Princess Nora University
Faculty of Computer & Information Systems

جامعة الأميرة نورة بنت عبد الرحمن
Princess Nora Bint Abdul Rahman University

ARTIFICIAL INTELLIGENCE

(CS 370D)

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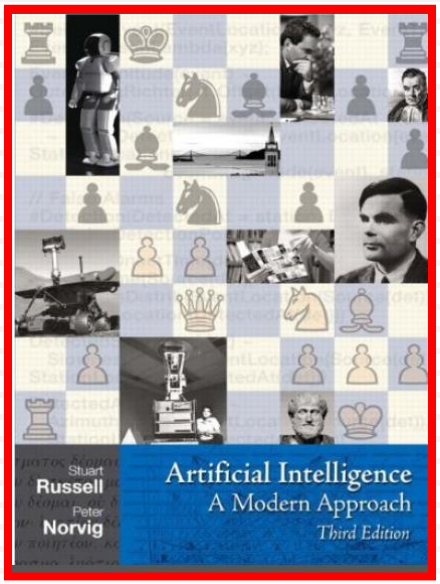

(CHAPTER-7)
LOGICAL AGENTS

Outline

- Agent Case (Wumpus world)
- Knowledge-Representation
- Logic in general - models and entailment
- Propositional (Boolean) logic

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Agent Case (Wumpus world)

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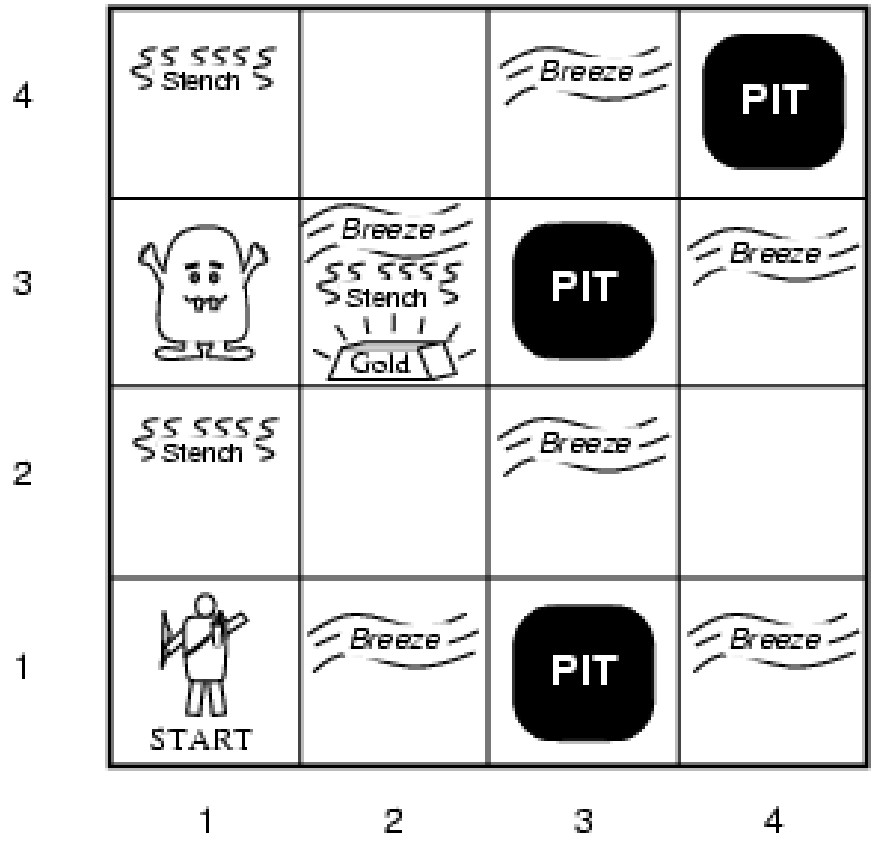
The Wumpus World



- ✓ The **wumpus** world is a cave consisting of rooms connected by passageways.
- ✓ Lurking somewhere in the cave is the terrible wmnpus, a beast that eats anyone who enters its room.
- ✓ The wumpus can be shot by an agent, but the agent has only one arrow.
- ✓ Some rooms contain bottomless pits (very deep hole) that will trap anyone who wanders into these rooms (except for the wumpus, which is too big to fall in).

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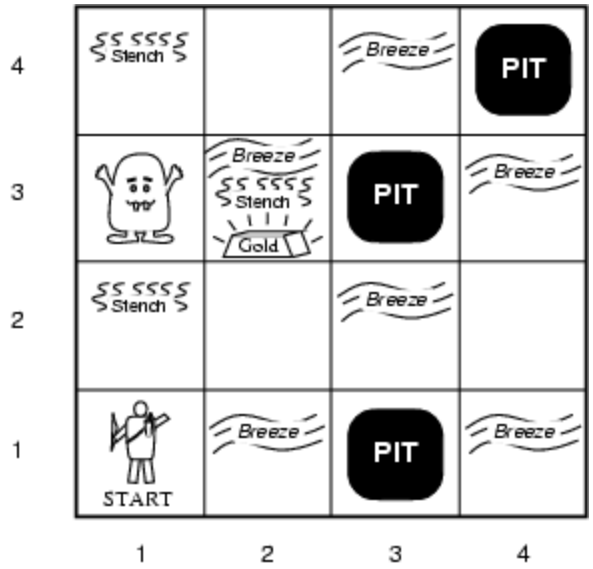
Wumpus World PEAS description

