Model Checking of Strategic Timed Temporal Logics (Extended Abstract)

Wojciech Penczek[1]

[1] *Zespó Teorii Systemow Rozproszonych i Obliczeniowych*
Instytut Podstaw Informatyki PAN
ul. Jana Kazimierza 5
01-248 Warszawa

1. Multi-agent Systems and ATL

Autonomous agents provide a powerful paradigm for modelling and analysing socio-technical systems. They encompass networks of communicating agents that make autonomous decisions based on AI methods. Modeling strategic behaviors in a real-time context is crucial for ensuring the safety and security of agent systems. Alternating-time temporal logic ($\mathbf{ATL}^*$) and its fragment $\mathbf{ATL}$ [1, 2] are logics that enable reasoning about strategic interactions in such systems by extending the framework of temporal logic with the game-theoretic concept of *strategic ability*. Therefore, $\mathbf{ATL}$ allows us to express statements about what groups of agents can achieve. These properties are useful for specifying, verifying, and reasoning about interactions in agent systems [11, 12, 7], as well as security and usability in e-voting protocols [5, 9]. They have become particularly relevant due to very active development of algorithms and tools for verification [15, 6, 8, 10], where the "correctness" is defined in terms of strategic ability.

2. Timed extensions of ATL and SCTL

In this lecture we investigate timed extensions of strategic logics including $\mathbf{ATL}$ and $\mathbf{ATL}^*$. We begin with discussing the syntax and semantics of $\mathbf{ATL}$ and its discrete time extension $\mathbf{TATL}$ [14, 13]. Then, we introduce two new strategy logics: Strategic $\mathbf{CTL}$ ($\mathbf{SCTL}$) and its timed extension Strategic Timed $\mathbf{CTL}$ ($\mathbf{STCTL}$) [4]. Each (timed) strategy logic is interpreted over two types of structures: models of synchronous (Time) Multi-Agent Systems MAS and of asynchronous (Time) Multi-Agent Systems AMAS. We consider two semantics related to information: imperfect (i) and perfect (I), and two semantics related to recall: imperfect (r) and perfect (R). Additionally, Time MAS and Time AMAS can be either discrete (D) or continuous (C). The lecture focuses on the model checking problem for $\mathbf{SCTL}$ and $\mathbf{STCTL}$, considering all the semantics mentioned above, and comparing their complexity with other strategy logics. Notably, we demonstrate that $\mathbf{SCTL}$ is more expressive than $\mathbf{ATL}$ for all semantics, including

PNSE'23, International Workshop on Petri Nets and Software Engineering, 2023
penczek@ipipan.waw.pl (W. Penczek)
https://home.ipipan.waw.pl/w.penczek/ (W. Penczek)

the timed versions as well. Furthermore, we analyze the model checking problem for different combinations of semantics. For instance, the model checking problem for $\mathbf{SCTL}_{\mathrm{ir}}$ has the same complexity as for $\mathbf{ATL}_{\mathrm{ir}}$, and the model checking problem for $\mathbf{STCTL}_{\mathrm{ir}}$ has the same complexity as for $\mathbf{TCTL}$. Additionally, we provide a practical demonstration of the feasibility of $\mathbf{STCTL}_{\mathrm{ir}}$ model checking using IMITATOR [3].

Acknowledgements This work was funded by the CNRS IEA project MoSART, and by NCBR Poland & FNR Luxembourg under the PolLux/FNR-CORE project SpaceVote (POLLUX-XI/14/SpaceVote/2023).

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