OREGON STATE UNIVERSITY
School of Electrical Engineering and Computer Science
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Midterm Exam Solutions

1. **[10 points]** True or False. Indicate whether the following statements are true or false. Briefly explain your answer in a sentence or two. Each question is worth two points.

(a) DFS always expands more nodes than A*. False, the number of nodes expanded by each algorithm depends on the graph.

(b) If you know for sure that your opponent panics every third move and chooses a random move (with uniform distribution over strategies), then the standard minimax algorithm or its variant still provides the best strategy against that opponent.

True, expecti-minimax can solve this version.

(c) If the heuristic value is zero for all nodes in the graph, A* is guaranteed to find an optimal solution.

True, it is still an admissible heuristic.

(d) With an inadmissible heuristic, A* will always find a non-optimal solution.

False. A* is not guaranteed to return an optimal solution with an inadmissible heuristic but it may find an optimal solution for a certain problem.

(e) A Nash equilibrium solution is the same as Pareto-optimal solution for a game.

False. They are not guaranteed to be the same. Example: Prisoner's dilemma example discussed in class.

2. **[15 points]** PEAS and Uninformed Search.

(a) (5 points) Consider the agent AlphaGo, which beat a human expert at the game Go. Recall that in the game of Go, two players take turns placing stones on a 19x19 board. The objective is to capture territory and/or the other player's stones by surrounding them. This question refers to a setting in which AlphaGo plays a single game (not a tournament) without timed moves. For each part below, enter the best design choice for this game.

Answers are highlighted in blue.

- Environment: Fully observable or partially observable?
- Environment: Static or dynamic?
- Game nature: episodic or sequential?
- Agent design: Choose from simple reflex agent, model-based reflex agent, goal-based agent and utility-based agent. Briefly explain your answer.

  Utility-based agent since we want to capture the board as much as possible.

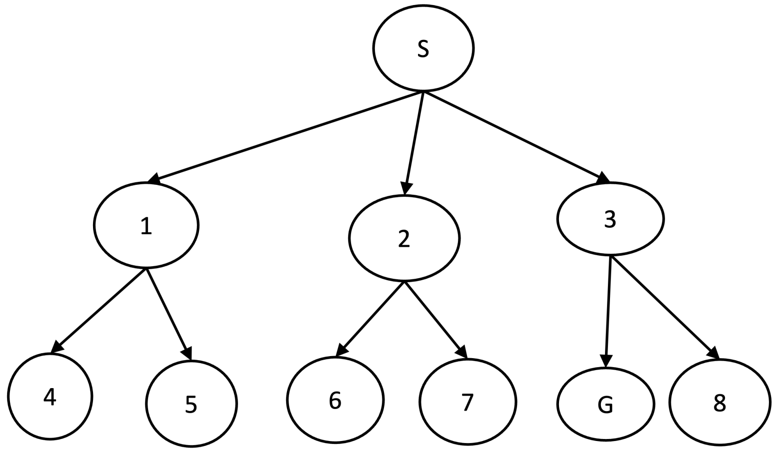

Figure 1: Graph for uninformed search

(b) (10 points) Solve the graph in Figure 1 using **Breadth First Search** (BFS) and complete the table below with the order in which the nodes will be expanded. **Note: Expand nodes in the order left to right.**

Expanded Nodes List	Frontier List
	{S}
{S}	{1,2,3}
{S,1}	{2,3,4,5}
{S,1,2}	{3,4,5,6,7}
{S,1,2,3}	{4,5,6,7,G,8}
{S,1,2,3,4}	{5,6,7,G,8}
{S,1,2,3,4,5}	{6,7,G,8}
{S,1,2,3,4,5,6}	{7,G,8}
{S,1,2,3,4,5,6,7}	{G,8}
{S,1,2,3,4,5,6,7,G}	{8}

3. **[20 points]** Informed and Local Search.

(a) (5 points) Consider formulating the 8-tile puzzle as a local search problem and representing a state as an array of 9 symbols corresponding to the tile positions. For example, for the configuration shown below, the state is represented as [6 4 3 1 2 7 8 B 5], with B for blank. (i) List the one-step successors for this problem. (ii) Propose an evaluation function for this problem and write the corresponding score for the configuration below.

