Artificial Intelligence
AI 2002
Lecture 11

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Knowledge

Humans know things …

- the knowledge helps them to do various tasks.

- **The knowledge has been achieved**
  - not by purely reflex mechanisms
  - but by the processes of **reasoning**

In AI, the example is **knowladge-based agent** which contains **set of sentences** referred as **knowledge-base.**

Knowledge-based Agent

<u>For a generic knowledge-based agent:</u>
A **percept is given** to the agent.

The agent **adds the percept** to its knowledge base.

Perform best action according to the knowledge base.

Tells the knowledge base that it has in fact **taken that action**.

Knowledge-based Agent

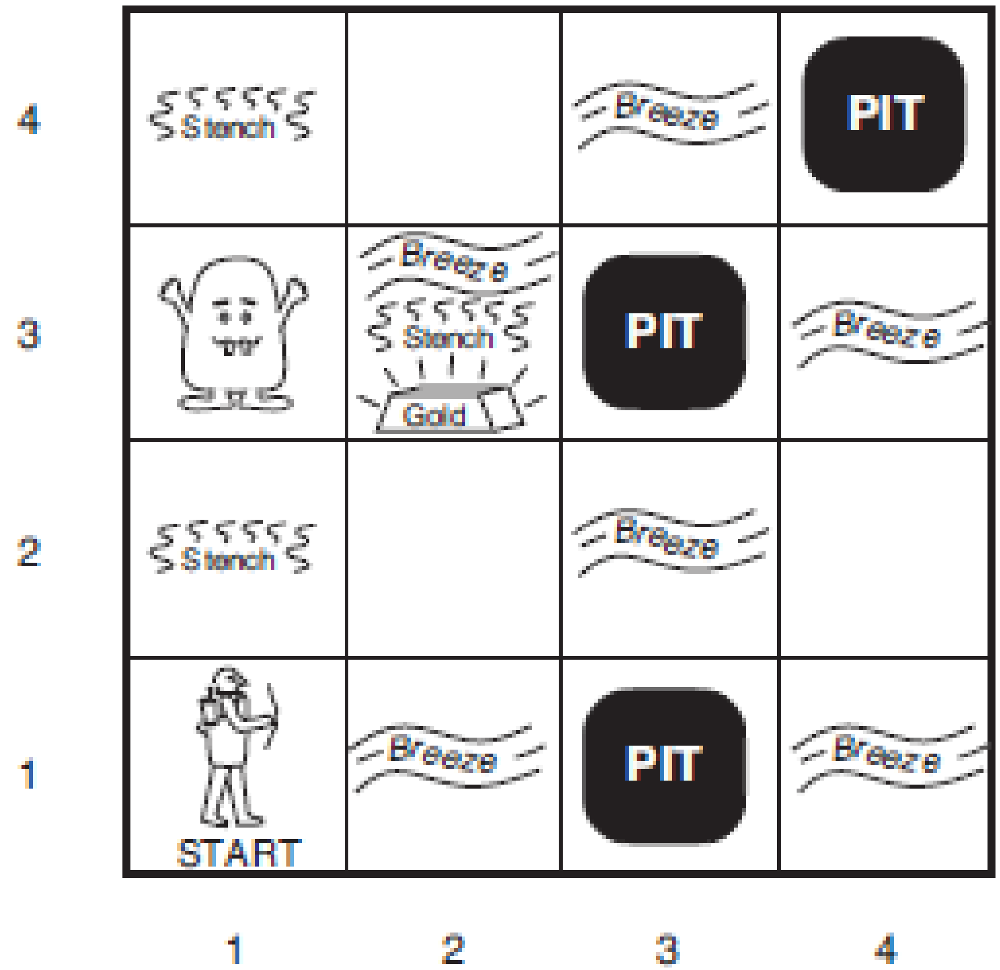
```
function KB-AGENT(percept) returns an action
  persistent: KB, a knowledge base
              t, a counter, initially 0, indicating time

  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
```

constructs a **sentence** asserting that the agent ***perceived the given percept*** at time ***t***

constructs a sentence that asks ***what action should be done*** at time ***t***

constructs a sentence that ***the chosen action was executed*** at time ***t***

The Wumpus World Example



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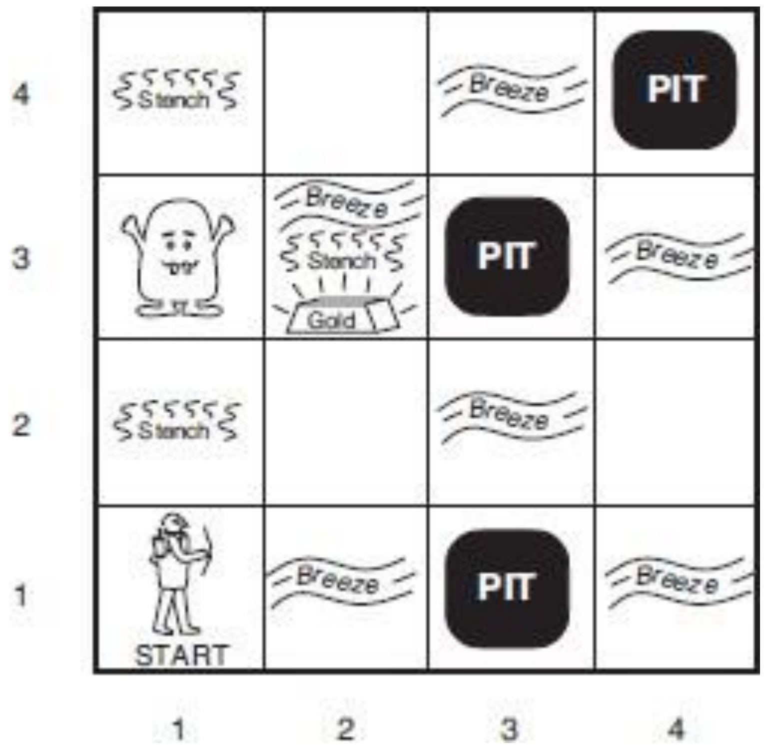
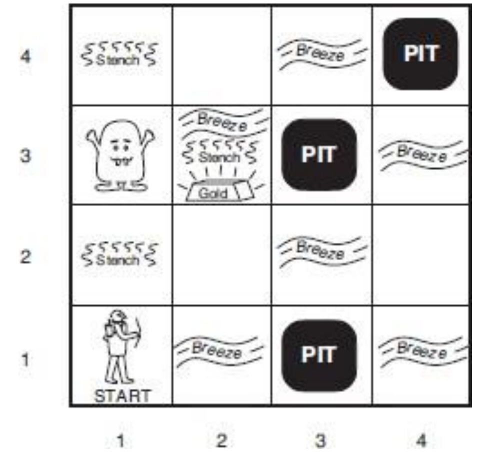


