Exercise 1

An agent C is in charge of keeping everybody safe at a party. In particular, a party is considered safe when each cell contains a maximum of one person (to achieve social distancing). Hence, the agents job is to visit cells containing more than one person and make one of the two move to another cell. The task is complete when all cells are safe and do not contain more than one person. C can move in any adjacent cell, horizontally and vertically, but not diagonally. C can move only to empty cells or to cells containing two people to be separated apart. People do not move except when moved by the agent. The figure shows the environment where the party is organised on two floors with a ladder connecting cells cell-0-0-A and cell-0-0-B. The figure shows also the initial configuration, where the agent C is at is at location cell-2-1-A.

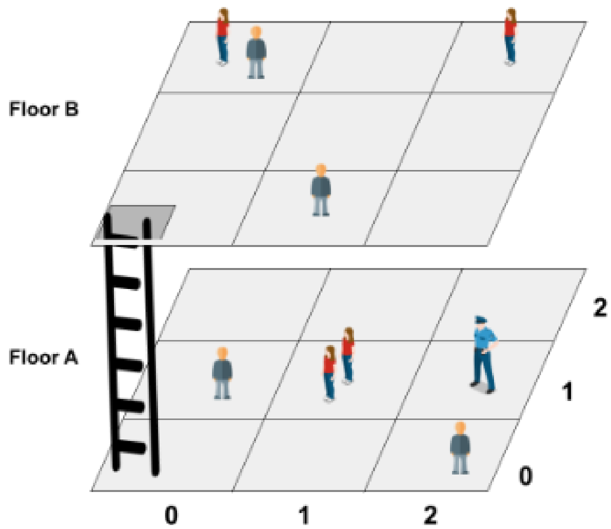

Figure 1: Domain

- (a) Model the problem in PDDL by defining the problem and domain files.
- (b) Show one possible sequence of actions leading to a goal state.
- (c) Draw the progression search graph up to the second level.

Exercise 2

Consider the following game tree corresponding to a two-player zero-sum game. Max is to start in the initial state (i.e., the root of the tree).

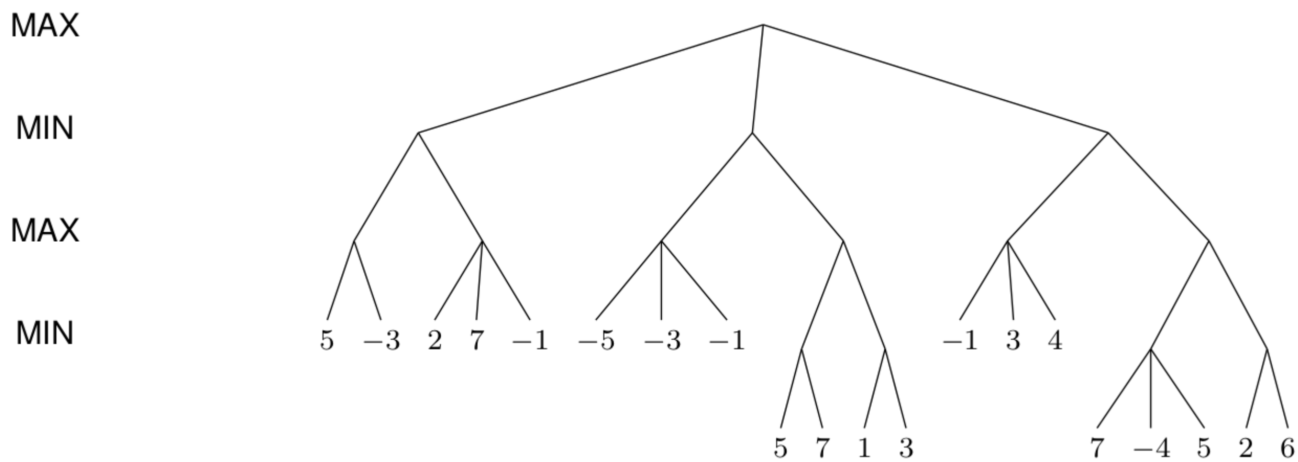

Figure 2: Game tree

- (a) Perform Minimax search on the tree, i.e., annotate all internal nodes with the correct Minimax value. Which move does Max choose?
- (b) Perform Alpha-Beta search on the tree. Annotate all internal nodes (that are not pruned) with the value that will be propagated to the parent node as well as the final $[\alpha, \beta]$ window before propagating the value to the parent. Mark which edges will be pruned. How many leaf nodes are pruned?
- (c) If possible, provide an example of reordering of leaf nodes that will results with more pruning performed.

