COMP7015 Artificial Intelligence **Semester 1, 2022/23**

Sample Solution to Written Assignment 1

Instructor: Dr. Kejing Yin Oct. 7, 2022

Problem 1: Formulating a Search Problem

Q1: The missionaries and cannibals problem can be formulated as follows:

(1) To define the **states**, we denote the number of missionaries, cannibals, and boat on the left side of the river by an array (m, c, b). Correspondingly, the number of missionaries, cannibals, and boat on the other side of the river are given by $3 - m$, $3 - c$, and $1 - b$.

(2) The **initial state** then can be denoted by $(3, 3, 1)$, i.e., three missionaries, three cannibals and one boat are on the left side of the river.

(3) The **goal state** is defined by $(0, 0, 0)$, i.e., all missionaries, cannibals and the boat are on the other side of the river.

(4) We use pq to denote an action of moving p missionaries and q cannibals across the river and use symbols $\rhd$ and $\lhd$ to denote the direction of moving people. The **all possible actions can be given by**: $01\rhd$, $02\rhd$, $10\rhd$, $11\rhd$, $20\rhd$, $01\lhd$, $02\lhd$, $10\lhd$, $11\lhd$, and $20\lhd$.

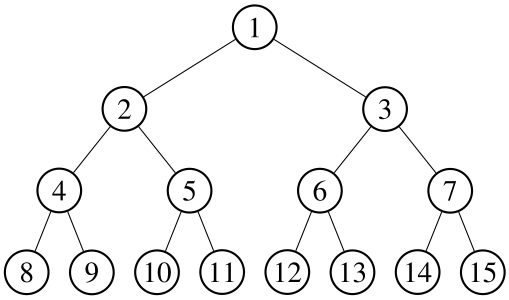
Q2: The state space is drawn in Fig. 1.

Q3: Either one of the following will be the correct answer:

- **BFS** or **uniform-cost search** as they both guarantee a cost-optimal solution.
- **Iterative deepening search** as it saves memory and guarantees to find a solution. Besides it is not required in this problem to find the cost-optimal solution, so even though it may not give the cost-optimal solution, it is still acceptable.

Problem 2: Uninformed Search

Q1: The portion of the state space for states 1 to 15 is as follows.



Q2: The order of visited nodes are as follows:

(1) **BFS**: 1, 2, 3, 4, 5, 11 *(if goal state is check when generating a node; recommended)*;

or 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 *(if goal state is check when expanding a node)*.

(2) **DFS**: 1, 2, 4, 8, 9, 5, 10, 11

(3) **Depth-limited search with limit 3**: 1, 2, 4, 8, 9, 5, 10, 11

(4) **Iterative deepening search**: 1, 1, 2, 3, 1, 2, 4, 5, 3, 6, 7, 1, 2, 4, 8, 9, 5, 10, 11

Q3: The tree-like DFS is the best algorithm to use. First, the state space is acyclic, so there will be no infinite loop issue. Second, when the goal state is a large number, other algorithms will require a lot of memory to store the visited list while tree-like DFS only require a small amount of memory.

