CS 441/541: Artificial Intelligence Name: ______________________

Midterm (46 pts. possible), Winter 2022

Rhodes

Please show a sufficient amount of work for full credit on exercises. If the question prompts you to simply provide an answer, it is acceptable to simply submit the answer (without explanation, if none is necessary). The exam is open book and open notes. **<u>However, you are not allowed to confer with fellow students or, nor are you permitted to use "le Google" to seek out a solution</u>**.

*Email your exam solutions to our grader by the assigned due date. You can submit typed or hand-written solutions (or a combination of both if this is preferred); please make an effort to ensure that your solutions are clear and legible.

1. (2 pts.) Describe several of the historical factors that led to the first "AI Winter" (which occurred in the 1970s).

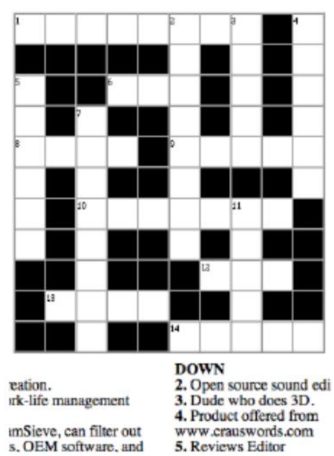
2. (2 pts.) You are developing an agent that solves crossword puzzle (like the one pictured to the right) using an exhaustive dictionary of possible words. States are partially-completed puzzles and actions place a word on the puzzle. On each line below, we've listed two possible environmental aspects; circle the one which better describes the crossword-puzzle environment.

a) fully observable vs. partially observable

b) single agent vs. multiagent

c) stochastic vs. deterministic

d) discrete vs. continuous



3. (9 pts.) (i) The greedy best-first search algorithm is complete. T F (circle)

(ii) Iterative deepening search is guaranteed to expand more nodes than breadth- first search (on any graph whose root is not the goal). T F

(iii) A* search with a heuristic that is not completely admissible may still find the shortest path to the goal state. T F

(iv) Consider a finite, acyclic search space where depth-first search is guaranteed to eventually find a solution and the root is not a goal. In this situation iterative deepening search will always explore more nodes than depth-first. T F

(v) Doubling your computer's speed allows you to double the depth of a tree search given the same amount of time. T F

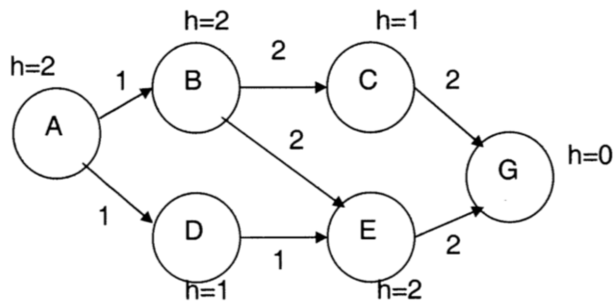
(vi) An agent that uses Minimax search, which assumes an oponent behaves optimally, may well achieve a better score when playing against a suboptimal enemy than the agent would against an optimal enemy. T F

(vii) Every admissible heuristic is consistent. T F

(viii) Monte Carlo tree search yields an optimal playing strategy against an optimal opponent. T F

(ix) Consider the following two bit strings: 01100000 and 10110111. Suppose that the fitness function is given by the number of bits that are 1. What should the crossover point be, in order to get in the next generation an individual with the highest possible fitness? Show the result of the crossover.

4. (3 pts.) The figure below shows a search-space graph, where A is the initial state and G denotes the goal. Edges are labeled with their true cost. We have a heuristic function, f(), written in the standard form: $f(n) = g(n) + h(n)$ where $g(n)$ is the cost to get from A to n and $h(n)$ is an estimate of the remaining distance to G.



(i) Is h admissible? Why or why not?

(ii) Is h consistent/monotonic? Why or why not?

5. (2 pts.) Give an example of a task environment for which *every* possible agent actions rationally (simple answers are best).

6. (2 pts.) Is the global coordination of simple "agents" possible, so that the agents are coordinated to solve a problem with complexity beyond the capabilities of each individual agent? Explain in a few sentences; give concrete examples where appropriate.

7. (5 pts.) In an environment that is an n x n grid, we have n cars that are located in squares $(1,1)$ through $(1,n)$ (i.e. in the bottom row). All of the cars have to be moved to the top row of the grid, but their order must be reversed. The car that started at $(1,i)$ must be moved to $(n,n-i+1)$, and so on. During each timestep, every one of the cars executes a legal move at the same time. There are five legal moves: North, East, South, West or Stay. Assume that multiple cars can be located in the same grid square.

