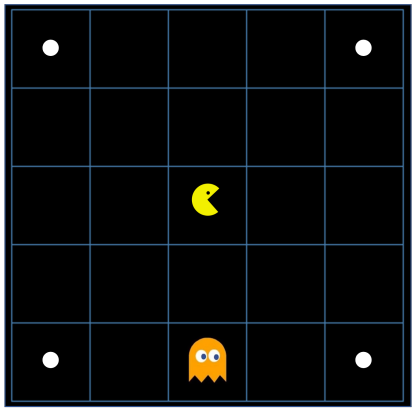
COMP 6721 Applied Artificial Intelligence (Winter 2023)

Assignment #1: State Space Search and Adversarial Search

Due: 11:59PM, February 5th, 2023

State Space Search

Question 1 Consider the simplified Pac-Man problem shown in the figure below, which is given as a 5×5 grid environment. In this version of the game, the Pac-Man starts in the center of the grid, with 4 food items in the grid corners. The goal is to eat the 4 food items while avoiding the ghost. An illegal state is one where both the Pac-Man and the Monster are in the same location. For simplicity, we assume that at each time step, the ghost moves first then the Pac-Man. Each agent can move one grid horizontally or vertically at each time step.



(a) Represent this problem as a search problem (for the Pac-Man) and choose a representation from the problem's states. Each state should be represented as a tuple. **Note:** if a certain attribute is not important when representing a certain state(s), you can use X to indicate "not important".

(b) Write down the initial state (as shown in the image).

(c) Write down the goal state.

(d) What are the possible actions for the Pac-Man?

(e) Draw 2 levels (2 steps) of the state space for this problem showing all possible states. Assume that the ghost is idle during these steps.

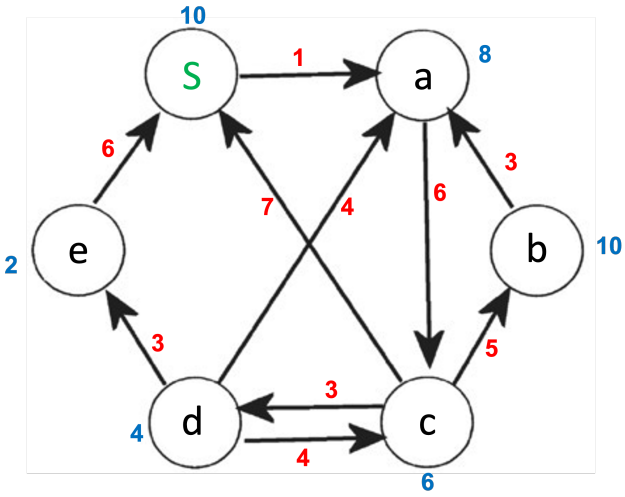
(f) Draw 1 level (1 Pac-Man step) of the state space for this problem showing all possible states. Assume that the ghost takes a moving step before the Pac-Man.

(g) How many illegal states are there? Give 4 examples of illegal states.

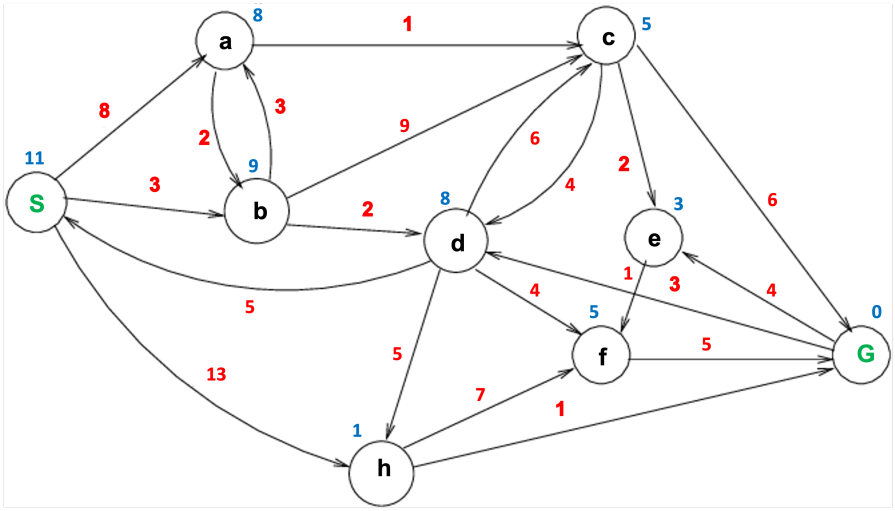
Question 2 For each of the following graphs/trees, use the following search strategies to show the states visited, along with the open and closed lists at each step (where it applies). The value on each node reflects a heuristic, while the edges are given cost values. You are required to explore the graph/tree starting from node S until the goal node G is explored or until no more nodes can be visited. **Nodes of equal importance should be explored in an alphabetical order (whenever the order is not specified by the algorithm itself, use alphabetical order).**.