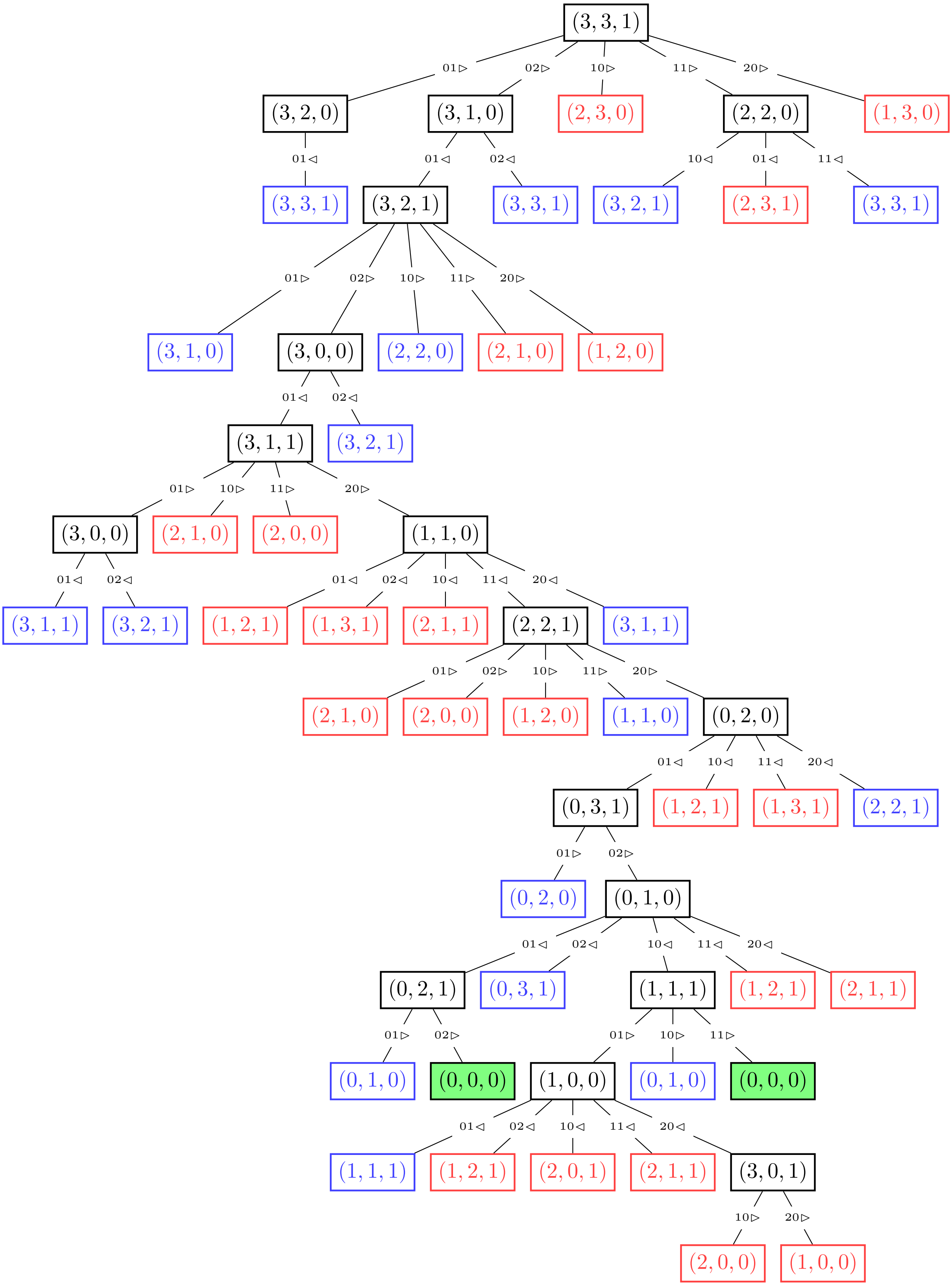
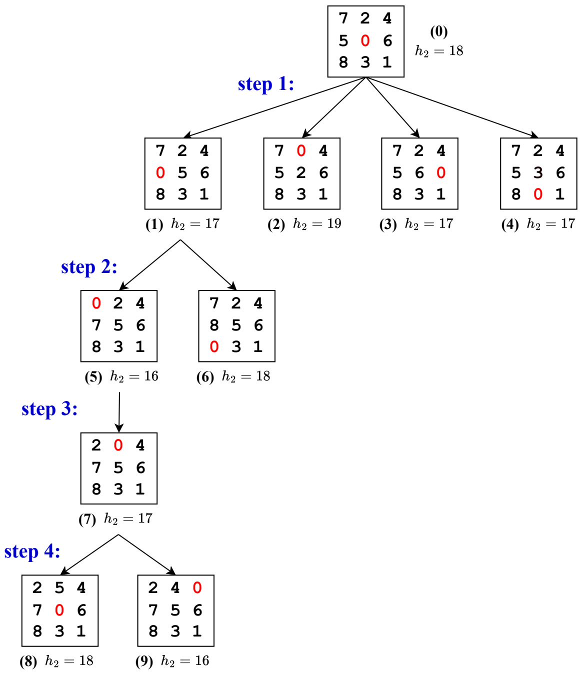


Figure 1: The complete state space of the missionaries and cannibals problem. The nodes in blue represent repeated states and that in red represent the states that violate the rules; therefore, they are not further expanded. The shaded in green are the goal states.

