Chapter 3:
Knowledge and Reasoning

- IMP Chapter
- Min 30 marks from this chapter

Knowledge and Reasoning

- Knowledge and Reasoning are important for artificial agents because they enable successful behavior(i.e correct decision) which is very hard to achieve otherwise.
- Knowledge of action and outcomes enables Problem Solving agent(Goal Based Agent) to perform well in complex environment.
- A knowledge based agent (KBA)can combine general knowledge with current percepts in case of partially visible environment to infer hidden aspects of state and take appropriate action

Knowledge and Reasoning

- **Reasoning/Inferring** is defined as capacity for consciously making sense of things and applying logic for establishing and verifying facts available in Knowledge Base. [CAPACITY TO TAKE DECISSION BASED ON KNOWLEDGE OBTAINED]
- Example : John threw the brick on the window and broke **it** .

Here we know **it** refer to window and not brick, so reasoning allow us to understand and infer correctly.

Explain Wumpus world Environment?

- Wumpus world is an Computer game
- It is a bench mark(performance measure) for intelligent agent
- It consist of cave having connected room
- Inside the cave resides wumpus (beast) who kill anyone entering room but agent can shot wumpus by one arrow he have
- Also the cave has few room with pits to trap agent
- Huge amount of gold is present in one of room so agent enter the cave
- Agent enter the cave to grab the gold without falling into pit or killed by wumpus.

Explain Wumpus world Environment?

- PEAS description

1.Performance measure:

- +1000 for grabbing gold,-1000 for falling in pit or killed by wumpus, -1 for each action(move) and

-10 for using arrow

2.Environment:

- Cave with 4*4 grid of rooms
- Agent enter at(1,1) and there no wampus/pit at (1,1)

Explain Wumpus world Environment?

3.Action/Actuators

- Move forward, Turn right 90 ,turn left 90, grab gold, shot wumpus (using arrow once)

4.Sensors

- Breeze-rooms adjacent to pits
- Stench-room adjacent to wumpus
- Glitter-room with gold
- Scream-wampus dead
- Bump-wall/obstacles

Explain Wumpus world Environment?

- Percept Sequence(Breeze,Stench,Glitter,Scream,Bump)

Grid	Percept Sequence	Finding and inference
(1,1)	(None , none , none , none, none)	**(2,1) and (1,2) are safe to move.**
(2,1)	(Breeze, none,none, none, none)	**(3,1) or (2,2) has pit so turn back to (1,1)**

Explain Wumpus world Environment?

Grid	Percept Sequence	Finding/infer
(1,2)	(None,Stench,none, none, none)	**(1,1) or (1,3) or(2,2) has wumpus but (1,1) is ok and if (2,2) has wumpus then stench must have sense at (2,1) so wumpus is at (1,3) so its safe to move (2,2)**
(2,2)	(None,none,none,none, none)	**(3,2) (2,3) and (1,2) are safe to move hence all direction are safe to move**
(2,3) [SUPPOSE}	(Breeze,Strench,Glitter,none, none)	**Grab the gold and game ends**

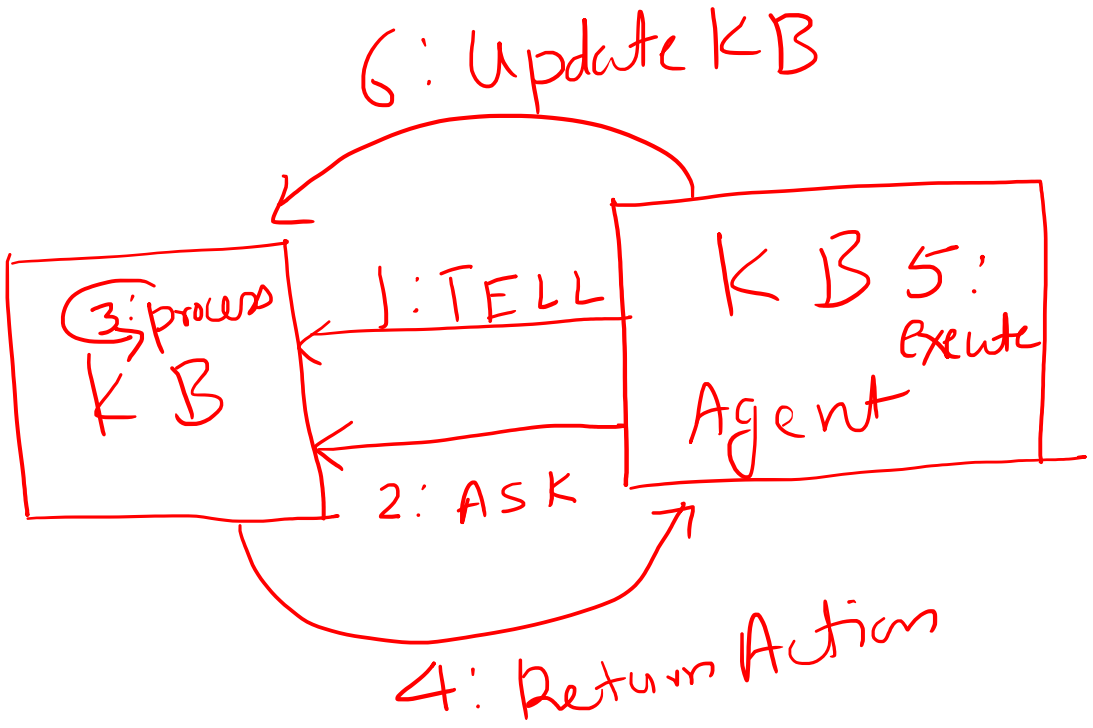
Explain Wumpus world Environment?

