Chapter: 4 Knowledge Representation

(12 to 14 marks) 2 Question

Data → Information → Knowledge → Intelligence →

- Knowledge is an abstract term that attempts to capture an individual understanding of a given subject.
- It is a subset of information that has been extracted, filtered or formatted.

Types of knowledge

1. Declarative knowledge:
   - It is passive knowledge in the form of statements or facts, notion, rules of the world.
   - E.g. Ram is a boy.

2. Procedural knowledge:
   - It is compiled or processed form of information which is related to performance of some task.
   - Description of procedures to achieve certain target ~~is~~ are example of procedural knowledge

3. Heuristic knowledge
   - They are rules of thumb or trick. It is used to make judgements and also to simplify solution of problem.

What is knowledge representation?

Knowledge consists of facts, concepts, rules, etc. It can be represented in different forms as images, spoken language, written words, etc. in human. The objective of knowledge representation is to express the knowledge about the world in a computer understandable form. It can be done using logic, semantic ~~wave~~ web, and scripts.

Logic

Prepositional logic:

A	B	A∧B	A∨B	¬A	¬B	A→B	A⇔B
0	0	0	0	1	1	1	~~0~~ 1
0	1	0	1	1	0	1	0
1	0	0	1	0	1	0	0
1	1	1	1	0	0	1	~~0~~ 1

Prepositional logic is ~~the~~ a declarative sentence which can be either true or false but not both.

a) Tautology
A prepositional 'P' is a tautology if it is true under all circumstances.

b) Contradiction:
A prepositional 'P' is a contradiction if it contains only false for all conditions.

c) Contigency:
A prepositional 'P' is a contigency if it truth table contains at least one true and 1 false.

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d) Contrapositive:

$\neg B \rightarrow \neg A$

e) Inverse:

Inverse of $A \rightarrow B$ is $\neg A \rightarrow \neg B$.

Rules of Inference

Statement	Tautological form	Common Name
① p / $\therefore p \vee q$	$p \rightarrow p \vee q$	Addition
② $p \wedge q$ / $\therefore p$	$(p \wedge q) \rightarrow p$	Simplification
③ p / q / $\therefore p \wedge q$	$(p) \wedge (q) \rightarrow (p \wedge q)$	Conjuction
④ $p \rightarrow q$ / p / $\therefore q$	$[(p \rightarrow q) \wedge p] \rightarrow q$	Modus ~~Ponen~~ Ponen
⑤ $p \rightarrow q$ / $\neg q$ / $\therefore \neg p$	$[(p \rightarrow q) \wedge \neg q] \rightarrow \neg p$	Modus tollens
⑥ $p \rightarrow q$ / $q \rightarrow r$ / $\therefore p \rightarrow r$	$(p \rightarrow q) \wedge (q \rightarrow r) \rightarrow (p \rightarrow r)$	Hypothetic Syllogism
⑦ $p \vee q$ / $\neg p$ / $\therefore q$	$[(p \vee q) \wedge \neg p] \rightarrow q$	Disjunction Syllogism

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Predicate logic:

It was developed to extend expressiveness of prepositional logic. It permits reasoning about whole objects as relational entities as well as class or subclass of object.

First order predicate logic allows quantifiers to range over object.
Second order predicate logic allows quantifiers to range over object and relations.
Third order predicate logic allows ~~quantify~~ quantifying over predicates of predicates.

