UIT2504
ARTIFICIAL INTELLIGENCE

2024/2025 Odd Semester

Knowledge and Reasoning: Introduction to Logic

Outline

- Knowledge-based agents
- Example: Wumpus world
- Logic in general – syntax, interpretations, models, entailment, derivations
- **Propositional Logic: syntax**
- **Propositional Logic: semantics**
- **Propositional Logic: Inference rules**

Knowledge-based Agents

- Knowledge base = set of sentences in a formal language
- Knowledge-based agent comprises of domain specific knowledge base and domain independent inference mechanism to process knowledge
- Knowledge is in declarative form
- Suitable for partially observable environments where *hidden* information can be inferred

A simple knowledge-based agent

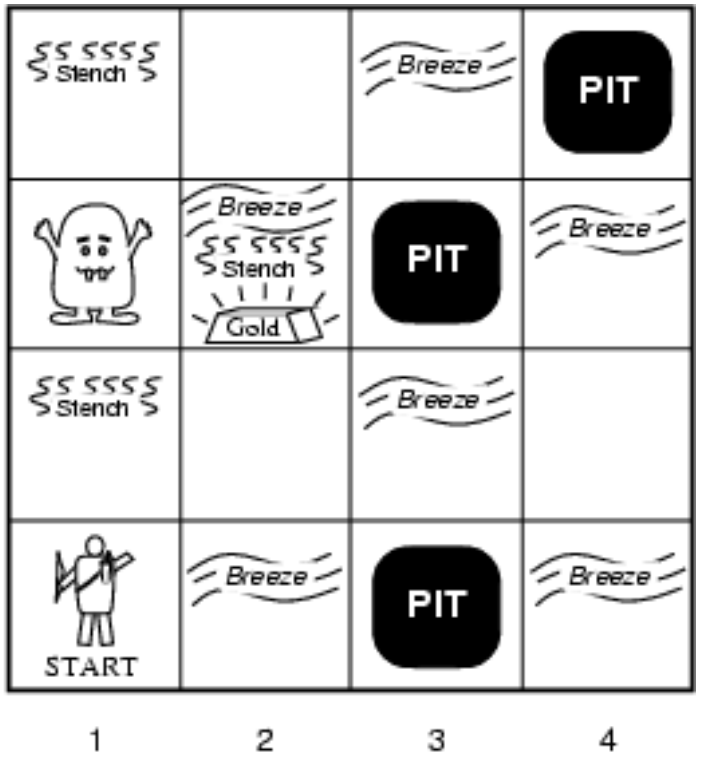
function KB-AGENT(*percept*) **returns** an *action*
  static: *KB*, a knowledge base
    t, a counter, initially 0, indicating time

  TELL(*KB*, MAKE-PERCEPT-SENTENCE(*percept*, *t*))
  action ← ASK(*KB*, MAKE-ACTION-QUERY(*t*))
  TELL(*KB*, MAKE-ACTION-SENTENCE(*action*, *t*))
  $t \leftarrow t + 1$
  return *action*

- Update internal representation of the world
- Infer hidden properties of the world
- Deduce appropriate actions

Example: Wumpus world

- **Performance:** +1000 for gold; -1000 if agent dies; -1 for each action; -10 for using arrow
- **Environment:** Agent starts on [1,1]; No pit, gold, or Wumpus on [1,1]; Squares adjacent to Wumpus are smelly; Squares adjacent to pit are breezy; Glitter in the square having gold; agent can grab gold if in same square
- **Actions:** Left turn, right turn, move forward, grab, shoot, climb
- **Sensors:** Stench, Breeze, Glitter, Bump, Scream



Environment Characterization

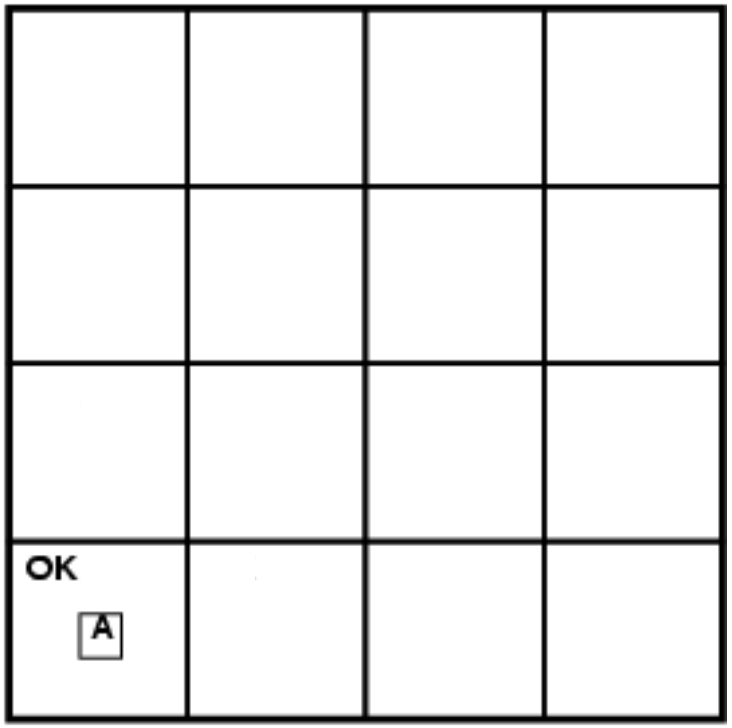
- Fully Observable?
- Deterministic?
- Episodic?
- Static?
- Discrete?
- Single agent?