1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2 OK	2,2	3,2	4,2
1,1 $\boxed{A}$ OK	2,1 OK	3,1	4,1

The Wumpus World



The PEAS description for Wumpus World: **Performance measure:**

+1000 for climbing out of the cave with the gold,

–1000 for falling into a pit or being eaten by the Wumpus,

–1 for each action taken

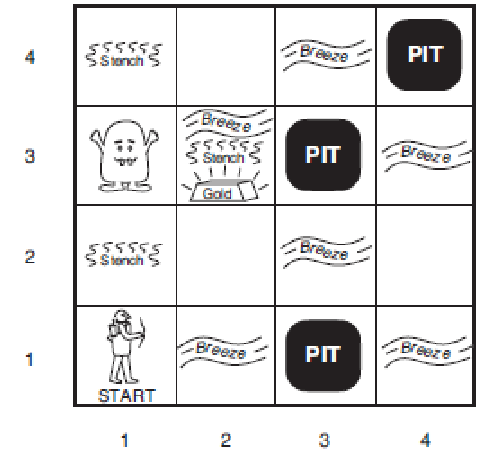
–10 for using up the arrow

Environment:

A 4×4 grid of rooms. The agent starts in the square labelled [1,1], facing to the right.

The game ends either when the agent dies or when the agent climbs out of the cave.

The Wumpus World



<u>The PEAS description for Wumpus World:</u>

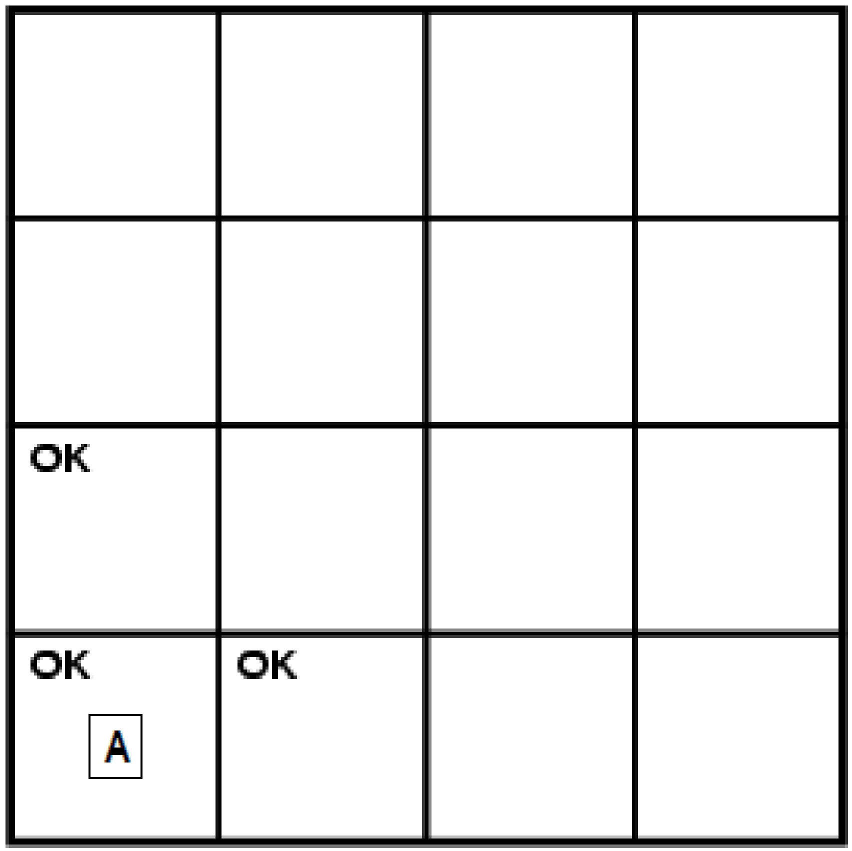
<u>Actuators:</u>

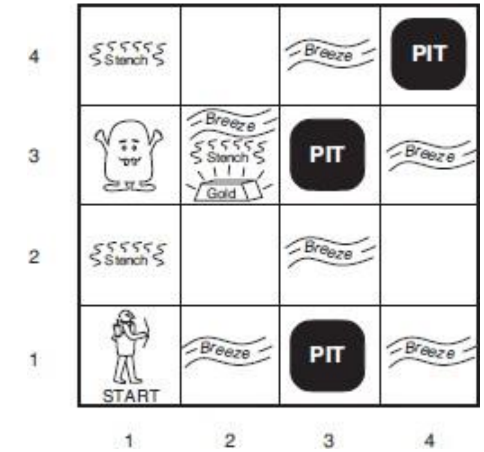
The agent can move *Forward, TurnLeft by 90◦, TurnRight by 90◦*, grab, shoot

<u>Sensors:</u>

- The square adjacent directly (not diagonally) to the square containing **Wumpus**, the agent will perceive a ***Stench***.
- The squares adjacent to a **pit**, the agent will perceive a ***Breeze***.
- The square with **gold**, the agent will perceive a ***Glitter***.
- An agent **walks into a wall**, it will perceive a ***Bump***.
- When the **Wumpus is killed**, it emits a woeful ***Scream*.**

