Knowledge Representation

- Humans are best at understanding, reasoning, and interpreting knowledge. Human knows things, which is knowledge and as per their knowledge they perform various actions in the real world.
- But how machines do all these things comes under knowledge representation and reasoning. Hence we can describe Knowledge representation as following:
  - Knowledge representation and reasoning (KR, KRR) is the part of Artificial intelligence which is concerned with AI agent's 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.
  - **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.**

Types of Knowledge

- Knowledge is awareness or familiarity gained by experiences of facts, data, and situations. Following are the types of knowledge in artificial intelligence:
  - Declarative Knowledge
  - Procedural Knowledge
  - Meta Knowledge
  - Heuristic Knowledge
  - Structural Knowledge

Types of Knowledge Cont..

1. Declarative Knowledge

- Declarative knowledge is to know about something.
- It includes concepts, facts, and objects.
- It is also called descriptive knowledge and expressed in declarative sentences.
- It is simpler than procedural language.

2. Procedural Knowledge

- It is also known as imperative knowledge.
- Procedural knowledge is a type of knowledge which is responsible for knowing how to do something.
- It can be directly applied to any task.
- It includes rules, strategies, procedures, agendas, etc.
- Procedural knowledge depends on the task on which it can be applied.

Types of Knowledge Cont..

3. Meta-knowledge:

- Knowledge about the other types of knowledge is called Meta-knowledge.

4. Heuristic knowledge:

- Heuristic knowledge is representing knowledge of some experts in a field or subject.
- Heuristic knowledge is rule of thumb based on previous experiences, awareness of approaches, and which are good to work but not guaranteed.

5. Structural knowledge:

- Structural knowledge is basic knowledge to problem-solving.
- It describes relationships between various concepts such as kind of, part of, and grouping of something.
- It describes the relationship that exists between concepts or objects.

Approaches to Knowledge Representation:

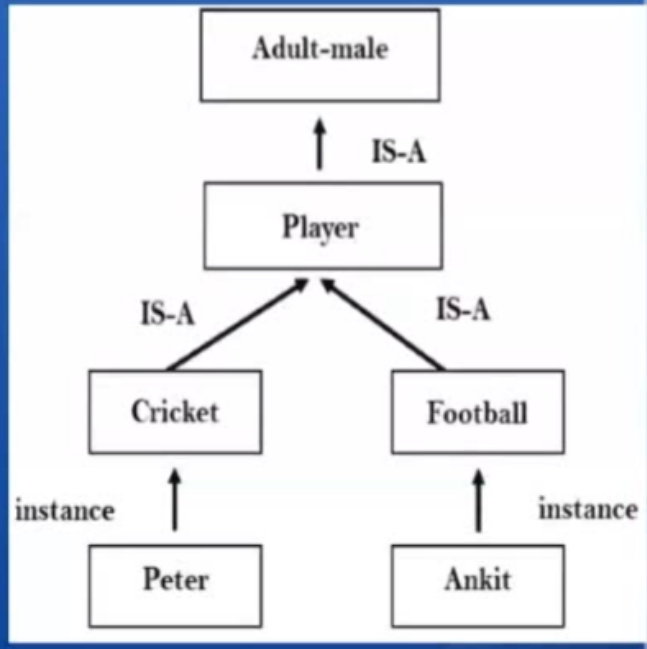
- There are mainly four approaches to knowledge representation, which are given below:
- 1. Simple relational knowledge:
  - It is the simplest way of storing facts which uses the relational method, and each fact about a set of the object is set out systematically in columns.
  - This approach of knowledge representation is famous in database systems where the relationship between different entities is represented.
  - This approach has little opportunity for inference.

Player	Wt.	Age
Player1	65	23
Player2	58	18
Player3	75	24

Approaches to Knowledge Representation Cont..

2. Inheritable knowledge:

- In the inheritable knowledge approach, all data must be stored into a hierarchy of classes.
- All classes should be arranged in a generalized form or a hierarchical manner.
- In this approach, we apply inheritance property.
- Elements inherit values from other members of a class.
- This approach contains inheritable knowledge which shows a relation between instance and class, and it is called instance relation.
- Every individual frame can represent the collection of attributes and its value.
- In this approach, objects and values are represented in Boxed nodes.We use Arrows which point from objects to their values.



Approaches to Knowledge Representation Cont..