Rules	Common Name
① $\forall x\, P(x)$ / $\therefore P(c)$ for all c — C is any element of the universe.	Universal instantation

(2) $\dfrac{\exists x\, P(x)}{\therefore P(c)}$ C is some element for which P(c) is true.	Existential instantation
(3) $\dfrac{P(c) \text{ for all } x}{\forall x\, P(x)}$ x should not be free in any given parameters.	Universal Generalization
(4) $\dfrac{P(c)}{\therefore \exists x\, P(x)}$ C is some element in the universe.	Existential Generalization

GOT	FOPL (1st Order Predicate logic)
Jon is a boy.	boy (Jon) Relation ↑ → Subject.
Jon likes Dany.	likes(Jon, Dany).
Jon is a boy and of medium height.	boy (Jon) ∧ medium height (Jon)
Jon & Davos like Dany.	like (Jon, Dany) ∧ like (Davos, Dany)

If Dany hadn't destory city then Jon hadn't killed Dany.	¬destroy (Dany, city) → ¬kill (Jon, Dany).
If Jon & Dany had co-operated then they could have rule 7 kingdom.	cooperate (Jon, Dany) ∧ cooperate (Dany, Jon) → rule (Jon, Dany, 7 kingdom)
Nobody likes taxes.	¬∃x : People (x) → likes (x, taxes)
All basketball players are tall.	~~∀x : (mushroom (x) ∧ purple (x)) →~~ ~~pois~~ ∀x : Basketball players (x) → tall (x)
There exist some basket-ball players who are short.	
All purple mushrooms are poisonous.	∀x: (mushroom (x) ∧ purple (x)) → poisonous(x)
Everyone who loves all animals are loved by someone.	∀x∀y: (people (x) ∧ animal(y) ∧ love (x,y)) → ∃z love (z, x).
Ram dislikes children who drink tea. ~~∀x: Gc~~	∀x (children (x) ∧ drink tea (x)) → ¬like (Ram, x).

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CNF (~~Conjug~~ Conjuctive normal form) (Clausal NF)

→ If different sentences are connected using AND then it is CNF.

DNF (Disjunctive normal form)

→ If different sentences are connected by using OR then it is DNF.

Predicate logic to CNF:

1. Eliminate the bidirectional symbol.

$P(x) \Leftrightarrow Q(x) \equiv (P(x) \rightarrow Q(x)) \wedge (Q(x) \rightarrow P(x))$

2. Eliminate the implication as.

$P(x) \rightarrow Q(x) \equiv \neg P(x) \vee Q(x)$

3. Use De morgan's rule if applicable

i) $\neg(P(x) \wedge Q(x)) \equiv \neg P(x) \vee \neg Q(x)$

ii) $\neg(P(x) \vee Q(x)) \equiv \neg P(x) \wedge \neg Q(x)$

4. Eliminate the existencial Quantifier.

Case-I:

If the existential quantifier is alone or inside the universal quantifier, replace all the variable associated with existential quantifier by some arbitary constant. This process is known as skolemization

E.g. $\forall x \exists y : P(x,y) \wedge Q(y,z)$

$\equiv \forall x\, P(x,A) \wedge Q(A,Z)$

Case-II:

If the existential quantifier is outside the universal quantifier or in between the universal quantifier then replace all the variable associated with the existential

quantifier by the function of all the variable associated with universal quantifier which are inside the quantifier. This process is known as functional skolemization.

E.g. $\forall x : \exists y : \forall z : \forall k : P(x,y,z) \wedge Q(y,z,k)$.

5. Drop all the universal Quantifier.

$\forall x : P(x) \equiv P(x)$

Resolution:

The following steps should be followed to prove the given premises.

Given premises can be solved by two ways:

i. Answer abstraction method.

ii. Contradication method.

VVImp

Steps for contradiction method.

1. Convert all premises into FOPL.
2. Convert all the FOPL into CNF.
3. Negate the predicate to be proved, convert it into CNF & add it into given premises.
4. Repeat the following process until a contradiction is found or no progress can be done.
   (i) Take any two premises & find out the resolvent.
   (ii) Add the resolvent in the given premises.
5. If the contradiction is fixed the negation of the predicate to be proved is false otherwise it is true.

E.g.

i.) $P \vee Q$

ii) $P \rightarrow S$

iii.) $\neg S$

Show that it gives Q.

⇒ Step 1:

i) $P \vee Q$

ii) $P \rightarrow S$

iii) $\neg S$

Step 2:

i) $P \vee Q$

ii) $\neg P \vee S$

iii) $\neg S$

Step 3:

Q

i) $\neg Q$.

