Project 2: Where is it?

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You are a LocatorBot. You know a space roomba was recently hired on your deep space salvage vessel *Nebulist*. Unfortunately, a blast of cosmic radiation accidentally fried its internal sensors, and it has no idea where it is, and cannot even see its surroundings.

Fortunately though, it is in radio contact with you, and you can issue commands to it to help it navigate. You don't know precisely where it is, but if it enters the location where you are, you'll be able to stick a radio tag on it and keep track of it in the future.

Based on the contents of Project 1, you could derive a sequence of commands to localize the space roomba, and then navigate it to you. Fortunately, however, you also have a Space Roomba Detector. If you activate it, you hear a beep (or no beep) based on how far away the space roomba is:

- $\mathbb{P}\left(\text{beep}|\text{LocatorBot in Cell } a, \text{SpaceRoomba in Cell } b\right) = e^{-\alpha(\text{dist}(a,b)-1)}$
- $\mathbb{P}\left(\text{no beep}|\text{LocatorBot in Cell } a, \text{SpaceRoomba in Cell } b\right) = 1 - e^{-\alpha(\text{dist}(a,b)-1)}$

where $\text{dist}(a, b)$ is the distance between cells a and cell b in the ship, and $\alpha > 0$ represents the sensitivity of the detector.

1 The Task

At the start, the roomba might be anywhere in the ship. Given the map of the ship, you can track the probability of the roomba being in any cell, based on a) the movement of the roomba based on the commands you issue, and b) the results you get from running the detector. The task is complete once you are certain which cell the roomba is in. If the roomba enters the cell you're located in, you immediately know the roomba is there.

2 Baseline Strategies

Note, these simulations, you'll need to actually initialize the space roomba as being in some cell (so that you, the student, will know if/when it enters the same cell as the LocatorBot).

Baseline Strategy 1: Run your optimal strategy from Project 1. Return the total number of moves taken.

Baseline Strategy 2: Iterate the following:

- Run the detector.
- Update the probabilities of where the bot is.
- For a potential bot cell of maximal probability, issue a command to move a bot at that location closer to the locator bot cell.

Once the location of the bot is identified, return the total number of moves + sense actions taken.

3 Your Strategies

For this project, your task is to develop a strategy to identify the location of the roomba in as few actions as possible (on average). Note that I am interested in minimizing the total actions + sensing.

4 Data, Analysis, and Writeup

1) Give an explicit formula for how the probabilities of where the roomba might be change after giving it a command to move. *Note: You'll need to consider the case where the movement brings it into the locator bot cell, and the case where it does not.*

2) Give an explicit formula for how the probabilities of where the roomba might be change after running the detector. *Note: You'll need to consider the case where the detector beeps, and the case where it does not.*

3) Outline the design choices of your strategy, how it chooses what action to take at a given time / given state of knowledge. Give any theoretical backing or justification you can.

4) Compare the performance of each strategy, generating a graph of a) moves, b) sense actions, c) total actions, as a function of α (holding the size of the ship constant at the largest you can).

5) Consider the problem if you are additionally allowed to give move commands to the locator bot. Derive a (fourth) strategy for determining when to move (and where) and when to issue move commands, or when to run the detector. Does allowing the locator bot to move reduce the number of needed actions? Why or why not? Be thorough in your analysis, justification, and experimentation.