- **Performance measure**
  - Gold→ +1000, death →-1000
  - -1 per step, -10 for using the arrow

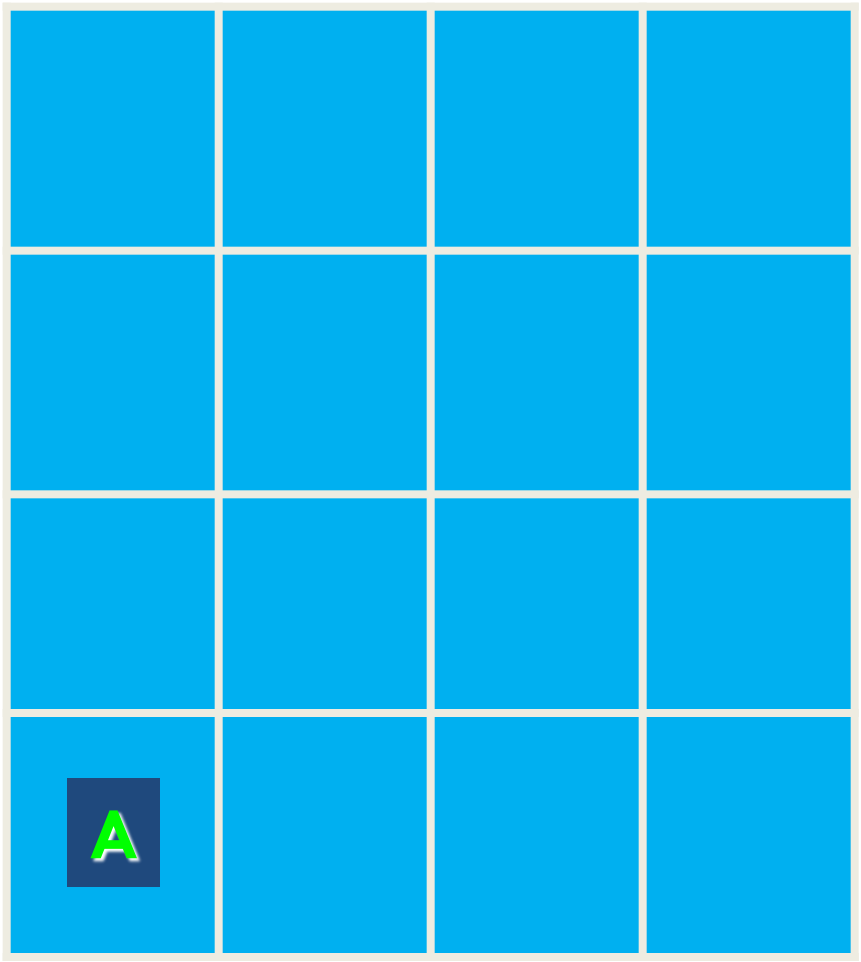
- **Environment**
  - Squares adjacent to wumpus are smelly
  - Squares adjacent to pit are breezy(windy)
  - Glitter **iff** gold is in the same square
  - Shooting kills wumpus if you are facing it
  - Shooting uses up the only arrow
  - Grabbing picks up gold if in same square
  - Releasing drops the gold in same square



- **Sensors**: Stench, Breeze (for movement), Glitter (gold), Bump (hit), Scream

- **Actuators**: Left turn, Right turn, Forward, Grab, Release, Shoot

Exploring Wumpus World



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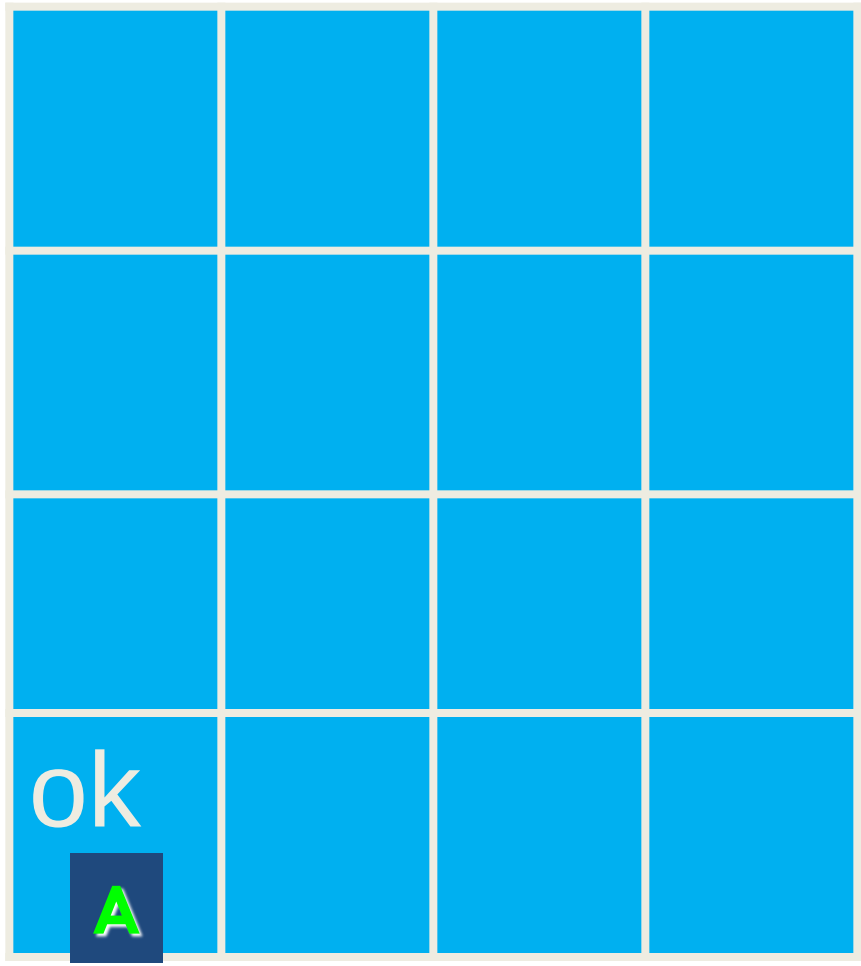
Exploring Wumpus World

Ok because:

Haven't fallen into a pit.

