

Knowledge Representation for Problem Solving

- A complete intelligent agent needs to be able to perform several tasks:
 - *Perception*: what is my state?
 - *Deliberation*: what action should I take?
 - *Action*: how do I execute the action?
- **State recognition** implies some form of *knowledge representation*
- **Figuring out the right action** implies some form of *inference*

Two levels to think about:

- Knowledge level; what does the agent know?
- Implementation level: how is the knowledge represented?

Key question: What is a good representation?

Knowledge Bases

The golden dream:

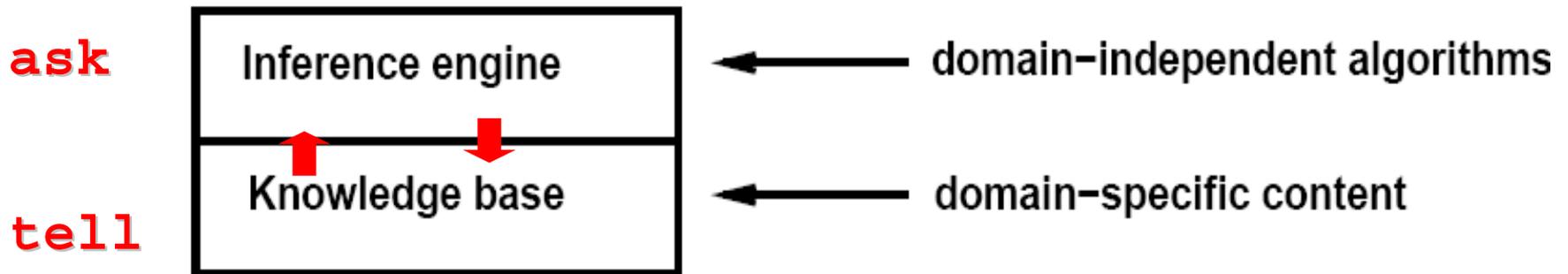
- **Tell** the agent what it needs to know (‘**declarative** approach’)
- The agent uses rules of inference to deduce consequences

Agents have two different parts:

- A *knowledge base*, which contains a set of facts expressed in some formal, standard language
- An *inference engine*, with general rules for deducing new facts when the agent is **asked**

Knowledge Base

Knowledge Base: set of sentences represented in a knowledge representation language and represents 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.

