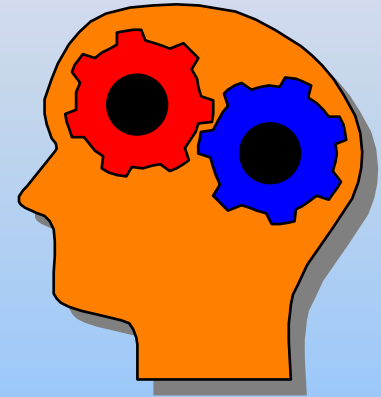


ARTIFICIAL INTELLIGENCE



CSC304

CZ3005

**School of Computer Engineering
Nanyang Technological University**



- **I Artificial Intelligence**
- **II Problem Solving**
- **III Knowledge and Reasoning**
- **IV Acting Logically**
- **V Uncertain Knowledge and Reasoning**
- **VI Learning**
- **VII Communicating, Perceiving and Acting**
- **VIII Conclusions**



- **Dr Chai Quek** **Profile of Lecturer**
- **Ph.D. – H.W. Edinburgh 1990**
 - An Intelligent Supervisory Control Schema
- **Area of Research: Learning Systems, Neural Network, Fuzzy System, Hybrid Fuzzy Neural Systems, Softcomputing, Computational Intelligence**
- **Application Areas: Computational Finance, Biomedical Engg, Intelligent Control, Intelligent Education, Soft modelling, (cognitive) sentiment mining**
- **Students groomed: over 12 gold medalists, 30 Ph.D.s, MSc, MEng etc.**
- **Hall 7 Head Counsellor, Assoc Chair (Students)**



Part III – Knowledge and Reasoning

- **6 Agents that Reason Logically**

- Knowledge-based Agents. – Representations.
- Propositional Logic. – The Wumpus World.

- **7 First-Order Logic**

- Syntax and Semantics. – Using First-Order Logic.
- Logical Agents. – Representing Changes.
- Deducing Properties of the World.
- Goal-based Agents.

- **8 Building a Knowledge Base**

- Knowledge Engineering. – General Ontology.



Part III – Knowledge and Reasoning

- **9 Inference in First-Order Logic**
 - Inference Rules. – Generalised Modus Ponens.
 - Forward and Backward Chaining. – Resolution.
- **10 Example classes - Prolog as KBS**
 - Starting week 10 – intro
 - Starting week 12 – assignment Wk 14 (Venue TBA)
(marks to be part of continuous assessments)



6 – AGENTS THAT REASON LOGICALLY

“In which we design agents that can form representations of the world, use a process of inference to derive new representations about the world, and use these new representations to deduce what to do.”



The Knowledge-Based Approach

- **Agents that *know***

- Achieve competence by being told new knowledge or by learning
- Achieve adaptability by updating their knowledge
- > *Knowledge representation*
 - State of the world, properties and evolution of the world; goals of the agent, actions and their effect

- **Agents that *reason***

- Use knowledge to deduce course of actions
- > *Knowledge inference*

Logic



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Knowledge-Based Agents

- **Knowledge base (KB)**
 - Set of sentences i.e., representations of facts (DB)
 - Knowledge representation language
- **Adding and querying knowledge**
 - **Tell**: add a sentence to the KB
 - **Ask**: retrieve knowledge from the KB
 - Answers must *follow* from what has been **Tell**'ed (told)
- **Inference mechanism**
 - Role: determine what follows from the KB



Problem Formulation of KBS

- **Knowledge Based System**

- States: Instances of the KB (sets of sentences)
 - Use **Tell** to build the KB
 - e.g. `Tell(KB, "Smoke \Rightarrow Fire")`
`Tell(KB, "Fire \Rightarrow Call_911")`
...
`Tell(KB, "Smoke")`
- Operators: Add / Infer a new sentence
- Goal: Answer a query
 - Use **Ask** to query the KB
 - e.g. `Ask(KB, "? Call_911")`



A Generic Knowledge-Based Agent

```
function KB-Agent (percept) returns action
  static KB,           // a knowledge base
         t             // a time counter, initially 0

  Tell (KB, Make-Percept-Sentence (percept, t))
  action ← Ask (KB, Make-Action-Query (percept, t))
  Tell (KB, Make-Action-Sentence (action, t))
  t ← t + 1
  return action
```

- > 3 steps: interpretation, inference, execution
- > KB: background knowledge (observed)
+ acquired information (deduced)



Example: the Wumpus World

- Problem description (**PAGE**)

- Environment

- Grid of squares, walls;
- Agent, gold, pits, wumpus.

