VITAMIN: VerIficaTion of A MultI ageNt system

Angelo Ferrando
University of Modena and Reggio Emilia
Modena, Italy
angelo.ferrando@unimore.it

Vadim Malvone
LTCI, Télécom Paris, Institut Polytechnique de Paris
Palaiseau, France
vadim.malvone@telecom-paris.fr

ABSTRACT

We present VITAMIN, a modular and user-friendly framework for formal verification of Multi-Agent Systems (MAS). VITAMIN provides extensible support for diverse logics and models, making it suitable for experts and non-experts. This demonstration highlights VITAMIN's capabilities emphasising its usability and compositional design.

KEYWORDS

Model Checking Tools, Multi-Agent Systems, Strategic Reasoning

ACM Reference Format:
Angelo Ferrando and Vadim Malvone. 2025. VITAMIN: VerIficaTion of A MultI ageNt system. In *Proc. of the 24th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2025), Detroit, Michigan, USA, May 19 – 23, 2025*, IFAAMAS, 3 pages.

1 INTRODUCTION

VITAMIN [9–11] is a novel, compositional framework designed to facilitate the formal verification of Multi-Agent Systems (MAS). The verification of MAS can be exceedingly complex due to their inherently distributed nature, the presence of autonomous and rational entities (agents), and the interplay of distinct communication and decision-making strategies. This complexity often hinders the widespread adoption of formal verification techniques outside specialised research settings, calling for solutions that are both robust and accessible.

VITAMIN distinguishes itself by integrating formal verification techniques with a modular and extensible architecture. It supports diverse logics and models without altering the core engine, enabling verification of strategic behaviours, temporal requirements, and rational interactions across various MAS scenarios. Unlike traditional monolithic tools, VITAMIN fosters experimentation, reuse, and incremental extension, reducing the complexity of advanced verification methods.

The platform leverages state-of-the-art software engineering, agent-based reasoning, and modern web-based interfaces. Its graphical interface, accessible via a browser, lowers the barrier for non-expert users, while advanced users can customise the backend with new algorithms, abstractions, or logic strategies.

A key innovation is the interactive verification allowing users to iteratively refine MAS models and specifications with immediate feedback. The intuitive graphical interface guides non-experts through model creation, bridging the gap between conceptual modelling and formal analysis. This user-centric approach makes MAS verification more approachable and iterative.

By combining advanced MAS verification techniques with user-friendly design, VITAMIN addresses the challenges of verifying complex, distributed systems. This demonstration will showcase its rapid model-building, formula specification, and verification capabilities. Ultimately, VITAMIN empowers researchers and practitioners to embrace formal verification for sophisticated multi-agent technologies.

2 TOOL

As shown in Figure 1, the main page of VITAMIN features a dashboard with three key elements. The first button ("Guide") links to a guide explaining how to use VITAMIN, both from the perspective of a user employing the tool and a developer aiming to extend its functionality.

The other two buttons allow users to access the verification process in two different modes. In the first mode ("Expert User"), users are prompted to provide a model as input via a text file (Figure 2) and to specify a formula in a text box. For the formula, users must also select the specification language of interest from a dropdown menu, as illustrated in Figure 3. Once the model and formula are provided, users can click the "Next: To Model Checking" button to initiate the verification process for the chosen model and logic. Further details on the syntax for model representation and specification can be found in the guide available within VITAMIN (discussed earlier).

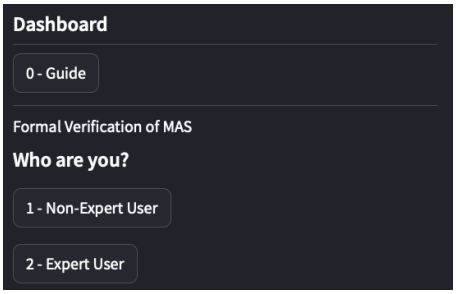

Figure 1: VITAMIN's dashboard.

The third button on the dashboard, labelled "Non-Expert User", provides an alternative verification mode. This functionality enables users to generate a model through a step-by-step process (like in Figure 4 in which the user can select the number of agents involved in the MAS and their names) that guides them in creating both the model and the specification. The various characteristics defining the model and specification are requested sequentially, ensuring a structured approach to assist users more effectively.

Proc. of the 24th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2025), Y. Vorobeychik, S. Das, A. Nowé (eds.), May 19 – 23, 2025, Detroit, Michigan, USA. © 2025 International Foundation for Autonomous Agents and Multiagent Systems (www.ifaamas.org).

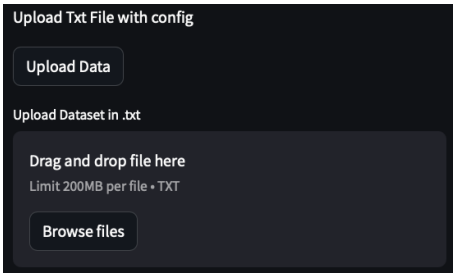

Figure 2: Model insertion.

