Research trajectory and main research lines

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Abstract

My interests lie in theoretical foundations of rigorous systems engineering, i.e., the development of methods for the representation, reasoning and control of complex systems. The common thread in my research is the development and analysis of such methods for *infinite* systems, including distributed systems and multi-agent systems. The main techniques I have employed are from mathematical logic, automata theory, and game-theory.

This document describes my scientific contributions organised by (overlapping) themes.

1 Algorithmic Model Theory

I have contributed to a research program called "Algorithmic Model Theory" whose aim is to develop and extend the success of Finite Model Theory to infinite structures that can be reasoned about algorithmically.

Specifically, my PhD work pioneered the development of automatic structures: this is a generalisation "regular languages" from sets to mathematical objects with structure, such as graphs, arithmetics, algebras, etc. The fundamental property of automatic structures is that one can automatically answer logic-based queries about them (precisely, their first-order theory is decidable). I gave techniques for proving that structures are or are not automatic (similar to, but vastly more complicated than, pumping lemmas for regular languages), I studied the computational complexity of deciding when two automatic structures are the same (isomorphic), and I found extensions of the fundamental property, thus enriching the query language [13, 17, 19, 20, 21, 22, 23, 24, 25, 29]. I have also worked on extensions of automatic structures to include oracle computation [26, 28].

2 Verification of Multi-Agent Systems

Multi-agent systems involve multiple individual agents (that may be people, software, robots) each with their own goals. Such systems can be viewed as multi-player games, and thus fundamental notions from game-theory (i.e., equilibria) are used to reason about them. In case the number of agents is not known, or not bounded a priori, one is dealing with an infinite-state system.

In a series of papers, I have contributed to a generalisation of a cornerstone paper on verification of such systems (”Reasoning about Rings”, E.A. Emerson, K.S. Namjoshi, POPL’95, 1995) from ring topologies to arbitrary topologies [1, 2, 10].

I launched the application of automata theory to the verification of high-level properties of light-weight mobile agents [30]. Followup work explored variations on this theme [6, 7, 27].

2.1 Verification of Quantitative Properties

I recently established and studied a logical formalism that is rich enough to count equilibria [3, 4]

Communication Primitives [12]

Timed: [11]

Probabilistic: [14] A fundamental problem in computer science is that of ensuring that a system satisfies a particular property. Moshe Vardi, Doron Bustan and I [**?**] considered the complexity of checking that a probabilistic system (modeled by a finite-state discrete-time Markov chain) satisfies properties expressed by automata operating on infinite words. The sorts of properties that can be expressed extend those of linear temporal logic, a typical example is ‘Does the Markov chain almost surely enter this state infinitely often’? We presented an optimal algorithm that checks whether a given Markov chain satisfies a specification given by an alternating Büchi automaton, thus extending known work on linear temporal logic [**?**].

3 Synthesis and Control

In contrast to verification, synthesis (control) aims for correct-by-construction design of (components of) dynamic systems. A basic mathematical model for such systems are multi-player game on graphs. In this model vertices represent states, edges represent transitions, and the players represent the agents. I have contributed foundational work that [15, 9]

traps: [16]

planning: [27]

4 Quantitative

[5, 8, 18]

References

[1] Benjamin Aminof, Swen Jacobs, Ayrat Khalimov, and Sasha Rubin. Parameterized model checking of token-passing systems. In *Verification, Model Checking, and Abstract Interpretation - 15th International Conference, VMCAI 2014, San Diego, CA, USA, January 19-21, 2014, Proceedings*, pages 262–281, 2014.

[2] Benjamin Aminof, Tomer Kotek, Sasha Rubin, Francesco Spegni, and Helmut Veith. Parameterized model checking of rendezvous systems. In *CONCUR 2014 - Concurrency Theory - 25th International Conference, CONCUR 2014, Rome, Italy, September 2-5, 2014. Proceedings*, pages 109–124, 2014.