Step 4:

$\neg Q$ $P \vee Q$ From (i)

P $\neg P \vee S$ From (ii)

S $\neg S$ From (iii)

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So, Q is true.//

(1) Cat likes fish.

(2) Cat eats everything they like.

(3) Mani is a cat.

To prove: Mani eats fish.

Step 1:

(1) $\forall x: cat(x) \rightarrow likes(x, fish)$

(2) $\forall x \forall y: (cat(x) \wedge likes(x,y)) \rightarrow eats(x,y)$

(3) $cat(Mani)$

Step 2:

(1) $\neg cat(x) \vee likes(x, fish)$

(2) $\neg(cat(x) \wedge likes(x,y)) \vee eats(x,y)$

(2) $\equiv \neg cat(x) \vee \neg likes(x,y) \vee eats(x,y)$

(3) $cat(Mani)$

Step 3:

$eats(Mani, fish)$

(iv) $\neg eats(Mani, fish)$

Step 4:

$\neg eats(Mani, fish)$ $\neg cat(x) \vee \neg likes(x,y) \vee eats(x,y)$

$\neg cat(Mani, \cancel{fish}) \vee \neg likes(Mani, fish)$ $cat(x) \vee likes(x, fish)$

$\neg cat(Mani)$ $cat(Mani)$

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a. Rajesh is a megastar

b. Megastar needs more money.

c. More the money you need more to be busy.

Is Rajesh more busy?

Step 1:

1.) megastar (Rajesh)

2.) $\forall x:$ megastar$(x) \rightarrow$ ~~needs(x, more money)~~ more mory(x).

3.) $\forall x:$ more money$(x) \rightarrow$ more busy(x).

Step 2:

1) megastar (Rajesh)

2) $\neg$megastar $(x) \vee$ more ~~memory~~ money (x)

3) $\neg$more money$(x) \vee$ more busy (x)

Step 3:

$\neg$more busy (Rajesh) -- (iv)

Step 4:

$\neg$morebusy (Rajesh)

$\neg$more money$(x) \vee$ more busy(x)

$\neg$more money (Rajesh)

$\neg$megastar$(x) \vee$ more money (x)

$\neg$ megastar (Rajesh)

megastar (Rajesh)

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As our assumed fact is wrong.

Hence, Rajesh is more busy.

Proved

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Ques

1. Marcus is a man.
2. Marcus is a Pompian
3. All Pompians are Romans.
4. Caesar is a ruler.
5. All Romans are either loyal to or hated Caesar.
6. Everyone is loyal to some one.
7. People only try to assasinate rule if they aren't loyal to
8. Marcus tried to assasinate Caesar.

To prove: Marcus hate Caesar.

Step 1:

1. man (Marcus)
2. Pompian (Marcus)
3. $\forall x:$ Pompian$(x) \rightarrow$ Roman(x)
4. ruler (Caesar)
5. $\forall x:$ Roman $(x) \rightarrow$ (loyal$(x$, Caesar$) \vee$ hate$(x$, Caesar$))$
6. $\forall x \exists y:$ loyal (x, y)
7. $\forall x \forall y:$ try assinate $(x, y) \leftrightarrow \neg$loyal (x, y)
8. try assasinate (Marcus, ~~Ra~~ Caesar)

Step 2:

1. man (Marcus)
2. Pompian (Marcus)
3. $\neg$ Pompian $(x) \vee$ Roman (x)
4. ruler (Caesar)
5. $\neg$Roman$(x) \vee$ loyal $(x$, Caesar$) \vee$ hate $(x$, Caesar$)$
6. loyal (x, y)
7. (try assinate $(x, y) \rightarrow \neg$loyal $(x, y)) \wedge$ ($\neg$loyal$(x, y) \rightarrow$ tryassasinate(x, y))

= ($\neg$tryassasinate $(x, y) \vee \neg$loyal $(x, y)) \wedge$ (loyal$(x, y) \vee$ tryassinate (x, y))

