9a. Planning in logic

Planning can be encoded as a special case of first order inference.
Situation calculus can be used.

9a.1 Situation calculus

(Russell and Norvig 2nd Ed. 10.3)

- set of situations: $s_1, s_2, \ldots$, or "states"
- set of actions: $a_1, a_2, \ldots$, which map situations to situations

Language

- predicate fluents: $on(x, y, s)$
- constants: A, B, C, T
- initial situation s_0; e.g.: $on(C, A, s_0) \wedge on(A, T, s_0) \wedge on(B, T, s_0)$
- goal: $\exists s\, on(A, B, s)$
- parametrized actions: terms denote action objects: $\text{move}(x, y)$, $\text{move}(A, B)$
- special "do" function: maps situations $\times$ actions $\rightarrow$ situations

  $\text{do}(\text{move}(C, T), s_0)$ is a term: name for the state s that results from applying action $\text{move}(C, T)$ on s_0
- unique names assumption: $\text{move}(A, B) \neq \text{move}(C, D)$,
  distinct terms denote distinct objects
- action preconditions represented by formulas; e.g., precondition of $\text{move}(x, y)$ is

$$\forall x \forall y \forall s\, [\forall w\, \neg on(w, x, s) \wedge (\neg on(w, y, s) \vee y = \text{T})]$$

- action effects; e.g., effect of of $\text{move}(x, y)$ is

$$on(x, y, \text{do}(\text{move}(x, y), s))$$

For example, action 'put x on y' (or move(x, y)) can be described by the sentence:

$$\forall x \forall y \forall s\, [\forall w\, \neg on(w, x, s) \wedge (\neg on(w, y, s) \vee y = \mathrm{T})] \rightarrow on(x, y, \mathrm{do}(\mathrm{put}(x, y), s))$$

This is called an *effect axiom*. It describes action 'put' that puts a block x on block y, and in this way we can move from situation s to situation do(put$(x, y), s)$. Function 'do' maps an action and a situation into the successor situation.

After introducing such axioms: effect axioms (EA), and *unique name assumption* (UNA, axioms that state that distinct terms denote distinct objects (e.g., put$(A, B) \neq$ put(C, D))), planning can be described as the task:

$$\mathrm{Th}(s_0) \cup \mathrm{EA} \cup \mathrm{UNA} \vdash \exists s \gamma(s)$$

Th(s_0) is the description of the initial situation, and $\exists s \gamma(s)$ is the goal, e.g, $\exists s\, on(A, B, s) \wedge on(B, C, s)$. Using resolution, we can attempt to establish:

$$\mathrm{Th}(s_0) \cup \mathrm{EA} \cup \mathrm{UNA} \cap \forall s \neg \gamma(s) \vdash \top \rightarrow \bot$$

If successful, during the inference the term s will be replaced with a nested 'do' term, which represents the plan.

Frame problem: If an action does not change some facts, then they remain the same in the next situation.

How do we express this?

A naive solution: frame axioms.

A better solution: successor state axioms (Page 332, Russell and Norvig 2nd Ed.)

Readings

Russell and Norvig 2nd Ed.: Section 10.3