- Goal

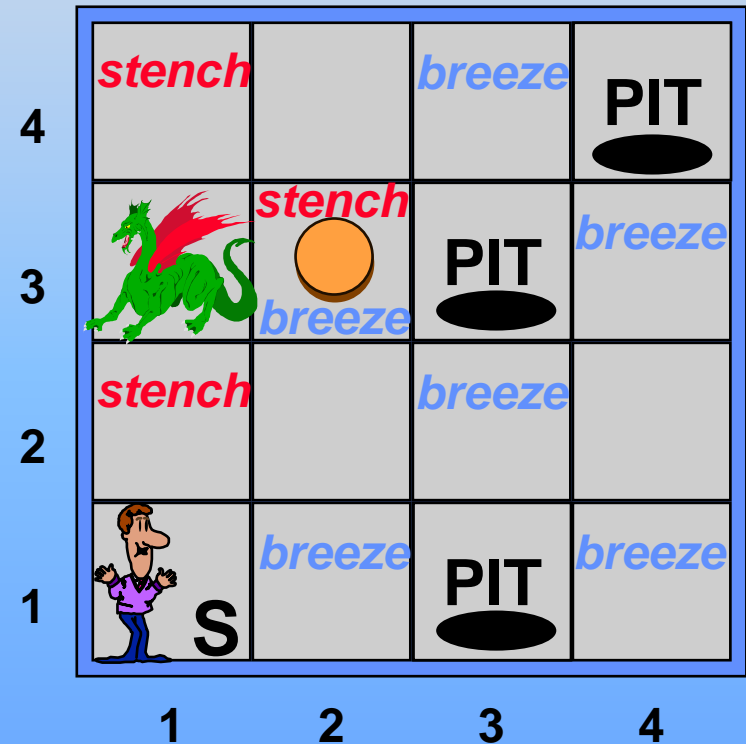
- Find the gold, return to S at [1,1].

- **Percepts**

- A list of 5 symbols, e.g. [Stench, Breeze, Glitter, Bump, Scream];
- Agent's location *not* perceived.

- **Actions**

- Go-Forward, Turn-Left, Turn-Right, Grab, Shoot (1 arrow only), Climb.





Levels of Knowledge

- **Epistemological level**

- Declarative description of knowledge

- e.g. facts: “there is smoke in the kitchen”, “it is not warm enough”
 - rules: “if there is smoke then there must be a fire”

- **Logical level**

- Logical encoding of knowledge (into sentences)

- e.g. facts: Smoke; rules: Implies(Smoke, Fire)

- **Implementation level**

- Physical representation of knowledge (sentences)

- e.g. - the string “Implies(Smoke, Fire)”, or
 - a “1” entry in a 2-dimensional array: Implies[X,Y]

Tell

Ask



The Wumpus World

- **Problem description (cont'd)**
 - Initial state
 - Agent at [1,1]; gold, pits and wumpus in random squares.
 - Path-cost
 - Climbing out with the gold: +1000 (without: 0)
 - Each action: –1
 - Getting killed (pit or wumpus): –10000
 - Knowledge
 - “In all squares adjacent to the one where the wumpus is, the agent will perceive a stench.”
 - “In all squares adjacent to a pit, the agent will perceive a breeze.”
 - In the square where the gold is, the agent will perceive a glitter.”
 - When walking into a wall, the agent will perceive a bump.”
 - When the wumpus is killed, the agent will perceive a scream.”

Acting and Reasoning in the Wumpus World

(0) Initial state

[nil, nil, nil, nil, nil]

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

A = Agent

B = Breeze

G = Glitter, Gold

OK = Safe square

(1) after {F}

[nil, Breeze, nil, nil, nil]