Environment Characterization

- Fully Observable? **No, only local perception**
- Deterministic? **Yes**
- Episodic? **No**
- Static? **Yes**
- Discrete? **Yes**
- Single agent? **Yes**

Exploring Wumpus World

- Start at [1,1]; Perceive [None, None, None, None, None]



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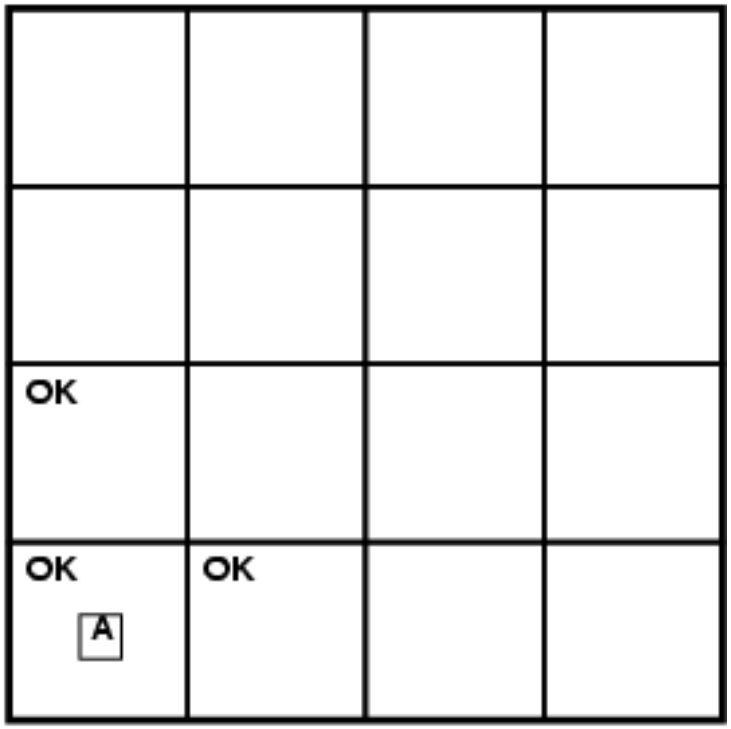
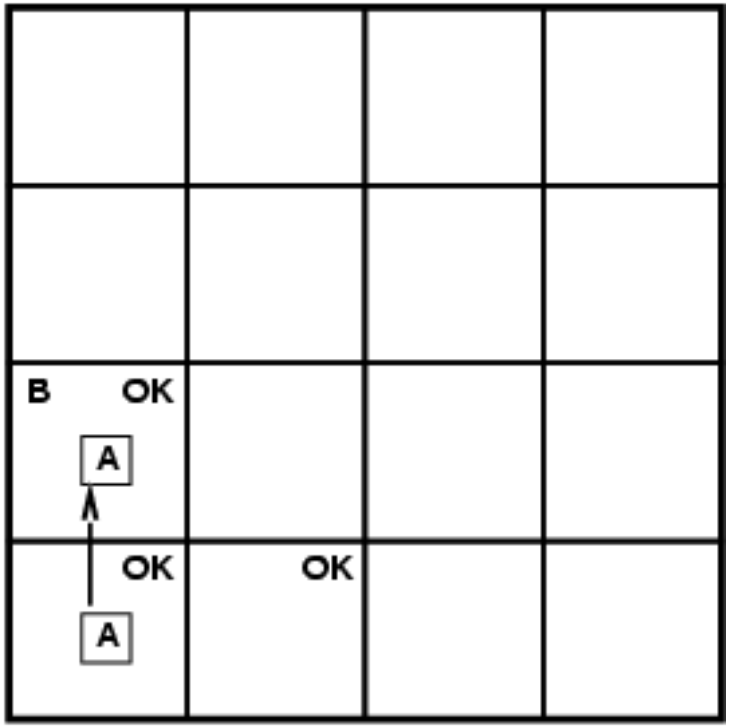


Exploring Wumpus World

•Move Forward; Perceive [None, Breeze, None, None, None]



