Agent Abstraction via Forgetting in the Situation Calculus

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ECAI 2020

Background

Abstraction plays an important role in Artificial Intelligence:

- heuristic, guide the search process in classical planning [Boddy, Fox, and Thiébaux 2007]
- method, form general solutions in generalized planning [Srivastava, Immerman, and Zilberstein 2008]
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Agent Abstraction
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- expressive first-order framework based on the Situation Calculus and ConGolog
- abstraction of dynamic domains (action theories)

Agent abstraction [Banihashemi et al. 2017]

A high-level (HL) action theory, a low-level (LL) action theory and a refinement mapping:

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  - HL fluent $\hookrightarrow$ LL formula, e.g.,

    $$all\_block\_ontable(s) \hookrightarrow \forall x.ontable(x, s)$$

  - HL action $\hookrightarrow$ LL program, e.g.,

    $$move\_to\_table(x) \hookrightarrow \pi y.unstack(x, y); putdown(x)$$

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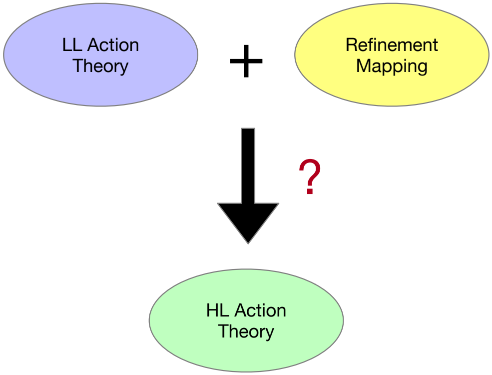
- sound abstraction: reasoning at HL $\hookrightarrow$ reasoning at LL

Problem



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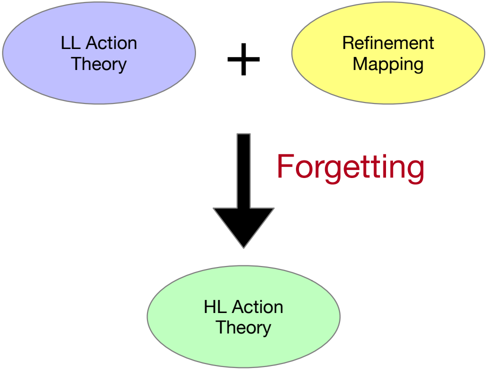
LL Action Theory
+
Refinement Mapping
Forgetting
HL Action Theory

Forgetting [Lin and Reiter 1994]

- Motivation: progression, i.e., update the knowledge base after an action was performed
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- Intuition: omit the information of the symbols while retaining all the facts that are ’irrelevant’ to these symbols
- Forgetting a predicate in a FO theory : not FO-definable [Lin and Reiter 1994]
- Forgetting a proposition in the propositional case is computable

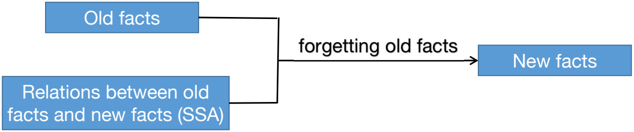
Contribution

Given a LL action theory, and a refinement mapping, we show

1. conditions: abstractions are representable by deterministic action theories and (Markovian) basic action theories
2. how to compute abstractions (HL theories) via forgetting

General idea

- Progression via forgetting:



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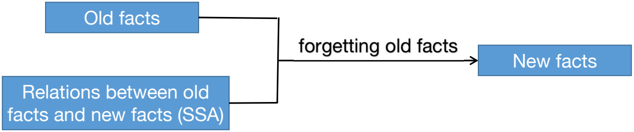
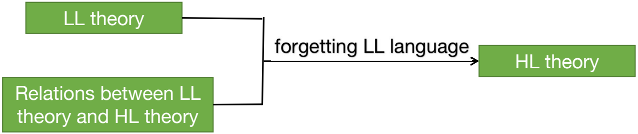


- Abstraction via forgetting:



Characterize abstraction via forgetting

Theorem

Given a low-level theory $\mathcal{D}_l$ and a non-deterministic uniform (NDU) refinement mapping m, we have that

$$forget(\mathcal{D}_l \cup \mathcal{D}'_{una} \cup \mathcal{D}_m; \mathcal{A}_l \cup \mathcal{F}_l \cup \{\mathbb{B}\})$$

is a sound and complete abstraction of $\mathcal{D}_l$.

- NDU: different executions of programs at the LL should be indistinguishable at the HL (deterministic action)

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- $\mathcal{A}_l$: LL actions; $\mathcal{F}_l$: LL fluents

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  - We can compute each part separately

Compute abstraction via forgetting

Compute $\mathcal{D}^h_{S_0}$, $\mathcal{D}^h_{ap}$ and $\mathcal{D}^h_{ss}$ separately

Theorem

Given a low-level BAT $\mathcal{D}_l$ and a Markovian refinement mapping m, let T be $\Sigma \cup \mathcal{D}^h_{una} \cup \mathcal{D}^h_{S_0} \cup \mathcal{D}^h_{ap} \cup \mathcal{D}^h_{ss}$, where

- $\mathcal{D}^h_{S_0} \doteq \mathit{forget}(\mathcal{D}_{S_0} \cup \Phi_m[S_0]; \mathcal{F}_l)$;
- $\mathcal{D}^h_{ap}$ contains the set of sentences: for any $\mathbf{A} \in \mathcal{A}_h$,
$$\begin{aligned} Poss(\mathbf{A}(\vec{x}), s) \equiv\ & \mathit{forget}(\mathit{prog}[\mathit{Init}(s), \pi^*_m] \\ & \wedge \mathcal{R}[\top(s), m(\mathbf{A})(\vec{x})] \wedge \Phi_m[s]; \mathcal{F}_l); \end{aligned}$$
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Then T is a sound and complete abstraction of $\mathcal{D}_l$.

Markov property: the executability conditions and the effects of actions are fully determined by the present state of the system

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Construct HL action precondition $Poss(\mathbf{A}(\vec{x}), s)$

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1. $prog[Init(s), \pi_m^*]$ traverses all m-reachable situations (state-constraint-like formula)
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In the propositional case, $Poss(\boldsymbol{A}(\vec{x}), s)$ is always computable

Conclusion & Future work

Given a LL action theory and a refinement mapping:

- how to characterize abstractions via forgetting under the non-deterministic uniform condition
- how to compute abstractions of the form BATs under the Markovian restriction (propositional case, computable)

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- extensions to HL theories that involve non-deterministic and non-Markovian actions
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- extensions to HL theories that involve non-deterministic and non-Markovian actions
- sufficient conditions under which abstractions are always FO-definable
- application of agent abstraction: in planning, provide a mapping as a guide
- study of automated generation of these mappings

Thank you!