Learning Action Models: Qualitative Approach

Thomas Bolander, DTU Compute, Tech Univ of Denmark
Joint work with: Nina Gierasimczuk, ILLC, Amsterdam
(based on paper to appear at LORI 2015)

DTU Compute
Department of Applied Mathematics and Computer Science

Introduction

What our paper is about:

- Formal learning theory applied to dynamic epistemic logic (DEL).
- First paper to study the problem of learnability of action models in DEL.
- The goal is build agents that can **learn to plan**.

Our results are only the first few unsteady baby steps in action model learning. The **really** interesting stuff is all the future work...

DEL by example: A hidden coin toss

We use the **action models** of DEL [Baltag *et al.*, 1998] with added postconditions (ontic actions) as in [Ditmarsch *et al.*, 2008].

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$$\overset{b}{\bullet}$$

epistemic model

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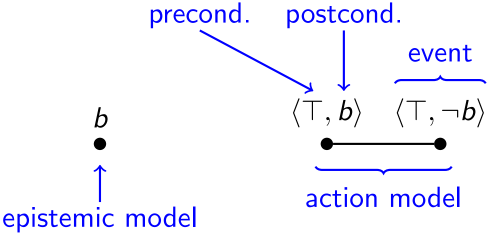

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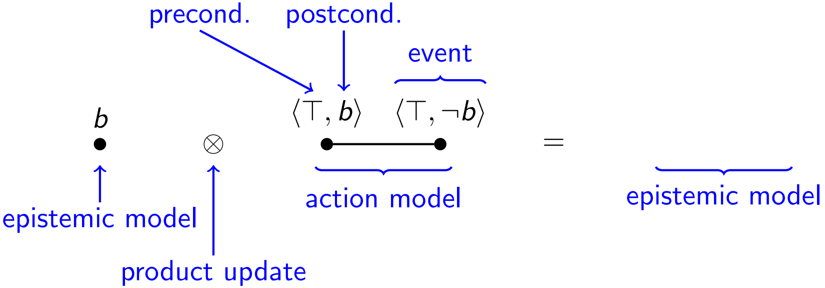

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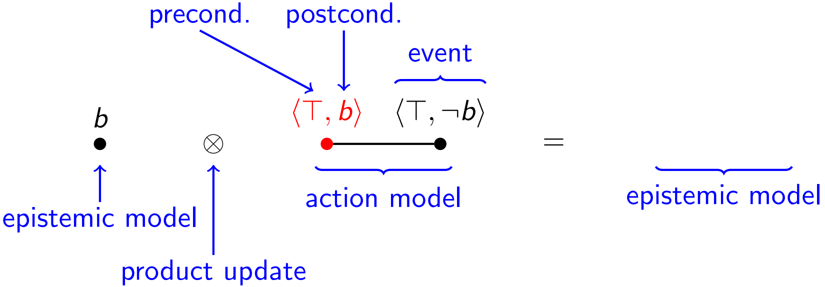

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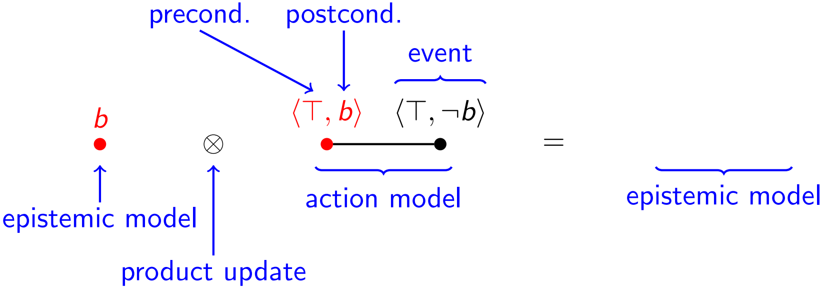

