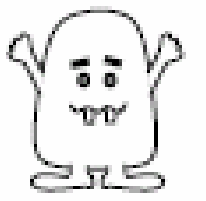
CSE 473

Chapter 7

Logical Agents I: Introducing the Wumpus



"Thinking Rationally"

- Computational models of human "thought" processes
- Computational models of human behavior
- Computational systems that "think" rationally
- Computational systems that behave rationally

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Logical Agents

- "Reflex agents find their way from Arad to Bucharest by dumb luck"
- Chess program calculates legal moves of its king, but doesn't know that no piece can be on 2 different squares at the same time
- Logic (Knowledge-Based) agents combine general knowledge with current percepts to infer hidden aspects of current state prior to selecting actions

  Crucial in partially observable environments

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Outline

- Knowledge-based agents
- Wumpus world
- Logic in general
- Propositional logic

  Inference, validity, equivalence and satisfiability

  Reasoning
  - Resolution
  - Forward/backward chaining

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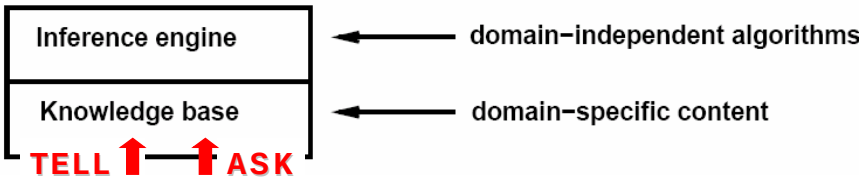
Knowledge Base

Knowledge Base : set of sentences represented in a knowledge representation language; stores assertions about the world.



Inference rule: when one ASKs questions of the KB, the answer should *follow* from what has been TELLed to the KB previously.

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Generic KB-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 ← *t* + 1
  return *action*

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Abilities of a KB agent

- Agent must be able to:
  - Represent states and actions
  - Incorporate new percepts
  - Update internal representation of the world
  - Deduce hidden properties of the world
  - Deduce appropriate actions

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Description level

- The KB agent is similar to agents with internal state
- Agents can be described at different levels
  - Knowledge level
    - What they know, regardless of the actual implementation (Declarative description)
  - Implementation level
    - Data structures in KB and algorithms that manipulate them, e.g., propositional logic and resolution

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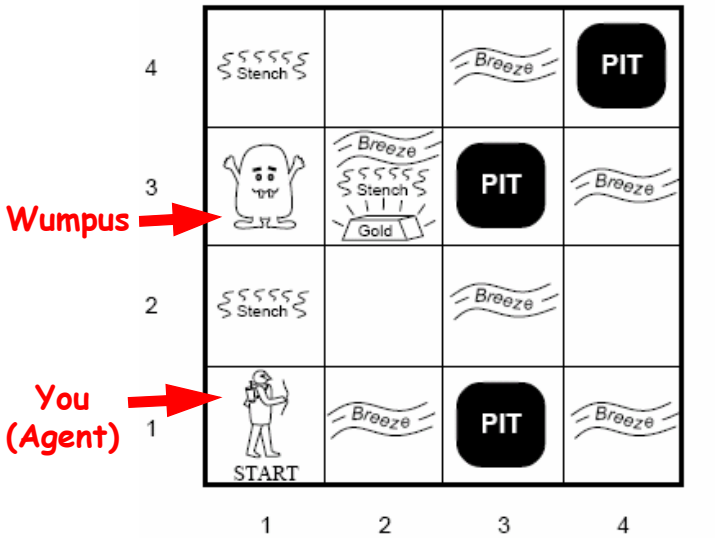
A Typical Wumpus World



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Wumpus World PEAS Description

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

Sensors Breeze, Glitter, Smell

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

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Wumpus World Characterization

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

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Wumpus World Characterization

- Observable? No, only local perception
- Deterministic?
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Wumpus World Characterization

- Observable? No, only local perception
- Deterministic? Yes, outcome exactly specified
- Episodic?
- Static?
- Discrete?
- Single-agent?

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Wumpus World Characterization

- Observable? No, only local perception
- Deterministic? Yes, outcome exactly specified
- Episodic? No, sequential at the level of actions
- Static?
- Discrete?
- Single-agent?

