

Logical Agents

CH 7

Slides courtesy of Andrea Thomaz
and Maithilee Kunda

Overview

- * **Reflex** agents

- * very little knowledge

- * **Goal-based** agents

- * specific kind of knowledge (transition model, heuristics, ...)

- * **Knowledge-based** agents

- * more generic kind of knowledge, and generic ways to combine == more flexible agents

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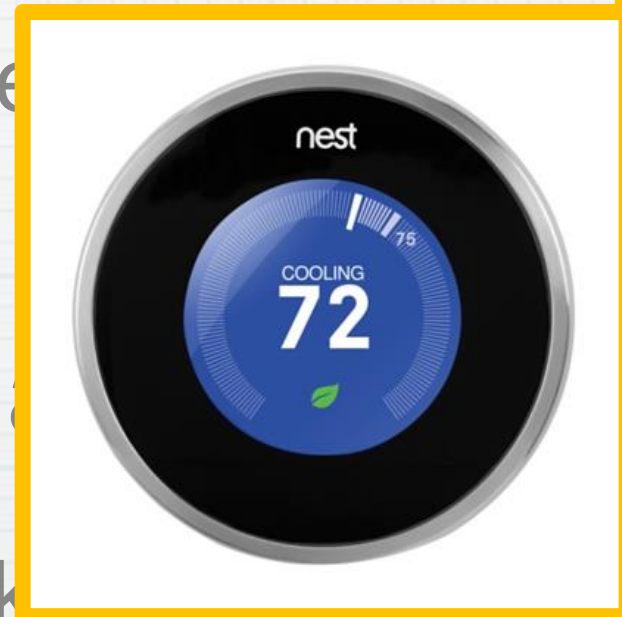
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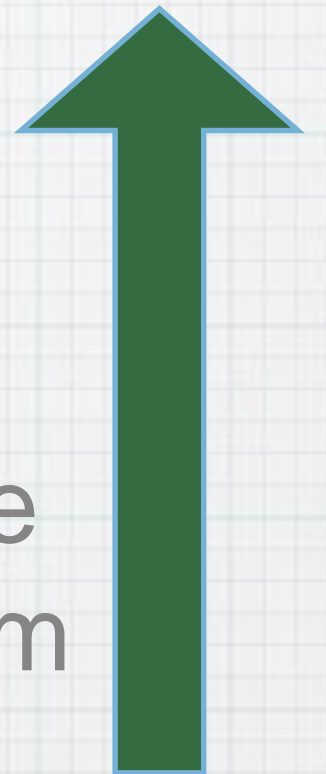
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Overview

- * Intro basic Logical Agent Design
 - * Wumpus World -- example environment
 - * Concepts of Logic in General
 - * Propositional Logic
 - * Inferences with ProLog
-
- * First-order Logic
 - * Inferences with FOL

On the
Midterm



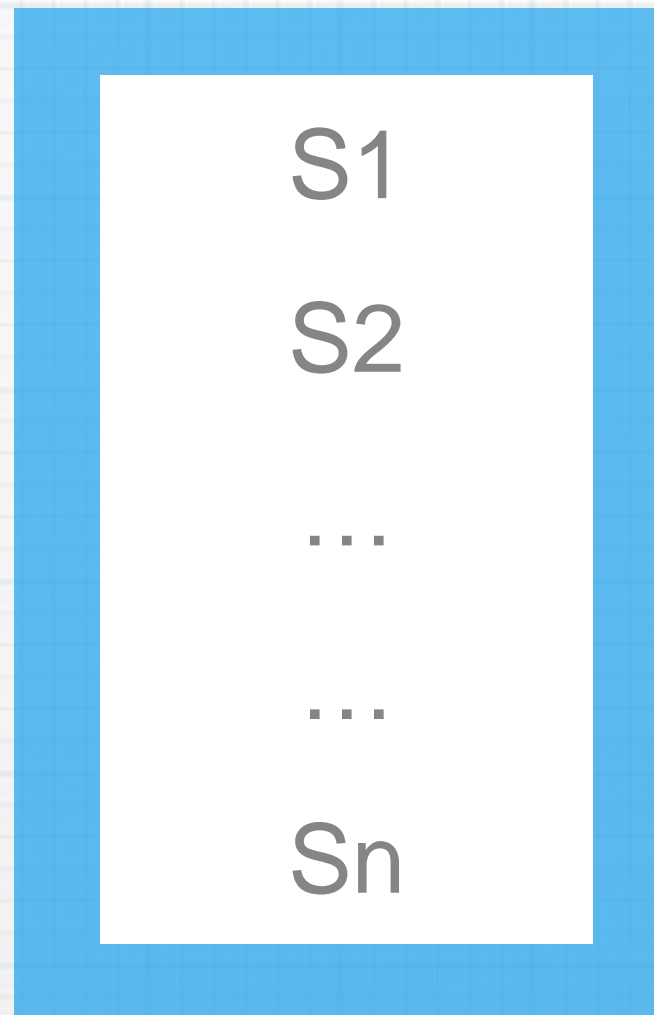
Knowledge-Based Agent Design

Knowledge Base (KB)