(a) The size of the state space is (circle one)

(i) $O(n^2)$ (ii) $O(n^3)$ (iii) $O(n^{2n})$ (iv) $O(n^{n^2})$

(b) The branching factor is roughly (circle one)

(i) 5 (ii) 5n (iii) 5^n (iv) $\binom{5}{5}$

(c) Suppose that car i is currently located at (x_i, y_i). Write a nontrivial admissible heuristic h_i for the number of moves it will take for that car to get to its goal location $(n,n-i+1)$, assuming that there are no other cars on the grid.

(d) Take the problem of moving all of the *n* cars to their destination. Which of the following heuristics are admissible when considering all of the cars at the same time? <u>Circle all correct answers</u>.

(i) $\sum_{i=1}^{n} h_i$ (ii) $\max\{h_1,...,h_n\}$ (iii) $\min\{h_1,...,h_n\}$ (iv) None of these

8. (2 pts.) For each of the following statements, explain in terms of the cost function the circumstances under which it is true.

(i) Breadth First search is a special case of Uniform Cost search.

(ii) Uniform Cost search is a special case of A* search.

9. (2 pts.) Give a description of a search space in which Iterative Deepening performs much worse than Depth First search. Give the respective complexities for this domain in Big O notation.

10. (2 pts.) Suppose that in addition to the admissible heuristic h(n), you are told that there is a solution whose true cost is K. How would you change A* to take advantage of this knowledge and reduce the number of nodes that need to be expanded? Does this method maintain optimality?

11. (4 pts.) Pseudo-code for the Simulated-Annealing algorithm is given below; note that in the version of the algorithm given, we wish to maximize the objective function (i.e. walk uphill).

function SIMULATED-ANNEALING($problem, schedule$) **returns** a solution state
  inputs: $problem$, a problem
    $schedule$, a mapping from time to "temperature"
  local variables: T, a "temperature" controlling the probability of downward steps

  $current \leftarrow$ MAKE-NODE($problem$.INITIAL-STATE)
  for $t = 1$ **to** ∞ **do**
    $T \leftarrow schedule(t)$
    if $T = 0$ **then return** $current$
    $next \leftarrow$ a randomly selected successor of $current$
    $\Delta E \leftarrow next$.VALUE – $current$.VALUE
    if $\Delta E > 0$ **then** $current \leftarrow next$
    else $current \leftarrow next$ only with probability $e^{\Delta E/T}$

(i) Describe the idea behind the Simulated-Annealing algorithm. Be sure to briefly explain the role of each component in the algorithm.

(ii) Indicate how you could change the Simulated-Annealing algorithm so that it implements a "strict" version of hill-climbing.

(iii) With regards to Simulated-Annealing, what is the probability of accepting the following moves? Assume the problem is trying to maximize the objective function. (If you don't have a calculator, you can leave your answers in the form of mathematical expressions)

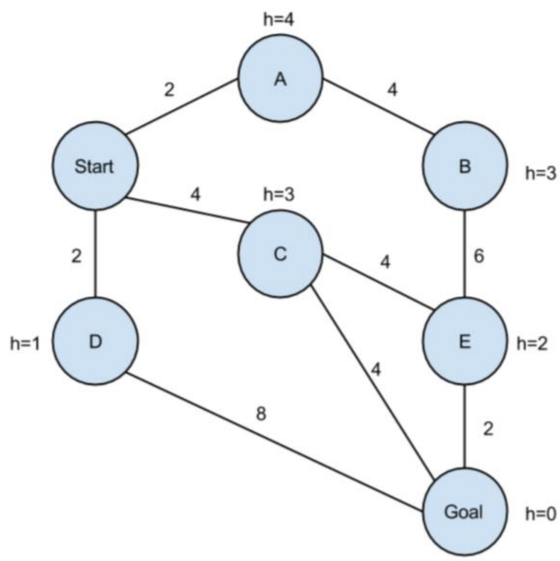
Current Evaluation	Neighborhood Evaluation	Temperature
16	15	20
25	13	25
76	75	276

12. (3 pts.) The Travelling Salesman Problem (TSP) is, again, a classic NP-hard problem in optimization, and is commonly stated as: "Given a list of cities and the distances between each pair of cities, what is the shortest possible route that visits each city?"

