Course Code: CSE3002
Course Name: Artificial Intelligence

Faculty Name:
D Ramkumar
AP/SCOPE
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Module-3

Module 3:	Knowledge Representation	8 Hours

Knowledge based agents- Prepositional Logic- First Order logic- Inferences.

Do you know what makes human beings different from machines?

What is AI / KR

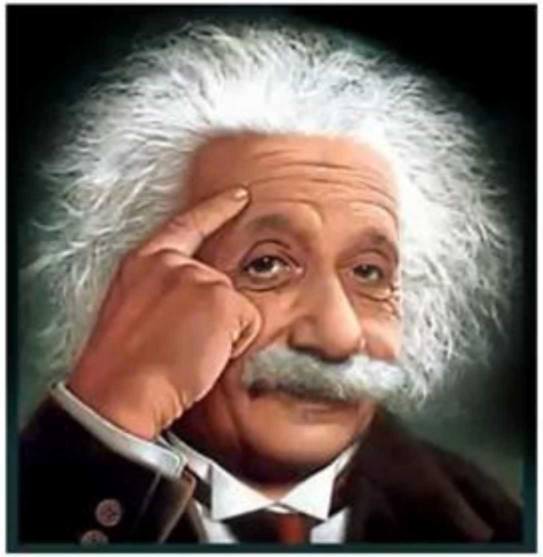
Computer/machine is empty box

AI

In AI we have to make machine intelligent so that it can work like human

To make a machine intelligent, we have to give knowledge to the machine/computer

Why humans are intelligent because they have knowledge/information/data with them gathered through experience

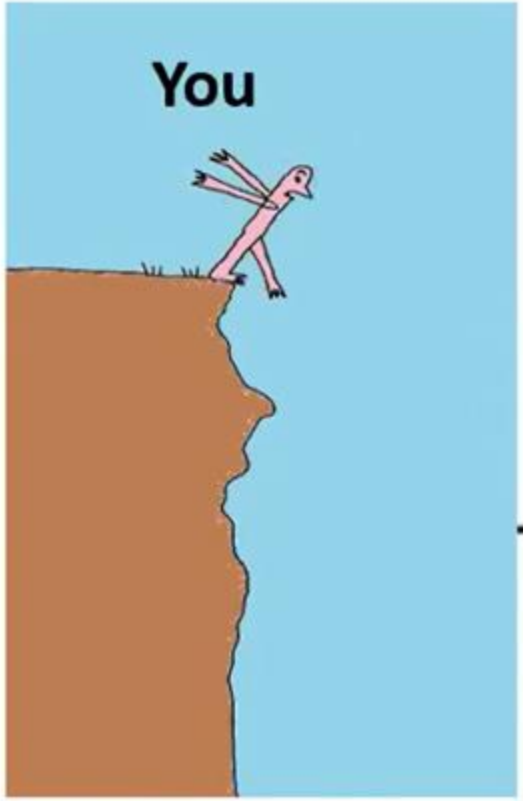


What is intelligence ?
Ability to use the gathered knowledge

Reasoning : Processing of knowledge

You are intelligent

- you have knowledge
- you have an ability to process gathered information
- you have an ability to take decision



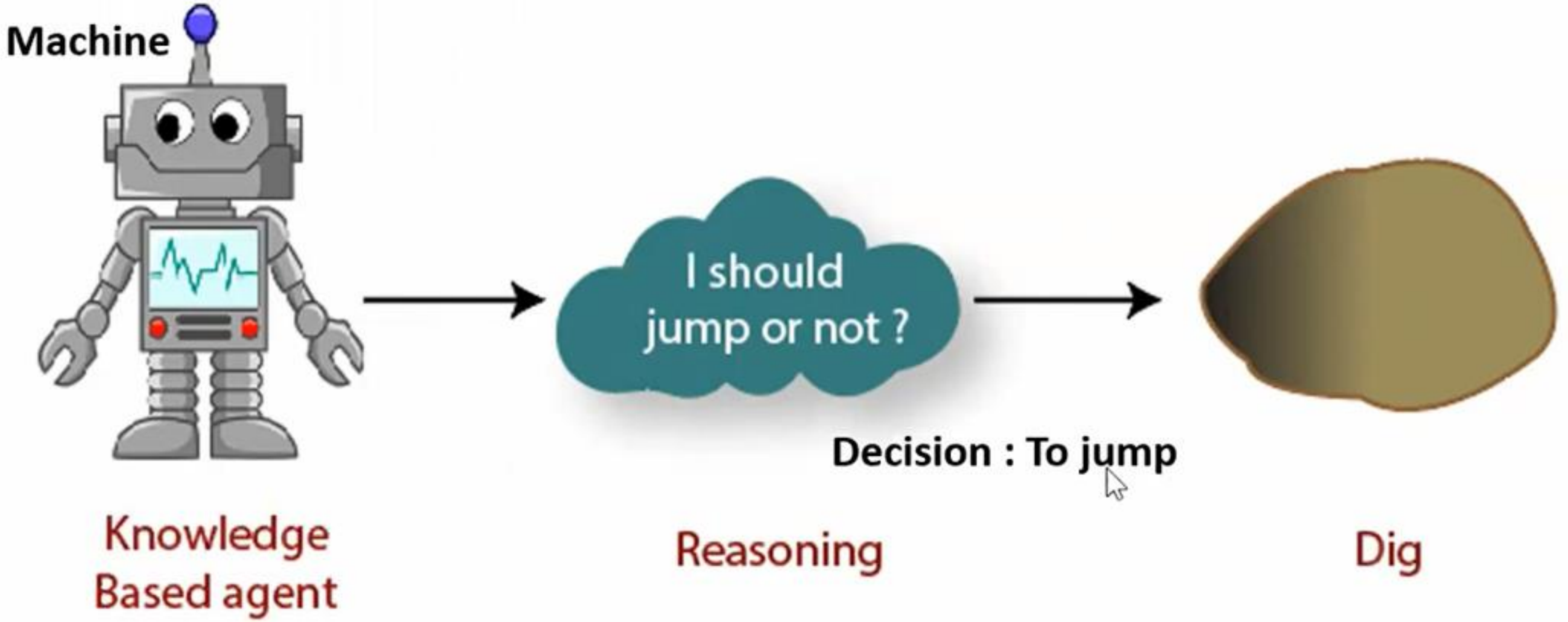
Decision : Not to jump

Knowledge Based agent

Reasoning

Dig

Machine will jump, because it does not have knowledge, intelligence and reasoning ability because it is not intelligent



Artificial Intelligence

Machine

To make it intelligent

Knowledge representation and reasoning (KRR):
We have to induce knowledge, intelligence and reasoning

We have to **induce right knowledge** in the machine so that it can process it to take right decision

Computer language : If we write right program we will get right output

Summary

- **There are three factors which are put into the machine, which makes it valuable:**

- **Knowledge:** The information related to the environment is stored in the machine.
- **Reasoning:** The ability of the machine to understand the stored knowledge.
- **Intelligence:** The ability of the machine to make decisions on the basis of the stored information.