List of sentences, assertions about the world



Tell:
Add new
sentences
to the KB



Ask:
Answer some
query based on
current facts of
the KB

Simple KB-agent

```
function KB-AGENT(percept) returns an action  
  static: 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
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The agent must be able to:

- Represent states, actions, etc.

- Incorporate new percepts

- Update internal representations of the world

- Deduce hidden properties of the world

- Deduce appropriate actions

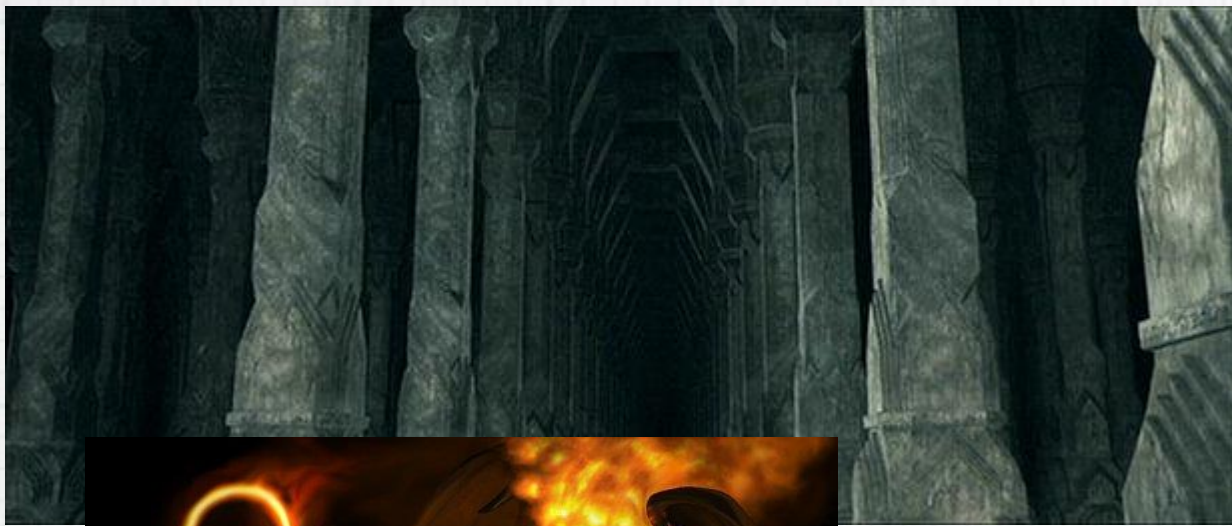
This is the big idea!

Logic Domain: The Wumpus World

- * System of caves and passageways
- * There is a wumpus!
It will eat you.
- * You have only one arrow.
- * There are bottomless pits.
- * There is gold.



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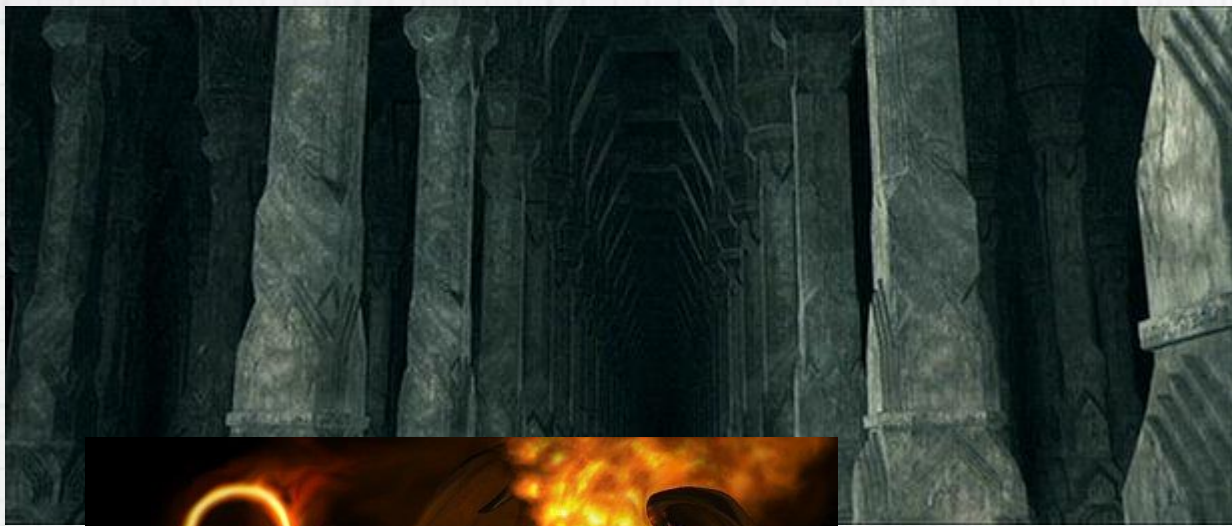


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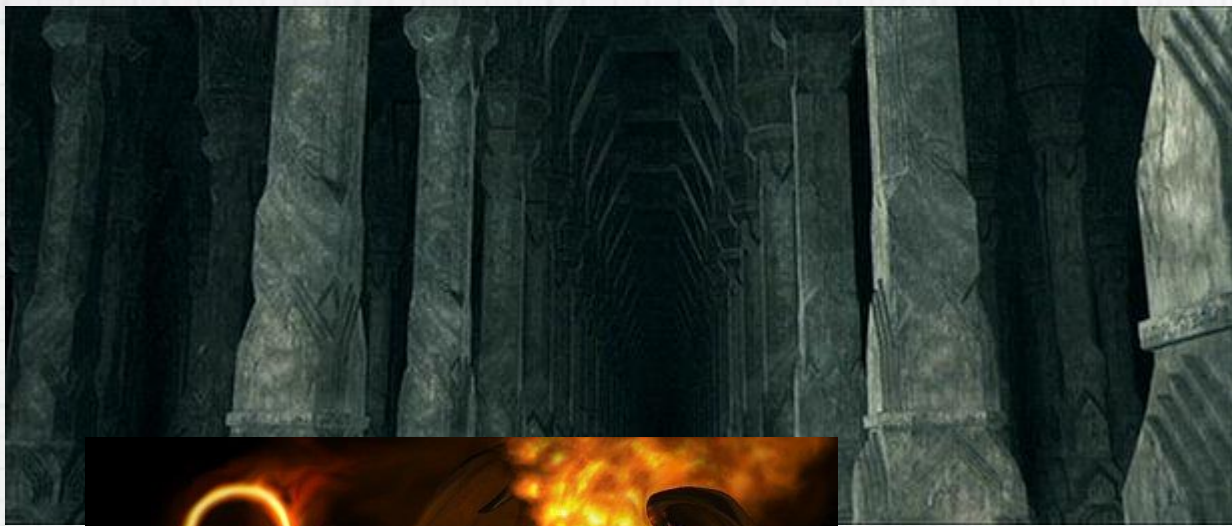
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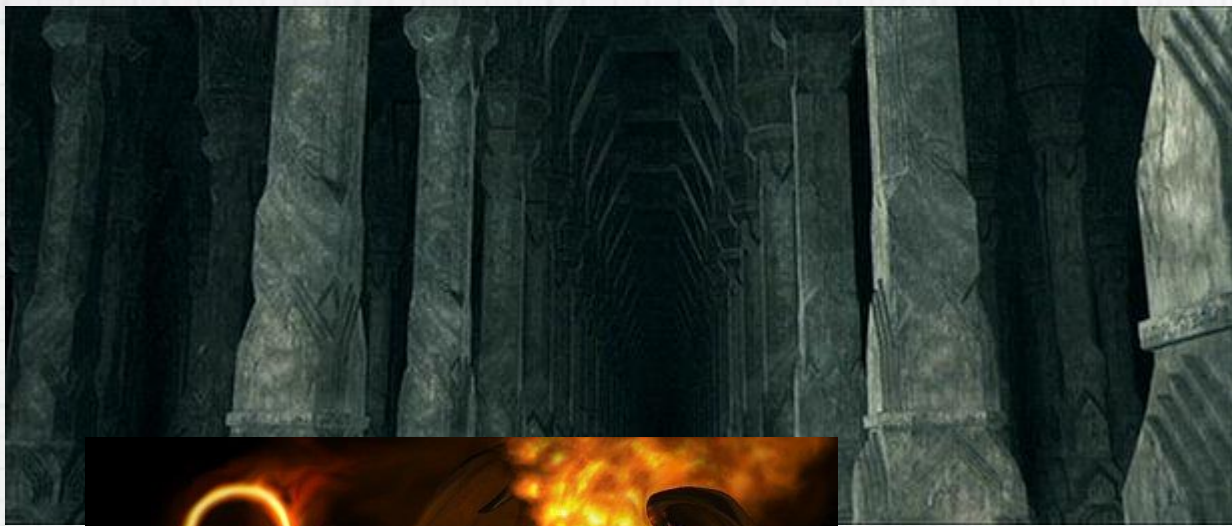


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- * You have only one ~~arrow.~~ wizard.



- * There are bottomless pits.
- * There is gold.

Wumpus World (PEAS)

Performance measure

