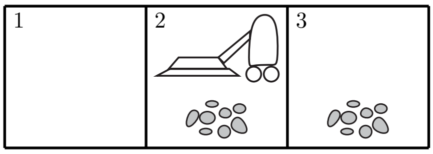
02180 Intro to AI
Exercises for week 4, 23/2-21

Exercise 1

To begin with, consider the deterministic and fully observable vacuum cleaner world with three squares, and the initial state being:



The goal states are the states where all squares are clean.

a. Draw a graph of the state space up to and including distance 2 from the initial state. Don't forget states that *lead* to other reachable states, and not only those that are reachable.

b. How many states are there up to distance 2 from the initial state? How many states are there in total for the problem with 3 squares? How many are goal states? How many of the states are reachable from the initial state?

   If there were n squares (horizontally) instead of 3, and there could be dirt in any and all of them in the initial states, how many states are there then in the state space, and how many of those are goal states?

Exercise 2

Now we move on to consider the *erratic* vacuum cleaner world with 3 squares, where the `Suck` action cleans the square of the robot, but also possibly any of the adjacent squares (e.g. when in square 2, performing a `Suck` action also possibly cleans square 1 and/or 3).

a. Using the tuple representation of states from the lecture, e.g. the initial state is $(c, d, d, 2)$, determine:

   1. $\textsc{Results}((d, c, d, 1)$, `Suck`)
   2. $\textsc{Results}((d, d, d, 1)$, `Suck`)
   3. $\textsc{Results}((d, d, d, 2)$, `Suck`)
   3. $\textsc{Results}((d, c, d, 2)$, `Suck`)

3. RESULTS($(c, d, d, 3)$, `Suck`)

b. Draw a graph of the state space up to and including distance 2 from the same initial state as the previous question. Each state can now have several outgoing edges with the same action label leading to different states.

c. Draw the AND-OR tree up to depth 2 (counting each and-or transition as 1 depth) with the given initial state as root. Mark the OR-nodes as:

- *GOAL*, if they're a goal state;
- *LOOP*, if they occur on the path to the root; and
- *OPEN*, if they're at depth 2 and are neither a goal or a loop state.

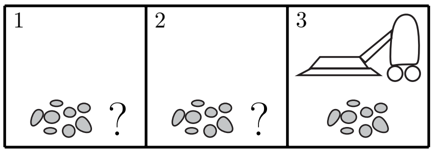
d. What is the maximal outgoing degree of any AND-node in the tree? Is there a state from which the AND-node of some action would have a higher out-degree, and if so then what state, action, and degree would that be?

e. Is there a solution in the AND-OR tree? Highlight the solution if it exists in the tree, and otherwise expand more of the tree so that it contains a solution and then highlight that. You can expand in any order you prefer. Write the conditional plan in the language from the slides; use parentheses to resolve ambiguous syntax.

f. Does the AND-OR tree correspond to any run of the AND-OR-GRAPH-SEARCH algorithm? If it doesn't, then draw a new AND-OR tree which could result from running the algorithm.

Exercise 3

Now consider the deterministic and partially observable *local-sensing* vacuum cleaner world, where the agent knows which square it is in, and senses whether that square is either clean or dirty after each action. The `Suck` action again only cleans the square that the agent is in. Consider the following initial state:



where the agent knows that there is dirt in square 3, but not whether square 1 or 2 are dirty or clean.

a. What is the initial belief state? You can use the tuple representation for each physical state. How many states are there in the belief state space? If there were n squares, then how many belief states are there?

b. We will use the notation X@Y where X is `clean` or `dirty` and Y is 1, 2, or 3 to denote percepts for the squares being clean or dirty. Hence, `dirty`@2 is the percept that square 2 is dirty. Now define the following physical states:

$s_0 \,:\, (c, d, c, 3)$

$s_1 \,:\, (c, d, c, 2)$

s_2 : $(c, d, d, 3)$

s_3 : $(c, c, c, 3)$

s_4 : $(c, c, d, 3)$

s_5 : $(d, c, d, 3)$

s_6 : $(d, d, d, 3)$

s_7 : $(d, c, c, 3)$

Using the introduced percept notation, determine the following:

- $\text{PERCEPT}(s_0)$
- $\text{PERCEPT}(s_1)$
- $\text{PERCEPT}(s_7)$
- $\text{POSSIBLE-PERCEPTS}(\{s_0, s_2, s_3, s_4\})$
- $\text{UPDATE}(\{s_0, s_2, s_3, s_4\}, \texttt{dirty@3})$
- $\text{RESULTS}(\{s_2, s_4, s_5, s_6\}, \texttt{Left})$

d. Assume the modelling change so that the robot has a vague sensor which can only determine which of the following two is the case: 1) there is dirt in the current square or an adjacent square; 2) the current square and all adjacent squares are clean. We can model this new situation with only two percepts, `dirty` and `clean`. Explain why. Then determine the same function values as in b, except the percept `dirty@3` is replaced by `dirty`.