PhD proposal

Title: Machine learning and verification of infinite-state systems

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Key words

Infinite-state systems, verification, machine learning, reachability, well structured transition systems, Petri nets.

General Context

In recent years, machine learning techniques have been very succesful in several application domains and are now widespread in big companies. For instance, Google, Facebook and Microsoft have both integrated (deep) learning techniques in tools: Cloud Machine Learning Engine (Google), Applied Machine Learning (Facebook), etc.

Since machine learning techniques only offer an empirical confidence level about the correctness of the result rather than a formal guarantee, it is a challenging task to use them in verification problems. Indeed the designer of a critical system needs to be sure that the required properties hold. Fortunately, machine learning techniques can be combined with decision algorithms in order to speed up the standard algorithms by taking into account the structure of the system. For instance, deciding reachability in finite transition systems by some exploration algorithm can be accelerated (in the positive case) by introducing randomness during the exploration. Such an approach has been studied in [4] and [1].

While verification problems of infinite-state systems may be undecidable even in restricted frameworks, there is a particular case of such systems *Well*

Structured Transition Systems (WSTS) [3] for which several relevant verification problems are decidable. Furthermore, in some cases, the reachability set can be finitely represented [2]. However the complexity of the algorithms is generally very high.

Among WSTS, Petri nets play a central role for several reasons. In particular, while reachability in Petri nets is decidable, it is an open issue whether this problem is primitive recursive. One of the algorithms that solve reachability in Petri nets presents an interesting feature from the point of view of machine learning [5]. It consists in the parallel execution of two semi-algorithms. The first one is a standard exploration of the reachability set that terminates if the final marking is reachable. The second one enumerates semi-linear sets closed by transition firings and stops when such a set contains the initial marking but not the final one.

Objectives

The aim of this PhD proposal is to design and experiment machine learning techniques for accelerating the verification algorithms of infinite-state systems. We plan to work into three complementary directions.

- When the state space has a finite representation (e.g. semilinear sets), one aims at using machine learning to guess the representation. As an extension, when this is not the case, one tries to guess finite representations of a pair (subset, superset) in order to answer in most of the cases to questions related to reachability;
- We want to introduce machine learning techniques to accelerate the two semi-algorithms whose combination solves the reachability problem of Petri nets. Here the interest is that whatever the answer will be, one of the acceleration will be effective;
- At a meta-level given a verification problem, when an algorithm can be tuned by different heuristics or different algorithms exist to solve it we want to apply machine learning to classify the models in such a way that the appropriate heuristics/algorithm will be selected.

Location

This PhD will be supervised at the Ecole Normale Supérieure Paris-Saclay.

Qualifications and Background

This PhD is opened to strongly motivated and excellent Bachelor or Master students who like discrete mathematics, theoretical computer science and algorithmics. A background in probability and/or statistics will be appreciated.

References

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