Homework 2: Infotaxis

Due: 11:59PM, April 16, 2025

Preliminaries

We have a robot moving in a grid environment of 25 by 25. At each time step, the robot can move up, down, left, or right for one grid cell. There is an unknown signal source in the environment emitting signals. The robot is equipped with a binary sensor with a reading '1' or '0'. Similar to Homework 1, the measurement model can be formulated as a Bernoulli distribution, and the likelihood of the Bernoulli distribution is specified based on the source location and the robot location, the details of which is visualized in Figure 3 below.

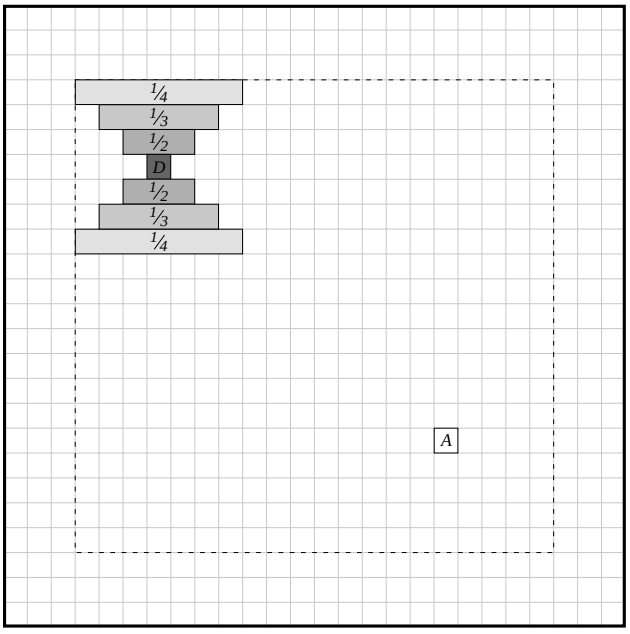

Figure 3: The measurement model in the Infotaxis problem setup. Assuming the letter 'D' is where the signal source is, the shades and numbers inside represent the likelihood of registering a sensor reading of '1' if the robot is in that region. The likelihood of registering a sensor reading of '0' is one minus the likelihood of registering a '1'.

Hint

The measurement model of this assignment is very similar to the one in Homework 1. There are two differences: (1) Instead of the "ring-shaped" likelihood function, here the likelihood function has a "dumbbell"-shape; (2) The measurement model in this homework is specified over a discrete space instead of a continuous space.

Examples of the Infotaxis algorithm in this problem setup can be found at: `https://www.youtube.com/watch?v=gi49c_V0Lpk`. Please use these videos as a reference for the visualization style of your submission.

To generate animations (even though you only need to submit the final plot), the matplotlib functions "cla" and "pause" functions can be very helpful. You can save each time step of the simulation as a ".png" file locally and generate a video based on the image sequence later.

Software

Python packages *NumPy* and *Matplotlib* are sufficient for this assignment. The computation of this assignment could take a while to finish on your computer, but it should not take more than *a few seconds* per time step. Even though not required, if you are interested in accelerating the computation, we encourage using Python package *JAX* or *PyTorch* with GPU acceleration (Google Colab provides free GPU access). Feel free to use Jupyter Notebook as the programming environment.

1. (20 pts) Randomly sample a source location and an initial location of the robot. Develop an exploration strategy, at each time step, select an action (up, down, left, right, stay still) to quickly explore the search space. After executing each action, simulate a measurement, and use Bayesian update to update the belief of the source location. Run your exploration strategy for 100 time steps.
   Turn in: A 2-by-5 grid plot showing the belief and the robot trajectory at time step: $10, 20, \ldots, 100$.

2. (80 pts) Randomly sample a source location and an initial location of the robot. Implement the Infotaxis algorithm to choose the optimal action at each time step to maximize the expected entropy reduction until convergence. Generate 3 trials.
   Turn in: Three 2-by-5 grid plots showing the belief and the robot trajectory at different time steps of each search trial. For example, if one search trial takes 137 time steps to converge, you can choose to visualize at time step: 10, 23, 36, 49, 62, 75, 88, 101, 124, 137.