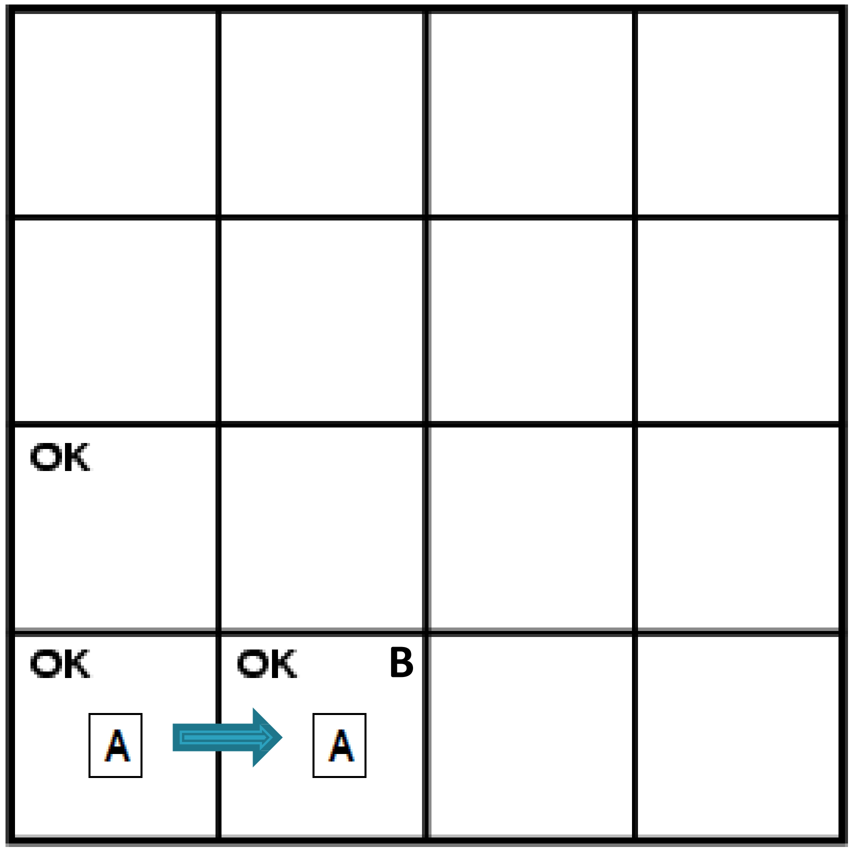
The Wumpus World

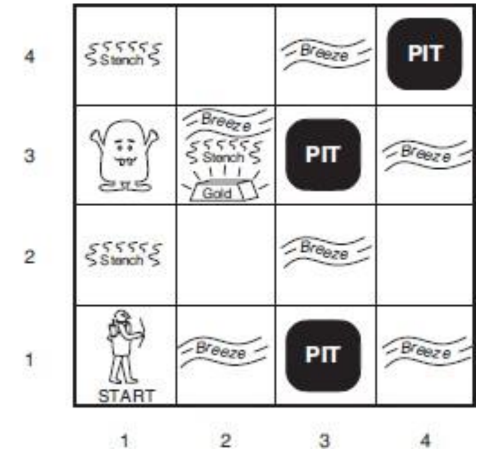




A = Agent
B = Breeze
G = Glitter, Gold
OK = Safe square
P = Pit
S = Stench
V = Visited
W = Wumpus

The Wumpus World





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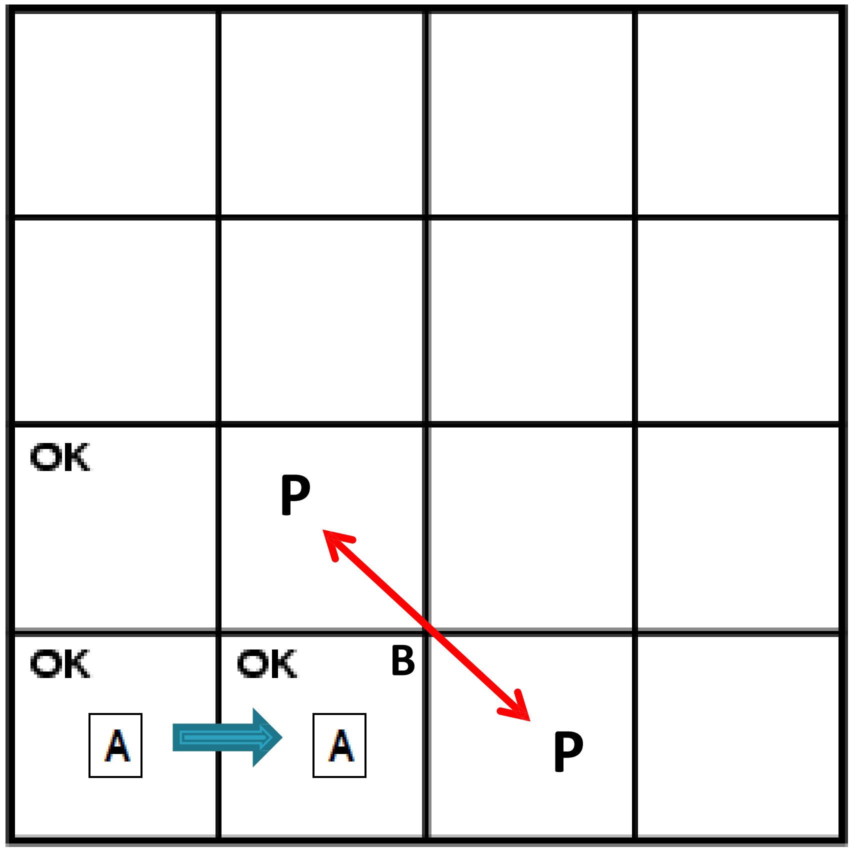

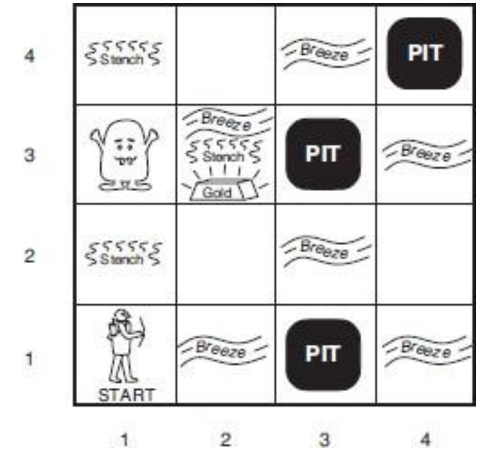

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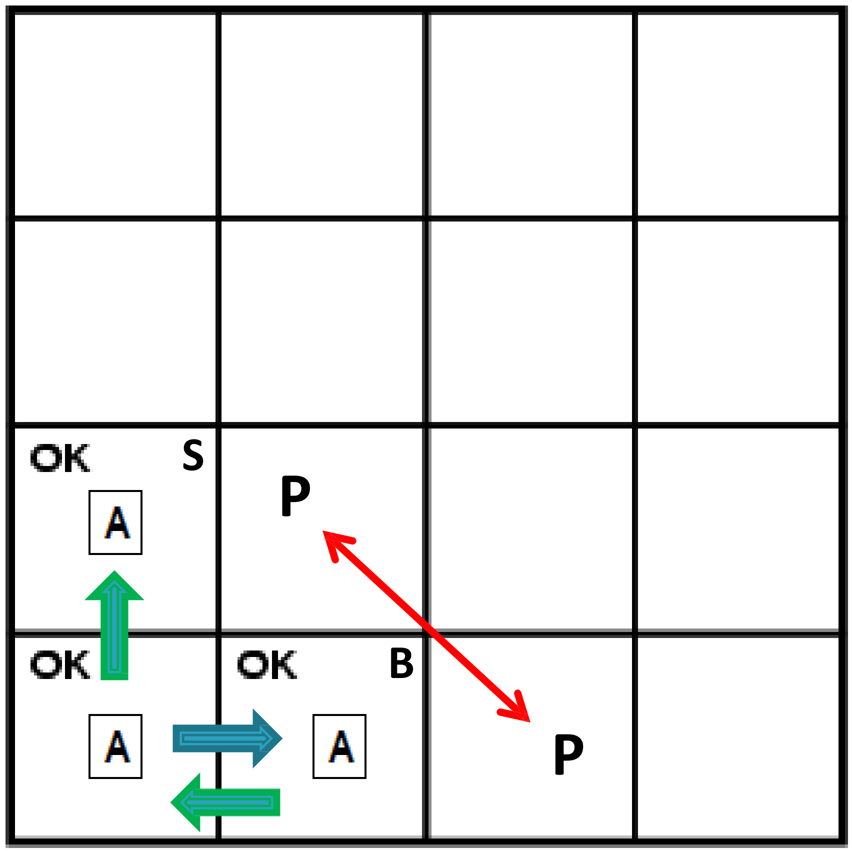