Knowledge Representation given to the machine should be correct

Example

- It is raining outside – correct
- Outside is raining – incorrect

Is it raining outside ?- correct

- It is raining outside ?- incorrect

If KR is correct machine's understanding will be correct

IT KR is wrong machine will behave wrong

What is knowledge representation?

- Knowledge representation and reasoning (KR, KRR) is the part of Artificial intelligence which concerned with AI agents thinking and how thinking contributes to intelligent behavior of agents.

- It is responsible for representing information about the real world so that a computer can understand and can utilize this knowledge to solve the complex real world problems such as diagnosis a medical condition or communicating with humans in natural language.

- It is also a way which describes how we can represent knowledge in artificial intelligence. Knowledge representation is not just storing data into some database, but it also enables an intelligent machine to learn from that knowledge and experiences so that it can behave intelligently like a human.

What to Represent:

Following are the kind of knowledge which needs to be represented in AI systems:

Object: There are many objects present in the human world. All information we have, related to all the objects, can be considered as a type of knowledge. For instance, a bus has wheels and a guitar has strings, etc.

Events: Events are the actions which occur in our world. Our understanding of the world is based on the idea we have about the various incidents that have occurred in our world. Thus, events refer to every action that happens in our world.

What to Represent:

Performance: The term is used to explain human behavior or the way they perform certain actions during different situations.

Meta-knowledge: Knowledge about things we are already aware of.

Facts: Facts are the truths about the real world and what we represent.

Knowledge-Base: The central component of the knowledge-based agents is the knowledge base. It is represented as KB. It refers to a set of information about any discipline, field, etc. For example, a knowledge base on road construction.

Types of knowledge

Following are the various types of knowledge:

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2. Mr. Nithin Singhania's father has a good business of iron and steel. He wants to go to USA for his MBA but his father thinks that he should join the business. On the basis of emerging trends, do you think that Mr. Singhania should send his son to USA? Give any three reasons in support of your answer.

Yes, according to me, Mr. Singhania should send his son to USA for his MBA because management is being recognized as a profession to a great extent because of the following reasons:

a) Well defined body of knowledge: Management is considered to be a well-defined body of knowledge that can be acquired through instructions. As a separate discipline, it contains a set of theories and principles formulated by various management experts. Moreover, it is taught in various schools and colleges all over the world.

b) Ethical code of conduct: Management in practice, like other professions, is bound by a code of conduct which guides the behavior of its members. Therefore, acquiring a degree in management will equip him with the good managerial skills and approach.

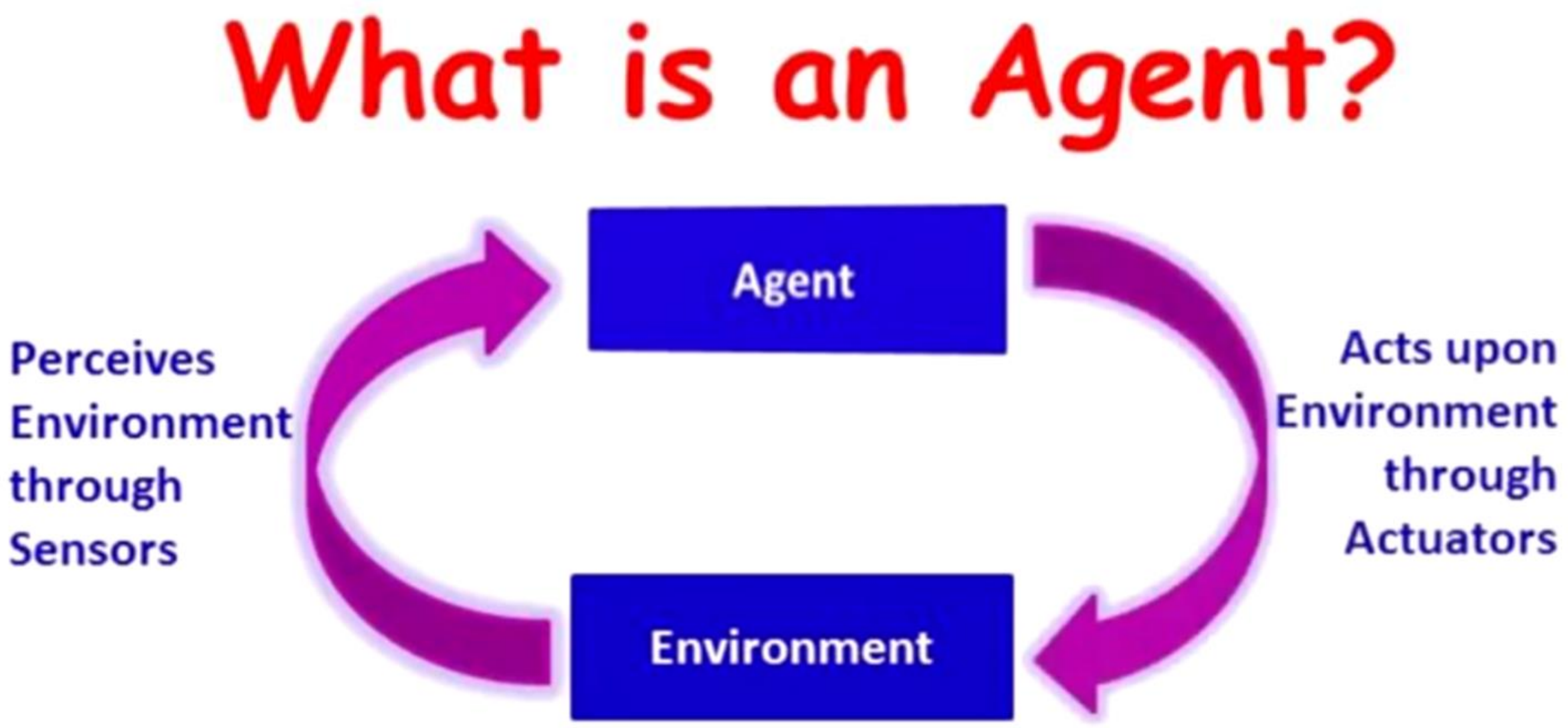
c) Service motive: A good management course will provide him an insight into the multiple goals that an organization should pursue. This knowledge will help him to serve both the objectives of profit maximization and social welfare effectively for his company.

Knowledge based Agent?

What is an Agent?

An agent can be anything that perceives environment through sensors and acts upon that environment through actuators.

Knowledge based Agent?



Knowledge-Based Agent

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- An intelligent agent needs knowledge about the real world for taking decisions and reasoning to act efficiently.
- Knowledge-based agents are those agents who have the capability of
  1. maintaining an internal state of knowledge,
  2. reason over that knowledge,
  3. update their knowledge after observations
  4. take actions.
- These agents can represent the world with some formal representation and act intelligently.