4				
3				
2	OK	P?		
1	V OK	A B OK	P?	
	1	2	3	4

P = Pit

S = Stench

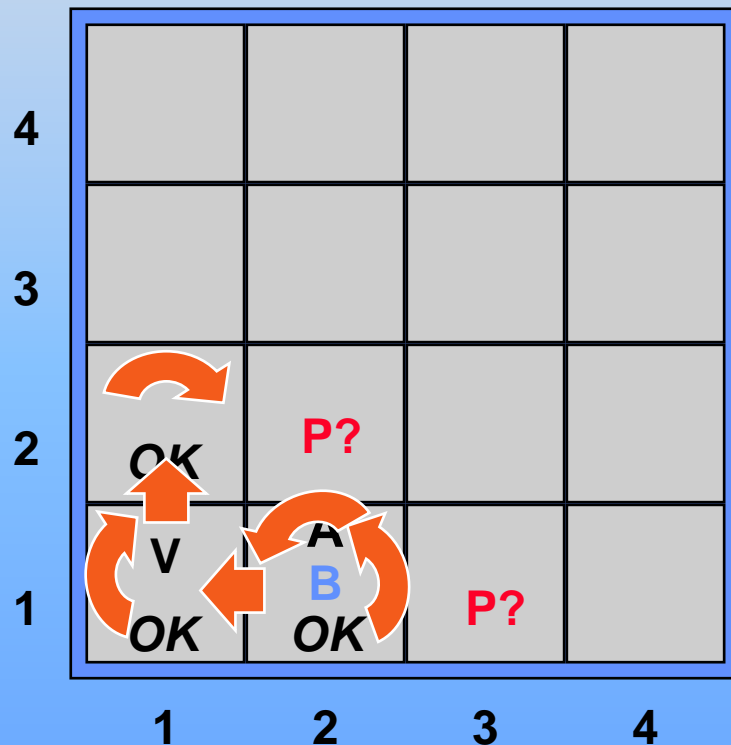
V = Visited

W = Wumpus

Acting and Reasoning in the Wumpus World

(1) after {F}

[nil, Breeze, nil, nil, nil]

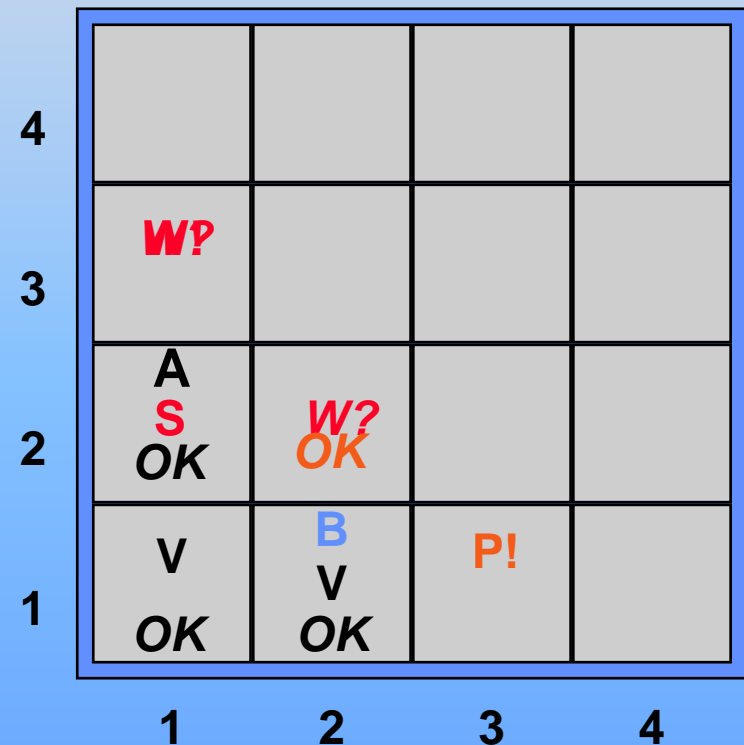


A = Agent
B = Breeze

G = Glitter, Gold
OK = Safe square

(6) after {F, L, L, F, R, F}

[Stench, nil, nil, nil, nil]



P = Pit
S = Stench

V = Visited
W = Wumpus

Acting and Reasoning in the Wumpus World

(6) after {F, L, L, F, R, F}
[Stench, nil, nil, nil, nil]

4				
3	W!	OK		
2	S OK	OK	OK	
1	V OK	B V OK	P!	
	1	2	3	4

A = Agent
B = Breeze

G = Glitter, Gold
OK = Safe square

(10) after {F, L, L, F, R, F, R, F, L, F}
[Stench, Breeze, Glitter, nil, nil]

4		P?		
3	W!	A S G B	P?	
2	S V OK	V OK	OK	
1	V OK	B V OK	P!	
	1	2	3	4

P = Pit
S = Stench

V = Visited
W = Wumpus

end