Research Project

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AI-Enhanced Verification for Multi-Agent Systems

The problem of assuring systems correctness is particularly felt in hardware and software design, especially in safety-critical scenarios. When we talk about a safety-critical system, we mean the one in which failure is not an option. To face this problem, several methodologies have been proposed. Amongst these, model checking [1] results to be very useful. This approach provides a formal-based methodology to model systems, to specify properties via temporal logics, and to verify that a system satisfies a given specification.

Notably, first applications of model checking just concerned closed systems, which are characterized by the fact that their behavior is completely determined by their internal states. Unfortunately, model checking techniques developed to handle closed systems turn out to be quite useless in practice, as most of the systems are open and are characterized by an ongoing interaction with other systems. To overcome this problem, model checking has been extended to multi-agent systems. In the latter context, temporal logics have been extended to temporal logics for the strategic reasoning such as Alternating-time Temporal Logic (ATL) [2], Strategy Logic (SL) [3], and their extensions.

The increasing complexity of multi-agent systems (MAS) poses significant challenges to traditional formal verification techniques, which often struggle with scalability, automation, and usability. This project explores how Artificial Intelligence (AI) can be leveraged to enhance the efficiency and applicability of formal verification methods for MAS.

The central idea is to integrate AI-driven approaches into the model checking and strategy synthesis processes used in the verification of MAS. By learning from verification traces, counterexamples, or model structures, AI components can guide the verification process, improving performance and reducing computational costs. Moreover, AI can support the automatic generation of strategies and abstractions, facilitating the analysis of dynamic or large-scale systems that would otherwise be intractable.

The project is structured around three main objectives:

1. Extension of existing verification frameworks with AI-based modules for heuristic guidance and abstraction refinement.
2. Design of AI-assisted verification algorithms, exploiting learning techniques to improve scalability and adaptability.
3. Integration into the VITAMIN tool [4], providing an experimental platform for evaluating the effectiveness of AI-enhanced verification.

Vision:
By combining formal reasoning with adaptive AI techniques, this research aims to make the verification of multi-agent systems more scalable, automated, and applicable to real-world dynamic environments.

Bibliography

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