gold +1000, death -1000
-1 per step, -10 for using the arrow

Environment

Squares adjacent to wumpus are smelly

Squares adjacent to pit are breezy

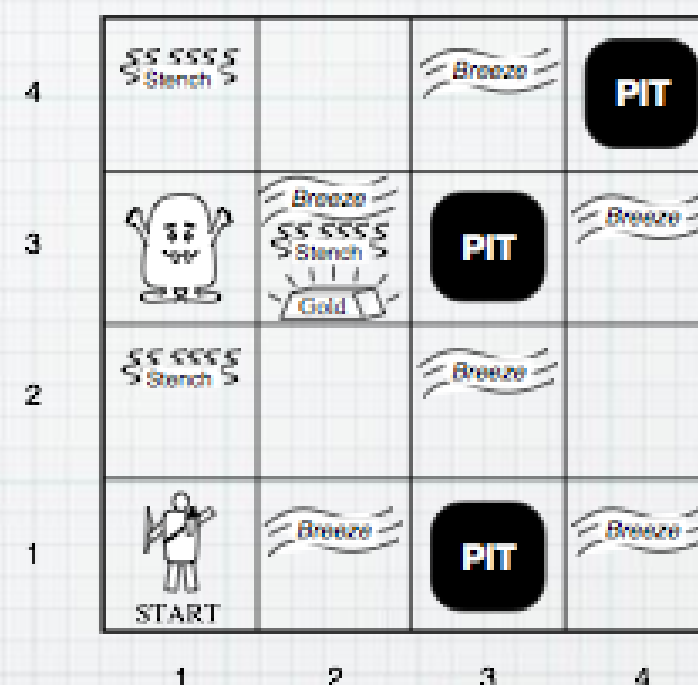
Glitter iff gold is in the same square

Shooting kills wumpus if you are facing it

Shooting uses up the only arrow

Grabbing picks up gold if in same square

Releasing drops the gold in same square



Actuators Left turn, Right turn,
Forward, Grab, Release, Shoot

Sensors Breeze, Glitter, Smell

Wumpus World

Observable??

Deterministic??

Episodic??

Static??

Discrete??

Single-agent??

Exploring in Wumpus World

	i=1	2	3	4
4				
3				
2				
j=1	OK <div>A</div>			

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Percept [1,1]: None

Action: Forward to [1,2]

Exploring in Wumpus World

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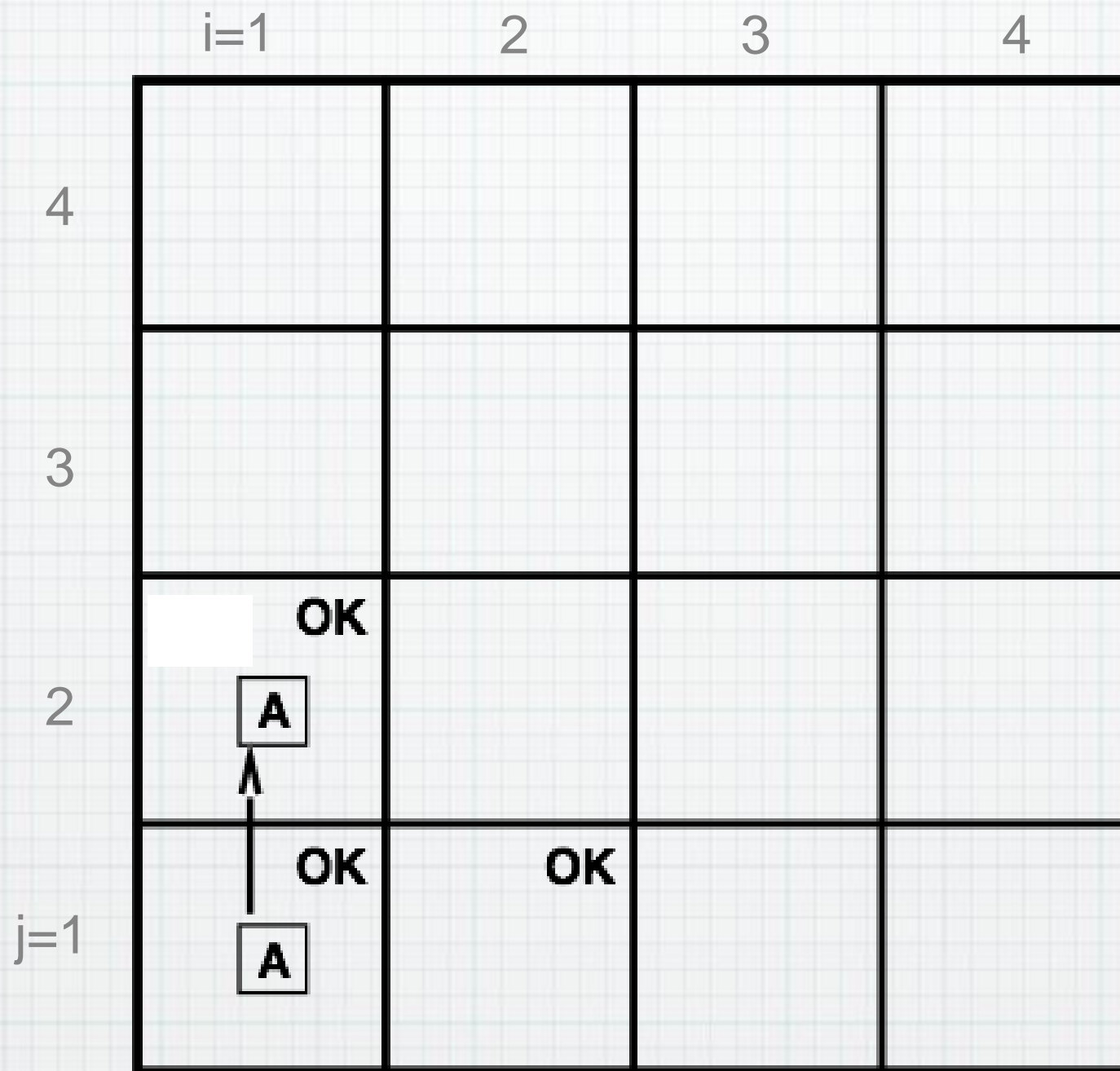
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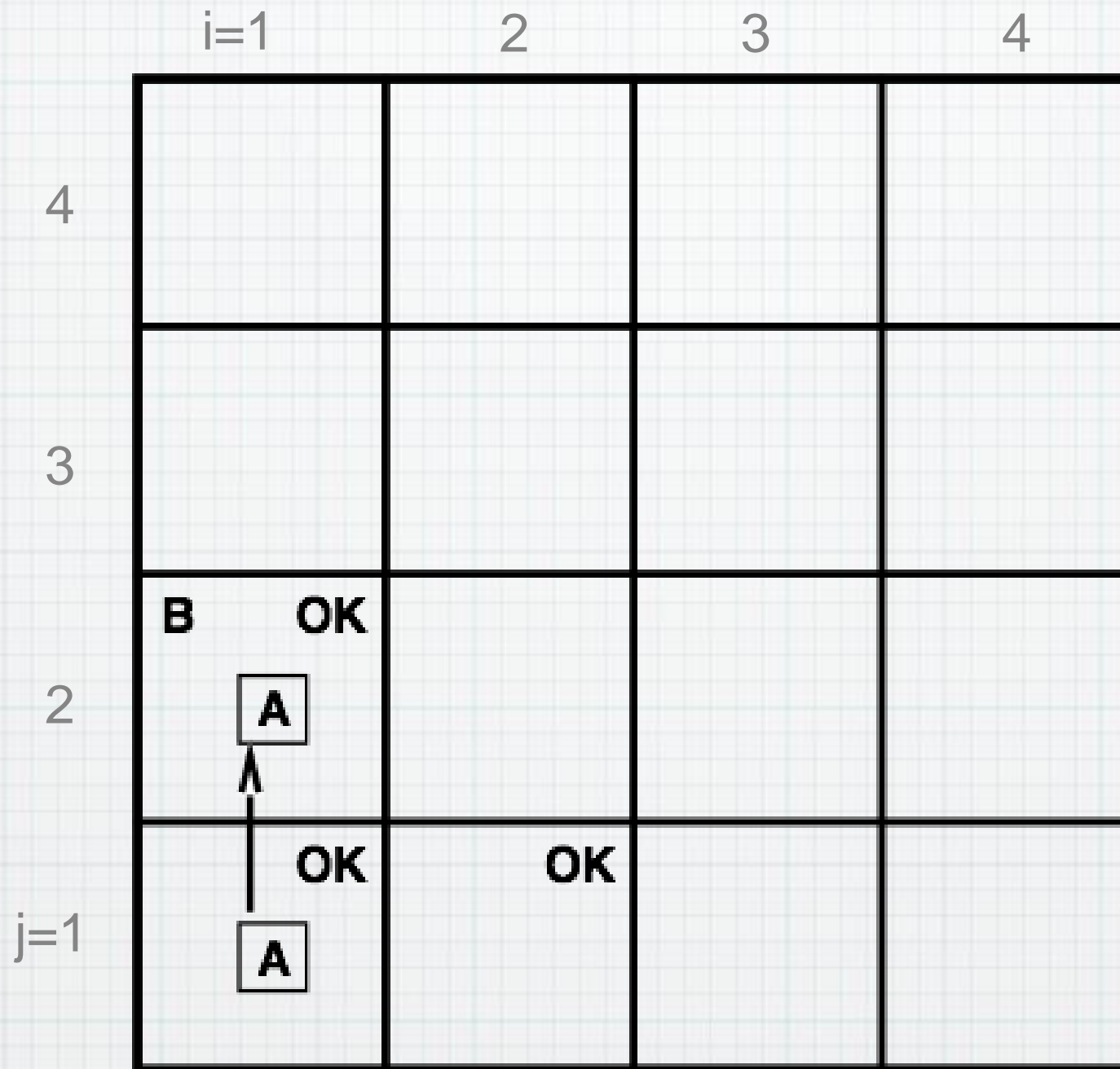
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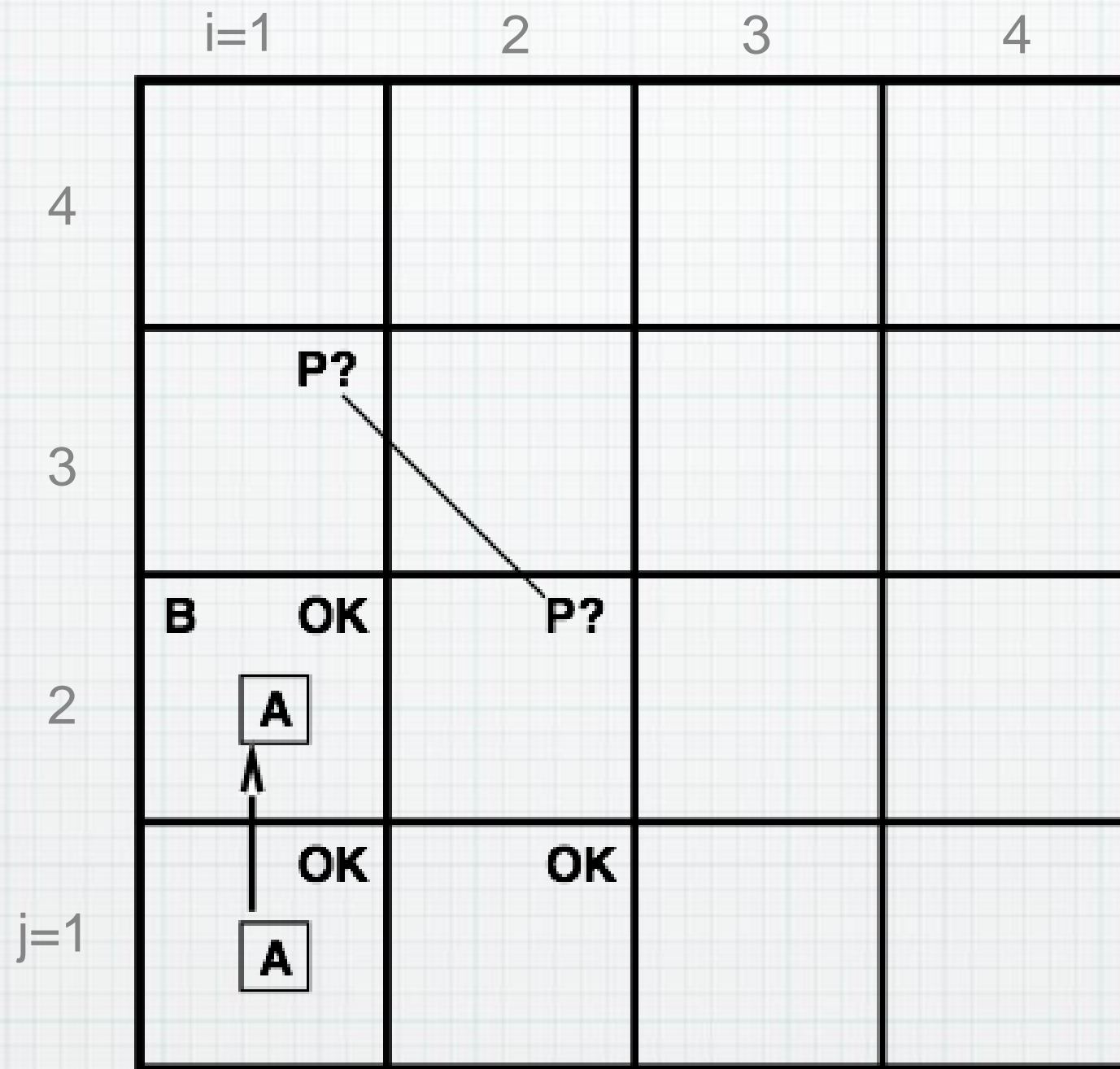
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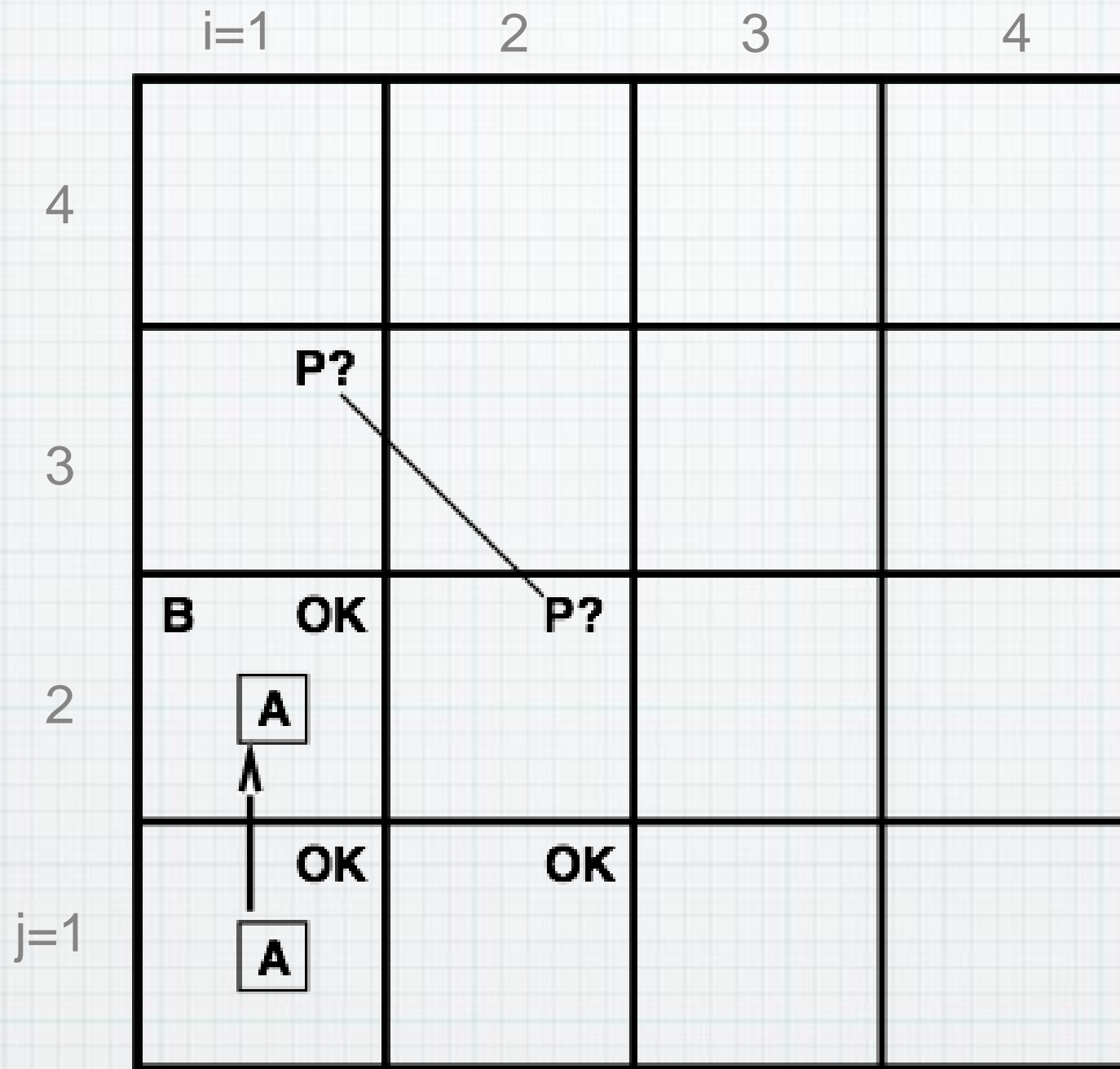
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Percept $[1,2]$: Breeze; Pit in $[1,3]$ or $[2,2]$