How it works?

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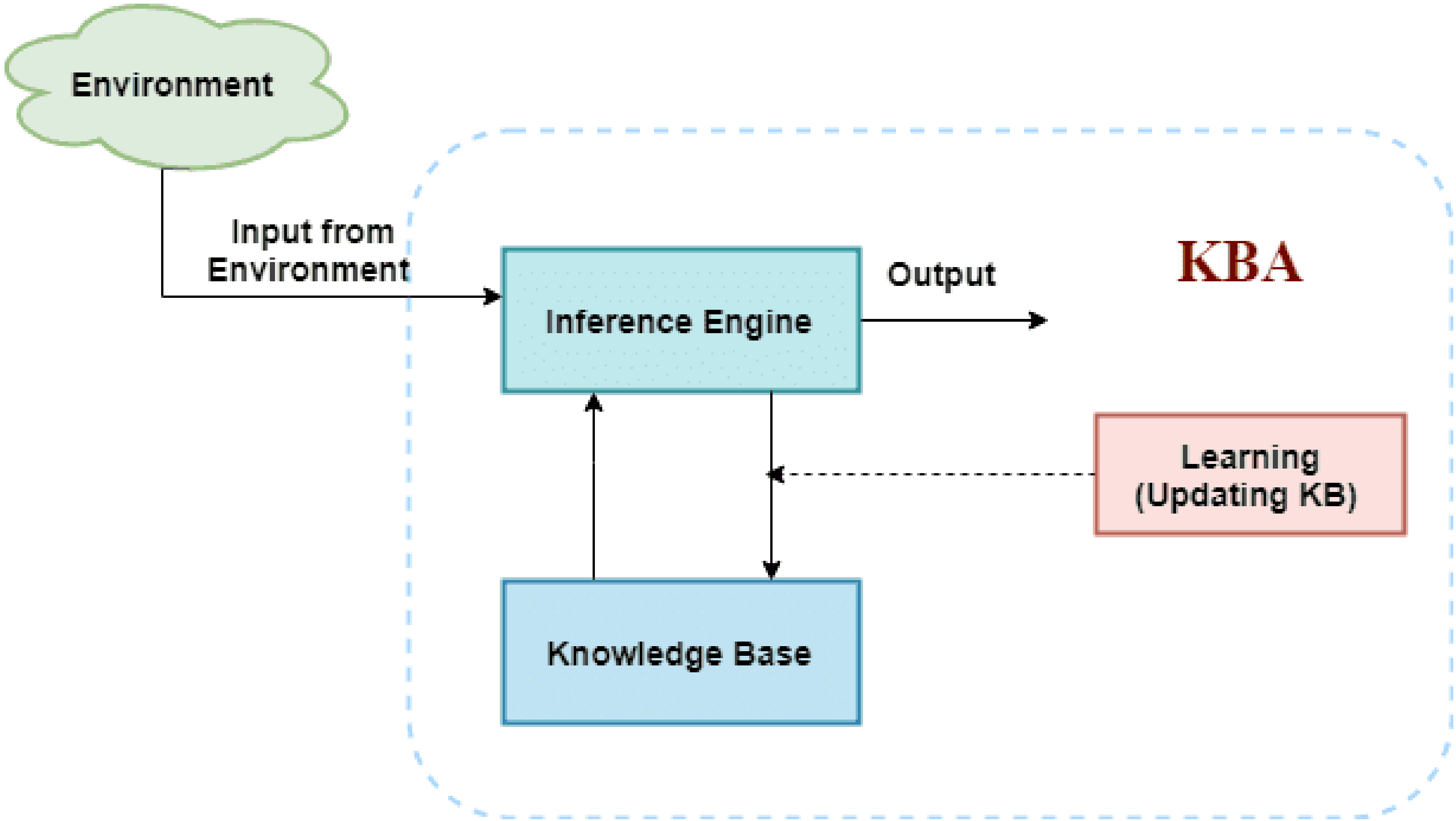

Architecture of knowledge-based agent

Knowledge-based agents are composed of two main parts:

- Knowledge-base and
- Inference system

Knowledge base

- A central component of a knowledge-based agent
- It is also known as KB.
- It is a collection of sentences
- These sentences are expressed in a language which is called a knowledge representation language.
- The Knowledge-base of KBA stores fact about the world.

Inference Engine

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- Inference means deriving new sentences from old.
- A sentence is a proposition about the world.
- Inference engine allows us to add a new sentence to the knowledge base.
- Inference engine applies logical rules to the KB to deduce new information.
- Inference engine generates new facts so that an agent can update the KB.
- An inference engine works mainly in two rules which are given as:

    1. Forward Chaining and 2.Backward Chaining

Operations Performed by KBA

Following are three operations which are performed by KBA in order to show the intelligent behavior:

- **TELL:** This operation tells the knowledge base, what it discern from the environment.
- **ASK:** This operation asks the knowledge base what action it should perform.
- **Perform:** It performs the selected action.

A generic knowledge-based agent:

Following is the structure outline of a generic knowledge-based agents program:

```
function KB-AGENT(percept):
persistent: 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
```

Various levels of knowledge-based agent:

1. Knowledge level:

The first level of a knowledge-based agent is the knowledge level, where we must explain what the agent knows and what the agent's goals are. We can correct its behavior using these specs. Let's say an automated taxi agent needs to get from station A to station B, and he knows how to get there, so this is a knowledge problem.

2. Logical level:

We understand how the knowledge representation of knowledge is stored at this level. Sentences are encoded in various logics at this level. At the logical level, knowledge is encoded into logical statements. We can expect the automated taxi agent to arrive at destination B on a rational level.

3. Implementation level:

Physical representation of logic and knowledge (implementation level). Agents at the implementation level take actions based on their logical and knowledge levels. At this phase, an autonomous cab driver puts his knowledge and logic into action in order to go to his destination.

Knowledge

Humans reason based on existing knowledge and draw conclusions. The concept of representing knowledge and drawing conclusions from it is also used in AI, and in this lecture we will explore how we can achieve this behavior.

Knowledge-Based Agents

These are agents that reason by operating on internal representations of knowledge.

What does "reasoning based on knowledge to draw a conclusion" mean?

Let's start answering this with a Harry Potter example. Consider the following sentences:

1. If it didn't rain, Harry visited Hagrid today.
2. Harry visited Hagrid or Dumbledore today, but not both.
3. Harry visited Dumbledore today.

Propositional Logic

Techniques of knowledge representation

There are mainly four ways of knowledge representation

1. logical representation
2. Semantic n/w representation
3. Frame representation
4. Production rules

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Logical representation:

- It is a lang with some concrete rules which deals with propositions & has no ambiguity in representation

→ It consists of precisely defined syntax & semantics which supports the sound inference. Each sentence can be translated into logics using syntax & semantic

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- Syntax: defines well-formed sentence in the
- Semantics: defines the truth or meaning of sent
  in a world.

