# CS 435 Artificial Intelligence: Homework 2
# Game Playing

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**Question 1-Depth First Search (DFS)**
The Depth First Search (DFS) will keep searching the path to the destination by first exploring the neighbor nodes that have not been reached. It doesn't care about the cost. Therefore, DFS will not necessarily find the optimal solution.

**tinyMaze:**
[SearchAgent] using function depthFirstSearch
[SearchAgent] using problem type PositionSearchProblem
Path found with total cost of 10 in 0.0 seconds
Search nodes expanded: 15
Pacman emerges victorious! Score: 500
Average Score: 500.0
Scores: 500.0
Win Rate: 1/1 (1.00)
Record: Win

**mediumMaze:**
[SearchAgent]: using function depthFirstSearch
[SearchAgent]: using problem type PositionSearchProblem
Path found with total cost of 130 in 0.0 seconds
Search nodes expanded: 146
Pacman emerges victorious! Score: 380
Average Score: 380.0
Scores: 380.0
Win Rate: 1/1 (1.00)
Record: Win

**bigMaze:**
[SearchAgent]: using function depthFirstSearch
[SearchAgent] using problem type PositionSearchProblem
Path found with total cost of 210 in 0.0 seconds
Search nodes expanded: 390
Pacman emerges victorious! Score: 300
Average Score: 300.0
Scores: 300.0
Win Rate: 1/1 (1.00)
Record: Win

**Question 2-Breadth First Search (BFS)**
If the cost of every step is the same, then BFS will always find the optimal path (with lowest cost) from the starting position to the destination.

**tinyMaze:**
[SearchAgent] using function bfs
[SearchAgent] using problem type PositionSearchProblem
Path found with total cost of 8 in 0.0 seconds
Search nodes expanded: 15
Pacman emerges victorious! Score: 502
Average Score: 502.0
Scores: 502.0
Win Rate: 1/1 (1.00)
Record: Win

**mediumMaze:**
[SearchAgent] using function bfs
[SearchAgent] using problem type PositionSearchProblem
Path found with total cost of 68 in 0.0 seconds
Search nodes expanded: 269
Pacman emerges victorious! Score: 442
Average Score: 442.0
Scores: 442.0
Win Rate: 1/1 (1.00)
Record: Win

**bigMaze:**
[SearchAgent] using function bfs
[SearchAgent] using problem type PositionSearchProblem
Path found with total cost of 210 in 0.1 seconds
Search nodes expanded: 620
Pacman emerges victorious! Score: 300
Average Score: 300.0
Scores: 300.0
Win Rate: 1/1 (1.00)
Record: Win

**Grad Stucent-Iterative Deepening Search:**
**tinyMaze:**
[SearchAgent] using function ids
[SearchAgent] using problem type PositionSearchProblem
Path found with total cost of 8 in 0.0 seconds
Search nodes expanded: 64
Pacman emerges victorious! Score: 502
Average Score: 502.0
Scores: 502.0
Win Rate: 1/1 (1.00)
Record: Win

**mediumMaze:**
[SearchAgent] using function ids
[SearchAgent] using problem type PositionSearchProblem
Path found with total cost of 70 in 0.2 seconds
Search nodes expanded: 8580
Pacman emerges victorious! Score: 440
Average Score: 440.0
Scores: 440.0
Win Rate: 1/1 (1.00)
Record: Win

**bigMaze:**
[SearchAgent] using function ids
[SearchAgent] using problem type PositionSearchProblem
Path found with total cost of 210 in 1.7 seconds
Search nodes expanded: 60211
Pacman emerges victorious! Score: 300
Average Score: 300.0
Scores: 300.0
Win Rate: 1/1 (1.00)
Record: Win

**Question 3-Uniform Cost Search (UCS):**
**mediumMaze:**
[SearchAgent] using function ucs
[SearchAgent] using problem type PositionSearchProblem
Path found with total cost of 68 in 0.0 seconds
Search nodes expanded: 269
Pacman emerges victorious! Score: 442
Average Score: 442.0
Scores: 442.0
Win Rate: 1/1 (1.00)
Record: Win

