SEARCH IN PARTIALLY OBSERVABLE ENVIRONMENTS

ENVIRONMENT

- Environment is fully observable => the agent knows for sure what state it is in. Percepts are available in every state.
- Environment is partially observable => the agent doesn't know for sure what state it is in. Percepts are available in few states.
- Environment is not observable => the agent doesn't know what state it is in. Percepts are not available in any state.

ENVIRONMENT

- Doctors often prescribe a broadspectrum antibiotic rather than using the conditional plan of doing a blood test, then waiting for the results to come back, and then prescribing a more specific antibiotic.
- Which one is better?

1. Wait for blood test results?
2. Execute Conditional plan meanwhile?

- The sensorless (absence of blood test report) plan saves time and money, and avoids the risk of the infection worsening before the test results are available.

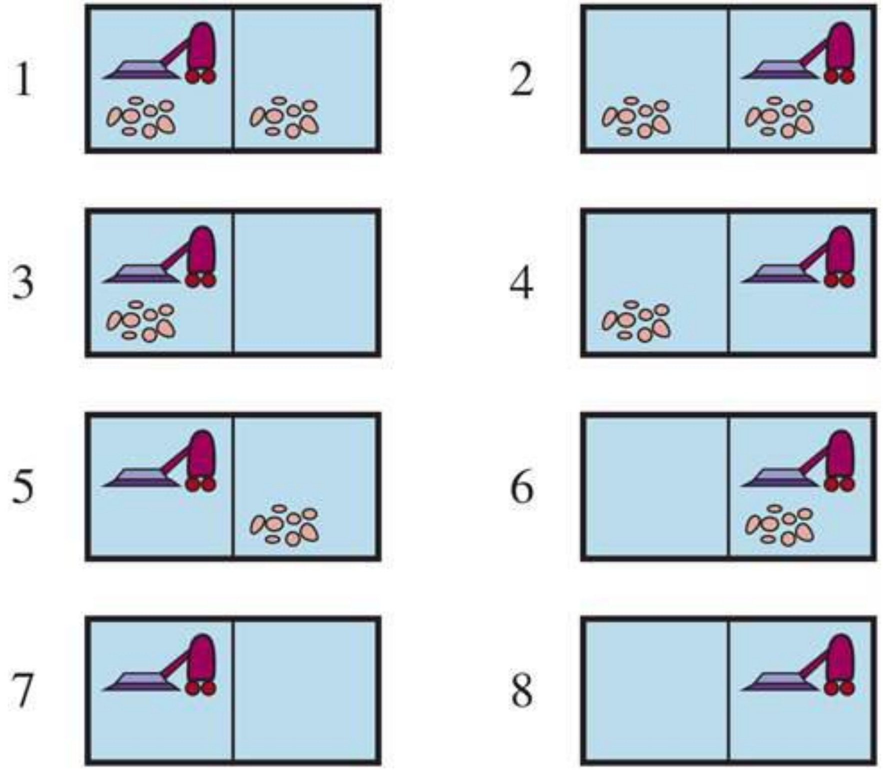
BELIEF STATES

- Consider a sensorless version of the (deterministic) vacuum world. Assume that the agent knows the geography of its world, but not its own location or the distribution of dirt.
- Initial belief state is {1,2,3,4,5,6,7,8}
- If the agent moves Right. Next state?

{2,4,6,8}

- [Right,Suck,Left,Suck] Next state?

{7}



SENSORLESS PROBLEMS

- Solution is sequence of actions, not a conditional plan.
- Search in the space of belief states rather than physical states.
- Percepts received after each action are completely predictable—they're always empty!

SEARCHING WITH NO OBSERVATION

- The original problem, P, has components $Actions_P$,$Result_P$ etc.
- Belief-state problem has the following components:
- **STATES:** The belief-state space contains every possible subset of the physical states. If P has N states, then the belief-state problem has 2^N belief states.
- **INITIAL STATE:** Typically, the belief state consisting of all states in P.

SEARCHING WITH NO OBSERVATION

- **ACTIONS:**
- Suppose the agent is in belief state $b = \{s_1, s_2\}$, but $ACTIONS_P(s_1) \neq ACTIONS_P(s_2)$; then the agent is unsure of which actions are legal. If we assume that illegal actions have no effect on the environment;

$$\textsc{Actions}(b) = \bigcup_{s \in b} \textsc{Actions}_P(s)$$

- If an illegal action might lead to catastrophe; it is safer to allow only the intersection, that is, the set of actions legal in all the states.

