INDRAPRASTHA INSTITUTE *of*
INFORMATION TECHNOLOGY **DELHI**

CSE643 – Artificial Intelligence

Monsoon 2022 session

Midsem exam

Max marks: 50 (will be scaled down to 25 marks)   18-Oct-22   3:00 PM to 5:00 PM

INSTRUCTIONS:

1. **Laptops, mobiles, ipads and notebooks are not allowed. Closed book quiz.**
2. **Ensure that in the answer sheet you write your name and roll number clearly. If you have additional sheets then write your name and roll number on that too. Tie up the answer sheets or put one inside the other and mention number of additional answer sheets. Submit the hard-copy answer sheets to the TAs by 5PM.**

Q1: There are two parts to this question (10 marks)

i) Express the following in FOPL.
   (a) House of A is above house of C, D's house is on E's floor and above F's house, B's house is below C.
   (b) House of A is green while house of C is not.
   (c) Every house is on some floor.
   (d) Every house that is free has nothing on it.
   (e) Every house that is green is free.
   (f) There is some house that is red and is not free.
   (g) Every house that is not green and is above house of B, is red.

ii) Express the above in CNF. Then use resolution refutation (draw the graph) and determine whether house of C is free or not free.

Answers for Q1: Predicates used:

house(x) – house of x

above(x, y) – for house of x is above house of y

green(x) – house of x is green

red(x) – house of x is red

floor(x, z) – house of x is on floor z

free(x) – house of x is free

i)

(a) house(A)^ house(C)^ above(A, C) ^ house(D) ^ house(E) ^ ((∀x) floor(D,x) → floor(E,x)) ^ above(D,F) ^ above(E,F) ^ house(B) ^ house(C) ^ above(C,B).
(b) green(A) ^ ¬green(C).
(c) ∀(x) (house(x) → ∃(y) floor(x, y)).
(d) ∀(x) (house(x) ^ free(x) → ¬∃(y)(above(y, x))).
(e) ∀(x) (house(x) ^ green(x) → free(x)).
(f) ∃(x) (house(x) ^ red(x) ^ ¬free(x)).
(g) ∀(x) (house(x) ^ ¬green(x) ^ above(x, B) → red(x)).

ii) CNF for the above.

1) house(A)
2) house(C)
3) above(A,C).
4) house(D).
5) house(E).
6) (∀(x) floor(D, x) → floor(E, x)) ≡ ¬floor(D, x) v floor(E, x).
7) above(D,F).
8) above(E,F).
9) house(B).
10) house(C).
11) above(C,B).
12) green(A).
13) ¬green(C).
14) ∀(p) (house(p) → floor(p, fl(p))). ≡ ¬house(p) v floor(p, fl(p)) -- (Skolem function fl(p) for existentially quantified y)
15) ¬house(q) v ¬free(q) v ¬above(y, q). -- (moving negation inside so (¬∃) becomes (∀))
16) ¬house(r) v ¬green(r) v free(r)
17) house(s) ^ red(s) ^ ¬free(s).
18) ¬house(t) ^ green(t) ^ ¬above(t,B) v red(t)

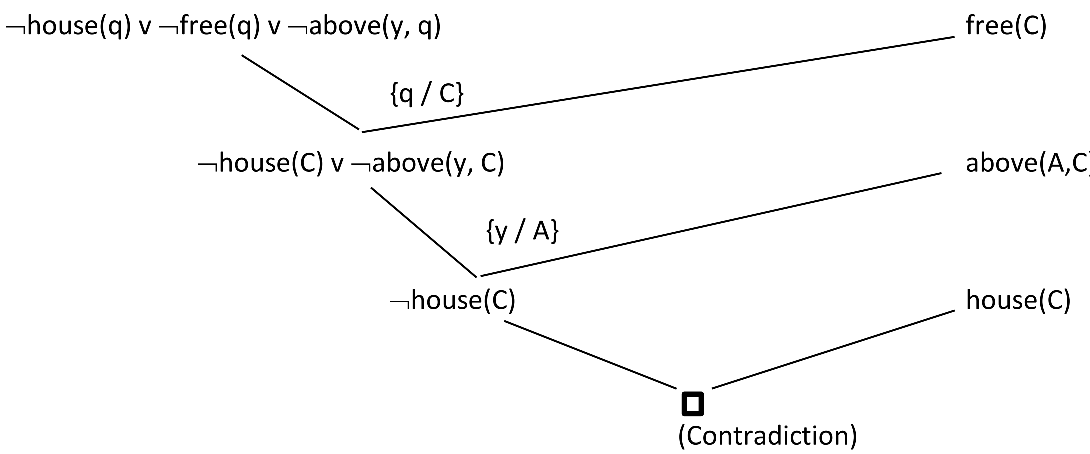
Verify Hypothesis by Refutation

We want to prove that house of C is not free. So we take its refutation and try to prove that house of C is free, i.e. we try to prove free(C).

