CS 520 – Final Exam Q1

Finding Your Way

A Report by

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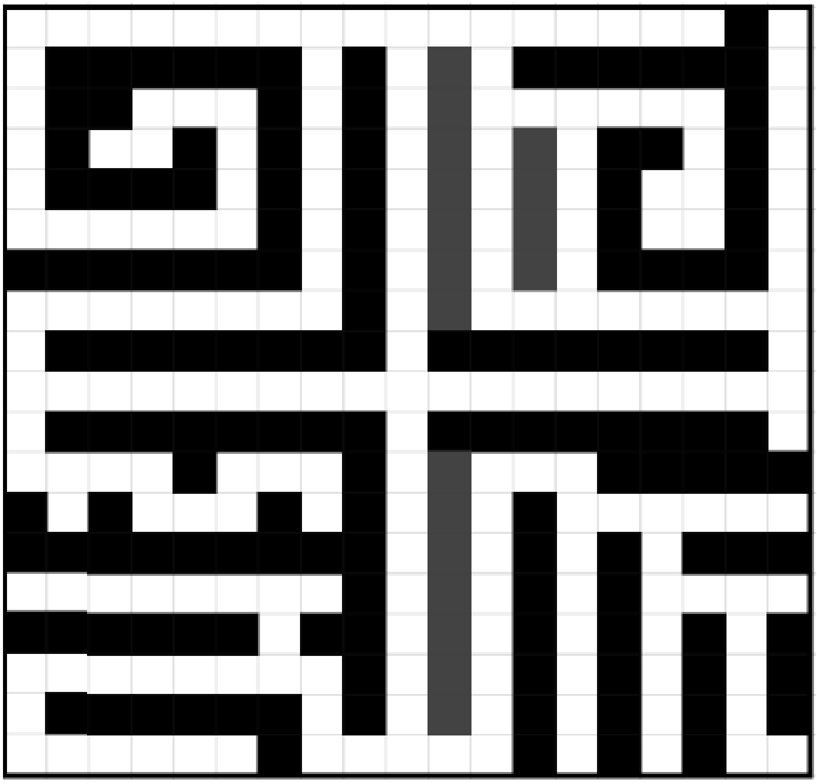
Environment:

In the give environment we have a maze similar to that of project 1 and our objective is to find a submarine drone with probability 1,using which we are required to shut down a hijacked nuclear reactor.

The repair sub drone is capable of moving from cell to cell within the reactor. However, there is a catch here, we actually don't know at any point of time where exactly the drone is at, due to the access methods we gained. The only functionality we have achieved is being able to pass on instructions to the drone in which direction it should move. But we can neither know the present position nor get response on where it has moved after an instruction is passed.

> **Question 1 (5 Points):** Before you do anything, what is the probability that the drone is in the top left corner? Why?

Given Reactor Schematic:



ANS: Initially, we have no information on where the drone is, i.e., it can be anywhere in the cells that are open (Not walls), in the given schematic there are 199 Open cells. Therefore, the Probability that the drone is in the top left corner is 1/199.

This is also the probability with which it can be in any of the open positions initially. So, we can initialize/fill the grid with 1/Open cells as the probability wherever it is Open.

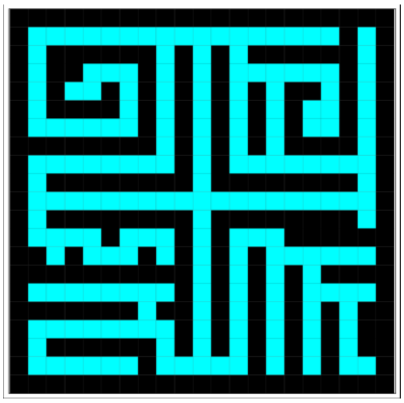
[Note: If the top-left corner is a wall then probability would be 0]

Consider issuing the command `DOWN'. While you don't know exactly where the drone is, you can say where it isn't - it isn't, for instance, in the top left corner anymore.

> **Question 2 (5 Points):** What are the locations where the drone is most likely to be? Least likely to be? How likely is it to be in all the other locations? Indicate your results visually.

