

QUESTIONS

1) LOGIC (25 pts)

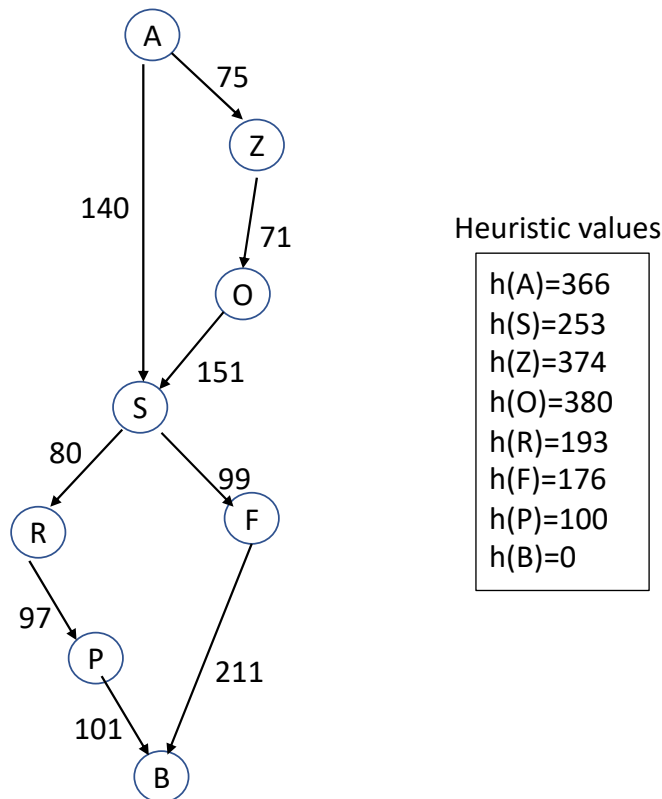
1. Show, using a truth table, that $\neg a \rightarrow (b \rightarrow c)$ and $b \rightarrow (a \vee c)$ are logically equivalent. Is $\neg a \rightarrow (b \rightarrow c)$ valid or satisfiable?
2. Prove that $A \Leftrightarrow B$ is logically equivalent to $A \vee B \Rightarrow A \wedge B$. Use Standard logical equivalence rules here, not the truth table method.
3. Translate the following English sentences into logical representations
 - i. A niece is a sibling's daughter
 - ii. Anette has at most two umbrellas.
 - iii. At least one professor teaches both "Experts in Team" course and an AI course.
4. Convert the following sentence into Conjunctive normal form (CNF). Show every step of the process and write the name of the operation used in the step, e.g., "Eliminate existential quantification".
 - i. $\forall x (R(x) \rightarrow (\forall y (R(y) \rightarrow R(f(x,y)))) \wedge \neg \forall y (S(x,y) \rightarrow P(y)))$
5. Given the following sentences:
 - 1) $\forall x,y (\text{Father}(x,y) \rightarrow \neg \text{Woman}(x))$
 - 2) $\forall x,y (\text{Mother}(x,y) \rightarrow \text{Woman}(x))$
 - 3) $\text{Mother}(\text{Sophie}, \text{April})$

Find out if Sophie is not the father of Edgar, using proof by contradiction (resolution refutation). That is, the question is: Is $\neg \text{Father}(\text{Sophie}, \text{Edgar})$ true?

The first resolution shall be done on the first and second sentences above. Any other solution that does not start with resolving 1 and 2 will not be given any points. Show every operation you have done on/with the sentences, skolemization, standardizing apart, substitution/unification, and the like you may need to do.

2) SEARCH (25 pts)

A search problem is represented in the following figure where A is the start and B is the goal node. Costs are shown on the edges while heuristic values for the nodes are shown in the box to the right. In this question solve ties by using left to right ordering, e.g., if there is a tie between R and F in the graph in the figure, then choose R.