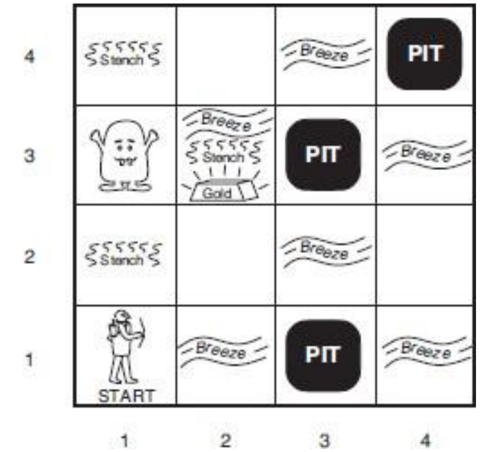

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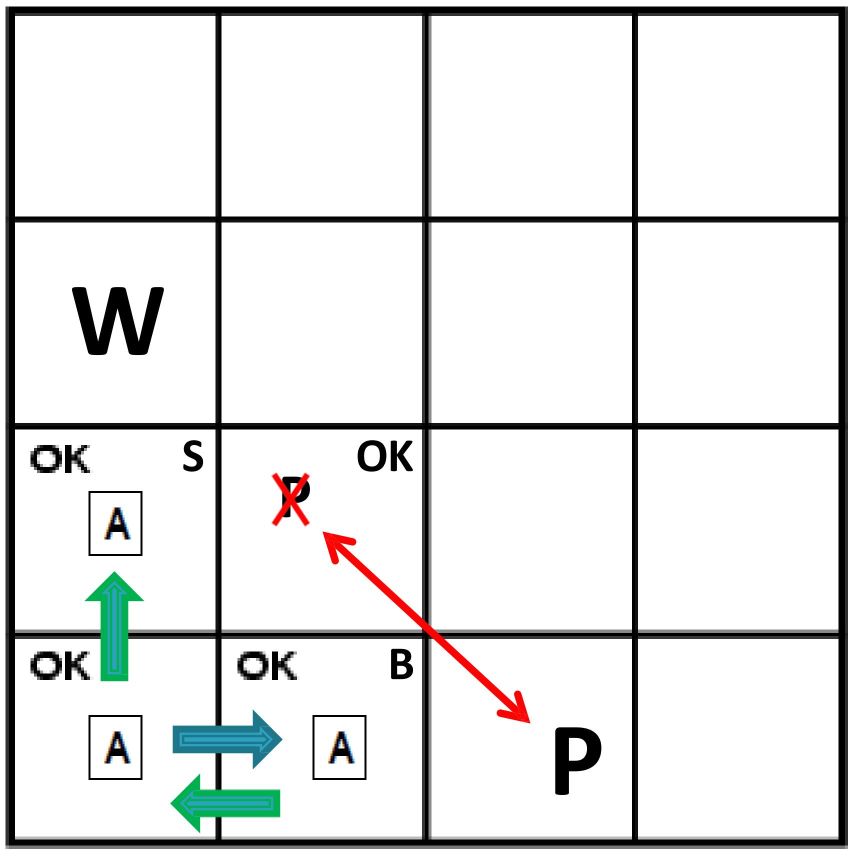

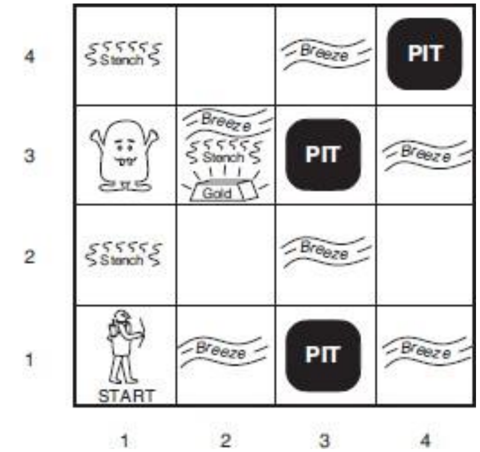

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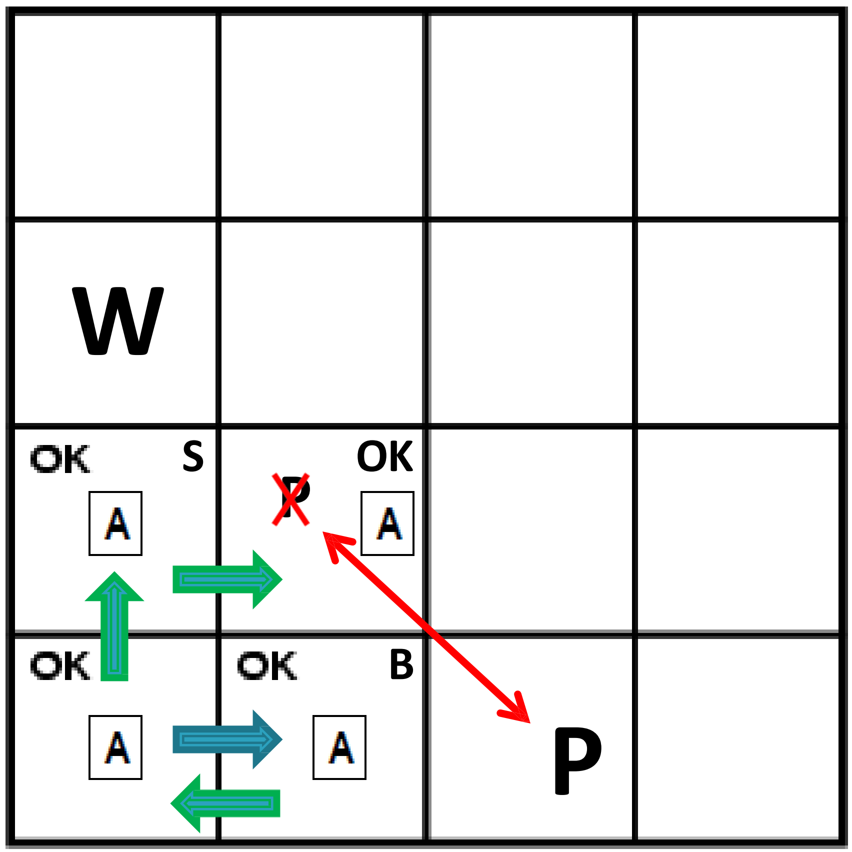

