Belief Change in the Situation Calculus

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Belief Change in the Situation Calculus

- Many (robotic) agents can actively sense their environment
- Sensing usually allows agent to acquire new information without altering state of environment
- By doing so, sensing actions are knowledge-producing actions
- We shall look at how sensing alters beliefs agent has about its environment
- Distinction between belief update (beliefs about environment change due to actions changing environment) and belief revision (beliefs about environment change due to sensing)

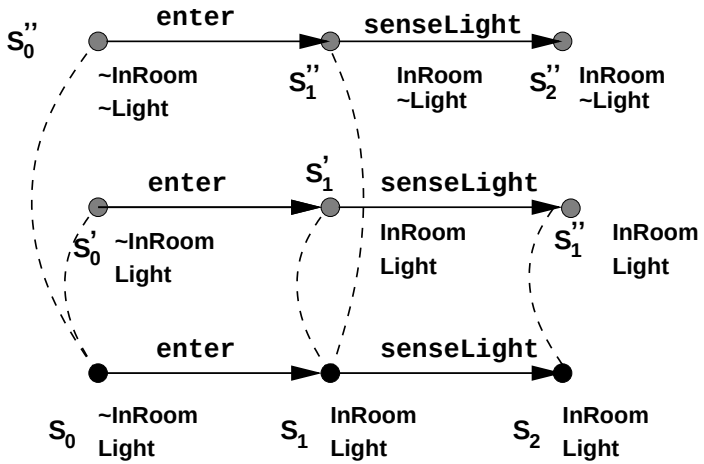
Overview

- Representing Knowledge/Belief in the Situation Calculus
- Belief Revision vs. Belief Update
- Belief and the Frame Problem
- Sensing: Knowledge-Producing Actions
- Frame Problem and Knowledge-Producing Actions
- Belief Change in the Situation Calculus
- Belief Change and Exogenous Actions
- Summary

Representing Knowledge/Belief in the Situation Calculus

- **Idea:** (Moore, 1980) treat situations as possible worlds
- While Moore (and others) considered 'knowledge' we shall only deal with 'belief' here
- Accessibility relation $B(s',s)$: situation s' is possible at situation s
- To say that we believe ϕ at situation s
  $Bel(\phi,s) = \forall s'.(B(s',s) \supset \phi[s])$

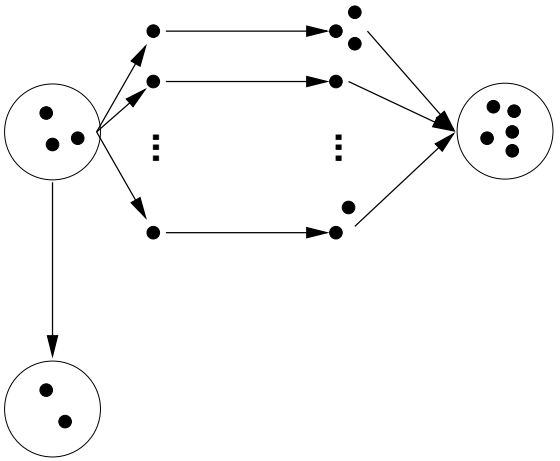
Belief in the Situation Calculus



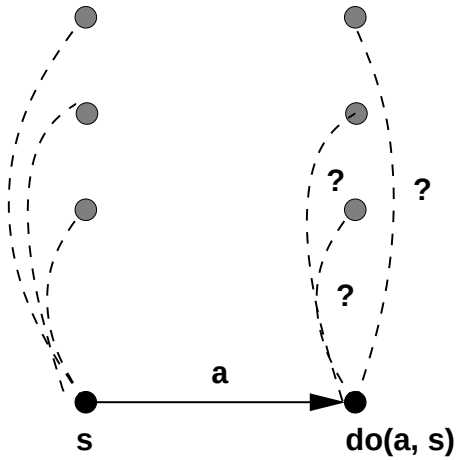
Consequences

- If ϕ does not contain a situation term, then agent always believes ϕ
- If sentence of form $\forall s.\phi(s)$, then agent always believes ϕ
  - therefore, agent believes precondition axioms and successor state axioms
  - doesn't necessarily believe initial situation
- Logical omniscience: agent believes all consequences of its beliefs

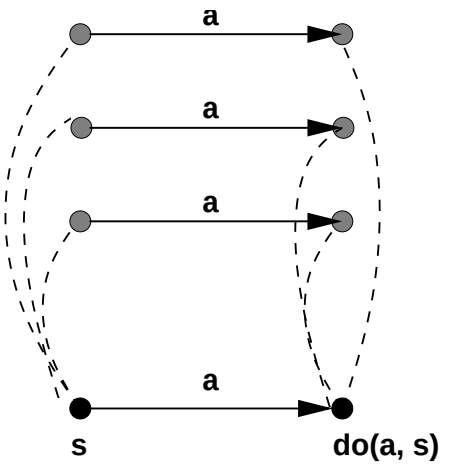
Belief Revision vs. Belief Update



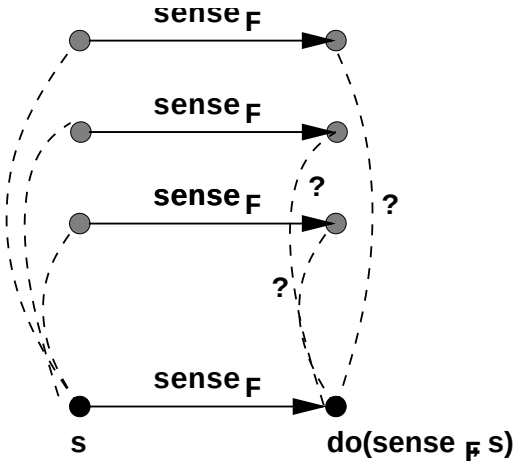
Belief and the Frame Problem



Actions



Sensing: Knowledge-Producing Actions



Frame Problem and Knowledge-Producing Actions

- Scherl and Levesque (1993) introduced successor state axiom for B-relation
- Levesque (1996) introduced predicate $SF(a,s)$: true iff sensor associated with sensing action a returns sensing value 1 in situation s
- Successor State Axiom for B
  $B(s'',do(a,s)) \equiv \exists s'.[B(s',s) \wedge s'' = do(a,s) \wedge (SF(a,s') \equiv SF(a,s))]$