Haven't been eaten by a Wumpus.



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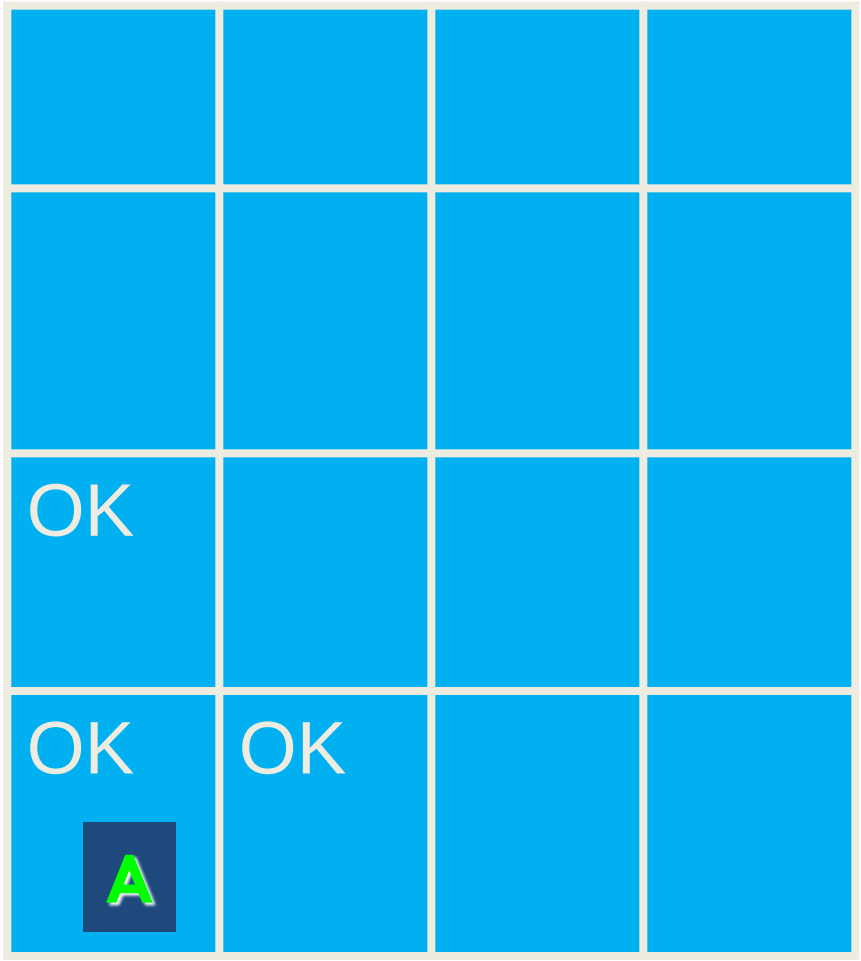
OK since

no Stench,

no Breeze,

neighbors are safe (OK).



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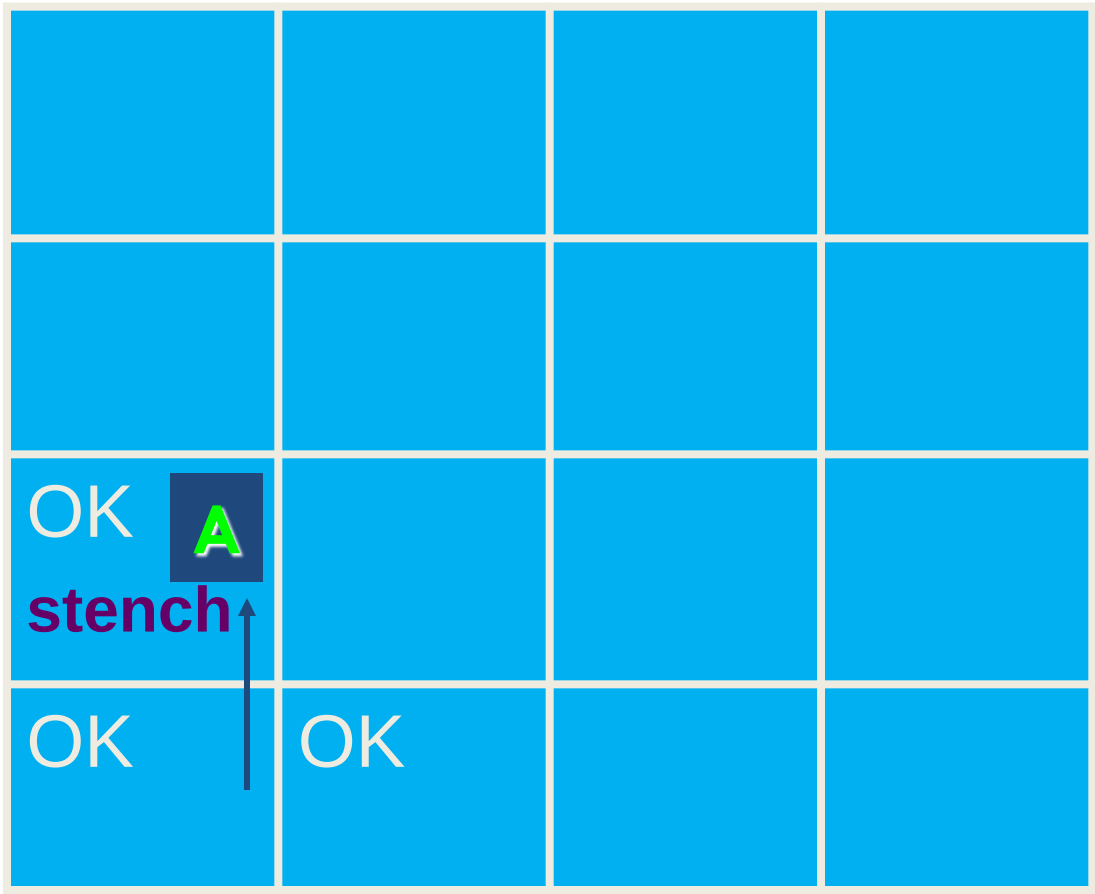
Exploring Wumpus World