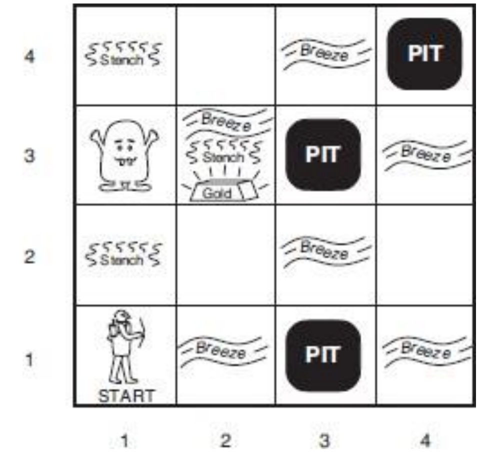

$\boxed{A}$ = *Agent*
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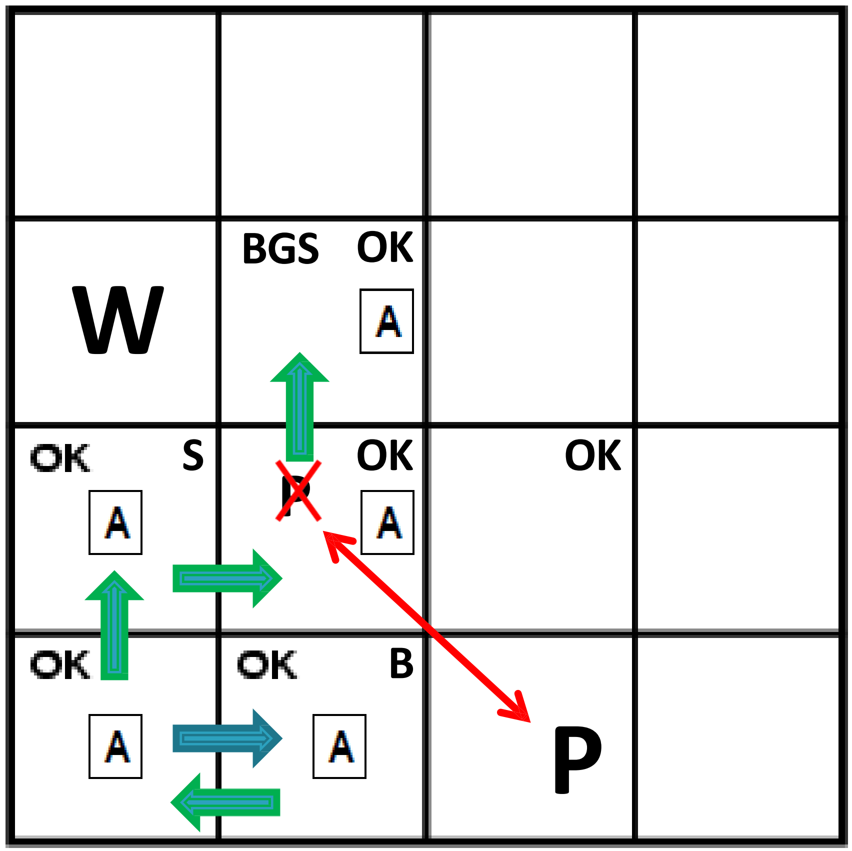
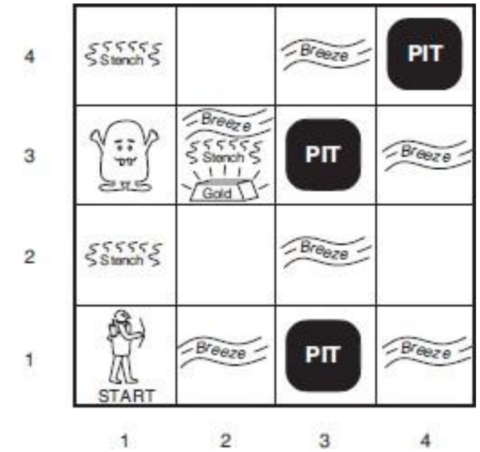
The Wumpus World





- **A** = *Agent*
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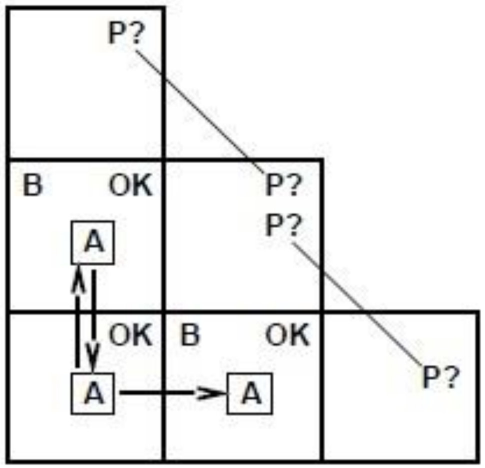
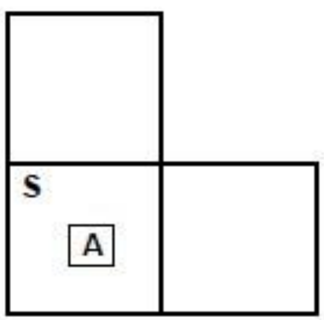
The Wumpus World



Breeze in (1,2) and (2,1)
$\Rightarrow$ no safe actions

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



Smell in (1,1)
$\Rightarrow$ cannot move
Can use a strategy of coercion:
shoot straight ahead
wumpus was there $\Rightarrow$ dead $\Rightarrow$ safe
wumpus wasn't there $\Rightarrow$ safe

Logic

Logic

How to represent these sentances?

The knowledge bases consist of sentences.

- **Logic**, a formal language, is the solution --- a way of manipulating expressions in the language.

- Logic has
  - Syntax
  - Semantics

Logic

Syntax:

What expressions are legal --- what are allowed to write down.

- The notion of syntax is clear enough with the example: "$x + y = 4$" is a well-formed sentence, whereas "$x4y+ =$" is not.

Semantics:

What legal expression means --- meaning of sentences

- the sentence "$x + y = 4$" is **true** in a **world** where x is 2 and y is 2, but **false** in a **world** where x is 1 and y is 1.
- *Syntax is a form and semantics is the content.*

Logic

Semantics:

The semantics defines the **truth** of each sentence with respect to each **possible world**.