- Agent draw a conclusion (inference) from available information(KB) and inference is correct if available information is correct.
- Drawing of conclusion from available information is called LOGICAL REASONING.

What do you mean by knowledge representation & explain construction of Knowledge based agents?(Univ Q)

- In order to solve complex problem in AI one need to have large amount of knowledge and some mechanism for manipulating that knowledge to create solution to new problems
- Knowledge representation deal specify how to present knowledge(facts) in KB so that it can be easily manipulated.
- In other words we want represent facts(truth of real world) in some chosen form(mostly symbols) that can be manipulated by program to infer new knowledge

KB Agent


6: Update KB
3: process KB
1: TELL
KB
5: Execute
Agent
2: ASK
4: Return Action

- The central component of knowledge-based agent is Knowledge-Base or KB.
- A KB is a collection of sentences and each sentence is expressed using Knowledge Representation Language(KRL).
- Each sentence represent some information (assertion) of the world
- KB agent program perform 2 tasks:

1.TELL: It tell the KB about what it perceived using sensor

2.ASK: It ask the KB about the action to be implemented(performed).

- TELL() and ASK() are written using knowledge representation language(KRL)
- KB agent execute TELL using propositional logic or FOL(First order Logic)/prediction logic
- KB agent execute ASK using resolution, forward chaining and backward chaining

Propositional Logic/Simple Logic

- We need a language to represent domain (possible world) facts
- A machine will able to think properly if it is in particular environment and we empower machine with knowledge of that domain/world
- Logic is one such language to represent knowledge in KB
- When we talk of any language it must have well defined syntax (grammar or rules) so inference machine can interpret it and semantics help to understand meaning so inference machine can take decision.

Propositional Logic/Simple Logic

- Syntax are used to represent language
- While Semantics help in determining the truth of sentence w.r.t particular world/model/domain .
- Both syntax and semantics must be well defined
- Example-

--kill(cat , rat)=?

Here above statement is correct in syntax but not in semantically as machine will not able to infer from it so **we need to provide information who is killed by whom.**

Propositional Logic/Simple Logic

- A declarative statement which is either true or false but not both is called statement or proposition in logic.
- Example:

-Amit is Intelligent (Atomic Proposition)→ P

-Amit is Hardworking (Atomic Proposition)→Q

-If Amit is intelligent and Amit is hardworking then Amit top exams (Compound Proposition)

→ [(P ^ Q)->R]

Propositional Logic/Simple Logic

- In logic every atomic statement is represented using symbol
- Every statement consist of object and function
- In our example Amit is an objects while hardworking/intelligent is called function
- So **Intelligent(Amit)**==Amit is intelligent

is true if Amit of which I am talking about is intelligent.