We move and smell a stench.



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Knoweldge Representation & Reasoning

Exploring Wumpus World

We can infer the following.

Note: **square (1,1) remains OK.**

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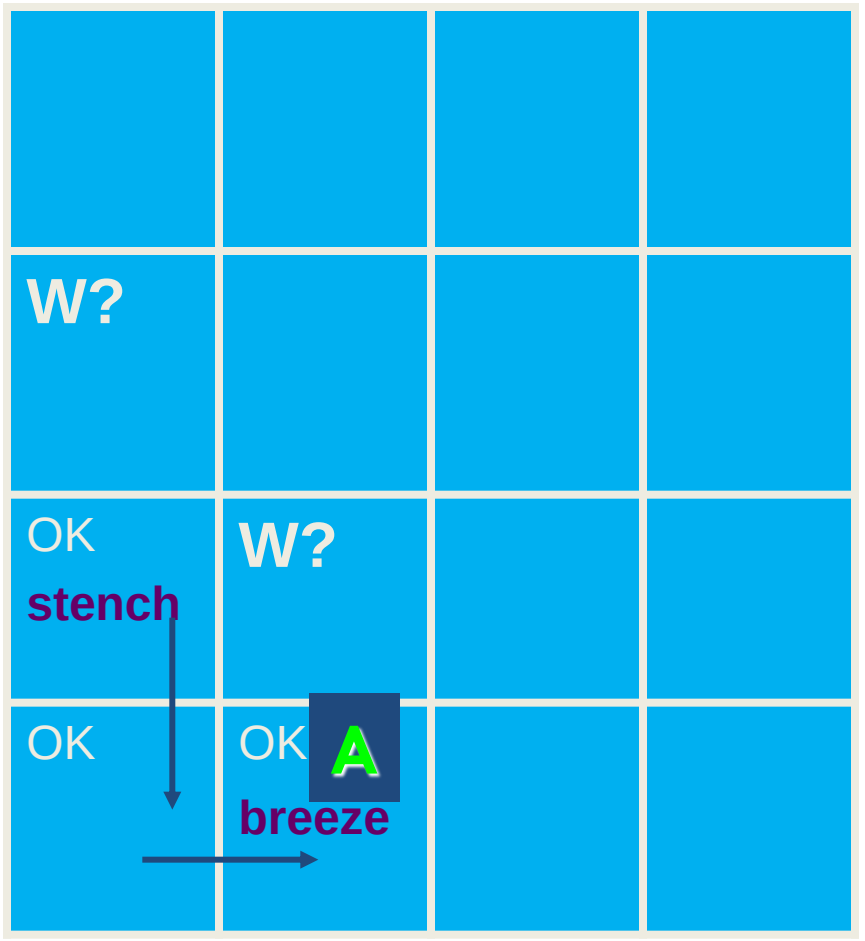
Exploring Wumpus World

Move and feel a breeze

What can we conclude?



