

Situation Calculus

CS 475

March 1, 2001

1 Introduction

Situation calculus is an approach to reasoning about action and change (RAC). A *fluent* is a property of the world that changes over time. The world (at any particular time), called a *situations*, can be described by a set of fluents. To say that fluent F holds in the situation S , we write

$$\text{Holds}(F, S) \tag{1}$$

We will use a special constant S_0 to denote the initial situation.

For example, in the wumpus world, we can represent the fact that the agent (we call him *Agent*) is at the square $[1, 1]$, we can write

$$\text{Holds}(\text{At}(\text{Agent}, [1, 1]), S_0) \tag{2}$$

Fluents only represent the properties of situations. *Actions* make the world changes from one situation to another situation. Actions have their *effects* such as the action of *forward* of the agent makes him being at the square $[1, 2]$ etc. We write $\text{Do}(a, s)$ to denote the situation resulting from the execution of action a in situation s . With this notation, we can represent the fact that moving forward ($a = \text{Forward}$) in a situation s will result in the agent being at the square $[1, 2]$ as follows:

$$\begin{aligned} &\forall s [\\ &\quad \text{Holds}(\text{At}(\text{Agent}, [1, 1]), s) \\ &\quad \rightarrow \text{Holds}(\text{At}(\text{Agent}, [1, 2]), \text{Do}(\text{Forward}, s)) \\ &] \end{aligned} \tag{3}$$

Similarly, we can represent the effect of the action *Turn_right* is that the agent will face *East* if he faces *North* before the action is executed as follows.

$$\begin{aligned} &\forall s [\\ &\quad \text{Holds}(\text{Facing}(\text{Agent}, \text{North}), s) \\ &\quad \rightarrow \text{Holds}(\text{Facing}(\text{Agent}, \text{East}), \text{Do}(\text{Turn_right}, s)) \\ &] \end{aligned} \tag{4}$$

2 Representing the Wumpus World

In the wumpus world, each situation can be characterized by:

- The position of the agent
- The location of the gold, the pit, and the wumpus
- The status of the agent (alive or dead)
- The stench of the wumpus that the agent can perceive (smell)
- The breeze of the pit that the agent can perceive (feel)
- The glitter of gold that the agent can perceive (see)

In all, we have the following constants

- *Agent* – our agent
- *Gold*, *Pit1*, *Pit2*, *Pit3*, and *Wumpus* – that represents the gold, the pits, and the wumpus, respectively, and
- the locations $[1, 1]$, $[1, 2]$, \dots , $[4, 4]$
- *Stench*, *Breeze*, *Glitter*

we can use the following fluents (predicates) to represent a situation

- $At(x, y)$ – “object x is at the location y ”, where x is an object (*Agent*, *Gold*, *Pit1*, *Pit2*, *Pit3*, or *Wumpus*), and y is a location
- $Alive(Agent)$ – “*Agent* is alive” ($\neg Alive(Agent)$ – *Agent* is dead) – Whoelse could be dead?
- $Has(z, y)$ – “location y has the property z ”, where $z \in \{Stench, Breeze, Glitter\}$ and y is a location

Some formulas about the properties of the world

1. *In the square containing the wumpus and in the directly (not diagonally) adjacent squares the agent will perceive a stench* – this can be represented by:

$$\forall y, y' \forall s [\begin{array}{l} Holds(At(Wumpus, y), s) \wedge Adjacent(y, y') \\ \rightarrow Holds(Has(y', Stench), s) \end{array} \quad (5)]$$

where $Adjacent(y, y')$ is a predicate describing the relation between two squares y, y' [What should we add? Should we write $Holds(Adjacent(y, y'), s)$ or just $Adjacent(y, y')$]

2. In the squares directly adjacent to a pit the agent will perceive a breeze

$$\forall y, y' \forall x \forall s [\begin{array}{l} (x = Pit1 \vee x = Pit2 \vee x = Pit3) \wedge \\ At(x, y) \wedge Adjacent(y, y') \\ \rightarrow Holds(Has(y', Breeze), s) \end{array}] \quad (6)$$

If we have a predicate called $Pit(x)$ or and

3. Complete the formulization of the environment (page 154 ..)

So far, we have only represented the properties of the environment (the relationship between fluents). What is missing here is the representation of actions and their effects. Now, let see which actions are necessary for us. From the description of the environment, we see the following:

1. *Forward* – the agent moves forward
2. *Turn_right* – the agent turns right
3. *Turn_left* – the agent turns left
4. *Shoot*(y, y') – the agent is in the square y and he shoots to the square y'
5. ???

