Internship Project

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Towards the probabilistic version of natural strategies

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 (MAS). 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.

In the verification of MAS, strategies are typically defined as functions that assign an action to each system state. Strategies can be ***memoryless****, where the agent only considers the current state, or* ***memoryfull****, where the agent considers the full history. Another important distinction concerns* ***agent visibility****, with MAS having either perfect or imperfect information. In general, memoryfull strategies under imperfect information are highly expressive but lead to* ***undecidable model checking problems*** *for logics such as ATL and SL. To address complexity, various techniques have been proposed, including symbolic and abstraction methods. An alternative approach involves* ***natural strategies [4]****, which model "simple" or bounded-rational strategies and have been introduced in both ATL [4] and SL [5] for perfect and imperfect information settings. Natural strategies reduce model checking complexity while retaining significant expressiveness.* ***However, natural strategies have so far only been studied in deterministic settings.*** *Introducing them in a* ***probabilistic context*** *is a novel and necessary step, enabling reasoning about agent abilities under uncertainty and probabilistic outcomes. This extension opens the way for new verification algorithms and logic frameworks that combine the simplicity of natural strategies with probabilistic reasoning.*

The objectives of this project are structured in four main steps:

1. ***Survey the state of the art*** *on formal verification for multi-agent systems and natural strategies, with a focus on probabilistic reasoning and strategic logics.*
2. ***Define a probabilistic extension of natural strategies****, enabling the specification of properties that combine strategic reasoning with probabilistic outcomes.*
3. ***Develop a verification algorithm*** *capable of checking these probabilistic natural strategies.*
4. ***Integrate the proposed logic and algorithm into the VITAMIN tool*** *[6], enabling the automated verification of probabilistic natural strategies under this new framework.*

Bibliography

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