# VITAMIN: VerificaTion of A Multi ageNt system

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### 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 nonexpert 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

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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 userfriendly 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.

| Logic Selection    |   |
|--------------------|---|
| Select your logic  |   |
| ATL                | ~ |
| Write your formula |   |
|                    |   |

Figure 3: Logic selection and formula insertion.

| Number of agent     |         |   |
|---------------------|---------|---|
| 1                   |         | ~ |
| Name of the agent n | umber 0 |   |
| A0                  |         |   |
|                     |         |   |
| Next : To State     |         |   |

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.

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