3. Inferential knowledge:

- Inferential knowledge approach represents knowledge in the form of formal logic.
- This approach can be used to derive more facts.
- It guarantees correctness.

- Example: Let's suppose there are two statements:
  - Marcus is a man
  - All men are mortal
  - Then it can represent as;
    - man(Marcus)
    - ∀x = man (x) ---> mortal (x)

Approaches to Knowledge Representation Cont..

- **4. Procedural knowledge:**
- Procedural knowledge approach uses small programs and codes which describes how to do specific things, and how to proceed.
- In this approach, one important rule is used which is If-Then rule.
- In this knowledge, we can use various coding languages such as LISP language and Prolog language.
- We can easily represent heuristic or domain-specific knowledge using this approach.
- But it is not necessary that we can represent all cases in this approach.

Requirements for Knowledge Representation System:

- A good knowledge representation system must possess the following properties.
  1. Representational Accuracy:
     - KR system should have the ability to represent all kind of required knowledge.
  2. Inferential Adequacy:
     - KR system should have ability to manipulate the representational structures to produce new knowledge corresponding to existing structure.
  3. Inferential Efficiency:
     - The ability to direct the inferential knowledge mechanism into the most productive directions by storing appropriate guides.
- 4. Acquisitional efficiency:
  - The ability to acquire the new knowledge easily using automatic methods.

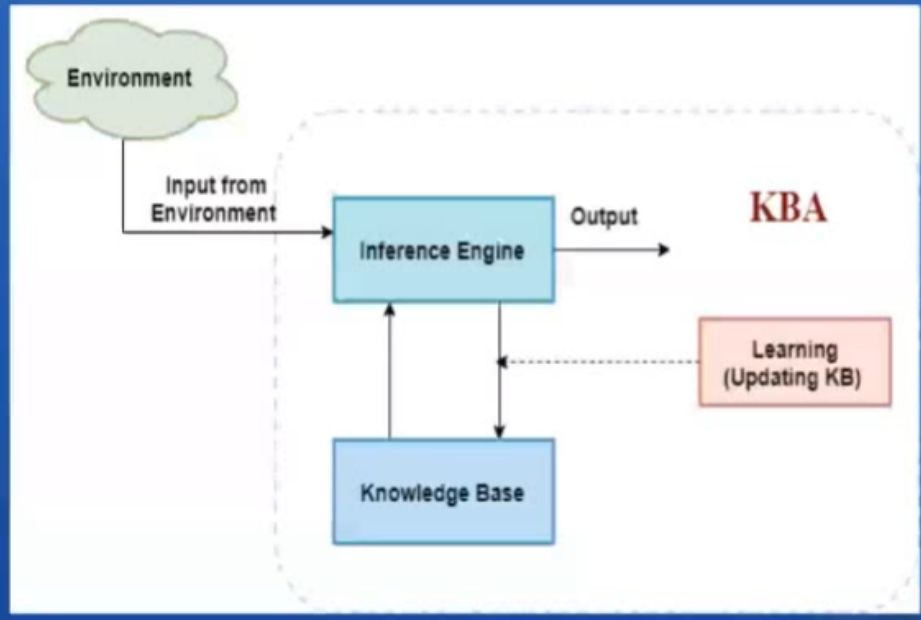
Knowledge-Based Agent in AI

- 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 maintaining an internal state of knowledge, reason over that knowledge, update their knowledge after observations and take actions.** These agents can represent the world with some formal representation and act intelligently.
- Knowledge-based agents are composed of two main parts:
  - Knowledge-base and
  - Inference system.

Knowledge Base Agent Cont..

- The diagram is representing a generalized architecture for a knowledge-based agent.
- The knowledge-based agent (KBA) take input from the environment by perceiving the environment.
- The input is taken by the inference engine of the agent and which also communicate with KB to decide as per the knowledge store in KB.
- The learning element of KBA regularly updates the KB by learning new knowledge.

- Knowledge base: Knowledge-base is a central component of a knowledge-based agent, it is also known as KB. It is a collection of sentences (here 'sentence' is a technical term and it is not identical to sentence in English). These sentences are expressed in a language which is called a knowledge representation language. The Knowledge-base of KBA stores fact about the world.