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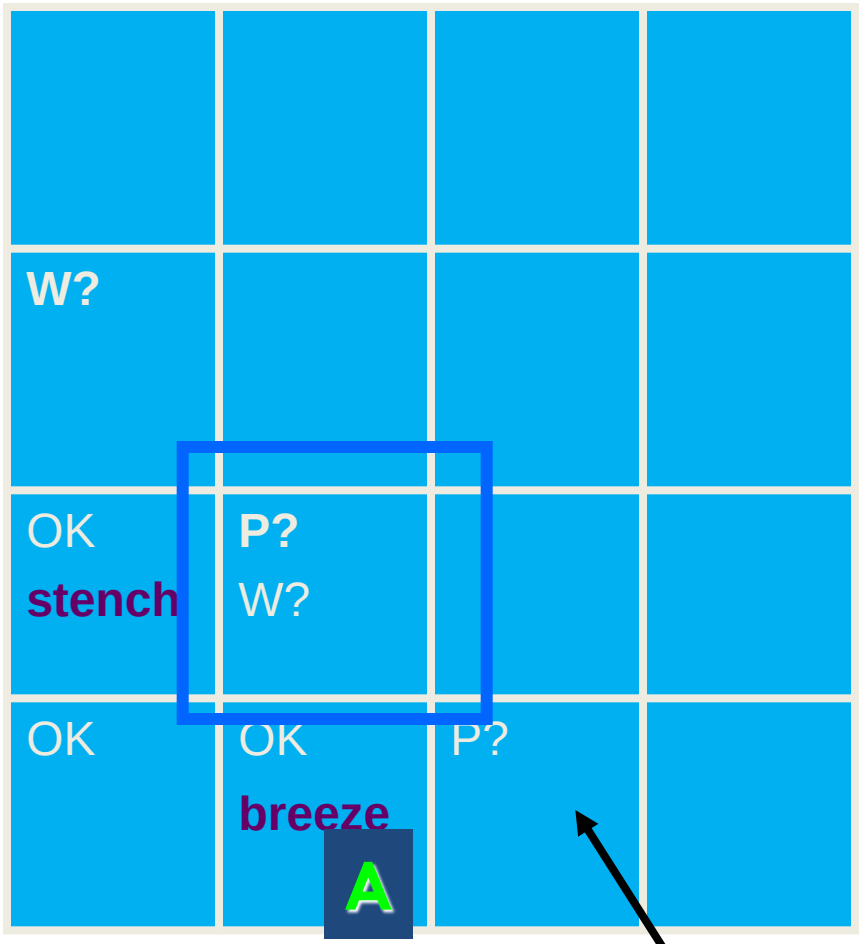
Exploring Wumpus World

But, can the 2,2 square really have either a Wumpus or a pit?

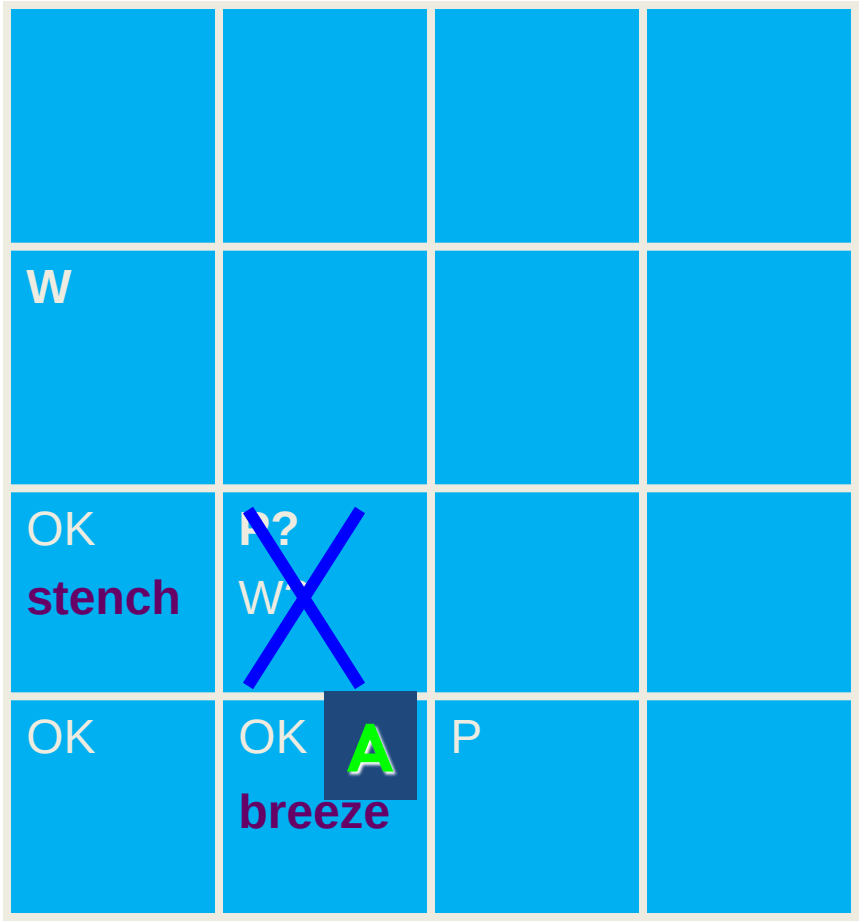


NO!