Action: turn back, go to $[2,1]$

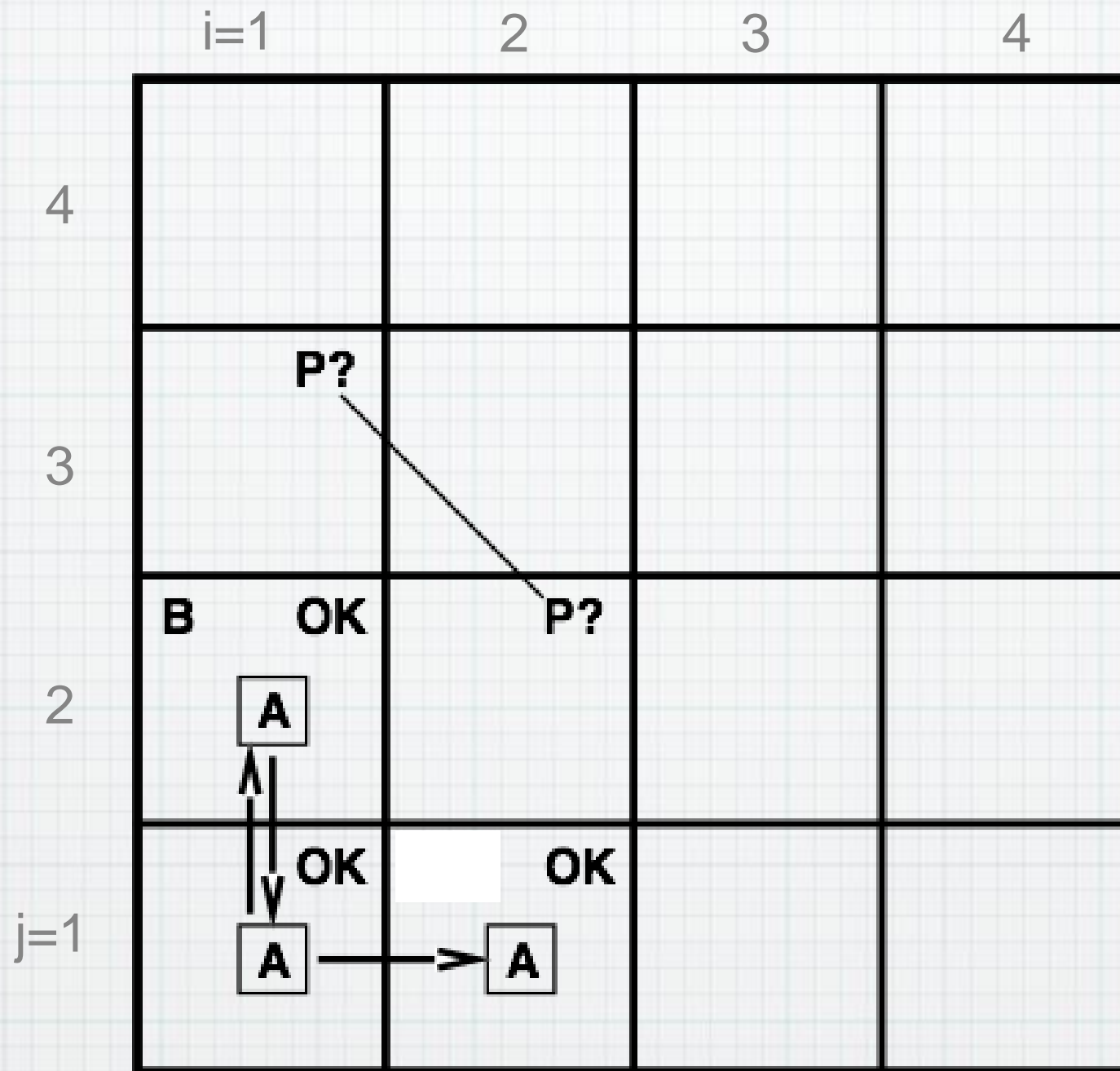
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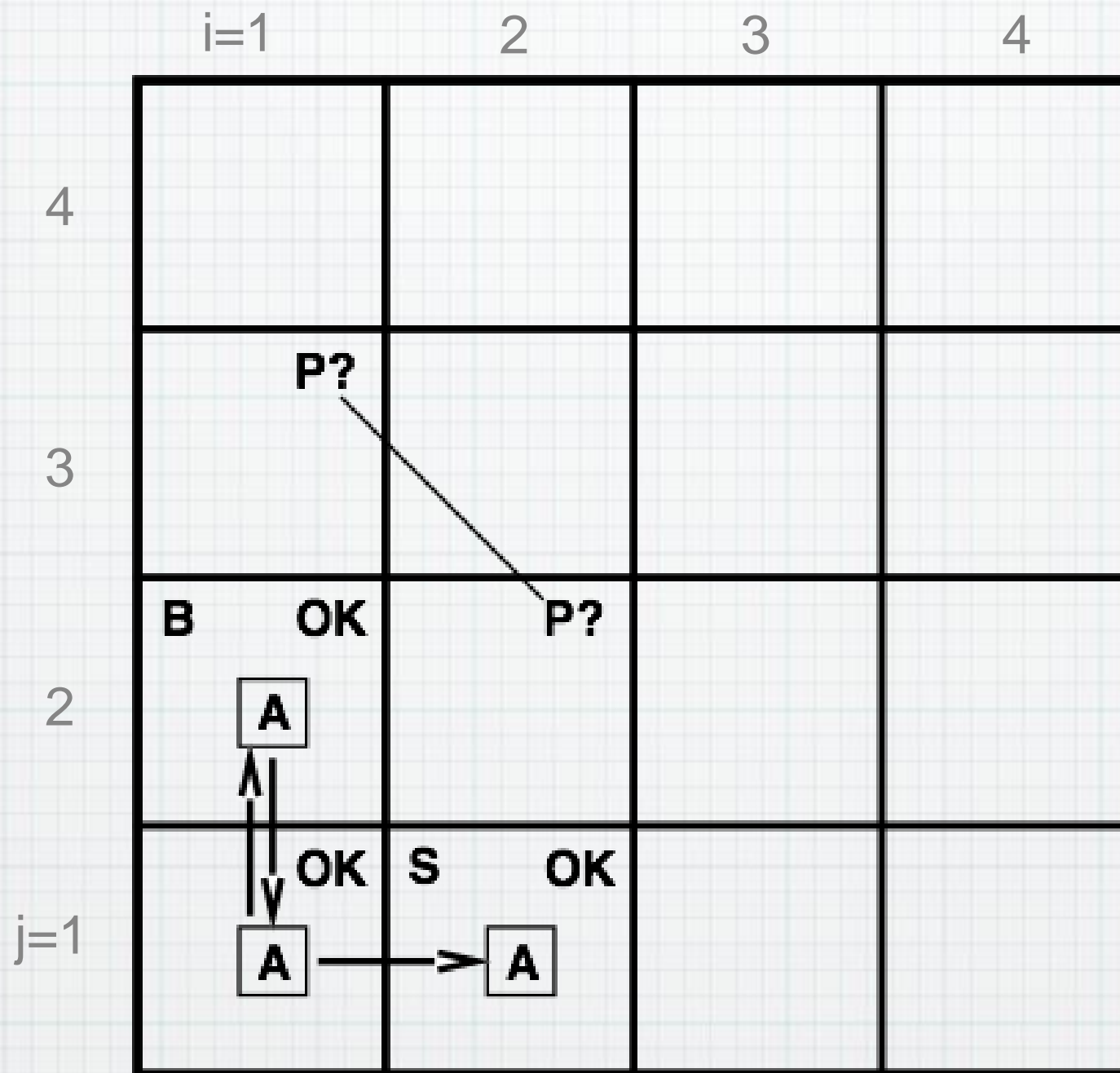
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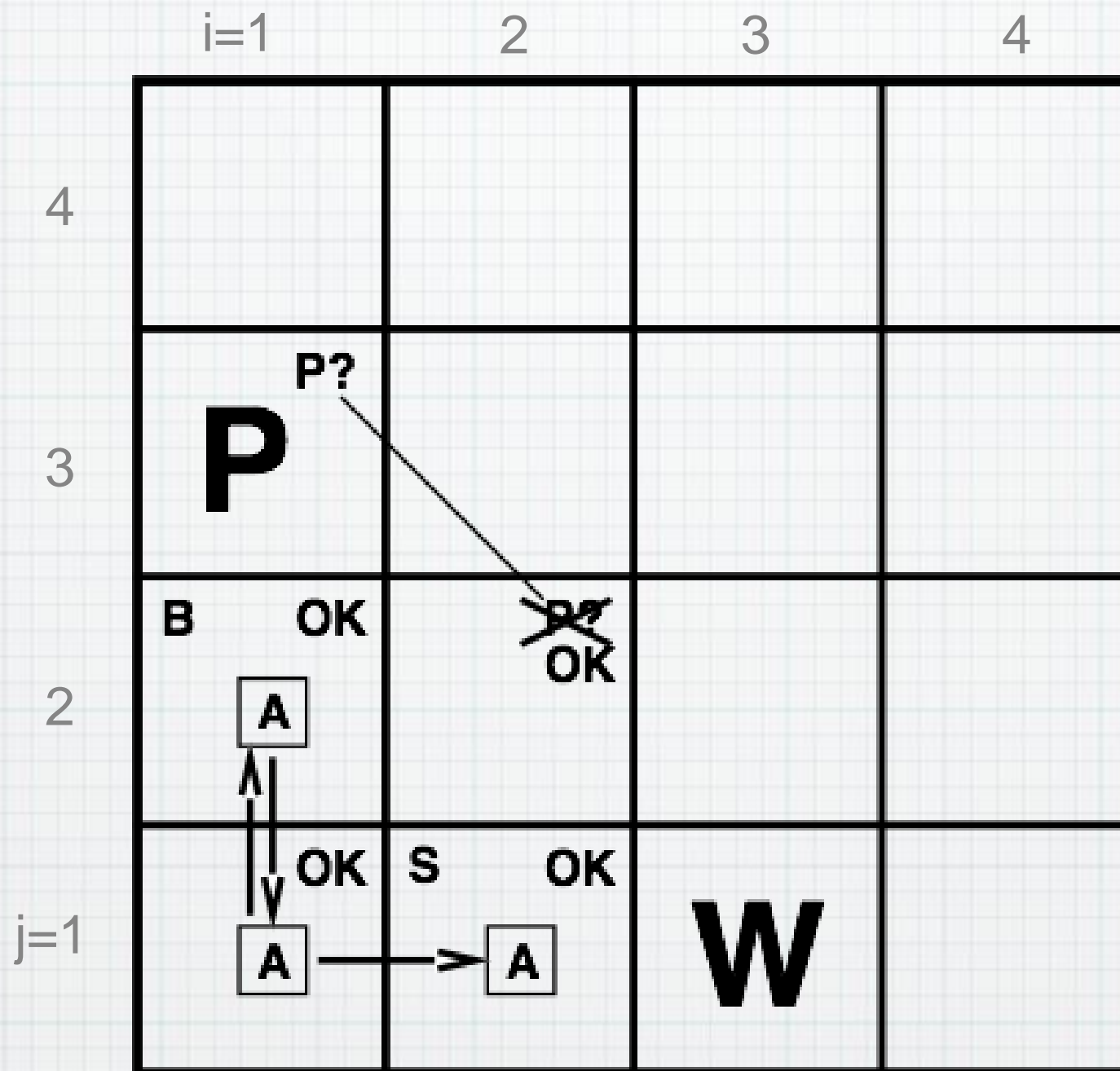


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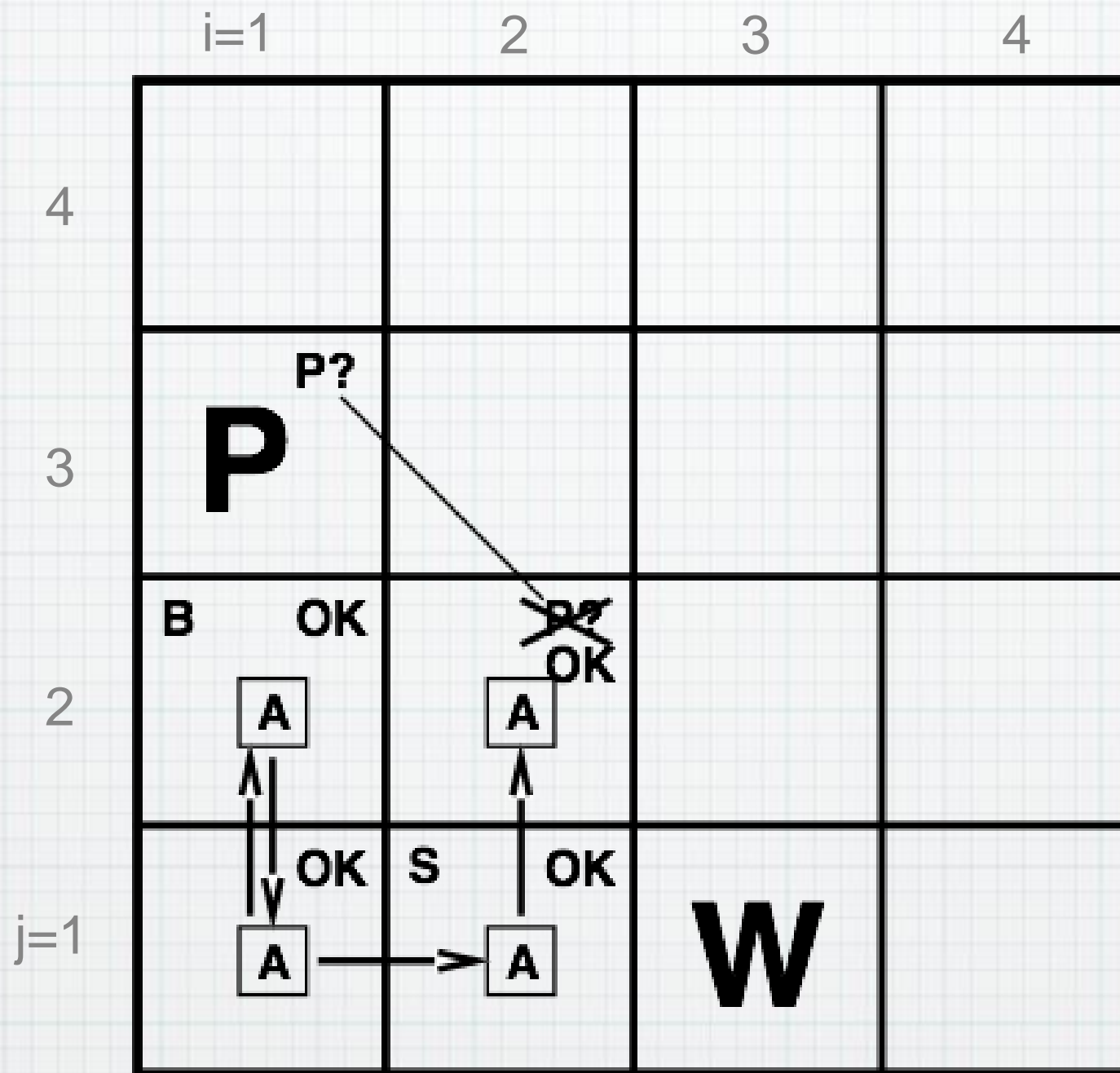
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Exploring in Wumpus World



Percept [2,1]: Smelly; W in [3,1] & [2,2] is OK

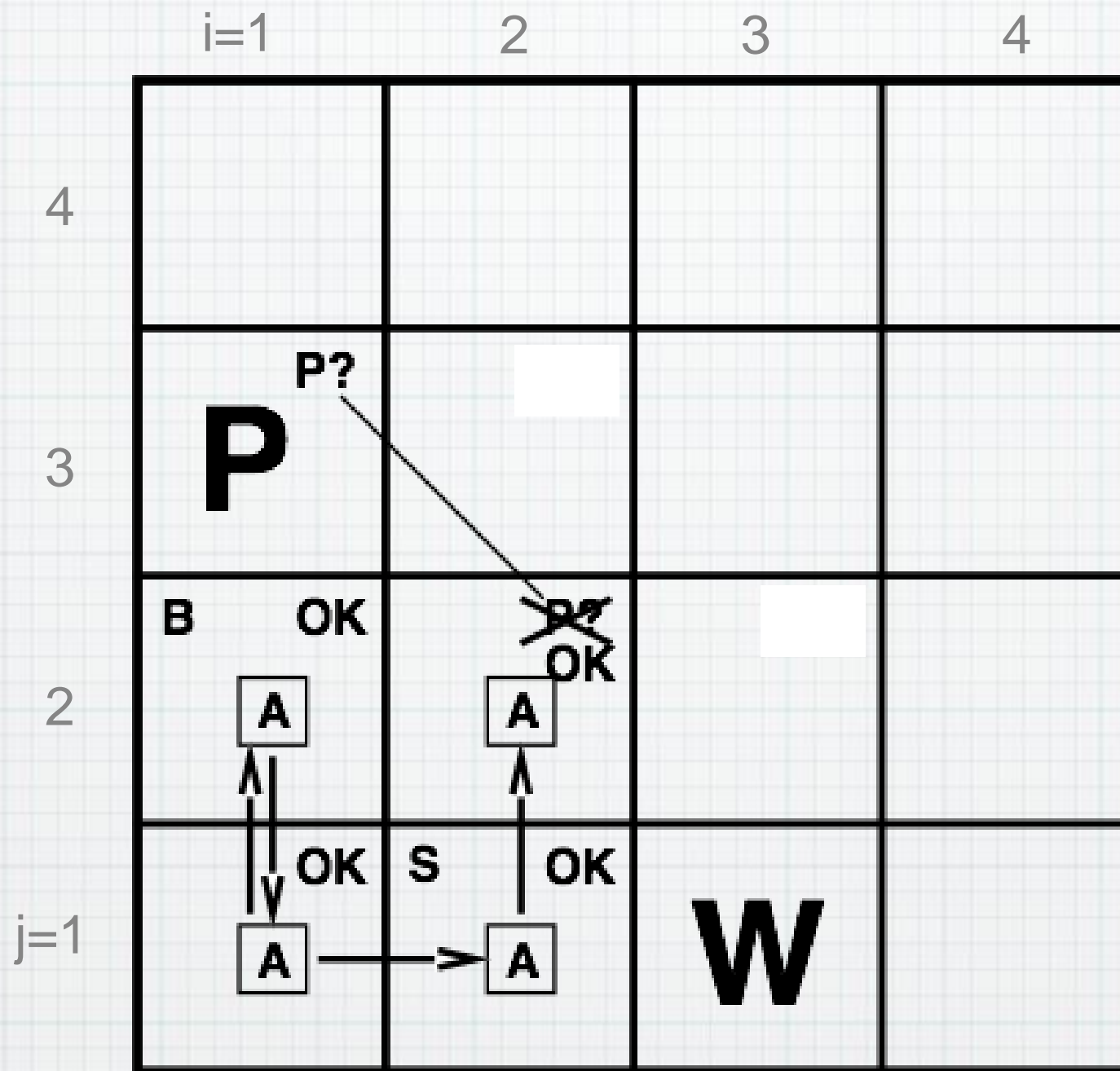
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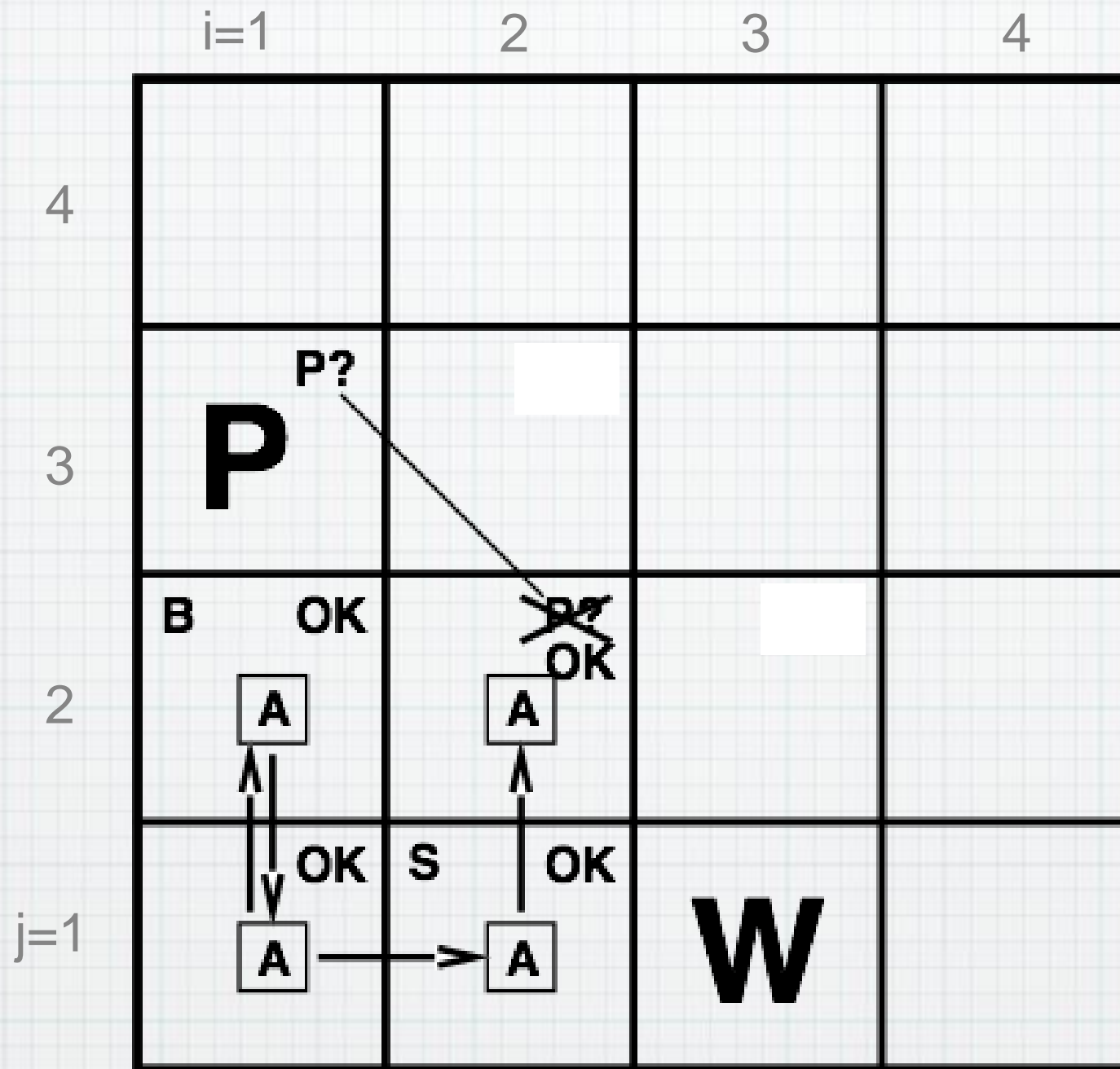
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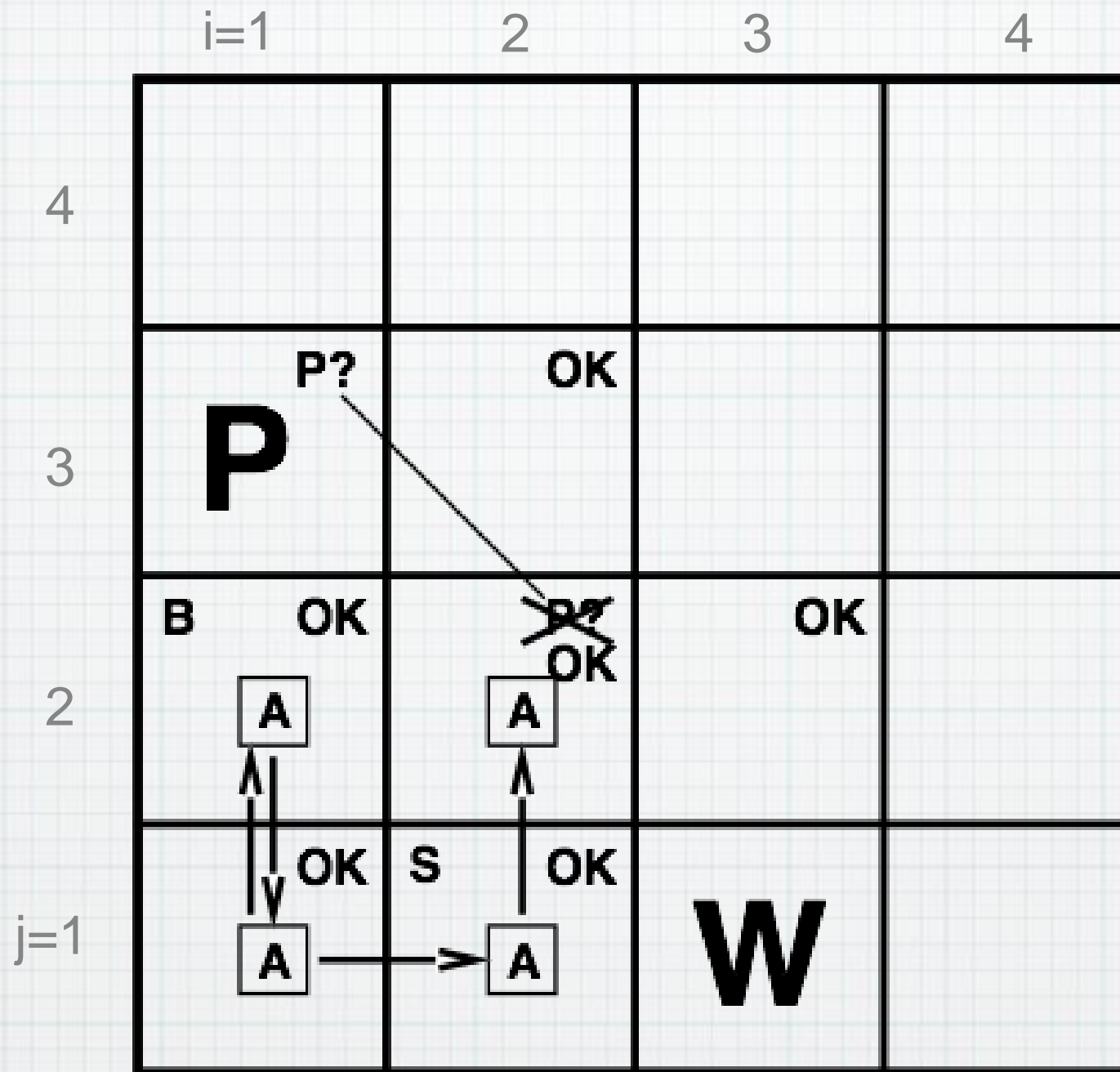


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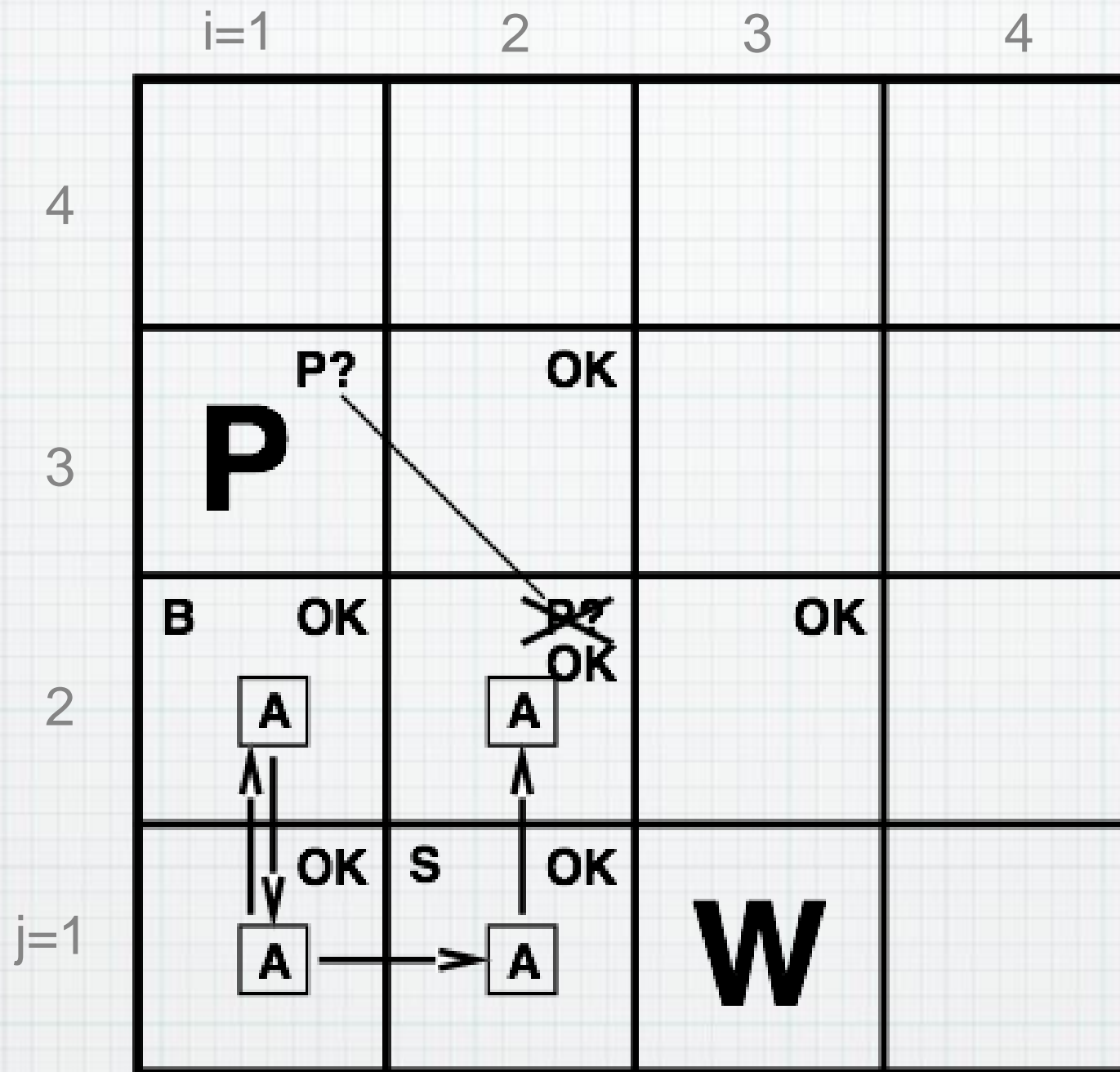
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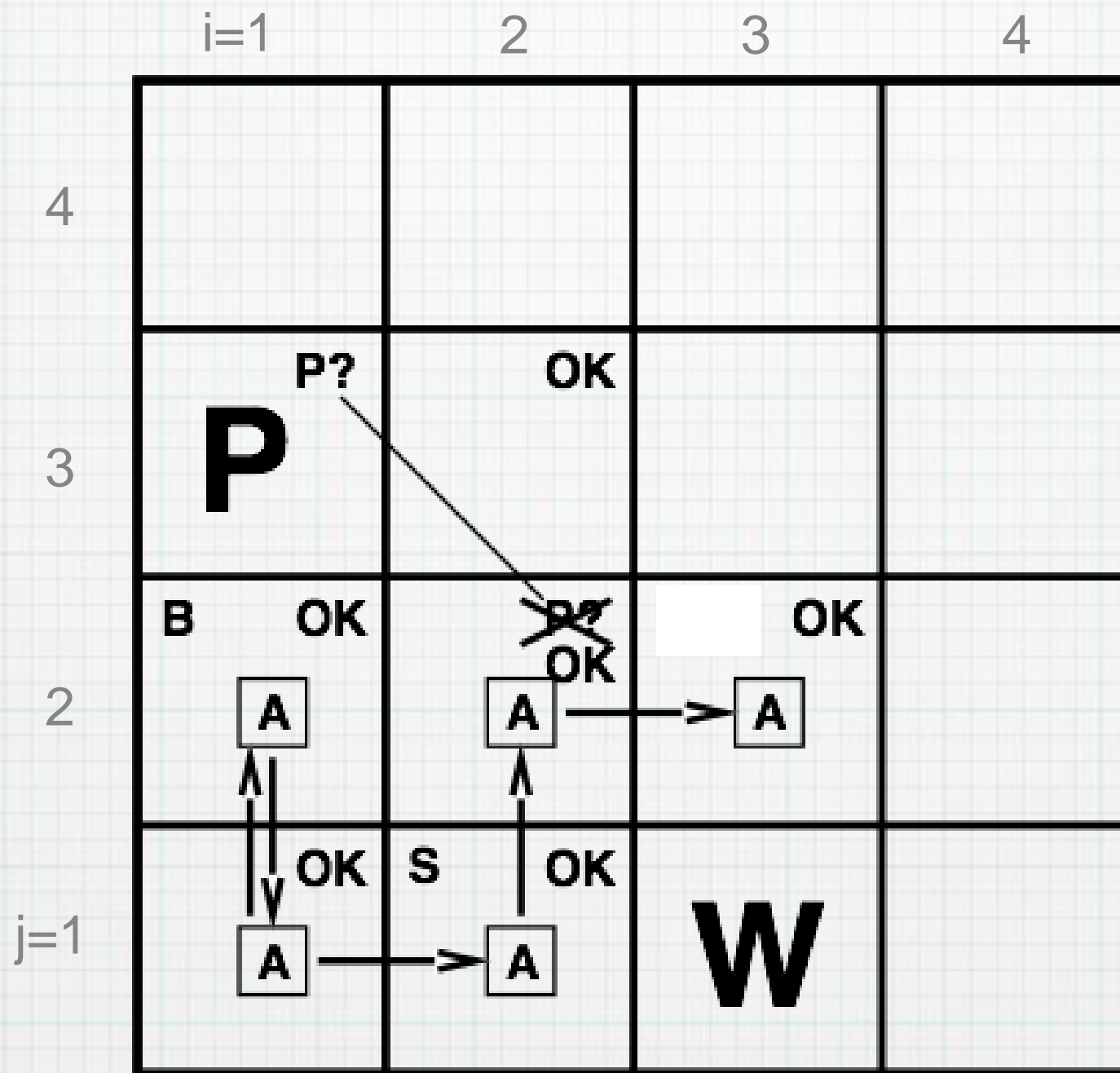
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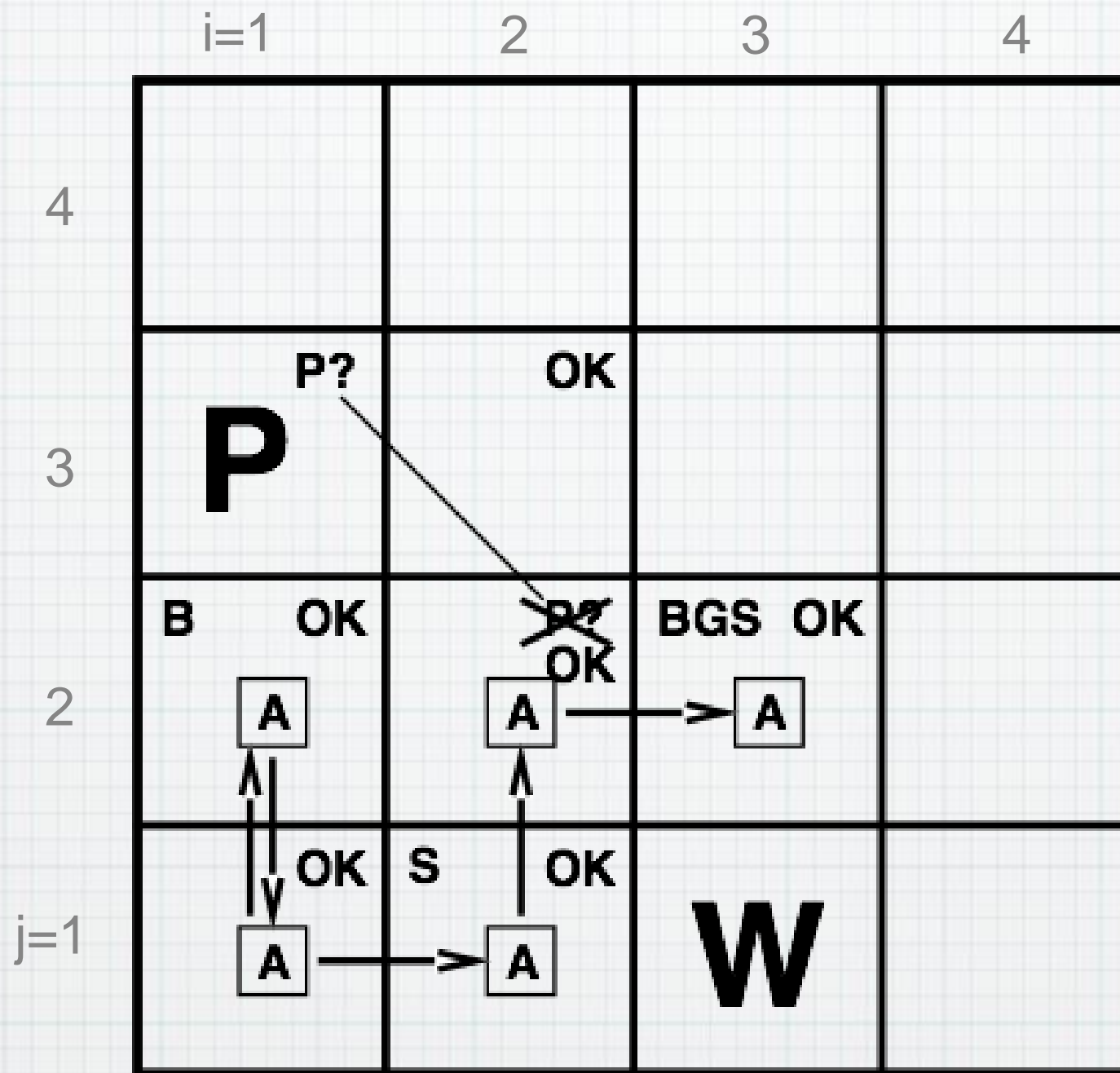
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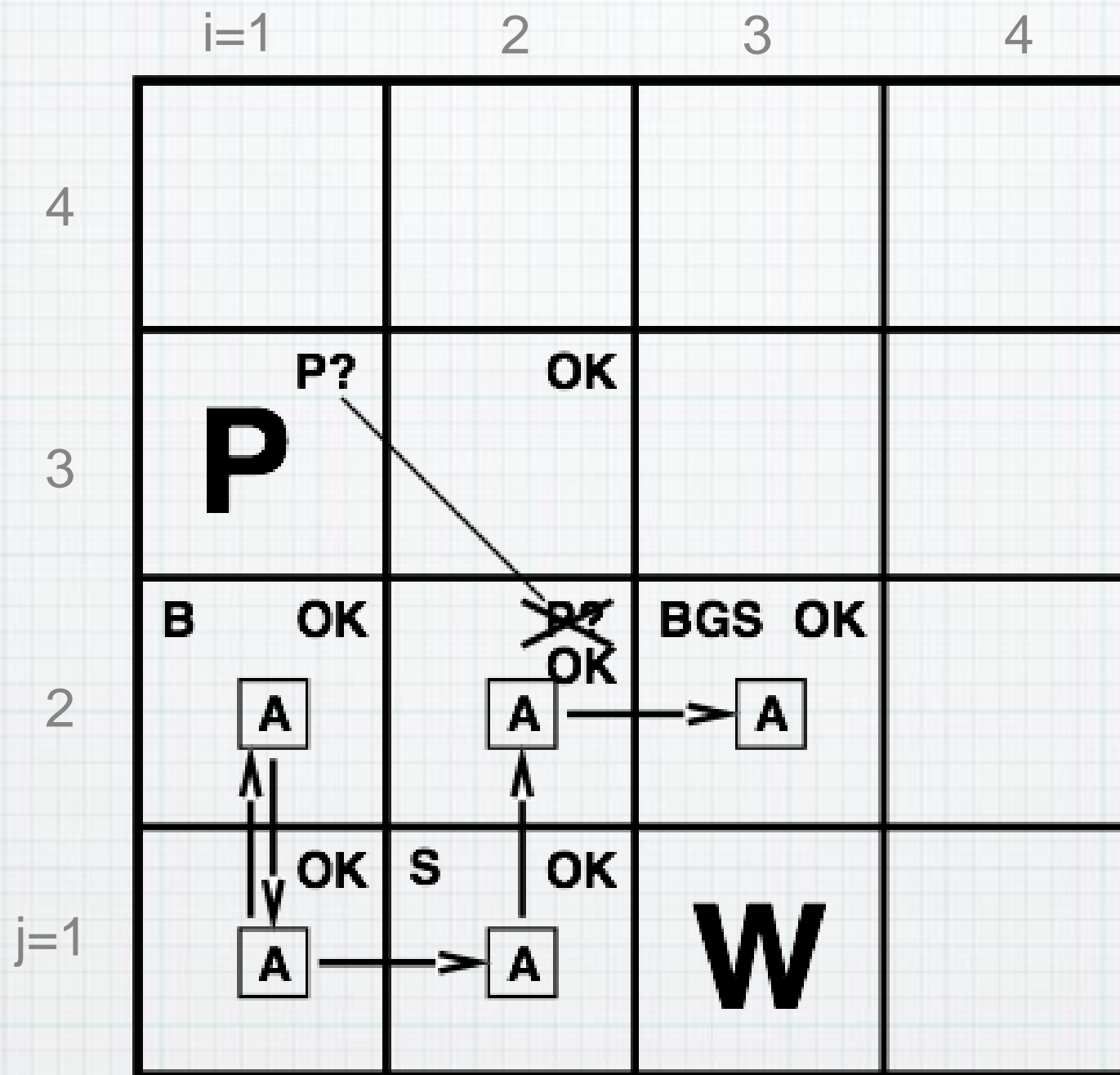


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Percept [3,2]: Breeze, Glitter, Smelly

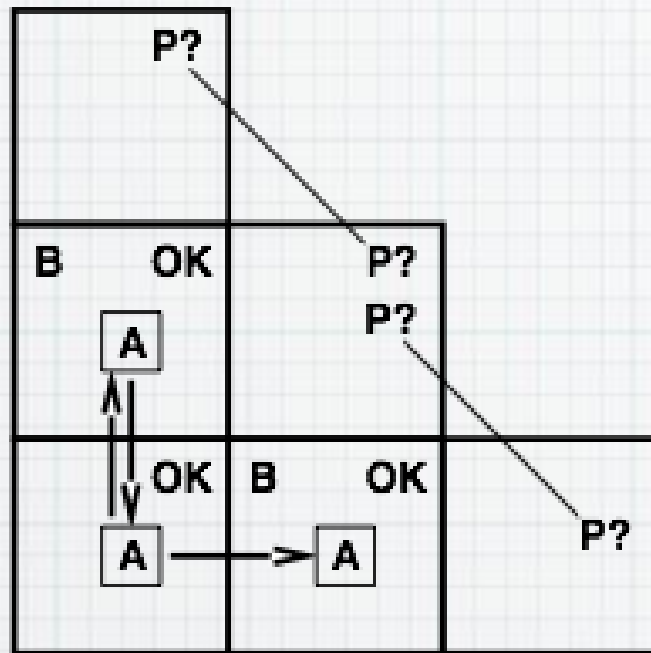
Exploring in Wumpus World



