Module 4

Knowledge Representation Using Logic

First-Order Logic in Artificial intelligence

- 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. Consider the following sentence, which we cannot represent using PL logic.

  "Some humans are intelligent", or

  "Sachin likes cricket."

To represent the above statements, PL logic is not sufficient, so we required some more powerful logic, such as first-order logic.

Predicate logic or First-order predicate logic

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

- First-order logic is a powerful language that develops information about the objects in a more easy way and can also express the relationship between those objects.

- First-order logic (like natural language) does not only assume that the world contains facts like propositional logic but also assumes the following things in the world: Objects, Relations, Functions etc

Predicate Calculus

- Predicate logic is a formal language consisting of events and symbols.

- It can be used to represent relationship between objects and drawing inferences.

- It can also be used to represent statements in a formal way

Basic elements of Predicate logic

Propositional logic assumes the world contains facts.

First-order logic (like natural language) assumes the world contains

- » Objects
- » Predicate
- » Functions
- » Constants
- » Variables
- » Connectives
- » Equality
- » Quantifier

Basic elements of Predicate logic

- Objects: people, houses, numbers, colors, baseball games, wars, …

- Predicate

  It is a word which represent the relationship between the objects.

Basic elements of Predicate logic

Predicates generally correspond to English VERBS

First argument is generally the subject, the second the object

- Hit(Bill, Ball) usually means “Bill hit the ball.”
- Likes(Bill, IceCream) usually means “Bill likes IceCream.”
- Verb(Noun1, Noun2) usually means “Noun1 verb noun2.”

Basic elements of Predicate logic

- Functions

Functions are used for evaluating an object.
They consists of function name and argument.

Wife(Rama) evaluates to Sita
where Wife function
and Rama argument

Function arguments are objects; function returns an object
– Objects generally correspond to English NOUNS

Basic elements of Predicate logic

- Constants

These are the words which represent person, object, events and concepts.

They do not change their values.

eg. Shakespear

Basic elements of Predicate logic

- Variables

  These are the words which takes different values depending on the circumstances.

eg. Write(a , b) where a= author and b = book

If a => Kalidasa, b=> Mekhadooth or Sakundalam

If a => Shakespear, b=> Hamlet

Atomic Formula

- Atomic formula is formed using one or more of the basic elements of predicate logic.

eg. Tagore writes Gitanjali.

Write(Tagore,Gitanjali) Atomic formula

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:

Chinky is a cat

cat (Chinky).

Complex Sentences

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

  The Logical Connectives:

  – $\Leftrightarrow$ biconditional

  – $\Rightarrow$ implication

  – $\wedge$ and

  – $\vee$ or

  – $\neg$ negation

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:
  1. **Universal Quantifier, (for all, everyone, everything)**
  2. **Existential quantifier, (for some, at least one).**

Universal Quantifier

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 $\forall$, which resembles an inverted A.

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

If x is a variable, then $\forall x$ is read as:

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

Universal Quantifier

$\forall$ **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 $\exists$, 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 ($\wedge$).

Existential Quantifier

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

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

$\exists$ x: boys(x) $\wedge$ intelligent(x)

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

Existential Quantifier

- The main connective for universal quantifier $\forall$ is implication $\rightarrow$.
- The main connective for existential quantifier $\exists$ is and $\wedge$.

Properties of Quantifiers:

- In universal quantifier, $\forall x \forall y$ is similar to $\forall y \forall x$.
- In Existential quantifier, $\exists x \exists y$ is similar to $\exists y \exists x$.
- $\exists x \forall y$ is not similar to $\forall y \exists x$.

Examples

1) Marcus is a man

Solution:

Man (Marcus)

2) Marcus was a Pompien

Solution:

Pompien (Marcus)

Examples

3) All Pompiens were Romans

Solution:

$\forall x : Pompien (x) \Rightarrow Roman(x)$

Examples

5) All purple Mushrooms are poisonous

Solution:

$$\forall x : \text{Mushroom}(x) \land \text{purple}(x) \Rightarrow \text{poisonous}(x)$$

Examples

6) Everyone is Loyal to Someone

Solution:

$\forall x \exists y : loyal(x,y)$