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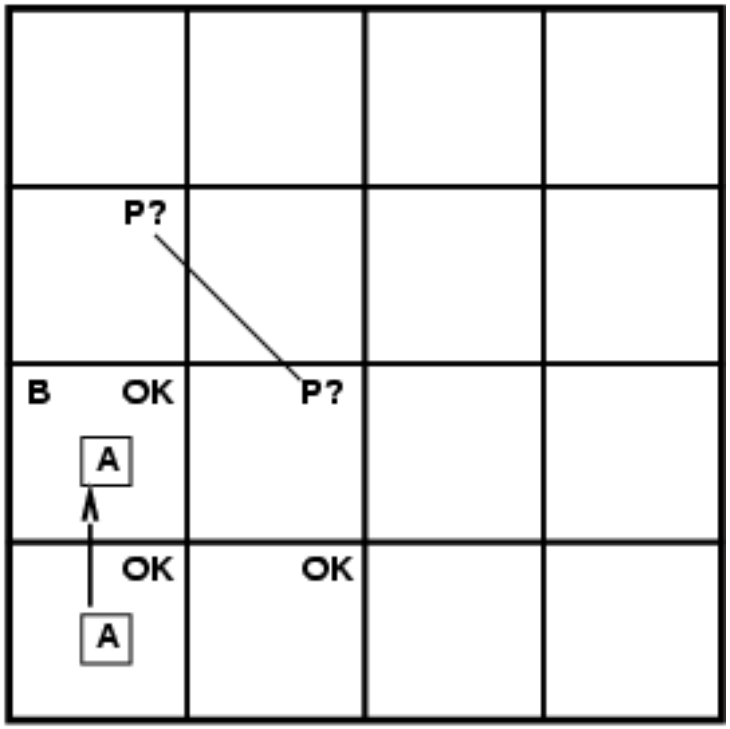
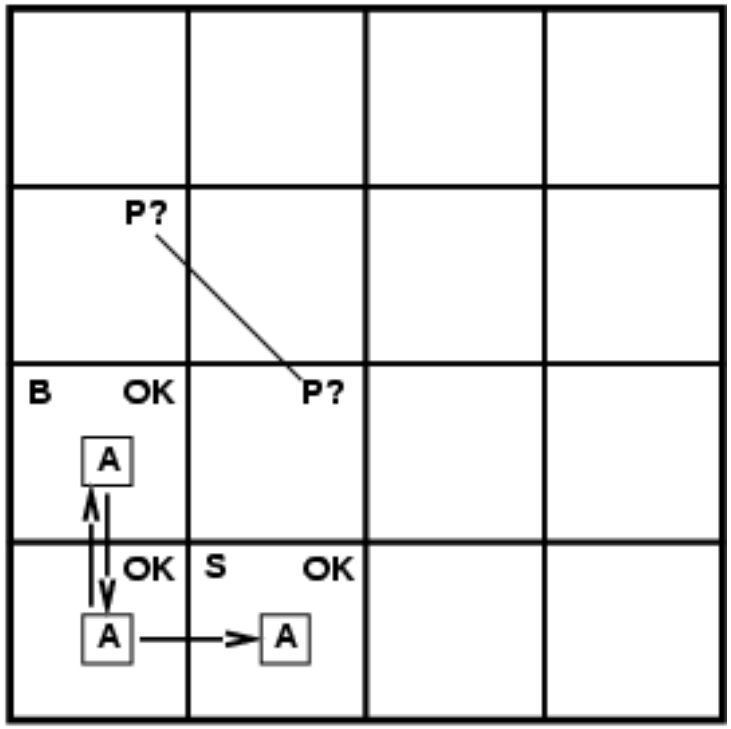


Exploring Wumpus World

•Move to [2,1]; Perceive [Stench, None, None, None, None]



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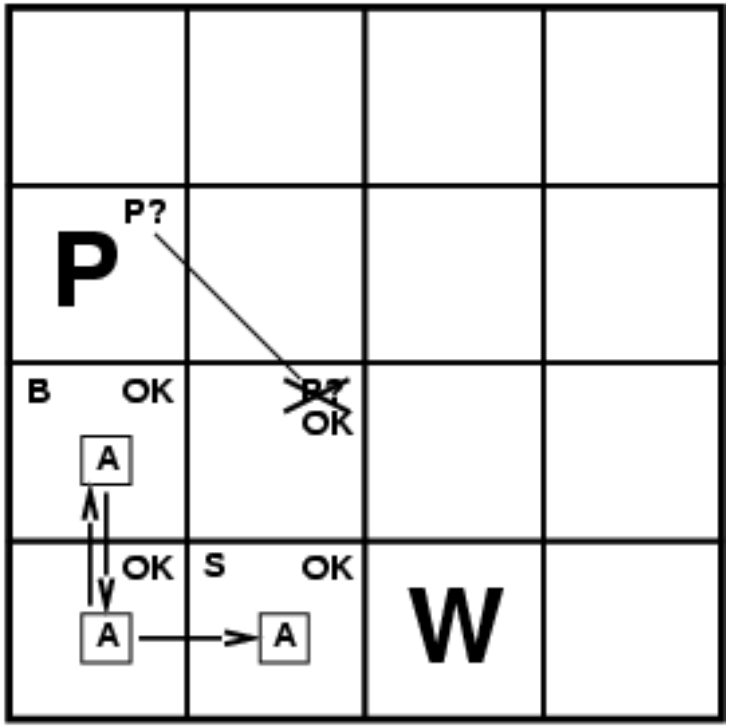
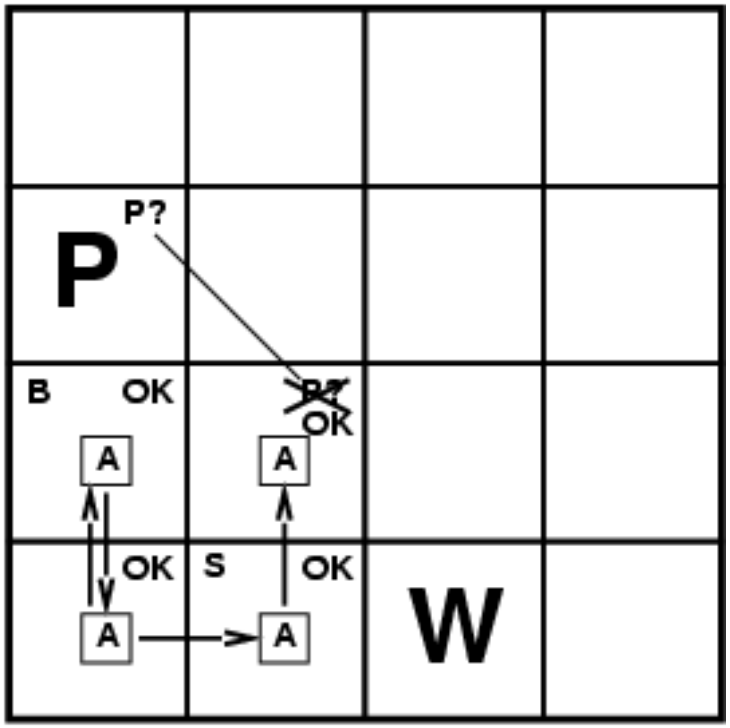


