

Symbolic models in Hintikka's World

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Abstract

Hintikka's World is a tool that shows how artificial agents can reason about higher-order knowledge (agent *a* knows that agent *b* knows that...). In this demonstration paper, we present symbolic models that enables to implement in *Hintikka's World* large examples such as real card games.

1 Introduction

TODO Higher-order knowledge of agents is relevant in many applications: game theory [Aumann, 1999], robotics ([Scassellati, 2002], [Devin and Alami, 2016]), specifications of distributed systems [Halpern and Fagin, 1989], etc. Dynamic epistemic logic (DEL) ([Baltag *et al.*, 1998], [van Ditmarsch *et al.*, 2008]) extends epistemic logic for describing and reasoning about epistemic properties and information change. The famous tool in the community is called DEMO [van Eijck, 2007] and is a model checker for DEL, that has been used in practice [van Ditmarsch *et al.*, 2012]. It also provide symbolic techniques [van Benthem *et al.*, 2015].

Nevertheless, there are no tools with an intuitive graphical user interface that may be used by roboticists, game theorists, psychologists, etc. In this paper, we present such a tool called *Hintikka's world*.

The idea of tool we propose, called *Hintikka's world* is simple: represent Kripke models by comic strips, as shown in Figure 1. The tool is available at the following address: <http://hintikkasworld.irisa.fr/>.

Hintikka's world is a proof of concept of a graphical user interface that shows artificial agents mental states. It could be used in debugging contexts and for explaining behaviors of the agents that takes their decisions with respect to their beliefs. In other words, it takes part in Explainable Artificial Intelligence. The artificial agent could be a humanoid robot that interact with humans ([Scassellati, 2002], [Devin and Alami, 2016]) or several autonomous agents that have imperfect information [Saffidine *et al.*, 2018].

Another application is to provide a tool for psychiatrists to test ability of children to reason about higher-order knowledge (see [Arslan *et al.*, 2015], [Wimmer and Perner, 1983]).

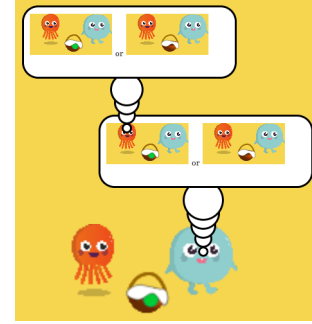


Figure 1: Graphical user interface of *Hintikka's world*

Finally, the tool has a pedagogical aim. It illustrates the concepts of Kripke models, modal formulas, model checking and satisfiability problem in a modal logic course. It also enables to explain easily how to model higher-order knowledge to other scientists.

First, the user can run AI examples that illustrate important concepts:

- Agents can learn information from messages of the form 'an agent does not know...': Muddy children puzzle, Consecutive numbers [van Ditmarsch and Kooi, 2015]
- False beliefs of agents: Sally and Anne [Wimmer and Perner, 1983]
- Public announcements that are secure in the sense that intruders of a system do not learn relevant information: Russian cards [van Ditmarsch, 2003]
- Evolution of knowledge in asynchronous systems [Knight *et al.*, 2017]
- Evolution of knowledge in agents that run knowledge-based programs over a QdecPOMDP [Saffidine *et al.*, 2018].
- Simulation of cellular automata, for proving undecidability of epistemic planning [Sébastien Lê Cong, 2018].

TODO motiver symbolic models

2 Symbolic models

TODO symbolic models sur Hanabi

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3 Demonstration Outline

TODO expliquer Hanabi et comment on peut y jouer

3.1 Already Implemented Examples

3.2 User Interaction

The tool adopts the point of view of Halpern and Vardi for modeling an epistemic situation: model checking is more suitable than theorem proving [Halpern and Vardi, 1991]. In other words, the current situation is modeled as a pointed Kripke model. By clicking on a given agent a , the interface opens a thought bubble that displays the possible worlds for agent a . Actually, the comic strips shows the unfolding of the current pointed Kripke model that represents the current situation.

On the left, the software shows buttons for possible actions (public announcement, public actions, private actions, etc.). Actions are modeled by pointed event models of Dynamic epistemic logic [Baltag *et al.*, 1998]. By clicking on a button, the corresponding action is executed: the product of the pointed Kripke model and the pointed event model becomes the current pointed Kripke model.

3.3 Building New Examples

The tool also allows the final user to building their own examples. They are two ways to specify a new epistemic situation. First, the user can describe the initial pointed Kripke model in JavaScript, by giving the list of worlds, their valuations and the epistemic relations. Second, the user can specify the initial situation by a formula ϕ epistemic logic. The BNF is:

$$\begin{aligned} \phi := & p \mid (\text{not } \phi) \mid (\phi \text{ and } \phi) \mid (\phi \text{ or } \phi) \\ & \mid (K a \phi) \mid (K_{\text{pos}} a \phi) \mid (CK G \phi) \mid (CK_{\text{pos}} G \phi) \end{aligned}$$

where p is an atomic proposition, a is an agent and G is a group of agents. E.g. ' p does not holds but agent a imagines that it is possible that p holds' ($((K_{\text{pos}} a p) \text{ and } (\text{not } p))$), agent a and b commonly know that agent c does not know the value of p ($(CK (a b) ((\text{not } (K b p)) \text{ and } (\text{not } (K b (\text{not } p))))$), etc. The user writes a set of formulas, one formula per line. Then the system solves the satisfiability problem and generates a pointed epistemic model.

4 System Description

TODO Expliquer comment c'est FAIT

4.1 Class Architecture

Figure 2 shows the main part of the architecture of *Hintikka's world*. The interesting part is the fact that the graphical user interface (GUI) is independent from the current example that is running (muddy children, Sally and Anne, etc.). In particular, adding a new example only requires to add a new class that inherits from `World` and to implement the method for drawing the scene from data (valuations, numbers, etc.) that are members of the class.

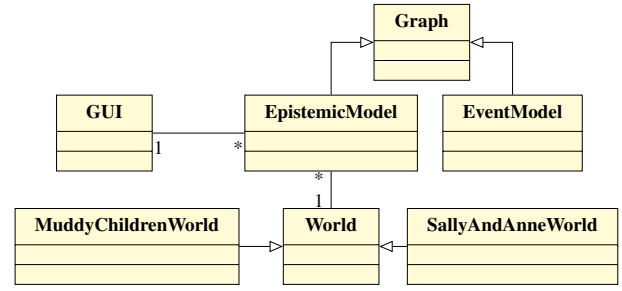


Figure 2: Architecture for the symbolic approach in *Hintikka's world*

4.2 Model Checking

The tool highly rely on model checking. Indeed, for instance, performing the public announcement of ϕ requires to compute the subset of worlds in which ϕ holds and to prune the current Kripke model. We chose to write the model checking procedure in Javascript. Since model checking is in PTIME – thus is an easy task – and is used intensively, it suitable to run it on the client-side for performance reasons.

4.3 Satisfiability Problem

5 Future Work

TODO implémzenter d'autres exemples etc.

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