19) We have free(C).
20) (19) and (15) unify and resolve to give ¬house(C) v ¬above(y, C).

21) (20) and (3) unify and resolve to give ¬house(C)
22) (21) and (2) gives rise to a contradiction and so our hypothesis is false. Therefore, house of C is not free.

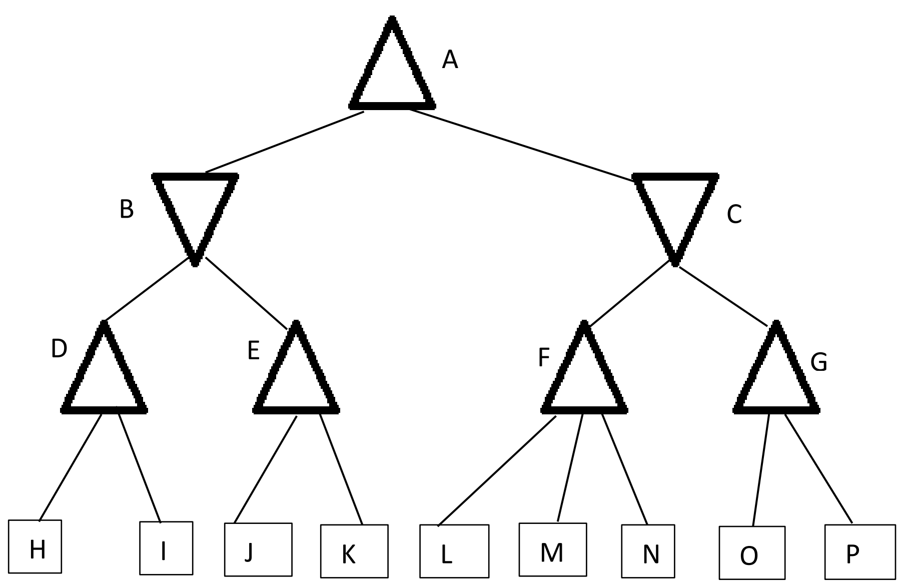
Resolution Graph



Q2: In the following 2-player game the upright triangles are the max nodes while the inverted triangles are the min nodes, and the square boxes (leaf nodes) are the utility nodes. (5 marks)

i) Determine the values for all max and min nodes for the following utility value assignments:
   a. H = 5; I = 3; J = -1; K = -2; L = -5; M = -2; N = 7; O = -7; P = -6
   b. H = 2; I = 3; J = 12; K = 12; L = 7; M = 8; N = 10; O = 9; P = 8

ii) Identify branches that will be pruned by alpha-beta pruning in both (a) and (b). Justify.



Answers for Q2:

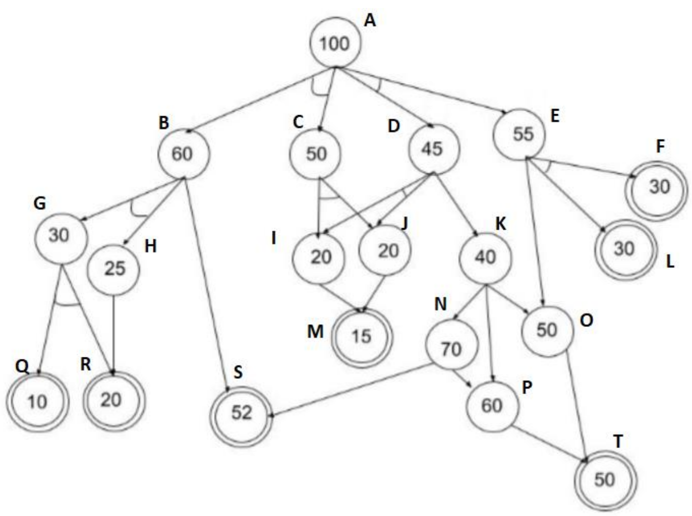
i) a) D=5, E= -1; F=7; G=-6; B= -1; C= -6; A= -1

b) D=3; E=12; F=10; G=9; B= 3; C=9; A=9

ii) A) No nodes are pruned as alpha (MAX's highest value) ≤ beta (MIN's lowest value) in all the nodes.

b) 3rd and 4th leaf nodes (i.e. J and K) and node E are pruned. Because B is a MIN node and we have D=3, and thus will set beta = 3, so whatever beta is chosen by MIN node from E has to ≤ 3. Since alpha value from J = 12, we have alpha ≥ beta and this nodes E, J, K can be pruned. Further, since alpha value from C = 9 which is ≥ B = 3, MAX will choose C rather than B, and thus we need not check on leaf nodes J and K.