Search strategies: BFS, DFS, Iterative Deepening DFS, Uniform cost search, Hill Climbing, Best-first search, Algorithm A.

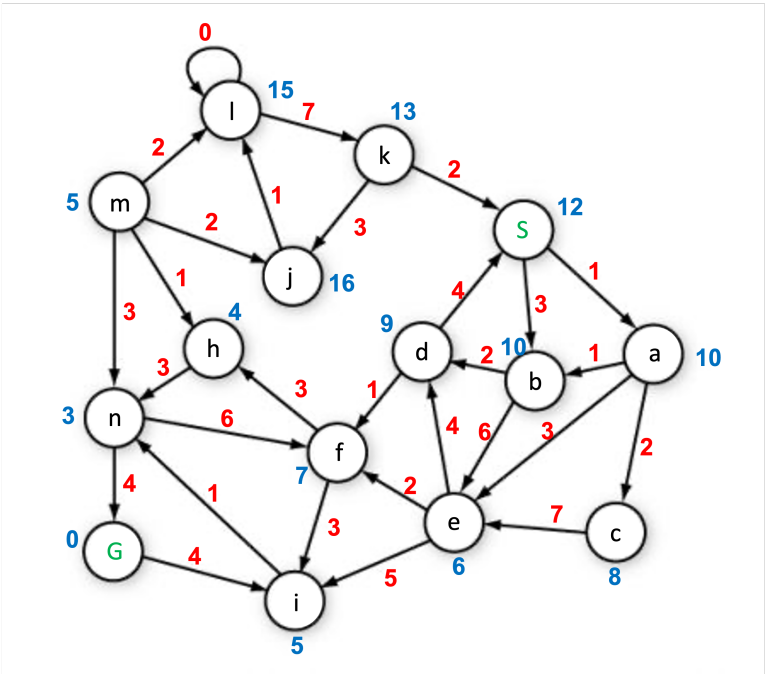
(a) S → "No Goal"



(b) S → G



(c) S → G



Question 3 The map below shows the distances (in miles) between some major cities in the US. Your friend is traveling from Chicago (Start) to New York (Goal) and needs your help to find the route with the shortest distance (in miles). Note: your answers should be based on the costs given, no heuristic values are available.

(a) From the list of search methods given in the previous question, which search method can you use to find the route with the shortest distance?

(b) Apply your search method of choice to the problem. Show the states (cities) visited, along with the open and closed lists at each step (if it applies). Stop once the goal state (New York) is visited.

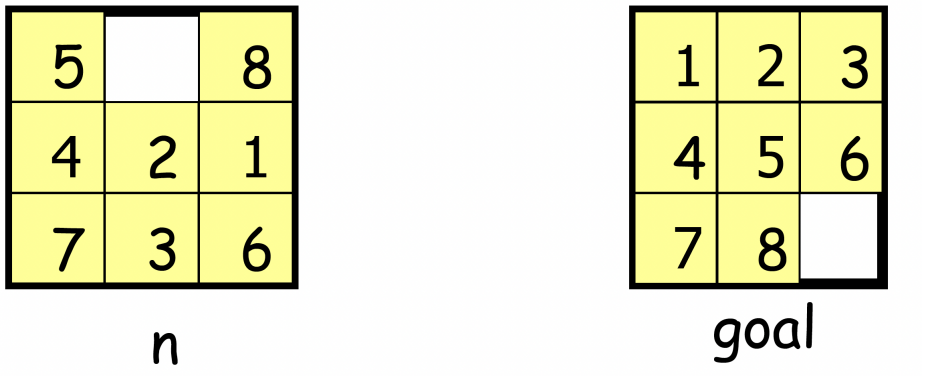
(c) Based on your search method, what route should your friend follow? What is the cost of this path?

Question 4 In this question, you will be asked to prove and design admissible and monotonic (consistent) heuristics for varying problems.

