Towards Partial Order Reductions for Strategic Ability (abstract)

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Strategic Ability, Asynchronous Agent Systems, and Partial-Order Reductions

Alternating-time temporal logic **ATL*** and its fragment **ATL** [1] extend temporal logic with the notion of *strategic ability*. They allow to express statements about what agents (or groups of agents) can achieve. For example, $\langle\langle i \rangle\rangle \mathrm{F}\, \mathsf{win_i}$ says that agent i can eventually win no matter what the other agents do. Such properties can be useful for specification, verification, and reasoning about interaction in agent systems.

In this paper, we make the first step towards strategic analysis of *asynchronous* multi-agent systems. Our contribution is threefold. First, we define a semantics of strategic abilities for agents in asynchronous systems, with and without perfect information. Secondly, we present some general complexity results for verification of strategic abilities in such systems. Thirdly, and most importantly, we adapt *partial order reduction (POR)* to model checking of strategic abilities for agents with imperfect information. We also present experimental results demonstrating that POR allows to significantly reduce the size of the model, and thus to make the verification more feasible. In fact, we show that the most efficient variant of POR, defined for linear time logic **LTL**, can be applied almost directly. The (nontrivial) proof that the **LTL** reductions work also for the more expressive strategic operators is the main contribution of this paper. Interestingly, the scheme does *not* work for verification of agents with perfect information.

Conclusions in a Nutshell

The theoretical complexity results follow the same pattern as those for synchronous MAS, though proving them required careful treatment. Consequently, model checking of strategic abilities under imperfect information for asynchronous systems is as hard as in the synchronous case. This makes model reductions essential for practical verification. The most important result of this paper consists

in showing that the partial order reduction for $\mathbf{LTL}_{-\mathbf{X}}$ can be almost directly applied to $\mathbf{ATL}_{\mathrm{ir}}$ without nested strategic modalities. The importance of the result stems from the fact that $\mathbf{LTL}_{-\mathbf{X}}$ has relatively weak distinguishing power, and therefore admits strong reductions, clustering paths into relatively few equivalence classes.

Interestingly, it turns out that the scheme does *not* work for $\mathbf{ATL}^*$ with perfect information strategies. Until now, virtually all the results have suggested that verification of strategic abilities is significantly easier for agents with perfect information. Thus, we identify an aspect of verification that might be in favour of imperfect information strategies in some contexts.

All the technical details can be found in the original paper [4].

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