1. (9 points) Consider the search problem of finding a path in the following directed graph from the start node $A$ to the goal node $G$. The number above each node is its heuristic value (e.g., $h(A) = 2$) and the number above the edge is the transition cost (e.g., $cost(C, D) = 3$). This question refers to generic tree search which is reproduced below, where a node is considered *expanded* when it is taken off the frontier and examined.

```
function TREE-SEARCH(problem) returns a solution, or failure
  initialize the frontier using the initial state of problem
  loop do
    if the frontier is empty then return failure
    choose a leaf node and remove it from the frontier
    if the node contains a goal state then return the corresponding solution
    expand the chosen node, adding the resulting nodes to the frontier
```

(a) The graph in Figure 1 below is searched with a variant of the tree search A*, which is identical to tree search A*, except that if the search visits a node $n$ that has already been expanded, it immediately skips $n$ instead of checking if it needs to reinsert $n$ in the frontier. Write the path found by this algorithm and indicate if the path is optimal. Draw the search tree (rooted at the start node) resulting from this algorithm and write the $f$-values next to each node. Provide the list of nodes expanded by the algorithm ordered from the first to last.

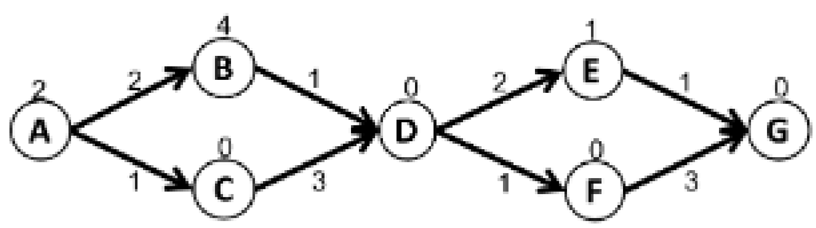


Figure 1:

(b) The graph in Figure 1 is searched with a variant of the tree search A*, which is identical to tree search A*, except that it declares completion when it first visits the goal node $G$ (instead of waiting for it to be expanded). Write the path found by this algorithm and indicate if the path is optimal. Draw the search tree (rooted at the start node) resulting from this algorithm and write the $f$-values next to each node. Provide the list of nodes expanded by the algorithm ordered from the first to last.

(c) The variant of tree search A* introduced in part (a) is used for search in the graph below in Figure 2. Write the path found by this algorithm on the new graph and indicate if the path is optimal. Explain the difference (if any) in the behavior of the search in parts (a) and (c).

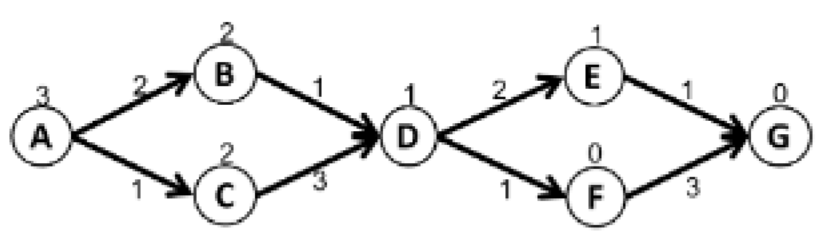


Figure 2:

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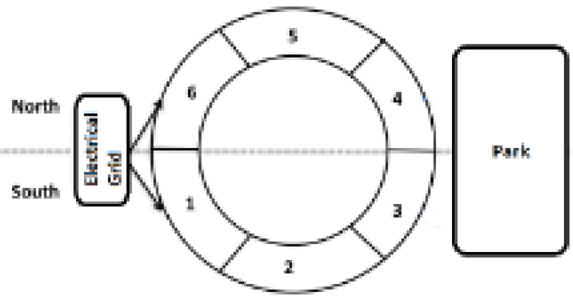
2. (10 points) A company is allocating offices to various departments in its circular-shaped building (figure below). The building has six offices, labeled 1 through 6, and six departments: Legal (L), Maps Team (M), Prototyping (P), Engineering (E), Technology-Head's office (T) and Storage (S). Offices can be *next to* one another, if they share a wall (for an instance, Offices 1-6). Offices can also be *across* from one another (specifically, Offices 1-4, 2-5, 3-6). The Electrical Grid is connected to offices 1 and 6. The Park is visible from offices 3 and 4. There are two *halves* of the building – South (Offices 1-3) and North (Offices 4-6).