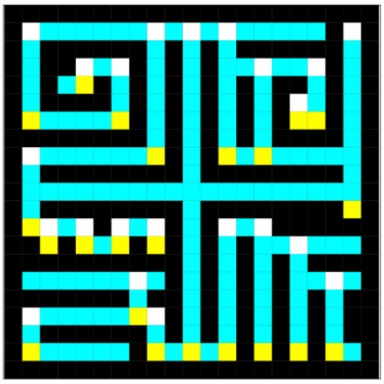
ANS: After passing few instructions and altering the states we can observe that the drone is more likely to be stuck at a wall. More precisely, greater the number of moves(directions), the drone can move at a location, the less likely it is going to stay there, accordingly wherever there are more walls around the drone restricting its movement, the drone is more likely to be there, let's call these states the Hotspots.

Let's perform the movement "Down" on the forementioned graph as suggested and observe what happens:



Initial State of the reactor

Here Cyan is the initial cold state but as we pass instructions, we can observe that the probabilities they converge to the Hotspots

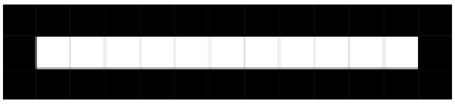


State of the reactor after move "DOWN" is applied.

Here, in our terms we can see by the movement down we were 100% sure that the drone would not be at positions like (0,0) (7,0) (2,3) which had no walls obstructing the down move and effectively the probability that it would be stuck at positions like (5,0) (3,3) etc would increase as the probability of the cell top to it gets added to it and the probability inside itself remains there as it has nowhere to go due to the wall. This way the heat of the position increases easily at positions where there are more walls obstructing the movements.

You realize that by issuing a sequence of instructions, you may be able to determine exactly where the drone is, and

thus, be able to use it to shut down the reactor.



Why can you do that here?

We can find the exact location here as, whatever possible move we take here converges the probabilities (rest of the moves[up, down] get blocked by walls) and effectively the probabilities get trapped at the ends of the grid.

One optimal way of doing it moving completely left 9 times or right 9 times.

Question 3 (25 Points): Write a program that takes a reactor schematic as a text file (see associated file for this reactor) and finds a sequence of commands that, at the end of which, you know *exactly* what cell the drone is located in. Be clear in your writeup about how you are formulating the problem, and the algorithms you are using to find this sequence.

What is the sequence for this reactor?

A Note on Expectations: There are many ways to formulate and solve this problem, but you should attempt to find the shortest possible sequence. Be clear and justify why your algorithm should output the shortest possible sequence, including any computational tricks or heuristics you might make use of. If you feel as though finding the shortest possible sequence is computationally infeasible, be clear and justify what you are doing to find a sequence that is as short as you can find. Solutions that are not guaranteed to find the shortest sequence may receive less credit, unless it is well justified why it should still generate short sequences. You can draw on anything from class in order to solve this problem. Your code should be commented, and it should be clear to the grader what each part of your code is doing, and that you know what your code is doing.

I have understood the statement "many ways to formulate this" can't get any better than this question,

Approach #1: There was the brute force moves method where I checked each set of moves possible which popped from my queue and added the following steps to the queue and so on till, I iterated throughout the whole maze. This approach worked fine and gave shortest sequences of moves for smaller mazes. But once I started scaling this it took forever to run.

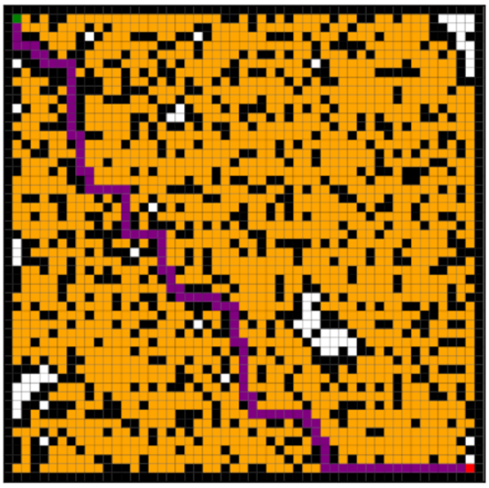
So, I scraped this Idea, and thought of a greedy approach

Approach #2: Here I simulate the 4 possible moves where I allot a reward to each simulation depending on the number of non-zero values(probabilities) left to converge and distance between farthest nodes because as these values reduced, I observed that we moved towards the goal state. But with this approach there was a point when the convergence stopped as the reward was equal to all 4 moves, and it couldn't decide which move to take. To resolve this, I added randomness to the move which would cause a change in values i.e., whenever the better move according to heuristic isn't changing the grid, I make a move other than that move, to create a change in values to keep the converging move forward.

