

Modern computing systems increasingly rely on the collaboration of multiple autonomous agents—software or hardware components that operate independently but cooperate to accomplish complex tasks. These systems, known as multi-agent systems, are used in logistics, intelligent transport, critical infrastructure, robot swarms, and decentralized control platforms. The most challenging to design and verify are open real-time multi-agent systems (ORTMAS)—those in which the number of agents may change dynamically and where system behavior must meet strict timing constraints.

The aim of this project is to develop new formal models, specification languages, and automated verification techniques for ORTMAS. The goal is to precisely define and check whether such systems always function correctly—regardless of the number of agents, their dynamic changes, or complex interactions. The verification will focus on properties such as real-time correctness, agents' knowledge and obligations, fault recovery mechanisms, and compliance with norms and commitments in evolving environments.

The project introduces a novel approach by combining several theoretical frameworks: temporal, epistemic, deontic, and commitment logics, while addressing the complex problem of handling open and dynamic systems. New logical languages will be developed for the precise specification of system properties, along with verification algorithms. The proposed methods will utilize advanced symbolic techniques (e.g., SAT, SMT, and decision diagrams), allowing the analysis of even extremely large state spaces. These methods belong to the approach known as model checking, which involves automatically verifying whether a system model satisfies given logical properties. Unlike traditional testing, model checking provides full mathematical guarantees of correctness—provided all relevant scenarios are covered. This allows for the detection of subtle errors and the generation of counterexamples illustrating undesirable behaviors.

The project will produce a publicly available verification tool supporting various classes of logic and application scenarios. It will be evaluated using specially designed benchmarks and realistic models, such as robot swarms operating in disrupted environments. Research results will be published in leading scientific journals, and the project will also support education—one of the planned outcomes is a doctoral dissertation.

The project addresses the well-known state explosion problem—the exponential growth in the number of possible system configurations as the number of agents and variables increases. In addition to developing theory and algorithms, the project will explore techniques such as symmetry reduction and abstraction, enabling the practical analysis of complex systems within a reasonable time frame.

The expected outcomes include: formal results on verification soundness and complexity, new algorithms, and a software platform capable of analyzing systems previously considered too complex for formal verification. The project responds to the urgent need for dependable methods for the design and supervision of ORTMAS systems, which are increasingly becoming part of our socio-technical infrastructure.