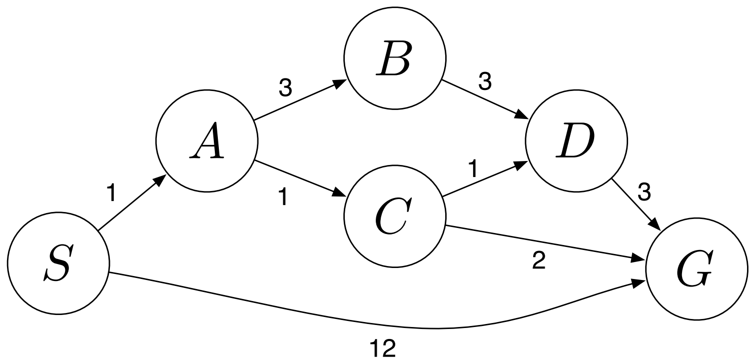
CS 188
Summer 2019

Section Handout 2

Q1. Search



Answer the following questions about the search problem shown above. Assume that ties are broken alphabetically. (For example, a partial plan $S \to X \to A$ would be expanded before $S \to X \to B$; similarly, $S \to A \to Z$ would be expanded before $S \to B \to A$.) For the questions that ask for a path, please give your answers in the form '$S - A - D - G$.'

(a) What path would breadth-first graph search return for this search problem?

(b) What path would uniform cost graph search return for this search problem?

(c) What path would depth-first graph search return for this search problem?

(d) What path would A* graph search, using a consistent heuristic, return for this search problem?

(e) Consider the heuristics for this problem shown in the table below.

State	h_1	h_2
S	5	4
A	3	2
B	6	6
C	2	1
D	3	3
G	0	0

(i) Is h_1 admissible? **Yes** **No**

(ii) Is h_1 consistent? **Yes** **No**

(iii) Is h_2 admissible? **Yes** **No**

(iv) Is h_2 consistent? **Yes** **No**

Q2. Search problems

It is training day for Pacbabies, also known as Hungry Running Maze Games day. Each of k Pacbabies starts in its own assigned start location s_i in a large maze of size MxN and must return to its own Pacdad who is waiting patiently but proudly at g_i; along the way, the Pacbabies must, between them, eat all the dots in the maze.

At each step, all k Pacbabies move one unit to any open adjacent square. The only legal actions are Up, Down, Left, or Right. It is illegal for a Pacbaby to wait in a square, attempt to move into a wall, or attempt to occupy the same square as another Pacbaby. To set a record, the Pacbabies must find an optimal collective solution.

(a) Define a minimal state space representation for this problem.

(b) How large is the state space?

(c) What is the maximum branching factor for this problem?

(A) 4^k (B) 8^k (C) $4^k 2^{MN}$ (D) $4^k 2^4$

(d) Let $MH(p, q)$ be the Manhattan distance between positions p and q and F be the set of all positions of remaining food pellets and p_i be the current position of Pacbaby i.

Which of the following are admissible heuristics?

h_A: $\frac{\sum_{i=1}^{k} MH(p_i,g_i)}{k}$
h_B: $\max_{1\leq i\leq k} MH(p_i, g_i)$
h_C: $\max_{1\leq i\leq k}[\max_{f\in F} MH(p_i, f)]$
h_D: $\max_{1\leq i\leq k}[\min_{f\in F} MH(p_i, f)]$
h_E: $\min_{1\leq i\leq k}[\min_{f\in F} MH(p_i, f)]$
h_F: $\min_{f\in F}[\max_{1\leq i\leq k} MH(p_i, f)]$

(e) Give one pair of heuristics h_i, h_j from part (d) such that their *maximum* — $h(n) = max(h_i(n), h_j(n))$ — is an admissible heuristic.

(f) Is there a pair of heuristics h_i, h_j from part (d) such that their *convex combination* — $h(n) = \alpha h_i(n) + (1-\alpha)h_j(n))$ — is an admissible heuristic for any value of α between 0 and 1? Briefly explain your answer.

Now suppose that some of the squares are flooded with water. In the flooded squares, it takes two timesteps to travel through the square, rather than one. However, the Pacbabies don't know which squares are flooded and which aren't, until they enter them. After a Pacbaby enters a flooded square, its howls of despair instantly inform all the other Pacbabies of this fact.

(g) Define a minimal space of belief states for this problem.

(h) How many possible environmental configurations are there in the initial belief state, before the Pacbabies receive any wetness percepts?

(i) Given the current belief state, how many different belief states can be reached in a single step?

(A) 4^k (B) 8^k (C) $4^k 2^{MN}$ (D) $4^k 2^4$