Logical Representation

→ Propositional logic

→ First order predicate logic

Prepositional Logic

Propositional logic (PL) is the simplest form of logic where all the statements are made by propositions. A proposition is a declarative statement which is either true or false. It is a technique of knowledge representation in logical and mathematical form.

Example:

a) It is Sunday.

b) The Sun rises from West (False proposition)

c) 3+3= 7(False proposition)

d) 5 is a prime number.

Propositional Logic (Either True or False, not Both)

Syntax

Semantic

$1+1=2$ T

$2+1=4$ F

ND is C. T

Some st. are Int. T/F

$\underbrace{12+}=4$

Atomic

$1+1=2$

Complex

$\neg$ Negation (Today is Not Friday)

$\vee$ Disjuction (You should Eat or Watch TV at a time)

$\wedge$ Conjuction (Please like my video And Subscribe my channel)

$\rightarrow$ if then (if there is rain then the roads are wet)

$\leftrightarrow$ iff (I will go to Mall iff I have to do shopping)

* You can access the internet from Campus only if you are CSE student or you are not freshman.

Syntax of propositional logic:

The syntax of propositional logic defines the allowable sentences for the knowledge representation. There are two types of Propositions:

a. **Atomic Propositions**
b. **Compound propositions**

- **Atomic Proposition:** Atomic propositions are the simple propositions. It consists of a single proposition symbol. These are the sentences which must be either true or false.

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> a) 2+2 is 4, it is an atomic proposition as it is a **true** fact.
>
> b) "The Sun is cold" is also a proposition as it is a **false** fact.

- **Compound proposition:** Compound propositions are constructed by combining simpler or atomic propositions, using parenthesis and logical connectives.

Example:

> a) "It is raining today, and street is wet."
>
> b) "Ankit is a doctor, and his clinic is in Mumbai."

Logical Connectives:

Logical connectives are used to connect two simpler propositions or representing a sentence logically. We can create compound propositions with the help of logical connectives. There are mainly five connectives, which are given as follows:

1. **Negation:** A sentence such as $\neg$ P is called negation of P. A literal can be either Positive literal or negative literal.

2. **Conjunction:** A sentence which has **∧** connective such as, **P ∧ Q** is called a conjunction.
   Example: Rohan is intelligent and hardworking. It can be written as,
   P= Rohan is intelligent,
   Q= Rohan is hardworking. → P∧ Q.

3. **Disjunction:** A sentence which has ∨ connective, such as **P ∨ Q**. is called disjunction, where P and Q are the propositions.

   Example: "Ritika is a doctor or Engineer",

   Here P= Ritika is Doctor. Q= Ritika is Doctor, so we can write it as **P ∨ Q**.

4. **Implication:** A sentence such as P → Q, is called an implication. Implications are also known as if-then rules. It can be represented as

   If it is raining, then the street is wet.

   Let P= It is raining, and Q= Street is wet, so it is represented as P → Q

5. **Biconditional:** A sentence such as **P⇔ Q is a Biconditional sentence, example If I am breathing, then I am alive**

   P= I am breathing, Q= I am alive, it can be represented as P ⇔ Q.

Following is the summarized table for Propositional Logic Connectives:

Connective symbols	Word	Technical term	Example
$\land$	AND	Conjunction	$A \land B$
$\lor$	OR	Disjunction	$A \lor B$
$\rightarrow$	Implies	Implication	$A \rightarrow B$
$\Leftrightarrow$	If and only if	Biconditional	$A \Leftrightarrow B$
$\neg$ or $\sim$	Not	Negation	$\neg A$ or $\neg B$

Truth Table:

In propositional logic, we need to know the truth values of propositions in all possible scenarios. We can combine all the possible combination with logical connectives, and the representation of these combinations in a tabular format is called **Truth table**. Following are the truth table for all logical connectives:

For Negation:

P	¬ P
True	**False**
False	**True**

For Conjunction:

P	Q	P∧Q
True	True	**True**
True	False	**False**
False	True	**False**
False	False	**False**

For disjunction:

P	Q	P ∨ Q.
True	True	**True**
False	True	**True**
True	False	**True**
False	False	**False**

For Implication:

P	Q	$P \to Q$
True	True	**True**
True	False	**False**
False	True	**True**
False	False	**True**

For Biconditional:

P	Q	$P \Leftrightarrow Q$
True	True	**True**
True	False	**False**
False	True	**False**
False	False	**True**

Truth table with three propositions:

We can build a proposition composing three propositions P, Q, and R. This truth table is made-up of 8n Tuples as we have taken three proposition symbols.

P	Q	R	¬R	Pv Q	PvQ→¬R
True	True	True	False	True	False
True	True	False	True	True	True
True	False	True	False	True	False
True	False	False	True	True	True
False	True	True	False	True	False
False	True	False	True	True	True
False	False	True	False	False	True
False	False	False	True	False	True

Suppose that the statement $p \to \neg q$ is false. Find all combinations of truth values of r and s for which

$(\neg q \to r) \land (\neg p \lor s)$ is true.

p	q	r	s	$\neg p$	$\neg q$	$\neg q \to r$	$\neg p \vee s$	$(\neg q \to r) \wedge (\neg p \vee s)$	$p \to \neg q$
T	T	T	T	F	F	T	T	T	F
T	T	T	F	F	F	T	F	F	F
T	T	F	T	F	F	T	T	T	F
T	T	F	F	F	F	T	F	F	F
T	F	T	T	F	T	T	T	T	T
T	F	T	F	F	T	T	F	F	T
T	F	F	T	F	T	F	T	F	T
T	F	F	F	F	T	F	F	F	T
F	T	T	T	T	F	T	T	T	T
F	T	T	F	T	F	T	T	T	T
F	T	F	T	T	F	T	T	T	T
F	T	F	F	T	F	T	T	T	T
F	F	T	T	T	T	T	T	T	T
F	F	T	F	T	T	T	T	T	T
F	F	F	T	T	T	F	T	F	T
F	F	F	F	T	T	F	T	F	T

$p \to \neg q$	$(\neg q \to r) \wedge (\neg p \vee s)$	r	s
F	T	T	T
F	T	F	T

- If the statement $q \wedge r$ is true, determine all combinations of truth values for p and s such that the statement $(q \rightarrow [\neg p \vee s]) \wedge [\neg s \rightarrow r]$ is true.

- Find all combinations of truth values for p, q and r for which the statement $\neg p \leftrightarrow (q \land \neg(p \rightarrow r))$ is true

What is logically equivalent to the following statements? "I pass only if you pass"

(Note that fail is equivalent to not pass.)

1. You pass only if I pass
2. If you fail then I fail
3. If you pass then I pass
4. You fail if I pass.

Use the truth tables method to determine whether $p \to (q \land \neg q)$ *and* $\neg p$ *are logically equivalent.*

Exercise 2.11.