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7 i.) ¬try assasinate (x,y) ∨ ¬loyal (x,y)
ii.) loyal (x,y) ∨ ¬try assasinate (x,y).
8. try assasinate (Marcus, Caesar)

Step 3:

¬hate (Marcus, Caesar)

Step 4:

¬hate (Marcus, Caesar)

¬Roman (x) ∨ loyal (x, Caesar) ∨ hate (x, Caesar)

¬Roman (x) ∨ loyal (x, Caesar) — with "Marcus" written above both x's

¬Pompein (Marcus) ∨ Roman (Marcus)

loyal (Marcus, Caesar) ∨ ¬Pompian (Marcus)

Pompian (Marcus)

loyal (Marcus, Caesar)

¬try assasinate (x,y) ∨ ¬loyal (x,y)

¬try assasinate (Marcus, Caesar)

try assasinate (Marcus, Caesar).

∅

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Q. (1) Everyone passing the exam and winning the lottery is happy
(2) Everyone who studies or lucky passes the exam.
(3) Ram didn't study but he is ~~happy~~ lucky
(4) Everyone who is lucky wins the lottery.
(5) Ram is happy?

Here:

Step 1:

a) ∀x : pass exam (x) ∧ win lottery (x) → happy (x).
b) ∀x : studies (x) ∨ lucky (x) → pass exam (x)
c) ~~¬study (x)~~ ∧ ¬study (Ram) ∧ lucky (Ram) — "lucky" written above ~~happy~~
d) ∀x : lucky (x) → win lottery (x).

Step 2: P = ¬pass exam (x) ∨ ¬win lottery ∨ happy (x)
a) ¬(pass exam (x) ∧ win lottery (x)) ∨ happy (x).
b) ¬ (studies (x) ∨ lucky (x)) ∨ pass exam (x).
c) ¬study (Ram) ∧ lucky (Ram)
d) ¬lucky (x) ∨ win lottery (x).

Step 3:

¬happy (Ram)

¬study (x) ∨ pass exam (x, ~~exam~~) ∧ (¬lucky (x) ∨ pass exam (x)).

b.) i. ¬study (x) ∨ pass exam (x)
ii. ¬lucky (x) ∨ pass exam (x).

c.) i. ¬study (Ram)
ii. lucky (Ram)

Step 4:

$\neg happy(Ram)$

$\neg passexam(x) \vee \neg win\ lottery(x) \vee happy(x)$

$\neg pass\ exam(Ram) \vee \neg win\ lottery(Ram)$

$\neg \cancel{study}$ lucky $(x) \vee pass\ exam(x)$

$\neg win\ lottery(Ram) \vee \neg \cancel{study}$ lucky (Ram)

$\neg lucky(x) \vee win\ lottery(x)$

$\cancel{\neg study(Ram) \vee}\ \neg lucky(Ram)$

$lucky(x)$

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Rules behind deducting System

Forward Chaining:

→ When board on available data, a decision is taken then the process is forward chaining.

→ It is data driven technique.

→ It works from an initial state & reach to goal.

Example:

If a boy is fast & tall then he is a ~~tall~~ sports boy.

Fast (boy) → $\boxed{\text{Sports boy}}$ ← Tall (boy)

Example - 2:

1. It is crime for an American to sell weapons to the enemy of America.
2. Nono is an enemy of America.
3. Nono has some missiles.
4. Missiles are weapon.
5. Colnel is an American
6. All the missiles sold to Nono were by Colnel

∴ Colonel is a criminal.