6	4	3
1	2	7
8		5

(i) [6,4,3,1,2,7,8,5,B], [6,4,3,1,B,7,8,2,5], [6,4,3,1,2,7,B,8,5]
(ii) Any of the heuristics we used for A* on this problem would serve here. E.g., number of misplaced tiles, Manhattan distance.

(b) (3 points) For the graph in Figure 2, which of the following is true about the heuristic. Briefly explain your answer.

(i) Heuristic is admissible

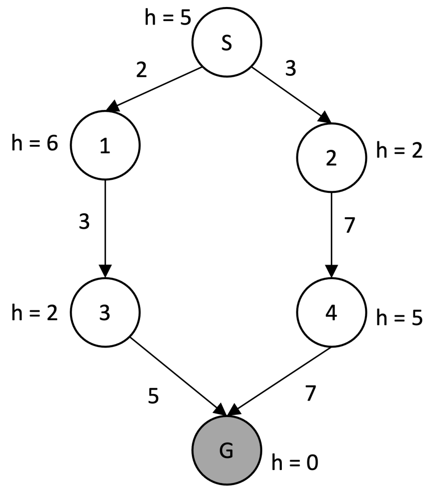

Figure 2: Graph for A* search

(ii) Heuristic is consistent

(iii) Heuristic is admissible and consistent

(iv) Heuristic is neither admissible nor consistent

Heuristic is admissible. Consistency violated at node 1 since $h(1) > 3 + h(3)$.

(c) (8 points) Solve the graph in Figure 2 using A* and report the (i) f best values for each node, (ii) the solution path and (iii) solution cost.

Node	f value
S	5
1	8
2	5
3	7
4	15
G	10

Solution path: S-1-3-G Solution cost: 10

(d) (4 points) Let h_1 be the heuristic values for the graph in Figure 2. Let h_2 be defined as follows. Which of the two is a better heuristic for the problem? Explain your answer.

Node	h_1	h_2
S	5	5
1	6	3
2	2	3
3	2	3
4	5	5
G	0	0

Both heuristics are admissible. h_2 is better because it is also consistent.

4. [**35 points**] Adversarial Search

(a) (10 points) Consider a modified adversarial search setting as shown in Figure 3. The order in which successors are evaluated affects the behavior of alpha-beta algorithm. The unlabeled nodes in Figure 3, can take values from the set $\{1, 3, 5\}$ (each node takes one value and each value is used only once). List these values in the order that produces the maximum amount of pruning from the alpha-beta algorithm. Show your calculations or clearly justify your answer.

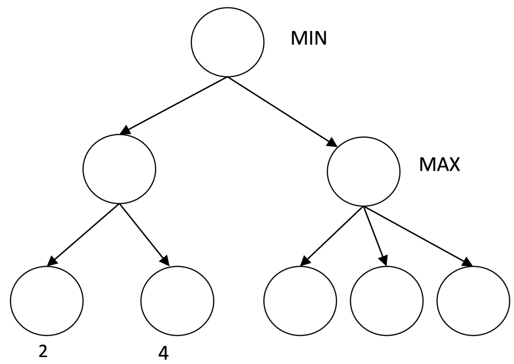

Figure 3: Game tree

5, 3, 1. (Ordering over 3 and 1 does not matter as long as 5 is first.)

(b) (15 points) Consider running alpha-beta pruning on the game tree in Figure 4 to answer the following questions. For both, justify your answer in terms of alpha and beta.

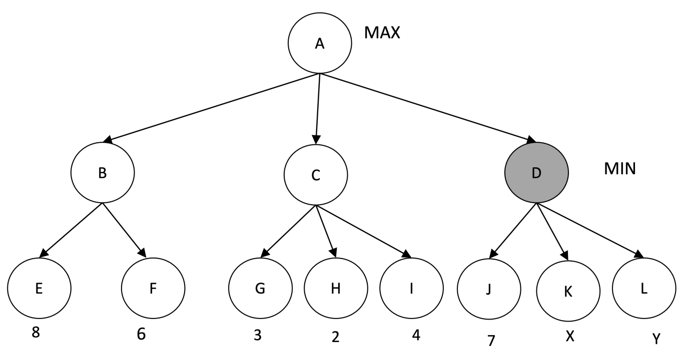

Figure 4: Game tree

(i) Indicate which (if any) branches are pruned during the minimax procedure before reaching the shaded node (D). Explain why.