Let's consider a propositional language where

- p *means* "Paola is happy",
- q *means* "Paola paints a picture",
- r *means* "Renzo is happy".

Formalize the following sentences:

1. "if Paola is happy and paints a picture then Renzo isn't happy"
2. "if Paola is happy, then she paints a picture"
3. "Paola is happy only if she paints a picture"

Solution.

1. $p \wedge q \to \neg r$

2. $p \to q$

3. $\neg(p \wedge \neg q)$ *..which is equivalent to* $p \to q$

☞ *The precision of formal languages avoid the ambiguities of natural languages.*

Let A =“Aldo is Italian” *and* B =“Bob is English”.
Formalize the following sentences:

1. “Aldo isn’t Italian”
2. “Aldo is Italian while Bob is English”
3. “If Aldo is Italian then Bob is not English”
4. “Aldo is Italian or if Aldo isn’t Italian then Bob is English”
5. “Either Aldo is Italian and Bob is English, or neither Aldo is Italian nor Bob is English”

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Solution.

1. $\neg A$
2. $A \wedge B$
3. $A \rightarrow \neg B$
4. $A \vee (\neg A \rightarrow B)$ *logically equivalent to* $A \vee B$
5. $(A \wedge B) \vee (\neg A \wedge \neg B)$ *logically equivalent to* $A \leftrightarrow B$

Let's consider a propositional langiage where

- A ="Angelo comes to the party",
- B ="Bruno comes to the party",
- C ="Carlo comes to the party",
- D ="Davide comes to the party".

Formalize the following sentences:

1. "If Davide comes to the party then Bruno and Carlo come too"
2. "Carlo comes to the party only if Angelo and Bruno do not come"
3. "Davide comes to the party if and only if Carlo comes and Angelo doesn't come"
4. "If Davide comes to the party, then, if Carlo doesn't come then Angelo comes"
5. "Carlo comes to the party provided that Davide doesn't come, but, if Davide comes, then Bruno doesn't come"
6. "A necessary condition for Angelo coming to the party, is that, if Bruno and Carlo aren't coming, Davide comes"
7. "Angelo, Bruno and Carlo come to the party if and only if Davide doesn't come, but, if neither Angelo nor Bruno come, then Davide comes only if Carlo comes"

Solution.

1. $D \to B \wedge C$
2. $C \to \neg A \wedge \neg B$
3. $D \leftrightarrow (C \wedge \neg A)$
4. $D \to (\neg C \to A)$
5. $(\neg D \to C) \wedge (D \to \neg B)$
6. $A \to (\neg B \wedge \neg C \to D)$
7. $(A \wedge B \wedge C \leftrightarrow \neg D) \wedge (\neg A \wedge \neg B \to (D \leftrightarrow C))$

Three boxes are presented to you. One contains gold, the other two are empty. Each box has imprinted on it a clue as to its contents; the clues are:

Box 1 "The gold is not here"

Box 2 "The gold is not here"

Box 3 "The gold is in Box 2"

Only one message is true; the other two are false. Which box has the gold?

Formalize the puzzle in Propositional Logic and find the solution using a truth table.

First-Order Logic in Artificial intelligence

In the topic of Propositional logic, we have seen that how to represent statements using propositional logic.

But unfortunately, in propositional logic, we can only represent the facts, which are either true or false.

PL is not sufficient to represent the complex sentences or natural language statements. The propositional logic has very limited expressive power.

- "Some humans are intelligent",

First-Order Logic

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First-order logic is another way of knowledge representation in artificial intelligence. It is an extension to propositional logic.

First-order logic is also known as Predicate logic or First-order predicate logic.

- As a natural language, first-order logic also has two main parts:
    a. **Syntax**
    b. **Semantics**

Syntax of First-Order logic:

The syntax of FOL determines which collection of symbols is a logical expression in first-order logic.

The basic syntactic elements of first-order logic are symbols. We write statements in short-hand notation in FOL.

Basic Elements of First-order logic:

Following are the basic elements of FOL syntax:

Constant	1, 2, A, John, Mumbai, cat,....
Variables	x, y, z, a, b,....
Predicates	Brother, Father, >,....
Function	sqrt, LeftLegOf, ...
Connectives	∧, ∨, ¬, ⇒, ⇔
Equality	==
Quantifier	∀, ∃

Basic Elements of First-order logic:

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Atomic sentences:

- Atomic sentences are the most basic sentences of first-order logic. These sentences are formed from a predicate symbol followed by a parenthesis with a sequence of terms.

- We can represent atomic sentences as **Predicate (term1, term2, ..., term n).**

Example: Ravi and Ajay are brothers: => Brothers(Ravi, Ajay).

Chinky is a cat: => cat (Chinky).

Basic Elements of First-order logic:

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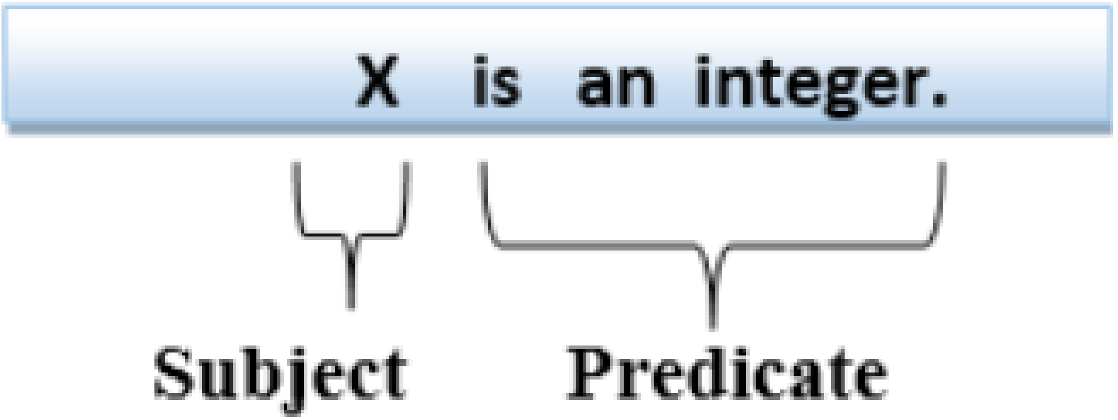
Complex Sentences:

- Complex sentences are made by combining atomic sentences using connectives.

First-order logic statements can be divided into two parts:

- **Subject:** Subject is the main part of the statement.
- **Predicate:** A predicate can be defined as a relation, which binds two atoms together in a statement.

Consider the statement: "x is an integer.", it consists of two parts, the first part x is the subject of the statement and second part "is an integer," is known as a predicate.