Consider the problem represented as a sequence of cities, 1..n. Note that a valid representation for TSP must consist of a permutation of the elements {1,…,n} so that each element appears once and only once in the string (i.e. no city is visited twice and no cities are skipped). For simplicity, suppose that the TSP "tour" can begin and end in any city.

Describe an effective solution to TSP (as described above) using a genetic algorithm. Please be sure that you address the details for each of the essential components in a GA; be specific about how you will apply the GA operations to adhere to the aforementioned "valid representation."

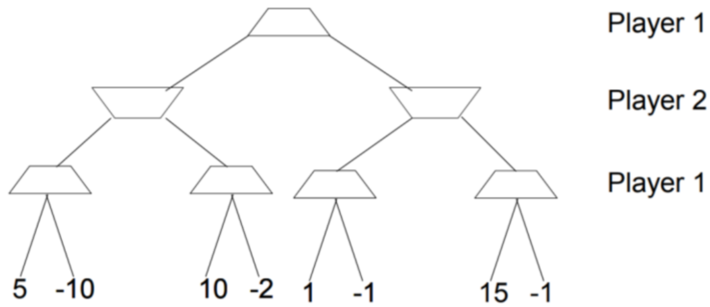
13. (4 pts.) Given the graph shown below, write down the order in which the states are visited by the following search algorithms. If a state is visited more than once, write it each time. Ties (e.g., which child to first explore in depth-first search) should be resolved according to alphabetic order (i.e. prefer A before Z). Remember to include the start and goal states in your answer. Treat the goal state as G when you break ties. Assume that algorithms execute the goal check when nodes are visited, not when their parent is expanded to create them as children.



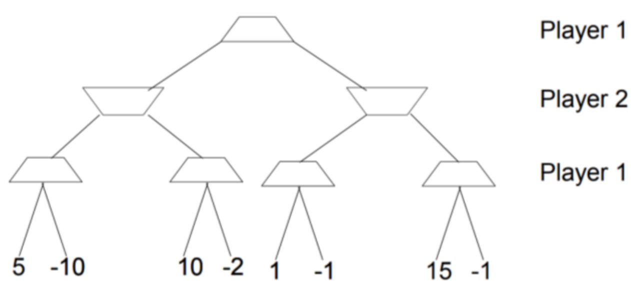
(i) Iterative deepening depth first search (start with *l* = 0)

(ii) A* search, where f(n)=g(n)+h(n)

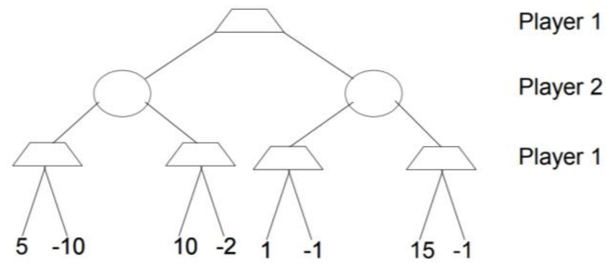
14. (4 pts.) (a) Consider the following zero-sum game with 2 players. At each leaf we have labeled the payoffs Player 1 receives. It is Player 1's turn to move. Assume both players play optimally at every time step (i.e. Player 1 seeks to maximize the payoff, while Player 2 seeks to minimize the payoff). Circle Player 1's optimal next move on the graph, and state the minimax value of the game. Show your work.



(b) Consider the following game tree. Player 1 moves first, and attempts to maximize the expected payoff. Player 2 moves second, and attempts to minimize the expected payoff. Expand nodes left to right. Cross out nodes pruned by alpha-beta pruning.



(c) Now assume that Player 2 chooses an action uniformly at random every turn (and Player 1 knows this). Player 1 still seeks to maximize her payoff. Circle Player 1's optimal next move, and give her expected payoff. Show your work.



Extra Credit: (totally optional, 3 pts.)

Once upon a time a farmer went to a market and purchased a fox, a goose, and a bag of beans. On his way home, the farmer came to the bank of a river and rented a boat. But in crossing the river by boat, the farmer could carry only himself and a single one of his purchases: the fox, the goose, or the bag of beans.

If left unattended together, the fox would eat the goose, or the goose would eat the beans.

The farmer's challenge was to carry himself and his purchases to the far bank of the river, leaving each purchase intact. How did he do it? Give the optimal solution (minimum number of steps).