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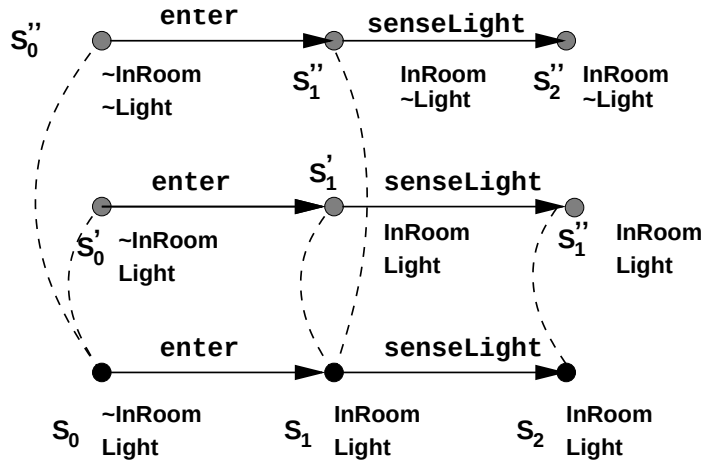

Belief Change in the Situation Calculus

- Shapiro *et al.* (2000) generalise these ideas by introducing plausibilities of situations $pl(s)$
- Successor State Axiom for pl
  $pl(do(a,s)) = pl(s)$
- Definition of belief
  $Bel(\phi,s) = \forall s'.[(B(s',s) \wedge (\forall s''.B(s'',s) \supset pl(s') \leq pl(s''))] \supset \phi[s']$

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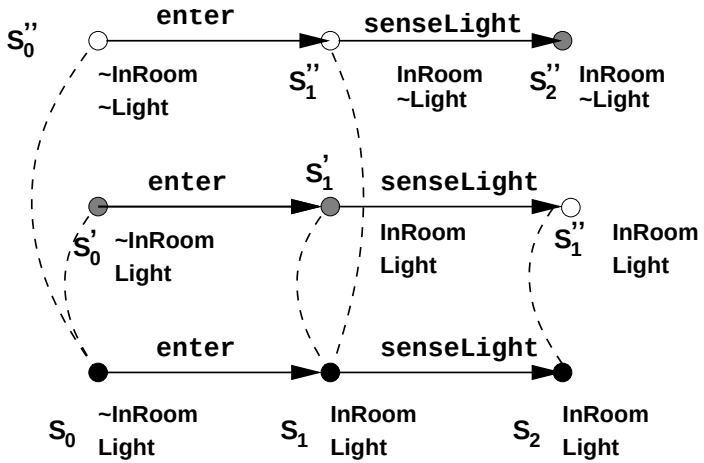
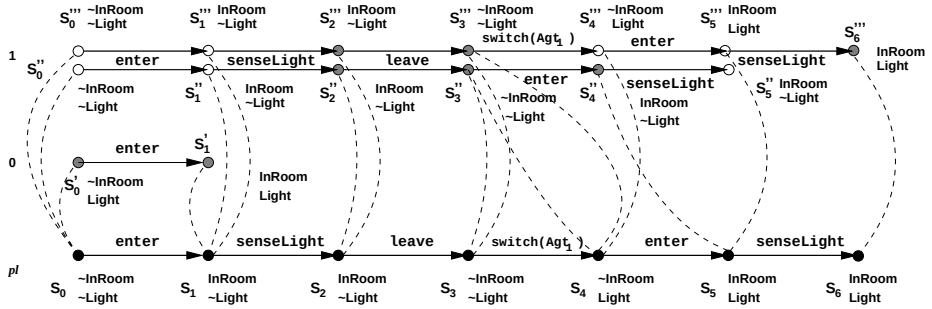


Consequences

- Introspection
  $Bel(\phi,s) \supset Bel(Bel(\phi),s)$
  $\neg Bel(\phi,s) \supset Bel(\neg Bel(\phi),s)$
- Awareness of Mistakes
  $Bel(\phi,s) \wedge Bel(\neg\phi,do(a,s)) \wedge (\forall s'.\phi[s'] \equiv \phi[do(a,s')]) \supset$
  $Bel(Previously(\neg\phi \wedge Bel(\phi)),do(a,s))$
- Some correspondence with AGM theory of belief revision and KM theory of update
- Non-fixed plausibilities give unintuitive results
  $Bel(\neg Light \wedge Bel(Light,do(senseLight,now)),S_0)$

Belief Change and Exogenous Actions



Conclusions

- Use idea of possible world semantics to give a notion of knowledge/belief in the situation calculus
- Treat situations as possible worlds in Kripke semantics
- Accessibility relation over situations used to define knowledge $Know(\phi, s)$ and belief $Bel(\phi, s)$
- Sensing actions are knowledge-producing actions
- Generalisations introduce plausibilities over situations and allow the hypothesis of exogenous actions to account for discrepancies in sensing