The term **model** can be used in place of **"possible world."**

If a sentence $\boldsymbol{\alpha}$ is true in model $\boldsymbol{m}$, we say that $\boldsymbol{m}$ **satisfies** $\boldsymbol{\alpha}$ or sometimes $\boldsymbol{m}$ is a **model** of $\boldsymbol{\alpha}$.

The notation $\boldsymbol{M(\alpha)}$ --- the set of all **models** of $\boldsymbol{\alpha}$.

Logic --- Entailment

Entailment:

means that **one thing follows from another**:

$$\alpha \models \beta$$

if and only if, in every model in which α *is true,* β *is also true*. We can write

$$\boxed{\alpha \models \beta \text{ if and only if } M(\alpha) \subseteq M(\beta)}$$

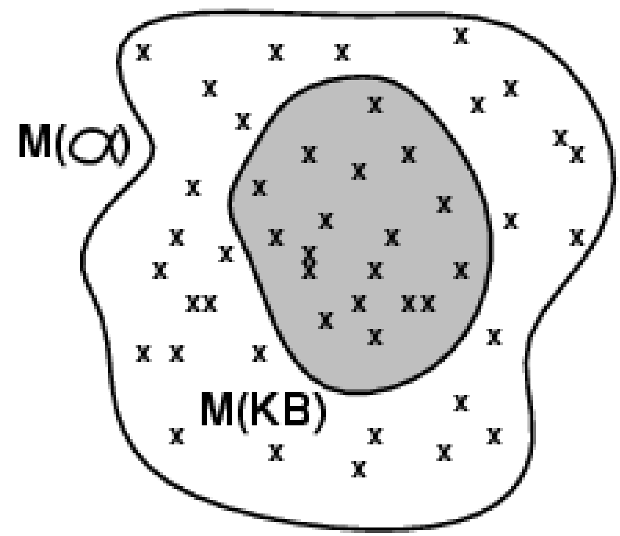
The notation $\subseteq$ means that: if $\alpha \models \beta$, then α is a *stronger assertion than* β

Logic --- Entailment

We say $\boldsymbol{m}$ is a model of sentence $\boldsymbol{\alpha}$ if $\boldsymbol{\alpha}$ is true in $\boldsymbol{m}$

$\boldsymbol{M(\alpha)}$ is the set of all models of $\boldsymbol{\alpha}$

Then $\boldsymbol{KB} \models \boldsymbol{\alpha}$ iff $\boldsymbol{M(KB)} \subseteq \boldsymbol{M(\alpha)}$



Example:

The sentence $\boldsymbol{x} = \boldsymbol{0}$ entails the sentence $\boldsymbol{xy} = \boldsymbol{0}$

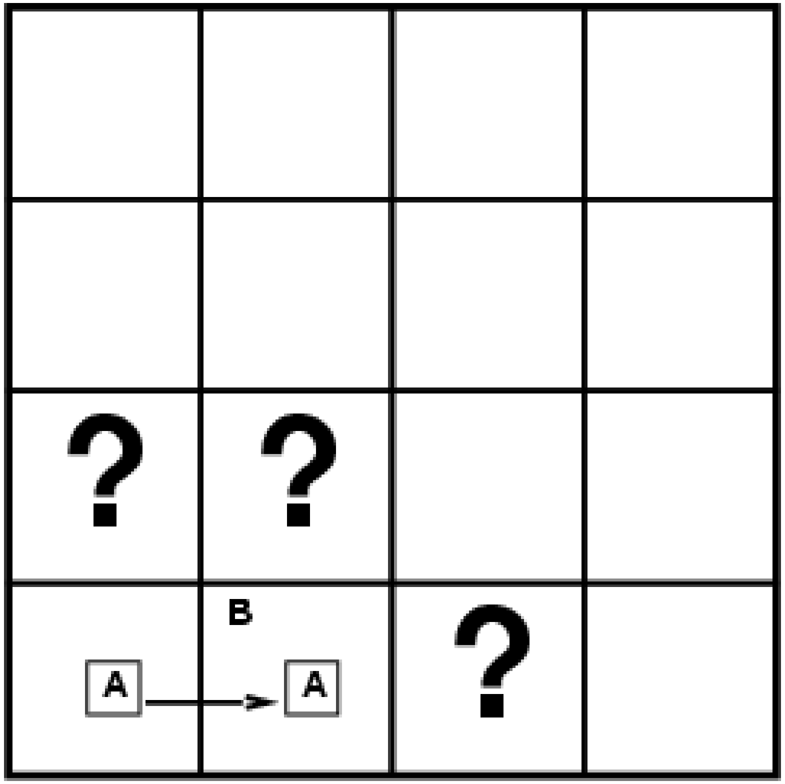
- In any model where $\boldsymbol{x}$ is zero, it is the case that $\boldsymbol{xy}$ is zero (regardless of the value of $\boldsymbol{y}$)

Entailment--- Wumpus World

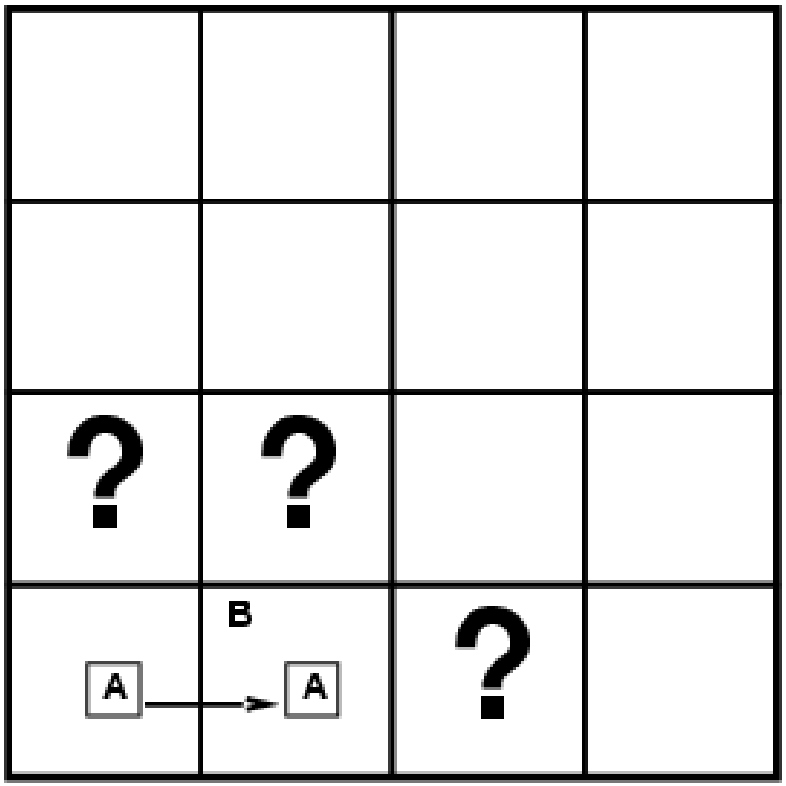
Situation after detecting nothing in [1,1], moving right, **breeze** in [1,2]

