

CS 471/571: Introduction to Artificial Intelligence, Fall 2023

Written Assignment 1: Solution

Deadline: Oct 11th, 2023

Instruction: You may discuss these problems with classmates, but please complete the write-ups individually. (This applies to BOTH undergraduates and graduate students.) Remember the collaboration guidelines set forth in class: you may meet to discuss problems with classmates, but you may not take any written notes (or electronic notes, or photos, etc.) away from the meeting. Your answers must be **typewritten**, except for figures or diagrams, which may be hand-drawn.

Q1. Word Ladder (30 points)

Wikipedia describes the rules for the word game Word Ladder as: The player is given a start word and an end word (of equal length). In order to win the game, the player must change the start word into the end word progressively, creating an existing word at each step. Each step consists of replacing a single letter. For example, the following is a solution to the Word Ladder puzzle between words “Cold” and “Warm”: COLD → CORD → CARD → WARD → WARM

1. (10 pts) Formulate the problem of solving word ladders as a search problem.

Answer. The start word is the start state and the goal test is to check if the current word is the goal word. A state is a valid word that can be generated. An action is to change one letter of the current word the lead to an existing word. The successor function determines the resulting valid word according to the action taken.

2. (10 pts) Consider a restriction where the words can only use the first seven letters (a-g). Draw the state space graph for converting “bee” to “dad”.

Answer. See Figure 1. Students can get a full credit if their graph has at least 10 states.

3. (10 pts) (Tree Search) Which part of the search tree is expanded by DFS?

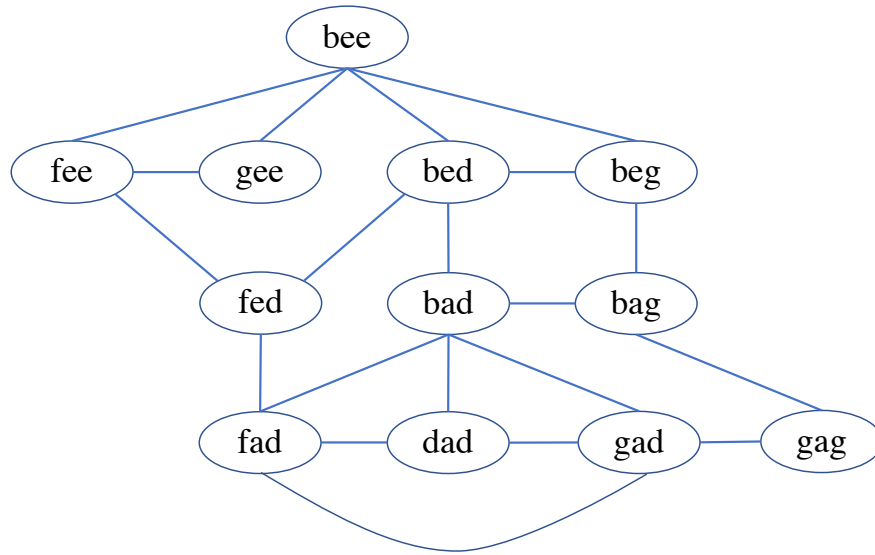
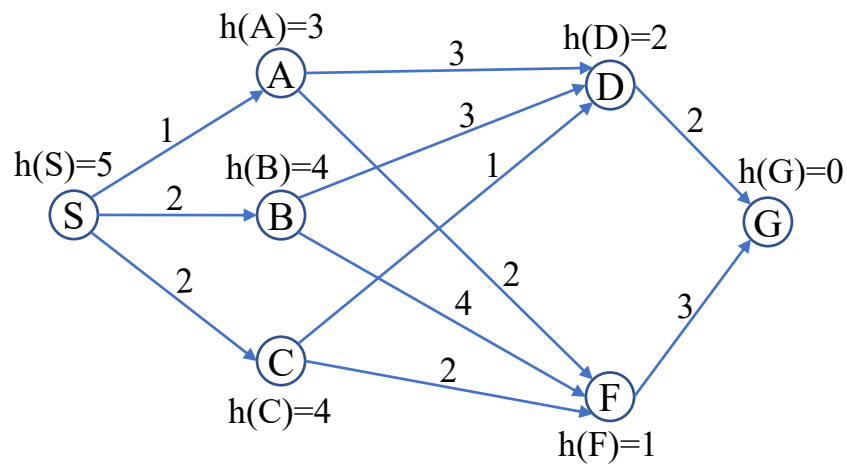


Figure 1: State space graph

Answer. For DFS, it depends on which order we use to select a node to expand in the search tree when a tie-break happen. For example, we may end up at the loop bee-fee-gee. Or we may follow the path bee-bed-bad-dad to reach the goal “dad”.

Q2. Graph Search (50 points)

Q2.1. Search Algorithms. (30 points) Consider the following graph. The start node is S and the goal node is G . For the following sub-questions, ties are broken in alphabetical order.



- (10 pts) In what order are states expanded by UCS? What path would UCS return?

Answer. Order: S, A, B, C, D, F, G . Path: $S - C - D - G$.

2. (10 pts) In what order are states expanded by Greedy? What path would Greedy return?

Answer. Order: S, A, F, G . Path: $S - A - F - G$

3. (10 pts) In what order are states expanded by A^* ? What path would A^* return?

Answer. Order: S, A, F, B, C, D, G . Path: $S - C - D - G$

Q2.2. Admissibility/Consistency. (20 points)

- (10 pts) Is the above heuristic function h admissible? Explain your answer.

Answer. The heuristic is not admissible since the heuristic cost at C : $h(C) = 4$ is strictly greater than the actual optimal cost from C to G which is $c(C - D) + c(D - G) = 3$

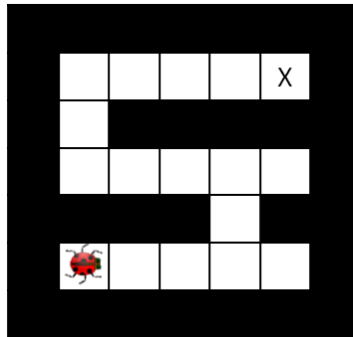
- (10 pts) For which TWO states (S, A, B, C, D, F , or G) could you change the heuristic values to make everything consistent? What range of values are possible to make this correction?

Answer. Heuristic costs at states S and C . We have: $h(S) \leq \min\{4, h(C) + 2\}$, $h(C) \leq 3$.

Important note. For graph search, we never expand a state type twice.

Q3. Hive Minds: Lonely Bug (20 points)

You control a single insect in a rectangular maze-like environment with dimensions $M \times N$. Figure below is an example of such environment. The insect must reach a designated target location X , also known as the hive. There are no other insects moving around. At each time step, an insect can either (a) move into an adjacent square if that square is currently free, or (b) stay in its current location. Squares may be blocked by walls, but the map is known. Optimality is always in terms of time steps; all actions have cost 1 regardless of the number of insects moving or where they move.



1. (10 pts) Provide a minimal correct state space representation? What is the state-space size?

Important note. Your computation should be for the general rectangular maze-like environment (not for the example provided).

Answer. A tuple $((x, y))$ encoding the (x) and (y) coordinates of the insect. The size of the state is (MN) .

Explanation. The position tuple is enough to calculate the goal test and successor functions.

Goal test: $(x,y)=\text{Goal}$

Successor: Similar to Pacman successors. EAST changes (x,y) to $(x+1,y)$, for example.

There are MN total values that the position (x,y) can take.

2. (10 pts) Provide two heuristics which are admissible.

Answer. (i) Manhattan distance from the insect's location to the hive; and (ii) Euclidean distance from the insect's location to the hive.