Logical Agents

Outline

I. Knowledge-based agents

II. The Wumpus world

III. Logic

* Figures/images are from the textbook site (or by the instructor).

I. Knowledge-Based Agents

- Problem solving agents do not know general facts.

  An 8-puzzle agent does not know that two tiles cannot occupy the same space.

- Their atomic representations are very limited.

  e.g., a list of all possible concrete states.

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♦ Intelligent agents need *knowledge about the world* in order to carry out reasoning for good decision making.

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- Intelligent agents need *knowledge about the world* in order to carry out reasoning for good decision making.

  - Represent states, actions, etc.
  - Incorporate new percepts.
  - Update internal representation of the world.
  - Deduce hidden properties of the world.
  - Deduce appropriate actions.

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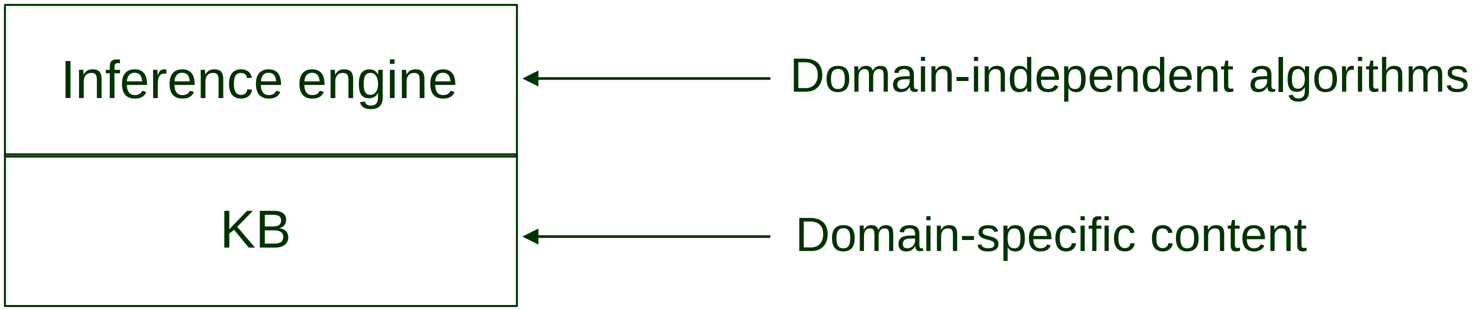

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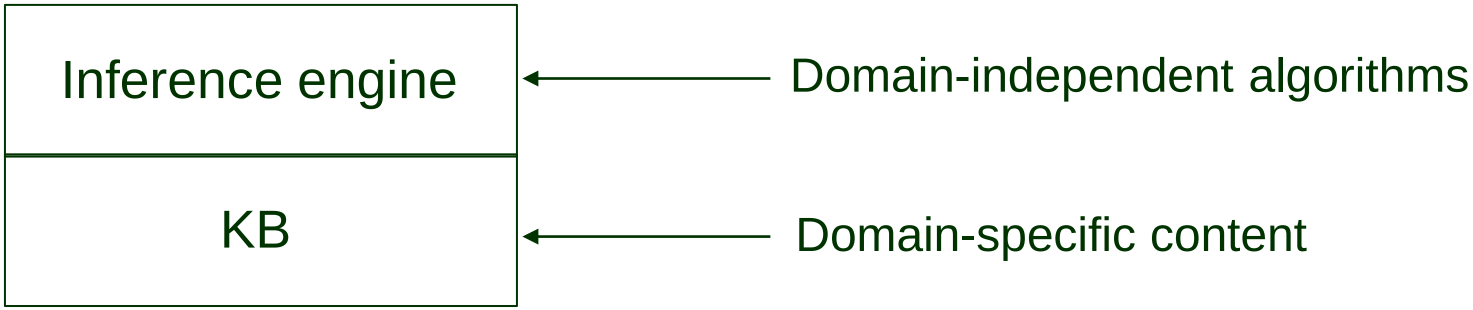

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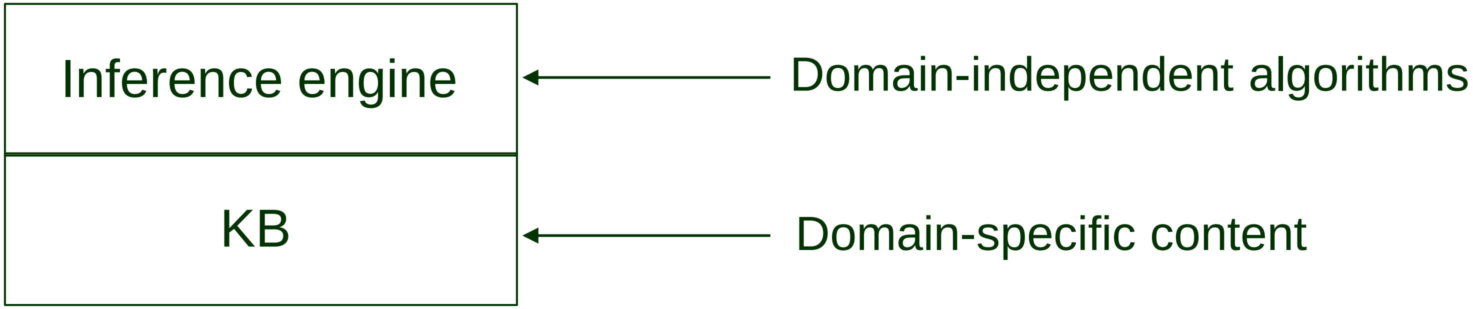

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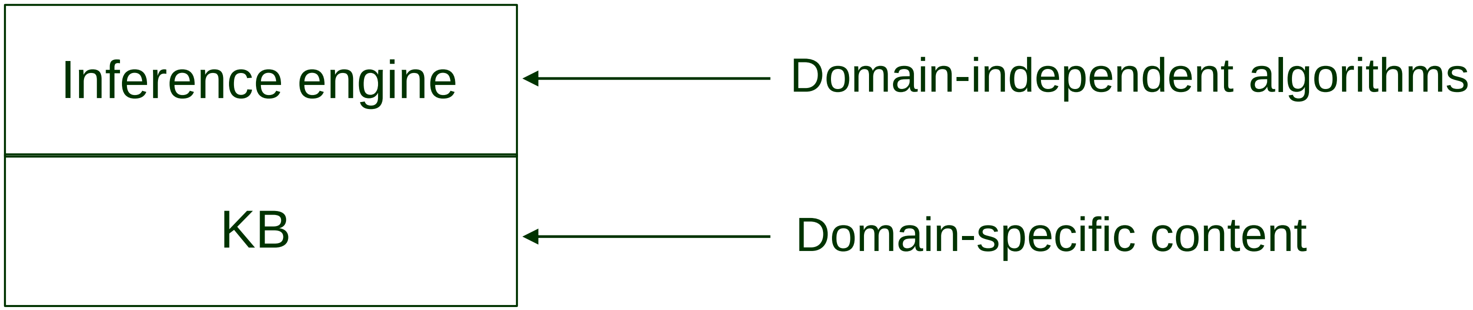

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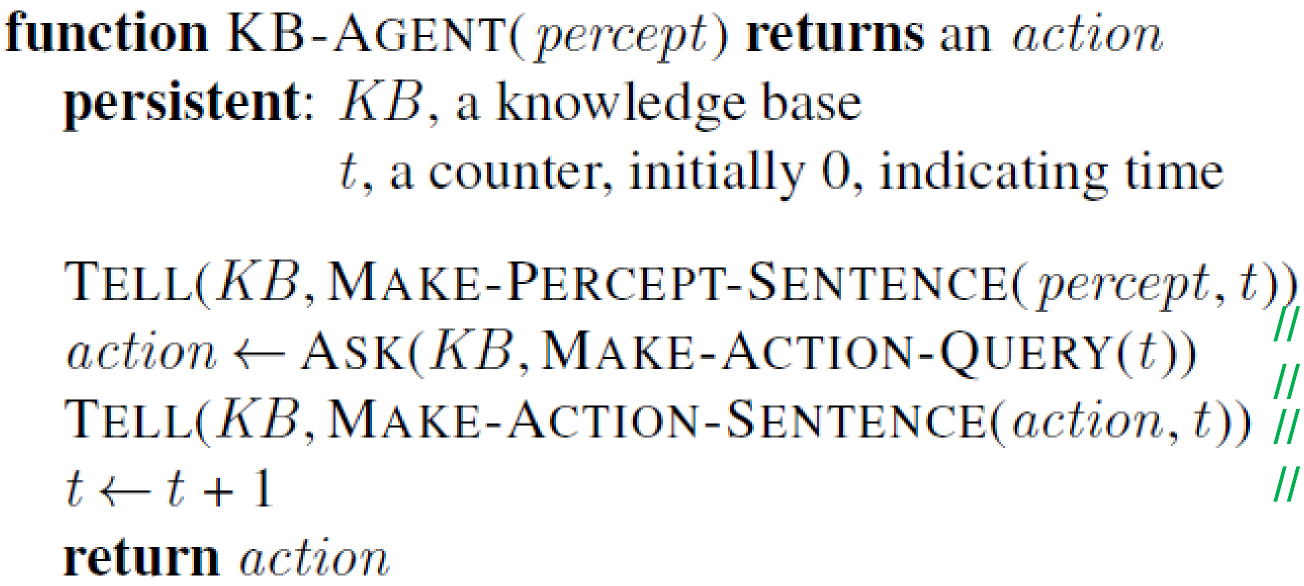
ASK: Query the KB.

Inference: Derive new sentences from old.

Generic Knowledge-Based Agent



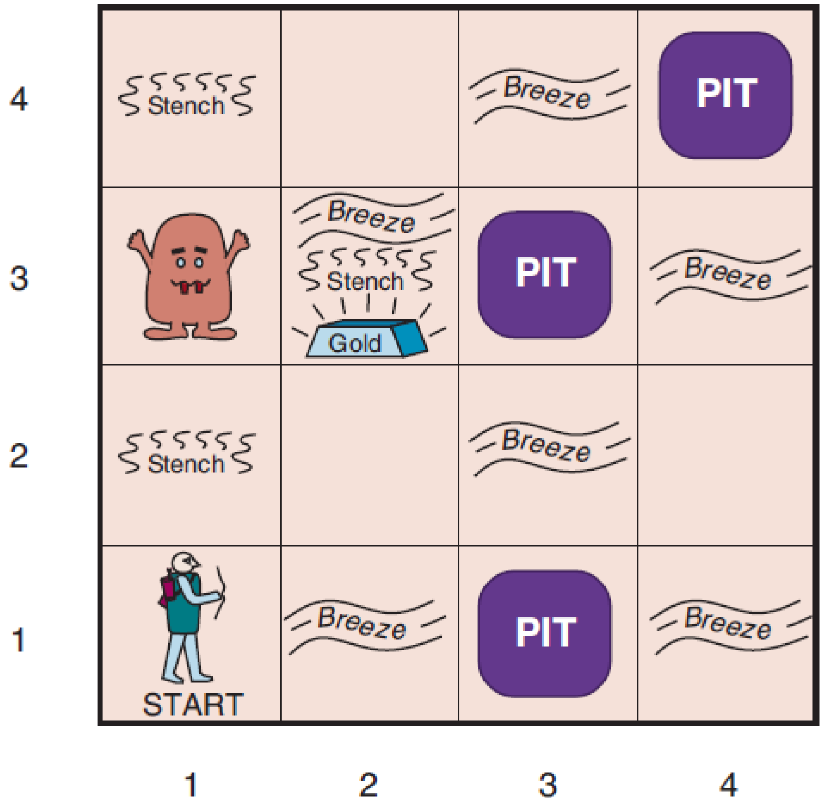
```
function KB-AGENT(percept) returns an action
    persistent: KB, a knowledge base
                t, a counter, initially 0, indicating time

    TELL(KB, MAKE-PERCEPT-SENTENCE(percept, t))
    action ← ASK(KB, MAKE-ACTION-QUERY(t))
    TELL(KB, MAKE-ACTION-SENTENCE(action, t))
    t ← t + 1
    return action
```

// asks what action
// it should perform.
// tells what action
// was chosen

II. The Wumpus World

Cave consisting of connected rooms.

- Some rooms contain pits that will trap whoever enters them.
- The wumpus lurks in one room ready to eat whoever enters the room.
- The wumpus can be shot by the agent, who has only one arrow.
- A heap of gold is in a different room than where the wumpus lurks.



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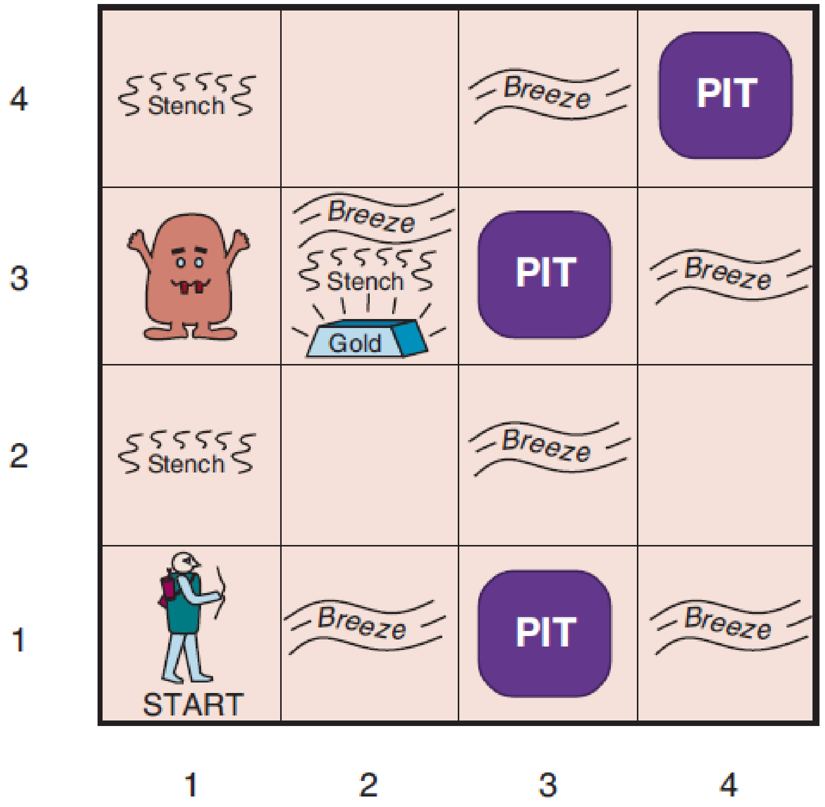
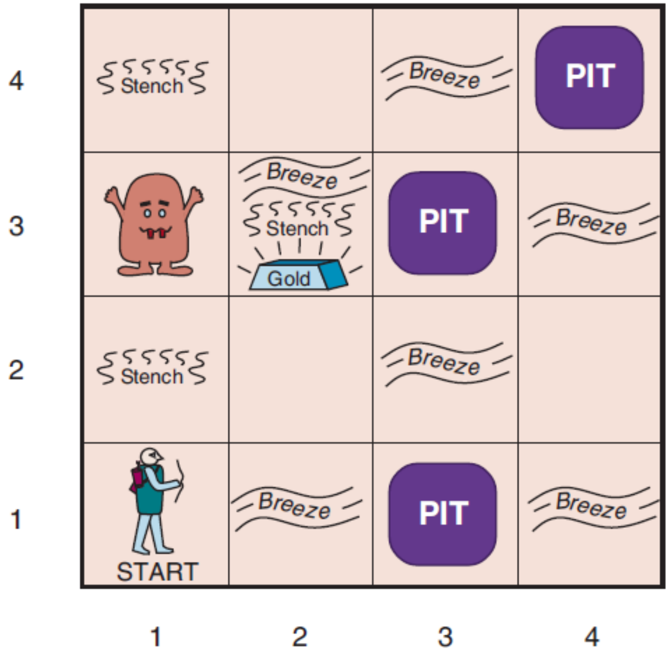


Goal: Find the gold and bring it back to the start without getting killed.