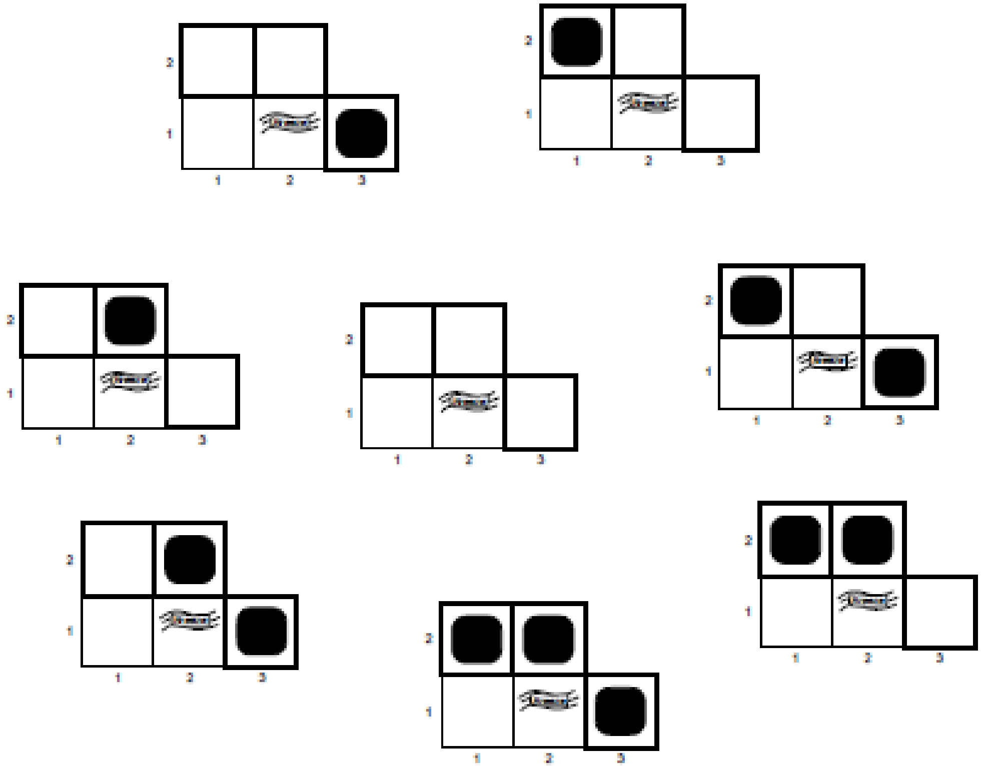
Consider possible models for **KB** assuming only pits