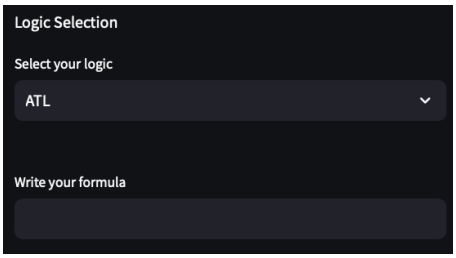

Figure 3: Logic selection and formula insertion.

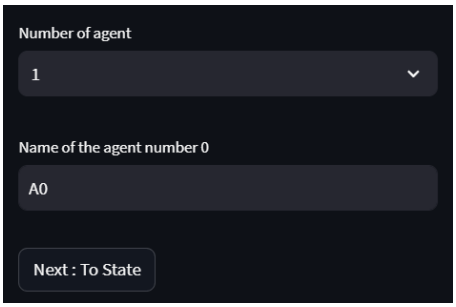

Figure 4: Non-Expert agent selection.

A video of the demonstration of VITAMIN can be found at:
https://www.youtube.com/playlist?list=PL7_3IMeFMCaC2dVUkEByoeML5L20nQD2P

3 EXISTING FUNCTIONALITIES

Thanks to its innovative and modular architecture, VITAMIN enables seamless and straightforward integration of new functionalities—such as models, logics, and verification methods—making it highly accessible for developers. As shown in Figure 5, hierarchical modules for model generation, logics, and verification methods have been introduced. In its current version, VITAMIN supports several models, logics, and related verification methods. Below, we outline the functionalities already available in the tool.

Models. For models, the following modules have been developed:

- Concurrent Game Structures (CGS) [1],
- Resource-Bounded CGS (RB-CGS) [13],
- Resource Action-based Bounded CGS (RAB-CGS) [4],
- Obstruction Models (OM) [5, 6],

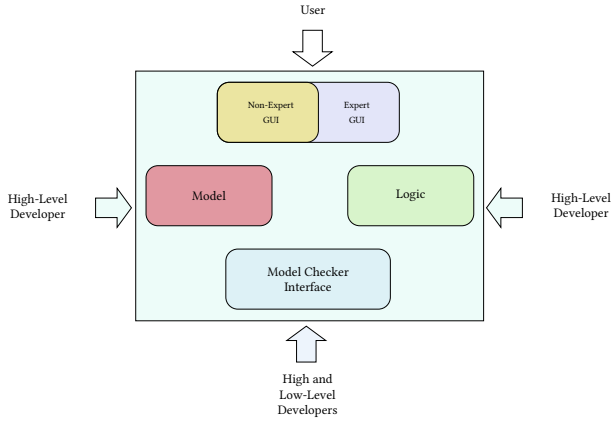

Figure 5: Architecture's overview.

- Weighted CGS (wCGS) [8], and
- Capacity CGS (cap-CGS) [2].

Logics. For logics, the following modules have been implemented:

- Computation Tree Logic (CTL) [7],
- Alternating-time Temporal Logic (ATL) [1],
- Resource-Bounded ATL (RB-ATL) [13],
- Resource Action-based Bounded ATL (RAB-ATL) [4],
- Obstruction Logic (OL) [5],
- Obstruction ATL (OATL) [6],
- ATL with Fuzzy Functions (ATLF) [8],
- Natural ATL (NatATL) [12],
- Natural SL [3], and
- Capacity ATL (cap-ATL) [2].

For all the aforementioned models and logics VITAMIN provides their explicit verification approaches.

4 CONCLUSIONS AND FUTURE WORK

We introduced VITAMIN, a comprehensive and adaptable framework designed for the model checking of MAS and beyond, with a strong focus on usability and extensibility. While VITAMIN remains a work in progress, its current state represents a significant advancement in the field of tools for formally verifying MAS, particularly due to its compositional architecture, which opens avenues for further exploration and enhancement. Although VITAMIN is presently at the prototype stage, its verification capabilities and compositional representation have already been implemented and tested across diverse scenarios involving various models and formulas. These practical applications demonstrate the tool's potential and effectiveness in addressing a range of verification tasks.

Our future efforts will concentrate on expanding VITAMIN and engaging with the MAS community to refine and extend its features. We also plan to explore additional models and logics within the framework as part of ongoing research. While this paper has primarily focused on the usability and extensibility of VITAMIN, future studies will delve deeper into specific implementations and applications of its components, further advancing its contributions to the field.

REFERENCES

[1] Rajeev Alur, Thomas A. Henzinger, and Orna Kupferman. 2002. Alternating-time temporal logic. *J. ACM* 49, 5 (2002), 672–713. https://doi.org/10.1145/585265.585270

[2] Gabriel Ballot, Vadim Malvone, Jean Leneutre, and Youssef Laarouchi. 2024. Strategic Reasoning under Capacity-constrained Agents. In *Proceedings of the 23rd International Conference on Autonomous Agents and Multiagent Systems, AAMAS 2024, Auckland, New Zealand, May 6-10, 2024*, Mehdi Dastani, Jaime Simão Sichman, Natasha Alechina, and Virginia Dignum (Eds.). International Foundation for Autonomous Agents and Multiagent Systems / ACM, 123–131. https://doi.org/10.5555/3635637.3662859