Task Environment

Performance measure

- +1000 (climbing out of the cave with the gold)
- –1000 (falling into a pit or being eaten by the wumpus)
- –1 (each action taken)
- –10 (using up the arrow)



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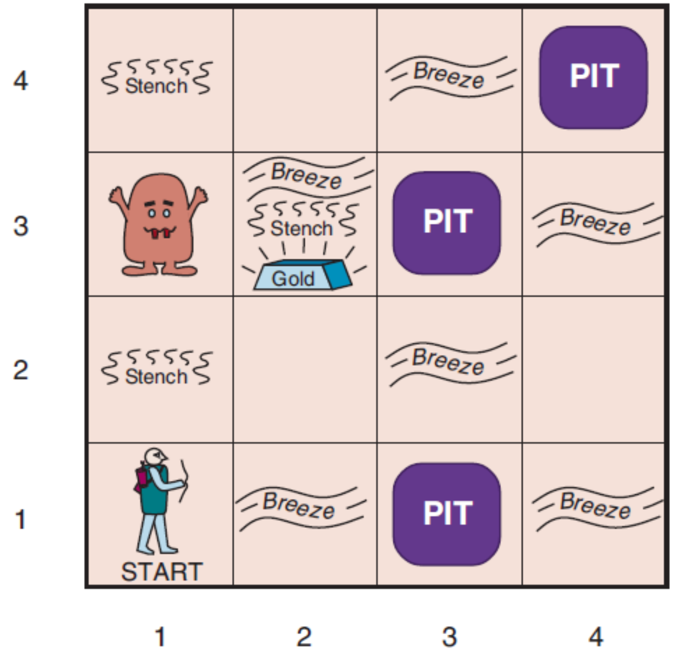


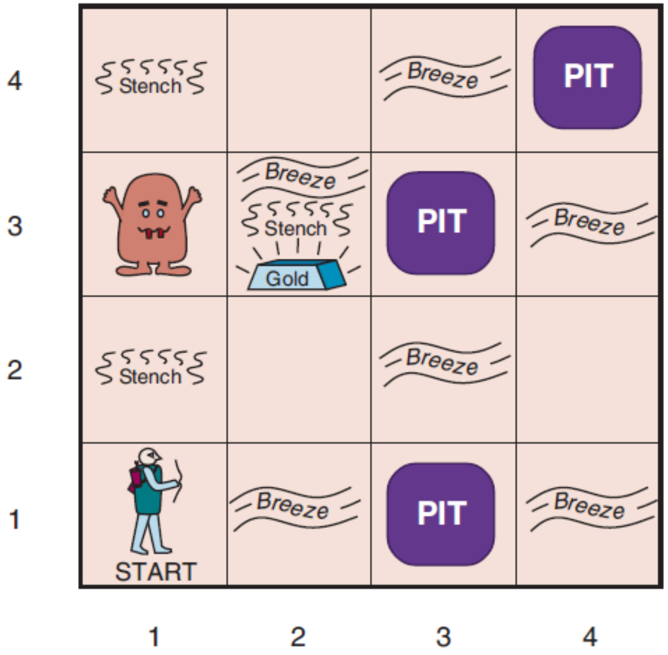
Environment

- 4×4 grid surrounded by walls
- $[1,1]$: the starting square for the agent, who faces east
- locations of the gold and the wumpus:
  - different from [1, 1]
  - otherwise randomly generated under uniform distribution
- 0.2 probability for a square other than $[1, 1]$ and without gold or wumpus to be pit

Actuators

Actuators:

1) *Forward*, *TurnLeft by* 90°, *TurnRight by* 90°
    - Death of the agent if it enters a square containing a pit or a live wumpus.
    - No movement if bumping into a wall.
2) *Grab*
    - Picks up the gold if it in the same square as the agent.
3) *Shoot*
    - Fire an arrow in the direction the agent is facing.
    - The arrow continues until hitting the wumpus (who gets killed consequently) or a wall.
4) *Climb*
    - Climb out of the cave if at $[1, 1]$.



Sensors

5 Sensors, each providing one bit of information:

1) *Stench*

- in the squares directly (not diagonally) adjacent to the wumpus

2) *Breeze*

- in the squares directly (not diagonally) adjacent to a pit

3) *Glitter*

- in the square where the gold is

4) *Bump*

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Percepts in the form of a 5-vector:

e.g., [*Stench, Breeze, None, None, None*]

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- Deterministic, discrete, static, and single-agent

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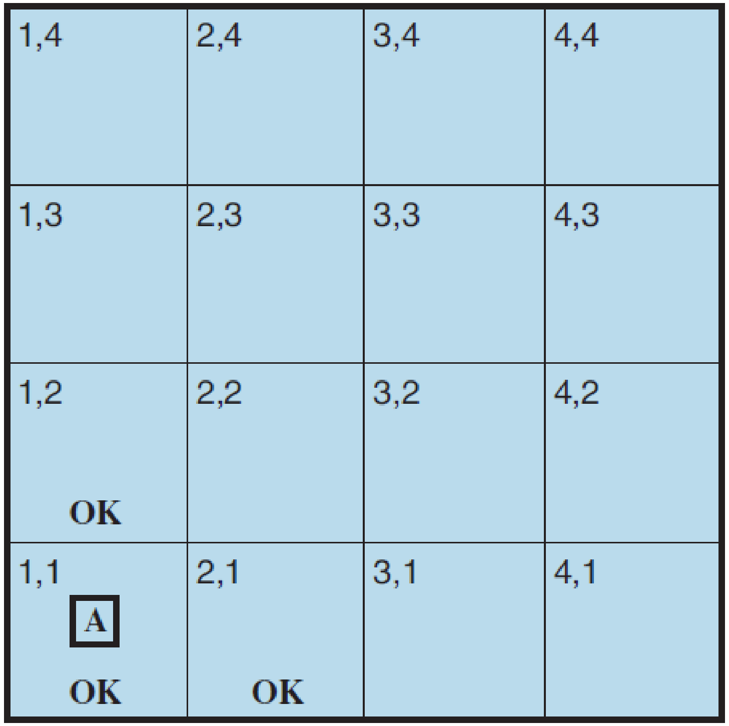

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G	= *Glitter, Gold*
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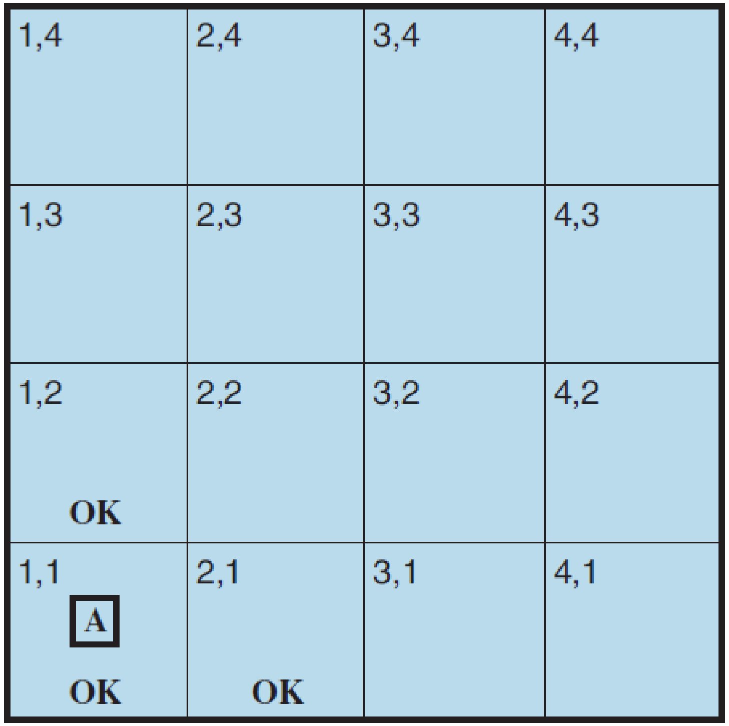

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1,1 A OK	2,1 OK	3,1	4,1

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Percept: [*None, None, None, None, None*]

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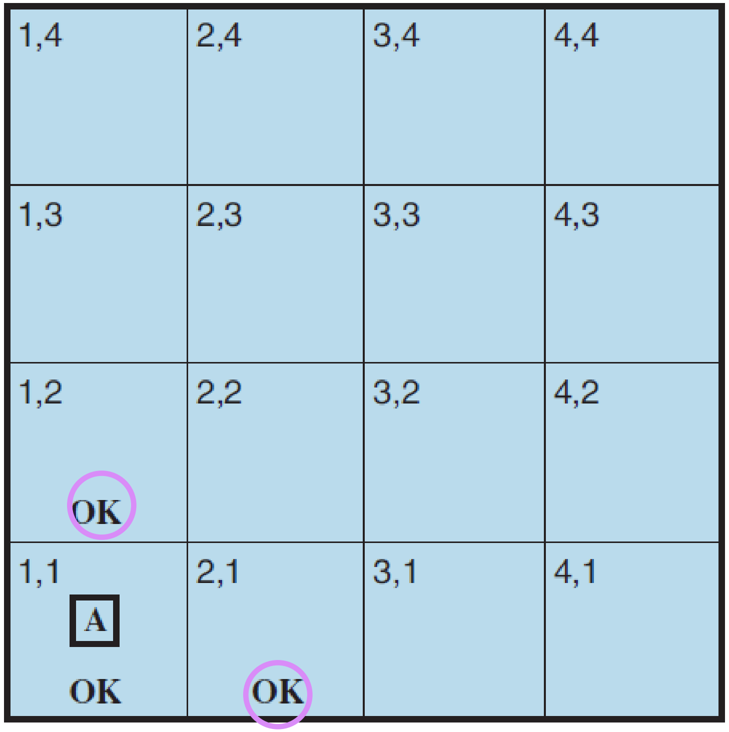

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[1,2] and [2, 1] are free of dangers.

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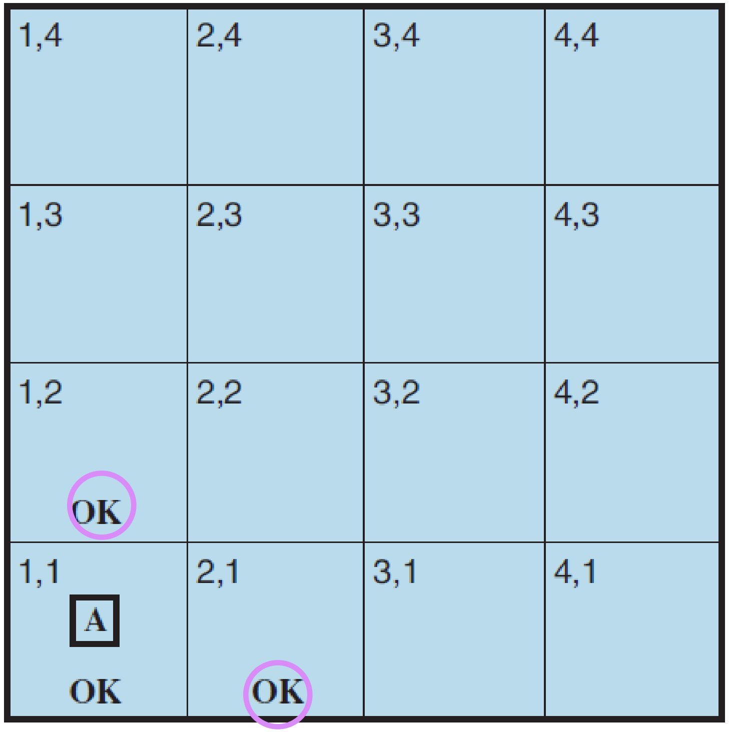

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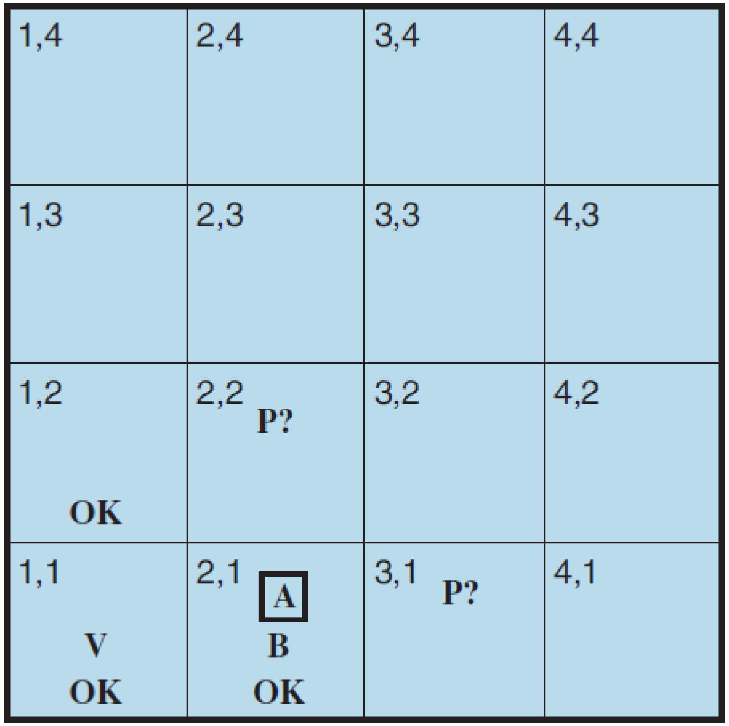

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Percept: [*None, None, None, None, None*]

