Machine Learning Meets Stochastic Model Checking*

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Introduction. Performance modelling is more and more concerned with the modelling of complex systems, in which the interactions of many heterogeneous entities produce complex emergent system-level behaviours. Examples span from sensor networks to cloud computing and to smart cities. When the interest is in predictive modelling, as is the case in performance, these models are necessarily quantitative, e.g. expressed as Continuous Time Markov Chains (CTMC) or as other kinds of stochastic processes. Their quantitative nature is reflected in their dependence on several parameters, which are often known with a considerable margin of uncertainty. Practically, this means that we most likely can provide a bounded interval supposed to contain the true value of a parameter, but not the true value itself. We will refer to this class of CTMC as Uncertain CTMC.

Problem and Methodology. The problem we address is, given an uncertain CTMC model, how to reason about it with automatic tools. Our approach is statistical, combining state-of-the-art Statistical Machine Learning tools, specifically designed to tackle uncertainty, with classic tools from formal methods, mainly Model Checking.

The first problem we face is how to estimate the satisfaction probability of a linear temporal logic property under such uncertainty [3]. We will show how we can reconstruct the functional dependency of the satisfaction probability on unknown parameters using Machine Learning techniques based on Gaussian Processes, which offer a flexible framework for regression and classification. We dubbed this approach Smoothed Model Checking, as it relies on smoothness properties of CTMCs.

An alternative way to deal with uncertainty is to try to eliminate it exploiting available observations of the real system modelled. As it is often easier to observe and capture qualitative properties, rather than performing precise measurements, we tackled the problem of parameter estimation from observations of truth values of temporal logic formulae [2]. Also in this case, Gaussian Processes and Bayesian Optimisation play a central role in the solution of this problem. In

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a similar way we can tackle the twin problem of system design [2, 1], which consists in finding optimal parameter values to enforce a desired behaviour, again given by a linear temporal property.

References

1. Ezio Bartocci, Luca Bortolussi, Laura Nenzi, and Guido Sanguinetti. On the robustness of temporal properties for stochastic models. *Electronic Proceedings in Theoretical Computer Science*, 125:3–19, August 2013.
2. L. Bortolussi and G. Sanguinetti. Learning and designing stochastic processes from logical constraints. In *Proceedings of QEST 2013*, 2013.
3. Luca Bortolussi and Guido Sanguinetti. Smoothed model checking for uncertain continuous time Markov chains. *CoRR ArXiv*, 1402.1450, 2014.