Quantifiers in First-order logic:

- A quantifier is a language element which generates quantification, and quantification specifies the quantity of specimen in the universe of discourse.
- These are the symbols that permit to determine or identify the range and scope of the variable in the logical expression. There are two types of quantifier:
    a. **Universal Quantifier, (for all, everyone, everything)**
    b. **Existential quantifier, (for some, at least one).**

Universal quantifier is a symbol of logical representation, which specifies that the statement within its range is true for everything or every instance of a particular thing.

The Universal quantifier is represented by a symbol ∀, which resembles an inverted A.

> Note: In universal quantifier we use implication "→".

If x is a variable, then ∀x is read as:

- **For all x**
- **For each x**
- **For every x.**

Example:

All man drink coffee.

- Let a variable x which refers to a man so all x can be represented in UOD as below:

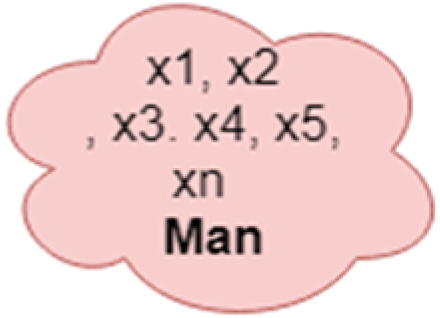
- **x1 drinks coffee**

  ∧
- **x2 drinks coffee**

  ∧
- **x3 drinks coffee**

  ∧
- .
- .

  ∧
- **xn drinks coffee**



Universe of Discourse

So in shorthand notation, we can write it as :

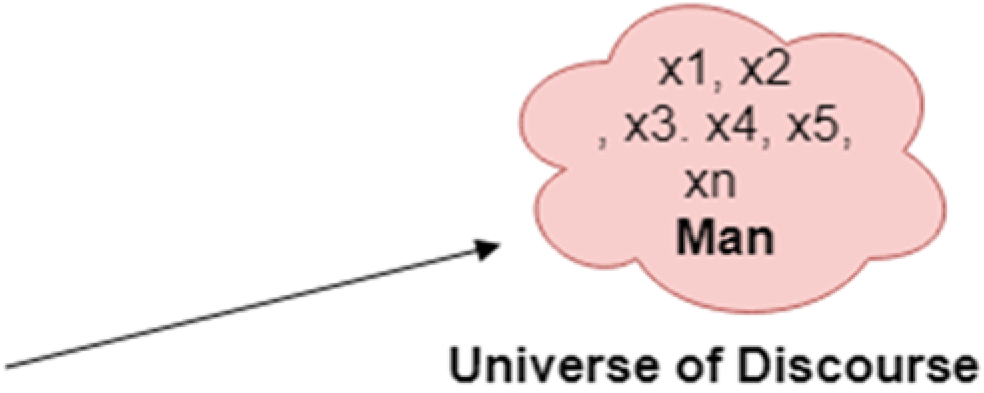
- **x1 drinks coffee**

  ∧
- **x2 drinks coffee**

  ∧
- **x3 drinks coffee**

  ∧
- .
- .

  ∧
- **xn drinks coffee**



So in shorthand notation, we can write it as :

∀x man(x) → drink (x, coffee).

It will be read as: There are all x where x is a man who drink coffee.

Existential Quantifier:

Existential quantifiers are the type of quantifiers, which express that the statement within its scope is true for at least one instance of something.

It is denoted by the logical operator ∃, which resembles as inverted E. When it is used with a predicate variable then it is called as an existential quantifier.

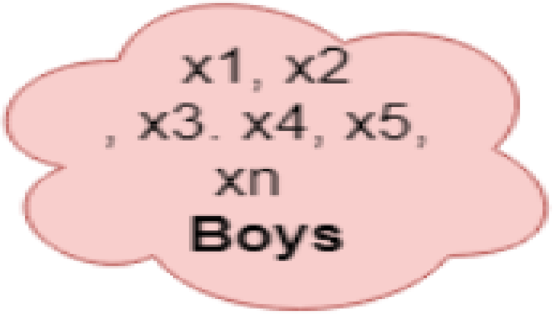
> Note: In Existential quantifier we always use AND or Conjunction symbol (∧).

If x is a variable, then existential quantifier will be ∃x or ∃(x). And it will be read as:

- **There exists a 'x.'**
- **For some 'x.'**
- **For at least one 'x.'**

Some boys are intelligent.

- x1 is intelligent
  ∨
- x2 is intelligent∨
- x3 is intelligent
  ∨
- .
- .
  ∨
- xn is intelligent



Universe of Discourse

So in short-hand notation, we can write it as:

∃x: boys(x) ∧ intelligent(x)

It will be read as: There are some x where x is a boy who is intelligent.

All birds fly.

$\forall x\ bird(x) \rightarrow fly(x)$

Every man respects his parent

"respect(x, y)," where x=man, and y= parent

$\forall x\ man(x) \rightarrow respects\ (x, parent)$

Some boys play cricket.

play(x, y)," where x= boys, and y= game

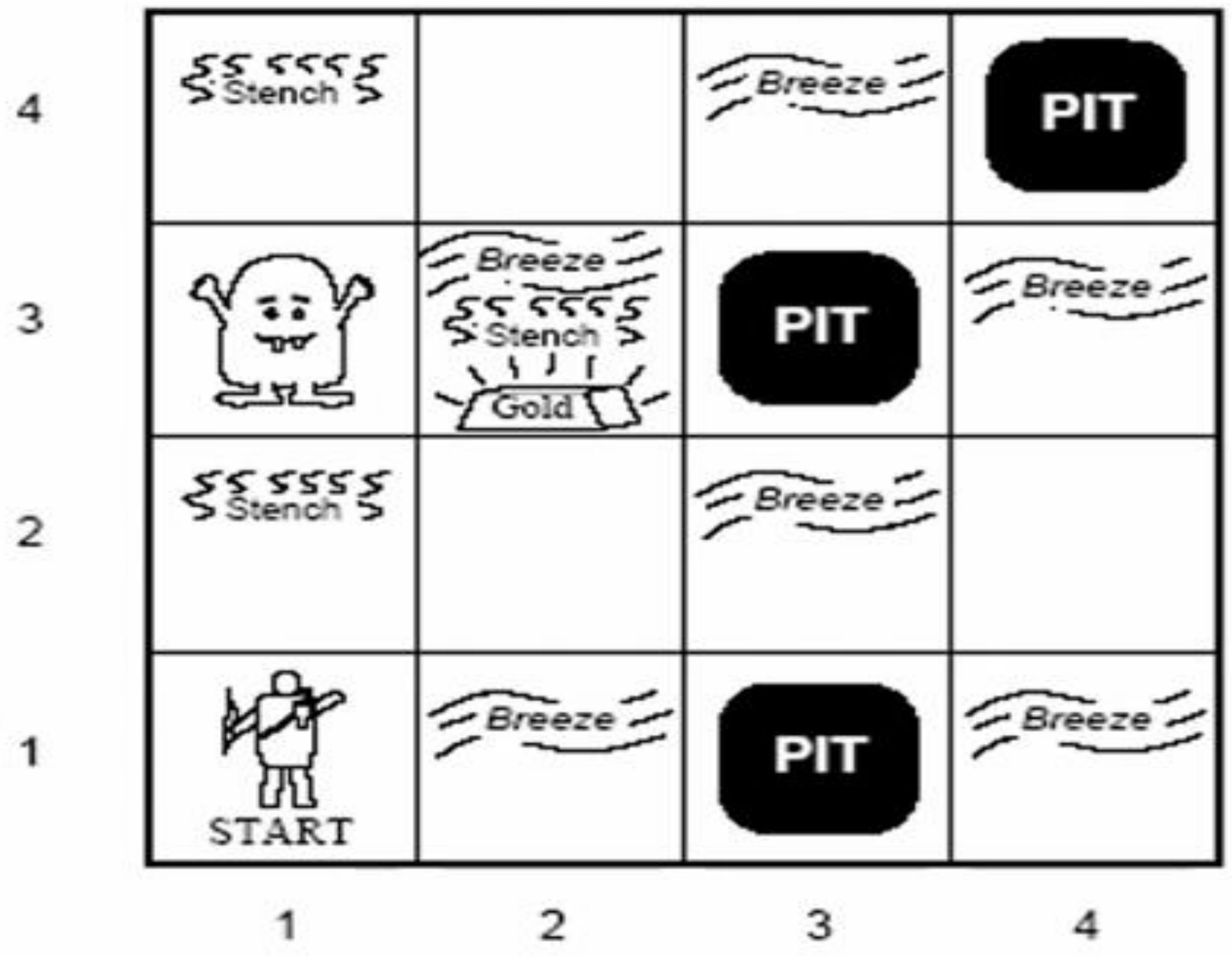
$\exists x\ boys(x) \rightarrow play(x, cricket)$.