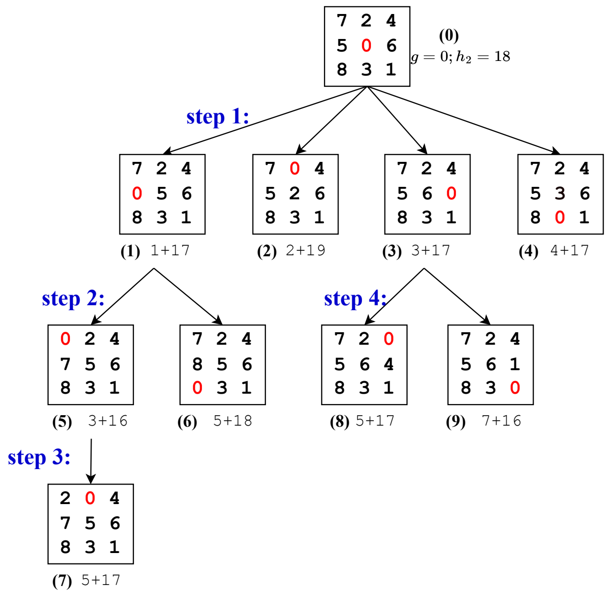
Problem 3: Heuristic Search (40 marks)

Q1: h_1 is admissible because for each misplaced number, it requires at least one step to recover it. So h_1 will not be larger than the actual cost for all states. h_2 is also admissible because for each misplaced tile, the minimum number to move it to the correct place is the Manhattan distance (since the tile can only move horizontally and vertically) between its current location and the goal location. Since there are other numbers blocking this shortest way, it will always take steps no less than the Manhattan distance. Therefore, h_2 will never overestimate the actual cost.

Q2: h_2 is a better heuristic function as it is a more accurate estimation of the cost from each state to the goal state. It is always grater than or equal to h_1 yet still admissible.



(a) Greedy Search



(b) A* Search. The numbers underneath each state are in the format of $g(n) + h_2(n)$, where g is the cost and h_2 is the heuristic function.

Figure 2: An example of the portion of the search tree after the first four steps using greedy search and A* search.

Q3: The resulting portion of the search tree is shown in Fig. 2a. In the first step, (0) is expanded because it is the only node in the frontiers. In the second step, (1), (3), and (4) have the smallest heuristic function h_2, so we randomly choose one to expand. In this example solution, we expand (1). In the third step, (5) is the node with smallest h_2, so we expand (5). In the fourth step, (3), (4), and (7) all have the same smallest h_2, so we randomly choose one. In this example solution, we expand (7).

Q4: The resulting portion of the search tree is shown in Fig. 2b. The numbers underneath each state are in the format of $g(n) + h_2(n)$, where g is the cost and h_2 is the heuristic function. In the first step, (0) is expanded because it is the only node in the frontiers. In the second step, (1) has the smallest $g + h_2 = 18$, so we expand (1). In the third step, (5) has the smallest $g + h_2 = 19$, so we expand (5). In the fourth step, (3) has the smallest $g + h_2 = 20$, so we expand (3).

Remarks: In the assignment question, although we stated that the cost of moving left, up, right, and down are 1, 2, 3, and 4, respectively, the $f = 1$ shown in the example figure appears to be confusing. Therefore, if you treat the cost of the four moves as all 1 and compute $g + h_2$ based on this uniform cost, your scores will not be deducted. The key is that you select the node with smallest $g + h_2$ from the frontiers list in every step.