The best value seemed to be 215 steps, with the greedy approach

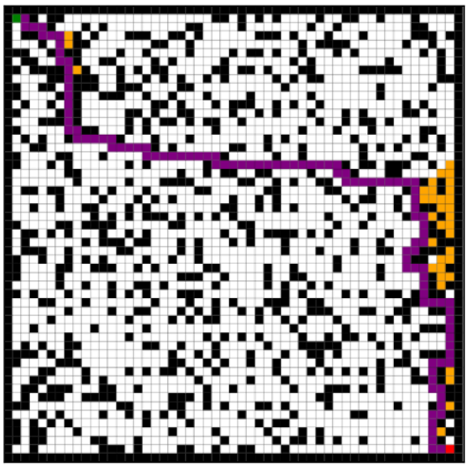
This seemed fine until I observed non-stability in the results, and there were few cases where it took forever to converge although I stopped immediate wiggling there were states which repeated and the heat values didn't converge.

Then I observed the approach #1 was right and accurate but just slow, which was the similar case we faced in for agent 2,3 in Project 1:Ghosts in the maze.



This is BFS, which to find the shortest path to a goal opened these many nodes(visited) represented in orange

To avoid this for agent 2 in project where we didn't need shortest path just an optimised algorithm which gives results quicker than BFS was required, Then there comes into play a variant of A* algorithm which I Used in Project 1, by providing a heuristic value which is more than the actual heuristic, we make the A* open much fewer nodes but the trade-off is ,it does not guarantee the optimal or shortest path, Effectively making it into a Best First Search Algorithm.



Here, we can see that Best First Search, though it did not give the very best possible path, it opened way lesser nodes

Depending on the heuristic provided the path lies between optimum and non-optimum with the trade-off being the computational time.

i.e., if you need faster results incline it towards Best first search which will enable you to get quick results but not optimal path, if you provide better heuristic, it will ensure you take the optimum path but will take more time to compute.

ANS 3): The Code is attached in the zip and is a IPYNB file, it has visualisations and necessary outputs.

Name the input file as input1.txt and place in the same directory and it works

Final Approach: The first approach where I used BFS of the state, instead of that, I used A*/Best First Search Approach, because I understood that A*/Best First Search will give me an optimal/almost optimal path in very less time.

The heuristic here from the observations involves:

1. We need to minimize the number of non-zero, which means they converged, and we are reaching to our end state.
2. We need to decrease the distance between the farthest positioned probabilities because doing this ensures that they are nearby and ready to converge.

Using this 2 information I applied the heuristic convergence and achieved a result that was optimal than my greedy approach, and the results are very quick.

Initially, I took the distances to be Manhattan distances between the points, but I later realized that the node must travel a BFS distance (shortest distance) to converge with the farthest node.

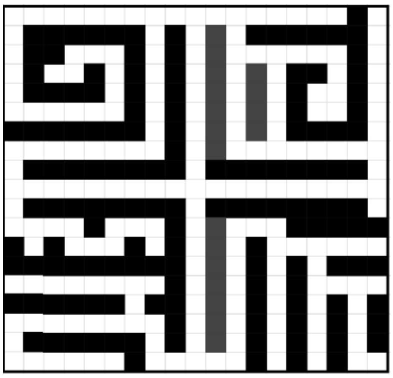
So, instead of Calculating BFS each time I pre-calculated the BFS for all open points in the grid to all open points and stored them for later usage and computational speed.

Upon adding this improvement, to the heuristic I observed a dip in speed, this showed my heuristic was moving towards A* and away from Best first search and the result of 208 steps confirmed that it was optimal than before.

Upon, trying to improve more, I remembered that the primary thing we are trying to reduce is the number of steps. So, including the number of steps in the heuristics and I had various trial and errors for the importance level of each of these metrics, using them properly in the heuristic enabled me to go even lower to a value of 135 steps.

Since the A* variant uses a heap which pops out the state with minimum value the more we improve the heuristic the optimal results we get. So, this way I can say that the result obtained is an optimal sequence.