And what about the other P? and W? squares

13

Exploring Wumpus World



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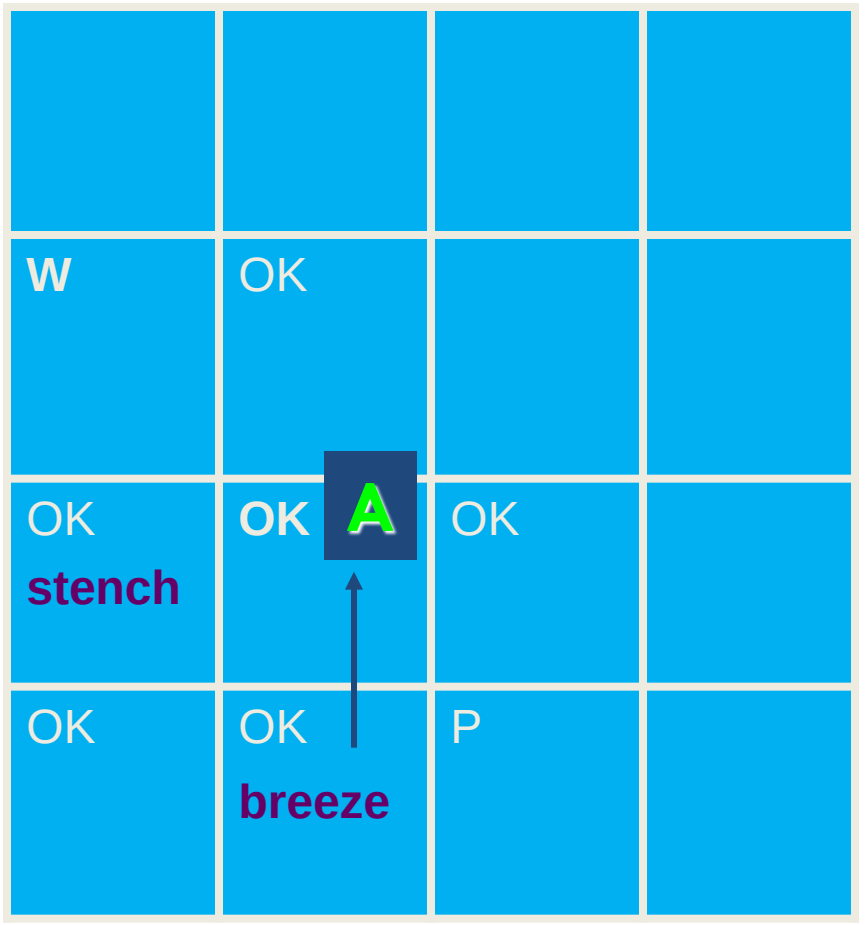

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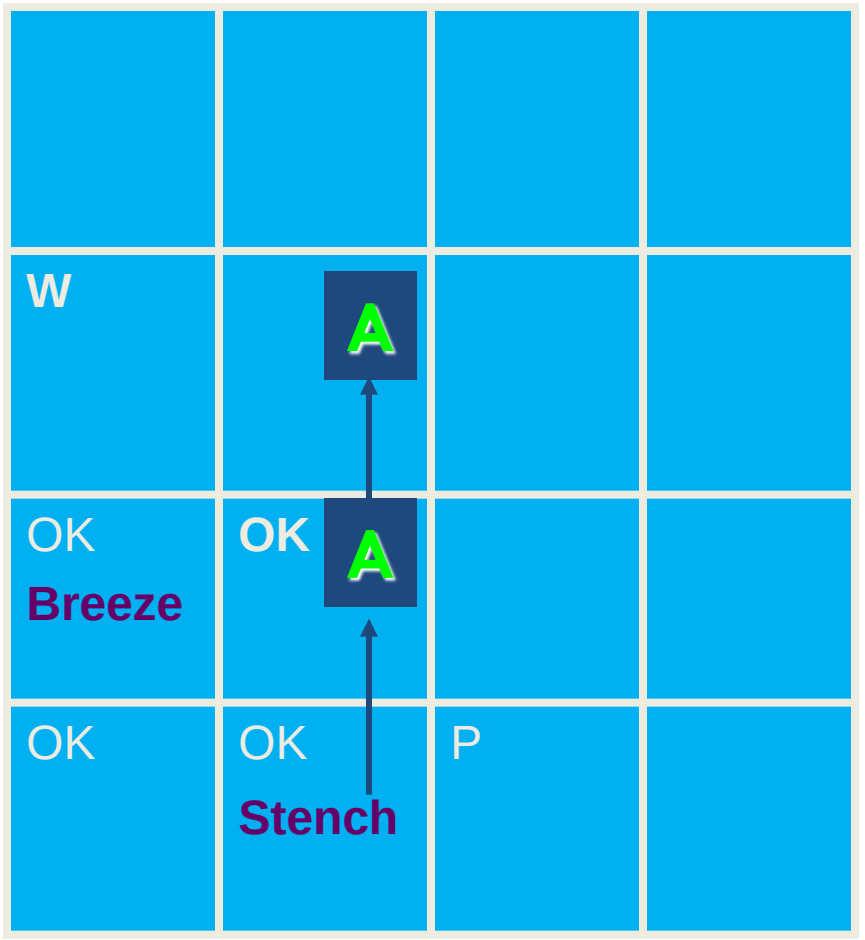
Exploring Wumpus World

…

And the exploration continues onward until the gold is found.

…



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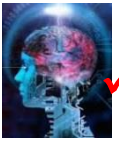
What does an agent need to perform well in the wumpus world?

- It needs to represent the knowledge about the wumpus world: ex, stench → wumpus nearby.
- It needs to incorporate new knowledge that it discovers when exploring the cave →feeling a breeze in the current square.
- Deduce from the preceding information the appropriate actions (safe and rewarding) :
- The agent needs a **knowledge-base.**

Each time the agent program is called, it does three things

✓ **First**, it TELLS the knowledge base what it perceives.

✓ **Second**, it ASKS the **knowledge base** what action it should perform



✓ **Third**, the agent program TELLS the knowledge base which action was chosen, and the agent executes the action.

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Knowledge bases

- **Knowledge base**: set of **sentences**. Each **sentence** is expressed in a language called a **knowledge representation language.**

- **Sentence**: a sentence represents some assertion about the world.

- **Inference**: Process of deriving new sentences from old ones.

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Types of Knowledge

Declarative knowledge	Concepts Facts Objects	Describes **what** is known about a problem. This includes simple statements that are asserted to be either **true** or **false**. This also includes a list of statements that more fully describes some **object** or **concept** (object-attribute-value triplet).

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Types of Knowledge

Procedural knowledge	Rules Strategies Agendas Procedures	Describes **how** a problem is solved. This type of knowledge provides direction on how to do something.