Propositional Logic/Simple Logic

- **Element of propositional logic**

1.A set of propositional symbols (P,Q,R etc) each of which represent atomic statement and can be true or false

2.A set of logical operators[AND(^) , OR(^{V}) ,NOT(~) ,Implication(→) , Bidirectional Implication(<->)]

3.True(T) and False(F) are called logical constant

Note:

A sentence is also called as WFF (Well Formed Formula)

If a KB contain N symbols there will be 2^{N} possible world/inference in all

Propositional Logic/Simple Logic

- If P an Q are 2 statements the truth value of logical operator will be:

P	Q	P^Q	P^{V} Q	P->Q	P<->Q	~p
F	F	F	F	T	T	T
F	T	F	T	T	F	T
T	F	F	T	F	F	F
T	T	T	T	T	T	F

Propositional Logic/Simple Logic

NOTE:

- Implication (→) mean **IF P then Q** is equivalent to (~P ^{V} Q)
- Bidirectional implication (<->) mean IF AND ONLY IF is equivalent to (P→Q ^ Q→P)
- A statement which is always true irrespective of domain is called **Tautology**(P ^{V} ~P) and statement which is always false irrespective of domain is called **contradiction**(P^~P) while a statement which can true or false is called **Contingency**

Equivalent Sentence

1. $P \vee P = P$
2. $P \wedge P = P$
3. $P \vee Q = Q \vee P$ and $P \wedge Q = Q \wedge P$
4. $\sim(P \vee Q) = \sim P \wedge \sim Q$ DeMorgans law
5. $\sim(P \wedge Q) = \sim P \vee \sim Q$ DeMorgans law
6. $P \rightarrow Q = (\sim P \vee Q)$
7. $P <-> Q = (P -> Q) \wedge (Q \rightarrow P) = (\sim P \vee Q) \wedge (\sim Q \vee P)$
8. $\sim(\sim P) = P$

Solve(asked 2times)univq

3. (a) Consider the knowledge base KB that contains the following propositional logic sentences. **10**

$Q \Rightarrow P$

$P \Rightarrow \neg Q$

$Q \vee R$

(i) Construct a Truth table trat shows the truth value of each sentence in KB and indicate the model in which the KB is true.

(ii) Does KB entail R ? Use the definition of entailment to justify your answer.

(iii) Does KB $R \Rightarrow \neg P$ entail ? Extend the truth table and use the definition of entailment to justify your answer.

(iv) Does KB $Q \Rightarrow \neg R$ entail ? Extend truth table and use the definition of entailment to justify your answer.

Advantage of Propositional logic

- It is simple KRL
- It is sufficient and efficient to solve simple AI based problems.
- It forms foundation of FOL.
- The process of Inference can be illustrated by propositional logic i.e Entailment

Drawback of PL

- It cannot express complex AI problem.
- PL is impractical even for small world like Wumpus World Game.
- Complex AI problem if represented using PL its is very wordy and lengthy.
- PL cannot represent relations i.e specialization, generalization etc.
- PL cannot represent properties of entities and relationship between them. etc.Eg: Pooja is tall: cannot be expressed using PL

FOL

- It is more expressive than PL as it can represent information using relations, variables and quantifiers.
- It is also knows as predicate logic.

First Order Logic SET 1

- Write following sentence using FOL

1. All student learning IS are intelligent
2. Everybody likes ice-cream
3. Not all like ice-cream
4. Every dolphin is a mammal
5. Some mammal lay eggs
6. No one like Ice-cream.

Set 2

6. All Indian student are hardworking

7. No indian student is hardworking

8.All student which are not indian are hardworking.

9.There is atleast one city in maharastra which has temple.

10.Everyone like city if it has atleast one temple.

Set 3

11. Every gardener likes sun.

12.You can fool someone at all time

13.All purple mushroom are poisonous.

14.No purple mushroom is poisonous

15There are exactly 2(types) purple mushroom

Set 4

16. Markus was man
17. Markus was Pompeian.
18. All Pompeian are romans.
19. Casear was a ruler
20. All roman were either loyal to Cesaer or hated him

Set 5

21. Everyone is loyal to someone
22. Someone is loyal to everyone
23. Everyone is loyal to everyone
24. People only try to assassinate the ruler if they are not loyal to.
25. All men are created equal

Set 6

26. Every student who takes French passes it
27. No person buy expensive policy
28. Not all student take both history and biology.
29. Only one student failed in history
30. Only one student failed in history and biology

SET 7

31.No one like the professor unless professor is smart

32.Politician can fool some of people all the time

33.They can fool all the people some of time

34.They cant fool all the people all the time

35.There is single barber in town

36 Those and only those who do not shave themselves are shaved by barber

Set 8

37. All men's are mortal.

38. All pompeians died when volcano erupted in 79 AD.

39. No mortal lives longer than 150 years.

40.If someone dies then he is dead at all later times.