Exploring Wumpus World

•Move to [2,2]; Perceive [None, None, None, None, None]



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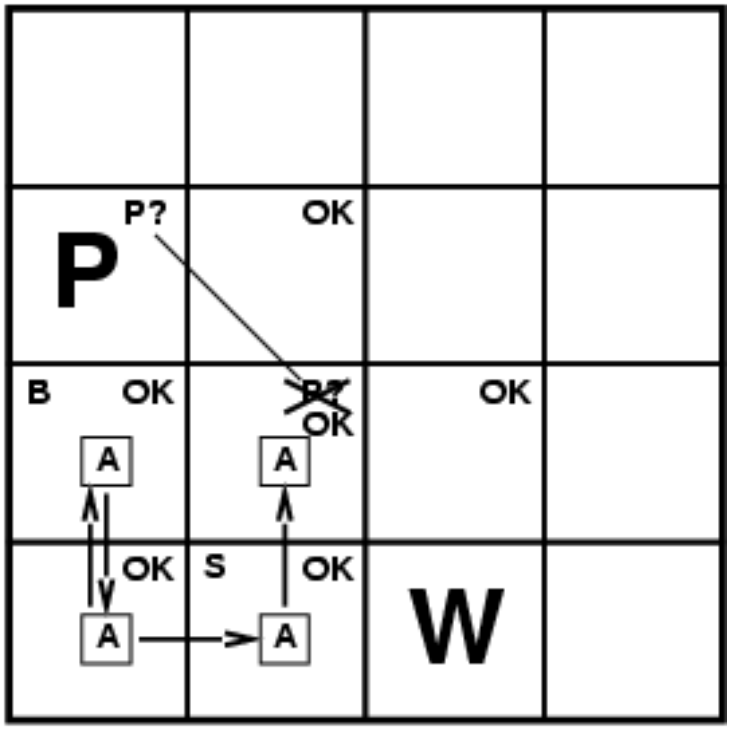
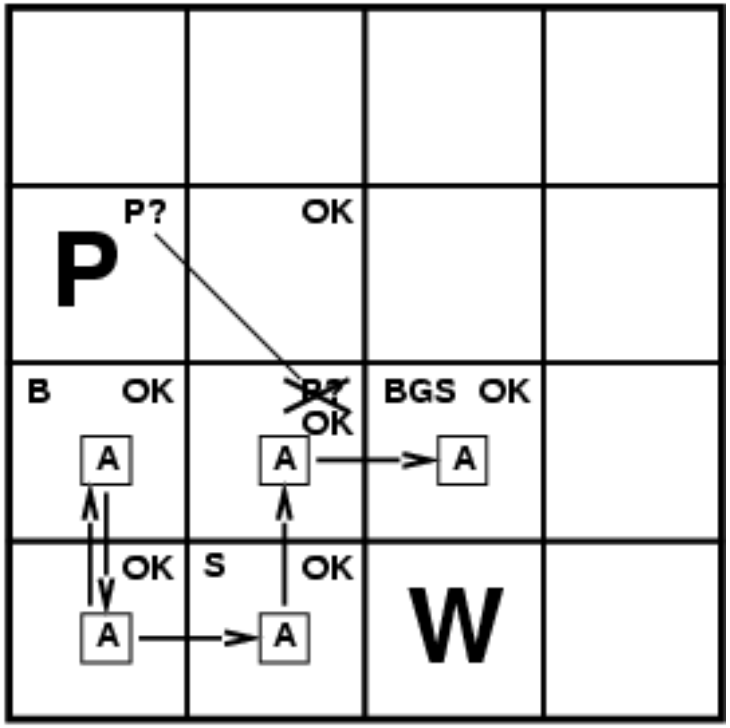
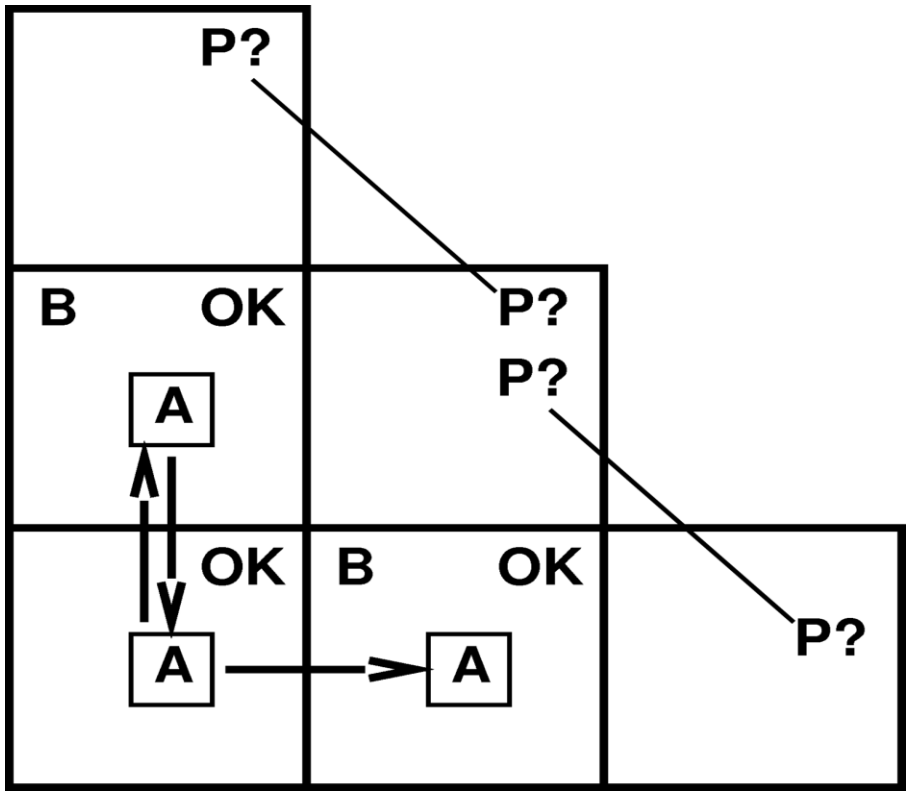