3 Boolean choices $\Rightarrow$ 8 possible models



Entailment--- Wumpus World

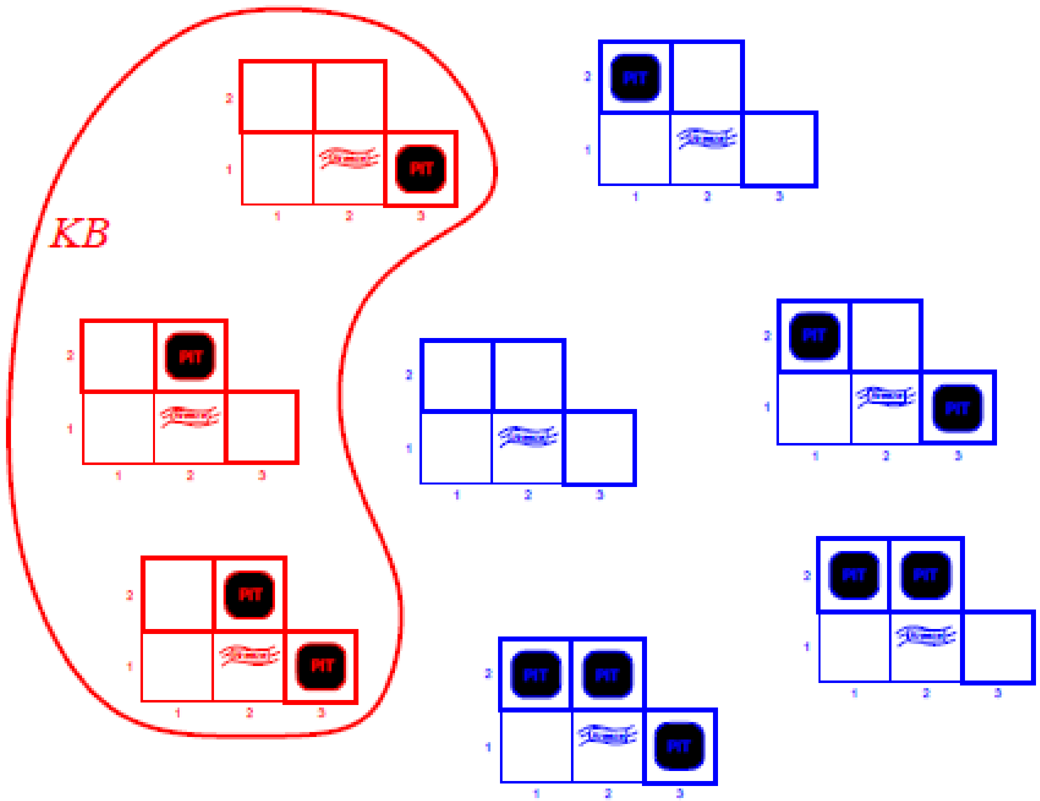




3 Boolean choices $\Rightarrow$ 8 possible models

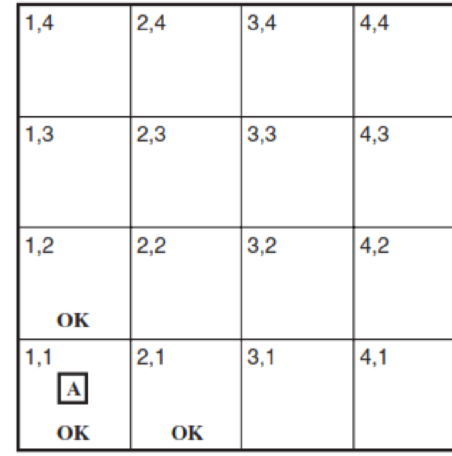
regardless of wumpus-world rules

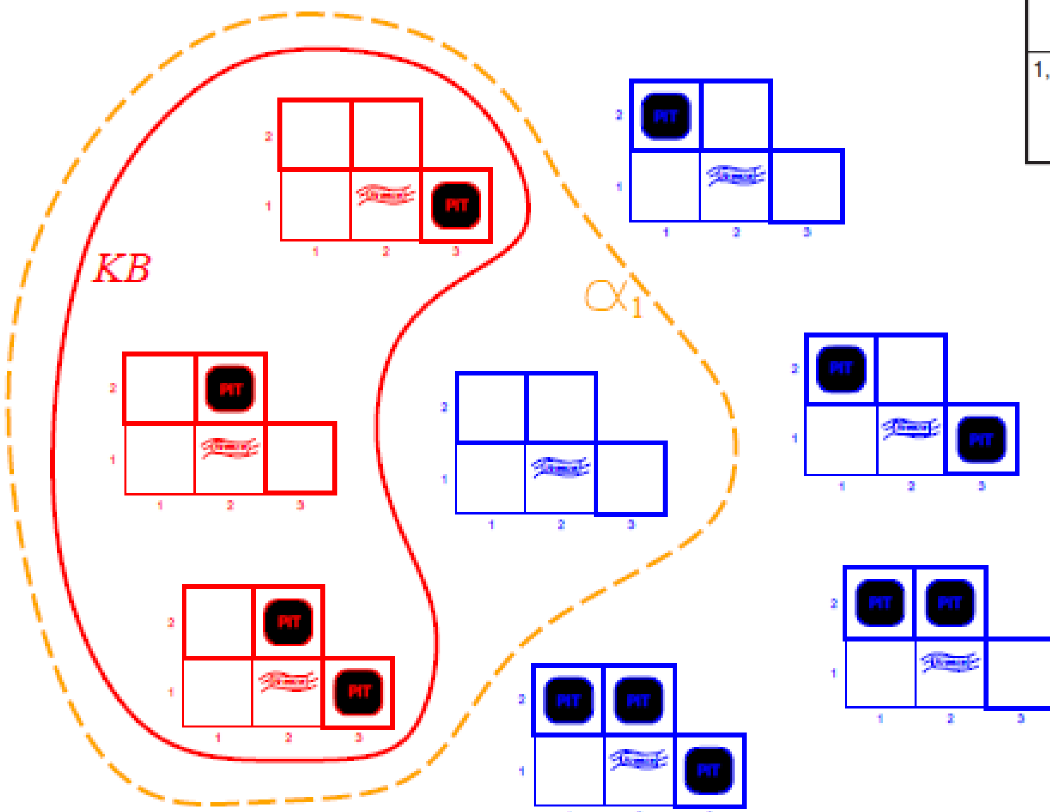
Entailment--- Wumpus World



KB = wumpus-world rules + observations

Entailment--- Wumpus World





KB = wumpus-world rules + observations

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

Entailment--- Wumpus World

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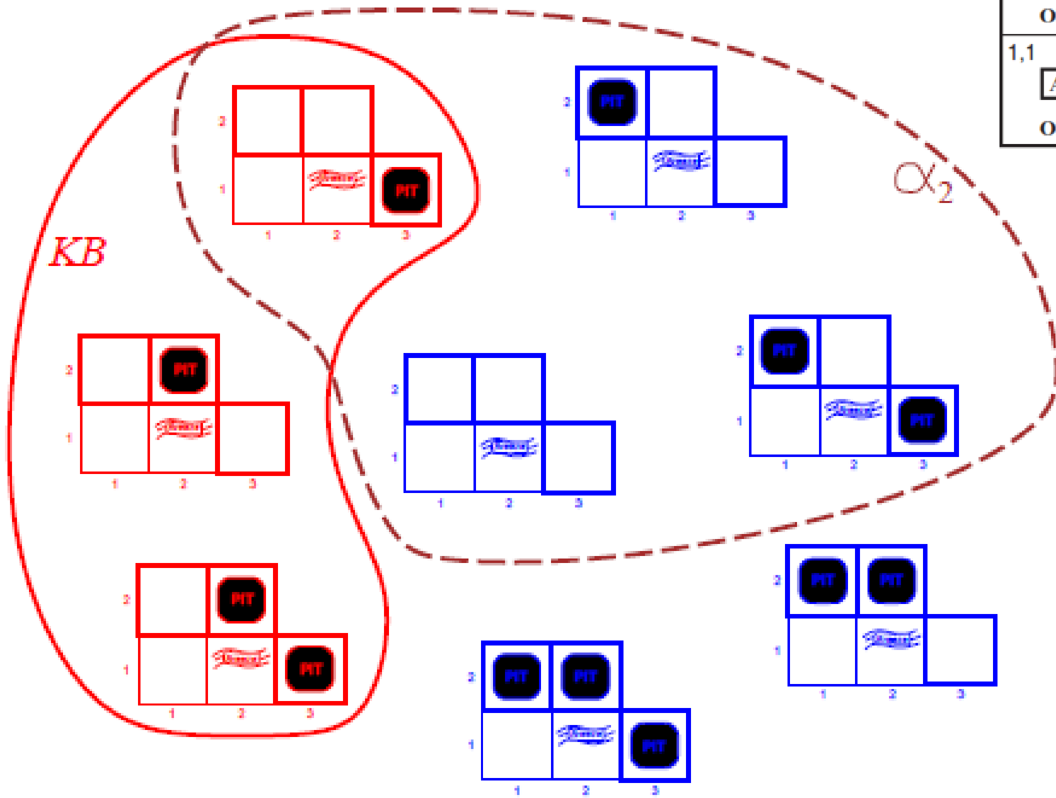

KB = wumpus-world rules + observations

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

Inference

If an inference algorithm $\boldsymbol{i}$ *can derive* $\boldsymbol{\alpha}$ *from* $\boldsymbol{KB}$, we write

$$KB \vdash_i \alpha$$

which is pronounced "**$\boldsymbol{\alpha}$ is derived from $\boldsymbol{KB}$ by $\boldsymbol{i}$**" or "**$\boldsymbol{i}$ derives $\boldsymbol{\alpha}$ from $\boldsymbol{KB}$**."

Soundness:

An inference algorithm that **derives only entailed sentences** is called **sound or truth preserving.**

Soundness is a highly desirable property.

Completeness:

An inference algorithm is complete if it can derive any sentence that is **entailed**.

Logic

We'll look at two kinds of logic:

Propositional Logic

which is relatively simple.

First-order Logic

which is more complicated.

Reading Material

Artificial Intelligence, A Modern Approach

Stuart J. Russell and Peter Norvig

Chapter 7.