41. Everyone who loves all animals is loved by someone.

HW

1. The owner of a car also owns a truck
2. One's mother is one's female parent.
3. Ones's husband is one's male spouse
4. Male and female are different
5. A grandparent is a parent of one's parent.

HW

6. A sibling is another child of ones's parent
7. An apple a day keep doctor away
8. Anyone with two or more wife is a cheater
9. Every chicken hatched from an egg
10. An equilaterial triangle has all sides and angle equivalent

- Consider following facts:-

1. Whoever can read is literate
2. Animals are not literate
3. Some animals are intelligent

Prove using resolution that:

SOMEONE WHO CANT READ IS ALSOINTELLIGENT

Resolution(Solution by Contradiction)

- This is most popular method to find inference /reasoning
- It is based on proof by contradiction i.e Assume exactly opposite what is asked to prove and then prove your assumption is wrong.
- It begin by contradicting the fact to be proved and proceed till KB return NULL or Empty clause
- It need sentence in CNF(Conjuctive normal form)

CNF

- Steps for converting Logical sentence to CNF(Conjunction/conjuctive/casual Normal form)

1 Remove Bicondition

2.Remove implication

3.Move negation inside

4.Do Unification

4.1 Universal Qualifier: Drop it directly

4.2 Existential Qualifier: First replace symbol with constant and drop quantifier

5.No ^ is permitted in CNF

CNF

- Example: P^Q in KB will be stored as 2 true statement as

1>P

2>Q .

Note:

- A facts must be used only once in resolution and its not mandatory that a conclusion will need all the facts.
- If conclusion is broken in more than one part than start with any one part and see all other part appear in resolution tree

Problem on resolution

- Example 1

1.Rimi is hungry

2.If Rimi is hungry she barks

3.If Rimi is barking Raja is angry.

Prove : Raja is angry using resolution

Problem on resolution

Example 2

Consider the following set of facts

1.It is humid

2.If it is humid then it is hot

3.If it is hot and humid then it is rainy season

Prove that:

It is rainy season

Example 3

Consider the following facts:

1.If maid stole the jewelry than butler was not guilty

2.Either maid stole the jewelry or she milked the cow

3.If maid milked the cow then butler got the cream

4.Therfore if butler was guilty then he got the cream

Using resolution prove that conclusion is true i.e 4^{th} fact

- Example 4

1. Ravi likes all kind of food
2. Apples and chicken are food
3. Anything anyone eat and is not killed it is food
4. Ajay eat peanut and is still alive
5. Rita eat everything Ajay eats

Using resolution prove that Ravi likes peanut

Example 5

2. (a) Consider the examples.

(i) If Triangle is equilateral then it is isosceles.

(ii) If Triangle is isosceles then two sides 'A' and 'B' are equal.

(iii) If 'AB' and 'AC' are equal then Angle 'B' and 'C' are equal.

(iv) ABC is an equilateral Triangle.

Prove that angle 'B' is equal to angle 'C' using inferencing techniques of modus ponen and Resolution.

- Example 5

1.If A is on the top B then B supports A

2.If A is above B and they are touching each other then A is on top of B

3.A cup is above the book

4.Cup is touching book,

Prove that **book support cup using resolution.**

Example 6

- Anyone in VIT knows someone who has bunk the class
- If a person has bunk a class, he has done something wrong
- If one has done something wrong then he cant be perfect.
- Amit is in VIT
- Only human are imperfect
- Anyone Manish knows is non-human

Using resolution prove that **Manish is not in VIT**

- Example 7:

1 Steve only likes easy courses.

2.Science Courses are hard

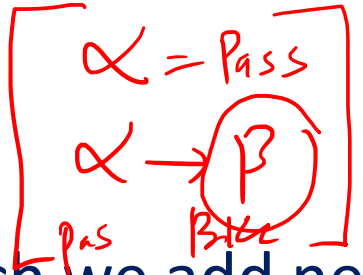
3.All the courses in Basket Wieving Department are easy.

4.BK301 is basket weaving course.

Use resolution to answer the question: “What courses Steve like”?