Exploring Wumpus World

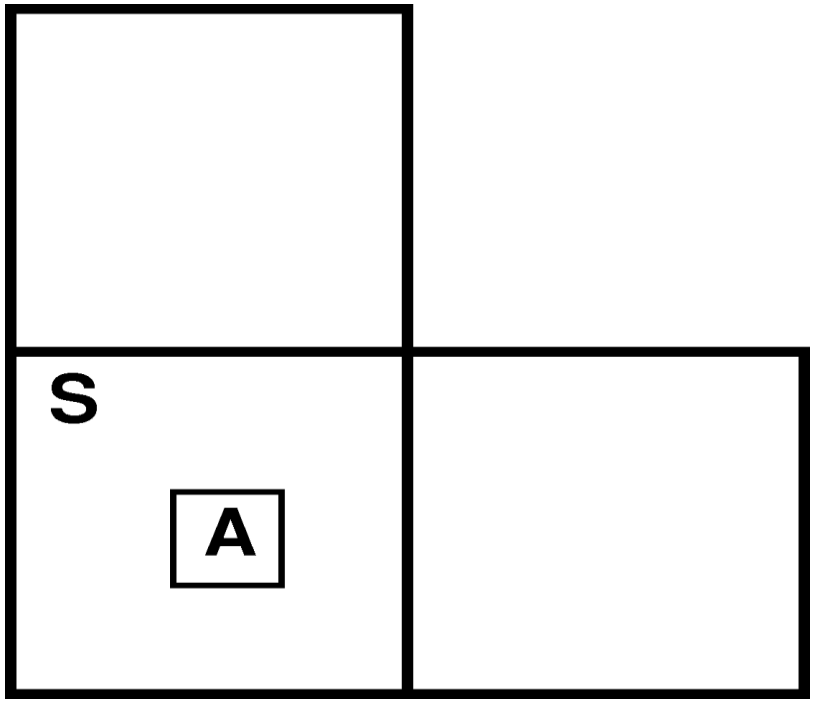
•Move to [3,2]; Perceive [Stench, Breeze, Glitter, None, None]



Special Situation



Special Situation



Logic in general

- Logics are formal languages for representing and processing knowledge
- Syntax defines the well-formed sentences in the language
- Semantics defines the "meaning" of a sentence

Logic in general

- Example: $x + y = 4$ is a well-formed sentence. $xy+4=$ is not!
- x and y can take values from a domain, say $\mathbb{N}$, the set of Natural numbers
- $x = 10$ and $y = 2$ is a possible world (**interpretation**) in which given sentence is false
- $x = 2$ and $y = 2$ is a possible world (interpretation) in which the sentence is true (such interpretations are called as **models**)

Logic in general

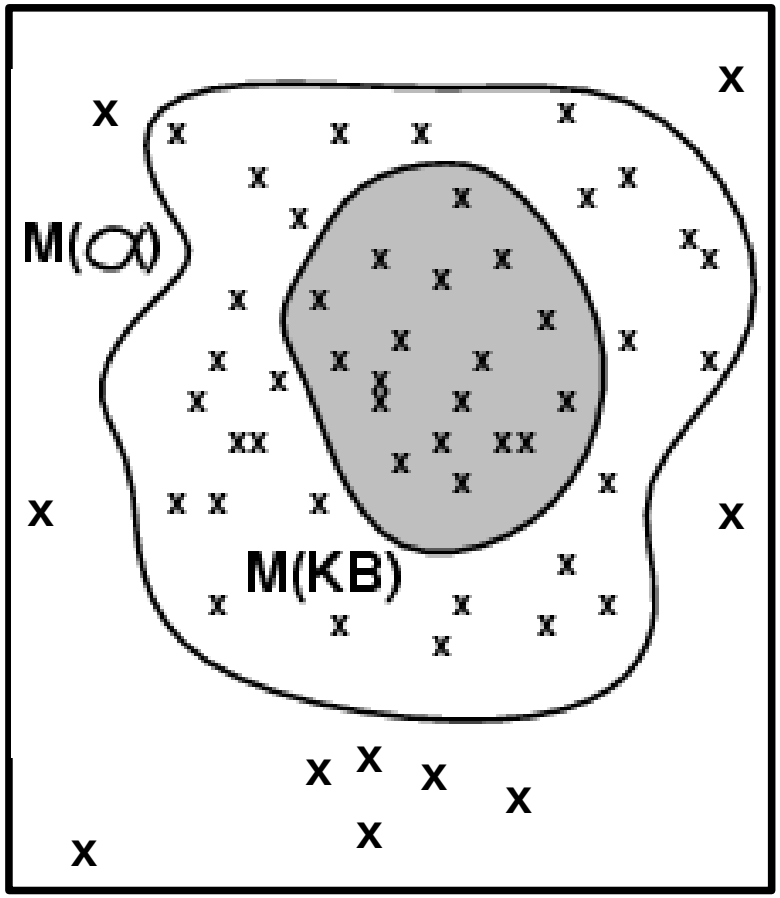
- Entailment means one thing follows from the other: KB $\models \alpha$
- KB **entails** α iff α is true in all the interpretations where KB is true
- $(x + y = 4) \models (y = 4 - x)$
- Entailment is a relationship between sentences based on semantics