**mediumDottedMaze:**
Path found with total cost of 1 in 0.0 seconds
Search nodes expanded: 186
Pacman emerges victorious! Score: 646
Average Score: 646.0
Scores: 646.0
Win Rate: 1/1 (1.00)
Record: Win

**mediumScaryMaze:**
Path found with total cost of 68719479864 in 0.0 seconds
Search nodes expanded: 108
Pacman emerges victorious! Score: 418
Average Score: 418.0
Scores: 418.0
Win Rate: 1/1 (1.00)
Record: Win

**Grad Stucent-New Cost Fuction for UCS:**
In this question set, I implemented a new cost function for UCS algorithm to solve the maze problem. The new cost function considers two modes of cost calculation: one is for finding all the food, and another is for escapeing the nearby ghosts. The cost function will fist find the nearest food and ghost and compare the distances from the current position to them. If the distance between the nearest ghost and the current position is short than that of the nearest food, then the mode will be "escape". Otherwise, the mode will be "eat". The mode will switch during the searching process according to the position of the pacman.

In the "eat" mode, the cost will simply be the manhattan distance between the nearest food and the current position of the pacman. In the "escape" mode, the cost function will first find the nearest ghosts locat at each side (north, south, east, and west) of the pacman. If the nearest ghost is at the north side, then the cost function will assign more cost when the next state is going north (one ghost might belong to two sides of the pacman). For finding the nearest ghost at the north side, the equation will be

$$\text{northNearest} = \text{maxX} + \text{maxY} - \text{util.manhattanDistance(pos, g)}$$

where "pos" is the current position of the pacman, "g" is the position of a ghost, and maxX and maxY are the length and width of the maze. The more the value, the nearer the ghost is. The cost function will use the same equation to find the value of each ghost at four sides. The cost function will then assign cost according to vertical direction and horizontal direction. And when the nearest ghost is at the north or south side, the cost for ghost will be:

$$\text{ghostCost} \mathrel{+}= (\text{northNearest} + 1.0) \,/\, (\text{southNearest} + 1.0)$$

Or, if the nearest ghost is at the east or west side, the cost for the ghost will be:

$$\text{ghostCost} \mathrel{+}= (\text{eastNearest} + 1.0) \,/\, (\text{westNearest} + 1.0)$$

The intuition for these equation is from the "StayEastSearchAgent" and "StayWestSearchAgent". For example, when a nearest ghost is at the north side, then "northNearest" must be larger than "southNearest". So when next step is going north, the cost will increase. Hence, it will encourage the pacman to go south.

If the cost function only considers the food, then the pacman will encounter the ghost very easily. So the problem is divided into several subproblems. Some part of the searching process is escaping the ghost, and when the ghost is far away, the searching process will switch to finding foods. Although this cost function might make the pacman to walk more steps, it can make the pacman safer since the pacman can have the ghost-escaping ability. This assigment only calculate the cost and find the path before the game starts. If it can recalculate the cost each time when the ghosts move, then we might be able to see the interaction of the pacman with the environemtn.

For the detailed result of this question, please see the content in the next page.

**mediumMaze:**
Path found with total cost of 68 in 0.0 seconds
Search nodes expanded: 259
Pacman emerges victorious! Score: 442
Average Score: 442.0
Scores: 442.0
Win Rate: 1/1 (1.00)
Record: Win

**mediumDottedMaze:**
Path found with total cost of 74 in 0.0 seconds
Search nodes expanded: 146
Pacman emerges victorious! Score: 646
Average Score: 646.0
Scores: 646.0
Win Rate: 1/1 (1.00)
Record: Win

**mediumScaryMaze:**
Path found with total cost of 92 in 0.0 seconds
Search nodes expanded: 226
Pacman emerges victorious! Score: 418
Average Score: 418.0
Scores: 418.0
Win Rate: 1/1 (1.00)
Record: Win