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Wumpus World Characterization

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- Static? Yes, Wumpus and pits do not move
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Wumpus World Characterization

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- Deterministic? Yes, outcome exactly specified
- Episodic? No, sequential at the level of actions
- Static? Yes, Wumpus and pits do not move
- Discrete? Yes
- Single-agent? Yes, Wumpus is essentially a "natural" feature

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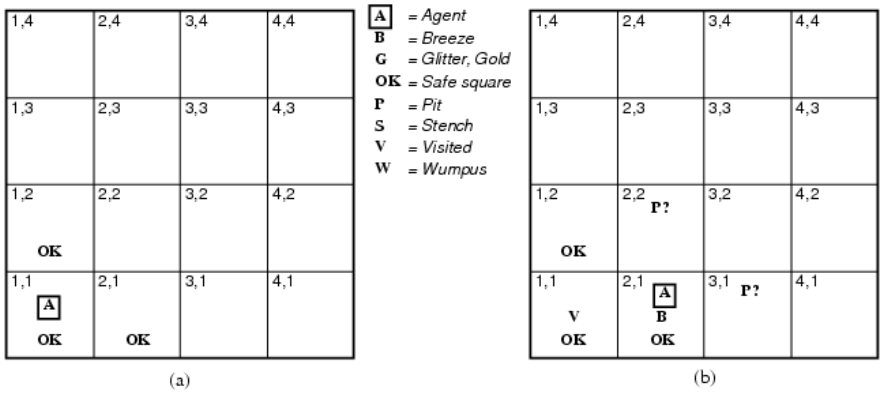
Exploring the Wumpus World



[1,1] KB initially contains the rules of the environment. First percept is [*none, none,none,none,none*], move to safe cell e.g. 2,1

[2,1] Breeze which indicates that there is a pit in [2,2] or [3,1], return to [1,1] to try next safe cell

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Exploring the Wumpus World

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

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

[1,2] Stench in cell which means that wumpus is in [1,3] or [2,2]
but not in [1,1]
YET … not in [2,2] or stench would have been detected in [2,1]
THUS … wumpus is in [1,3]
THUS [2,2] is safe because of lack of breeze in [1,2]
THUS pit in [3,1]
move to next safe cell [2,2]

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Exploring the Wumpus World

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

[2,2] Move to [2,3]
[2,3] Detect glitter, smell, breeze
Pick up gold
THUS pit in [3,3] or [2,4]

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What is a logic?

- A formal language
  - Syntax – what expressions are legal (well-formed)
  - Semantics – what legal expressions mean
    - In logic the truth of each sentence evaluated with respect to each possible world
- E.g the language of arithmetic
  - X+2 >= y is a sentence, x2+y is not a sentence
  - X+2 >= y is true in a world where x=7 and y =1
  - X+2 >= y is false in a world where x=0 and y =6

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Entailment

- One thing follows from another

  $KB \models \alpha$
- KB entails sentence α *if and only if* α is true in all worlds where KB is true.

  E.g. x+y=4 entails 4=x+y
- Entailment is a relationship between sentences that is based on semantics.

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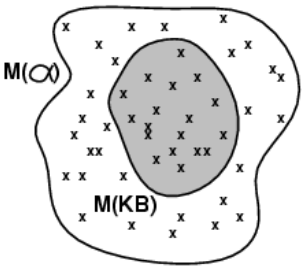
Models

- Logicians typically think in terms of models, which are formally structured worlds with respect to which truth can be evaluated
- *m* is a model of a sentence α if α is true in *m*
- $M(\alpha)$ is the set of all models of α
- Then KB $\models \alpha$ iff $M(KB) \subseteq M(\alpha)$

  E.g. *KB* = CSE 473 students are bored and CSE 473 students are sleepy;
  α = CSE 473 students are bored



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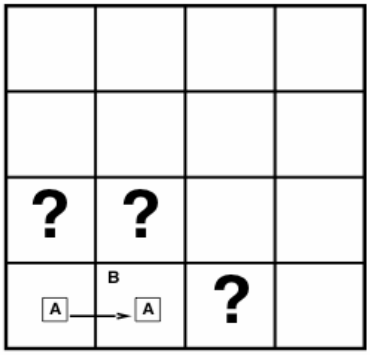
Wumpus world model

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

Consider possible models for ?s assuming only pits

3 Boolean choices ⇒ 8 possible models



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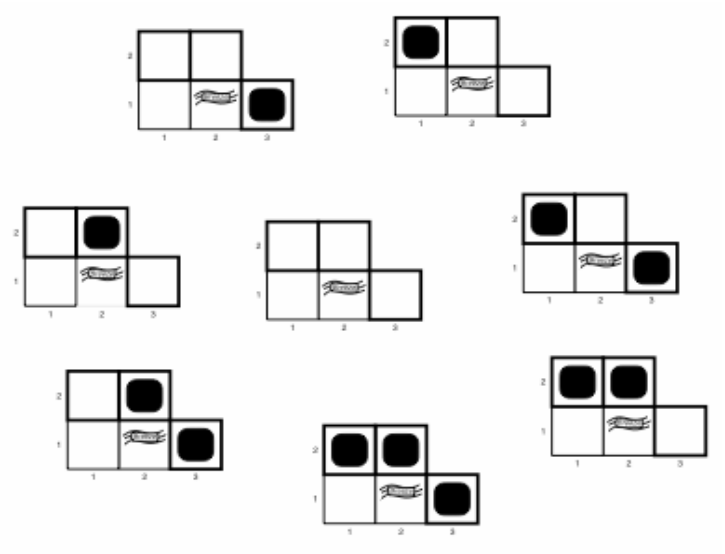
Wumpus world model



