Synthesis of epistemic protocols

Concurrency and Communication group

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1 Settings

We discussed synthesis in the context of co-operative multi-agent systems, with specific reference to communication and concurrency. Strategic considerations and agency are relevant here but we chose to sidestep them.

- Input: description of the system, initial situations, goal situations
- Output: plans / knowledge based programs

Examples: Russian card problem, SADI (talk by Valentin Goranko)
Potential applications: autonomous cars, etc.

2 Models

	Synthesis	Synchronous Distributed Synthesis	Desription modelling	history dependence	unbounded concurrency
DEL	(cf Guillaume)	last slide of Guillaume	Symbolic (event types)	no	To be done
Interpreted systems	unclear	KB programs	event occurrences	yes	To be done
LTS	Reachability	Decomposition	Unfoldings	yes	homomorphisms

In DEL, knowledge is given explicitly in models and dynamics is inferred by means of products (of an epistemic model and an action model). On the contrary, in interpreted systems, dynamics is explicitly given and knowledge is inferred (it is grounded; two runs are equivalent for an agent iff he has the same local state in both of the runs).

3 Parameters

When we speak of synthesis, we should not talk only about the *existence* of a solution (to achieve the goal) but also about the *quality* of the solution. In this regard, it is important to pin down what parameters we wish to optimize on.

- Number of agents (cost of distribution)
- Number of messages (length of plan)
- Size of messages
- Memory of agents (resources)

The size of messages is especially relevant when we consider formulas to be messages as in DEL. These formulas can be succinct and hence may hide complexity. They are also variable length, whereas traditionally fixed length messages are used for counting and complexity.

It is interesting to consider *Trade-offs* between cost of distribution and memory (if you distribute more, agents need additional memory to store the knowledge they acquire about the global state).

4 Questions

- Expand the table: the comparison above needs to be formalized into formal mappings and finer detail needs to be added.
- It is possible that all these models can be embedded in games and studied in the game theoretic way. Specifically, with each Interpreted System model, we can associate a coordination game (with the grand coalition of all players working against an environment) in such a way

that protocol synthesis reducees to synthesis of (distributed) winning strategies (for the coalition).

- Distributed synthesis is very interesting in the asynchronous case, and much work remains to be done in this area. The DEL framework is essentially synchronous, and basic work is needed to analyse asynchrony. There is a great deal of work on asynchronous communication in the Interpreted Systems model, but not on synthesis. There is relevant recent work on asynchronous distributed synthesis in a game theoretic setting.

- Given a global specification (external perspective), decomposition into local agents / processes (like in knowledge based programs) is challenging, and variations based on communication medium need to be studied. (guaranteed communication/failures, broadcast/point-point, bounded delays, unique initial state VS multiple initial states etc.)

- Methodology/Heuristic for KB programs / epistemic protocols: While synthesis questions address automated methods, it is also interesting to investigate heuristics that help us build epistemic protocols for classes of problems, such as being developed for gossip problems. Rather than devise one new method for each, we need a methodology. Goranko's talk on SADI illustrated the use of divide and conquer, gossip protocols illustrate the greedy paradigm. Is there an example for dynamic programming?

- Expressiveness of logics. Could we generalize Van Benthem's theorem to epistemic logic and FO($\rightarrow, \sim_1, \ldots, \sim_n$)? Identify decidable fragments. Relate to Monadic Second Order logics.

- Security implications (information hiding). In logical formulations, negation is for free and hence information revealing has the same status as information hiding. Algorithmically these are very different: ensuring that A knows something is easier (inform A) than ensuring that A does not learn it. There is a great deal of work on this in the area of security policies and protocols, with strong links to epistemic reasoning, but much work remains to be done.