**Question 4-A* search using manhattanHeuristic:**
**tinyMaze:**
[SearchAgent] using function astar and heuristic manhattanHeuristic
[SearchAgent] using problem type PositionSearchProblem
Path found with total cost of 8 in 0.0 seconds
Search nodes expanded: 14
Pacman emerges victorious! Score: 502
Average Score: 502.0
Scores: 502.0
Win Rate: 1/1 (1.00)
Record: Win

**mediumMaze:**
[SearchAgent] using function astar and heuristic manhattanHeuristic
[SearchAgent] using problem type PositionSearchProblem
Path found with total cost of 68 in 0.0 seconds
Search nodes expanded: 222
Pacman emerges victorious! Score: 442
Average Score: 442.0
Scores: 442.0
Win Rate: 1/1 (1.00)
Record: Win

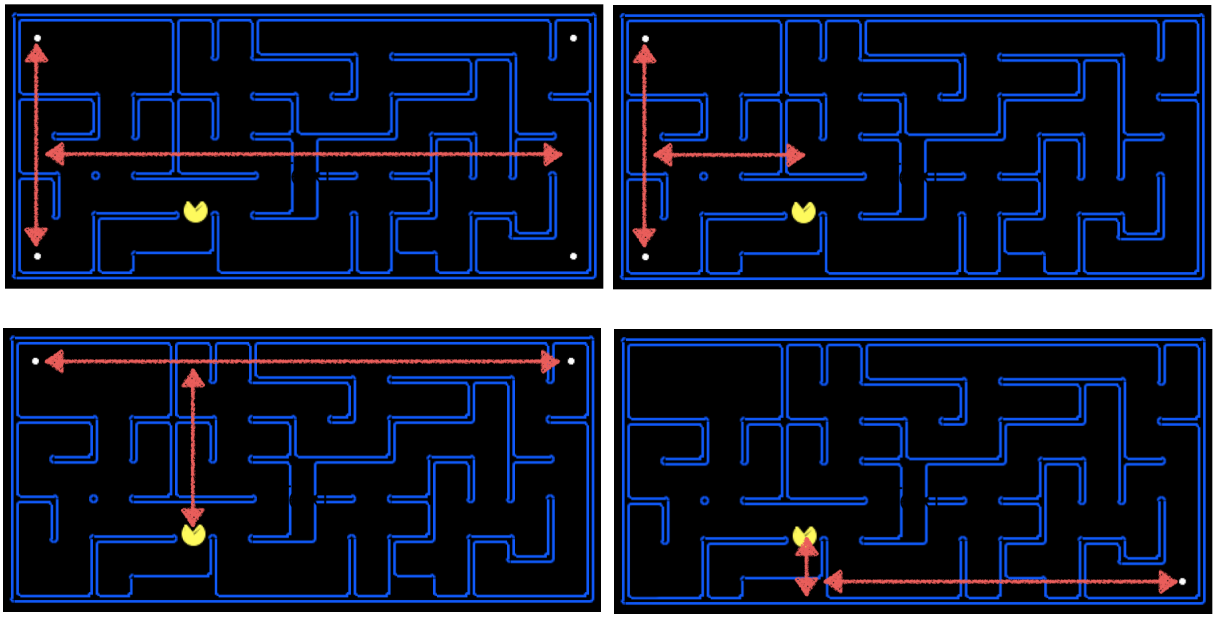
**bigMaze:**
[SearchAgent] using function astar and heuristic manhattanHeuristic
[SearchAgent] using problem type PositionSearchProblem
Path found with total cost of 210 in 0.2 seconds
Search nodes expanded: 549
Pacman emerges victorious! Score: 300
Average Score: 300.0
Scores: 300.0
Win Rate: 1/1 (1.00)
Record: Win

**Question 5-Solves the corners problem with a BFS agent:**
**tinyCorners:**
[SearchAgent] using function bfs
[SearchAgent] using problem type CornersProblem
Path found with total cost of 28 in 0.0 seconds
Search nodes expanded: 252
Pacman emerges victorious! Score: 512
Average Score: 512.0
Scores: 512.0
Win Rate: 1/1 (1.00)
Record: Win

