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Preface

This volume contains the papers presented at the 22nd International Conference on Implementation and Application of Automata (CIAA 2017) organized by the Laboratoire d'Informatique Gaspard-Monge (CNRS UMR 8049), Université Paris-Est, during June 27–30, 2017, in Paris, France.

The CIAA conference series is a major international venue for the dissemination of new results in the implementation, application, and theory of automata. The previous 21 conferences were held in various locations all around the globe: Seoul (2016), Umeå (2015), Giessen (2014), Halifax (2013), Porto (2012), Blois (2011), Winnipeg (2010), Sydney (2009), San Francisco (2008), Prague (2007), Taipei (2006), Nice (2005), Kingston (2004), Santa Barbara (2003), Tours (2002), Pretoria (2001), London Ontario (2000), Potsdam (WIA 1999), Rouen (WIA 1998), and London Ontario (WIA 1997 and WIA 1996). Like its predecessors, the theme of CIAA 2017 was the implementation of automata and applications in related fields. The topics of the presented papers include state complexity of automata, implementations of automata and experiments, enhanced regular expressions, and complexity analysis.

There were 31 submissions from 20 different counties: Algeria, Brazil, Bulgaria, Canada, Chile, China, Czech Republic, France, Germany, Iceland, India, Italy, Malta, Poland, UK, Russia, Slovakia, South Africa, South Korea, and Sweden. Each submission was reviewed by at least three reviewers and thoroughly discussed by the Program Committee (PC). The committee decided to accept 17 papers for oral presentation. The program also includes three invited talks by Véronique Cortier, Kim G. Larsen, and Damien Pous.

We would like to thank the members of the PC and the external reviewers for their work and for the thorough discussions that took place. We also thank all the authors of submitted papers who made CIAA 2017 possible. The work of the PC and the collating of the proceedings were greatly simplified by the EasyChair conference system.

We would furthermore like to thank the editorial staff at Springer, and in particular Alfred Hofmann and Anna Kramer, for their guidance and help during the process of publishing this volume. We are also grateful to the IUT de Marne-la-Vallée for providing the rooms for the conference. Finally, we are grateful to the conference sponsors for their generous financial support: Labex Bézout, Laboratoire d'Informatique Gaspard-Monge (UMR 8049) and Université Paris-Est Marne-la-Vallée.

We all look forward to CIAA 2018 in Charlottetown, Canada.

June 2017

Arnaud Carayol
Cyril Nicaud

Organization

CIAA 2017 was organized by the Laboratoire d'Informatique Gaspard-Monge at Université Paris-Est Marne-la-Vallée, France.

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Kim G. Larsen	Aalborg University, Denmark
Damien Pous	CNRS, ENS Lyon, France

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Abstract of Invited Papers

Electronic Voting: How Logic Can Help

Véronique Cortier

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Electronic voting should offer at least the same guarantees than traditional paper-based voting systems. In particular, voting systems should ensure ballot privacy (no one knows how I voted) and verifiability (voters can check the whole voting process). In order to achieve this, electronic voting protocols make use of cryptographic primitives, as in the more traditional case of authentication or key exchange protocols. All these protocols are notoriously difficult to design and flaws may be found years after their first release. Formal models, such as process algebra, Horn clauses, or constraint systems, have been successfully applied to automatically analyze traditional protocols and discover flaws. Electronic voting protocols however significantly increase the difficulty of the analysis task. Indeed, they involve for example new and sophisticated cryptographic primitives such as mixnets (e.g. in Civitas [4]) or homomorphic encryption (e.g. in [1, 5]), new dedicated security properties, and new execution structures.

Standard protocols like authentication or key-exchange protocols typically involve trace based properties, for which many procedures and tools have been developed in the context of security protocols. Tools include for example, ProVerif [3], Avispa [2], Scyther [6], or Tamarin [8]. However, ballot privacy is modeled as an equivalence property [7], for which fewer techniques exist.

After an introduction to electronic voting, we will describe the current techniques for e-voting protocols analysis and review the key challenges towards a fully automated verification.

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Timed and Untimed Energy Games

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Abstract. Energy games have recently attracted a lot of attention. These are games played on finite weighted (timed) automata and concern the existence of infinite runs subject to boundary constraints on the accumulated weight, allowing e.g. only for behaviours where a resource is always available (non-negative accumulated weight), yet does not exceed a given maximum capacity. In this extended abstract we give an overview of the various results that have been obtained on this topic.

Untimed Energy Games

In [9] we have extend energy games to a multiweighted and parameterized setting, allowing us to model systems with multiple quantitative aspects. We present reductions between Petri nets and multiweighted automata and among different types of multi-weighted automata and identify new complexity and (un)decidability results for both one- and two-player games. We also investigate the tractability of an extension of multiweighted energy games in the setting of timed automata.

In [11] we reconsider the multiweighted energy problem assuming an unknown upper bound and calculate the set of vectors of upper bounds that allow an infinite run to exist. For both a strict and a weak upper bound we show how to construct this set by employing results from previous works, including an algorithm given by Valk and Jantzen for finding the set of minimal elements of an upward closed set.

In [8] we introduce and study average-energy games, where the goal is to optimize the long-run average of the accumulated energy. We show that this objective arises naturally in several applications, and that it yields interesting connections with previous concepts in the literature. We prove that deciding the winner in such games is in NP inter coNP and at least as hard as solving mean-payoff games, and we establish that memoryless strategies suffice to win. We also consider the case where the system has to minimize the average-energy while maintaining the accumulated energy within pre-defined bounds at all times: this corresponds to operating with a finite-capacity storage for energy. We give results for one-player and two-player games, and establish complexity bounds and memory requirements.