After visiting the child nodes of B, $\alpha = 6$. Nodes H and I can be pruned after visiting G, since the minimax value at C is ≤ 3 which is $< \alpha$.

(ii) Give a condition relating X and Y such that pruning occurs just before reaching node L.

If $X < 6$, then Y can be pruned, irrespective of the value assigned to it. This is because the minimax value at D will be ≤ 6, and MAX will choose B.

(iii) Provide a utility value for all the leaf nodes (other than the current values in the graph) such that **no pruning** occurs.

E: 7, F:5, G:7, H:8, I:4, J:6,X:6, Y:3

(c) (10 points) Figure 5 is a portion of a game tree. At this point, MAX is choosing between a guaranteed utility of 10 versus tossing a series of coins. Which action should MAX choose (left or right)? Use the expectiminimax algorithm to decide, and show your work.

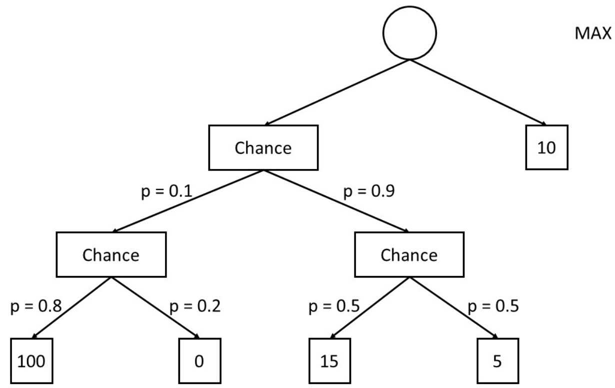

Figure 5: Game tree

Solution is in the Figure 6. MAX should choose the left strategy.

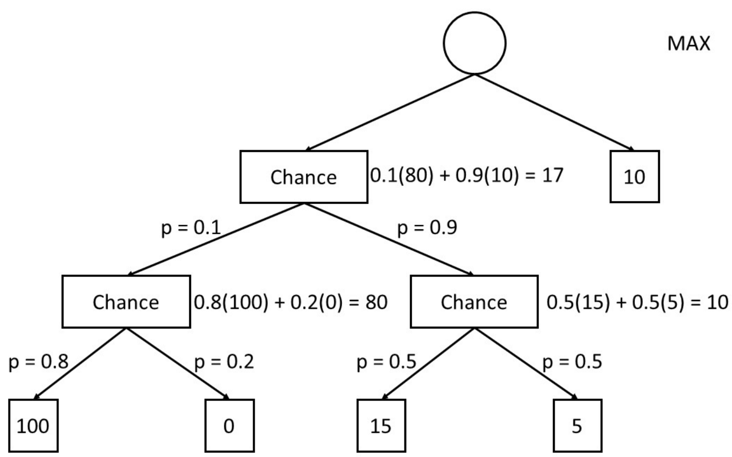

Figure 6: 4c Solution

5. [**20 points**] Game Theory

Consider the following game with two players A and B, each with two strategies S1 and S2. Their payoffs in the table are in the form (x, y) where x denotes A's payoff and y denotes B's payoff value.

		B	
		S1	S2
A	S1	2,5	-4, 4
	S2	-3, 7	10,10

(i) [4 points] Is there a dominant pure strategy for each player? If yes, list them. If no, explain why.

The players do not have a dominant pure strategy. For A: $-3 < 2$ but $10 \not< -4$. For B: $5 > 4$ but $7 < 10$.

(ii) [4 points] List all Nash equilibria that exist in this game, assuming players play pure strategies.

(A:S1, B:S1), (A:S2, B:S2)

(iii) [3 points] List all Pareto optimal solutions in this game., assuming players play pure strategies.

(10,10)

(iv) [7 points] Suppose player B chooses a mixed strategy where B plays strategy S1 with probability $p_1 = 0.5$ and plays strategy S2 with probability $p_2 = 0.5$. What is A's best response strategy that maximizes A's payoff, given B's mixed strategy? Show your calculations. A's payoff for S1 = $0.5 * 2 + 0.5 * -4 = -1$
A's payoff for S2 = $0.5 * -3 + 0.5 * 10 = 3.5$. Hence, A's best response strategy is S2.