Representing the effects of actions:

$$\begin{array}{l} Holds(At(Agent, [n, m + 1]), Do(a, s)) \leftrightarrow \\ a = Forward \wedge Holds(At(Agent, [n, m]), s) \wedge Holds(Facing(North), s) \\ \vee \\ Holds(At(Agent, [n, m + 1]), s) \wedge a \neq Forward \end{array} \quad (7)$$

But the agent can face ‘South’, ‘East’, and ‘West’ also ...

$$\begin{array}{l} Holds(At(Agent, [n, m - 1]), Do(a, s)) \leftrightarrow \\ a = Forward \wedge Holds(At(Agent, [n, m]), s) \wedge Holds(Facing(South), s) \\ \vee \\ Holds(At(Agent, [n, m - 1]), s) \wedge a \neq Forward \end{array} \quad (8)$$

$$\begin{array}{l} Holds(At(Agent, [n + 1, m]), Do(a, s)) \leftrightarrow \\ a = Forward \wedge Holds(At(Agent, [n, m]), s) \wedge Holds(Facing(East), s) \\ \vee \\ Holds(At(Agent, [n + 1, m]), s) \wedge a \neq Forward \end{array} \quad (9)$$

$$\begin{aligned}
& \text{Holds}(\text{At}(\text{Agent}, [n-1, m]), \text{Do}(a, s)) \leftrightarrow \\
a = \text{Forward} \wedge \text{Holds}(\text{At}(\text{Agent}, [n, m]), s) \wedge \text{Holds}(\text{Facing}(\text{West}), s) \\
& \quad \vee \\
& \text{Holds}(\text{At}(\text{Agent}, [n-1, m]), s) \wedge a \neq \text{Forward}
\end{aligned} \tag{10}$$

Find out what is missing in the above equations? Can we rewrite (7)-(10) as one single axioms? For now, let continue with other actions:

$$\begin{aligned}
& \text{Holds}(\text{Facing}(\text{North}), \text{Do}(a, s)) \leftrightarrow \\
(a = \text{Turn_right} \wedge \text{Holds}(\text{Facing}(\text{West}), s)) \\
& \quad \vee \\
(a = \text{Turn_left} \wedge \text{Holds}(\text{Facing}(\text{East}), s)) \\
& \quad \vee \\
(\text{Holds}(\text{Facing}(\text{North}), s) \wedge a \neq \text{Turn_right} \wedge a \neq \text{Turn_left})
\end{aligned} \tag{11}$$

Write the axioms for other directions!!!

$$\begin{aligned}
& \text{Holds}(\text{Alive}(\text{Wumpus}), \text{Do}(a, s)) \leftrightarrow \\
& \text{Holds}(\text{Alive}(\text{Wumpus}), s) \wedge \\
\neg(a = \text{Shoot}(y, y') \wedge \text{Holds}(\text{At}(\text{Agent}, y), s) \wedge \text{Holds}(\text{At}(\text{Wumpus}, y'), s))
\end{aligned} \tag{12}$$

Question: What do I miss in (12)?

Continue with other actions, effects, ...

What holds at the beginning?

$$\begin{aligned}
& \text{Holds}(\text{Alive}(\text{Agent}), S_0) \\
& \text{Holds}(\text{Alive}(\text{Wumpus}), S_0) \\
& \text{Holds}(\text{At}(\text{Agent}, [1, 1]), S_0) \\
& \text{Holds}(\text{At}(\text{Wumpus}, [1, 3]), S_0) \\
& \text{Holds}(\text{At}(\text{Pit1}, [3, 1]), S_0) \\
& \text{Holds}(\text{At}(\text{Pit2}, [3, 3]), S_0) \\
& \text{Holds}(\text{At}(\text{Pit3}, [4, 4]), S_0) \\
& \text{Holds}(\text{At}(\text{Gold}, [2, 3]), S_0) \\
& \text{Holds}(\text{Facing}(\text{North}), S_0)
\end{aligned} \tag{13}$$

HOMEWORK Complete the description of the wumpus world.