ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

ORGANISATION OF ISLAMIC COOPERATION (OIC)

Department of Computer Science and Engineering (CSE)

MID-SEMESTER EXAMINATION **WINTER SEMESTER, 2021-2022**

DURATION: 1 HOUR 30 MINUTES **FULL MARKS: 75**

CSE 4711: Artificial Intelligence

Answer **all 3 (three)** questions. Marks of each question and corresponding CO and PO are written in the right margin with brackets.

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1. Consider the game of Pacman, where the main protagonist Pacman has to move through an $M \times N$ grid eliminating ghosts. Pacman starts from an empty square and can choose one of the four following actions: left, right, up, and down to move to another square, if it does not contain a wall or go beyond the board. Pacman can eliminate a ghost by moving to the same square as the ghost. The goal is to eliminate all the G ghosts present on the board.

   For simplicity, we assume that the ghosts are stationary and the cost of executing each action is 1.

   a) Determine the size of the minimal state space graph. 1 (CO1) (PO1)

   Solution: $O\left(M \times N \times 2^G\right)$
   Pacman can be in one of the $M \times N$ squares.
   For each square, there can either be a ghost or no ghost, which gives a total 2^G possibilities.
   Rubric:
   - 1 point for the exact value.

   b) With proper justification, determine whether each of the following heuristics is only admissible, only consistent, none of them, or both of them: 4×6 (CO3) (PO2)

      i. The sum of the Manhattan Distance from Pacman to every ghost.

      Solution: None of them.
      Consider the example where all the ghosts are adjacent and lined up horizontally. If there are three ghosts and Pacman is on their left, the sum of the Manhattan Distance will be $1 + 2 + 3 = 6$, which is an overestimate of the actual cost of 3, since Pacman only needs to move three spaces to eliminate all the ghosts.
      - 1 point for the correct choice.
      - 5 points for justification.

      ii. The number of remaining ghosts.

      Solution: Both of them.
      In each turn, Pacman can only eliminate at most one ghost, and therefore the number of ghosts will be a lower bound on the number of moves necessary to eliminate all the ghosts, making this heuristic admissible. Additionally, since between moves, the number of ghosts can only be reduced by at most one, the heuristic is also consistent.
      - 1 point for the correct choice.
      - 5 points for justification.

iii. The minimum Manhattan Distance between Pacman and any of the ghosts.

Solution: Both of them.
Pacman, at the very least, needs to cross the minimum of the distances between Pacman and the ghosts to reach the closest ghost. For this reason, the heuristic is consistent, which also implies admissibility

- 1 point for the correct choice.
- 5 points for justification.

iv. The number of remaining ghosts multiplied by the minimum Manhattan Distance between Pacman and any of the ghosts.

Solution: None of them.
Consider the case where Pacman is very far from the closest ghost, but all the ghosts are next to each other. The heuristic will give us an overestimate to collect all the ghosts because going the minimum distance value to each ghost is an overestimate once you have reached the closest ghost.

- 1 point for the correct choice.
- 5 points for justification.

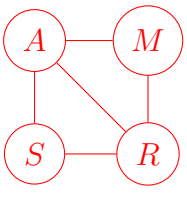
2. a) Four people, Ali (A), Sristy (S), Maliha (M), and Rafid (R) are looking to rent space in an apartment building. There are three floors in the building: 1, 2, and 3 (where 1 is the lowest and 3 is the highest). More than one person can live on a single floor, but each person must be assigned to some floor. The following constraints must be satisfied on assignment:

- A and S must not live on the same floor.
- If A and M live on the same floor, they must be on floor 2.
- If A and M live on different floors, one of them must be on floor 3.
- R must not live on the same floor as anyone else.
- R must live on a higher floor than M.

