COMP 3211 – Fundamentals of Artificial Intelligence
2025 Spring Semester – Assignment 2 Written Part (82 points)
Date Assigned: Mar 9, 2025
Due Time: 23:59 on Mar 23, 2025

How to submit it:

- Submit your written answers as a pdf file to canvas. If your submission is a scan of a handwritten solution, make sure that it is of high enough resolution to be easily read.
- Please avoid plagiarism. ***You must acknowledge individuals who assisted you, or sources where you found solutions.*** Failure to do so will be considered plagiarism.
- No late submission will be accepted.

1. (10 points) Consider the route finding problem in Page 25 of *Lecture 3 Search*. We want to travel by train from *Arad* to *Bucharest*. The roadmap shows the train distances between different places. Formulate this problem as a search problem by specifying the states, initial state, goal test, operators, and operator costs.

2. (12 points) Now we are assigning n students to two different halls, one with capacity m and another one with capacity k. We have $m + k \geq n$. Some students dislike each other and if such two students are assigned into the same hall, it leads to a conflict. Given the list of dislike pairs, our goal is to find the hall assignment for all students such that each hall does not exceed capacity and does not have any conflict.

   2.1 Formulate this problem as a constraint satisfaction problem by defining: variables, their domains, constraints.

   2.2 Suppose there are 5 students s_1, s_2, s_3, s_4, s_5. s_1 and s_4 dislike each other; s_1 and s_5 dislike each other; s_3 and s_5 dislike each other. The two halls have capacity 3 and 2. Use constructive method to assign the halls for the 5 students by running the constraint propagation in the constraint graph. You only need to give one correct solution with the corresponding constraint propagation process.

3. (15 points) Suppose you are trying to solve the following puzzle. The puzzle involves 3-digit numbers from 100 to 999. You are given two numbers called S and G. You are also given a set of numbers called *bad*. A move consists of transforming one number into another by adding 1 to one of its digits or subtracting 1 from one of its digits; for instance, a move can take from 678 to 679; or from 234 to 134. Moves are subject to the following constraints:

   - You cannot add to the digit 9 or subtract from the digit 0.

- You cannot make a move which transforms your current number into one of the numbers in the set *bad*.
- You cannot change the same digit twice in two successive moves.

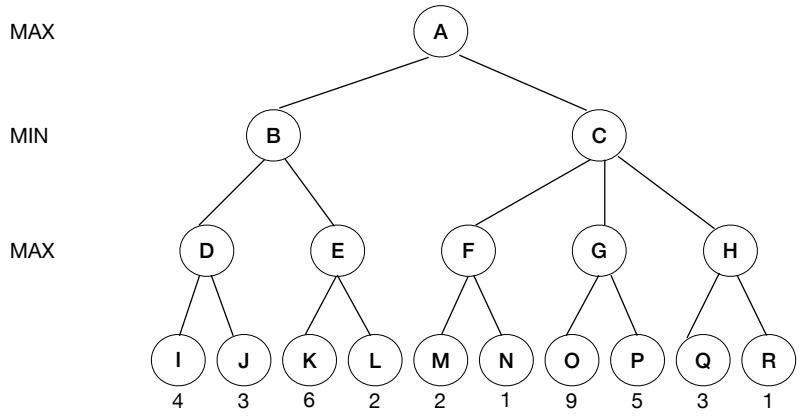
Your task is to solve the puzzle by getting from S to G in the fewest possible moves.

3.1 If you want to formulate this problem as a search problem, how should the state be represented?

3.2 Now you want to use A* search to find a solution to the puzzle. Let the heuristic function be the sum of the absolute differences between the digits in the current state and the digits in the goal state G. Is this heuristic function admissible? Please briefly explain why.

3.3 When $S = 567$, $G = 777$, $bad = \{666, 667\}$, use this heuristic function in 3.2 to carry out two steps of A* search-by-tree (check only ancestors for repeated states) starting with the root node: 1. expand the root, and indicate which node will be chosen for expansion next; 2. expand the chosen node and indicate which node will be chosen for expansion next. You can use any tie-breaking rule. You can answer the question by OPEN list sequence or by drawing a search tree with the chosen nodes clearly marked.

4. (20 points) Consider the following game tree, where the leaves are terminal nodes, and the numbers next to them are their utility values:



4.1 Perform minimax on the game tree, what are the values of each non-terminal node? Which action will the root node take?

4.2 Perform alpha-beta pruning with left to right ordering on the game tree, which nodes are pruned?

4.3 Perform alpha-beta pruning with right to left ordering on the game tree, which nodes are pruned?

5. (10 points) Recall our boundary-following robot with 8 sensory inputs: $(s_1, s_2, \ldots, s_8)$. Suppose initially the robot has sensory inputs $(0, 0, 0, 0, 0, 0, 0, 0)$

and there is no tight space in the environment. The correct behavior is that the robot should follow a boundary in a consistent way, clockwise if it's inside the wall of the room, and counter-clockwise if it is outside an obstacle in the room. Formulate this task as a MDP.

6. (15 points) Consider the following two investment decisions: buy a certified deposit (CD) which will pay you a 10% annual interest rate, and buy some stocks which will either give you a 30% annual return (with 0.7 probability) or incur a 10% loss for you (with 0.3 probability). In terms of expected utility, you should of course buy stocks. However, suppose you are conservative and cannot tolerate any loss of your principal. In this case, you have no choice but to deposit your money into a CD. Now consider this problem for a 3 years time span. You start with 1 unit of money. Each year you can choose only one way to invest your entire fund (meaning you are not allowed to diversify, like 50% CD, 50% stocks). You definitely don't want to lose any money at the end of the 3 years, but you are okay with a "temporary" loss during the time (for example, it is okay for you to lose some money in the first year as long as you can make it up later). Formalize this problem as a Markov decision process and compute its optimal policy.

   Hints A state needs to contain information about how many money you have in this state. In other words, a state needs to encode the history: which actions you have done so far and what their outcomes are if the actions are non-deterministic.