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Some General Knowledge Representations

1. Logical Representations
2. Production Rules
3. Semantic Networks
   - Conceptual graphs, frames
4. *Description Logics* (not covered in this course)

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1-Logical Representation

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1-Logical Representation

- A language with concrete rules
- Many ways to translate between languages
  - A statement can be represented in different logics
  - And perhaps differently in same logic
- Not to be confused with logical reasoning
  - Logics are languages, reasoning is a process (may **use** logic)

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1-Logical Representation

Syntax and Semantics

- **Syntax**
  - Rules for constructing legal sentences in the logic
  - Which symbols we can use (English: letters, punctuation)
  - How we are allowed to combine symbols
- **Semantics**
  - How we interpret (read) sentences in the logic
  - Assigns a meaning to each sentence

- Example: "All lecturers are seven foot tall"
  - A valid sentence (syntax)
  - And we can understand the meaning (semantics)
  - This sentence happens to be false (there is a counter example)

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Logic

- Oldest form of knowledge representation in a computer is logic
- Logic is concerned with the truthfulness of a chain of statements.
- An argument is true if and only if, when all assumptions are true, then all conclusions are also true.
- **Two kinds of logic:**
  1. **Propositional Logic**
  2. **Predicate Calculus**

- Both use symbols to represent knowledge and operators applied to the symbols to produce logical reasoning

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1.Propositional Logic (PL)

- Propositional logic represents and reasons with propositions.
- P.L. assigns symbolic variable to a proposition such as
  - A = The car will start
- In. P. L. if we are concern with the **truth** of the statement, we will check the truth of A.

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1.Propositional Logic (PL)

Operators	Symbol
AND	$\wedge$, &, $\cap$
OR	$\vee$, $\cup$, +
NOT	$\neg$, ~
IMPLIES	$\supset$, $\rightarrow$
EQUIVALENT	$\equiv$

1.Propositional Logic (PL)

- Propositions that are linked together with connectives, such as **AND**, **OR**, **NOT**, **IMPLIES**, and **EQUIVALENT**, are called **compound statements.**

- Example:

IF	The Students Work Hard	→	A	
AND	Always come to lectures	→	B	
AND	Do all their homework's	→	C	
THEN	they will get an A	→	D	

- Using the symbols: $A \wedge B \wedge C \rightarrow D$

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1.Propositional Logic (PL)

Truth Table

A	B	A and B	A or B	Not A	A ≡ B
F	F	F	F	T	T
F	T	F	T	T	F
T	F	F	T	F	F
T	T	T	T	F	T

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1.Propositional Logic (PL)

- **Implies Operator:** $C = A \rightarrow B$
- For implication C, if A is true, then B is implied to be true
- The implies return a F when A is TRUE and B is FALSE Otherwise it return a TRUE.

A	B	C
F	F	T
F	T	T
T	F	F
T	T	T

Ex : A = it is raining
B= I have an umbrella

Ex : A = program code
B= output

1.Propositional Logic (PL)

Idempotent Laws	$A \rightarrow B \equiv \neg A \cup B$ $A \cap \neg A \equiv F$ $A \cup \neg A \equiv T$
Commutative Laws	$A \cap B \equiv B \cap A$ $A \cup B \equiv B \cup A$
Distributive Laws	$A \cap (B \cup C) \equiv (A \cap B) \cup (A \cap C)$ $A \cup (B \cap C) \equiv (A \cup B) \cap (A \cup C)$
Associative Laws	$A \cap (B \cap C) \equiv (A \cap B) \cap C$ $A \cup (B \cup C) \equiv (A \cup B) \cup C$
Absorptive Laws	$A \cup (A \cap B) \equiv A$ $A \cap (A \cup B) \equiv A$
DeMorgan's Laws	$\neg(A \cap B) \equiv \neg A \cup \neg B$ $\neg(A \cup B) \equiv \neg A \cap \neg B$

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1.Propositional Logic (PL)

- **P.L. offers techniques for capturing facts or rules in symbolic form and then operates on them through use of logical operators.**
- PL provide method of managing statements that are either TRUE or FALSE.
- Prolog is based on PC

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2.Predicate Calculus (PC)

- Some P.L. weakness:

1. Limited ability to express knowledge and lose much of their meanings.
2. Not all statements can be represented.

All *men are mortals.*

Some *dogs like cats.*

- Thus, need a more general form of logic capable of representing the details.

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2.Predicate Calculus (PC)

- Propositional logic combines atoms
  - An atom contains no propositional connectives
  - Have no structure (today_is_wet, john_likes_apples)

- **Predicates** allow us to talk about objects
  - Properties: is_wet(today)
  - Relations: likes(john, apples)
  - True or false

- In **predicate logic** each atom is a predicate
  - e.g. first order logic, higher-order logic

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First Order Logic

- More expressive logic than propositional
- Enhances processing by allowing the use of variables and functions.

Use symbols that represent

constants are objects: john, apples

predicates

are properties and relations:

likes(john, apples)

variables

represent any object: likes(X, apples)

functions

transform objects:

likes(john, fruit_of(apple_tree))

- Operate on these symbols using PL operators.

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2.Predicate Calculus (PC)

- **Constant**

- Specific objects or properties about a problem.
- Begin with lower case.
- Example: ahmad, elephant and temperature
- ahmad represent object Ahmad. Can also use A or X instead of Ahmad.