Percept [3,2]: Breeze, Glitter, Smelly

Action: grab gold!

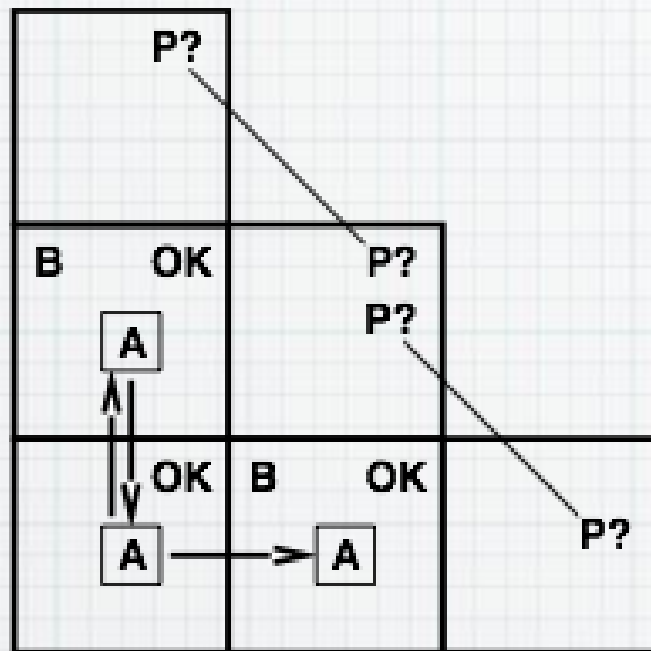
Harder Decisions



Breeze in (1,2) and (2,1)
⇒ no safe actions



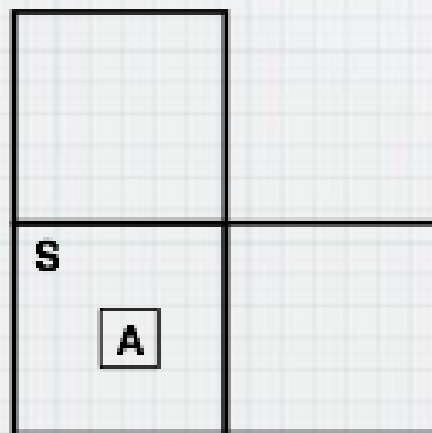
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Assuming pits uniformly distributed,
(2,2) has pit w/ prob 0.86, vs. 0.31

Smell in (1,1)
⇒ cannot move



Logic in General Representation & Reasoning

Logic In General

- * **Logics:** formal languages for representing information s.t. conclusions can be drawn
- * **Syntax:** defines sentences in the language
- * **Semantics:** defines meaning of sentence (defines truth of a sentence in a world)

Logic In General

E.g., the language of arithmetic

$x + 2 \geq y$ is a sentence; $x^2 + y >$ is not a sentence

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$x + 2 \geq y$ is false in a world where $x = 0, y = 6$

Particular instantiation of variables, a possible world, is called a **model**

Entailment

- * Entailment: one thing follows from another

$$KB \models \alpha$$

Knowledge base KB entails sentence α
if and only if
 α is true in all worlds where KB is true

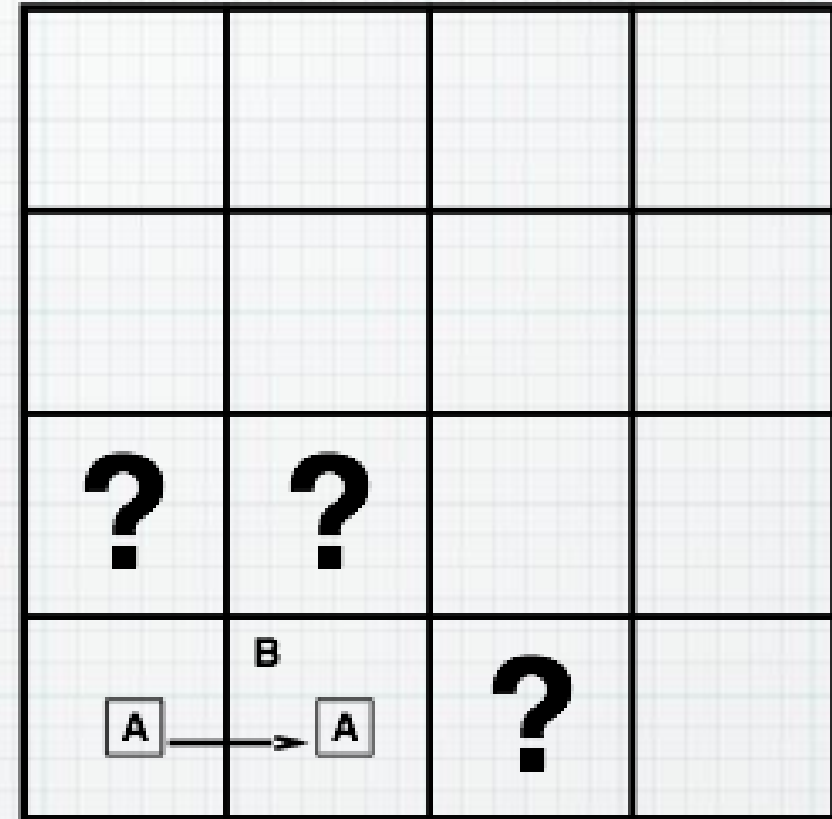
- * Example, KB with sentence: “ $x+y=4$ ”
 - * entails sentence: “ $4=x+y$ ”