The constraints for office allocation ($c_1, \dots, c_8$) are listed below. Note that $c_8$ is to be modeled as multiple pairwise constraints, not a large n-ary constraint.

| | |
|---|---|
| $c_1$ | Legal wants a view of park. |
| $c_2$ | Technology-Head's office must not be across from Maps. |
| $c_3$ | Prototyping must have an electrical connection. |
| $c_4$ | Storage must be next to Engineering. |
| $c_5$ | Engineering must be across from the Technology-Head's office. |
| $c_6$ | Prototyping and Legal cannot be next to one another. |
| $c_7$ | Prototyping and Engineering must be on opposite sides of the building (if one is on the North side, the other must be on the South side). |
| $c_8$ | No two departments can occupy the same office. |

(a) Draw a constraint graph for the the problem. Note: only for clarity of drawing leave out $c_8$ from the diagram for this part.

(b) Write the number of unary constraints in the constraint graph. The table below shows the variable domains after unary constraints have been enforced and the value 1 has been assigned to the variable $P$. Please write for each variable (L, M, P, E, T and S) the values that will be *eliminated* by performing Forward Checking after this assignment.

| | | | | | | |
|---|---|---|---|---|---|---|
| L | | | 3 | 4 | | |
| M | 1 | 2 | 3 | 4 | 5 | 6 |
| P | 1 | | | | | |
| E | 1 | 2 | 3 | 4 | 5 | 6 |
| T | 1 | 2 | 3 | 4 | 5 | 6 |
| S | 1 | 2 | 3 | 4 | 5 | 6 |

(c) The table below shows the variable domains after unary constraints have been enforced, the value 1 has been assigned to the variable $P$, and now the value 3 has been assigned to variable $T$. Please write for each variable (L, M, P, E, T and S) the values that will be *eliminated* if arc consistency is enforced after this assignment. Will the result be different if forward checking is applied before arc consistency?

| | | | | | | |
|---|---|---|---|---|---|---|
| L | | | 3 | 4 | | |
| M | 1 | 2 | 3 | 4 | 5 | 6 |
| P | 1 | | | | | |
| E | 1 | 2 | 3 | 4 | 5 | 6 |
| T | | | 3 | | | |
| S | 1 | 2 | 3 | 4 | 5 | 6 |

3. (6 points) Assume that it is your birthday today. Your hostel mate wants a treat and is asking you to buy her/him an ice cream. Both of you agree to the following strategy: you will select the place (IIT campus or Hauz Khas market), your hostel mate will select the shop. Ice creams at the shop can only be collected through a vending machine. But that machine is faulty and is handing out ice-creams uniformly at random, irrespective of customer's choice. Your hostel mate wants the most expensive outcome, but you want to spend the least given the agreed strategy. The table below lists the ice cream prices (in brackets). Prices that are not known (X and Y) are assumed to be non-negative.

| Place | Shop Name | Ice Cream Flavours |
|---|---|---|
| IIT Campus | Mother Dairy | Mango (Rs. 50), Orange (Rs. 20) |
| | Café Coffee Day | Chocolate (Rs. 50), Vanilla (Rs. 30) |
| Hauz Khas | Giani's Shop | Strawberry (Rs. 25), Fruit (Rs. 35) |
| | Kulfi Shop | Kesar Kulfi (Rs. 36), Pista Kulfi (Rs. X), Badam Kulfi (Rs. Y) |

(a) Draw the corresponding game tree and provide values for all nodes that do not depend on X and Y.

