Master research internship: Convergence, regularities in epistemic structures

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1 Context

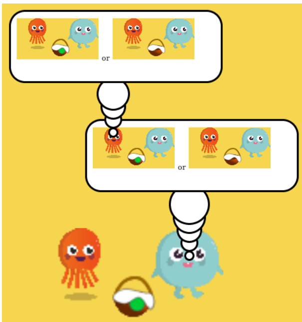

Figure 1: Graphical user interface of *Hintikka's world*.

Epistemic reasoning, that is reasoning about knowledge (e.g. agent a knows that agent b knows that...) is relevant in many applications: game theory [4], robotics ([17], [12]), specifications of distributed systems [14], etc. Dynamic epistemic logic (DEL) ([5], [19]) extends epistemic logic for describing and reasoning about epistemic properties and information change. We invite the reader to use the software *Hintikka's World* (`http://hintikkasworld.irisa.fr/`, [18]) that is a pedagogical tool to learn models of DEL (see Figure 1).

The overall goal of the internship is to investigate the decidability frontier of *epistemic planning* [7]: , that is, generating a plan – a sequence of actions – in order to satisfy an epistemic goal. In this context, actions are complex: they can be public announcements, private announcements, private exchange of cards such as in Cluedo [20], etc. Therefore, they may (1) modify the real world, but also (2) the agents' information about their environment, typically their knowledge.

2 State of the art

Epistemic planning has been proven to be undecidable in the general case; there are several proofs in the literature: [8], [2], [11]. Consequently, attempts to restrict the classes of planning instances have been considered, and some of them have been proven to be decidable. There are essentially two main dimensions for restricting the classes that have been:

- The dimension of the effect of actions, called *postcondition*: the sub-class of *non-ontic actions* restricts the instances to actions whose postconditions do not modify the world as opposed to *ontic* actions.
- The *modal depth of the preconditions of the actions*: preconditions could be Boolean (e.g. the cube should be on the table for the gripper to be able to take it), or have modal depth 1 (e.g. the agent should know that the cube is on the table for deciding to take it), or modal depth 2 (e.g. the agent should know that another agent knows that the cube is on the table for deciding to take it), etc.

Table 1 sums up the state-of-art concerning the decidability and undecidability of epistemic planning depending on the considered sub-class of instances. Decidability results in [3], [13] rely on the analysis of a (possibly) infinite structure, called a *DEL structure*, arising from the iterative applications of actions. In a nutshell, a DEL structure (see Figure 2) is similar to a computation tree – as considered in classic temporal logics – equipped with additional transverse edges between nodes that describe the knowledge of agents. Decidability of epistemic planning where preconditions of actions are Boolean and postconditions are arbitrary has been proven by showing that the DEL structure is automatic [6], [15] and by rephrasing the planning problem as a model checking problem against first-order logic. The concept of *automatic structure* is the analogous of the one of *regular languages* but for structures.

postconditions / preconditions	non-ontic postconditions	arbitrary postconditions
Boolean preconditions	PSPACE-c [9]	decidable [3], [13]
1-depth modal preconditions	**open problem**	undecidable [8], [11]
2-depth modal preconditions	undecidable [10]	undecidable
⋮	⋮	⋮

Table 1: The decidability frontier in epistemic planning.

3 Subject of the internship

The subject of the internship is to develop new approaches that may help solving the open problem in Table 1 and obtaining new complexity results in epistemic planning. To this aim, we will address the following questions. Depending on the restrictions on the class of planning instances, one has to

1. exhibit the structural properties of DEL structures, that may be more involved than automaticity as in e.g. [1] and corresponding logics that can be decided over such structures.
2. establish remarkable properties of the family of epistemic models arising from a finite sequence of actions, such as its regularity, some convergence to a limit point in applying epistemic actions in the spirit of [16].

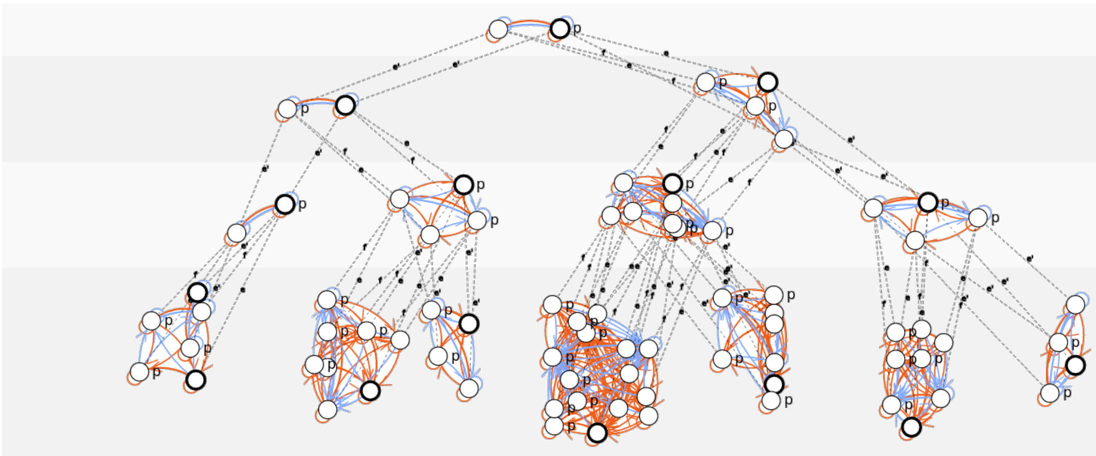

Figure 2: Example of a DEL structure (picture up to level 3).

4 Prerequisites

The candidate for this internship is required to have skills in mathematical reasoning and writing. In particular, a background in logic, automata theory, algorithms, complexity theory is high appreciated.

References

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