We formulate the scenario as Constraint Satisfaction Problem (CSP) considering each person as a variable and the floors as values in their domains.

i. Sketch the constraint graph for the CSP. 5 (CO2) (PO2)

Solution:



Rubric:

- 0.5 points for each node
- 0.5 points for each correctly included arc
- 0.5 points for each correctly omitted arc

ii. Apply arc consistency to determine the remaining values in the domain of each variable. 9 (CO3) (PO2)

Solution: $A = \{2, 3\}$
$S = \{1, 2, 3\}$
$M = \{1, 2\}$
$R = \{2, 3\}$
3 is removed from M because, for that assignment R will not be able to live above M.
1 is removed from R because, for that assignment M will not be able to live below R.
1 is removed from A because, for that assignment M must live in 3, which has been removed previously.
Rubric:

- 0.5 points for each correctly included value
- 0.5 points for each correctly omitted value
- 1 point for each explanation

iii. Let's assume A chooses to live on floor 3. Solve the CSP to determine which person lives on which floor. 7 (CO3) (PO1)

Solution: $A = 3$
$S = 1$
$M = 1$
$R = 2$
If A stays on 3, R cannot be on the same floor. So, $R = 2$.
If R stays on 2, M needs to stay below. So, $M = 1$.
If A stays on 3, S cannot be on the same floor. So, $S = \{1, 2\}$
Again, R will not allow anyone to stay on 2. SO, $S = 1$.
Rubric:

- 1 point for each correct value (except A).
- 1 point for each explanation.

b) Assume that we have a tree-structured CSP with 100 variables. Each variable can take 5 values. Compare the performances of Tree-CSP-solver with Naïve Backtracking on a computer that can process 10 million nodes/second. 4 (CO1) (PO1)

Solution: Worst-case solution for naïve backtracking: $n^d = 5^{100}$ nodes.
Time required: $\frac{5^{100}}{10^6} = 2.5 \times 10^{56}$ years.
Worst-case solution for Tree-CSP-solver: $nd^2 = 100 \times 5^2 = 2500$ nodes.
Time required: $\frac{2500}{10^6} = 2.5$ milliseconds.
Rubric:

- 1 point for correct equation.
- 1 point for result.

3. a) "Artificial Intelligence (AI) is the science of making machines that act rationally" - Justify the 7 (CO2) (PO2)

statement by comparing it with other schools of thought on AI.

Solution: Thinking rationally requires finding the rules that govern the correct thought and automating them using big computations. But it does not scale well. Thinking like people requires understanding how brains work and emulating that. But brains are difficult to understand and might not always make the best choice. Acting like people correlates scenarios with human actions to emulate how humans act. But emulating humans does not necessarily mean intelligence as imitating other animals might not give us the best result. Acting rationally focuses on what decisions are made, not the thought process. Each outcome has utilities assigned to them based on our preference. Machines maximize the expected utility.

Rubric:

- 0.5 points for describing each schools of thought.
- 1 point for cons of 3 schools.
- 2 points for pros of acting rationally.

b) In the state space graph shown in Figure 1, the values beside each arc denote the cost of executing the action for going to a successor state. 3×6 (CO1) (PO1)

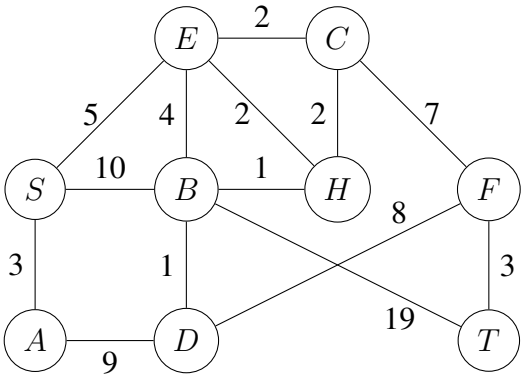


Figure 1: State Space Graph for Question 3(b).

Assume that S is the start state and T is the goal state. We will run graph search variants of different search algorithms to find a path from the S to T. When expanding the successors of a state, we will break ties in alphabetic order.

For each of the following search algorithms, determine the order in which the states are expanded, and the path returned:

i. Depth-First Search

Solution: States expanded: $S \to E \to H \to C \to F \to T$
Path returned: $S \to E \to H \to C \to F \to T$
Rubric:

- 3 points for expansion order
- 3 points for the path.

ii. Breadth-First Search

Solution: States expanded: $S \rightarrow A \rightarrow B \rightarrow E \rightarrow D \rightarrow H \rightarrow T$
Path returned: $S \rightarrow B \rightarrow T$
Rubric:

- 3 points for expansion order
- 3 points for the path.

iii. Uniform Cost Search

Solution: States expanded: $S \rightarrow A \rightarrow E \rightarrow C \rightarrow H \rightarrow B \rightarrow D \rightarrow F \rightarrow T$
Path returned: $S \rightarrow E \rightarrow C \rightarrow F \rightarrow T$
Rubric:

- 3 points for expansion order
- 3 points for the path.