In [12] we reconsider average-energy games focusing on the problem of determining upper bounds on the average accumulated energy or on the capacity while satisfying a given lower bound, i.e., we do not determine whether a given bound is sufficient to meet the specification, but if there exists a sufficient bound to meet it. In the classical setting with positive and negative weights, we show that the problem of determining the existence of a sufficient bound on the long-run average accumulated energy can be solved in doubly-exponential time. We consider recharge game, where all weights are negative, but there are recharge edges that recharge the energy to some fixed capacity. We show that bounding the long-run average energy in such games is complete for exponential time.

Weighted Timed Automata and Games

The model of weighted timed automata was introduced in [1] as an extension of timed automata, with prices on both transitions and locations. For this model we considered the minimum-cost reachability problem: i.e. given a weighted timed automaton and a target state, determine the minimum cost of executions from the initial state to the target state. This problem generalizes the minimum-time reachability problem for ordinary timed automata. We prove decidability of this problem by offering an algorithmic solution, which is based on a combination of branch-and-bound techniques and a new notion of priced regions. The latter allows symbolic representation and manipulation of reachable states together with the cost of reaching them. Later the associated decision problem has been shown to be PSPACE-complete.

Now considering weighted timed *games* the cost-optimal reachability problem is shown to be undecidable in [2] already in the setting of three clocks. For the case of weighted timed games with a single clock decidability of cost-optimal reachability was shown decidable in [7] in triple-exponential time. This result is improved in [10] which provides a single-exponential algorithm. For this improvement a new algorithm for solving one-clock weighted timed games, based on the sweep-line technique from computational geometry and the strategy iteration paradigm from the algorithmic theory of Markov decision processes has been introduced.

Timed Energy Games

The paper [4] introduces the problem of existence and construction of infinite schedules for finite weighted automata and one-clock weighted timed automata, subject to boundary constraints on the accumulated weight. More specifically, the paper considers automata equipped with positive and negative weights on transitions and locations, corresponding to the production and consumption of some resource (e.g. energy). We ask the question whether there exists an infinite path for which the accumulated weight for any finite prefix satisfies certain constraints (e.g. remains between 0 and some given upper-bound). We also consider a game version of the above, where certain transitions may be uncontrollable. In the setting of one-player, one-clock weighted timed automata we show that the problem of deciding the existence of an infinite admissible run is decidable.

In [3] we study one-clock priced timed automata in which prices can grow linearly (dp/dt = k) or exponentially (dp/dt = kp), with discontinuous updates on edges. We propose EXPTIME algorithms to decide the existence of controllers that ensure existence of infinite runs or reachability of some goal location with non-negative observer value all along the run. These algorithms consist in computing the optimal delays that should be elapsed in each location along a run, so that the final observer value is maximized (and never goes below zero).

In [5, 6] we show that the existence of an infinite lower-bound-constrained run is in general undecidable for weighted timed automata with four or more clocks.

Also in [13] and [9] it is shown that the lower- and upper-bound-constrained run problem is undecidable in case of 2 costs or 2 clocks.

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CoInductive Automata Algorithms

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We consider the problem of checking equivalence or inclusion of finite automata. Algorithms for such a task are used in model-checking for instance, where one can build an automaton for a formula and an automaton for a model, and then check that the latter is included in the former. More advanced constructions need to build a sequence of automata by applying a transducer, and to stop whenever two subsequent automata recognise the same language [4]. Another field of application is that of various extensions of Kleene algebra [7], whose equational theories are reducible to language equivalence of various kinds of automata: regular expressions and finite automata for plain Kleene algebra [12], "closed" automata for Kleene algebra with converse [2, 9], or guarded string automata for Kleene algebra with tests (KAT) [14].

Equivalence of deterministic finite automata (DFA) can be checked either via minimisation [10] or, more directly, through Hopcroft and Karp's algorithm [11]. The complexity of the latter algorithm has been studied by Tarjan [18]: checking language equivalence of two states in a DFA with n states over an alphabet of size k requires $O(nk\alpha(k,n))$ operations, where $\alpha(k,n)$ is a *very* slow-growing inverse of Ackermann's function. This might look rather satisfactory, except that: (1) in most applications one starts with non-deterministic automata (NFA), and (2) sometimes the alphabet is too large to be iterated naively.

For the first point, it is well-known that NFA can be determinised using the powerset construction, and that there can be exponentially many reachable sets. In fact, language equivalence becomes PSPACE-complete for NFA over an alphabet with at least two letters [15]—and coNP-complete with one letter. De Wulf, Doyen, Henzinger and Raskin have proposed algorithms based on *antichains* [19], that exploit the specific structure of determinised automata to avoid systematically exploring all reachable states. Together with Filippo Bonchi, we have discovered that both Hopcroft and Karp's algorithm and the antichain algorithms actually make use of a reasoning principle which is well-known in concurrency theory: *coinduction* [16]. This lead us to a new algorithm [3], which can improve exponentially over both Hopcroft and Karp's algorithm and more recent antichain-based algorithms [1, 8, 19].

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The second point is raised for instance with the automata required for deciding Kleene algebra with tests [13]. We propose to use symbolic automata [17], where the transition function is represented in a compact way using binary decision diagrams (BDD) [5, 6]. Coinductive algorithms such as above then make it possible to explore reachable pairs symbolically, and to avoid redundancies. We show in particular a nice integration with the disjoint sets forest data-structure from Hopcroft and Karp's algorithm.

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Contents