Step 1: FOPL

1. $American(x) \wedge \cancel{Sell}\ weapon(\cancel{x}) \wedge \cancel{Enemy(y)}\ EnemyofA(y) \wedge sell(x,y,z) \rightarrow criminal(x)$
2. ~~Enemyof(Nono), America)~~ $EnemyofA(Nono)$
3. $\exists x : Missle(x) \wedge has(Nono, x)$
4. ~~Weapon (Missiles)~~ $Missiles(x) \rightarrow wapon(x)$

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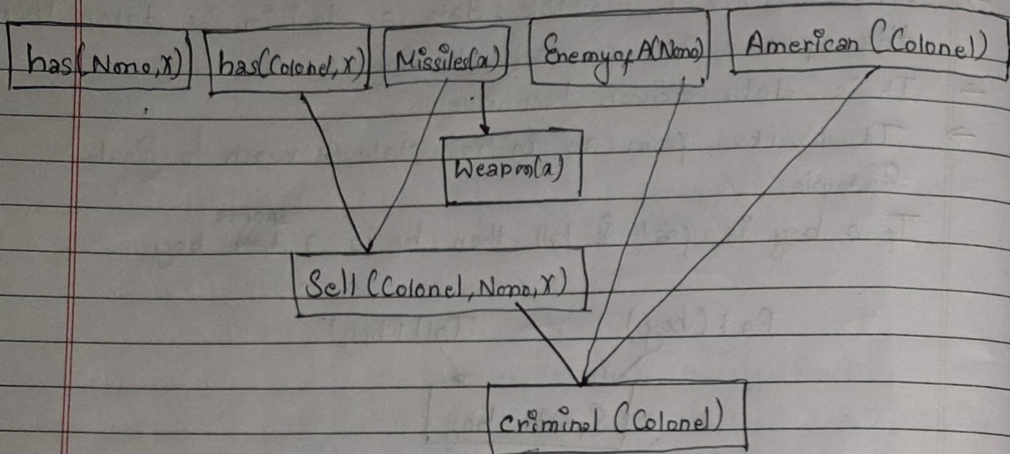
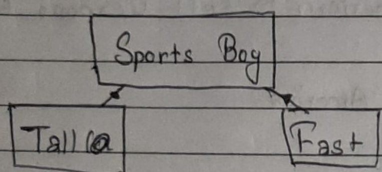
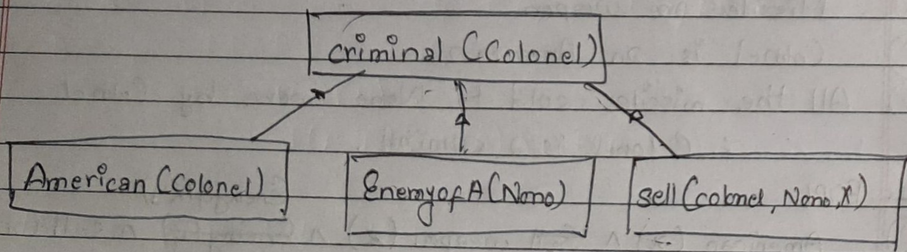
5) American (Colonel)
6) $\forall x$: Missiles$(x) \wedge$ has (Colonel, X) $\rightarrow$ sell (Colonel, Nono, X)



2) Backward Chaining:



$\Rightarrow$



$x = f(b)$

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- It is based on the decision, how the initial state is fetched. It is also called as decision driven or goal driven inference technique.

~~Unity test~~: Unification

- It is all about making the expression look identical so for the given expression to make them look identical we need to do substitution.
- A substitution $\{t_i/V_i\}$ of term t_i in place of variable V_i.

E.g.:

★ $P(x, f(y))$ $\quad$ $P(a, f(g(x)))$

Substitution set: $(a/x,\ g(a)/y)$

★ $Q(a, g(x,a), f(y))$, $Q(a, g(f(b), a), X)$

$f(b) = X$
$X = f(y)$
$b = y$

Substitution set: $(a/a,\ f(b)/x,\ b/y)$

- Horn clause

It is a disjunction of ~~literal~~ premises with atmost one positive premise & all the others are negative.
It is named after Alfred Horn who described it in 1951.