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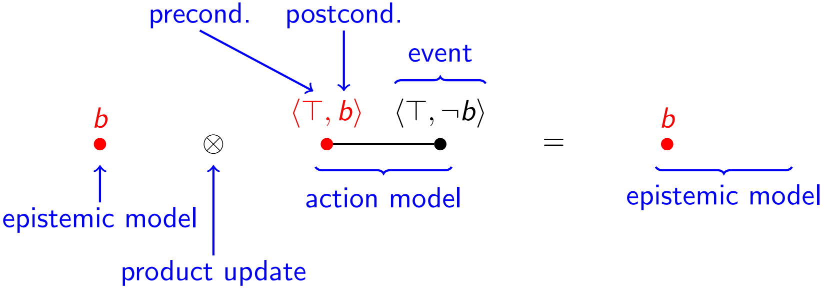

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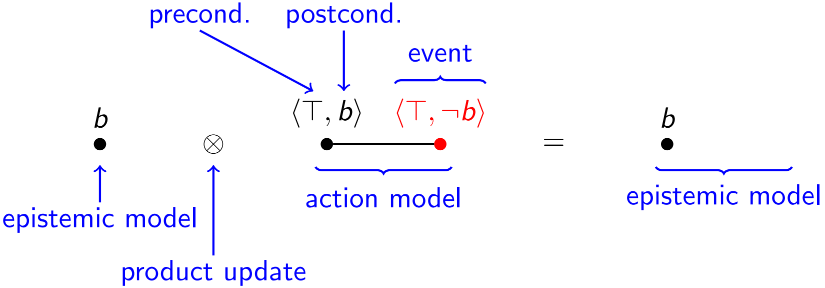

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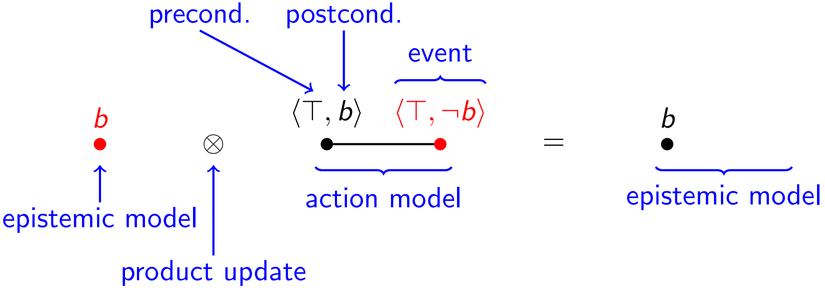

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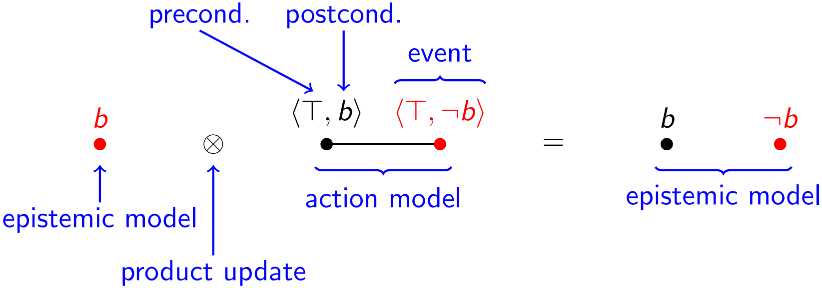

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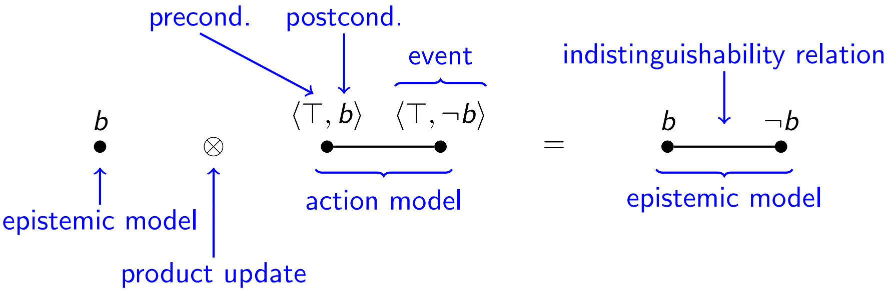

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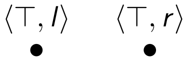

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Observations, streams and identifiability

- Agents learn actions (action models) by a **stream** (infinite sequence) of **observations** (s, s') for that action: when executing the action in state s, state s' will result.
- **Finite identifiability**: after a finite sequence of observations, the agent says "stop" and identifies the correct action model.
- **Identifiability in the limit**: after a finite sequence of observations, the agent settles on a particular action model and never changes her mind (but is never able to say "stop").