(a) An example of an 8-puzzle is given in the figure below. The goal is to move the tiles one at a time until the goal is reached, in which the tiles are ordered. Given a state n, prove that the following heuristic for the 8-puzzle is admissible:

$$h(n) = \sum_{i=1}^{8} Manh(T_{i,n}, T_{i,g}) \tag{1}$$

where $T_{i,n}$ is position of tile i in state n, $T_{i,g}$ is the position of tile i in the goal state, and $Manh(T_{i,n}, T_{i,g})$ is the Manhattan Distance between tiles $T_{i,n}$ and $T_{i,g}$.



(b) For the Pac-Man problem given in Question 1, design an admissible heuristic that gives a value for each state. You can completely ignore the existence of the ghost.

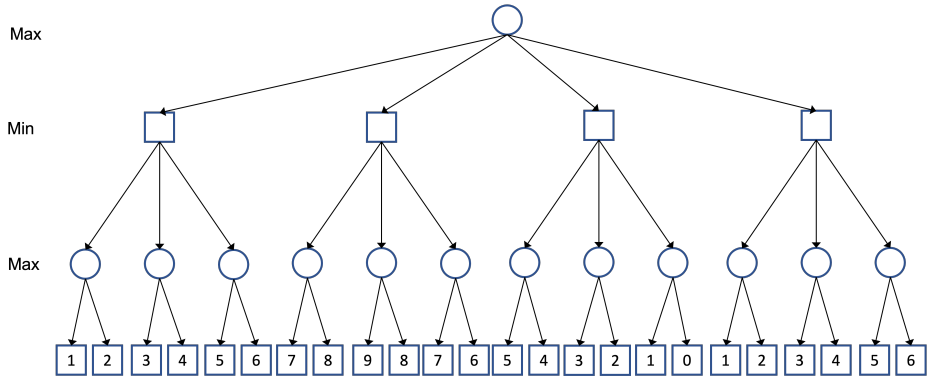
Adversarial Search

Question 1 For each of the following trees:

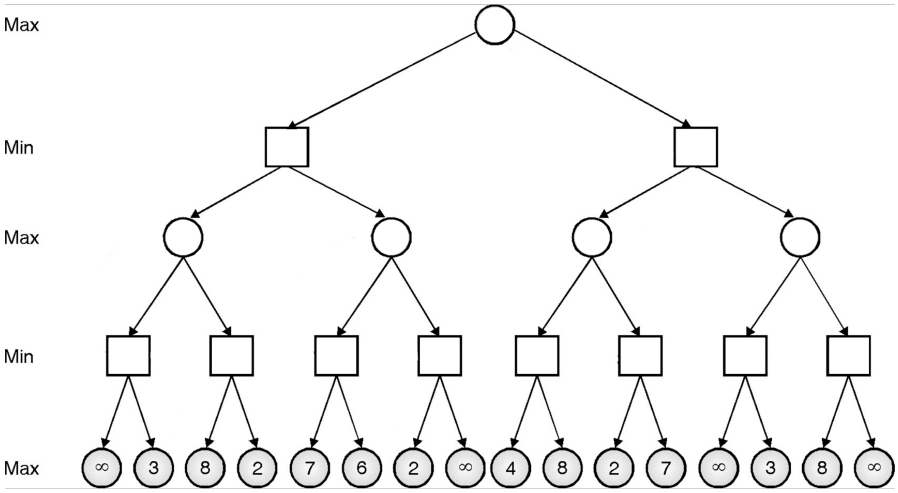
- Compute the minimax game values for all the given nodes.
- Explore the tree using Alpha-Beta pruning. Indicate all parts of the tree that are pruned, and indicate the winning path or paths. For each node, show the alpha/beta values throughout the process
- Re-draw the trees (with minimax values) by re-ordering the children of each internal node (maintaining an equivalent tree) such that the pruning is maximized.

- Preform alpha-beta pruning again on the re-ordered trees and indicate the difference in pruning (total number of nodes pruned compared to the previous version of the tree).

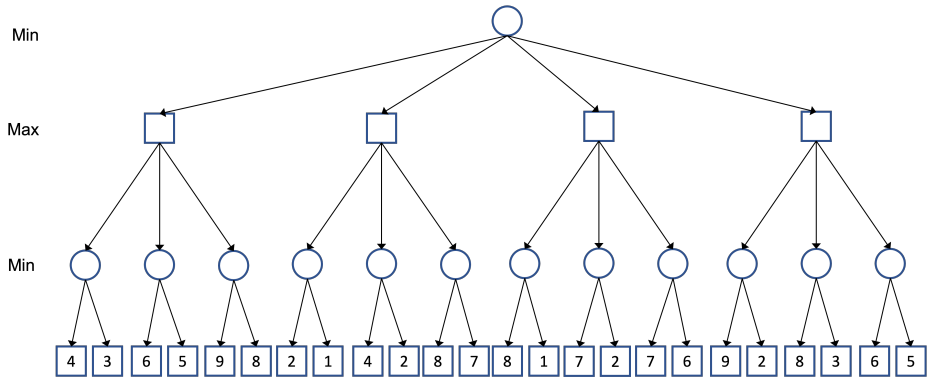
(a) ..