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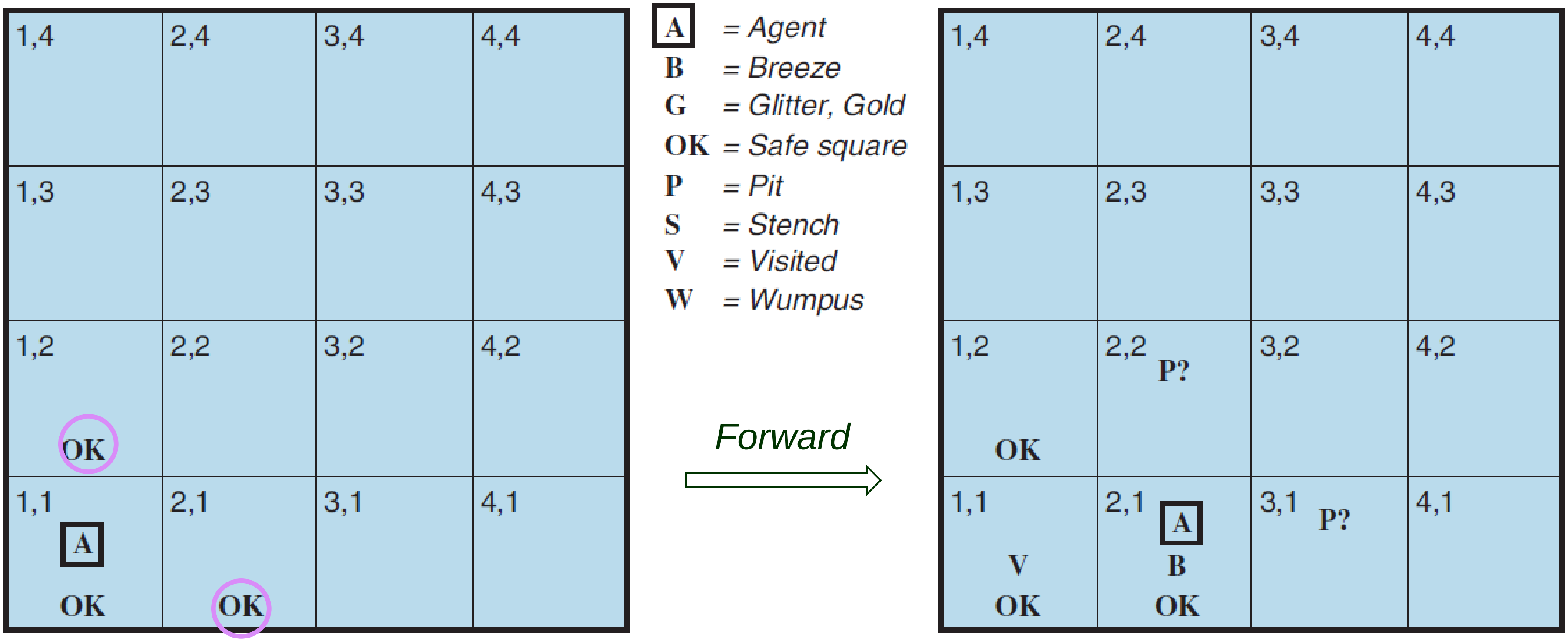

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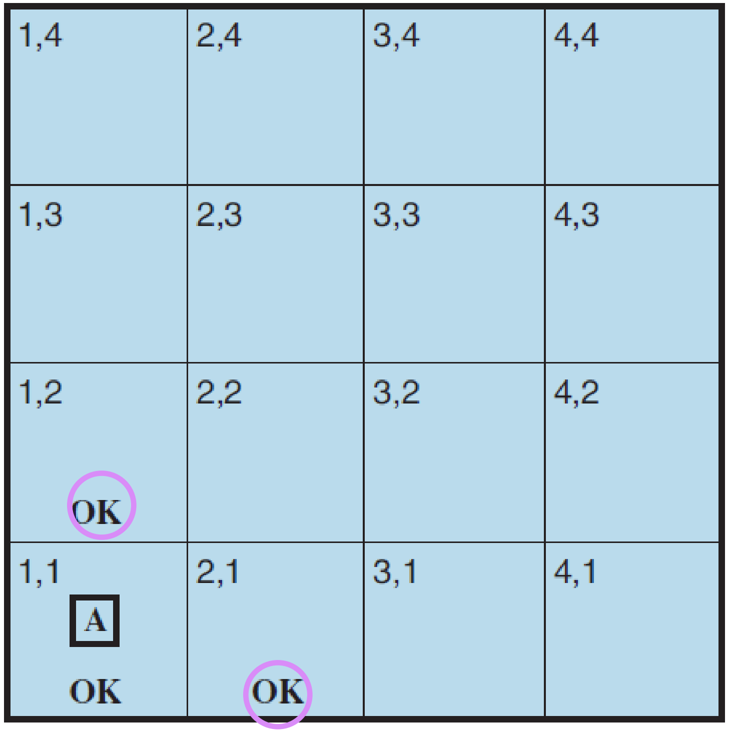

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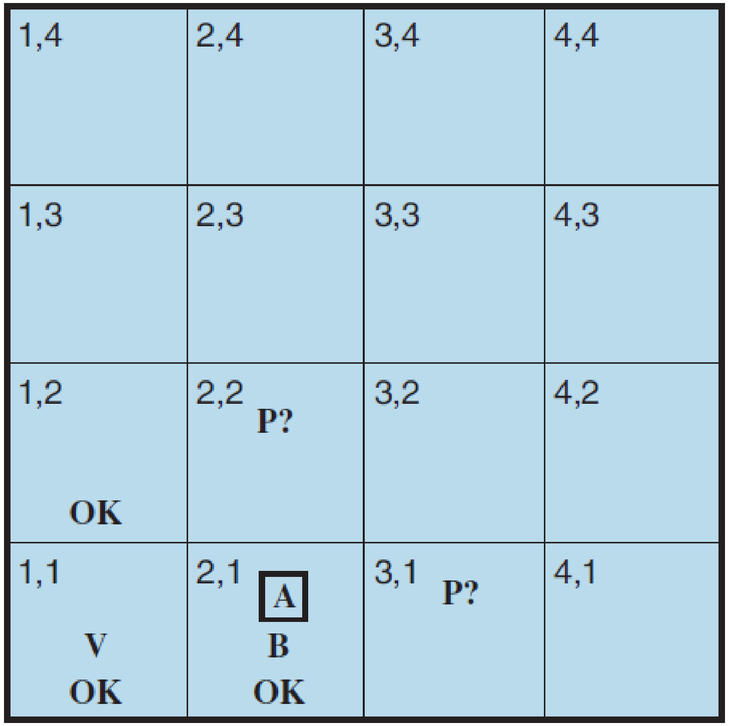

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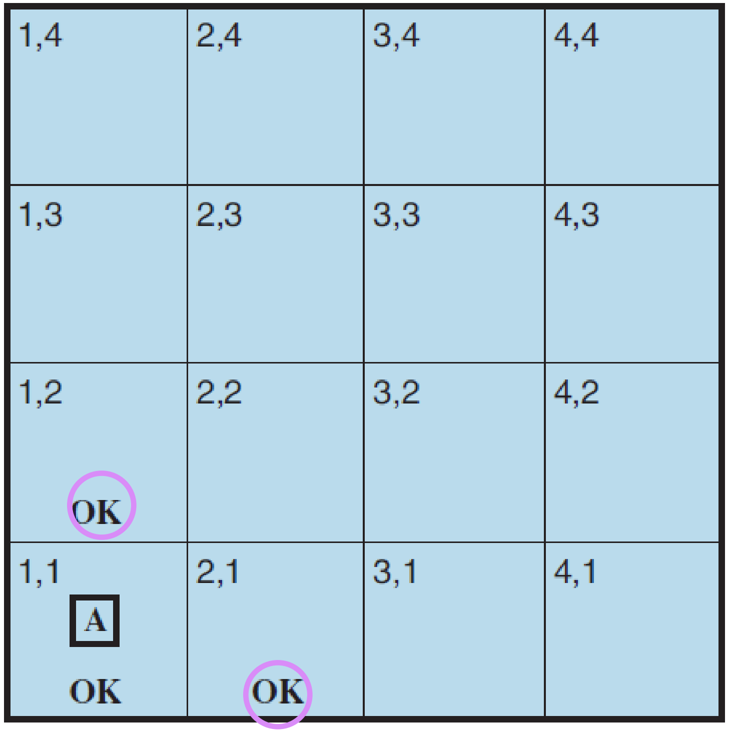

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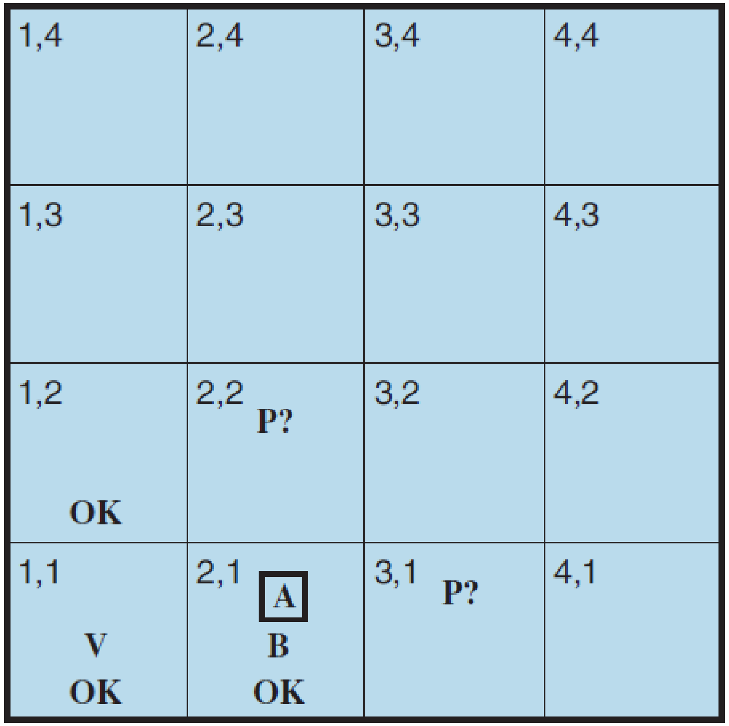

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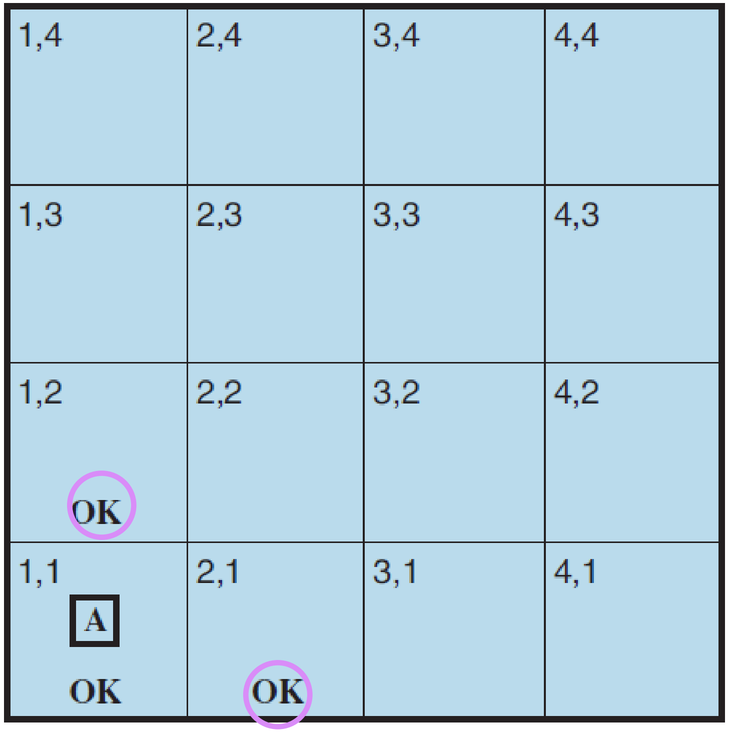

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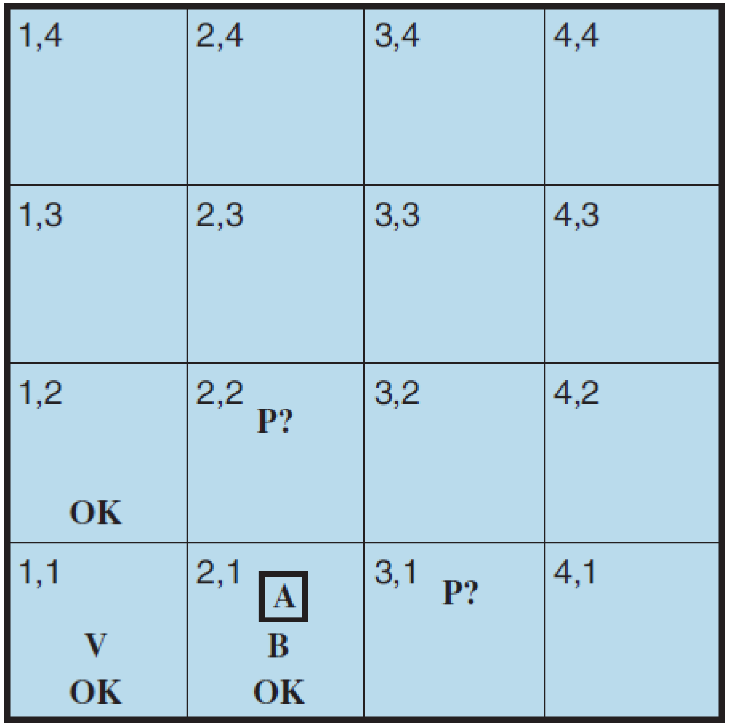

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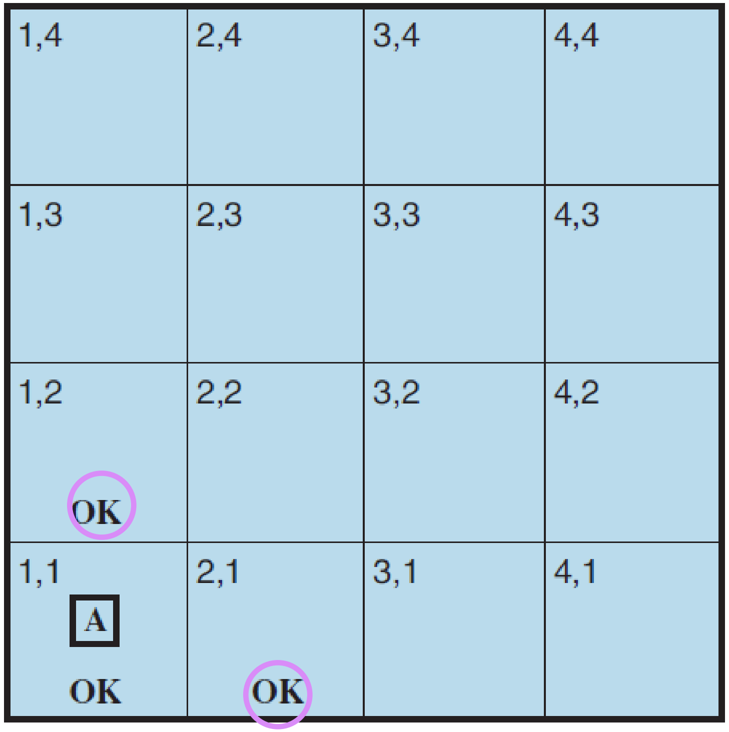