 - * and sentence: “ $y=4-x$ ”

Entailment in Wumpus

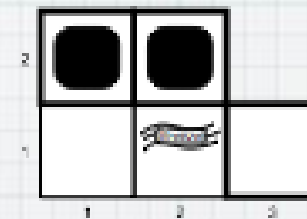
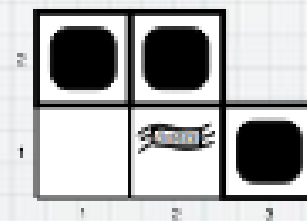
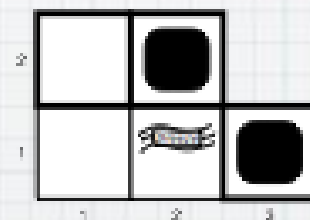
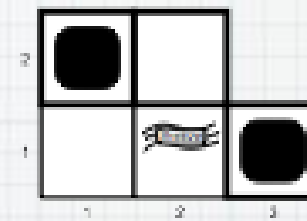
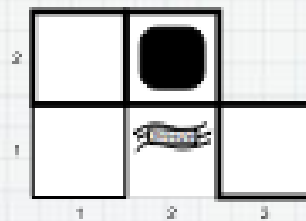
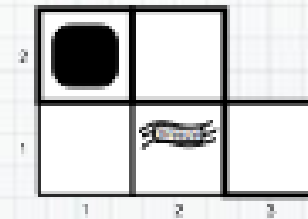
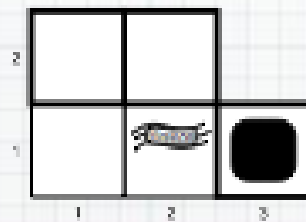
Situation after detecting nothing in [1,1],
moving right, breeze in [2,1]

Consider possible models for ?s
assuming only pits

3 Boolean choices \Rightarrow 8 possible models

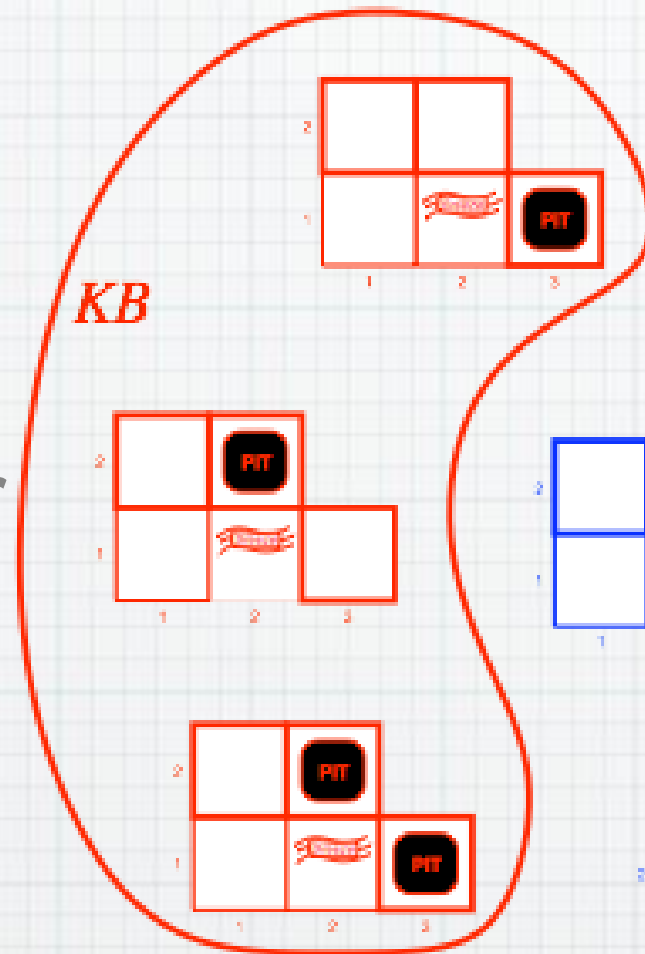


Wumpus Models

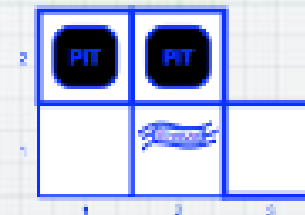
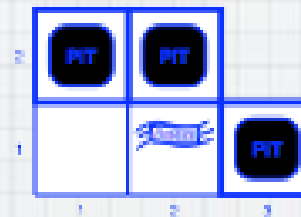
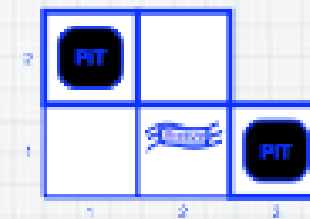
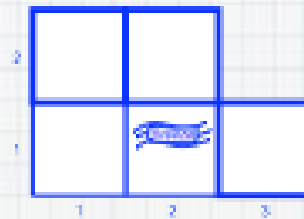
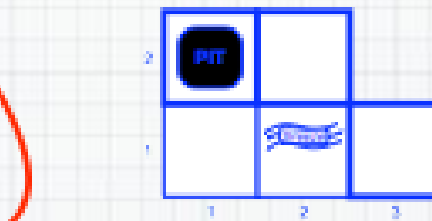


Wumpus Models

These models
are consistent
with the rules
and our
percepts so far



These models
don't agree with
the rules about
“Breezes”

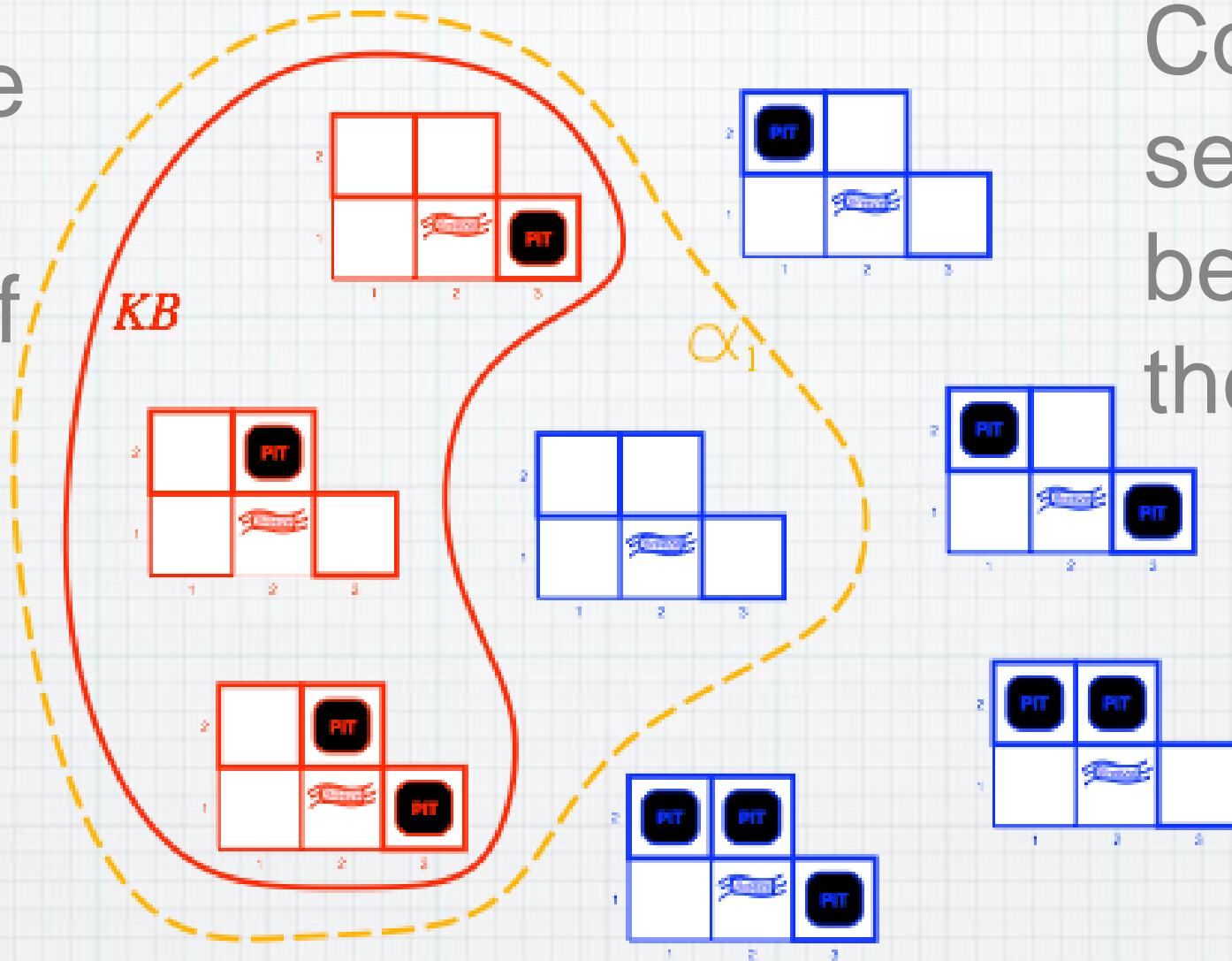


KB = wumpus-world rules + observations

Model Checking

Find all models where query is true...check if KB is within this set

Conclude: sentence can be added to the KB

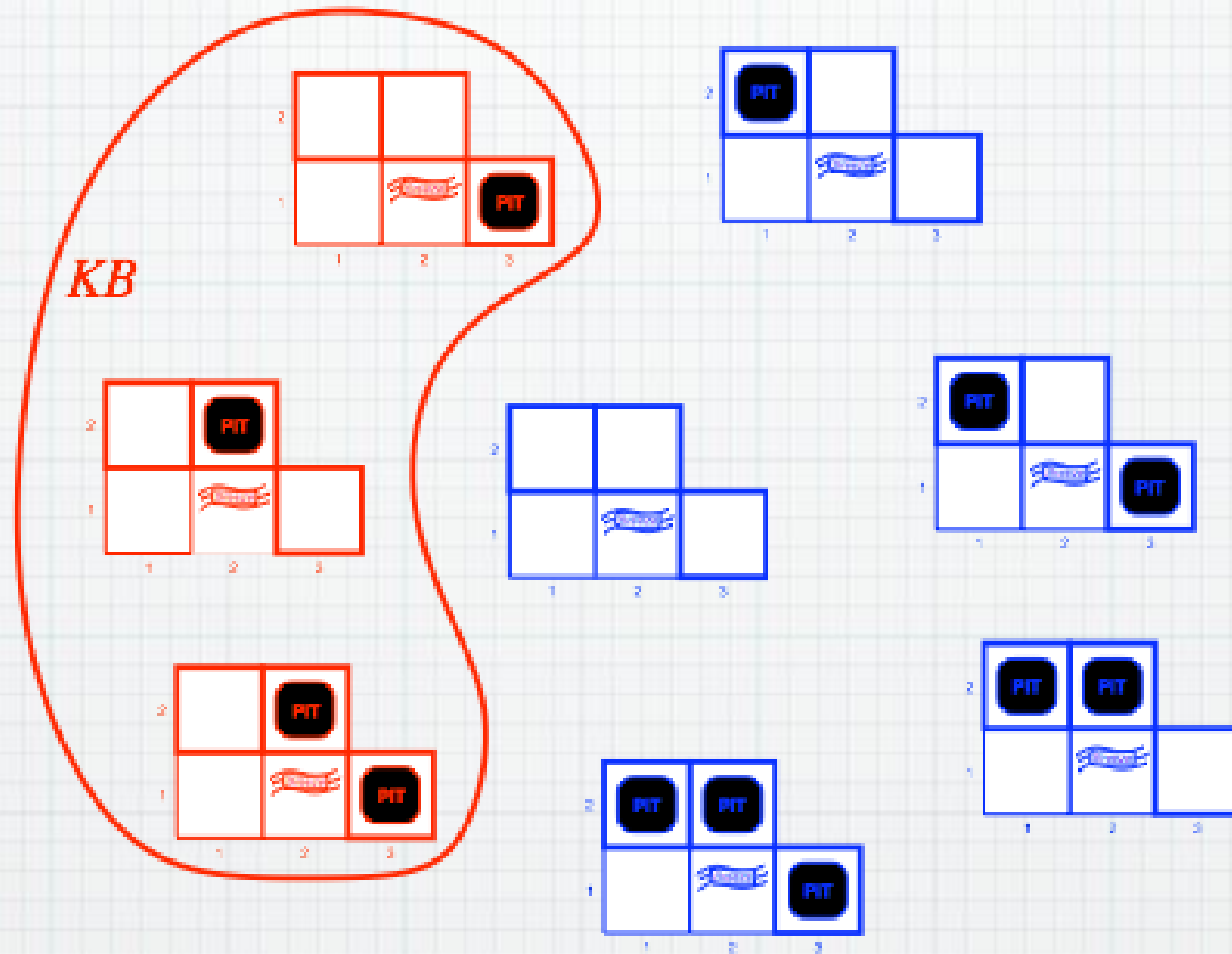


KB = wumpus-world rules + observations

α_1 = "[1,2] is safe", $KB \models \alpha_1$, proved by model checking