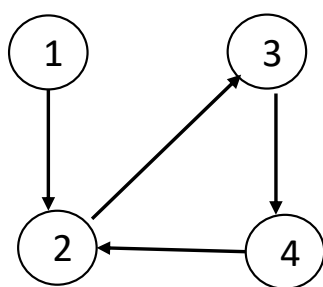
- 1) Write down the expanded nodes in the order they are expanded when Breadth First search algorithm for graph search is applied. Write down the nodes in the frontier at each step. What is the returned solution? Is the solution optimal? Is that expected? Very briefly explain your answer.
- 2) Write down the expanded nodes in the order they are expanded when Depth First search algorithm for graph search is applied. Write down the nodes in the frontier at each step. What is the returned solution? Is it optimal? Is this expected? Very briefly explain your answer.
- 3) Write down the expanded nodes in the order they are expanded when uniform cost search algorithm for graph search is applied. Write down the nodes in the frontier at each step. What is the returned solution? Is it optimal? Is this expected? Explain very briefly your answer.
- 4) A* graph search algorithm:
 - a) What is the condition to guarantee that A* search algorithm returns a cost-optimal solution for graph search.
 - b) Is $h(n)$ for all nodes n in the graph admissible? If not, write which are not.
 - c) What would the A* algorithm for graph search return as solution? Write down the nodes in the frontier at each step. Write down the expanded nodes in the order they are expanded. Is the solution cost-optimal? Briefly explain your answer.

- d) What would the same A* algorithm return for $h(R) = 227$ instead of 193? Is $h(R)$ admissible now? What is the returned solution? Is it cost-optimal?
- e) Is your answer in 4 d) inconsistent/contradicts with your answer in 4 a)? Elaborate on your answer and provide a description of the relationship between admissibility and cost-optimality for A* search algorithm that covers and explains the situation above.

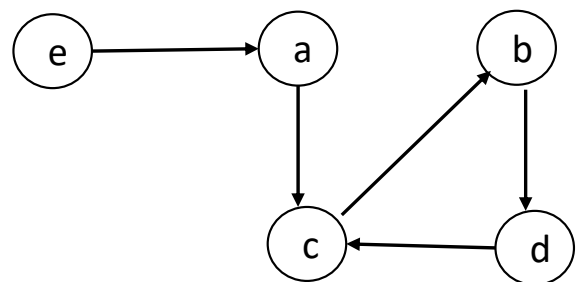
3) CSP (10 pts)

Your task is to compare two given graphs and decide whether one contains a copy of the other. Two graphs G1 (where nodes are named using integer numbers) and G2 (where nodes are referred to in terms of the letters of the alphabet), shown in the figure, are given. You will solve this as a constraint satisfaction problem (CSP) and find out if there is a copy of graph G1 in graph G2. «Copy» here means that the same number of nodes with the same connections between them. In other words, you will match these two graphs.

You can use the node-names of G1 (shown in the figure as 1,2,3,4) in the variable names, i.e., x_1, \dots, x_4 . Regarding the constraints, there is one global “all different”, i.e., AllDiff, constraint expressing that all the variables will have a different value, and four local constraints, each representing the constraints on an edge (arc) in G1, e.g., between node 1 and node 2.



G1



G2

- 1) Write down the variables (i.e., $X = \{x_1, x_2, x_3, x_4\}$) and the domain of each variable (e.g., $D(x_1) = \{\dots\}$)
- 2) Write down the constraints required for the mapping between the two graphs. Represent the constraints as explicit lists of allowed values for edges in the form of $\{(x_i - v, x_j - v'), \dots\}$ where the entry $(x_i - v, x_j - v')$ means that

(x_i, x_j) is an edge in G_1 , and there is an edge (v, v') in G_2 . That is, it is legal that variable x_i in G_1 has value v (from G_2) when variable x_j in G_1 has label v' (From G_2) whenever (x_i, x_j) is an edge in G_1 and (v, v') is an edge in G_2 .

- 3) Use backtracking search with forward checking to solve this CSP problem. Draw the search tree. The order of variable assignment is in numerical order, i.e., 1,2,3,4 while the assignment of values is in opposite/reverse alphabetical order. That is, you start with the assignment x_1 = the last letter in alphabetical order in the domain of x_1 .