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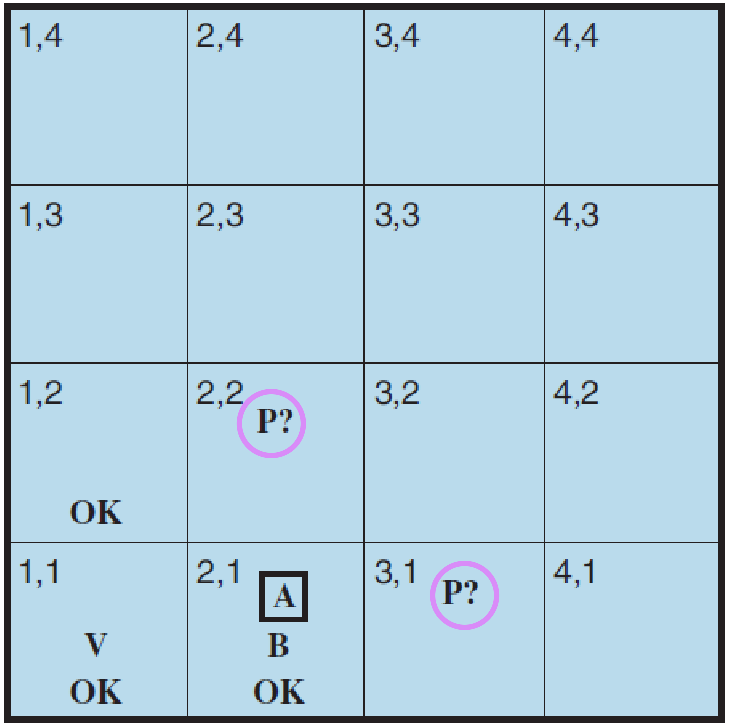

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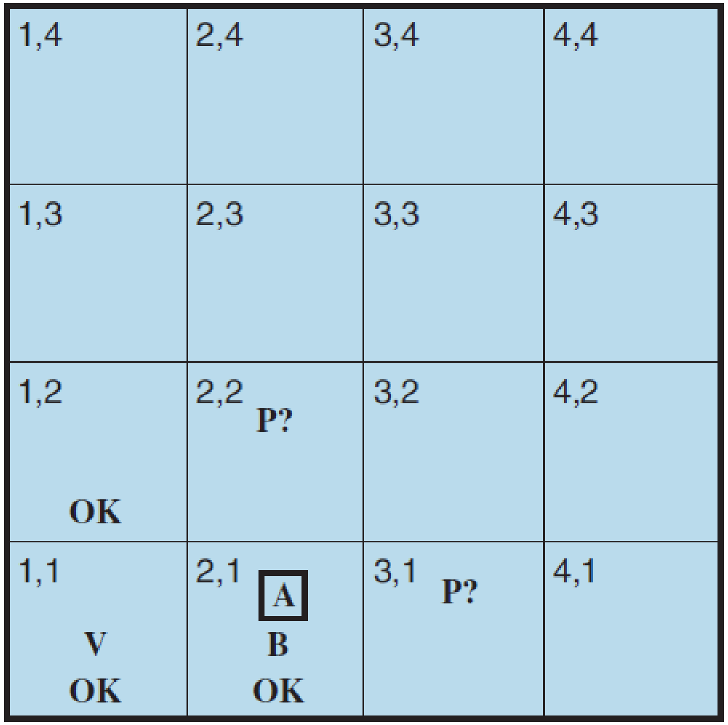

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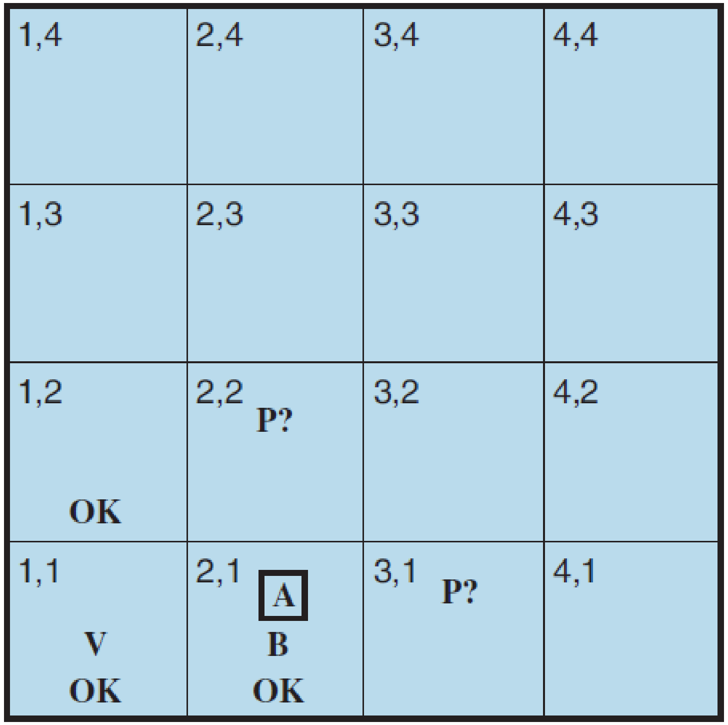

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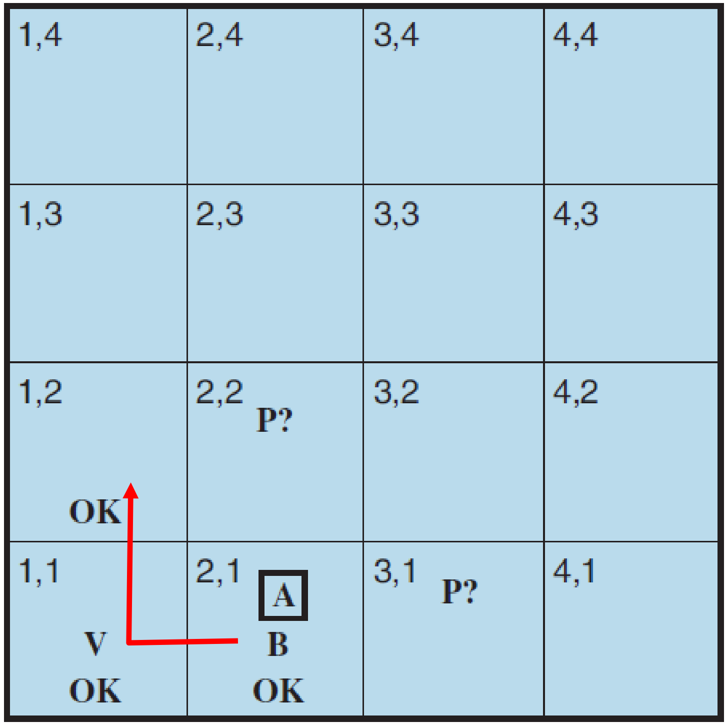

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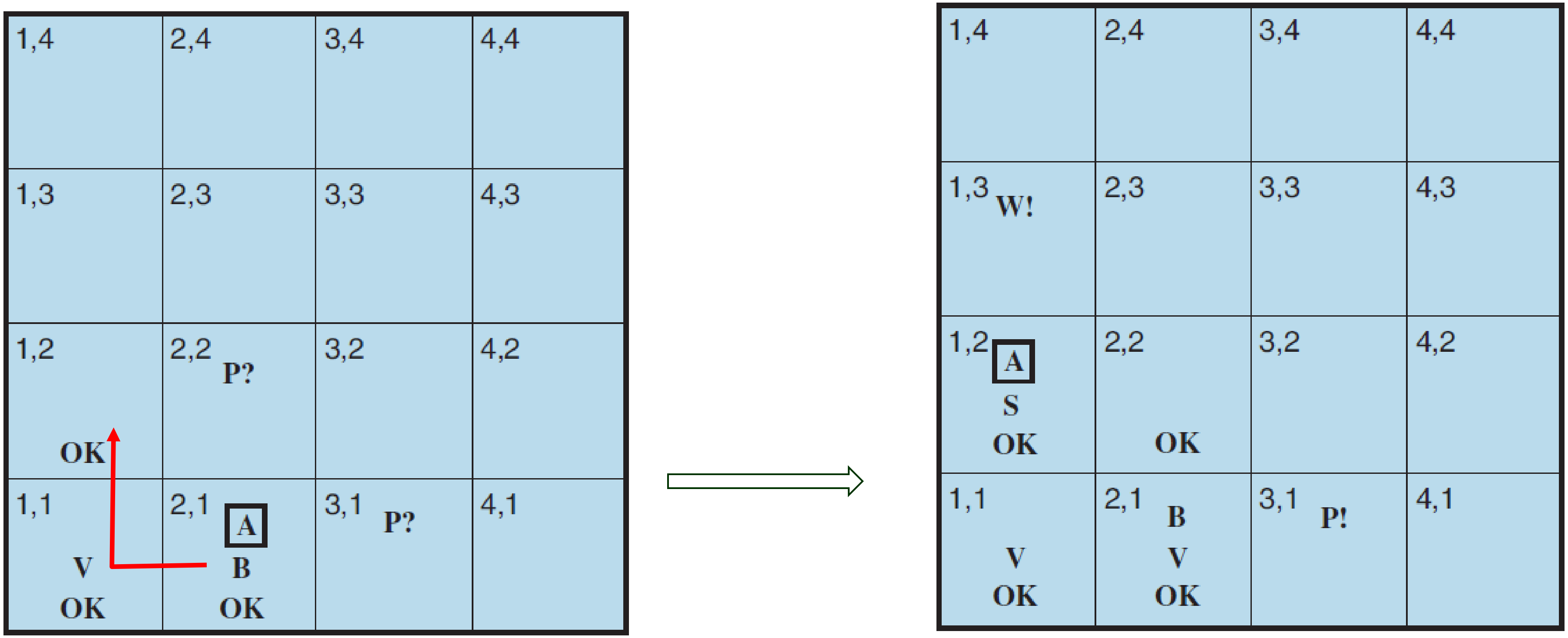

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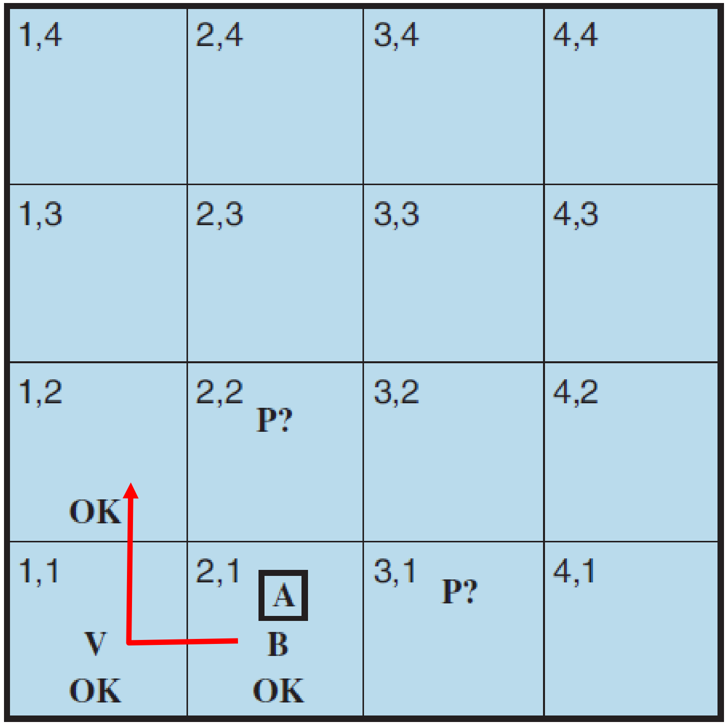

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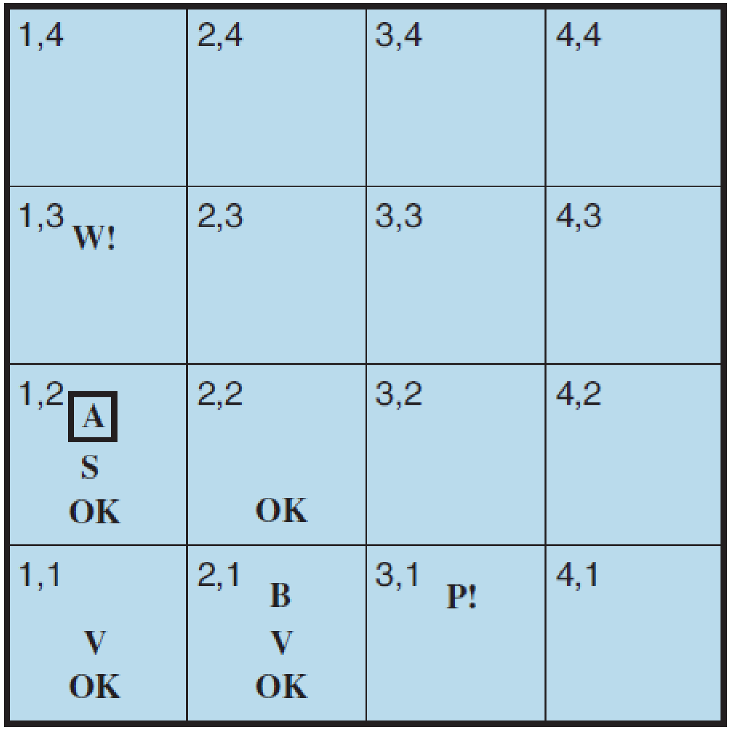

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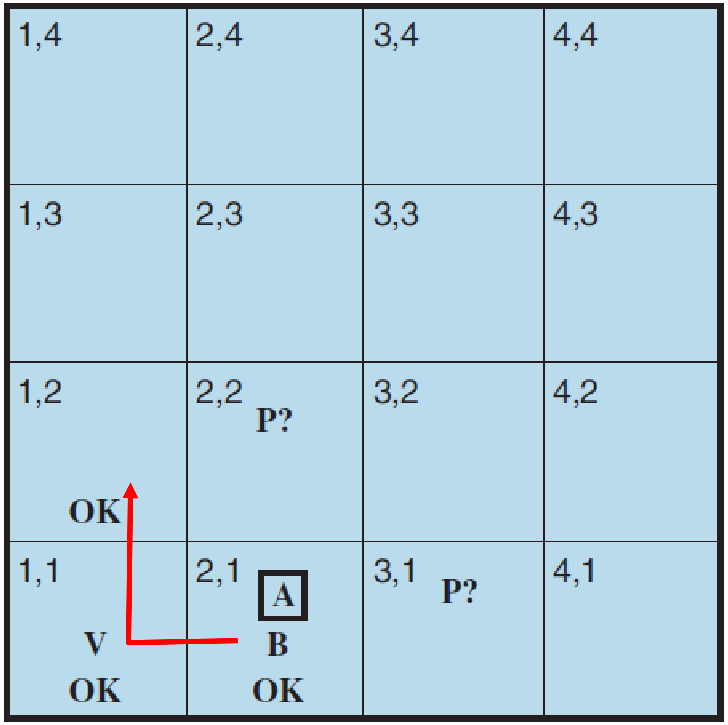

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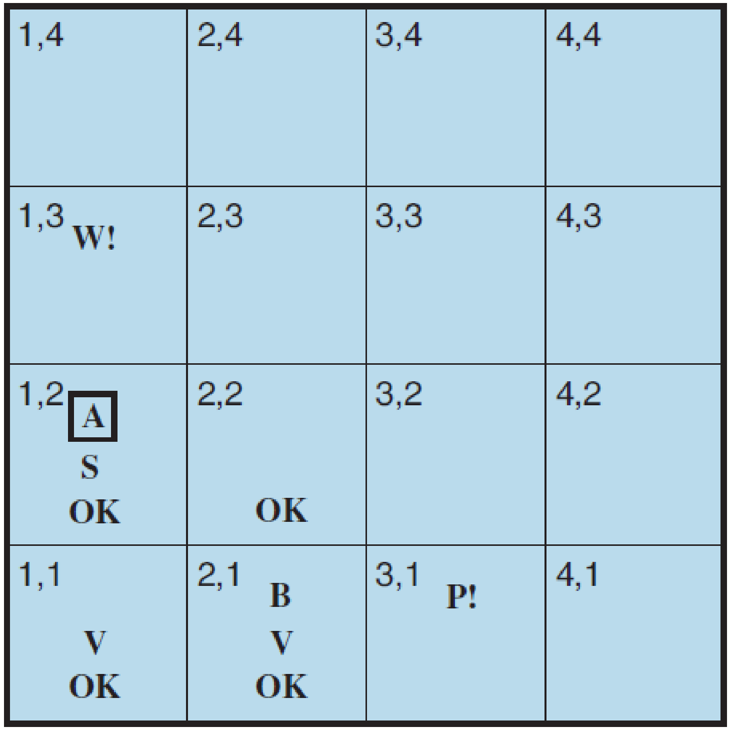

