Research Project

Supervisors: *Angelo Ferrando, Vadim MALVONE*

Contact: angelo.ferrando@unimore.it , vadim.malvone@telecom-paris.fr

Keywords: *Formal verification, Multi-Agent Systems, Artificial Intelligence*

Students required: *1*

AI-Enhanced Verification for Multi-Agent Systems: User-Friendly Interface Development

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. While model checking provides a formal methodology to model systems, specify properties, and verify that a system satisfies a given specification, its use is often **limited to experts**, due to the complexity of specifying models and formal properties.

To make verification accessible to non-expert users, this project focuses on the **development of a user-friendly interface**, where AI techniques assist users in model creation, formula generation, and result interpretation.

Non-expert users often struggle with:

- Defining multi-agent system models without deep knowledge of formal methods.
- Writing temporal logic formulas to specify desired properties.
- Understanding verification counterexamples and strategy outputs.

AI techniques can be integrated into the model checking process to overcome these usability challenges. By learning from existing models, verification traces, or counterexamples, AI components can:

- Guide model creation, highlighting critical components and interactions.
- Suggest temporal formulas and strategy objectives automatically.
- Provide abstractions that simplify complex systems while preserving essential information.

The project is structured around three main objectives:

1. **Design and development of a user-friendly interface** that allows non-expert users to define agents, actions, and interactions visually.

2. **Integration of AI-driven assistance for model and formula generation**, exploiting learning techniques to suggest models and properties.
3. **Integration into the VITAMIN tool** [4], providing an experimental platform where users can define models, generate formulas, and verify multi-agent systems without needing deep formal methods expertise.

Vision:
By combining formal reasoning with AI-guided automation and intuitive user interfaces, this research aims to **democratize access to multi-agent system verification**, making it scalable, automated, and practical for engineers, designers, and analysts who are not experts in formal methods.

Bibliography

[1] E. M. Clarke, O. Grumberg, and D. A. Peled. Model Checking. MIT Press, 1999.

[2] R. Alur, T.A. Henzinger, and O. Kupferman. Alternating-Time Temporal Logic. JACM, 49(5):672–713, 2002.

[3] F. Mogavero, A. Murano, G. Perelli, and M. Y. Vardi. Reasoning About Strategies: On the Model-Checking Problem. TOCL, 15(4):34:1--34:47, 2014.

[4] A. Ferrando and V. Malvone: VITAMIN: A Compositional Framework for Model Checking of Multi-Agent Systems. CoRR abs/2403.02170 (2024).