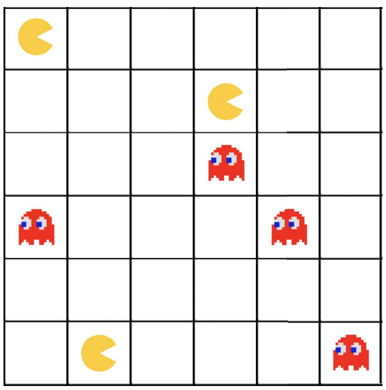
Q2. Pacfriends Unite

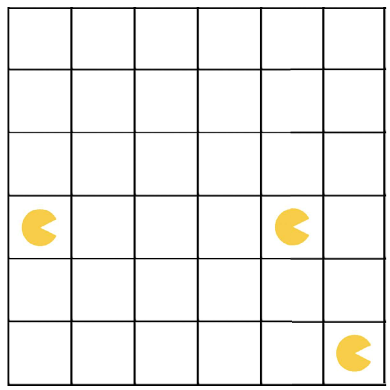
Pacman and his Pacfriends have decided to combine forces and go on the offensive, and are now chasing ghosts instead! In a grid of size M by N, Pacman and $P-1$ of his Pacfriends are moving around to collectively eliminate **all** of the ghosts in the grid by stepping on the same square as each of them.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