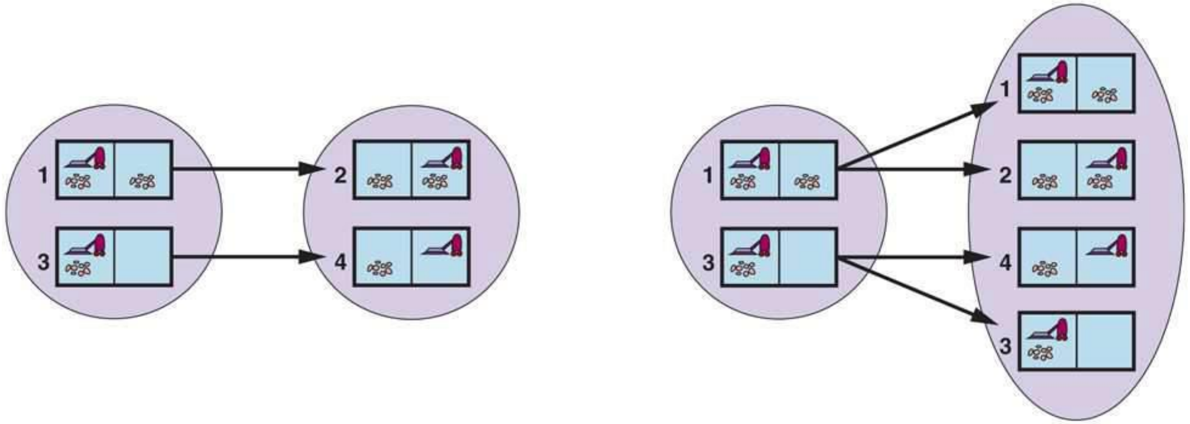
SEARCHING WITH NO OBSERVATION

- Deterministic actions

$$b' = \textsc{Result}(b, a) = \{s' : s' = \textsc{Result}_P(s,a) \text{ and } s \in b\}$$

- Nondeterministic actions

$$\begin{aligned} b' = \textsc{Result}(b, a) &= \{s' : s' \in \textsc{Results}_P(s,a) \text{ and } s \in b\} \\ &= \bigcup_{s \in b} \textsc{Results}_P(s,a)\,, \end{aligned}$$



(a) (b)