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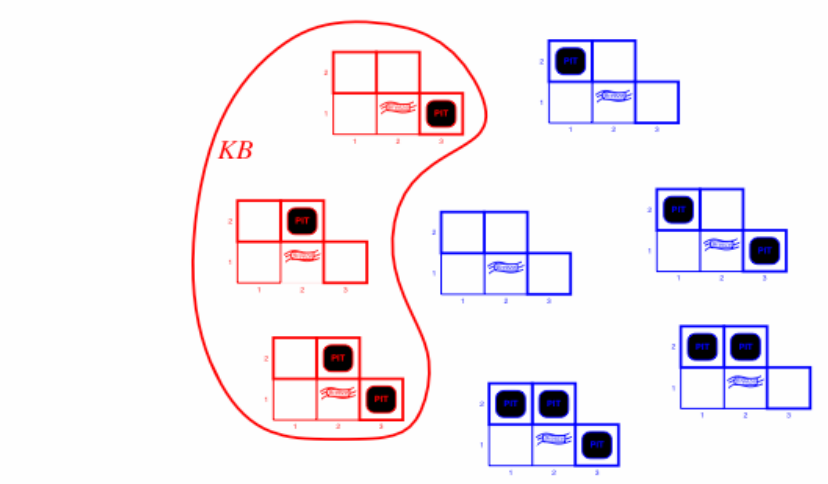
Wumpus world model



KB = wumpus-world rules + observations

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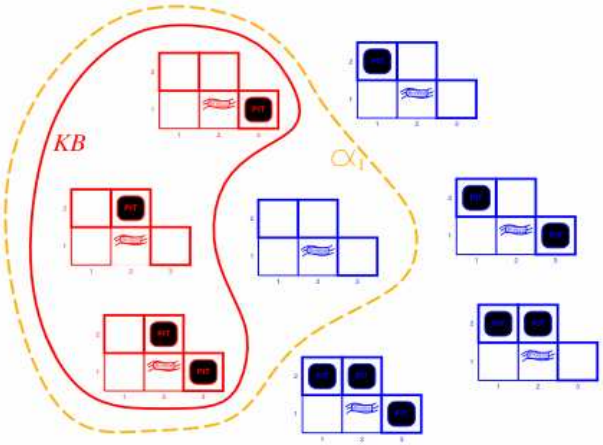
Wumpus world model



KB = wumpus-world rules + observations

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

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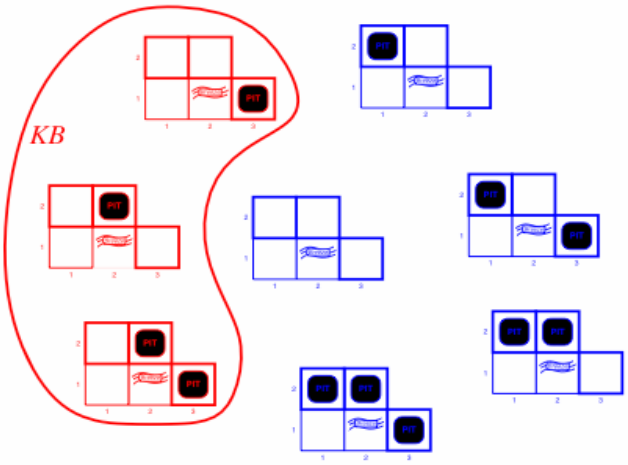
Wumpus world model



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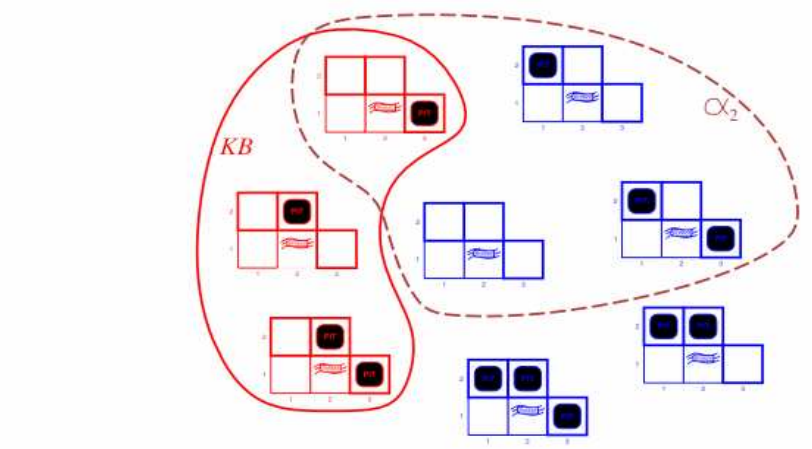
Wumpus world model



KB = wumpus-world rules + observations

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

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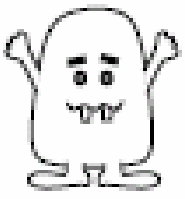
Next Time

- Propositional Logic
- Reasoning:
  - Resolution
  - Forward/backward Chaining



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