Reasoning : Type of Inference Technique

- The inference technique that uses only rules to draw inference is called reasoning.
- Reasoning is also called chaining.
- They are of two types



1:Forward chaining : It is a process in which we add new sentences(facts) in KB this help KB to generate new conclusion that in turn give new inference(results/finding).{Use Modes Ponen in forward direction}

2.Backward chaining : It is a process where we want to prove something(goal) so we use facts available in KB to get conclusion(results)).{Use Modes Ponen in backward direction}

Forward Chaining

- In this we start with atomic sentences in KB and apply **Modus Ponens** in forward direction and we add new atomic sentences so new inference can be made i.e new facts can be discovered.
- It is used to add new facts to KB
- To apply forward chaining each sentence in KB must be **Horn sentence**(i.e each sentence must be atomic or an implication with conjunction of atomic sentence at LHS and single atom sentence at RHS)

$\alpha \vee \beta X \quad \alpha ; \alpha \rightarrow \beta ; \alpha \wedge \beta \rightarrow \gamma$

Forward chaining

- Forward chaining requires **unification** of two similar sentences by substitution of variables.

Example: **knows(John,x)** is a sentence and KB contain sentence as **knows(John,Jane)** then **UNIFY(knows(John,x),knows(John,Jane))={x/Jane}**

- Forward chaining is normally triggered by the addition of new facts(premise(P)) to KB, the idea here is to find all implication that have P as premise and if other premise hold true then we add consequence of implication to KB i.e consequence is true.

Forward chaining

Example:

1. The law says that it is a crime for America to sell weapons to hostile(unfriendly) nations. The country Nono an enemy of America and own some missiles and all its missiles are sold by Colonel West ,who is American . ***Prove that colonel West is an criminal.***

Solution:

Step1: Present sentence in Horn form in KB

1.American(x) ^ weapon(y) ^nation(z)^hostile(z) ^sell(x,y,z)→criminal(x). // rule

2.own(Nono, x)^ Missile(x)→sell(West,x,Nono).//rule

3.Missile(x)→weapon(x).// rule

4.Enemy(x,America)→Hostile(x). // rule

5. American(West) //fact

6. Nation(Nono)) // fact

7. Enemy(Nono,America) //fact

8.own(Nono,m1) // fact

9. Missile(M1)) // fact

Forward chaining

Step 2: **Add atomic sentence one by one to KB do forward chaining each time and add additional facts generated.**

1.FORWARD-CHAIN(KB, American(West)):It unifies premise 1 but no new Inference drawn as other premise are unknown.

2.FORWARD-CHAIN(KB, Nation(Nono)):It unifies premise 1 but no new Inference drawn as other premise are unknown.

3.FORWARD-CHAIN(KB, Enemy(Nono,America)): It unifies premise 4 with unifier{x/Nono} and generate a new inference as "**Nono is enemy and hostile to America**"

4.FORWARD-CHAIN(KB, Owns(Nono,M1)):It unifies premise 2 with unifier{x/M1} but no new Inference drawn as other premise are unknown.

5. FORWARD-CHAIN(KB, Missile(M1)):It unifies premise 2 and 3 and draw new Inference as **“Colonel West sells M1 to Nono”. and ”M1 is a weapon”**

6. Now since all premise of sentence 1 are known/true so using forward chaining we can prove that “Colonel West is Criminal”.

Backward Chaining(Univ Q)

- This algorithm works in backward direction(i.e from the goal state) and make use of facts in KB to prove the the goal(conclusion)
- It use Modus Ponens in backward direction(**from conclusion we derive premises**).
- It is used to find condition that will fulfill the goal
- It proceed by analyzing(unify) the premise of Horn sentence and if premise are true then conclusion is also true.

Example1: On backward chaining

1. Ravi likes all kind of food
2. Apples and chicken are food
3. Anything anyone eat and is not killed it is food
4. Ajay eat peanut and is still alive

Using Backward chaining prove that Ravi likes peanut ?

Example 02

1. If triangle is equilateral then it is Isosceles.

2. If triangle is Isosceles then its two sides ‘A’ and ‘B’ are equal. (In general)

3.If side ‘AB’ and ‘AC’ are equal then angle ‘B’ and ‘C’ are equal. (specific)

4. ABC is an equilateral triangle.

PROVE ‘ANGLE B is EQUAL TO ANGLE C’ using Inference technique of Modus Ponens & Resolution.

Backward chaining:

Note:

- In backward reasoning we start with goal state(to be proved) and at each step we match the current state with RHS and if matches we replace current state with LHS with appropriate binding of variables to constant.
- All sentence cannot be converted to horn clause (eg: A V B)

- Chapter 03 Completed