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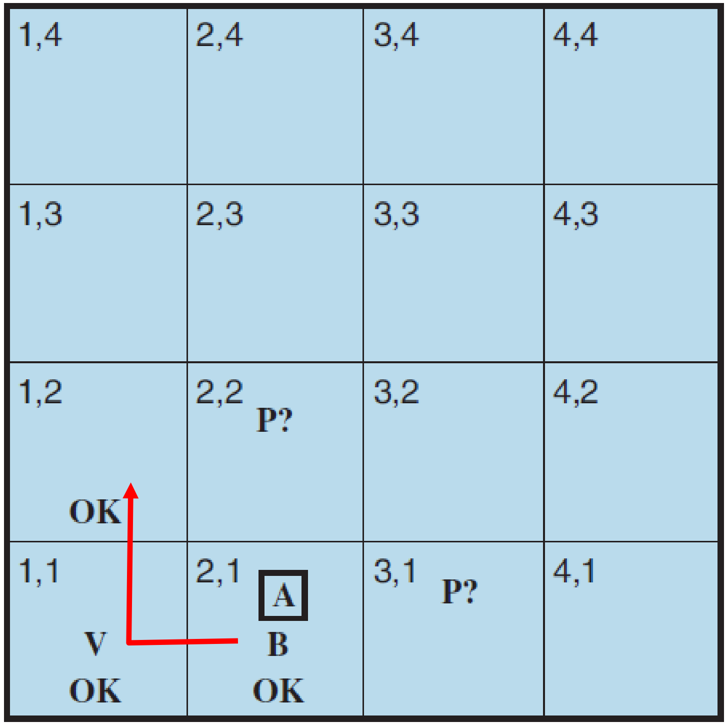

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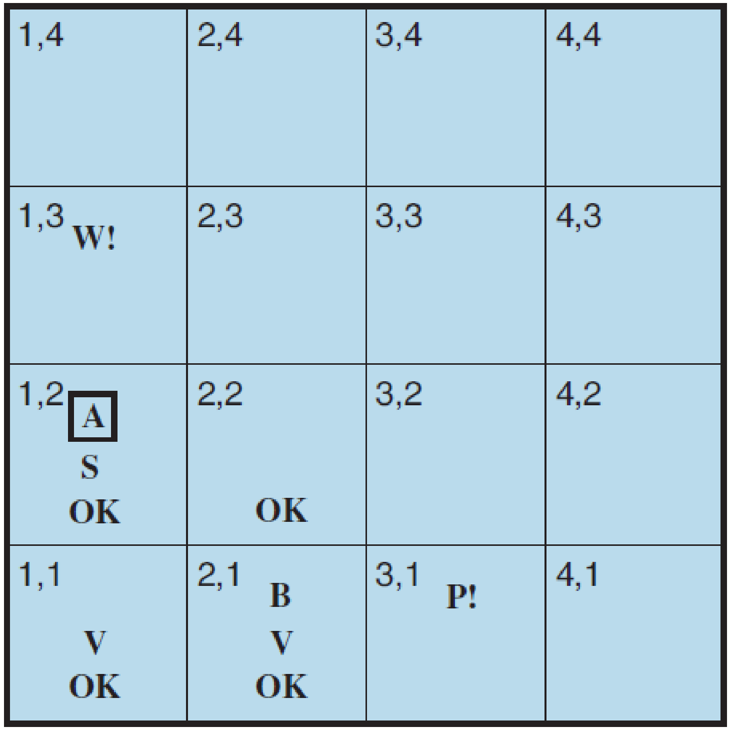

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Be prudent: Turn around, go back to [1,1] and move onto [1, 2].

[Stench, None, None, None, None]

⇓

The wumpus is in [1,1] , [2,2] , or [1, 3].

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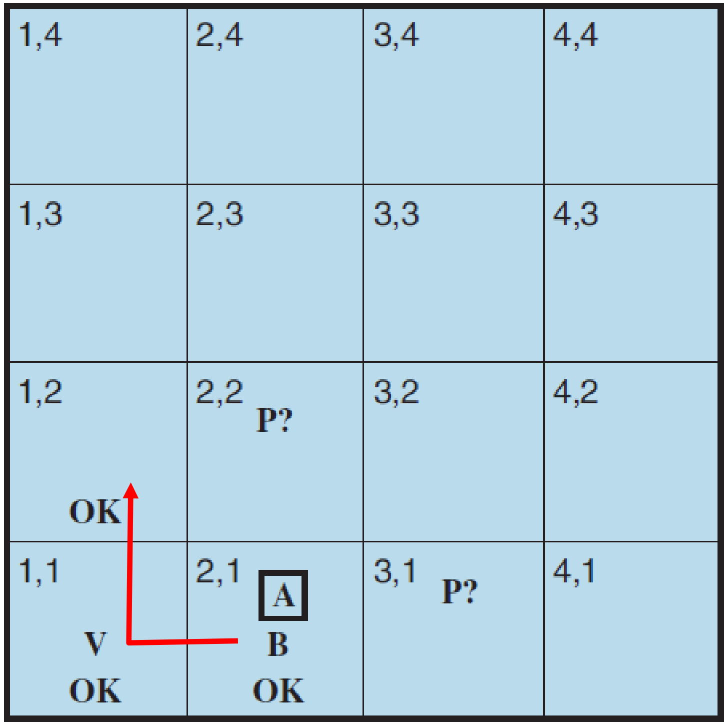
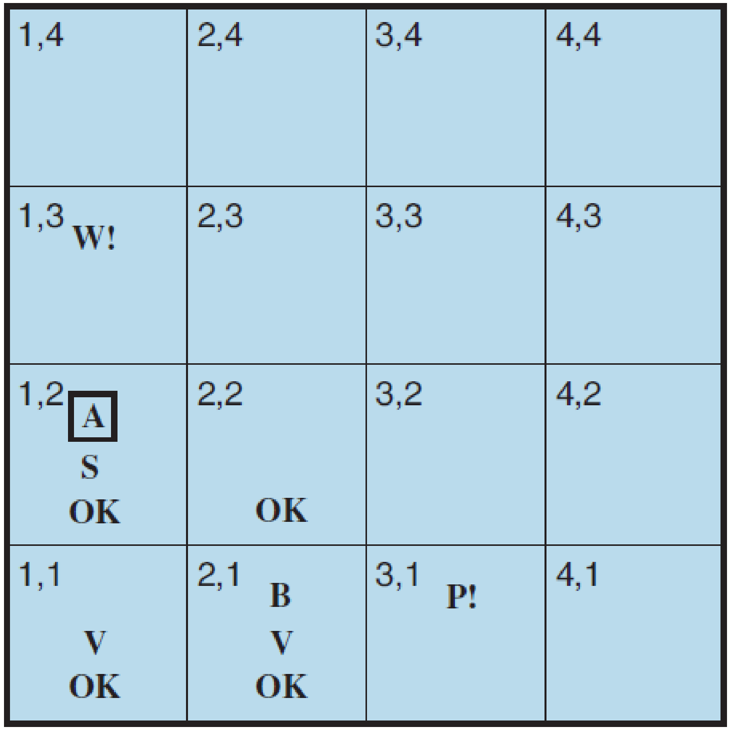
Next Step



1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2 OK	2,2 P?	3,2	4,2
1,1 V OK	2,1 A B OK	3,1 P?	4,1



1,4	2,4	3,4	4,4
1,3 W!	2,3	3,3	4,3
1,2 A S OK	2,2 OK	3,2	4,2
1,1 V OK	2,1 B V OK	3,1 P!	4,1

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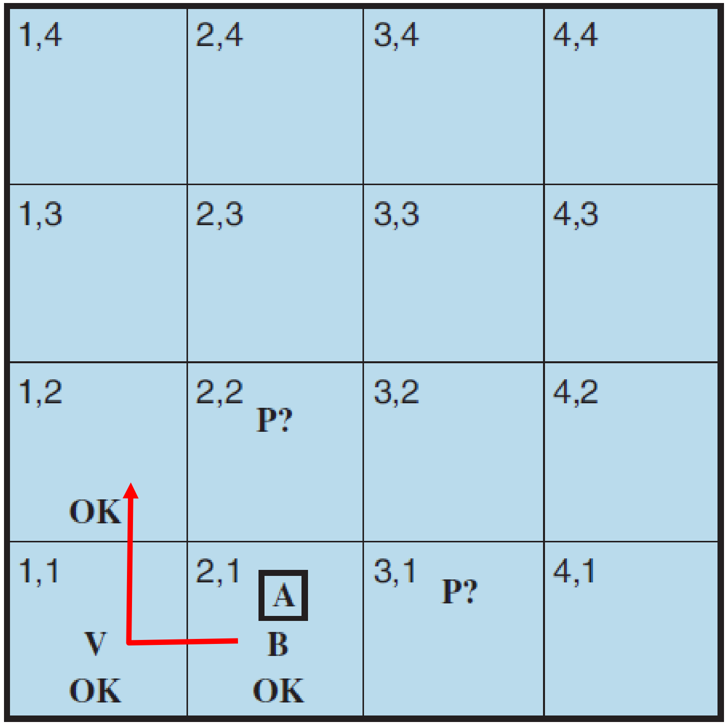

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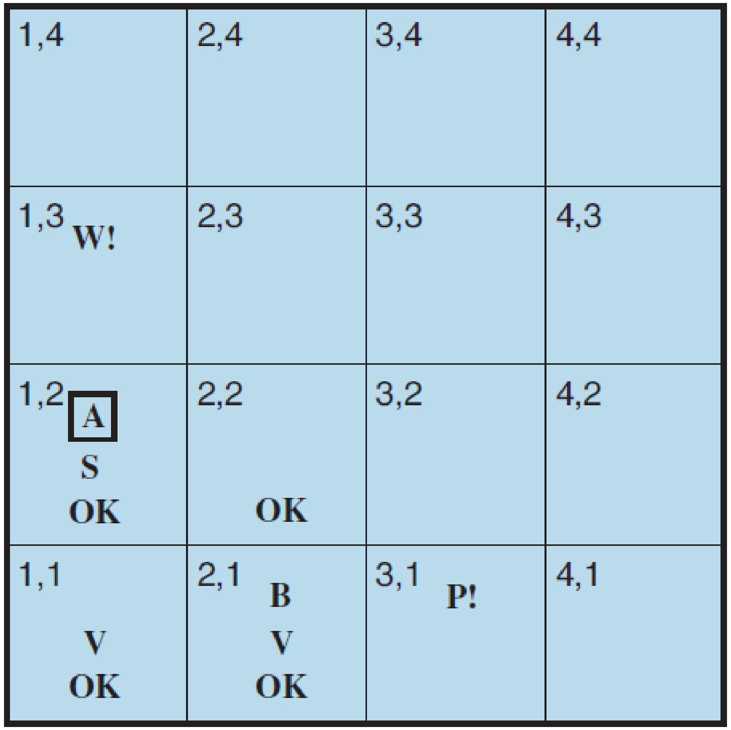

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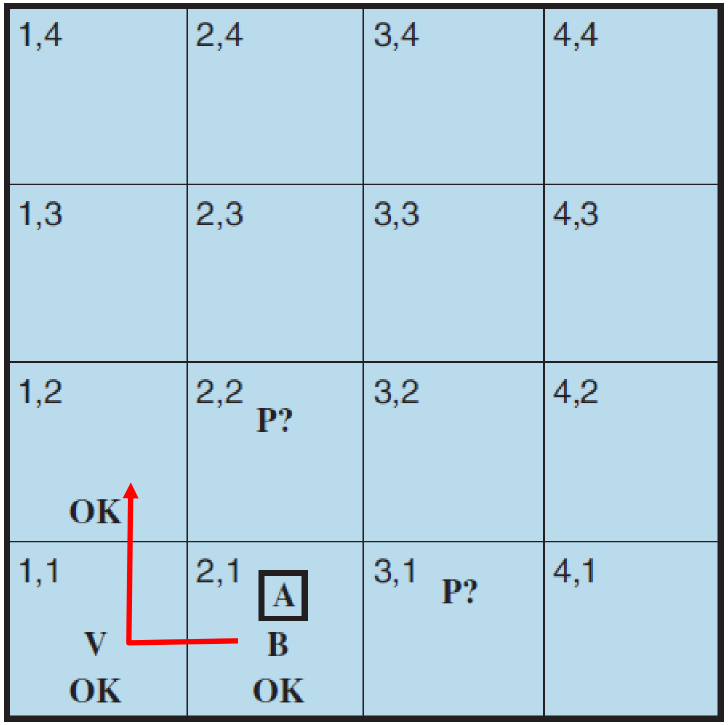

1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
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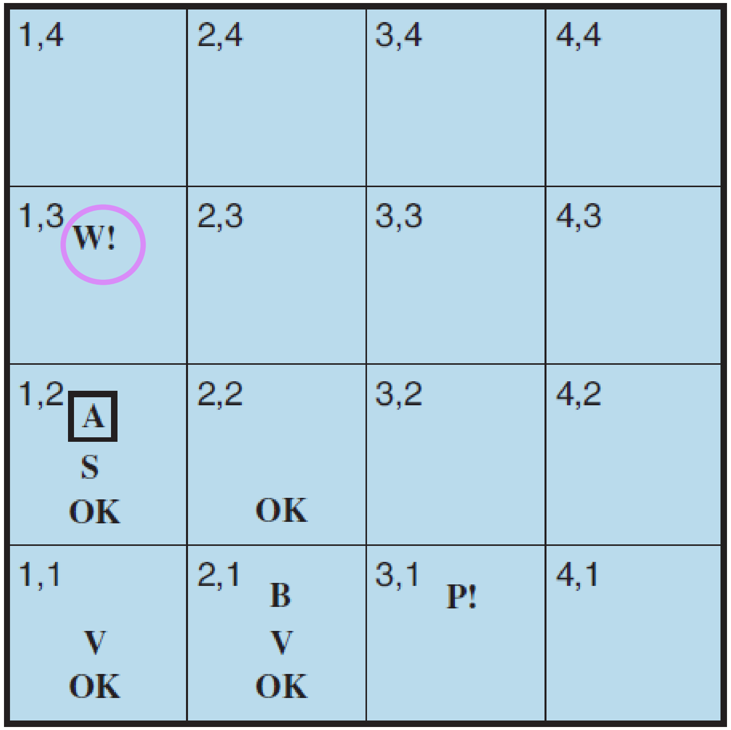