(b) What values of $X$ will make you pick IIT for the treat (instead of Hauz Khas) regardless of the price of $Y$? Justify (1-2 lines).

(c) If the price of Badam Kulfi is at most Rs. 30, what values of $X$ will result in an ice cream from Giani's shop regardless of the exact price of Badam Kulfi? Justify (1-2 lines).

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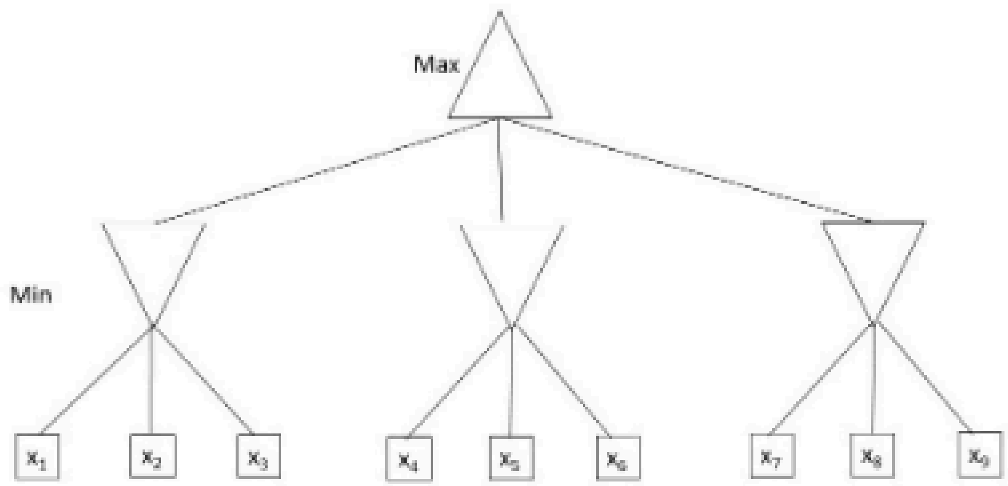
4. (6 points) The following figure depicts a game tree in which the maximizer (Max node) makes the decision at the top level and the minimizer (Min node) makes the decision at the second level. An alpha-beta pruning search will be run on the tree where children nodes will be expanded from left-to-right and pruning will not be applied on equality. Variables $(x_1, x_2, \ldots, x_9)$ denote terminal utilities and can have positive integer values (may not be constant sum).

   (a) Please write an assignment for $x_1, x_2, \ldots, x_9$, chosen such that alpha-beta search will not be able to do any pruning at all.

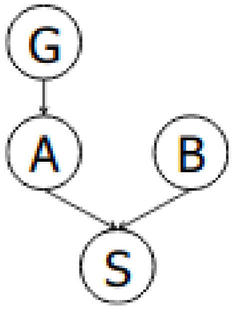
   (b) Next, please write upto two constraints such that when satisfied no pruning is possible in the tree. Constraints can only involve variables $(x_1, x_2, \ldots, x_9)$ and operators ($min()$, $max()$, $<$, $>$). For reference, a constraint can be written as: $min(x_1, x_9) > max(x_2, x_8)$.



5. (9 points) Suppose that a patient can have a symptom $S$ that can be caused by two different diseases ($A$ and $B$). It is known that the variation of gene $G$ affects the manifestation of disease $A$. The Bayesian Network and corresponding conditional probability tables are shown below. The symbols $+$ and $-$ indicate True and False values respectively.