**mediumCorners:**
[SearchAgent] using function bfs
[SearchAgent] using problem type CornersProblem
Path found with total cost of 106 in 0.3 seconds
Search nodes expanded: 1966
Pacman emerges victorious! Score: 434
Average Score: 434.0
Scores: 434.0
Win Rate: 1/1 (1.00)
Record: Win

**Grad Student-Heuristic for corner problem**

For the corner problem, I implemented a new heuristic that needs 179 and 931 search nodes expanded for "tinyCorners" and "mediumCorners" respectively (for more detail, please see the results shown below). The basic idea of this heuristic is to find the longest distance of corners and the current position for the vertical and horizontal aspects. See the following examples:



The red line means the longest distance in the vertical and horizontal directions. I designed this heuristic because I thought that the cost should not only relate to the nearest unvisited corner but also relate to other unvisited corners. By only taking one distance in one direction into account, this algorithm is a consistent cost function since when the pacman walks one step, the heuristic cost (sum of the two distances) will change at most one and the cost for one step is one, making $h(n) \leq c(n, a, n') + h(n')$ hold true.

**tinyCorners:**

Path found with total cost of 28 in 0.0 seconds
Search nodes expanded: 179
Pacman emerges victorious! Score: 512
Average Score: 512.0
Scores: 512.0
Win Rate: 1/1 (1.00)
Record: Win

**mediumCorners:**

Path found with total cost of 106 in 0.2 seconds
Search nodes expanded: 931
Pacman emerges victorious! Score: 434
Average Score: 434.0
Scores: 434.0
Win Rate: 1/1 (1.00)
Record: Win

**Question 7-Solves the eating all the dots problem with A* with a null heuristic:**
**testSearch:**
[SearchAgent] using function astar and heuristic nullHeuristic
[SearchAgent] using problem type FoodSearchProblem
Path found with total cost of 7 in 0.0 seconds
Search nodes expanded: 14
Pacman emerges victorious! Score: 513
Average Score: 513.0
Scores: 513.0
Win Rate: 1/1 (1.00)
Record: Win

**trickySearch**
[SearchAgent] using function astar and heuristic nullHeuristic
[SearchAgent] using problem type FoodSearchProblem
Path found with total cost of 60 in 68.8 seconds
Search nodes expanded: 16688
Pacman emerges victorious! Score: 570
Average Score: 570.0
Scores: 570.0
Win Rate: 1/1 (1.00)
Record: Win

**Grad Student-Solves the eating all the dots problem with A* with a foodHeuristic:** For this food problem, I implemented a heuristic that finds the farest distance from the current position to the farest food. For the distance calculation, I used mazeDistance function to find the actual distance between any two nodes. The mazeDistance uses breadth first search, which is very time comsuming if we need to find many maze distances. To save the computation time, I also adpoted dynamic programming skill, using the "problem.heuristicInfo". The heuristic needs 10 and 4239 search nodes expanded for the tinySearch and trickySearch mazes respectively (for more detail, please see the results shown below). I designed this heuristic because I thought that the heuristic cost function should consider the farest distance to a food. When a pacman reach a nearest food, it still needs to go to the farest food eventually and that farest distance usually affects the final total steps more than the nearest one does.

This algorithm is consistent since when the pacman walks one step, the heuristic cost will change at most one and the cost for one step is still one, thus making $h(n) \leq c(n, a, n') + h(n')$ hold true.

**testSearch:**
Path found with total cost of 7 in 0.0 seconds
Search nodes expanded: 10
Pacman emerges victorious! Score: 513
Average Score: 513.0
Scores: 513.0
Win Rate: 1/1 (1.00)
Record: Win

**trickySearch:**
Path found with total cost of 60 in 7.4 seconds
Search nodes expanded: 4239
Pacman emerges victorious! Score: 570
Average Score: 570.0
Scores: 570.0
Win Rate: 1/1 (1.00)
Record: Win