Model Checking

Find all
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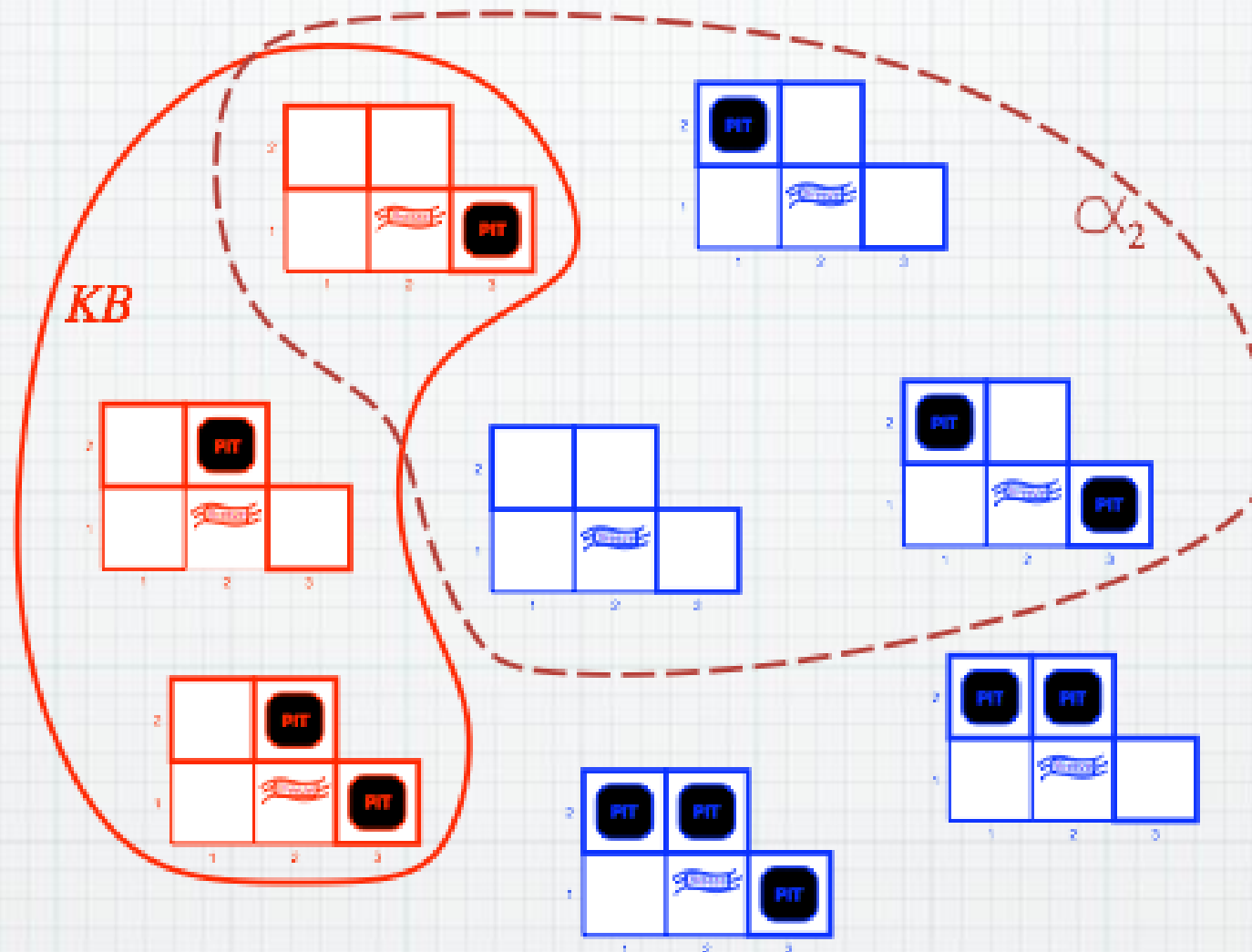


KB = wumpus-world rules + observations

Model Checking

Find all models where query is true...check if KB is within this set

Conclude: sentence not consistent with the KB



KB = wumpus-world rules + observations

α_2 = "[2,2] is safe", $KB \not\models \alpha_2$

Inference

$KB \vdash_i \alpha$ = sentence α can be derived from KB by procedure i

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Consequences of KB are a haystack; α is a needle.

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Preview: we will define a logic (first-order logic) which is expressive enough to say almost anything of interest, and for which there exists a sound and complete inference procedure.

That is, the procedure will answer any question whose answer follows from what is known by the KB .

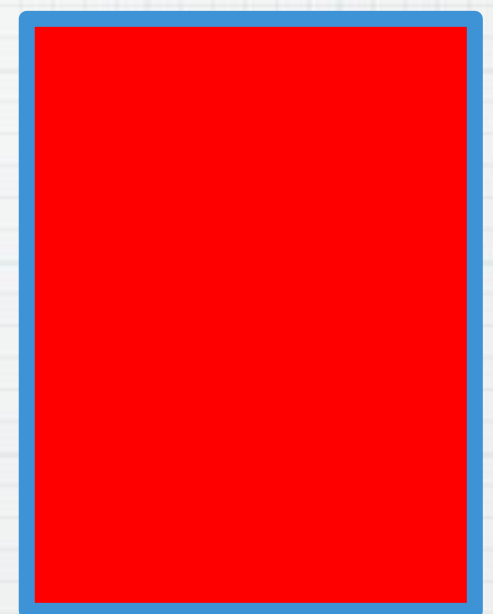
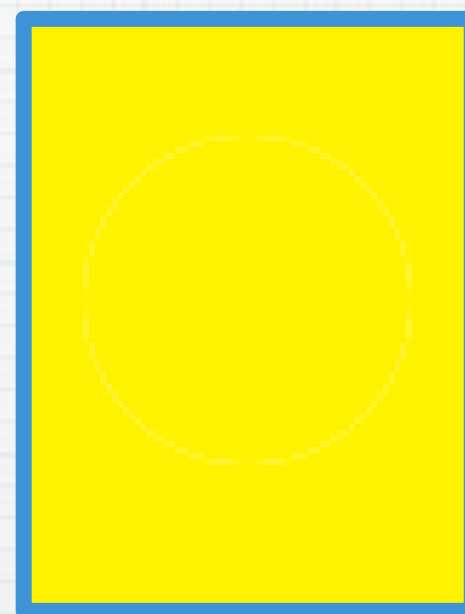
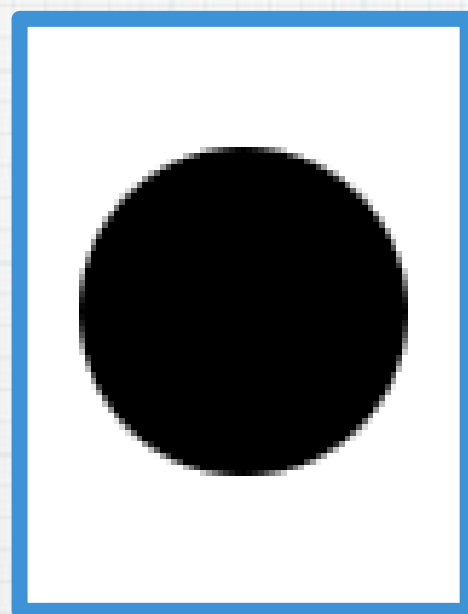
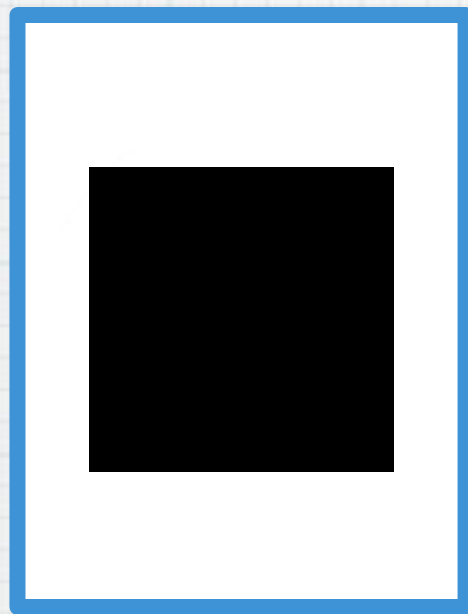
Extra: The logical
agent called YOU

Extra: The logical agent called YOU

- * Imagine that you are the quality control technician at a factory that prints cards that are used in signaling exercises.
