Strategic Abilities of Asynchronous Agents: Semantic Side Effects

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Previous Work: Partial Order Reduction for ATL

- Formalism: Asynchronous Multi-agent Systems (AMAS)
- Alternating-time Temporal Logic ATL*
- Main result: POR algorithm for LTL adapted to ATL, the subset of ATL* without nested strategic operators
- “Free lunch”: applying existing methods and tools for a new purpose (and using a more expressive logic!)

Semantic Problems with Strategic Ability in AMAS

- AMAS semantics follows the classical modeling tradition inherited from distributed systems
- However, adding the concept of strategic ability results in several problematic phenomena
- Side-effects: unexpected or counterintuitive formal interpretations of some strategic formulae

Example 1: Conference in Times of COVID-19

Left: an AMAS with General, Organizing Committee and Steering Committee chairs gc, oc, and sc
Right: its interleaved interpreted system (model) M
Highlighted: joint strategy of coalition \(\langle gc, oc \rangle\) and the transitions it enables in model M

Semantic Problems: Deadlocks and Finite Paths

- Example 1: the whole model M has no deadlock states, as typically expected from automata networks
- However, some strategies still might lead to deadlocks
- The joint strategy of \(\langle gc, oc \rangle\) produces only one infinite path: 000-giveup002-giveup...
- AMAS semantics disregards finite paths though!
- Counterintuitively, we get \(M, 000 \models \langle\langle gc, oc \rangle\rangle \top\) - open

Semantic Problems: Asymmetric Interaction

- Example 1: \(M, 101 \models \langle\langle gc \rangle\rangle \top\) - epid, since gc can pick online at its local state 1 to ensure low epidemic risk
- Then, oc has to synchronize with gc on event online
- On the other hand, we also have \(M, 101 \models \langle\langle oc \rangle\rangle \top\) - epid, obtained by oc’s strategy selecting onsite at state 0
- Agents’ repertoire functions in AMAS are based on the assumption that any single event can be chosen
- No natural specification of the opposite situation (transition determined by another agent)

Example 2: Conference, Slightly Modified

Highlighted: joint strategy of coalition \(\langle gc, oc \rangle\) and the transitions it enables in model \(M'\)

Semantic Problems: Empty Strategy Outcomes

- Example 2: \(M'\) has no deadlock states, yet all the joint strategies of \(\langle gc, oc \rangle\) produce only finite runs
- Finite paths are not included in the outcome sets, and semantics rules out strategies with empty outcomes
- Consequently, \(\neg \langle\langle gc, oc \rangle\rangle \top\), which is definitely wrong!
- Removing non-emptiness clause on outcomes does not help: in this case, \(\langle\langle gc, oc \rangle\rangle G \top\) can be demonstrated

Summary

We identified several problematic side-effects in the original AMAS semantics that manifest when reasoning about strategic ability using the logic ATL
- AMAS is too restricted to model all strategic aspects of asymmetric synchronization (e.g. coalition agents being forced by their opponents’ choices)

References