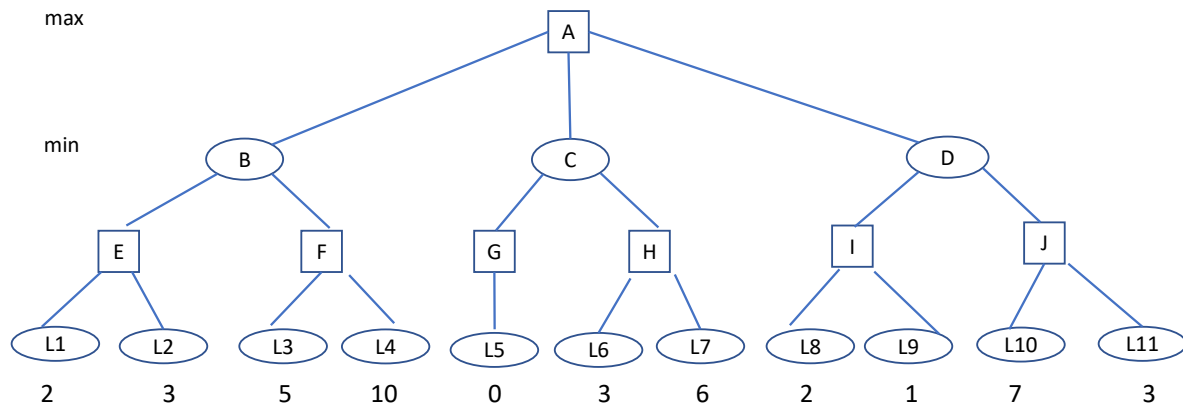
4) PLANNING (10 pts)

- 1) In what way are Partial Order Planning (PoP) process and the resulting plans different from the ones in the progressive and regressive planning? In what situations is it suitable and attractive to use PoP?
- 2) Assume you are going to a Christmas party tonight and you want to put on some jewellery, more specifically a gold ring on each of your pointing finger. It is cold outside and you need to put on gloves as well. Naturally, you need to put on the rings before you put on gloves. You will use a partial order planner to make a plan. You have these action: RightGlove (means put on a glove on your right hand), LeftGlove, RightRing (put on a ring on your right hand), and LeftRing. You will use partial order planning to generate a plan.
 - a. Write the required action schemas in the PDDL language.
 - b. Draw the partial plan with the dependencies between the actions.
 - c. Write down the plan. Use this notation: Action-1; (Action2, Action 3)... which means that Action-1 is followed by either Action2 or Action3 in the plan.

5) ADVERSARIAL SEARCH (10 pts)

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- 1) Apply minimax algorithm on the tree in the given figure and find the values of all the nodes above the leaf nodes. Write down the values of nodes A-J. What is the value of the solution for the agent *max*?



- 2) Apply alpha-beta pruning algorithm to find nodes can be pruned. Write down the names of the nodes (i.e., the letters in the squares and ellipses), either leaves or the nodes of which all children are pruned. For example if $L3$ and $L4$ are both pruned then it is sufficient to write node F only. Give the reason why each pruned node is pruned, by referring to alpha and beta values

6) SHORT-QUESTIONS (20 pts)

- 1) Game theory: Does the payoff matrix in the given figure represent an instance of the Prisoner Dilemma game? Explain your answer - why is it, or why is it not.

	Coop	Defect
Coop	4,4	-1,8
Defect	8,-1	2,2

- 2) Knowledge Representation

- a. What are the three ways to represent states and transitions between them? Describe each of them very briefly and describe what kinds of tasks (e.g., planning, or classical search task) we used each of them in this course.

- b. What are semantic networks capable of representing? What kind of reasoning mechanism/methods do they rely on?
- 3) AI-Ethics: What kind of connection can you make between P of PEAS (in Chapter 2) and ethical issues in AI? This is an open question which needs you to support your answer with arguments. In other words, explain your answer – concisely.
- 4) Environment type: Assume a human agent is collecting beautiful, rare orchids in the rain forest. They suddenly notice that some birds are following them and pick the orchids just when the agent reaches to the orchids. Is this a deterministic, stochastic or strategic environment? Explain your answer.