- * You see cards coming down the conveyor belt and you have to turn them over to check whether they follow a certain rule.

If a card has a circle on one side, then it has the color yellow on the other side.

If a card has a circle on one side, then it has the color yellow on the other side.



- * You got laid off. But, you managed to get a new job at a local bar as the bouncer.
- * You see people, and you see drinks, and your job is to make sure that everyone is following the law.

If a person drinks an alcoholic drink, then they must be over the age of 21 years old.

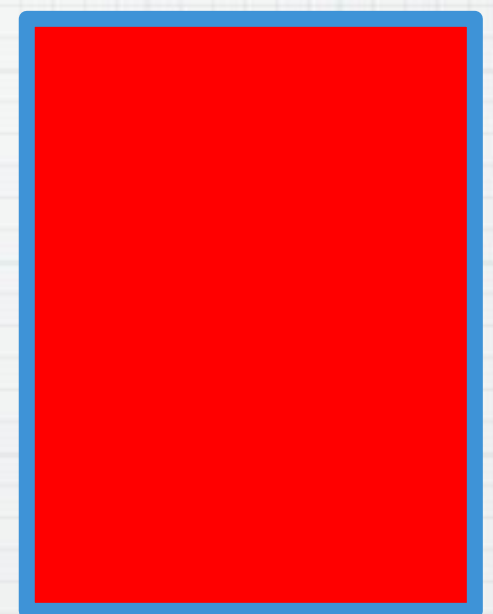
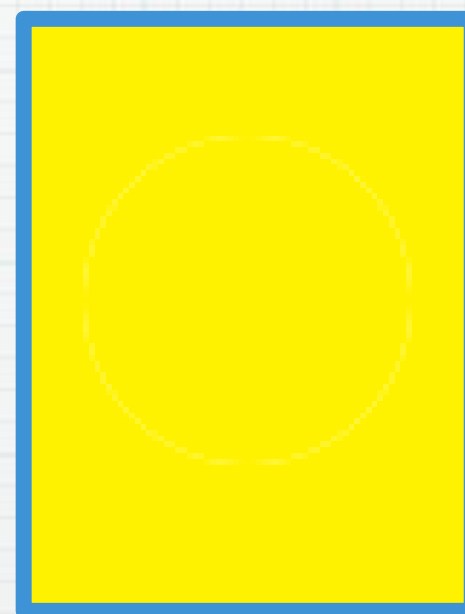
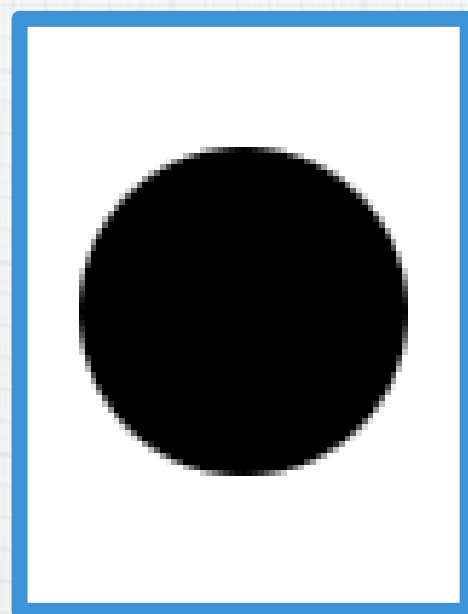
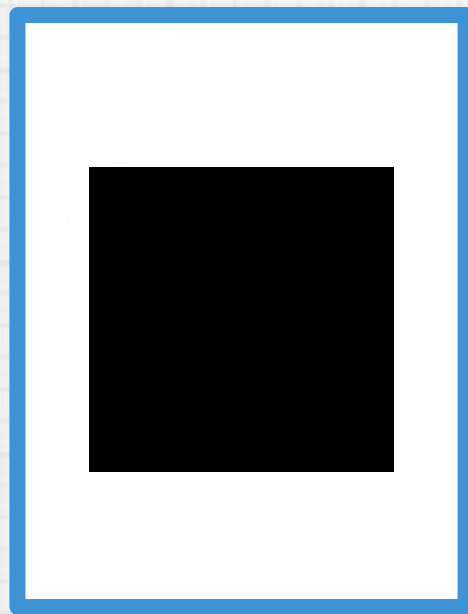
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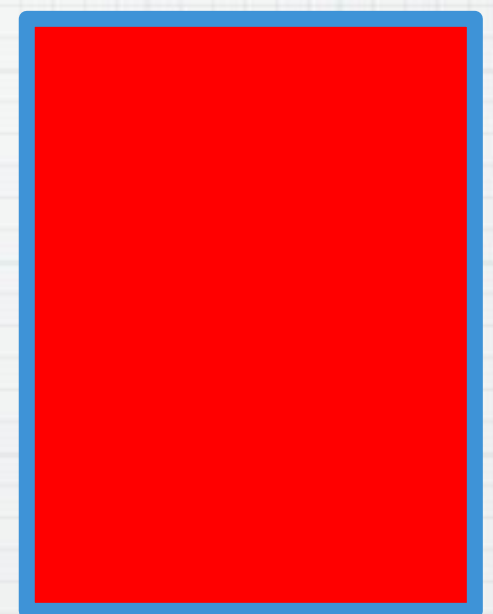
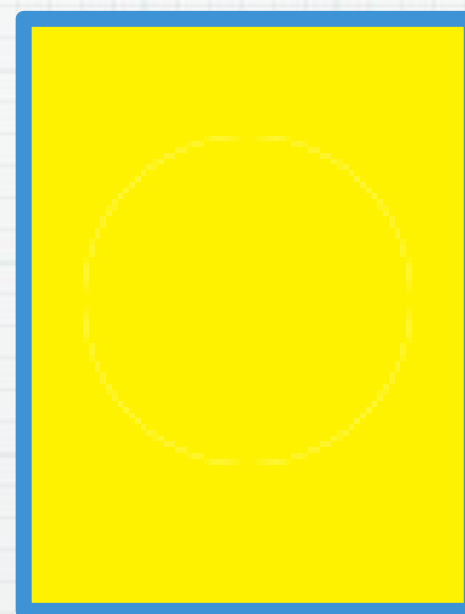
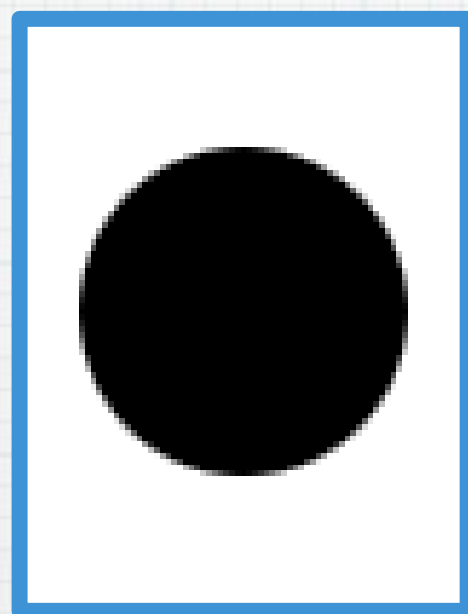
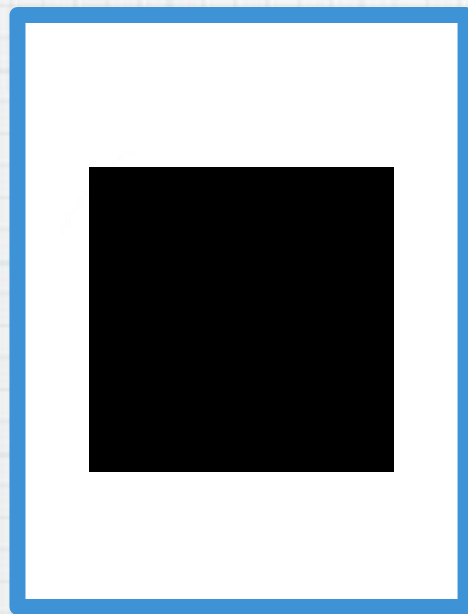
**22
years
old**

**17
years
old**

If a card has a circle on one side, then it has the color yellow on the other side.



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Why?

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- * This task is called the **Wason Selection Task**.