Exercise 3

- (a) Transform the following formula in CNF specifying all the steps.

$$\neg((((A \land B) \to C) \land (A \lor B \lor C)) \to ((A \leftrightarrow B) \to C))$$

- (b) Use resolution to determine if this formula is inconsistent.

$$(\neg A \lor \neg D) \land (\neg A \lor D) \land (B \lor C \lor \neg D) \land (A \lor B) \land (\neg C \lor \neg D) \land (A \lor \neg B \lor \neg D) \land (A \lor \neg B \lor D)$$

- (c) Perform DPLL on the following formula to look for a satisfiable assignment. Assume that DPLL selects variables in alphabetical order (i.e., A, B, ...), and that the splitting rule first attempts the value False (F).

$$\{\{\neg B\}, \{A, B, C, D\}, \{\neg C, \neg D\}, \{C, \neg D\}, \{A, \neg B, D\}, \{A, \neg C\}\}$$

Exercise 4

Consider the state space in Figure 3, where A is the initial state and I the goal state. The transitions are annotated by their costs.

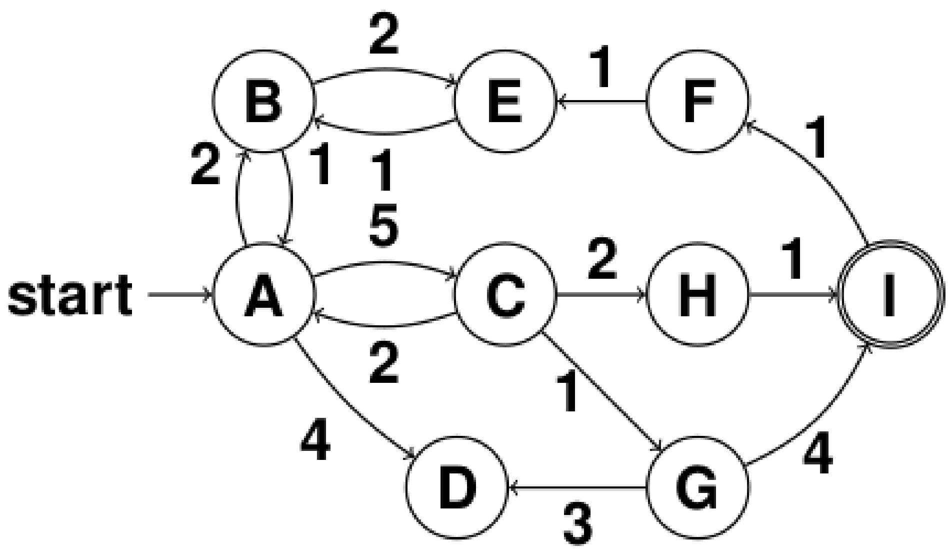

Figure 3: State space

- (a) Run the A^* search algorithm on this problem. As a heuristic estimate for a state s, use the minimal number of edges that are needed to reach a goal state from s (or ∞ if s is not solvable, e.g., h(C)=2). Draw the search graph and annotate each node with the g and h value as well as the order of expansion. Draw duplicate nodes as well, and mark them accordingly by crossing them out. If the choice of the next state to be expanded is not unique, expand the lexicographically smallest state first. Give the solution found by A^* search. Is this solution optimal? Justify your answer.
- (b) Run the hill climbing algorithm on this problem. Use the heuristic function from part (a). For each state, provide all applicable actions and the states reachable using these actions. Annotate states with their heuristic value. Specify which node is expanded in each iteration of the algorithm. If the choice of the next state to be expanded is not unique, expand the lexicographically smallest state first. Does the algorithm find a solution? If yes, what is it and is it optimal?
- (c) Could the hill-climbing algorithm stop in a local minimum without finding a solution? If yes, give an example heuristic h : $\{A, B, ..., I\} \rightarrow \mathcal{N}_0^+ \cup \{\infty\}$ for the state space depicted that leads hill-climbing into a local minimum, and explain what happens. If no, please explain why.