1,4	2,4	3,4	4,4
1,3 W!	2,3	3,3	4,3
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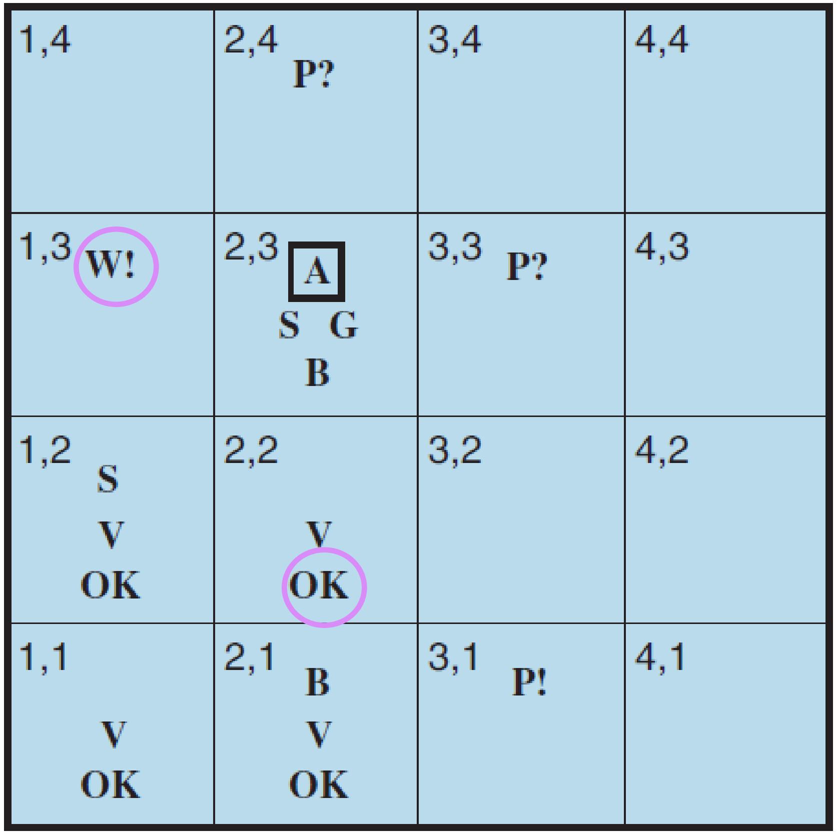

[*Stench*, *None*, *None*, *None*, *None*]

The wumpus is in [1, 3].

More Inference

1,4	2,4 P?	3,4	4,4
1,3 W!	2,3 A S G B	3,3 P?	4,3
1,2 S V OK	2,2 V OK	3,2	4,2
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[*Stench, None, None, None, None*]

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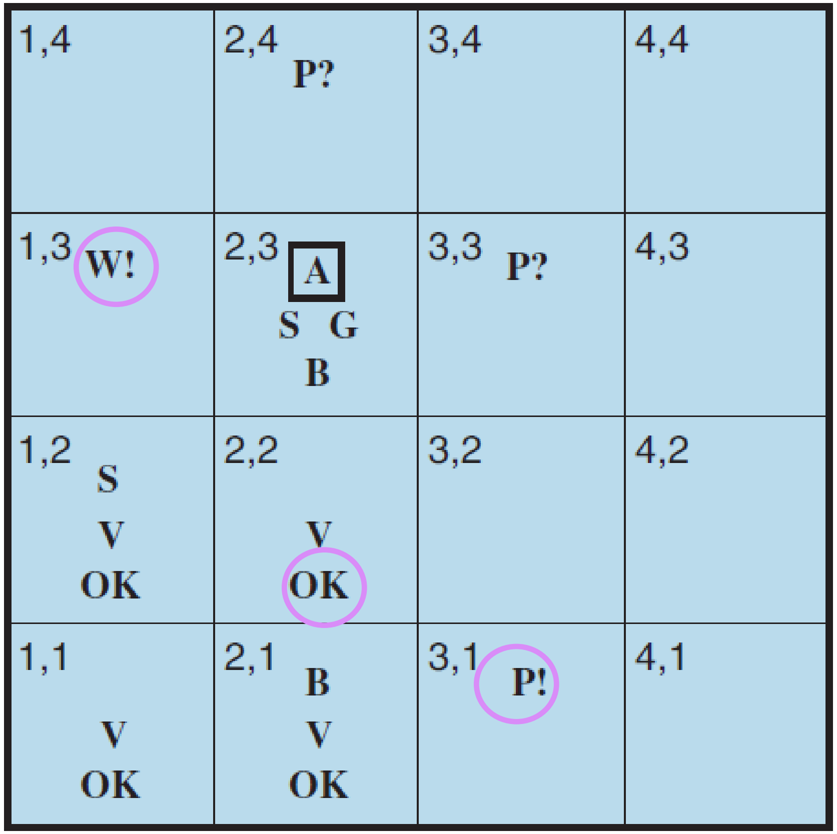

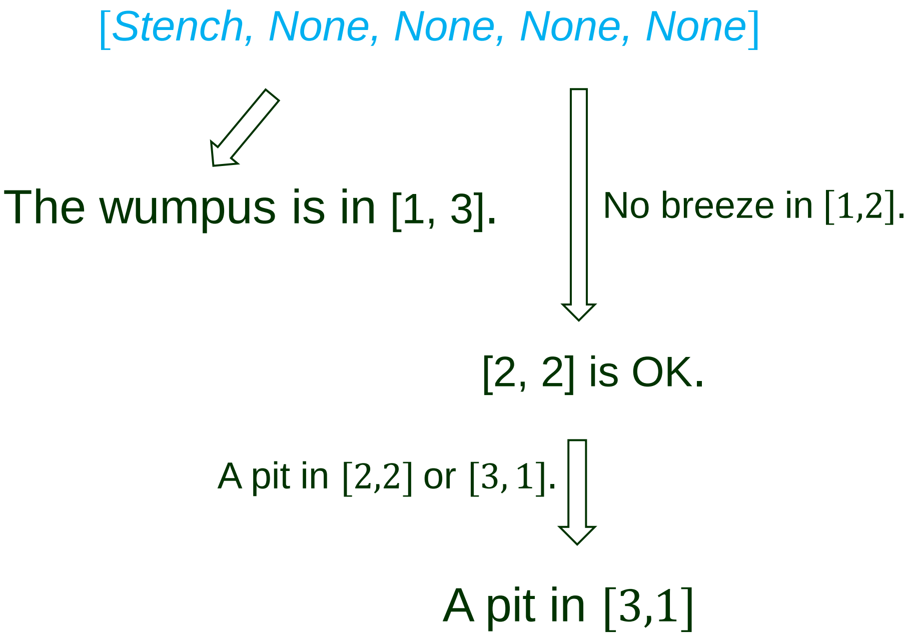

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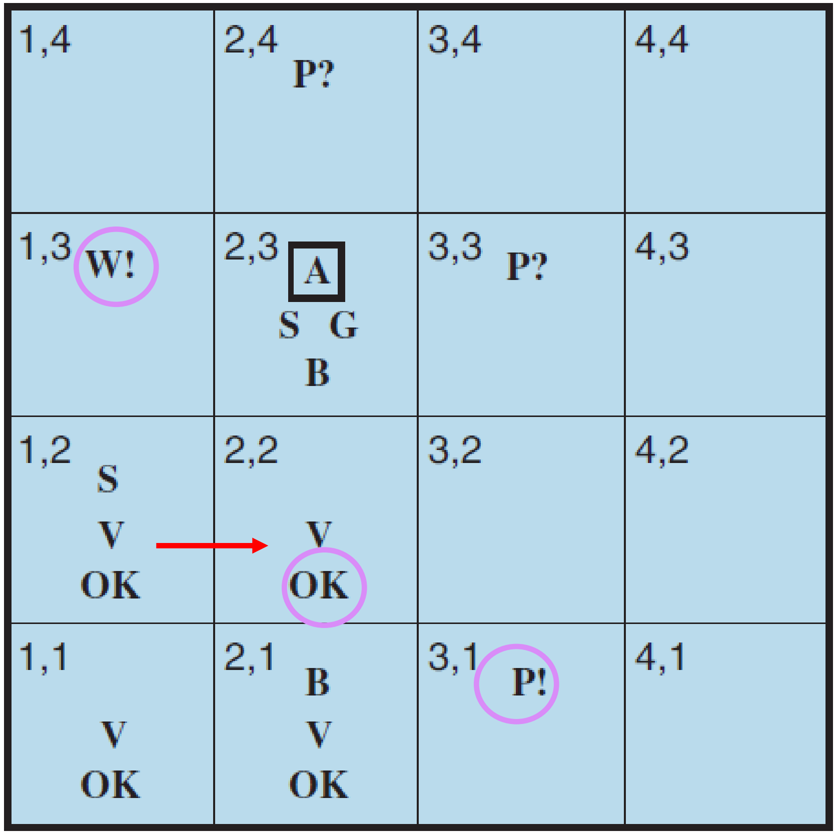

1,4	2,4 P?	3,4	4,4
1,3 W!	2,3 A S G B	3,3 P?	4,3
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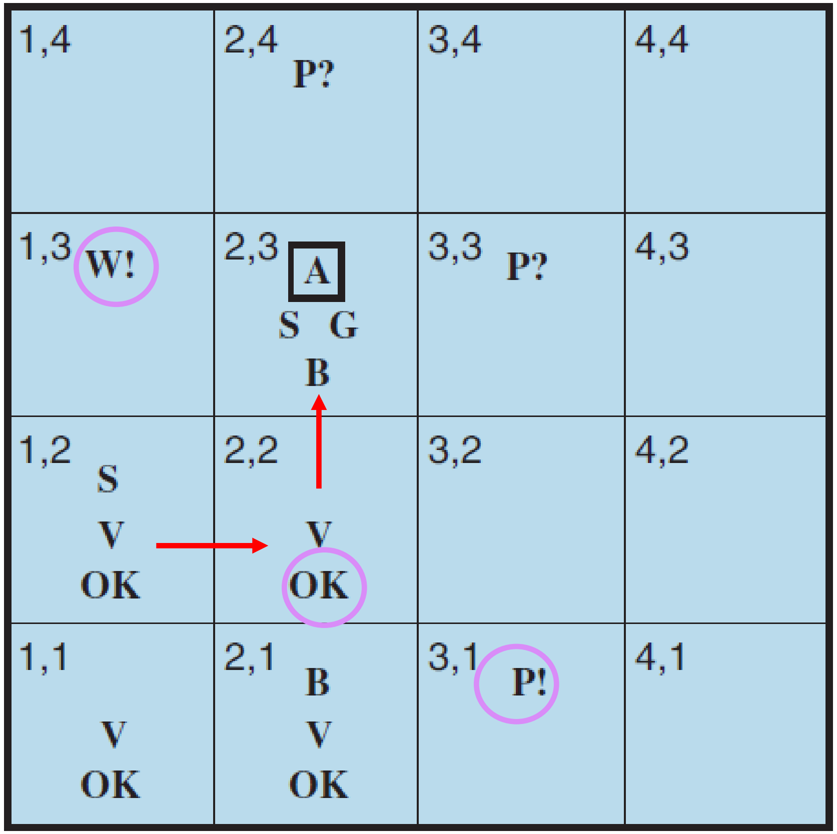

1,4	2,4 P?	3,4	4,4
1,3 W!	2,3 A S G B	3,3 P?	4,3
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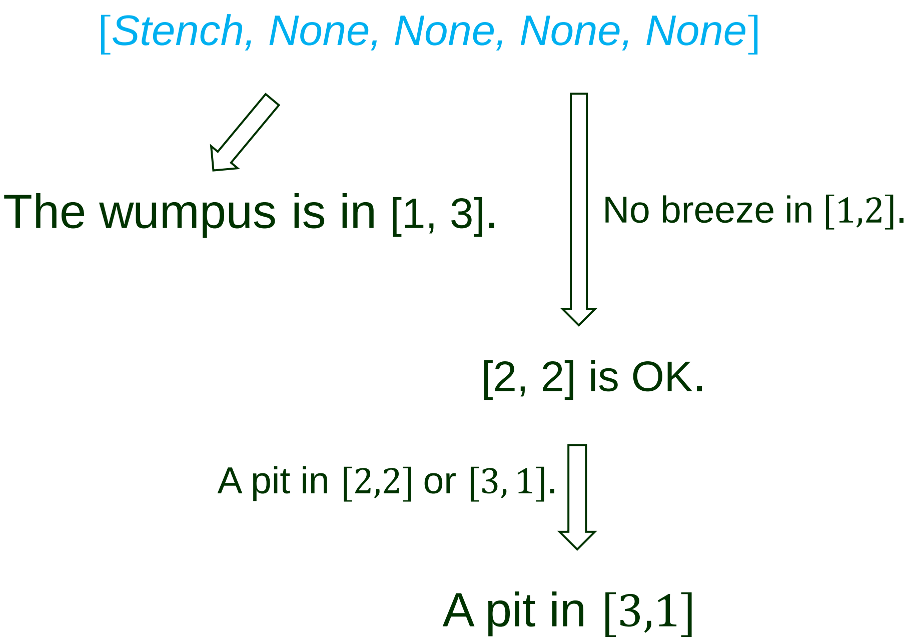

[Stench, None, None, None, None]

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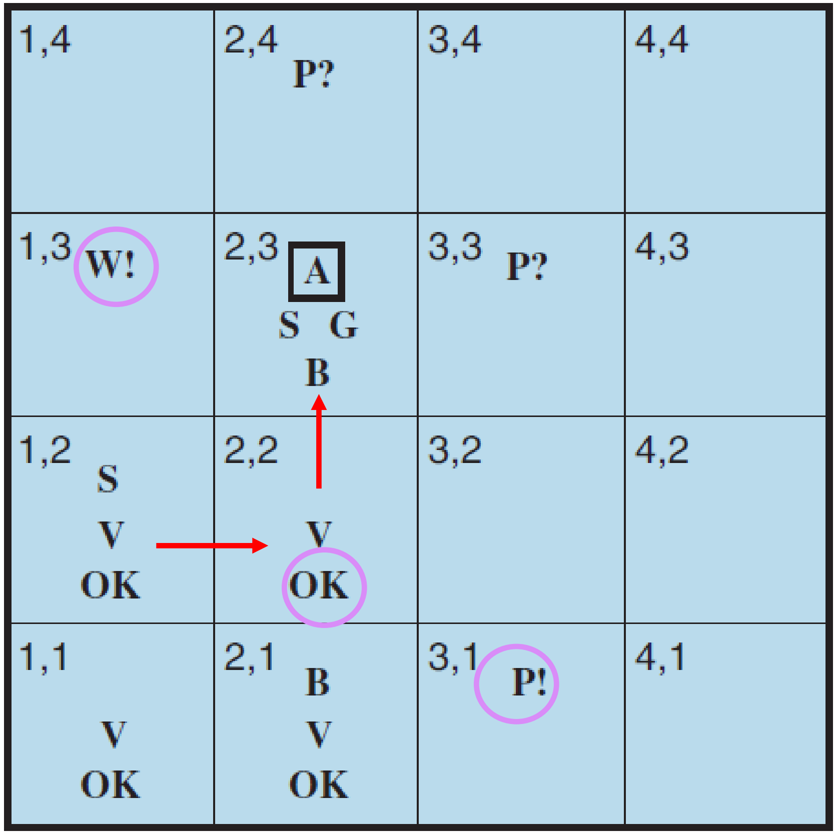