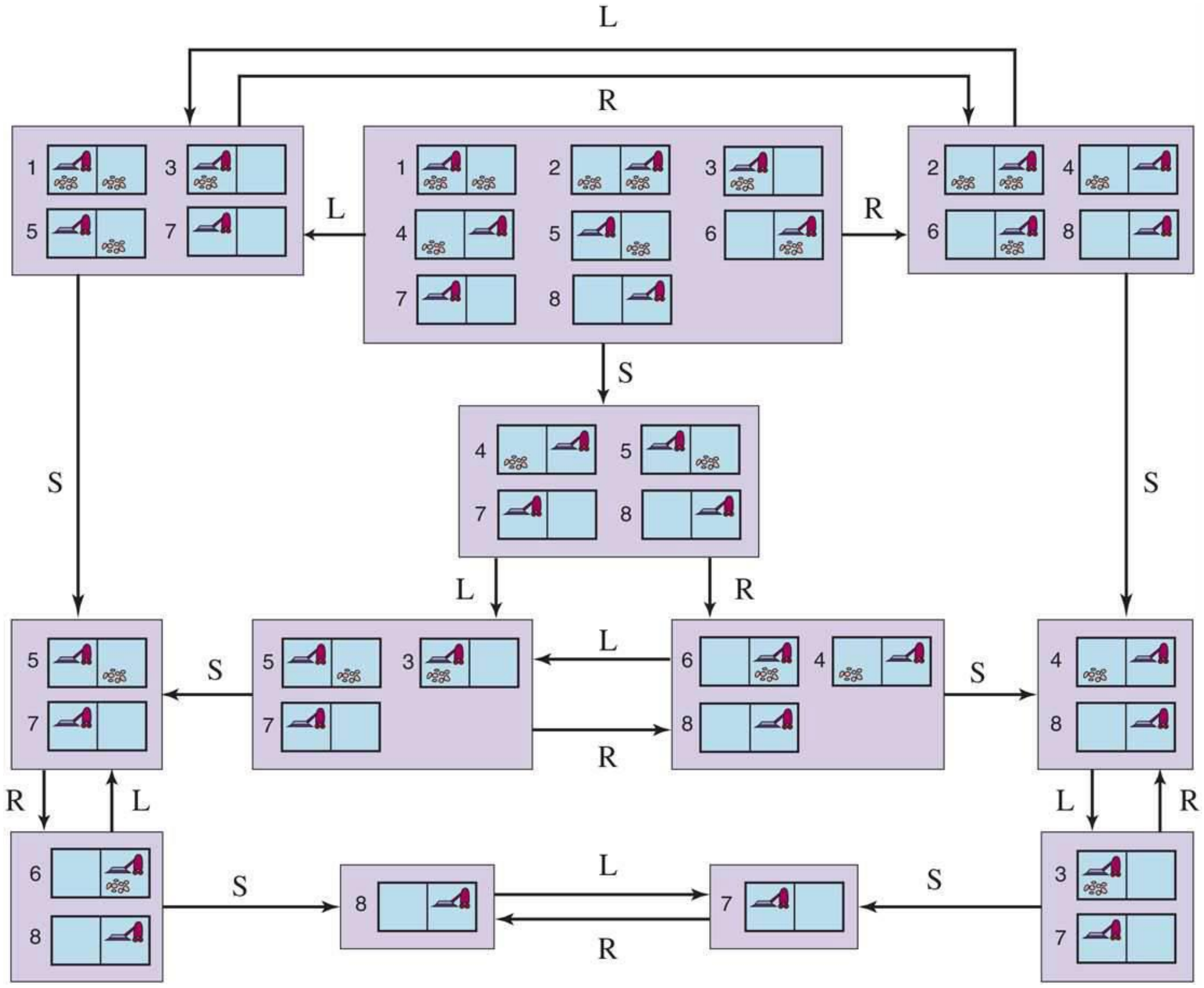
SEARCHING WITH NO OBSERVATION

- **GOAL TEST**: The agent possibly achieves the goal if any state s in the belief state satisfies the goal test of the underlying problem, IS-GOAL$_P$(s). The agent necessarily achieves the goal if every state satisfies IS-GOAL$_P$(s).

- **ACTION COST**: If the same action can have different costs in different states, then the cost of taking an action in a given belief state could be one of several values.

SEARCHING WITH NO OBSERVATION

VASTNESS OF BELIEF-STATE SPACE



INCREMENTAL BELIEF-STATE SEARCH ALGORITHMS

- Build up the solution one physical state at a time.
- The sensorless vacuum world, the initial belief state is {1,2,3,4,5,6,7,8}, and we have to find an action sequence that works in all 8 states.

- Just as an AND–OR search has to find a solution for every branch at an AND node, this algorithm has to find a solution for every state in the belief state; the difference is that AND– OR search can find a different solution for each branch, whereas an incremental belief-state search has to find one solution that works for all the states.

SEARCHING IN PARTIALLY OBSERVABLE ENVIRONMENTS

- 8-puzzle problem
- Nondeterministic Sensing:

PERCEPT(s): Returns a set of possible percepts

- Fully observable:

PERCEPT(s) = s for every state s

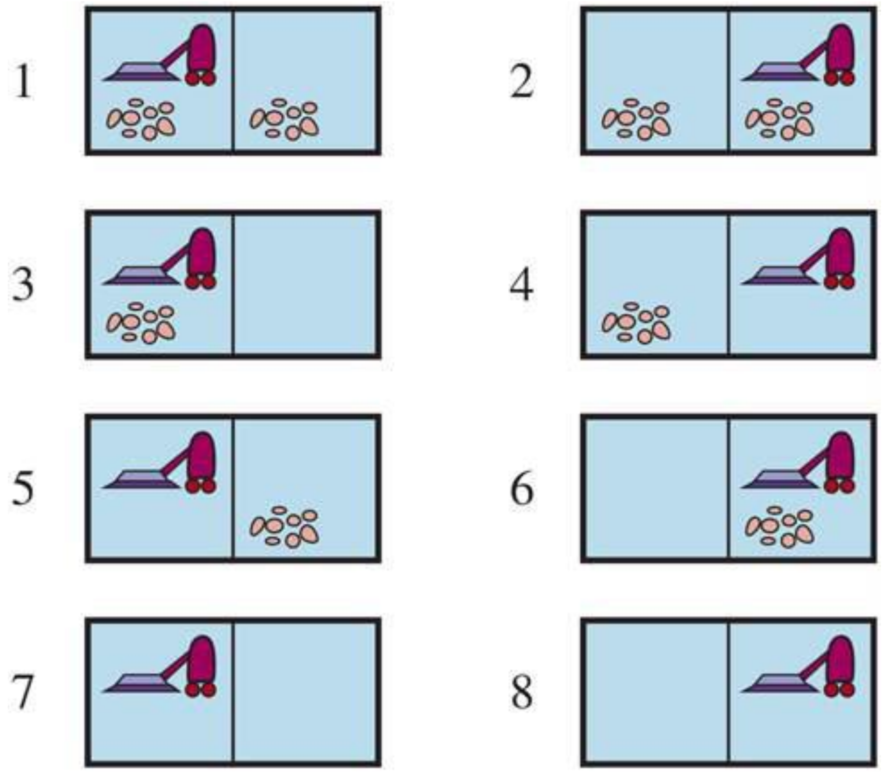
- Sensorless:

