

# TCQV 2016: Trends and Challenges in Quantitative Verification

*Mysore Park Workshop Series, 1st to 4th of February, 2016*

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## Preamble

The workshop on trends and challenges in quantitative verification was attended by 46 participants, of whom 26 were faculty members or researchers from various institutes and research laboratories around the world. There was a substantial participation by Indian universities, with 25 PhD students or post-doctoral fellows and 13 Indian faculty members attending the workshop. The topics covered in the workshop included recent theoretical and practical advances in quantitative verification, new application domains and interconnections with new areas as well as several upcoming challenges for the community of researchers in this area. The workshop began on afternoon of February 1st 2016 and finished by noon on February 4th 2016. There were 14 one hour long invited talks and 4 half hour PhD student talks spread over these 4 days. The talks were interspersed with several breaks throughout to promote discussion and interaction. On February 2nd evening, the participants enjoyed an excursion to Brindavan Gardens as well as a banquet at a Heritage hotel.

## Technical content of the talks

### Day 1 (Afternoon) *New questions for classical quantitative models*

Mahesh Vishwanathan from UIUC gave the first talk of the workshop. His talk dealt with the conversion of LTL to automata. Converting LTL to non-deterministic Büchi automata leads to an exponential blowup. This logic to automaton conversion is in the core of many applications. In some of the applications, for instance - runtime-monitoring and MDP model checking, the resulting NBA needs to further be determinized, resulting in a double exponential blow-up. In this talk, Mahesh presented methods to convert fragments of LTL to probabilistic automata. The equivalent probabilistic automata had only an exponential blowup. He showed how these probabilistic automata can directly be used for Run-time monitoring and MDP model-checking. This reduces the complexity by an exponential factor for certain nice classes of LTL.

Blaise Genest from CNRS, Rennes gave the second talk of the day. The subject was languages of Markov chains. Taking the view of Markov chains as transformers of probability distributions, he spoke about the symbolic representations of their dynamics as symbolic trajectories over a finite alphabet. He showed how this model can be used to reason about dynamical properties of biological processes. He then related the quantitative verification problem in this setting to a long-standing open problem on linear recurrences, called the Skolem problem. He then showed restrictions on the structure of the Markov chain, more specifically the eigenvalues,

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which allowed to obtain regular languages of symbolic trajectories and thus tackle the verification questions. Finally, there were two PhD student talks, the first by Ratul Saha from NUS on quantitative analysis of distributed probabilistic systems and second by Khushraj Madnani from IIT Bombay on metric temporal logic with counting.

**Day 2 (Morning):** *Recent developments in Timed and stochastic models*

The second day started with a talk by Igor Walukiewicz from University of Bordeaux, who spoke about new developments for the classical reachability problem in timed automata. State-of-the-art solutions to this problem proceed by a forward analysis of the automaton using so-called zones. The talk presented two techniques to reduce the number of zones explored during the search, giving rise to faster algorithms in practice.

The next talk was given by Krishna Shankara Narayanan of IIT Bombay, who surveyed results on the model of stochastic timed games. This model integrates continuous-time Markov chains and timed automata and generalizes existing models that have stochastic and real-time behaviours. After introducing the model and state-of-the-art results, she presented some new undecidability and decidability results for qualitative and quantitative reachability problems for stochastic timed games with one and two players. She also pointed out open problems in this area.

Holger Hermanns, from University of Saarland, was the last speaker in this session. He spoke about Markov automata, a very general compositional continuous-time formalism for modeling stochastic timed systems. After providing strong motivation for the model, he surveyed the existing results and extensions of the model, and presented a set of challenging open problems in this area.

**Day 2 (Afternoon):** *New problems and avenues for quantitative approaches* This session began with a talk by Nathalie Bertrand, from INRIA Rennes, on a parametrized verification questions for Markov decision processes: given a population of  $N$  identical Markov decision processes that follow a uniform control policy, does the maximum probability that a given proportion of the processes reach a target set of states meet a threshold? After providing a motivation for this question from analysis of biological population dynamics, she proceeded to show that this problem is rather hard even in a boolean case when Markov decision processes are replaced by finite-state automata. After demonstrating some examples she provided results for this restricted boolean case with complexity bounds and mentioned open problems left.