Logic in general

- M(KB): set of all models of KB
- KB $\models \alpha$ iff $M(KB) \subseteq M(\alpha)$
- Consider, for example,

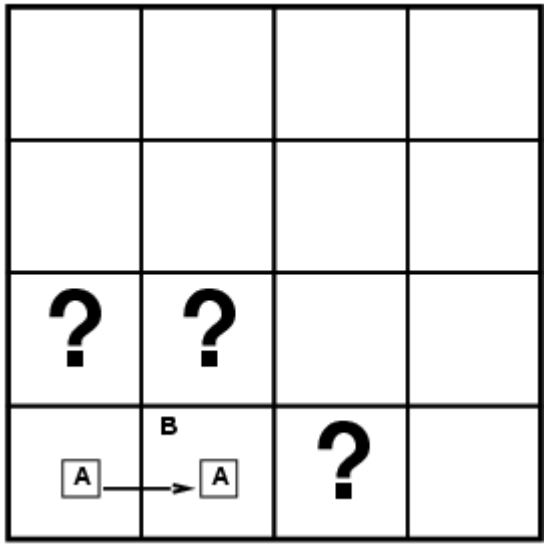
  $(x + y = 4) \models (y \leq 4)$
- Inference in logic:

  $KB \stackrel{?}{\models} \alpha$

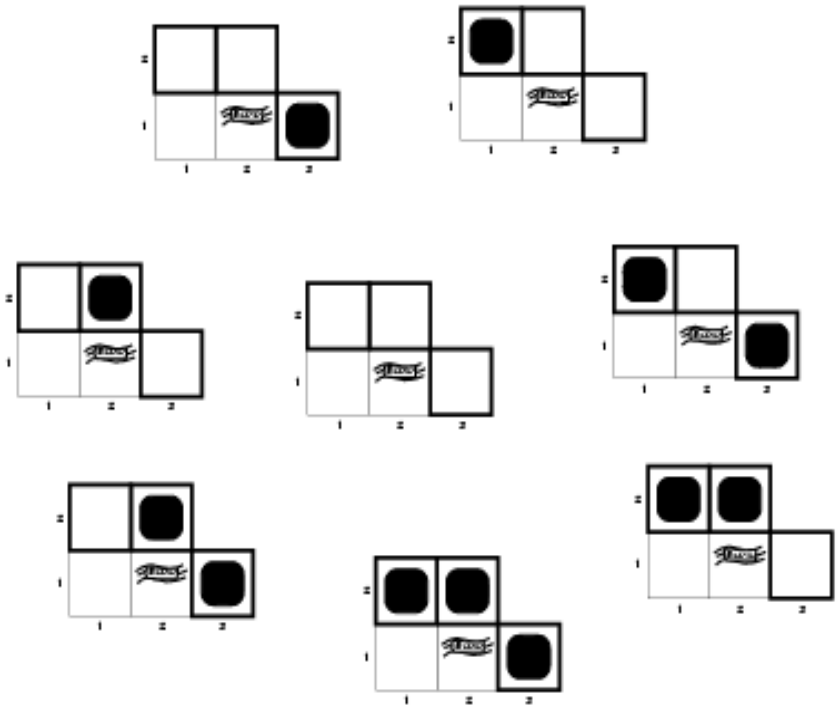


Entailment in Wumpus World

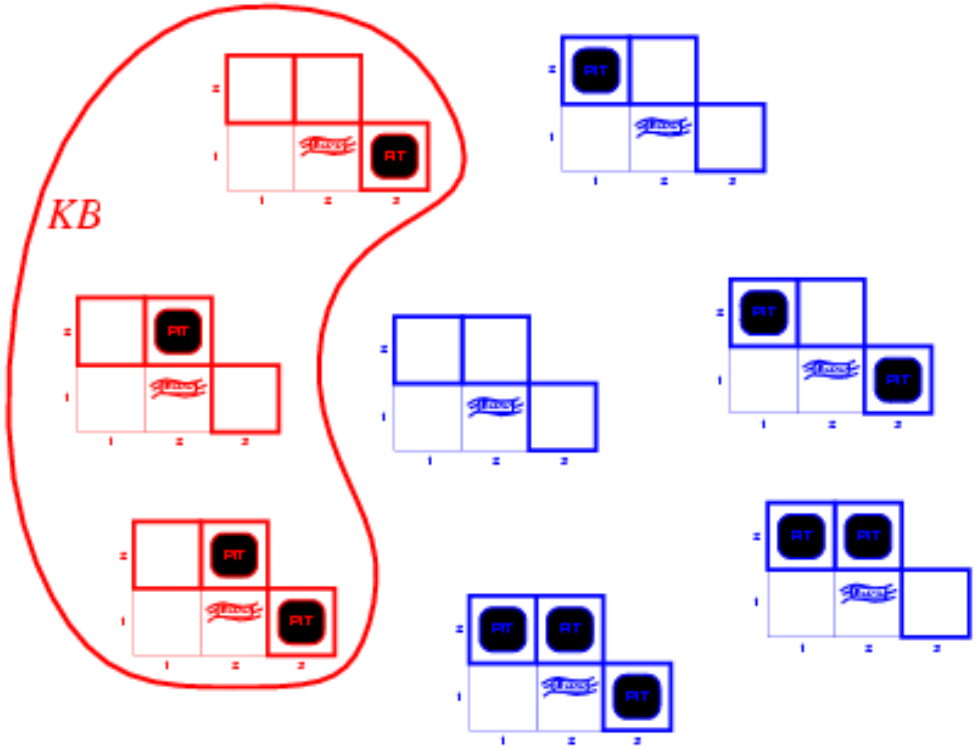
- Situation after detecting nothing in [1,1], moving right, breeze in [2,1]
- Consider interpretations for KB considering only pits
- 3 boolean choices imply 8 possible interpretations