PERCEPT(s) = null

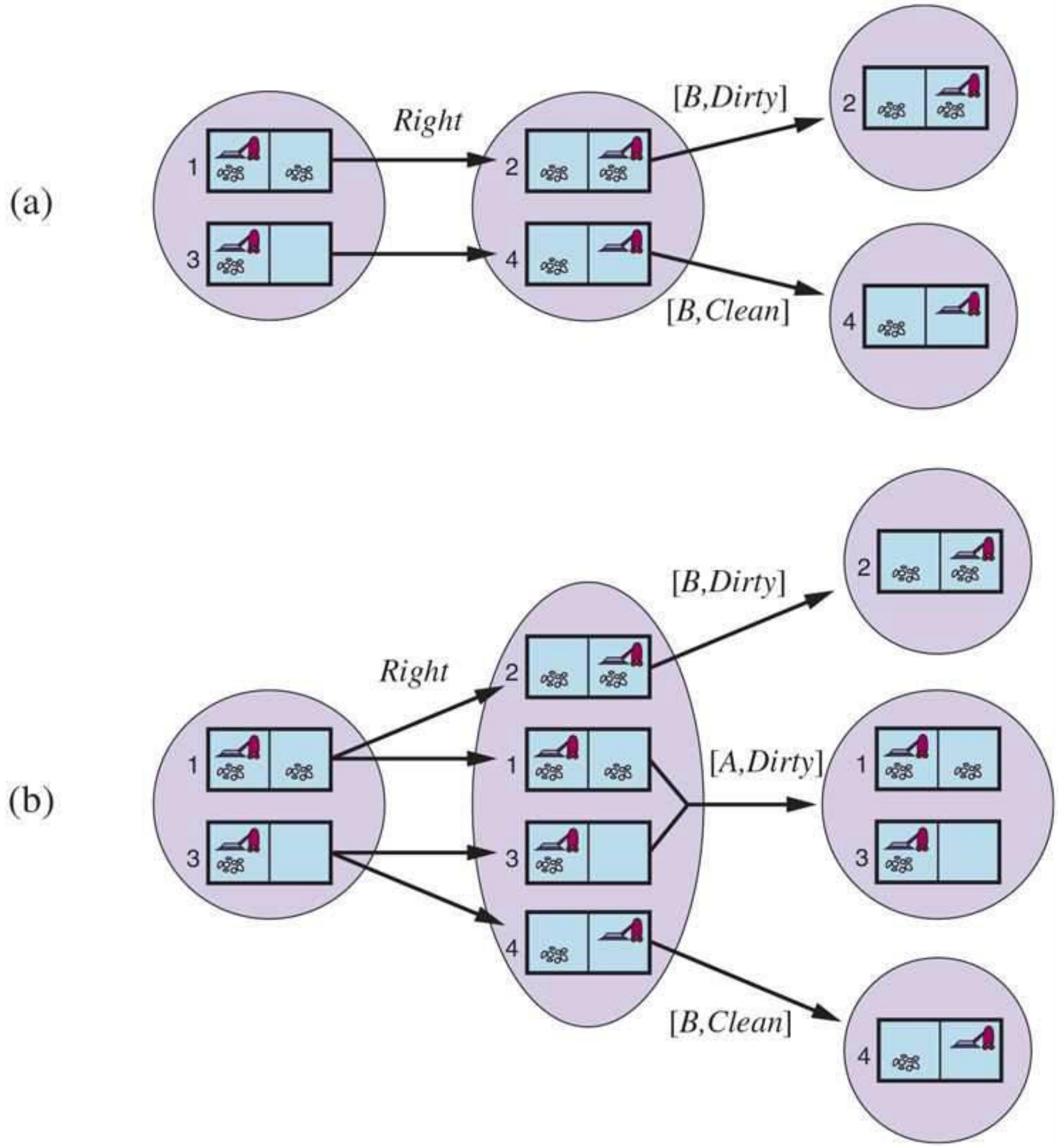
BELIEF STATES

- PERCEPT in state 1 is [L,Dirty].
- PERCEPT in state 3 is also [L,Dirty].

- With partial observability, it will usually be the case that several states produce the same percept.