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 ← t + 1  
  return action
```

- MAKE-PERCEPT-SENTENCE (*percept*, *t*)
 - Takes a percept and a time and return a sentence asserting that the agent perceived the percept at the given time
- MAKE-ACTION-QUERY (*time*)
 - Takes as an input, time, and returns a sentence that asks what action should be performed at that time

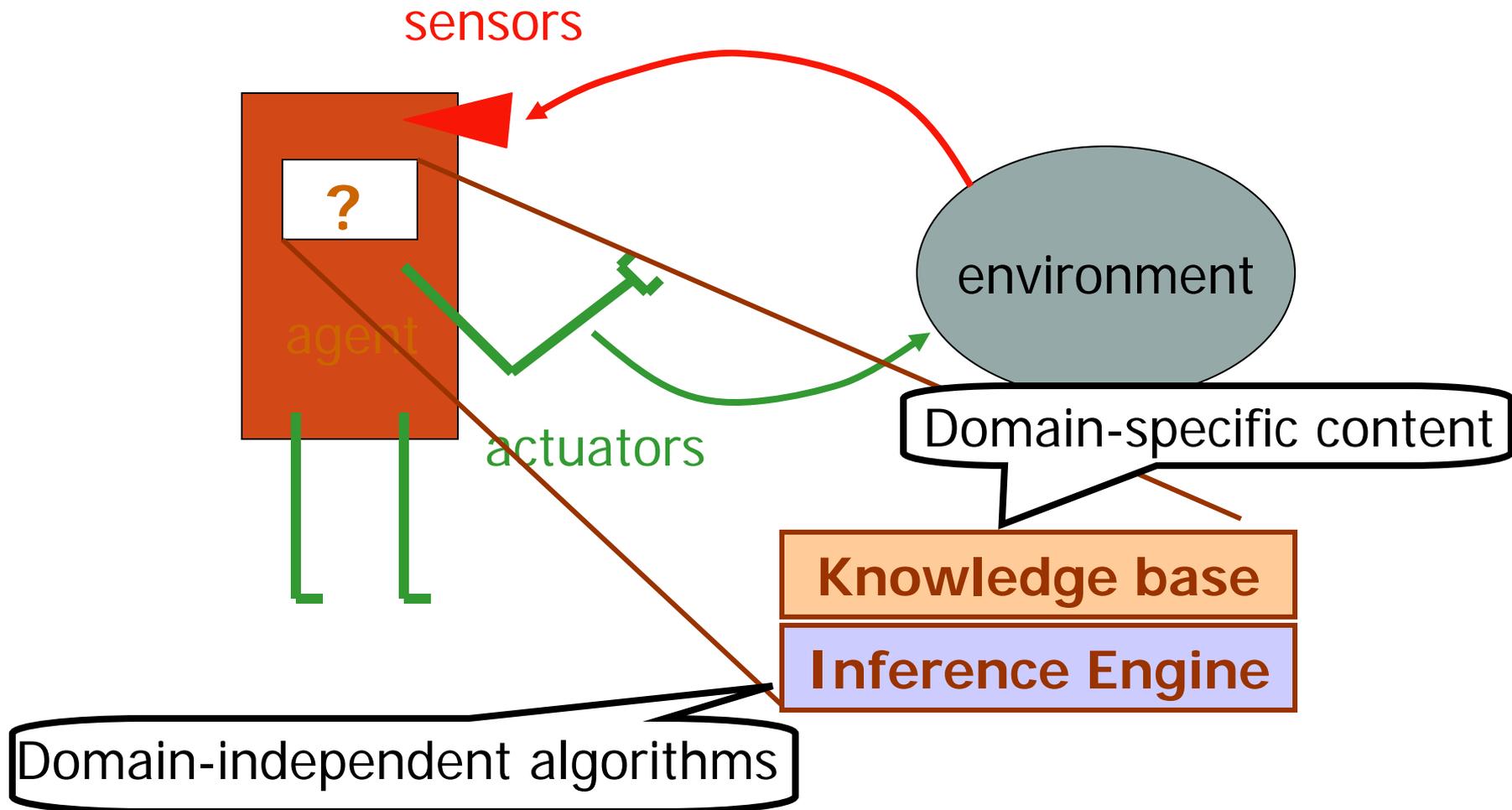
In summary:

- The Knowledge Base is a set of sentences.
 - ▶ Syntactically well-formed
 - ▶ Semantically meaningful
- A user can perform two actions to the KB:
 - ▶ Tell the KB a new fact
 - ▶ Ask the KB a question

Logical Agents

- Reflex agents find their goal state by dumb luck
- **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

Knowledge-Based Agent



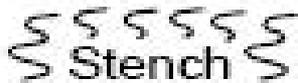
4



3



2



1



1

2

3

4

The Wumpus World (**Goals**)

The Wumpus computer game

- The agent explores a cave consisting of rooms connected by passageways.
- Lurking somewhere in the cave is the Wumpus, a beast that eats any agent that enters its room.
- Some rooms contain bottomless pits that trap any agent that wanders into the room.
- Occasionally, there is a heap of gold in a room.
- The **goal** is to collect the gold and exit the world without being eaten

Wumpus **PEAS** description

- **Performance measure:**

gold: +1000, death: -1000, -1 per step, -10 use arrow

- **Environment:**

- Squares adjacent to wumpus are smelly
- Squares adjacent to pit are breezy
- Glitter iff gold is in the same square
- Bump iff move into a wall
- Woeful scream iff the wumpus is killed
- 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:** Stench, Breeze, Glitter, Bump, Scream
- **Actuators:** Left turn, Right turn, Forward, Grab, Release, Shoot

What can we say about the Environment in the Wumpus world?

- Is it STATIC or DYNAMIC ?

Static

- Is it fully observable?

Partially (the agent has to figure out the Map based on local perception)

- Is it DETERMINISTIC?
 - ? What kind of effect do the actions have?

- **Deterministic**

Exploring the Wumpus World

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

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

(a)

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

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(b)

[1,1] The KB initially contains the rules of the environment.

