Probabilistic Model Checking for Autonomous Agent Strategy Synthesis - Extended Abstract

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Abstract. We describe work that was presented at the NASA Formal Methods Symposium and published in the symposium proceedings [1]. We give an overview of the probabilistic models that we presented for autonomous agent search and retrieve missions. We summarise how probabilistic model checking and the probabilistic model checker PRISM were used for optimal strategy generation with a view to returning the generated strategies to the UAV embedded within controller software.

1 Introduction

Autonomous vehicles such as unmanned aerial vehicles, autonomous underwater vehicles and autonomous ground vehicles have widespread application in both military and commercial contexts. Understandably, there are concerns about safety and reliability. Critically, *can controllers be generated automatically and in such a way as to ensure that the resulting behaviour is safe, efficient and secure under all conceivable operational scenarios and system failures?*

Guaranteeing reliability of autonomous controllers using testing alone is infeasible. Formal verification offers hope in this direction having been used both for controller synthesis and for verifying the reliability and safety of autonomous controller logic. In [1] we investigate the use of probabilistic model checking and the probabilistic model checker PRISM for automatic controller generation. Our ultimate goal is to develop software, based on the techniques described here that can be embedded into controller software to generate *adaptable* controllers that are *verified* to be *optimal*, *safe* and *reliable* by design.

2 Prism and strategy generation

PRISM [4] is a probabilistic model checker that allows for the analysis of a number of probabilistic models including MDPs. The models that we use in [1] are Markov Decision Processes (MDPs). In an MDP transitions include nondeterminstic actions followed by probabilistic choice. PRISM supports the computation of optimal probabilistic and expected reachability values for MDPs. PRISM can also synthesise strategies achieving such optimal values. Such a

Scenario	Controller Choice
2	when to recharge
3	+ search path
4	+ whether search sensors are in Low/High mode
5	+ multiple agents
6	+ agents can idle

Table 1. Scenarios: with non-deterministic actions

strategy is represented as a list of (optimal) action choices for each state of the MDP under study, this list can then be fed back into PRISM to generate the underlying DTMC, and hence allow further analysis of the strategy. For details on strategy synthesis see, for example [5].

3 Scenarios

In [1] a range of scenarios relevant for autonomous agents were modelled as MDPs and we showed how PRISM could be used for verification and controller synthesis. These were based on an initial model derived from Simulink models for an Unmanned Aerial Vehicle (UAV) [3]. Each scenario is inspired by realistic situations for a range of autonomous vehicle applications but is abstracted to a scenario involving an *autonomous agent* searching for objects within a defined area. In each case we use non-determinism to represent either maximum and minimum bounds for certain parameter values (scenario 1, based on a model initially developed in [2], or choices to be made by the controller). We then use PRISM to identify a strategy in each case that maximises/minimises either a reachability probability or an expected reward value. We then generate a pair of files (containing states and transitions respectively) from the strategy which can be then used by a simulation model and ultimately within controller software. In Table 1 we indicate the (increasing) aspects of controller choice that are represented using non-determinism in each scenario.

References

1. Giaquinta, R., Hoffmann, R., Ireland, M., Miller, A., Norman, G.: Strategy synthesis for autonomous agents using PRISM. In: Proc. NFM'18. LNCS 10811, Springer (2018)
2. Hoffmann, R., Ireland, M., Miller, A., Norman, G., Veres, S.: Autonomous agent behaviour modelled in PRISM: A case study. In: Proc. SPIN'16. LNCS 9641, Springer (2016)
3. Ireland, M., Hoffmann, R., Miller, A., Norman, G., Veres, S.: A continuous-time model of an autonomous aerial vehicle to inform and validate formal verification methods, http://arxiv.org/abs/1609.00177v1
4. Kwiatkowska, M., Norman, G., Parker, D.: PRISM 4.0: Verification of probabilistic real-time systems. In: Proc. CAV'11. LNCS 6806, Springer (2011)
5. Kwiatkowska, M., Parker, D.: Automated verification and strategy synthesis for probabilistic systems. In: Proc. ATVA'13. LNCS 8172, Springer (2013)