The Sequence of steps for given question is:



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['LEFT', 'LEFT', 'UP', 'UP', 'UP', 'UP', 'UP', 'LEFT', 'LEFT', 'LEFT', 'UP', 'UP', 'LEFT',
'LEFT', 'LEFT', 'LEFT', 'LEFT', 'LEFT', 'LEFT', 'LEFT', 'LEFT', 'LEFT', 'LEFT', 'LEFT',
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'LEFT', 'UP', 'UP', 'UP', 'UP', 'RIGHT', 'RIGHT', 'RIGHT', 'RIGHT', 'RIGHT', 'RIGHT',
'RIGHT', 'RIGHT', 'RIGHT', 'RIGHT', 'RIGHT', 'RIGHT']
135
```

Representation and Final Result:

An in-between state with cold and hotspots denoted accordingly from cyan being least likely to red being most likely

The point at which it converges in the end

Question 4 (15 Points): Write a program that outputs a a 19x19 reactor schematic that has the longest possible sequence of commands needed to locate the drone that you can find. Be clear in your writeup about how you are formulating the problem, and the algorithms you are using to find this reactor schematic.

A Note on Expectations: There are many ways to formulate and solve this problem, though brute force is largely infeasible and unadvised. It is not required that you find the absolute worst possible schematic, but you should indicate clearly and justify why your approach will find bad schematics (forcing long command sequences). Less thorough and informed solutions may receive less credit. I would start with smaller dimensional reactors before scaling up.

Strategy to implement a maze generator which would be depending on the following statements:

1. Note that if the reactor had no internal separators and was totally empty, it would be easy to locate the drone; similarly, if the reactor had maximal internal separators to the point where only one cell was unblocked, it would be easy to locate the drone. The solution must be somewhere in the middle.

2. So, we know heuristic search is optimal, but whenever the heuristic is not admissible its ends up opening a greater number of nodes and if its admissible and more than actual value it ends up giving the longer path.

Consider the heuristic of Problem 3 we understood that we are far away from the solution (the sequence is still left) based on these metrics

1. We need to minimize the number of non-zero, which means they converged, and we are reaching to our end state.

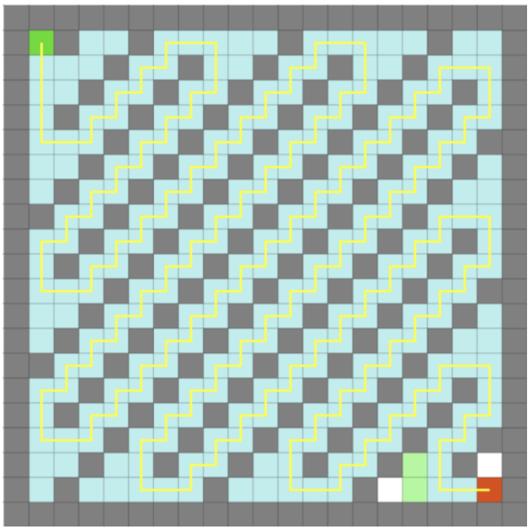
2. We need to decrease the distance between the farthest positioned probabilities because doing this ensures that they are nearby and ready to converge.

3. The length of sequence of moves has also to be minimized

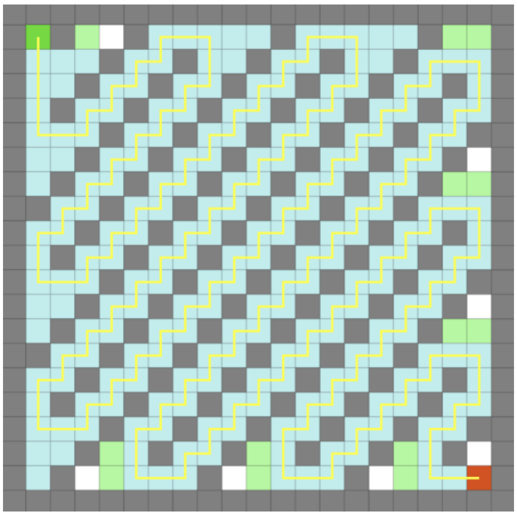
So, for a maze we need to make the initial starting BFS distance as maximum as possible so re-iterating Statement 2, if we can make that longest path as the only path that's one way, we can make sure the sequence of steps is maximized

Also the number of non-zero values present means, that you are that far from the solution. Similarly, information is given from Statement 1, we understand that number of open cells play a part too so add that to the heuristic while generating the maze and maintaining an optimum value helps

Also having a ,maze structure with walls blocking most of the cells when any direction move help to reduce the number of cell converging and therefore maximize the number of steps required.



Shortest path calculated by A*



Shortest Path by Best First Search

We can observe that the only path to the goal is the longest path, given A* gave shortest path and yet it is same as the Best first Search

Having a grid like this would mean:

1. The Open Cells are not too high and not too low just optimal
2. The Distance between Farthest Nodes is also high
3. The only path to the goal node is the shortest path

Therefore, by proofs above I can confirm that the above grid is one of the grids with most longest sequence of steps to complete