Not all students like both Mathematics and Science.

"like(x, y)," where x= student, and y= subject

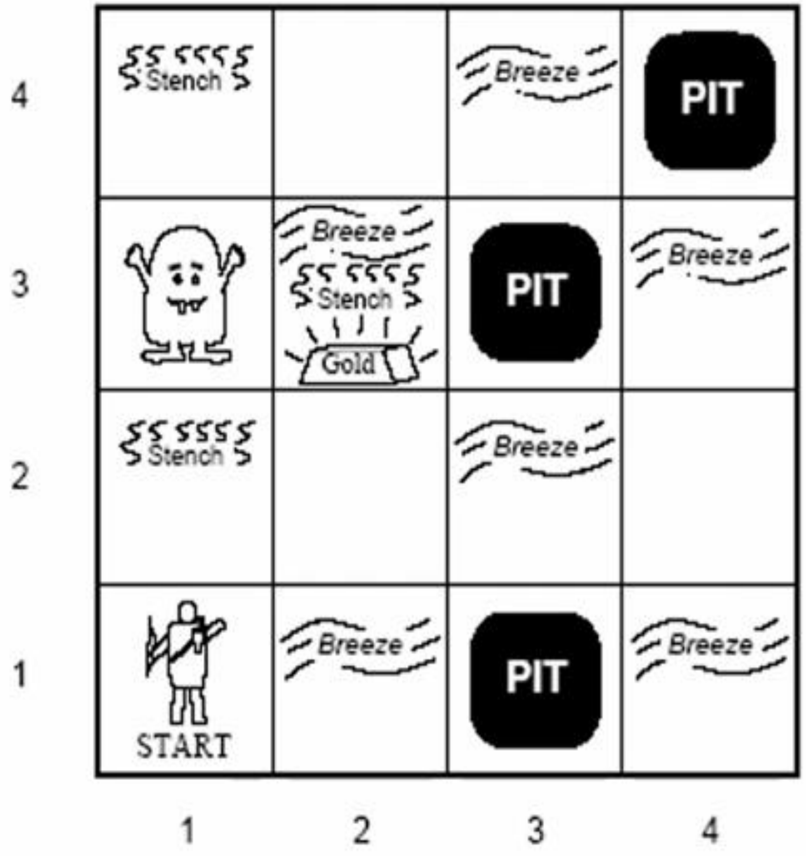
$\neg\forall\ (x)\ [\ student(x) \rightarrow like(x, Mathematics) \land like(x, Science)]$

