ARTIFICIAL INTELLIGENCE

Knowledge Representation & Reasoning

F24 AI & MMG

KNOWLEDGE REPRESENTATION AND REASONING

► Contents:

> ► Introduction to Knowledge Representation

> ► Propositional Logic

> ► First Order Logic

> ► Propositional Logic V/S First Order Logic

> ► Applications of Knowledge Representation and Reasoning

INTRODUCTION

- **Knowledge:** Facts and skills accumulated through experience.

- **Representation:** How knowledge is stored (facts, rules, logic).

- **Reasoning:** process of using knowledge to reach new conclusions or make decisions.

  - How to use that knowledge to make decisions, solve problems, or answer questions.

- **Definition**: It is the study of **how to represent information** about the world in a form that a **computer system can use to solve complex problems** and make intelligent decisions.

  - It allows AI to represent facts, objects, and relations in a way that a computer can process.

- **Objective of Knowledge Representation & Reasoning:** Store useful information about the world and use it to draw conclusion, solve problems, and make decisions.

INTRODUCTION

► **Analogy**: Imagine a library where Books = knowledge (representation). A librarian = reasoning (they use the books to answer your question).

► **Example**:

  ► Knowledge: "All humans are mortal.", "Socrates is a human."

  ► Reasoning: Therefore → "Socrates is mortal."

WHY IS KNOWLEDGE REPRESENTATION IMPORTANT IN AI?

► **Facilitates Reasoning**: Helps AI systems to simulate human-like reasoning processes.

  ► Makes it easier to infer new knowledge from existing data.

► **Foundation for Machine Learning & Natural Language Processing:** Enhances the ability of machines to understand, learn, and interpret complex human concepts.

► **Supports Decision-Making in AI:** Used in expert systems and robotics for planning and decision-making based on structured knowledge.

KEY COMPONENTS OF KNOWLEDGE REPRESENTATION

► **Objects:** Entities that exist in the world (e.g., a person, car, or animal).

► **Relations:** How objects are connected (e.g., "Ali owns a car").

► **Facts:** Statements that describe the state of the world (e.g., "The sky is blue").

► **Rules:** Conditional statements that define how knowledge is derived or used (e.g., "If it rains, then bring an umbrella").

PROPOSITIONAL LOGIC (TRUE/FALSE)?

- **Definition:** Propositional Logic (PL) is a symbolic logic that deals with propositions (statements) that can be either true or false.
- Basic Components:
  - Propositions: Statements like "P" or "Q" which can be true or false.
  - Logical Operators:
    - NOT - Negation (¬): Negates the value.
    - OR – Disjunction (∨): At least one proposition must be true.
    - AND - Conjunction (∧): Both propositions must be true.
    - IF-Then – Implies (→): If the first proposition is true, then the second must be true.
    - IFF (↔) If and Only If: both statements must either be true together or false together.

PROPOSITIONAL LOGIC - EXAMPLES

▶ NOT - Negation (¬): P = "It is raining"

  ▶ ¬P (It's not raining)

▶ OR – Disjunction (∨): P= "You should talk", Q = "Listen at a time"

  ▶ P ∨ Q (You should talk or listen at a time)

▶ AND - Conjunction (∧): P = "We will go to University", Q = "We will attend lectures"

  ▶ P ∧ Q (We will go to University and We will attend lectures)

▶ IF -Then – Implies (→): P = "There is a rain", Q = "The roads will be wet"

  ▶ P → Q (If There is a rain then The roads will be wet)

▶ IFF – If and Only If (↔): P = "I will cook", Q = "I feel hungry"

  ▶ P ↔ Q (I will cook food if I feel hungry)

FIRST ORDER LOGIC / PREDICATE LOGIC?

▶ **Definition:** It is more powerful than propositional logic which extends PL by including objects, relations, and quantifiers.

▶ **Analogy**: If Propositional Logic is like saying **"This apple is red"**, then First-Order Logic is like saying **"All apples are red"** or "There exists an apple that is red."

▶ **Basic Components:**

   ▶ Constants: Specific objects in the domain (e.g., "Alice," "Bob").

   ▶ Variables: Represent general objects (e.g., x, y).

   ▶ Predicates: Describe properties or relations (e.g., Owns(Ali, Car)).

   ▶ Quantifiers: (Quantifiers are symbols)

      ▶ Universal Quantifier (∀): Applies to all instances (e.g., "For all x").

      ▶ Existential Quantifier (∃): Applies to at least one instance (e.g., "There exists an x").

FIRST ORDER LOGIC - EXAMPLES

- PL: "Ali is a student." (just a fact)

- FOL: ∀x (If x is a student → x studies). (For all x, if x is a student, then x studies.)

- FOL: ∃x (x is a student ∧ x studies at night). (There exists a student who studies at night.)

- All Boys like Cricket:
  - ∀x: Boys(x) → Like (x, Cricket)

- Some Boys like football
  - ∃x: Boys(x) ∧ Like (x, football)

FIRST ORDER LOGIC - EXAMPLES

▶ Ahmed takes either AI or Geometry:

  ▶ Takes (Ahmed, AI) ∨ Takes (Ahmed, Geometry)

▶ Ahmed takes AI and Geometry:

  ▶ Takes (Ahmed, AI) ∧ Takes (Ahmed, Geometry)

▶ Ahmed takes AI and Geometry but not both on the same time:

  ▶ Takes(Ahmed, AI) ↔ ¬ Takes (Ahmed, Geometry)

TASK: WRITE SYMBOLIC REPRESENTATION

- Some students likes Ahmed

- No student likes Ahmed

- All students are intelligent

- All job holding persons are happy

- All happy peoples smile

- Someone is educated

- Someone is smiling

PROPOSITIONAL LOGIC V/S FIRST ORDER LOGIC

Feature	Propositional Logic (PL)	First Order Logic (FOL)
Expressiveness	Less expressive, deals with simple propositions	More expressive, handles objects, relations, and quantifiers
Variables	No variables	Uses variables to represent objects
Quantifiers	No quantifiers	Uses universal ($\forall$) and existential ($\exists$) quantifiers
Complexity	Simpler	More complex
Example	$P \wedge Q$	$\forall x$ (Student(x) $\rightarrow$ Studies(x))