[3] Benjamin Aminof, Vadim Malvone, Aniello Murano, and Sasha Rubin. Graded strategy logic. In *Proceedings 4th International Workshop on Strategic Reasoning, SR 2016, New York, USA.*, 2016.

[4] Benjamin Aminof, Vadim Malvone, Aniello Murano, and Sasha Rubin. Graded strategy logic: Reasoning about uniqueness of nash equilibria. In *Proceedings of the 2016 International Conference on Autonomous Agents & Multiagent Systems, Singapore, May 9-13, 2016*, pages 698–706, 2016.

[5] Benjamin Aminof, Aniello Murano, and Sasha Rubin. On CTL* with graded path modalities. In *Logic for Programming, Artificial Intelligence, and Reasoning - 20th International Conference, LPAR-20 2015, Suva, Fiji, November 24-28, 2015, Proceedings*, pages 281–296, 2015.

[6] Benjamin Aminof, Aniello Murano, Sasha Rubin, and Florian Zuleger. Verification of asynchronous mobile-robots in partially-known environments. In *PRIMA 2015: Principles and Practice of Multi-Agent Systems - 18th International Conference, Bertinoro, Italy, October 26-30, 2015, Proceedings*, pages 185–200, 2015.

[7] Benjamin Aminof, Aniello Murano, Sasha Rubin, and Florian Zuleger. Automatic verification of multi-agent systems in parameterised grid-environments. In *Proceedings of the 2016 International Conference on Autonomous Agents & Multiagent Systems, Singapore, May 9-13, 2016*, pages 1190–1199, 2016.

[8] Benjamin Aminof, Aniello Murano, Sasha Rubin, and Florian Zuleger. Prompt alternating-time epistemic logics. In *Principles of Knowledge Representation and Reasoning: Proceedings of the Fifteenth International Conference, KR 2016, Cape Town, South Africa, April 25-29, 2016.*, pages 258–267, 2016.

[9] Benjamin Aminof and Sasha Rubin. First cycle games. *Information and Computation,*, 2016.

[10] Benjamin Aminof and Sasha Rubin. Model checking parameterised multi-token systems via the composition method. In *Automated Reasoning - 8th International Joint Conference, IJCAR 2016, Coimbra, Portugal, June 27 - July 2, 2016, Proceedings*, pages 499–515, 2016.

[11] Benjamin Aminof, Sasha Rubin, Francesco Spegni, and Florian Zuleger. Liveness of parameterized timed networks. In *Automata, Languages, and Programming - 42nd International Colloquium, ICALP 2015, Kyoto, Japan, July 6-10, 2015, Proceedings, Part II*, pages 375–387, 2015.

[12] Benjamin Aminof, Sasha Rubin, and Florian Zuleger. On the expressive power of communication primitives in parameterised systems. In *Logic for Programming, Artificial Intelligence, and Reasoning - 20th International Conference, LPAR-20 2015, Suva, Fiji, November 24-28, 2015, Proceedings*, pages 313–328, 2015.

[13] Vince Bárány, Erich Grädel, and Sasha Rubin. Automata-based presentations of infinite structures. In Javier Esparza, Christian Michaux, and Charles Steinhorn, editors, *Finite and Algorithmic Model Theory*, pages 1–76. Cambridge University Press, 2011. Cambridge Books Online.

[14] Doron Bustan, Sasha Rubin, and Moshe Y. Vardi. Verifying omega-regular properties of markov chains. In *Computer Aided Verification, 16th International Conference, CAV 2004, Boston, MA, USA, July 13-17, 2004, Proceedings*, pages 189–201, 2004.

[15] Giuseppe De Giacomo, , Antonio Di Stasio, Aniello Murano, and Sasha Rubin. Imperfect information games and generalized planning. In *International Joint Conference on Artificial Intelligence (IJCAI 2016)*, 2016.