Wumpus World



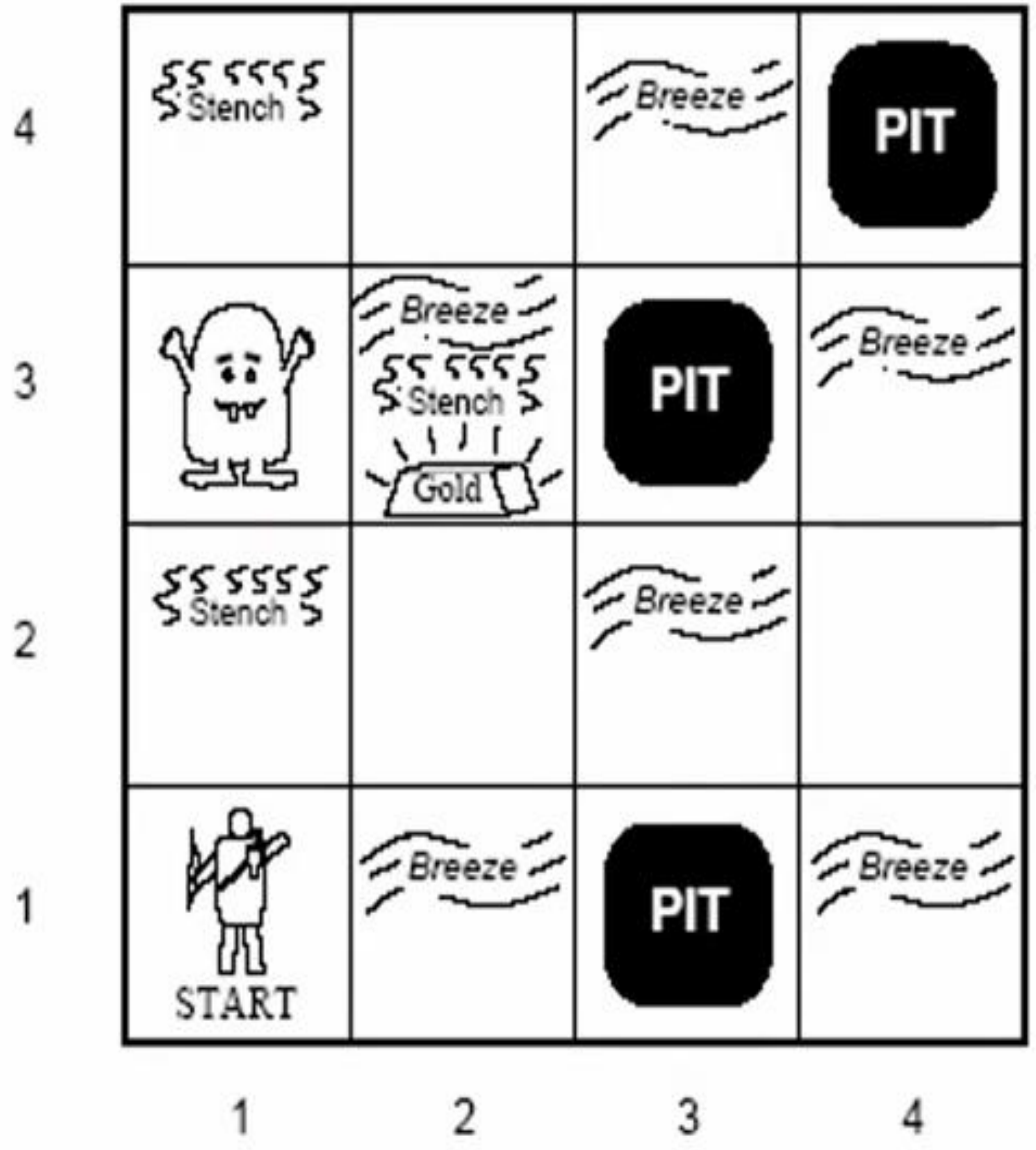
Wumpus World

- The Wumpus World is a cave consisting of rooms (4 X 4) connected by pathways.
- The Wumpus hiding somewhere in the cave, and 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 that will trap anyone who enters into these rooms.
- The only goal in this environment is the possibility of finding a bundle of gold.



Wumpus World

- Environment
  - Square adjacent to the Wumpus are smelly
  - Squares adjacent to the 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 the gold if in the same square
  - Releasing drops the gold in the same square
- Performance Measure
  - Gold +1000, Death – 1000
  - Step -1, Use arrow -10
- Actuators
  - Left turn, right turn, forward, grab, release, shoot
- Sensors
  - Breeze, glitter, and smell



Wumpus World…

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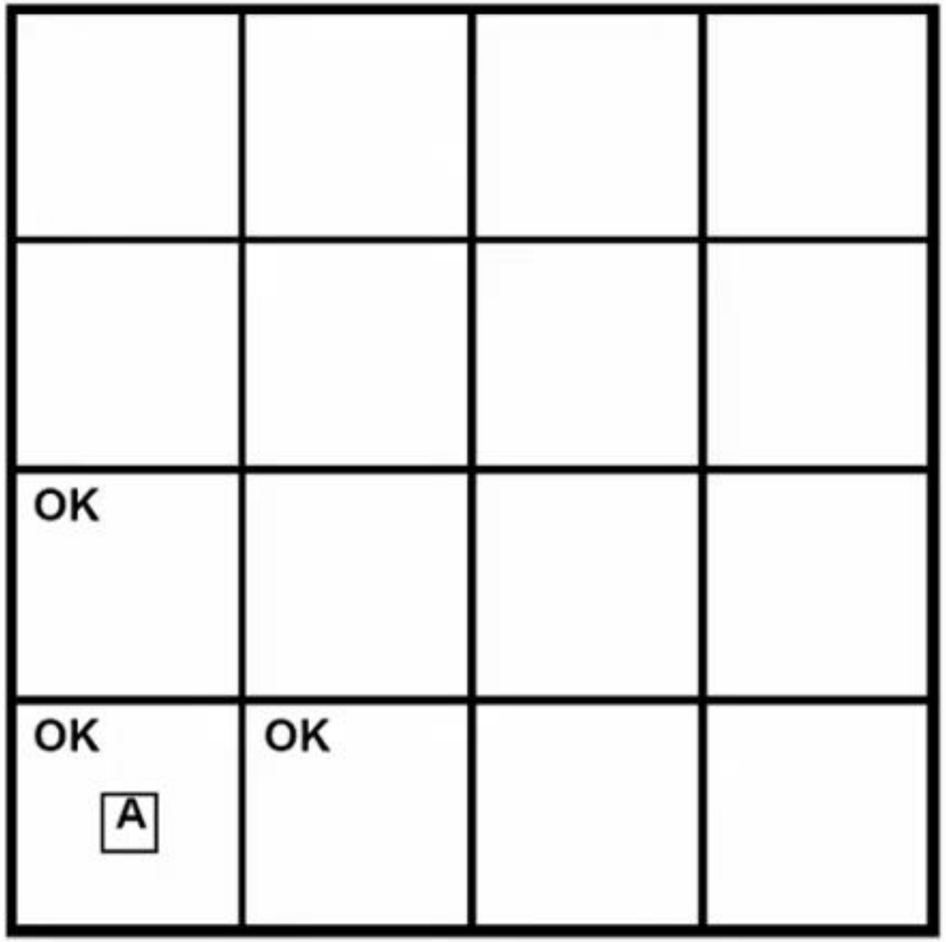
- Characterization of Wumpus World Environment
- Observable
    - partial, only local perception
- Deterministic
    - Yes, outcomes are specified
- Episodic
    - No, sequential at the level of actions
- Static
    - Yes, Wumpus and pits do not move
- Discrete
    - Yes
- Single Agent
    - Yes

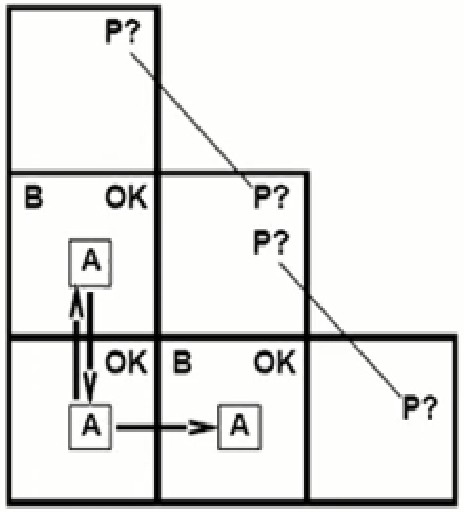
Wumpus World…



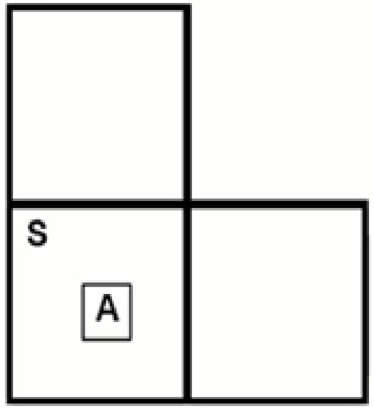
- Variables used…
- A – Agent
- B – Breeze
- G – Glitter, Gold
- OK – Safe Square
- P – Pit
- S – Stench
- V – Visited Square
- W – Wumpus

Other Sticky Situations

- Breeze in (1,2) and (2,1)
  - No safe actions



- Smell in (1,1)
  - Cannot move



Thank You