[3] Francesco Belardinelli, Wojtek Jamroga, Vadim Malvone, Munyque Mittelmann, Aniello Murano, and Laurent Perrussel. 2022. Reasoning about Human-Friendly Strategies in Repeated Keyword Auctions. In *21st International Conference on Autonomous Agents and Multiagent Systems, AAMAS 2022, Auckland, New Zealand, May 9-13, 2022*, Piotr Faliszewski, Viviana Mascardi, Catherine Pelachaud, and Matthew E. Taylor (Eds.). International Foundation for Autonomous Agents and Multiagent Systems (IFAAMAS), 62–71. https://doi.org/10.5555/3535850.3535859

[4] Davide Catta, Angelo Ferrando, and Vadim Malvone. 2024. Resource Action-Based Bounded ATL: A New Logic for MAS to Express a Cost Over the Actions. In *PRIMA 2024: Principles and Practice of Multi-Agent Systems - 25th International Conference, Kyoto, Japan, November 18-24, 2024, Proceedings (Lecture Notes in Computer Science, Vol. 15395)*, Ryuta Arisaka, Víctor Sánchez-Anguix, Sebastian Stein, Reyhan Aydogan, Leon van der Torre, and Takayuki Ito (Eds.). Springer, 206–223. https://doi.org/10.1007/978-3-031-77367-9_16

[5] Davide Catta, Jean Leneutre, and Vadim Malvone. 2023. Obstruction Logic: A Strategic Temporal Logic to Reason About Dynamic Game Models. In *ECAI 2023 - 26th European Conference on Artificial Intelligence, September 30 - October 4, 2023, Kraków, Poland - Including 12th Conference on Prestigious Applications of Intelligent Systems (PAIS 2023) (Frontiers in Artificial Intelligence and Applications, Vol. 372)*, Kobi Gal, Ann Nowé, Grzegorz J. Nalepa, Roy Fairstein, and Roxana Radulescu (Eds.). IOS Press, 365–372. https://doi.org/10.3233/FAIA230292

[6] Davide Catta, Jean Leneutre, Vadim Malvone, and Aniello Murano. 2024. Obstruction Alternating-time Temporal Logic: A Strategic Logic to Reason about Dynamic Models. In *Proceedings of the 23rd International Conference on Autonomous Agents and Multiagent Systems, AAMAS 2024, Auckland, New Zealand, May 6-10, 2024*, Mehdi Dastani, Jaime Simão Sichman, Natasha Alechina, and Virginia Dignum (Eds.). International Foundation for Autonomous Agents and Multiagent Systems / ACM, 271–280. https://doi.org/10.5555/3635637.3662875

[7] Edmund M. Clarke and E. Allen Emerson. 1981. Design and Synthesis of Synchronization Skeletons Using Branching-Time Temporal Logic. In *Logics of Programs, Workshop, Yorktown Heights, New York, USA, May 1981 (Lecture Notes in Computer Science, Vol. 131)*, Dexter Kozen (Ed.). Springer, 52–71. https://doi.org/10.1007/BFB0025774

[8] Angelo Ferrando, Giulia Luongo, Vadim Malvone, and Aniello Murano. 2024. Theory and Practice of Quantitative ATL. In *PRIMA 2024: Principles and Practice of Multi-Agent Systems - 25th International Conference, Kyoto, Japan, November 18-24, 2024, Proceedings (Lecture Notes in Computer Science, Vol. 15395)*, Ryuta Arisaka, Víctor Sánchez-Anguix, Sebastian Stein, Reyhan Aydogan, Leon van der Torre, and Takayuki Ito (Eds.). Springer, 231–247. https://doi.org/10.1007/978-3-031-77367-9_18

[9] Angelo Ferrando and Vadim Malvone. 2024. Hands-on VITAMIN: A Compositional Tool for Model Checking of Multi-Agent Systems. In *Proceedings of the 25th Workshop "From Objects to Agents", Bard (Aosta), Italy, July 8-10, 2024 (CEUR Workshop Proceedings, Vol. 3735)*, Marco Alderighi, Matteo Baldoni, Cristina Baroglio, Roberto Micalizio, and Stefano Tedeschi (Eds.). CEUR-WS.org, 148–160.

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

[11] Angelo Ferrando and Vadim Malvone. 2024. VITAMIN: A Tool for Model Checking of MAS. In *Multi-Agent Systems - 21st European Conference, EUMAS 2024, Dublin, Ireland, August 26-28, 2024, Proceedings (Lecture Notes in Computer Science, Vol. to appear)*, Rem Collier, Alessandro Ricci, and Vivek Nallur (Eds.). Springer.

[12] Wojciech Jamroga, Vadim Malvone, and Aniello Murano. 2019. Natural strategic ability. *Artif. Intell.* 277 (2019). https://doi.org/10.1016/J.ARTINT.2019.103170

[13] Hoang Nga Nguyen, Natasha Alechina, Brian Logan, and Abdur Rakib. 2018. Alternating-time temporal logic with resource bounds. *J. Log. Comput.* 28, 4 (2018), 631–663. https://doi.org/10.1093/LOGCOM/EXV034