The first percept is [none, none, none, none, none],

[Stench/None, Breeze/None, Glitter/None, Bump/None, Scream/None]

move to safe cell e.g. 2,1

Exploring the Wumpus World

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

(a)

- A** = Agent
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1,4	2,4	3,4	4,4
1,3	2,3	3,3	4,3
1,2	2,2 P?	3,2	4,2
1,1 V OK	2,1 A B OK	3,1 P?	4,1

(b)

$[2,1] = \text{breeze}$

indicates that there is a pit in $[2,2]$ or $[3,1]$,

return to $[1,1]$ to try next safe cell

4	SSSSS Stench	Breeze	PIT	
3	Wumpus Breeze SSSSS Stench Gold	PIT	Breeze	
2	SSSSS Stench	Breeze		
1	START Breeze	PIT	Breeze	
	1	2	3	4

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)

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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

(b)

[1,2] Stench in cell which means that wumpus is in [1,3] or [2,2]
 YET ... not in [1,1]
 YET ... not in [2,2] or stench would have been detected in [2,1]
 (this is relatively sophisticated reasoning!)

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)

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(b)

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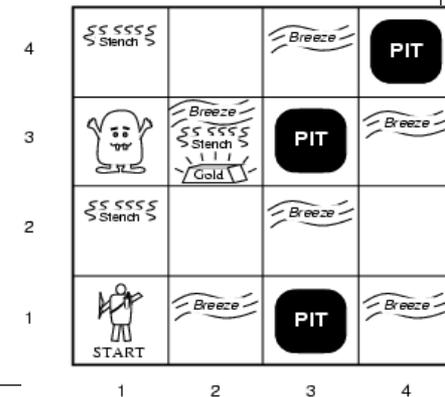
(this is relatively sophisticated reasoning!)

THUS ... wumpus is in [1,3]

THUS [2,2] is safe because of lack of breeze in [1,2]

THUS pit in [3,1] (again a clever inference)

move to next safe cell [2,2]



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(a)

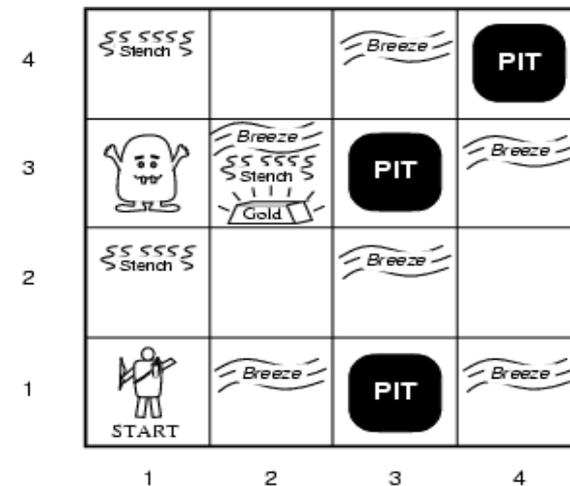
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1,4	2,4 P?	3,4	4,4
1,3 W!	2,3 A S G B	3,3 P?	4,3
1,2 S V OK	2,2 V OK	3,2	4,2
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(b)

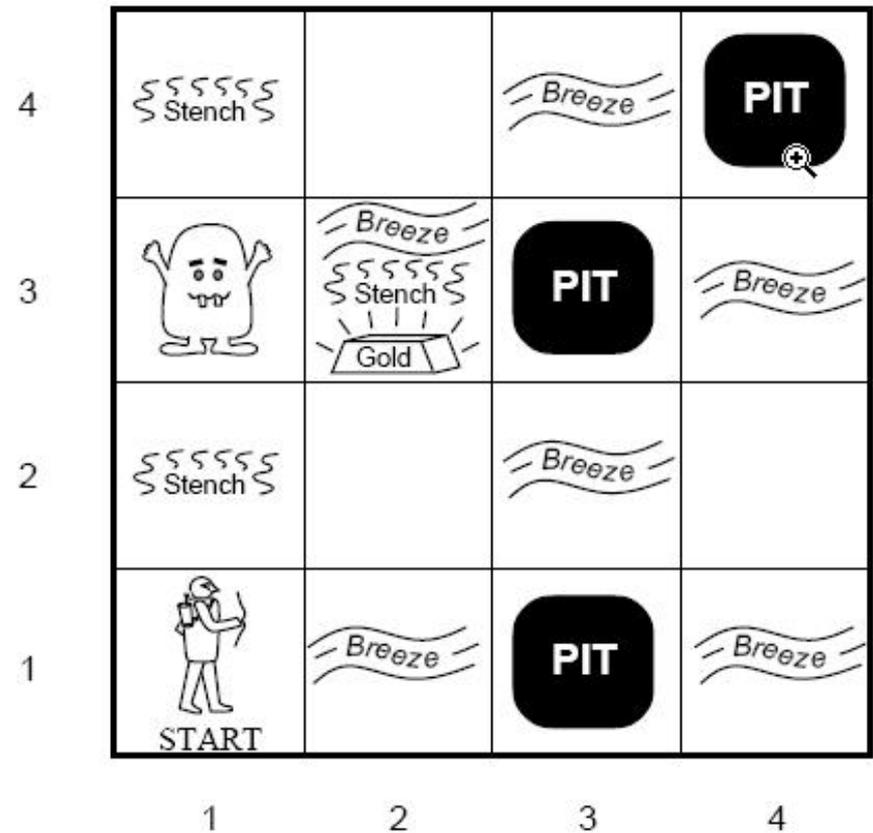
[2,2] move to [2,3]

[2,3] detect glitter , smell, breeze
 THUS pick up gold
 THUS pit in [3,3] or [2,4]



Representing the world

- Wumpus world general knowledge
 - relate pits and breezes
 - relate wumpus and stench
 - relate gold to glitter



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 - relate pits and breezes
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Wumpus world environment facts

- 16 propositions for pits
- 16 propositions for breeze
- 16 propositions for wumpus
- 16 propositions for stench
- 16 propositions for gold
- 16 propositions for glitter