Entailment in Wumpus World

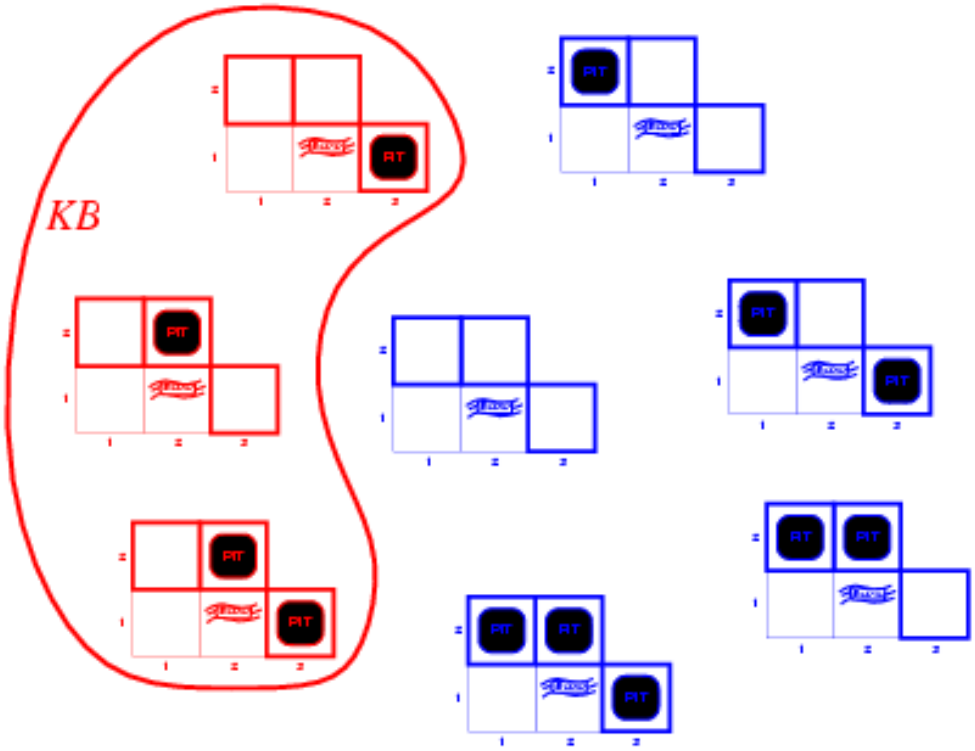


Entailment in Wumpus World



KB: Rules of the Wumpus world + observations

Entailment in Wumpus World

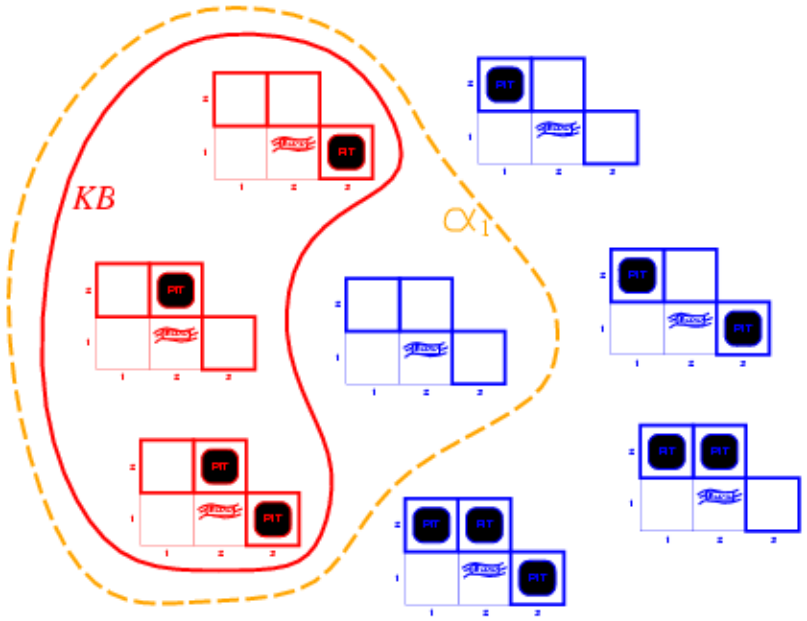


KB: Rules of the Wumpus world + observations

α_1 : [1,2] is safe

$KB \stackrel{?}{\models} \alpha_1$

Entailment in Wumpus World

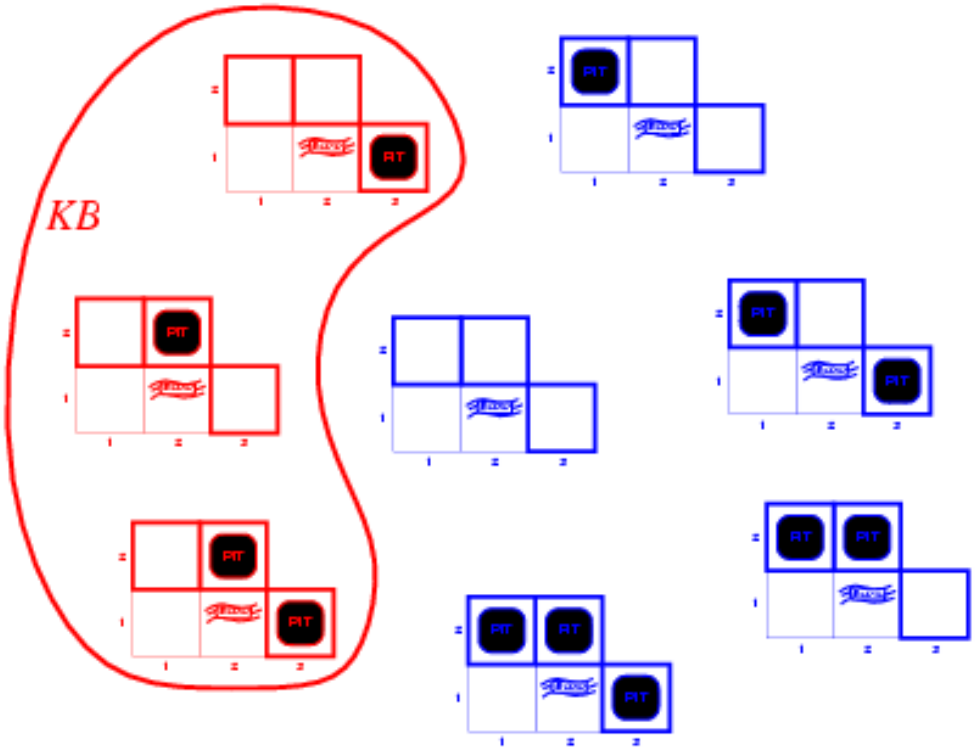


KB: Rules of the Wumpus world + observations

α_1 : [1,2] is safe

KB $\models \alpha_1$ can be proved by **model checking**!

Entailment in Wumpus World

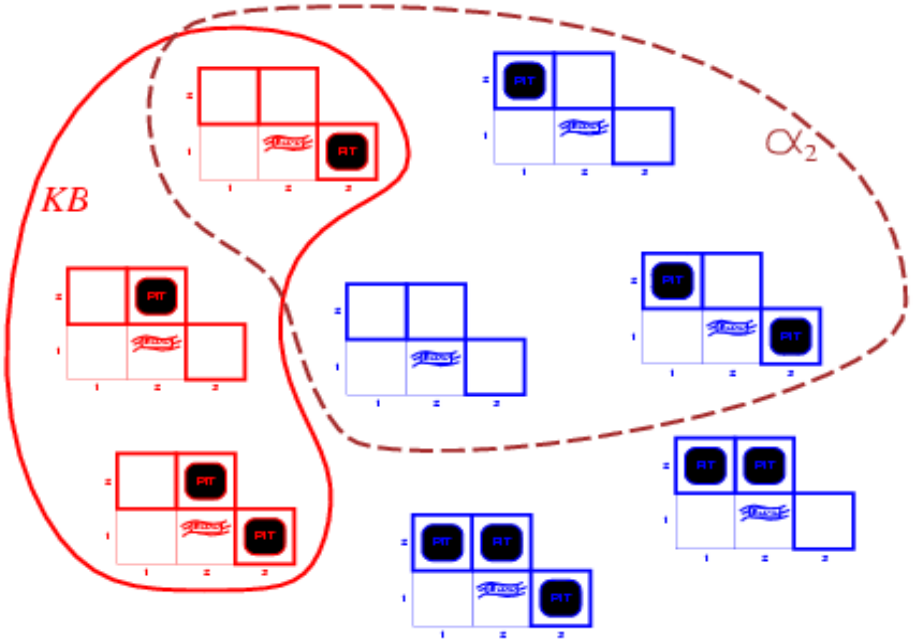


KB: Rules of the Wumpus world + observations

α_2 : [2,2] is safe

$KB \stackrel{?}{\models} \alpha_2$

Entailment in Wumpus World



KB: Rules of the Wumpus world + observations

α_2 : [2,2] is safe

KB $\not\models \alpha_2$

Derivations

- KB $\vdash \alpha$ if α can be **derived** from KB using syntactic **inference rules**

$$x + y = 4$$

$$x + y - y = 4 - y$$

$$x = 4 - y$$

- Inference procedure is **sound** if every α derivable is entailed by KB
- Inference procedure is **complete** if every α that is entailed by KB can be derived from KB
- When we have sound and complete inference procedure, KB $\stackrel{?}{\models} \alpha$ can be reduced to KB $\stackrel{?}{\vdash} \alpha$

Questions?

What Next?

- Read Chapter 7
- We will continue with knowledge and reasoning
- Next few lectures will focus on propositional logic
- You can start reading sections 7.4 and beyond