Q3: In the AND-OR graph given below find the value of the root node for the optimal solution for the graph. Note that the *values given inside all single circle* nodes is the *estimate of the cost* or the heuristic value, while the *value given inside all double circle nodes* is the *actual value of the SOLVED node*. The cost of each edge is 10 units. Show all your steps for computation. (5 marks)



Answer for Q3

Starting from Solved nodes we compute the value of intermediate nodes for optimal solution as follows:

i) O=60, E (from F,L since it is AND node) = 30+30+10+10 = 80, E (from O since it is OR node) = 60+10 = 70, thus min cost of E = 70.

ii) N = min (path from P, path from S) = min(70, 72) = 70, K = min(path from O, P, N) = min(70, 70, 70) = 70. D = min(K, (J,K)) = min(70, (35+35)) = 70, C = 70.

iii) H = 30, G = 30+20 = 50, B= min(path from S, (G,H)) = min(62, (80))=62, A = min(path from (B,C), path from (D,E)) = min((152), (160)) = 152.

iv) Thus A = 152 and gives the optimal solution as A-B-C-S-I-J-M

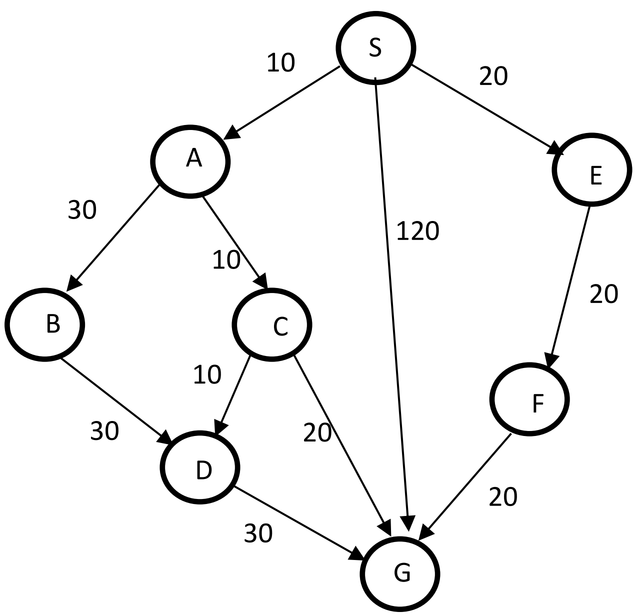
Q4: Explain using formal notations what it means for a statement to be valid in propositional logic.

(2 marks)

Answer for Q4

A statement s in a given knowledge base KB is evaluated in propositional logic to determine its truth value {**T** or **F**}. An interpretation i for propositional logic is a mapping assigning a truth value to each of the simple sentences of the given knowledge base KB. A statement s is satisfied for an interpretation i if and only if for that interpretation i the statement s evaluates as true **T**. A sentence s is *valid* in propositional logic if and only if it is *satisfied* by every interpretation i belonging to the set of all possible interpretations I in a domain D. The interpretations I are a set of possible truth assignments to the propositional variables that represent the given sentences.

Q5: Assume the following search graph is given. The actual path cost is given with the nodes. However, when we start traversing the graph from node S we do not know those costs upfront (and discover them when we traverse from one node to another) and go by heuristics. (5 marks)



Let us assume we have to choose between the following three heuristic functions, h1, h2 and h3. The values of the heuristics between each node is given in the table below. Determine whether each of the heuristics are admissible and consistent. Justify the answers.

State	**h1(s)**	**h2(s)**	**h3(s)**
S	30	20	20
A	30	20	20

B	50	50	50
C	20	30	20
D	20	20	10
E	10	20	10
F	10	10	10
G	0	0	0

Answers for Q5:

A heuristic h(n) is admissible if, for every node n, it underestimates the cost to the goal, that is $h(n) \leq h^*(n)$; basically a lower bound on $h^*(n)$, where $h^*(n)$ is the cost of the optimal path to the goal.

