Knowledge Representation
&
Predicate Logic

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Knowledge Representation

- Knowledge representation (KR) is an important issue in both cognitive science and artificial intelligence.
  - In cognitive science, it is concerned with the way people store and process information.
  - In artificial intelligence (AI), main focus is to store knowledge so that programs can process it and achieve human intelligence.

Knowledge Representation

- A knowledge representation is most fundamentally a *substitute* for the thing itself, used to enable an entity to determine consequences by reasoning about the world.
- **Reasoning** is the use of symbolic representations of some statements in order to derive new ones.

What is predicate logic (PL)?

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- A **predicate logic** is an expression of one or more variables defined on some specific domain. A **predicate** with variables can be made a proposition by either assigning a value to the variable or by quantifying the variable.

Predicate logic (PL):

- A **predicate** is a statement that contains variables (**predicate** variables), and they may be true or false depending on the values of these variables.
- **Predicate logic** is the generic term for symbolic formal systems like first-order **logic**, second-order **logic**, many-sorted **logic**, or infinitary **logic**.

Predicate Logic (PL):

- The Predicate Logic has three logical notions.
    1) Term,
    2) Predicate
    3) Quantifier

(1). Term:

- a constant (single individual or concept i.e.,5, john etc.),
- a variable that stands for different individuals
- n-place function $\mathbf{f(t_1, \ldots, t_n)}$, where $t_1, \ldots, t_n$ are terms.
- A function is a mapping that maps **n terms** to a term.

Predicate Logic (PL):

- **Predicate:**
  - a relation that maps n terms to a truth value (T) or false value (F).

- **Quantifier:**
  - Universal (∀) quantifier
  - Existential(∃) quantifier

  - **∀ and ∃ are used for conjunction with variables.**

Examples

- *"x loves y"* is represented as **LOVE(x, y)** which maps it to true or false, when x and y get instantiated to actual values.

- *"john's father loves john"* is represented as **LOVE(*father*(john), john).**

  ❖ Here ***father*** is a **function** that maps *john* to his father.

Examples

- ***x is greater than y*** is represented in predicate calculus as **GT(x, y)**.
- It is defined as follows:

  GT(x, y) = T , if x > y

  = F , otherwise

- Symbols like **GT** and **LOVE** are called **predicates .**

❖ **Predicates two terms and map to T or F depending upon the values of their terms.**

Examples – Cont..

- Translate the sentence "***Every man is mortal***" into Predicate formula.
- Representation of statement in predicate form
  - ❖"**x is a man**" and "**MAN(x)**,
  - ❖**x is mortal**" by **MORTAL(x)**
- Every man is mortal :

  $(\forall x)\ (MAN(x) \rightarrow MORTAL(x))$

Here, $\forall x$ is read as "for all x" and $\rightarrow$ is read as "implies".

Syntax and semantics for Propositional Logic

- **Valid statements or sentences in PL(Predicate Logic) are determined according to the rules of propositional syntax**.
- This syntax governs the combination of basic building blocks such as propositions and logical connectives.
- **Propositions are elementary atomic sentences.**

Cont……

- **Propositional Logic may be either true or false but may take on no other value.**
- **Examples** (**Simple propositions**):
  - ❖ It is raining.
  - ❖ It is a shining day.
  - ❖ Snow is white.
  - ❖ Snow is black.
  - ❖ People live on the Earth.
  - ❖ People live on the Moon.

Cont….

- **Examples (Compound propositions):**
  - ❖It is raining and the wind is blowing.
  - ❖If you study hard you will be rewarded.
  - ❖The sum of 10 and 20 is not 40.
  - ❖The sum of 20 and 10 is 40.
- T and F are special symbols having the values true and false.

Conti…

- **Logical Connectives:**

Symbol	Meaning
~	for not or **negation**
&	for **and** or **conjunction**
v	For **or** or **disjunction**
→	For **if … then** or **implication**
↔	For **if and only if** or **double implication**

Syntax

- The syntax of PL is defined recursively as follows:
- T and F are formulas.
- IF P and Q are formulas, the following are also formulas:
- (˜P)
- (P&Q)
- (PVQ)
- (P→Q)
- (P↔Q)

Example

- Represent the following facts in predicate logic:
- *(i). All employees earning Tk. 3,00,000/= or more per year have to pay taxes.*
- $\forall x\ ((E(x)\ \&\ GE(i(x), \mathit{300000})) \rightarrow T(x))$
- *(ii). People only try to assassinate rulers they are not loyal to.*
- $\exists y: \forall x : person(x) \wedge ruler(y) \wedge tryassassinate(x, y) \rightarrow \neg loyalto\ (x, y)$
- *(iii). John likes all kinds of food.*
- *Like (john, all-kinds-of-food)*

Assignment-1

Write PL for the following sentences:-

1. Every elephant is gray.
2. There is a white alligator.
3. All students are smart.
4. Every student in this class has visited India and Nepal.
5. Some roses are black.

Semantics

- **The semantics or meaning of a sentence is just the value true or false: that is, it is as assignment of a truth value to the sentences.**
- An interpretation for a sentence or group of sentences in an assignment of the truth value to each propositional symbol.

Conti…

- **Example:** Consider the statement = (P & ~Q)
- Clearly, there are four distinct interpretations for this sentences.

Interpretation	P	Q
1	True	False
2	True	True
3	False	True
4	False	False

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Semantic Rules for statements

Consider t and t' denotes true statements, f and f' denotes false statements, and a is any statement.

Rules Number	True Statements	False Statements
1.	T	F
2.	¯f	¯t
3.	t&t'	f&a
4.	tVa	a&f
5.	aVt	fVf'
6.	a→t	t→f
7.	f→a	t↔f
8.	t↔t'	f↔t
9.	f↔f'	

Example:

- Let ***I*** assign true to ***P*** , false to ***Q*** and false to ***R*** in statement **((P & ⁻Q) →R)VQ**.
- **What is the meaning of the statement?**

Answer:

- Rule 2 gives **⁻Q** as **true.**
- Rule 3 gives **(P & ⁻Q)** as **true**.
- Rule 6 gives **(P & ⁻Q) →R** as **false**.
- **Rule 5** gives the statement **((P & ⁻Q) →R)VQ** value as **false**.

Assignment-2

- Find the meaning of the statement

  $(^{-}P \vee Q) \& R \rightarrow S \vee (^{-}R \& Q)$

  for each of the interpretations given below.
- (a). I_1 : P is true, Q is true, R is false, S is true.
- (b). I_2 : P is true, Q is false, R is true, S is true.

- **THE END**
- **THANKS**