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2.Predicate Calculus (PC)

- **Predicates**

- Divide proposition into 2 parts:
- predicate: assertion about object
- argument: represent the object
- Example: To represent Azizi teach Expert system(ES),
  - teach (azizi, ES)
  - teach is a *predicate*, denoting relationship between arguments. The 1st letter must be in lower case.

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2.Predicate Calculus (PC)

- **Variables**

- Represent general classes of objects or properties
- Written as symbols beginning with upper case.
- To capture the proposition Azizi teach ES, we write:
  - **teach (X,Y)**
  - **X = Azizi and Y = ES**

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2.Predicate Calculus (PC)

- **Functions**

- Permits symbol to be used to represent function.
- A function denotes a mapping from entities of a set to a unique element of another set.
  - **father(azizi) = zakaria mother(azizi) = zaharah.**
  - **Can be also used within predicates. For example:**
  - **husband (father(azizi), mother(azizi)) = husband(zakaria,zaharah)**

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2.Predicate Calculus (PC)

- **Operations**
- PC uses the same operators found in P.L.
- Proposition: John likes Mary likes(john,mary)
- Bob likes Mary likes(bob,mary)
- 2 persons like Mary. To account for jealousy:
  - **likes (X,Y) AND likes(Z,Y) implies NOT likes (X,Z)**

or

  - **likes (X,Y) ∧ likes (Z,Y) → ¬likes(X,Z)**

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2.Predicate Calculus (PC)

- P.C. introduce 2 symbols called variable quantifiers.

1. ∀ universal quantifier: **for all.**
2. ∃ existential quantifier: **there exist**

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2.Predicate Calculus (PC)

- ∀ Indicates the expression is TRUE for all values of designated variable.
- Example:
  - ∀ X likes (X,mary)
  - means for all values of X, the statement is true, everybody likes Mary

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2.Predicate Calculus (PC)

- ∃ indicates the expression is TRUE for some values of the variable; at least one value exist that makes the statement true:
- ∃ X likes (X,mary)

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2.Predicate Calculus (PC)

- Parentheses are used to indicate the scope of quantification
- $\forall$ X (likes(X,mary) $\wedge$ nice(mary) $\rightarrow$ nice (X))
  - determines all instances of X who like Mary and if Mary is nice, then it is implied that those who like Mary are also nice.

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Reasoning with logic

- PC can provide reasoning capability to intelligent system
- Reasoning requires the ability to infer conclusions from available facts.
- One simple form of inference is modus ponen:
  - **IF** A is true

    AND A $\rightarrow$ B is true

    THEN B is true

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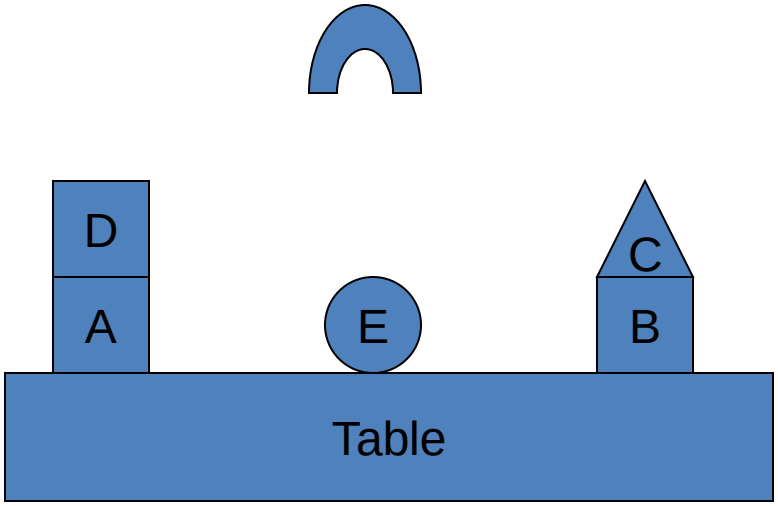
Reasoning with logic

- Robot Control Example
- The function of the robot is move a specified block to some specified location



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Reasoning with logic

Robot Control Example

- Description of the block world using PC using the following logical assertions:

1. **cube(a), cube(b), cube(d), pyramid(c), sphere(e), hand(hand), table (table1)**
2. **on(a,table1), on(b,table1), on(d,a), on(c,b)**
3. **holding(hand,nothing)**

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Reasoning with logic

- Robot Control Example
- The goal might be to put some block on other block, for example put block **b** onto block **a**:

  put_on(b,a)

- To accomplish this the robot need to obtain block **b** and make certain that block **a** is clear:

  hand_holding(b) ∧ clear(a) → put_on(b,a)

- To move any block, in variable form:

  ∀X ∃Y (hand_holding(X) ∧ clear(Y) → put_on(X,Y))

where X is the block to be move and Y is the target block

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Reasoning with logic

- Robot Control Example

- One of the robot task when instructed to pick up and move some blocks is to determine if it is clear.

- If not clear, need to remove any item on the block:

$$\forall X (\neg \exists Y \ on(Y,X) \rightarrow clear(X))$$

For all X, X is clear if there does not exist a Y such that Y is on X, would produce the following assertions:

clear(c), clear(d)

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Logic is a Good Representation

- Fairly easy to do the translation when possible
- Branches of mathematics devoted to it
- It enables us to do logical reasoning
  - Tools and techniques come for free
- Basis for programming languages
  - Prolog uses logic programs (a subset of FOL)

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Thank you

End of Chapter 7-part1

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