A heuristic h(n) is consistent if, for every node n and every successor n' of n, the estimated cost of reaching the goal from n is no greater that the step cost of getting to n' plus the estimated cost of reaching the goal from n', i.e. $h(n) \leq c(n, n') + h(n')$.

i) Heuristic h1 is admissible and consistent. Justification: Cost of optimal path from S to G: 40, A to G: 30, B to G: 60, C to G: 20, D to G: 30, E to G: 40, F to G: 20. We can see all h1(s) ≤ cost of optimal path. So h1(s) is admissible. Similarly we can see that S to G: 40 ≤ (10+30) and ≤ (20+10); A to G: 30 ≤ (10+20) and ≤ (30+50); B to G ≤ (30+20); C to G: 20 ≤ (20) and ≤ (10+20); E to G: 10 ≤ 40; F to G: 10 ≤ 20. Thus, h1(s) is consistent.

ii) Heuristic h2 is neither admissible nor consistent: since C to G: 20 but h2(s) is 30, so is not admissible. Similarly, for C to G: 30 ≥ 20 (optimal cost), thus h2(s) is not consistent either.

iii) Heuristic h3 is admissible. We can see admissibility but it is not consistent since h3(B): 50 ≥ (30+10). Thus, h3(s) it is not consistent.

Q6: This question has two parts. (4 marks)

i) Given the propositional rule $A \rightarrow B$ and given proposition B can we conclude A? Is this conclusion sound? If yes, explain why with an example. And if no, explain why with an example.

ii) Given the following propositions: A, B, C, D, ¬E, F, ¬G determine the truth value of the following sentences:

$$E1: B \land D \land (C \land E \rightarrow F)$$
$$E2: C \land E \land (B \land D \rightarrow G)$$

Answer for Q6

i) No, we cannot conclude A. If we conclude A it won't be sound. Since $A \rightarrow B$ reduces to $\neg A \lor B$ and we are given B then if we try to resolve and prove A, we are unable to prove A. Thus, we cannot say about A. We note that A may be TRUE or FALSE, so A cannot be concluded. For example, given the sentence S: If it is rainy then you cannot go for a picnic. And given "you cannot go for a picnic" then you cannot derive that "it is rainy". The sentence S is however TRUE since "you cannot go for a picnic" is TRUE.

ii)

a. E1 evaluates to TRUE as $C \wedge E \rightarrow F$ is equivalent to $(\neg C \vee \neg E \vee F)$ and since $\neg E$ and F is given then this evaluates to TRUE and since B and D are given then E1 evaluates to TRUE.
b. E2 evaluates to FALSE since $(B \wedge D \rightarrow G)$ is equivalent to $(\neg B \vee \neg D \vee G)$. Here G is FALSE as $\neg G$ is given and since B and D are TRUE this evaluates to FALSE. Further since $\neg E$ is given then E2 will evaluate to FALSE. Thus, E2 evaluates to FALSE.

Q7: An airline wants to schedule pilots for its flights. All pilots can fly for a maximum of 8 hours in a day. A junior co-pilot needs a senior pilot scheduled in the same flight. Pilots need to have a license for the aircraft they are flying. No pilot can operate more than 1 flight a day. Formulate this as a CSP problem and write the constraints in FOPL. (9 marks)

Answers for Q7

Variables

{Pilots, PilotLevel, FlightFlyingTime, FlightNum, FlightNumAircraftType, PilotLicenseAircraftType, PilotOperatedFlightInADay}

Domain

$D_{Pilot} = \{P_1, P_2, \ldots, P_n\}$

$D_{PilotLevel} = \{Senior, Junior\}$

$D_{FlightFlyingTime} = \{F_{1t}, F_{2t}, \ldots, F_{mt}\}$

$D_{FlightNum} = \{F_1, F_2, \ldots, F_m\}$

$D_{FlightNumAircraftType} = \{Ft_1, Ft_2, \ldots, Ft_k\}$

$D_{PilotLicenseAircraftType} = \{Pt_{xz}\}$

$D_{PilotOperatedFlightInADay} = \{Fo_{xy}\}$

Constraints (note these are not logical statements but constraints)

No pilot can operate more than 1 flight a day.

