Q1. Search

For this problem, assume that all of our search algorithms use tree search, unless specified otherwise.

(a) For each algorithm below, indicate whether the path returned after the modification to the search tree is guaranteed to be identical to the unmodified algorithm. Assume all edge weights are non-negative before modifications.

(i) Adding additional cost $c > 0$ to every edge weight.

	Yes	No
BFS	○	○
DFS	○	○
UCS	○	○

(ii) Multiplying a constant $w > 0$ to every edge weight.

	Yes	No
BFS	○	○
DFS	○	○
UCS	○	○

(b) **For part (b)**, two search algorithms are defined to be **equivalent** if and only if they expand the same states in the same order and return the same path. **Assume all graphs are directed and acyclic.**

(i) Assume we have access to costs c_{ij} that make running UCS algorithm with these costs c_{ij} equivalent to running BFS. How can we construct new costs c'_{ij} such that running UCS with these costs is equivalent to running DFS?

○ $c'_{ij} = 0$ ○ $c'_{ij} = 1$ ○ $c'_{ij} = c_{ij}$

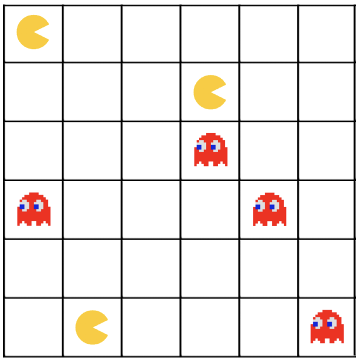
○ $c'_{ij} = -c_{ij}$ ○ $c'_{ij} = c_{ij} + \alpha$ ○ Not possible

Q2. Pacfriends Unite

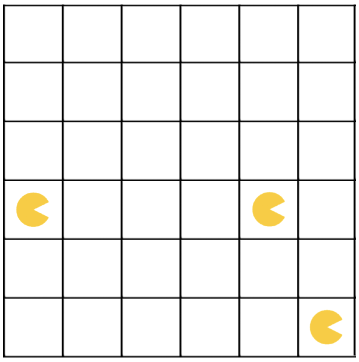
Pacman and his Pacfriends have decided to combine forces and go on the offensive, and are now chasing ghosts instead! In a grid of size M by N, Pacman and $P - 1$ of his Pacfriends are moving around to collectively eliminate **all** of the ghosts in the grid by stepping on the same square as each of them. Moving onto the same square as a ghost will eliminate it from the grid, and move the Pacman into that square.

Every turn, Pacman and his Pacfriends may choose one of the following four actions: *left, right, up, down*, but may not collide with each other. In other words, any action that would result in two or more Pacmen occupying the same square will result in no movement for either Pacman or the Pacfriends. Additionally, Pacman and his Pacfriends are **indistinguishable** from each other. There are a total of G ghosts, which are indistinguishable from each other, and cannot move.

Treating this as a search problem, we consider each configuration of the grid to be a state, and the goal state to be the configuration where **all** of the ghosts have been eliminated from the board. Below is an example starting state, as well as an example goal state:



(a) Possible Start State



(b) Possible Goal State

Assume each of the following subparts are **independent** from each other. **Also assume that regardless of how many Pacmen move in one turn, the total cost of moving is still 1.**

(a) Suppose that Pacman has no Pacfriends, so $P = 1$.

(i) What is the size of the minimal state space representation given this condition? Recall that $P = 1$.

○ MN
○ MNG
○ $(MN)^G$
○ $(MN)^{G+1}$
○ 2^{MN}
○ 2^{MN+G}
○ $G(2)^{MN}$
○ $MN(2)^G$

For each of the following heuristics, select whether the heuristic is only admissible, only consistent, neither, or both. Recall that $P = 1$.

(ii) $h(n)$ = the sum of the Manhattan distances from Pacman to every ghost.