Example. Possible stream on language with a single proposition p:

$$(\emptyset, \{p\}), (\{p\}, \emptyset), (\emptyset, \{p\}), (\{p\}, \emptyset), (\emptyset, \{p\}), (\{p\}, \emptyset), \ldots$$

Basic results on learnability

Restrictions on action models (actions) imposed in **all** of the following (including all results):

- Only **fully observable** actions: partially observable are not learnable in the strict sense.
- Only **propositional** actions: all preconditions of all events are formulas of propositional logic (not epistemic formulas).

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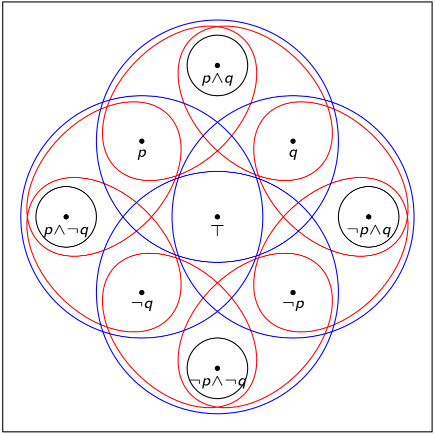
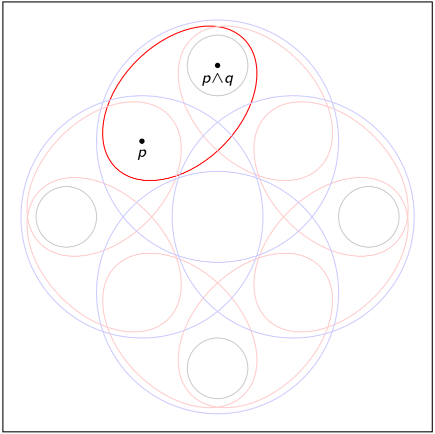
Theorem 2. The set of (possibly non-deterministic) actions is not finitely identifiable, only identifiable in the limit.

Learning actions via update: precondition-free atomic actions





Left: Initial action model containing all possible postconditions. The blue and red sets correspond to possible observations.

Right: The action model after receiving the observation $(\{q\}, \{p, q\})$.

Learning actions via update: (non-atomic) deterministic actions with maximal preconditions

Maximal preconditions: all preconditions are maximally consistent conjunctions of propositional literals (e.g. $p \wedge \neg q$ in the language over $\{p, q\}$).

Examples in the language over a single proposition $\{p\}$.

$\langle p, \top \rangle \quad \langle \neg p, \top \rangle$
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A simple update is no longer sufficient. But sufficient to always conjecture the set of minimal events using the following order:

$$e \leq e' \quad := \quad \mathit{pre}(e') \models \mathit{pre}(e) \text{ and } \mathit{post}(e') \models \mathit{post}(e)$$

Example. $\langle p, r\rangle \leq \langle p \wedge q, r \wedge s\rangle$. (Ockham's razor, cf. Kevin's talk!)

Important: All non-minimal events are preserved "in the background".

Example. Learning the functioning of an n-bit counter. Case $n = 2$:

Current action model:

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Current state of counter:

b_1	b_2
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Resulting action model: $n + 1$ events (instead of 2^n as in the case of maximal preconditions).

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Future work:

- Extended classes of actions: arbitrary pre- and post-conditions, partial observability, multiple agents (joint learning).
- Computational complexity.
- Proactive learning (using consecutive streams).
- Ultimate goal: general learning-and-planning agents.