Proceedings of the 5th international conference Developments in Language Theory, DLT'01*, volume 2295 of *Lecture Notes in Computer Science*, pages 145–154. Springer, 2002.
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- [Cac02c] Thierry Cachat. Two-way tree automata solving pushdown games. In Erich Grädel, Wolfgang Thomas, and Thomas Wilke, editors, *Automata, Logics, and Infinite Games [GTW02]*, volume 2500 of *Lecture Notes in Computer Science*, pages 303–317. Springer, 2002.
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- [Cac06a] Thierry Cachat. Controller synthesis and ordinal automata. In Susanne Graf and Wenhui Zhang, editors, *Proceedings of the 4th International Symposium on Automated Technology for Verification and Analysis, ATVA'06*, volume 4218 of *Lecture Notes in Computer Science*, pages 215–228. Springer, 2006.

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- [GTW02] Erich Grädel, Wolfgang Thomas, and Thomas Wilke, editors. *Automata, Logics, and Infinite Games: A Guide to Current Research*, volume 2500 of *Lecture Notes in Computer Science*. Springer, 2002.
- [Kla04] Felix Klaedtke. On the automata size for Presburger arithmetic. In *Proceedings of the 19th Annual IEEE Symposium on Logic in Computer Science (LICS 2004)*, pages 110–119. IEEE Computer Society Press, 2004. A full version of the paper is available from the author's web page.
- [KV00] Orna Kupferman and Moshe Y. Vardi. An automata-theoretic approach to reasoning about infinite-state systems. In E. A. Emerson and A. P. Sistla, editors,

Proceedings of the 12th International Conference on Computer Aided Verification, CAV'00, volume 1855 of *Lecture Notes in Computer Science*, pages 36–52. Springer, 2000.

- [LRSP06] Vassily Lyubetsky, Lev Rubanov, Alexander Seliverstov, and Sergey Pirogov. Model of gene expression regulation in bacteria via formation of RNA secondary structures. *Molecular Biology*, 40(3):440–453, 2006.
- [Mau96] Françoise Maurin. Exact complexity bounds for ordinal addition. *Theoretical Computer Science*, 165(2):247–273, 1996.
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- [Wal01] Igor Walukiewicz. Pushdown processes: Games and model checking. *Information and Computation*, 164(2):234–263, January 2001. Full version of [Wal96].