| $P(G)$ | |
|---|---|
| $+g$ | 0.1 |
| $-g$ | 0.9 |

| $P(A\|G)$ | | |
|---|---|---|
| $+g$ | $+a$ | 1.0 |
| $+g$ | $-a$ | 0.0 |
| $-g$ | $+a$ | 0.1 |
| $-g$ | $-a$ | 0.9 |




| $P(B)$ | |
|---|---|
| $+b$ | 0.4 |
| $-b$ | 0.6 |

| $P(S\|A,B)$ | | | |
|---|---|---|---|
| $+a$ | $+b$ | $+s$ | 1.0 |
| $+a$ | $+b$ | $-s$ | 0.0 |
| $+a$ | $-b$ | $+s$ | 0.9 |
| $+a$ | $-b$ | $-s$ | 0.1 |
| $-a$ | $+b$ | $+s$ | 0.8 |
| $-a$ | $+b$ | $-s$ | 0.2 |
| $-a$ | $-b$ | $+s$ | 0.1 |
| $-a$ | $-b$ | $-s$ | 0.9 |

Determine the following probabilities (show steps in 1-2 lines):

(a) The probability that a patient has disease $A$?

(b) Probability that a patient has the disease carrying gene variation $G$ given that they have disease $A$?

(c) Probability that a patient has disease $A$ given that they have symptom $S$ and disease $B$?

(d) Probability that a patient has the disease carrying gene variation $G$ given that they have disease $B$?

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6. (5 points) Please write the correct option(s) for the questions below. Note that more than one option may be correct. A correct answer will receive 1 point each and no points otherwise. No negative marking in this part.

   (a) Pruning is possible in an Expectimax tree when which one of the following conditions are true?
      i. The children of the expectation node are leaves.
      ii. The children of the expectation nodes have specified ranges.
      iii. The child to prune is last.
      iv. All values are positive.

   (b) Which of the following algorithms can be used to find an optimal search solution when the memory is bounded and the optimal solution is reachable?
      i. Iterative deepening A*
      ii. Weighted A*
      iii. Simplified Memory-Bounded A*
      iv. A*

   (c) In simulated annealing, bad moves are more probable in which conditions?
      i. When the temperature is high
      ii. When the temperature is low
      iii. When the difference between new and old values is high
      iv. When the difference between new and old balues is low

   (d) Which of the differences between genetic algorithms (GA) and simulated annealing (SA) are true?
      i. GA maintains multiple candidate solutions
      ii. SA is used for minimization problems whereas GA is used for maximization problems.
      iii. SA has no parameters to set whereas GA requires you to set several parameters such as the crossover rate.
      iv. GA will always converge to an optimal solution faster than SA on any given problem.

   (e) Which of the following correspond to a valid joint distribution over the variables A, B, C, D?
      i. $P(A) \cdot P(B) \cdot P(C|A) \cdot P(C|B) \cdot P(D|C)$
      ii. $P(A) \cdot P(B|A) \cdot P(C) \cdot P(D|B, C)$
      iii. $P(A) \cdot P(B|A) \cdot P(C) \cdot P(C|A) \cdot P(D)$
      iv. $P(A|B) \cdot P(B|C) \cdot P(C|D) \cdot P(D|A)$

7. (5 points) Please write if the following statements are True or False. A correct answer will receive (+0.5) point each, an incorrect answer will receive a negative (−0.25) point and no points for leaving blank.

   (a) The k-states maintained in local beam search share information between each other.

   (b) Using hill-climbing search requires that you have a formula for the gradient of the function you are trying to optimize.

   (c) When enforcing arc-consistency in a CSP, the set of values for variables which remain when the algorithm terminates does not depend on the order in which arcs are processed from the queue.

   (d) AlexNet (2012) achieved the state of the art result on the protein folding task.

   (e) DENDRAL was an expert system used to demonstrate language understanding in a micro world.

   (f) If an AI system can pass the Turing Test for a question-answering task is will be considered as acting rationally.

   (g) A cancer detection system that provides an explanation for its predictions is more likely to be considered a weak AI system compared to a strong AI system.

   (h) Playing the game of Chess is a task with a multi-agent, deterministic, episodic and fully observed domain.

   (i) The alpha-beta search cuts the largest amount off the tree when we examine the best move first.

   (j) In a CSP with n variables, a Backtracking Search that checks for strong $n$-consistency will backtrack at least once.