SOLVING PARTIALLY OBSERVABLE PROBLEMS



SEARCHING IN PARTIALLY OBSERVABLE ENVIRONMENTS

- Prediction stage: The prediction stage computes the belief state resulting from the action, RESULT(b, a). The "hat" over the means "estimated". PREDICT(b, a) $\hat{b} = \textsc{Result}(b, a)$
- Possible percepts: The possible percepts stage computes the set of percepts that could be observed in the predicted belief state.

$$\textsc{Possible-Percepts}(\hat{b}) = \{o : o = \textsc{Percept}(s) \text{ and } s \in \hat{b}\}$$

- Update stage: The update stage computes, for each possible percept, the belief state that would result from the percept.

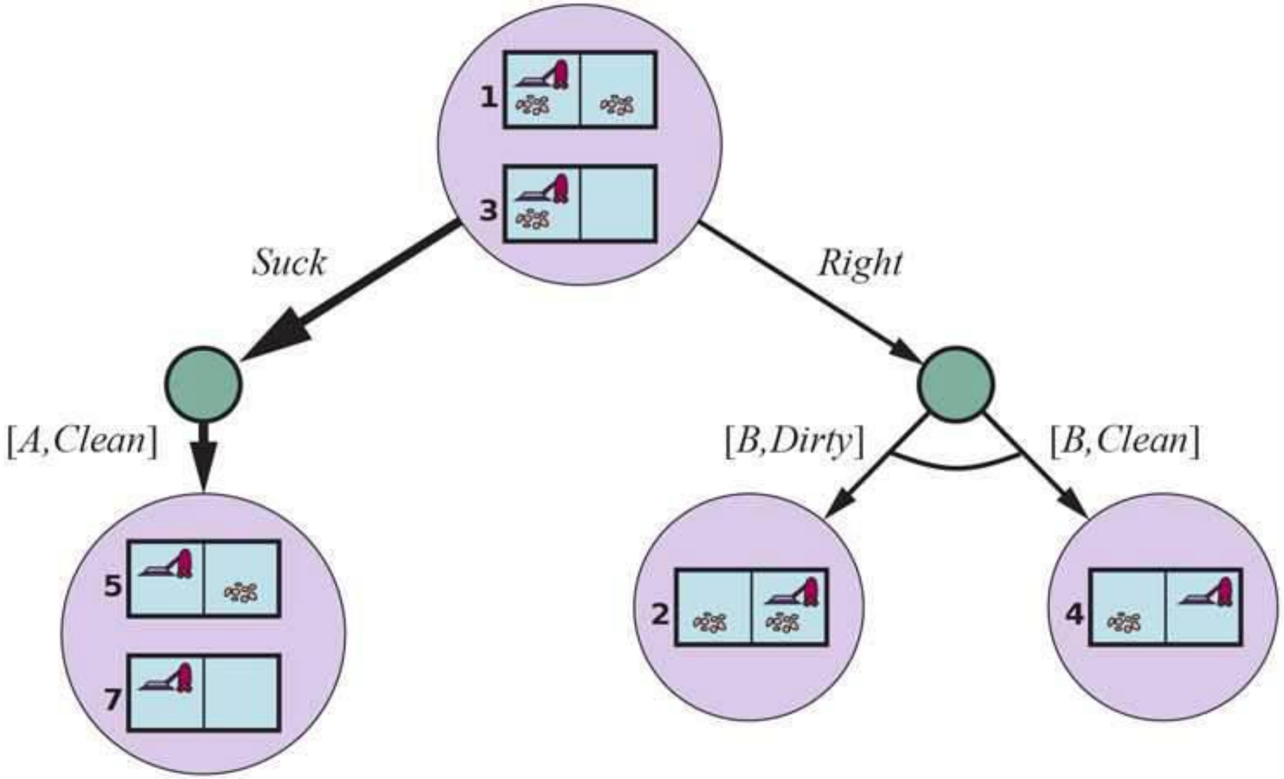
$$b_o = \textsc{Update}(\hat{b}, o) = \{s : o = \textsc{Percept}(s) \text{ and } s \in \hat{b}\}$$

- The possible belief states resulting from a given action and the subsequent possible percepts

$$\textsc{Results}(b, a) = \{b_o : b_o = \textsc{Update}(\textsc{Predict}(b, a), o) \text{ and } o \in \textsc{Possible-Percepts}(\textsc{Predict}(b, a))\}$$

SOLVING PARTIALLY OBSERVABLE PROBLEMS

$[Suck, Right, \textbf{if } Bstate = \{6\} \textbf{ then } Suck \textbf{ else } [\,]]$



KINDERGARTEN VACUUM WORLD WITH LOCAL SENSING