Strategic Abilities of Asynchronous Agents: Semantic Side Effects

Wojciech Jamroga, Wojciech Penczek, Teofil Sidoruk

Institute of Computer Science, Polish Academy of Sciences
{jamroga, penczek, t.sidoruk}@ipipan.waw.pl

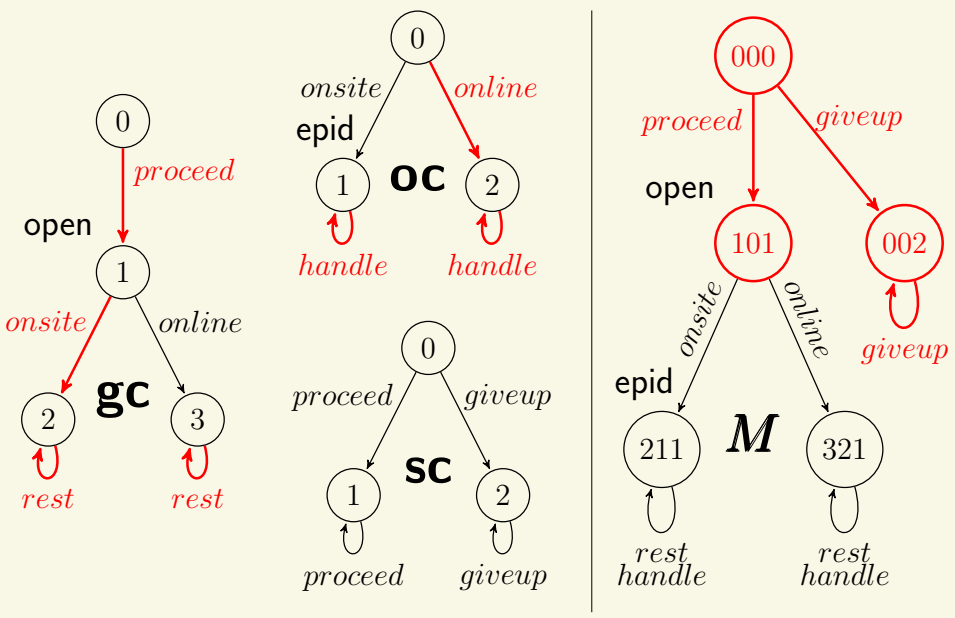
Previous Work: Partial Order Reduction for ATL

- Formalism: Asynchronous Multi-agent Systems (AMAS)
- Alternating-time Temporal Logic $\mathbf{ATL}^*$
- Main result: POR algorithm for $\mathbf{LTL}$ adapted to $\mathbf{ATL}$, the subset of $\mathbf{ATL}^*$ 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 distibuted 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 $\langle\langle gc, oc\rangle\rangle$ and the transitions it enables in model M

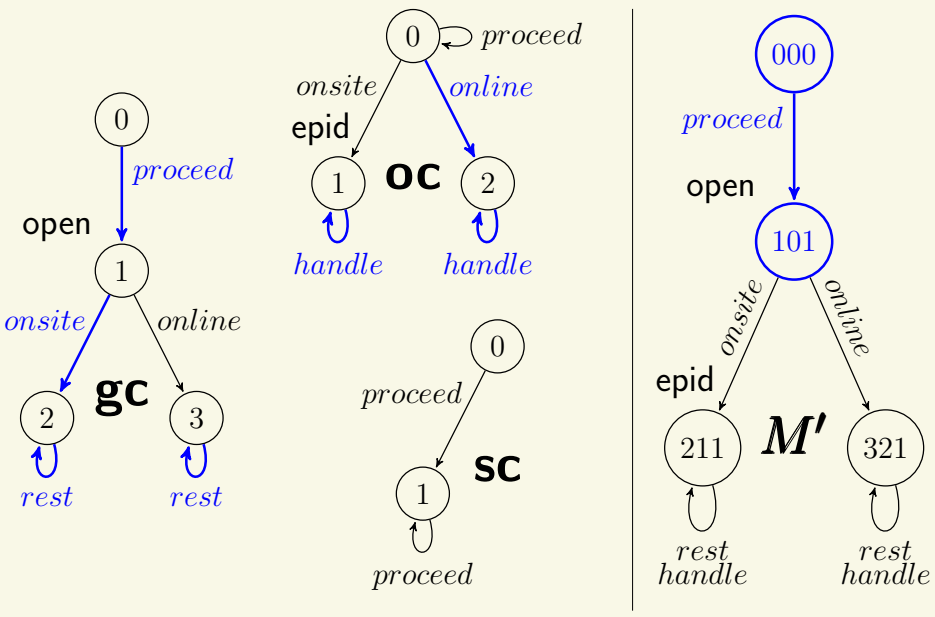
Semantic Problems: Deadlocks and Finite Paths

- **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 $\langle\langle gc, oc\rangle\rangle$ produces only one infinite path: $000\, giveup\, 002\, giveup \ldots$
- AMAS semantics disregards finite paths though!
- Counterintuitively, we get $M, 000 \models \langle\langle gc, oc\rangle\rangle \mathbf{G} \neg \text{open}$

Semantic Problems: Asymmetric Interaction

- **Example 1:** $M, 101 \models \langle\langle gc\rangle\rangle \mathbf{G} \neg \text{epid}$, 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 $M, 101 \models \langle\langle oc\rangle\rangle \mathbf{F}\, \text{epid}$, 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 $\langle\langle gc, oc\rangle\rangle$ 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 $\langle\langle gc, oc\rangle\rangle$ produce only finite runs
- Finite paths are not included in the outcome sets, and semantics rules out strategies with empty outcomes
- Consequently, $\neg\langle\langle gc, oc\rangle\rangle \mathbf{F} \top$, which is definitely wrong!
- Removing non-emptiness clause on outcomes does not help: in this case, $\langle\langle gc, oc\rangle\rangle \mathbf{G} \bot$ 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 $\mathbf{ATL}$
- AMAS is too restricted to model all strategic aspects of asymmetric synchronization (*e.g.* coalition agents being forced by their opponents' choices)

References

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