[16] Andrey Grinshpun, Pakawat Phalitnonkiat, Sasha Rubin, and Andrei Tarfulea. Alternating traps in muller and parity games. *Theor. Comput. Sci.*, 521:73–91, 2014.

[17] Hajime Ishihara, Bakhadyr Khoussainov, and Sasha Rubin. Some results on automatic structures. In *LICS 2002, 17th IEEE Symposium on Logic in Computer Science, 22-25 July 2002, Copenhagen, Denmark, Proceedings*, page 235, 2002.

[18] Lukasz Kaiser, Sasha Rubin, and Vince Bárány. Cardinality and counting quantifiers on omega-automatic structures. In *STACS 2008, 25th Annual Symposium on Theoretical Aspects of Computer Science, Bordeaux, France, February 21-23, 2008, Proceedings*, pages 385–396, 2008.

[19] Bakhadyr Khoussainov, André Nies, Sasha Rubin, and Frank Stephan. Automatic structures: Richness and limitations. In *LICS 2004, 19th IEEE Symposium on Logic in Computer Science, 14-17 July 2004, Turku, Finland, Proceedings*, pages 44–53, 2004.

[20] Bakhadyr Khoussainov, André Nies, Sasha Rubin, and Frank Stephan. Automatic structures: Richness and limitations. *Logical Methods in Computer Science*, 3(2), 2007.

[21] Bakhadyr Khoussainov and Sasha Rubin. Graphs with automatic presentations over a unary alphabet. *Journal of Automata, Languages and Combinatorics*, 6(4):467–480, 2001.

[22] Bakhadyr Khoussainov and Sasha Rubin. Automatic structures: Overview and future directions. *Journal of Automata, Languages and Combinatorics*, 8(2):287–301, 2003.

[23] Bakhadyr Khoussainov, Sasha Rubin, and Frank Stephan. On automatic partial orders. In *LICS 2003, 18th IEEE Symposium on Logic in Computer Science, 22-25 June 2003, Ottawa, Canada, Proceedings*, pages 168–177, 2003.

[24] Bakhadyr Khoussainov, Sasha Rubin, and Frank Stephan. Definability and regularity in automatic structures. In *STACS 2004, 21st Annual Symposium on Theoretical Aspects of Computer Science, Montpellier, France, March 25-27, 2004, Proceedings*, pages 440–451, 2004.

[25] Bakhadyr Khoussainov, Sasha Rubin, and Frank Stephan. Automatic linear orders and trees. *ACM Trans. Comput. Log.*, 6(4):675–700, 2005.

[26] Alex Kruckman, Sasha Rubin, John Sheridan, and Ben Zax. A myhill-nerode theorem for automata with advice. In *Proceedings Third International Symposium on Games, Automata, Logics and Formal Verification, GandALF 2012, Napoli, Italy, September 6-8, 2012.*, pages 238–246, 2012.

[27] Aniello Murano, Giuseppe Perelli, and Sasha Rubin. Multi-agent path planning in known dynamic environments. In *PRIMA 2015: Principles and Practice of Multi-Agent Systems - 18th International Conference, Bertinoro, Italy, October 26-30, 2015, Proceedings*, pages 218–231, 2015.

[28] Alexander Rabinovich and Sasha Rubin. Interpretations in trees with countably many branches. In *LICS 2012, Proceedings of the 27th Annual IEEE Symposium on Logic in Computer Science, Dubrovnik, Croatia, June 25-28, 2012*, pages 551–560, 2012.

[29] Sasha Rubin. Automata presenting structures: A survey of the finite string case. *Bulletin of Symbolic Logic*, 14(2):169–209, 2008.

[30] Sasha Rubin. Parameterised verification of autonomous mobile-agents in static but unknown environments. In *Proceedings of the 2015 International Conference on Autonomous Agents and Multiagent Systems, AAMAS 2015, Istanbul, Turkey, May 4-8, 2015*, pages 199–208, 2015.