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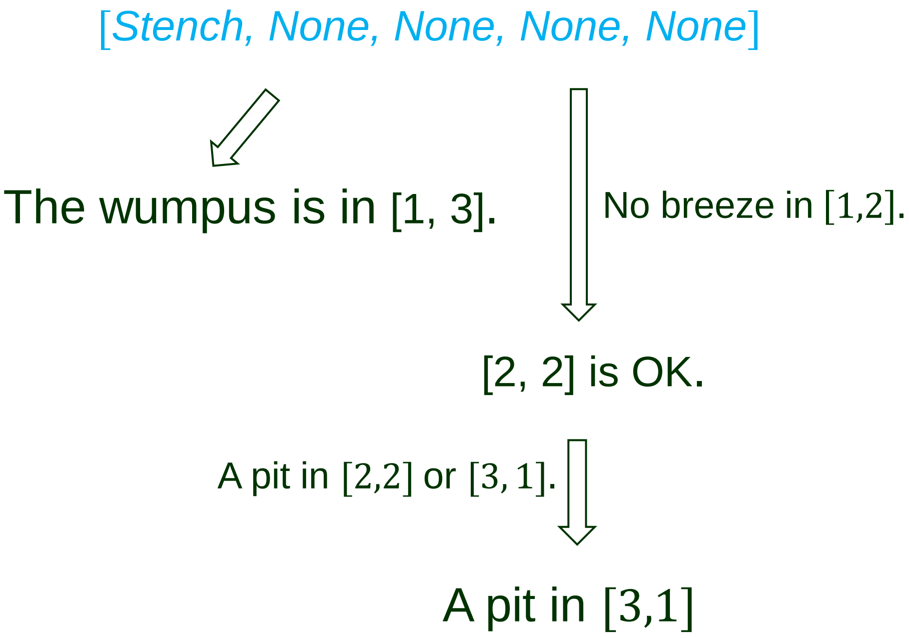

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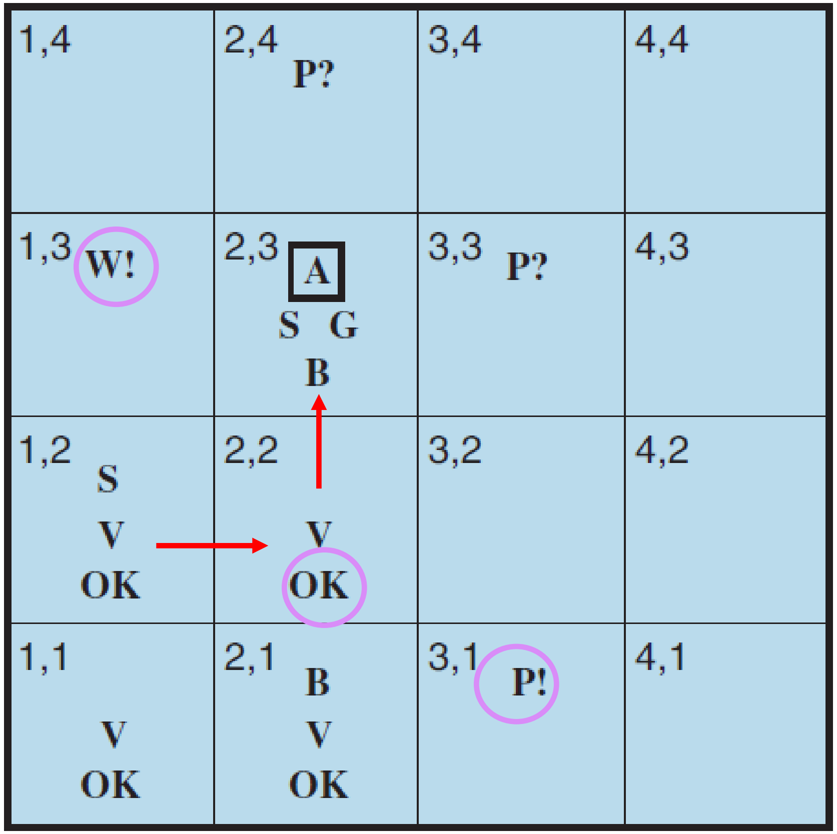

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A conclusion drawn is guaranteed if the available information is correct.

- Moves to (2, 2).
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III. Logic

- A systematic study of rules of inference.
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Every sentence must be either true or false in each possible world.

Model and Reasoning

Model m: assigns values to variables.

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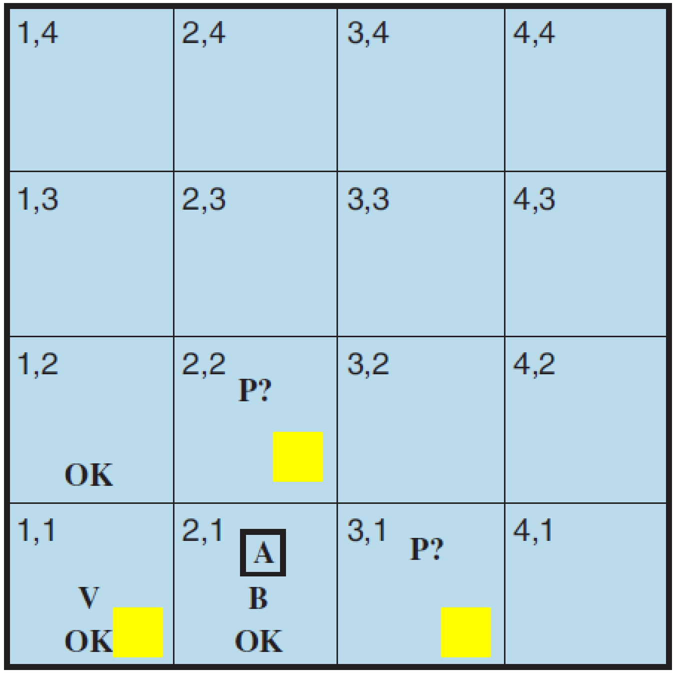
Example $x = 0$ entails $xy = 0$.

Back to the Wumpus World



Knowledge base (KB) includes

- All the rules.
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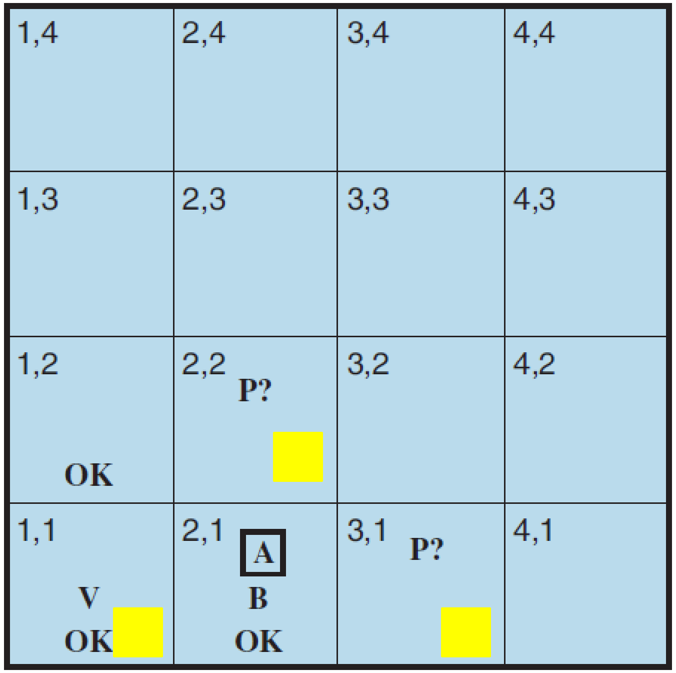

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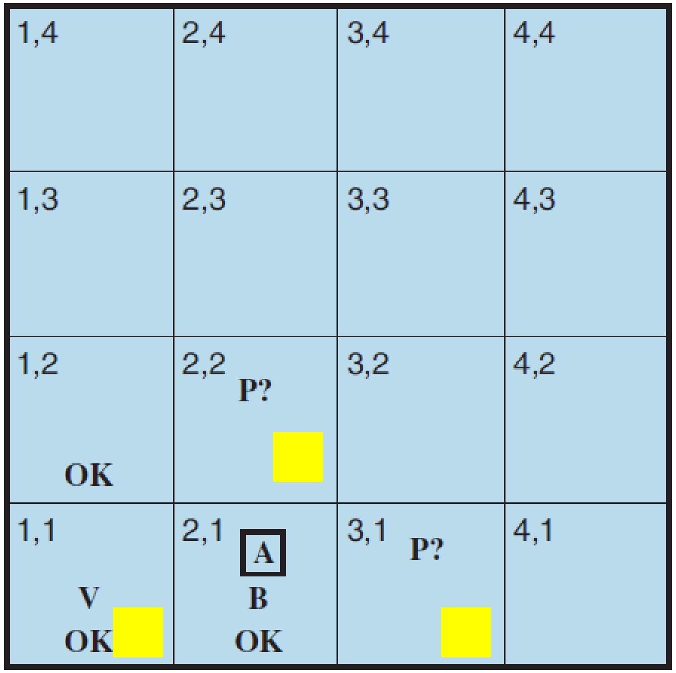

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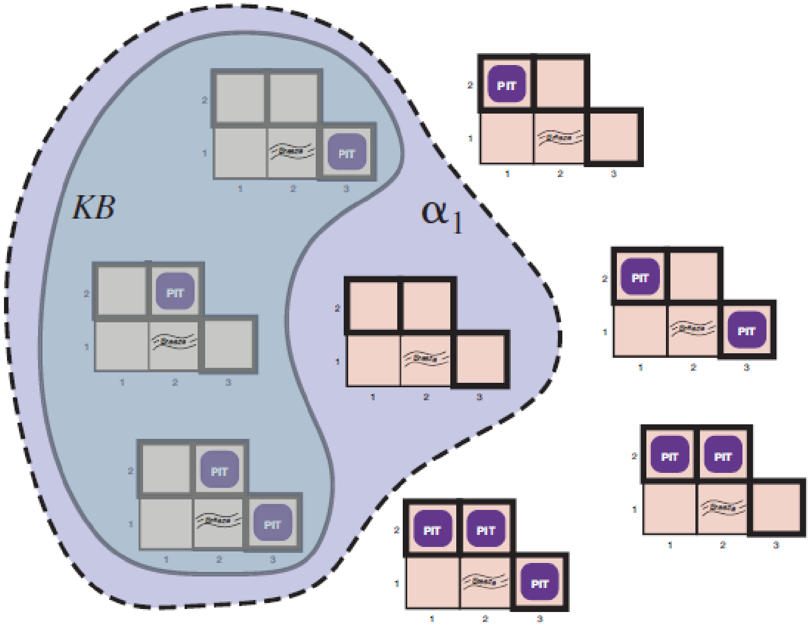
8 possibilities if ignoring the KB.

Which Neighbors Contain a pit?



8 possible models for the presence of pits in squares $[1,2]$, $[2,2]$, and $[3,1]$.

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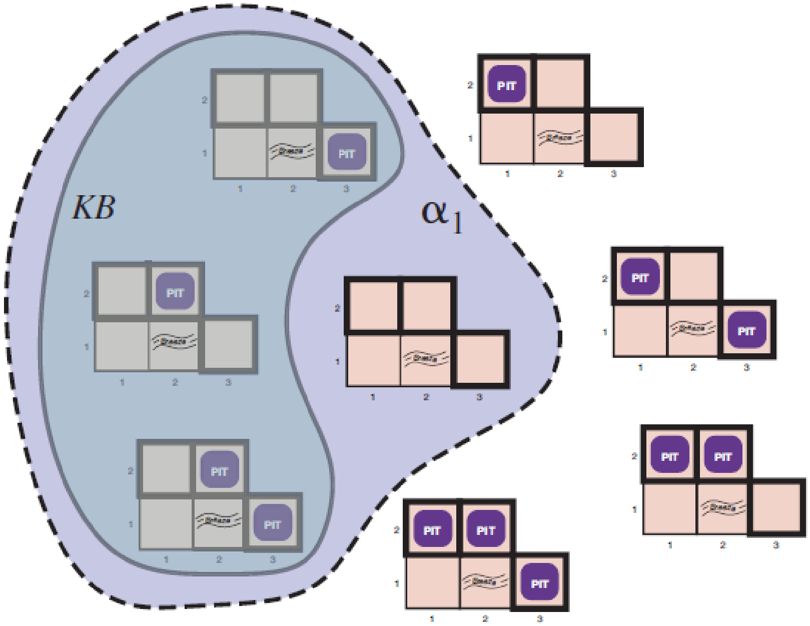

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3 models in which the KB is true given the two percepts.

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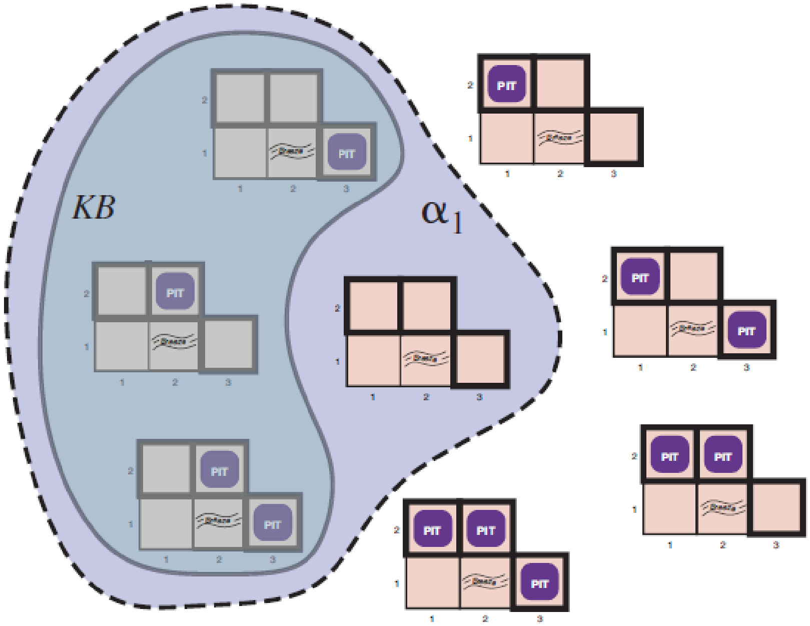