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Statistical Reasoning

- Reasoning is the process by which we use the knowledge & we have to draw conclusion or infer something new about a domain of interest.
- In the logic based approach, we have assumed that everything is either true or false. However, it is often useful to represent the fact that we believe something is probably true with probability 0.5, 0.6
- This is useful for dealing with problem where there is randomness or unpredictability.

Probability theory:

- Simple probability ~~remai~~ with unconditional events i.e. if we know the probability of event A ie $P(A)$ & the probability of event B is $P(B)$ then the probability that both will occur $P(A \cap B) = P(A) \cdot P(B)$

- If two events are intradependent & the outcome of one effects that of other then it is called conditional probability. If $P(A)$ & $P(B/A)$ is given then probability of both occuring is

~~P(A∪B)~~ =

$$P(A \cap B) = P(A) \times P(B/A)$$

Baye's probabilistic theorem

$$P(A \cap B) = P(B) * P(A/B) \quad -- (1)$$

$$P(A \cap B) = P(A) * P(B/A) \quad -- (2)$$

$$P(A) \times P(B/A) = P(B) \times P(A/B)$$

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$$\boxed{P(B/A) = \frac{P(B) * P(A/B)}{P(A)}}$$

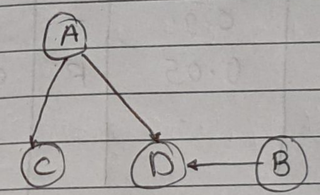
* Bayesian (Belief) Probabilistic inference network

Rules:

I. If node x_i has no parent then its probability is said to be unconditional and it is written as $P(x_i)$ instead of $P(x_i / Parent(x_i))$

II. The nodes having parent are called conditional nodes.

III. If the value of the node is observed then the node is evidence nodes.

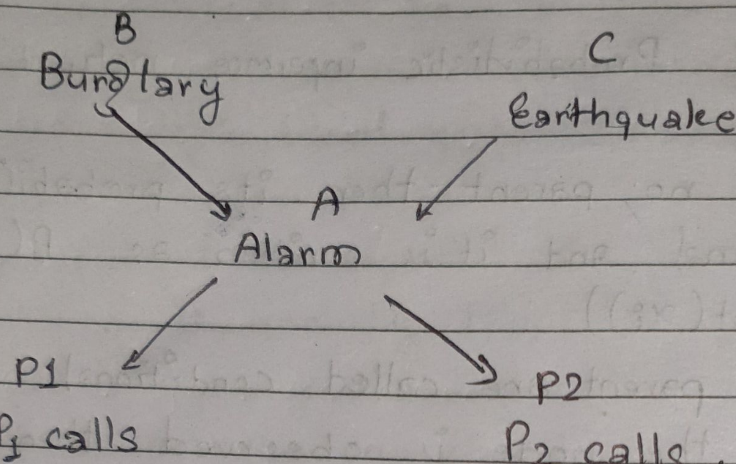


$P(A) = 0.3$
$P(B) = 0.7$
$P(C/A) = 0.4$
$P(C/\sim A) = 0.3$
$P(D/A,B) = 0.7$
$P(D/A,\sim B) = 0.3$
$P(D/\sim A,B) = 0.2$
$P(D/\sim A,\sim B) = 0.01$

All events are true . $P = ?$

$P(A) \times P(B) \times P(C/A) \times P(D/A,B)$.

Event A, B are false but C & D are true,
$= P(\sim A) \times P(\sim B) \times P(C \mid \sim A) \times P(D \mid \sim A, \sim B)$



$P(B=T) = 0.001$	B	E	P(A)	A	$P(P_1 = T)$	A	$P(P_2 = T)$
$P(E=T) = 0.002$	T	T	0.95	T	0.9	T	0.7
	T	F	0.94	F	0.05	F	0.01
	F	T	0.29				
	F	F	0.01				

Probability that P1 & P2 calls when both earthquake & Burglary doesn't occur?
$= P(P_1 \mid A) \times P(P_2 \mid A) \times P(A \mid \sim B, \sim E) \times P(\sim B) \times P(\sim E)$