Propositional 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 but not both. 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 Review

- Propositional logic is also called Boolean logic as it works on 0 and 1.
- In propositional logic, we use symbolic variables to represent the logic, and we can use any symbol for a representing a proposition, such A, B, C, P, Q, R, etc.
- Propositions can be either true or false, but it cannot be both.
- Propositional logic consists of an object, relations or function, and logical connectives.
- These connectives are also called logical operators.
- The propositions and connectives are the basic elements of the propositional logic.
- Connectives can be said as a logical operator which connects two sentences.
- A proposition formula which is always true is called tautology, and it is also called a **valid sentence.**
- A proposition formula which is always false is called Contradiction.
- A proposition formula which has both true and false values is called contingency.
- Statements which are questions, commands, or opinions are not propositions such as "Where is Rohini", "How are you", "What is your name", are not propositions.

Types of Propositions

- There are two types of Propositions:
  - Atomic Propositions
  - 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.
- Example:
  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 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:
- Negation: A sentence such as ¬ P is called negation of P.
  - A literal can be either Positive literal or negative literal.
- 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.
- 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.
- 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
- 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.

Summary Logical Connectives

- Summary

Connective symbols	Word	Technical term	Example
∧	AND	Conjunction	A ∧ B
∨	OR	Disjunction	A ∨ B
→	Implies	Implication	A → B
⇔	If and only if	Biconditional	A ⇔ B
¬ or ~	Not	Negation	¬ A or ¬ B

Logical equivalence:

- Logical equivalence is one of the features of propositional logic. Two propositions are said to be logically equivalent if and only if the columns in the truth table are identical to each other.
- Let's take two propositions A and B, so for logical equivalence, we can write it as A⇔B. In below truth table we can see that column for ¬A∨ B and A→B, are identical hence A is Equivalent to B

A	B	¬A	¬A∨ B	A→B
T	T	F	**T**	**T**
T	F	F	**F**	**F**
F	T	T	**T**	**T**
F	F	T	**T**	**T**

Properties of Logical Operators

Commutativity:

- P ∧ Q= Q ∧ P, or
- P ∨ Q = Q ∨ P.

Associativity:

- (P ∧ Q) ∧ R= P ∧ (Q ∧ R),
- (P ∨ Q) ∨ R= P ∨ (Q ∨ R)

Identity element:

- P ∧ True = P,
- P ∨ True= True.

Distributive:

- P ∧ (Q ∨ R) = (P ∧ Q) ∨ (P ∧ R).
- P ∨ (Q ∧ R) = (P ∨ Q) ∧ (P ∨ R).

DE Morgan's Law:

- ¬ (P ∧ Q) = (¬P) ∨ (¬Q)
- ¬ (P ∨ Q) = (¬ P) ∧ (¬Q).

Double-negation elimination:

- ¬ (¬P) = P.

Some Terminologies

Following are some terminologies related to inference rules:

- Implication: It is one of the logical connectives which can be represented as P → Q. It is a Boolean expression.
- Converse: The converse of implication, which means the right-hand side proposition goes to the left-hand side and vice-versa. It can be written as Q → P.
- Contrapositive: The negation of converse is termed as contrapositive, and it can be represented as ¬ Q → ¬ P.
- Inverse: The negation of implication is called inverse. It can be represented as ¬ P → ¬ Q.

TABLE 1 Rules of Inference.

Rule of Inference	*Tautology*	*Name*
p $p \rightarrow q$ $\therefore q$	$(p \wedge (p \rightarrow q)) \rightarrow q$	Modus ponens
$\neg q$ $p \rightarrow q$ $\therefore \neg p$	$(\neg q \wedge (p \rightarrow q)) \rightarrow \neg p$	Modus tollens
$p \rightarrow q$ $q \rightarrow r$ $\therefore p \rightarrow r$	$((p \rightarrow q) \wedge (q \rightarrow r)) \rightarrow (p \rightarrow r)$	Hypothetical syllogism
$p \vee q$ $\neg p$ $\therefore q$	$((p \vee q) \wedge \neg p) \rightarrow q$	Disjunctive syllogism
p $\therefore p \vee q$	$p \rightarrow (p \vee q)$	Addition
$p \wedge q$ $\therefore p$	$(p \wedge q) \rightarrow p$	Simplification
p q $\therefore p \wedge q$	$((p) \wedge (q)) \rightarrow (p \wedge q)$	Conjunction
$p \vee q$ $\neg p \vee r$ $\therefore q \vee r$	$((p \vee q) \wedge (\neg p \vee r)) \rightarrow (q \vee r)$	Resolution