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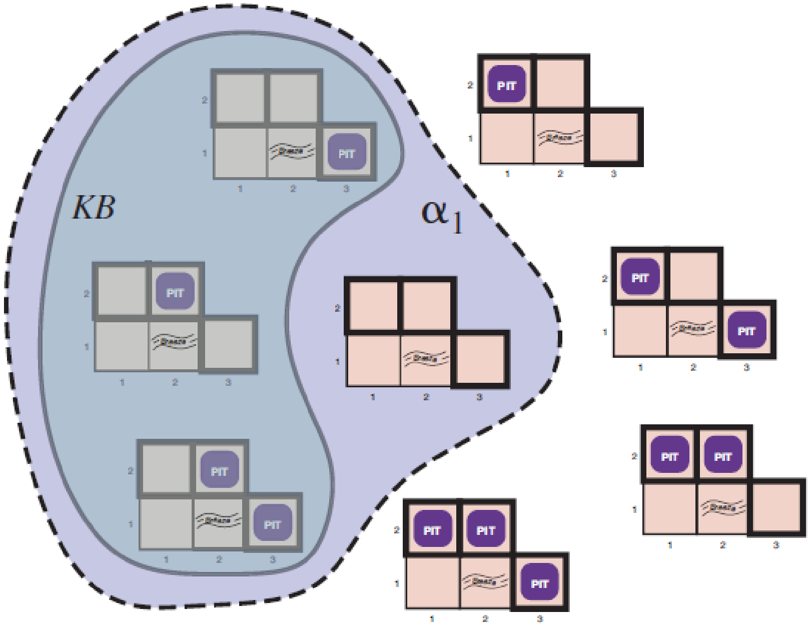

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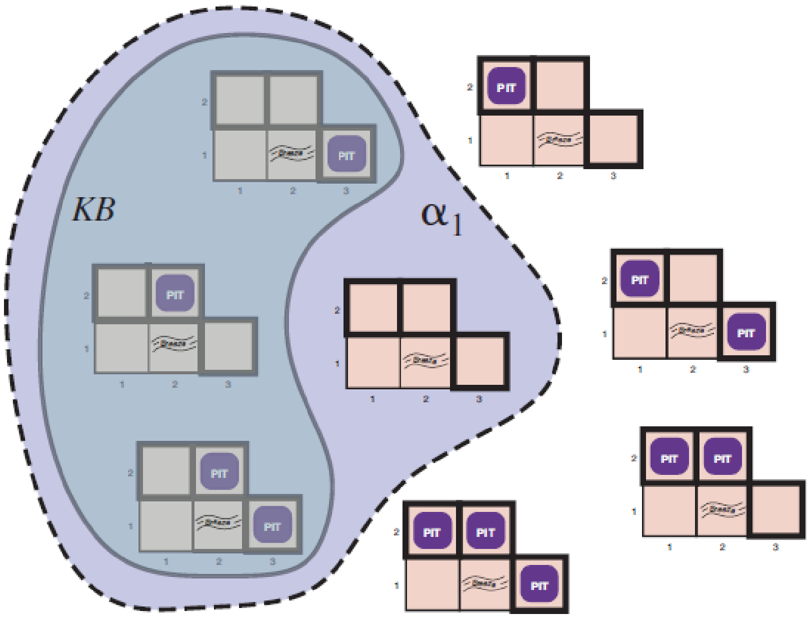

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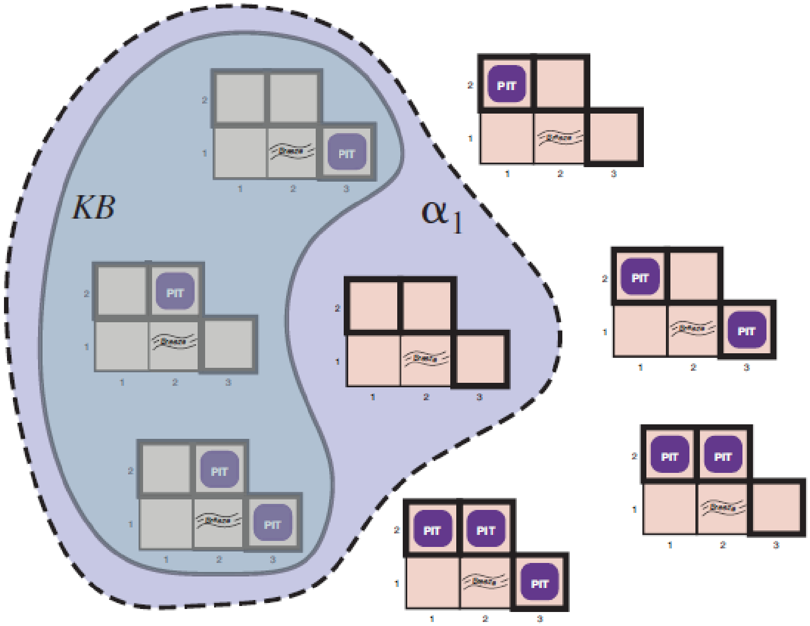

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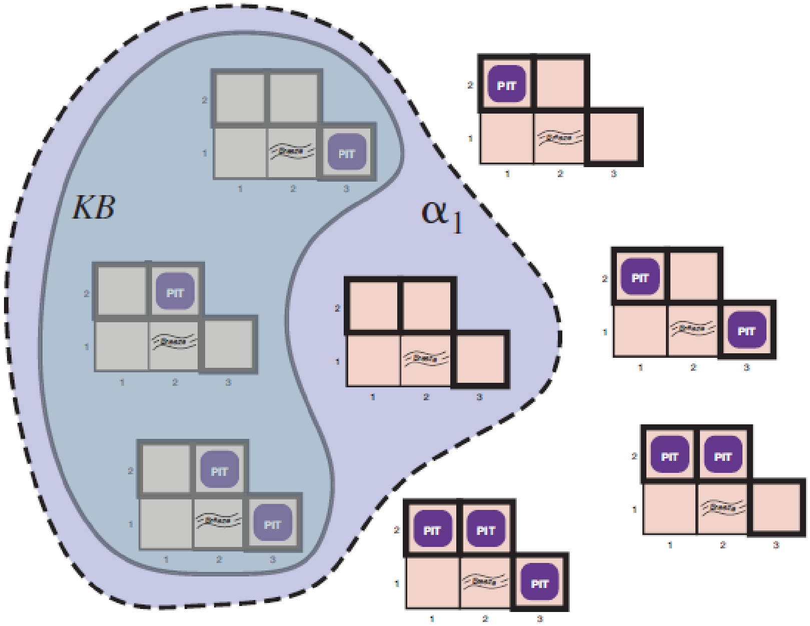

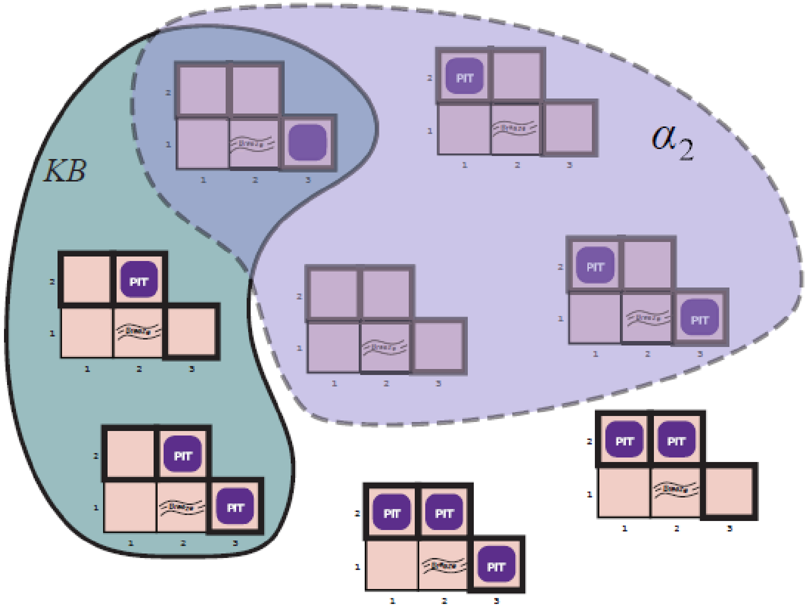

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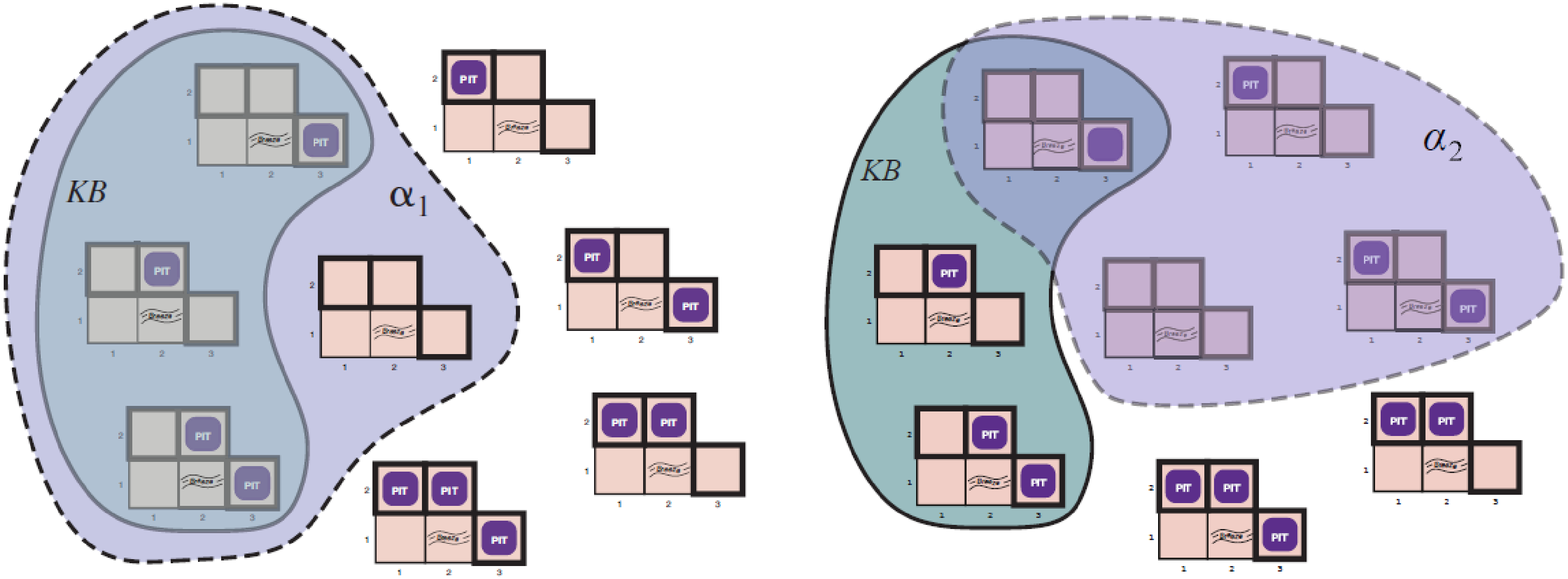

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$KB \models \alpha_1$ since $\boxed{M(KB) \subseteq M(\alpha_1)}$

$KB \not\models \alpha_2$ since $M(KB) \not\subseteq M(\alpha_2)$

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♣ It is *complete* if it can derive any sentence that is entailed, that is,

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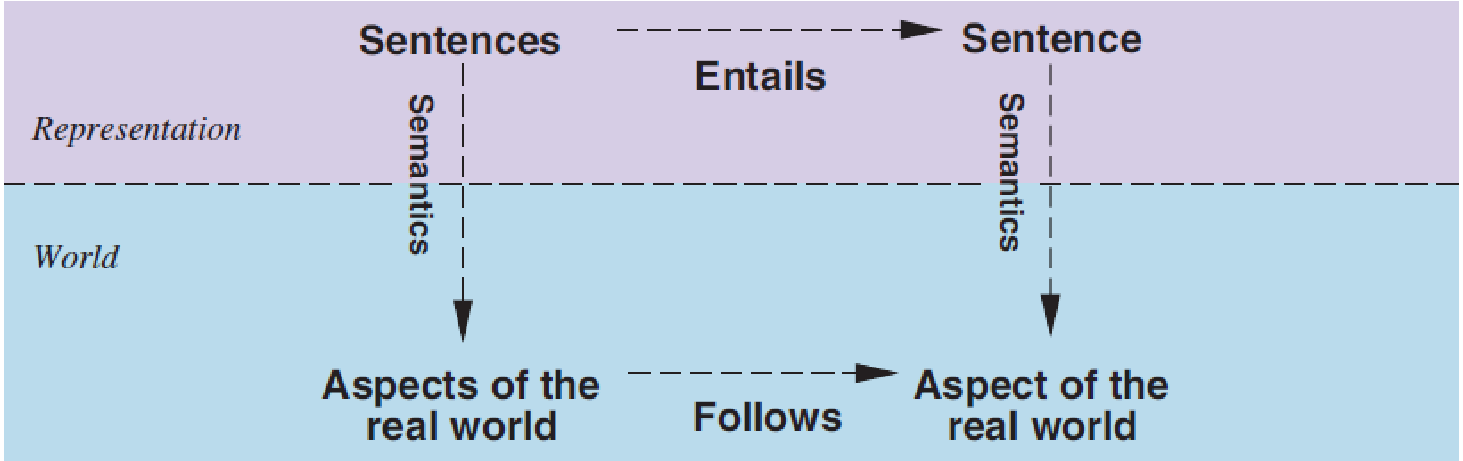
Logical Reasoning

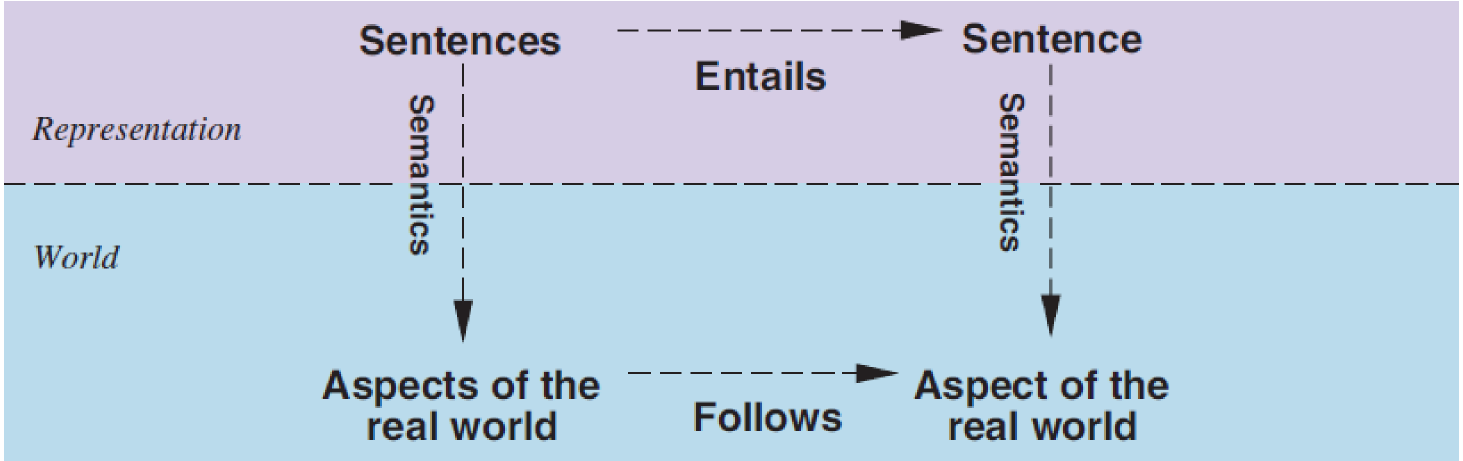
A process whose conclusions are guaranteed to be true in any world in which the premises (the *KB* in this case) are true.



Correspondence between world and representation

Logical Reasoning

A process whose conclusions are guaranteed to be true in any world in which the premises (the *KB* in this case) are true.



Correspondence between world and representation