(b) ..



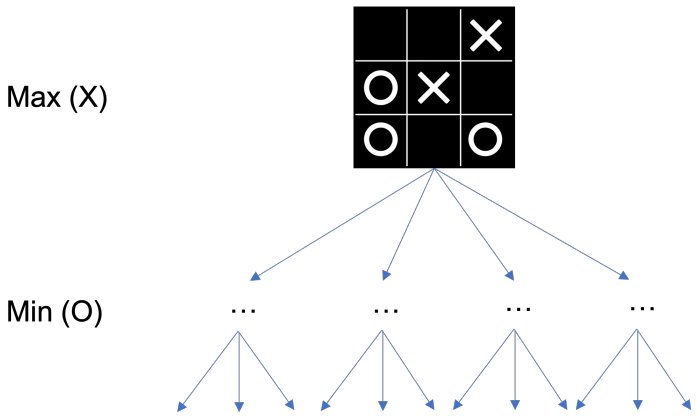
(c) ..



Question 2 In the example below, you are the X player in a tic-tac-toe game, with 4 possible moves. For each of your possible moves, the O player has 3 possible moves.

To evaluate a certain scenario, you use the following evaluation function:

value $V = 0$
for all rows, columns, diagonals R **do**:
    if R contains three Xs **then**:
        $V = V + 1000$
    else if R contains three Os **then**:
        $V = V - 1000$
    else if R contains two Xs **then**:
        $V = V + 100$
    else if R contains two Os **then**:
        $V = V - 100$
    else if R contains one X **then**:
        $V = V + 10$
    else if R contains one O **then**:
        $V = V - 10$
    end if
end for
return V



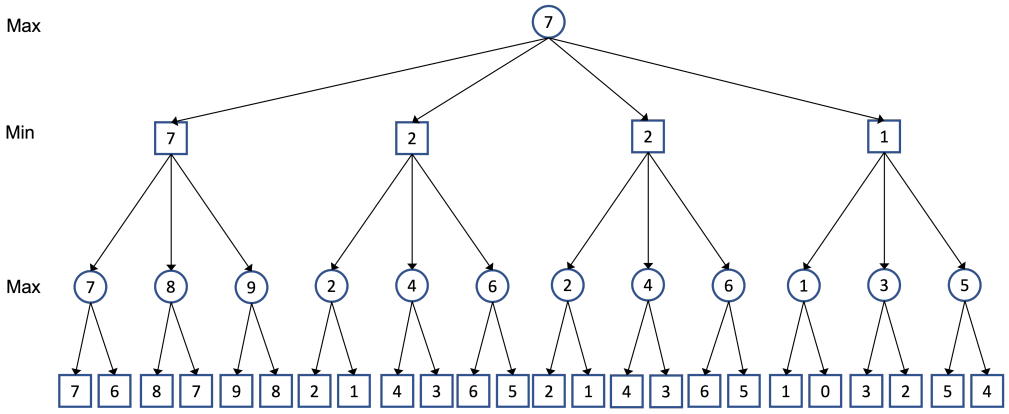
Draw all the possible configurations following the actions of player X (4 configurations) and player O ($4 \times 3 = 12$ configurations). Evaluate the last layer of configurations using the aforementioned evaluation function, and compute the minimax game values for the rest of the nodes. Indicate the winning path.

Question 3 Ahmed and Soorena are involved in a big argument. The figures below show two equivalent trees, A and B. Ahmed claims that the alpha-beta pruning in tree A is maximized, while Soorena claims that the pruning is maximize in tree B. Your help is needed! Which tree has the maximized pruning (more nodes pruned)? Use alpha-beta pruning to find the number of nodes pruned. After declaring the winner between Ahmed and Soorena, you need to provide a

justification for the conclusion you reached. In your justification, use the main idea of ordering the nodes of a tree to get a maximum cutoff.

* Disclaimer: Ahmed and Soorena will maintain full professionalism while grading this question, regardless of who you declare as the winner ☺.

Tree A:



Tree B: