

# From Concurrency Models to Numbers: Performance, Dependability, Energy

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Compositional model construction and model checking are two aspects of a modern strategy to guarantee correctness of system design. In the era of power-aware, wireless and distributed systems, correctness guarantees for such systems must become quantifiable. Instead of guaranteeing that a system is performing the expected tasks, we are ultimately interested in guaranteeing that the system performs its task within a given time bound and with (energy) costs within a given limit. Or better: that the probability thereof is above a given threshold. In this lecture series I paint the landscape of behavioural models for probability, time, and cost, with a mild focus on concurrent Markov models and process calculi. I discuss foundational and practical aspects of compositional modelling and model checking such systems.

The lecture series is divided into three principal parts.

The first part discusses compositional construction of probabilistic models. We start off with a review of modelling principles for concurrent systems based on labelled transition systems (LTS). We then discuss how to add simple probabilistic experiments to this model, and learn about two possible options: (Discrete-time) Markov chains change the nature of the LTS model, while probabilistic automata provide a conservative extension of LTS and the underlying compositional theory. We then turn our attention to probabilistic experiments in continuous time, as they appear in continuous-time Markov chains. Again, we discuss two possible options: Changing the nature of the LTS model, or extending it in a conservative fashion. The latter gives rise to the model of interactive Markov chains.

The second part discusses algorithmic aspects of model checking for probabilistic extensions of the temporal logic CTL, for the four models introduced above. We first look at discrete-time Markov chains, then probabilistic automata, focussing on the logic PCTL. We then turn our attention to CSL model checking of continuous-time Markov chains and interactive Markov chains.

In the third part we will learn about extensions of the principal models, and about a selection of interesting applications. We first look at extensions with costs or rewards enabling us to reason about consumption of energy or other resources. We also discuss what can be gained by adding the notion of clocks, as in timed automata, to probabilistic automata. We further address the status of basic and advanced tool support for the entire modelling spectrum presented. We finally discuss two industrial cases tackled recently, one from ST-Microelectronics on GALS hardware, and one from Bull on message passing interfaces in high-performance computation.

## References

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