The last talk in this session was by Pushmeet Kohli, Microsoft research at Cambridge, who gave a high-level talk on the current state-of-the-art in image processing and machine-learning techniques and how these results are having a high impact in several applications. He then proceeded to show shortcomings and indeed failing of these approaches and gave intriguing posers to where formal reasoning and analysis could possibly aid in improving the results and avoiding errors.

**Day 3 (Morning):** *Sampling methods and probabilistic programming.*

The first talk was by Supratik Chakraborty from IIT Bombay on hashing-based methods for approximate sampling and counting. Supratik started by explaining how counting and sampling under constraints are basic questions with applications in several areas of computer science. After mentioning how existing approaches fail or do not scale up, he proceeded to demonstrate a new algorithm based on hashing and SAT/SMT solvers, which scales up to hundreds of thousands of variables while maintaining strong theoretical guarantees on the result. Sriram Rajamani, from Microsoft Research in Bangalore, spoke next on probabilistic programming. He started by addressing the increasing need for such programming frameworks and then

proceeded to discuss about the tool developed by his lab for this purpose. He further instigated an invigorating discussion on the merits and de-merits of this approach as well as where the challenges lie ahead. The final talk in this session, by Joost-Pieter Katoen from Aachen, was also on probabilistic programming from a much more theoretical and semantic standpoint. He spoke about how issues of termination that plague this domain can be thought about and this how this leads to a better theoretical understanding of the programming constructs as well as the challenges.

**Day 3 (Afternoon):** *Machine learning and statistical methods in quantitative verification* Jan Kretinsky, from Technical University of Munich, spoke about how powerful machine learning techniques such as reinforcement learning could be used in quantitative verification. After providing a broad survey, he demonstrated several examples to illustrate the methodology and provoked a discussion on the different questions that could be addressed as well as the techniques that could be developed using this idea. The next talk was by Kim Larsen from Aalborg University, who spoke about the various extensions of the popular tool UPPAAL that can be used to model and analyse a host of formalisms, from timed automata and games to priced timed automata, energy automata. He further explained how the recent advances in this tool now provide support for optimization, synthesis of strategies for safety and liveness objectives and stastical model checking.

Amit Gurung, a PhD student from NIT Shillong, completed the day's proceedings with a interesting talk on a tool for parallel reachability analysis of continuous systems on multi-core processors.

**Day 4 (Morning):** *Hybrid models and cyber-physical systems* Pavithra Prabhakar, from Kansas State University, started the final day's proceeding with a talk on Hybrid systems and how to develop algorithms that can verify stability for them , i.e., the notion that small perturbations to the input only result in small changes in the eventual behavior of the system. She presented two different methods, one using predicate abstraction and the other using a CEGAR-framework, to analyze stability in hybrid systems as well as a novel hybridization technique to construct hybrid system abstractions. Martin Franzle, from University of Oldenburg, spoke about a model extending probabilistic hybrid automata via parametric probabilistic branching. After showing some illustrative applications, he presented a novel method to synthesize parameter instances of such models by combining techniques from machine learning and statistical model checking as well as SAT-solving.

Prakash Saivasan, a PhD student from Chennai Mathematical Institute, wrapped up the proceedings of the workshop with a talk on model checking of multi-pushdown systems via loop acceleration techniques.

## Summary

We believe that the workshop provided an exciting environment for exchange of ideas and transfer of knowledge. The talks were unanimously rich in content and often ended with interesting discussions and debates continuing during coffee and lunch breaks. We were happy to see the response from the Indian academic community as well as several PhD students who benefited from the workshop. We hope that this will result in increased attention within the Indian academic community towards research in this active area of quantitative verification.

We thank the Mysore Park Workshop series for their sponsorship and Infosys for providing the ideal venue to host the workshop at their campus. We also thank the support staff of Mysore Park campus who enabled us to hold the workshop with minimal administrative overhead.