○ only admissible
○ only consistent
○ neither
○ both

(iii) $h(n)$ = the number of ghosts times the maximum Manhattan distance between Pacman and any of the ghosts.

- ◯ only admissible
- ◯ only consistent
- ◯ neither
- ◯ both

(iv) $h(n)$ = the number of remaining ghosts.

- ◯ only admissible
- ◯ only consistent
- ◯ neither
- ◯ both

(b) Suppose that Pacman has exactly one less Pacfriend than there are number of ghosts; therefore $P = G$. Recall that Pacman and his Pacfriends are indistinguishable from each other.

(i) What is the size of the minimal state space representation given this condition? Recall that $P = G$.

- ◯ MNP
- ◯ $MNGP$
- ◯ $(MN)^G$
- ◯ $(MN)^{(G+P)}$
- ◯ $(MN)^P 2^G$
- ◯ $(MN)^G P$
- ◯ $(MN)^{G+1}$
- ◯ $(MN)^{(G+1)P}$
- ◯ $\binom{MN}{P}$
- ◯ $\binom{MN}{P} 2^G$
- ◯ $\binom{MN}{P}(MN)^G$
- ◯ $\binom{MN}{P}\binom{MN}{G}$
- ◯ 2^{MN}
- ◯ 2^{MN+G+P}
- ◯ $GP(2)^{MN}$

For each of the following heuristics, select whether the heuristic is only admissible, only consistent, neither, or both. Recall that $P = G$.

(ii) $h(n)$ = the largest of the Manhattan distances between each Pacman and its closest ghost.

- ◯ only admissible
- ◯ only consistent
- ◯ neither
- ◯ both

(iii) $h(n)$ = the smallest of the Manhattan distances between each Pacman and its closest ghost.

- ◯ only admissible
- ◯ only consistent
- ◯ neither
- ◯ both

(iv) $h(n)$ = the number of remaining ghosts.

- ◯ only admissible
- ◯ only consistent
- ◯ neither
- ◯ both

(v) $h(n) = \frac{\text{number of remaining ghosts}}{P}$.

- ◯ only admissible
- ◯ only consistent
- ◯ neither
- ◯ both

Q3. [Optional] Local Search

(a) Hill Climbing

(i) Hill-climbing is complete. ☐ True ☐ False

(ii) Hill-climbing is optimal. ☐ True ☐ False

(b) Simulated Annealing

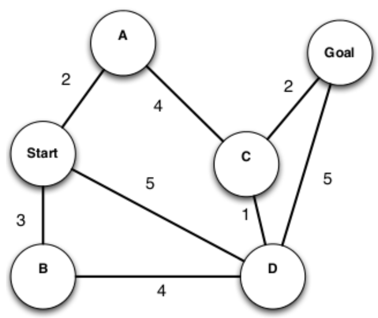
(i) The higher the temperature T is, the more likely the randomly chosen state will be expanded. ☐ True ☐ False

(ii) In one round of simulated annealing, the temperature is 2 and the current state S has energy 1. It has 3 successors: A with energy 2; B with energy 1; C with energy 1-ln 4. If we assume the temperature does not change, What's the probability that these states will be chosen to expand after S eventually?

(iii) On a undirected graph, If T decreases slowly enough, simulated annealing is guaranteed to converge to the optimal state. ☐ True ☐ False

(c) Local Beam Search

The following state graph is being explored with 2-beam graph search. A state's score is its accumulated distance to the start state and lower scores are considered better. Which of the following statements are true?



☐ States A and B will be expanded before C and D.

☐ States A and D will be expanded before B and C.

☐ States B and D will be expanded before A and C.

☐ None of above.

(d) Genetic Algorithm

(i) In genetic algorithm, cross-over combine the genetic information of two parents to generate new offspring.

☐ True ☐ False

(ii) In genetic algorithm, mutation involves a probability that some arbitrary bits in a genetic sequence will be flipped from its original state.

☐ True ☐ False