$C1 = \{ \forall x \forall y: P_x \wedge (|Fo_{xy}| \leq 1) \}$

All pilots can fly a maximum of 8 hours in a day

$$C2 = \{ \forall x\ \forall y\ \forall t: P_x \wedge F_y \wedge (|Fo_{xy}| > 0) \wedge (F_{yt} \leq 8) \}$$

Pilots need to have a license for the aircraft they are flying

$$C3 = \{ \forall x\ \forall y\ \forall z: P_x \wedge F_y \wedge (|Fo_{xy}| > 0) \wedge (Ft_z = Pt_{xz}) \}$$

A junior co-pilot needs a senior pilot scheduled in the same flight.

$$C4 = \{ \forall x\ \forall y\ \forall z: P_x \wedge P_y \wedge F_z \wedge (|Fo_{xz}| > 0) \wedge (|Fo_{yz}| > 0) \wedge (PilotLevel_x \ddagger PilotLevel_y) \}$$

Q8: You have to design an AI system to evaluate and approve house-loan applications. Assume the knowledge of government and banking regulations is given below. Now using the concepts you have learnt so far, represent this knowledge using rule-based reasoning and show where forward-chaining and backward-chaining can occur. (10 marks)

General guidelines for lenders and borrowers: As per RBI guidelines, lenders may approve home loan applications of borrowers who meet the eligibility criteria, can display their repayment capacity and have a CIBIL or credit score of 750 and above. Lenders must also ensure that borrowers submit all the necessary documents including personal and income documents and those who have ability to meet loan repayment rules laid down by lenders.

Guidelines on loan to value ratio: As per the new rules and regulations for home loans in India, Borrowers may avail a loan amount of 90% of the actual value of the property (LTV) if the property is valued at Rs 30 lakhs or less. In case of loan amounts exceeding Rs 30 lakhs but up to Rs 75 lakhs, the maximum LTV ratio can be 80%. In case an individual decides to purchase a home valued at Rs 75 lakhs and above by taking out a home loan, then the maximum LTV can be 75%.

Guidelines on loan repayment rules: Loan repayment will have a principal component of 2% and an interest component of 8% of the remaining principal amount. Monthly repayment should be capped to a maximum of 30% of salary / earnings received.

Guidelines on prepayment charges: Home loans are typically high value loans that last for durations lasting from 10 to 30 years and borrowers must pay an interest rate on the principal loan amount. The interest component is generally a huge amount but this can be significantly reduced if one is able to prepay the loan, partially or completely before the chosen loan tenure.

As per the latest rules and regulations on home loans, the RBI waived of the prepayment charges. Lenders are prohibited from charging a prepayment penalty for home loan prepayments in case of floating interest rates.

Answer for Q8

Rule1: If Borrower is eligible and Borrower-displays-repayment-capacity and has a CIBIL or credit score ≥ 750 then approve home loan and Loan-taken is TRUE.

Rule 2: If Borrower submits all the necessary documents including personal and income documents and has ability to meet loan repayment rules then Borrower is eligible.

Rule 3: If the Value-of-Property ≤ Rs 30 lakhs then Maximum-loan-amount (LTV) = 90% of the actual value of the property.

Rule 4: If the Value-of-Property > Rs 30 lakhs and ≤ Rs 75 lakhs then the Maximum-loan-amount (LTV) = 80% of the actual value of the property.

Rule 5: If the Value-of-Property > Rs 75 lakhs then the Maximum-loan-amount (LTV) = 75% of the actual value of the property.

Rule 6: If Loan-taken then Loan-repayment = (0.02 * PrincipalComponent + 0.08 * (PrincipalComponent – 0.02 * PrincipalComponent) and Borrower-displays-repayment-capacity.

Rule 7: If Loan-repayment > (0.3* salary-earnings) then Loan-repayment = (0.3 * salary-earnings)

Rule 8: If Loan-taken and (loan duration ≥ 10 years and ≤ 30 years) and Borrower-displays-repayment-capacity then borrower must pay PrincipalComponent and InterestComponent of loan amount.

Rule 9: If Loan-taken then borrower can prepay loan and prepayment-penalty = 0.

Backward-chaining:

Rule 1 backward-chains to Rule 2 to determine if borrower is eligible.

Rule 1 backward-chains to Rule 6 to determine if borrower displays repayment capacity.

Rule 8 backward-chains to Rule 6.

Forward-chaining:

Rule 3, 4, 5 are forward-chaining to set LTV based on property value.

Rule 7 is forward-chaining rule as it puts a cap on loan-repayment whenever it exceeds 30% of salary or earnings.

Rule 9 is a forward-chaining rule.