INFO8006: Project 2 - Report

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1 Bayes filter

a. The sensor model describes how likely it is that the sensor indicates a certain value given our belief that the ghost position is at location X_t at time t.

   Therefore the probability distribution of the evidence E_t at time t given the supposed ghost position is the same as the noise distribution in the rusty sensor. The noise of the sensor is sampled from a binomial distribution centered at zero as given in *_get_evidence*() with p=0.5 and n=4. Range of noise values is $[-2; 2]$.

$$\begin{aligned} P(E_t|X_t) &= P(E_t - distance(X_t, P_t)) \\ &= P(noise\ of\ sensor) \\ &= \mathcal{B}(n = 4, p = 0.5, k = E_t - distance(X_t, P_t) + n * p) \end{aligned} \tag{1}$$

   with P_t is position of Pacman at time t

b. As seen in the getDistribution implementation for each ghost type, a factor has been given to each legal move of the ghost. Factor is 1 if the move leads the ghost closer to Pacman and 2^f if it leads it away from Pacman. Then after normalization of the factors into probabilities, a move is drawn based on those probabilities and assigned to the ghost at time t. f varies for each ghost type in the following manner:

$$f = \begin{cases} 0 & \text{if Ghost = Confused} \\ 1 & \text{if Ghost = Afraid} \\ 3 & \text{if Ghost = Scared} \end{cases} \tag{2}$$

   Therefore our transition model is a probability distribution over the legal moves for each X_t, conditioned as follows: Legal Moves = {N, S, W, E} $fromX_t$ excluding moves leading to walls

$$P(X_{t+1}|X_t)(f) = \alpha * \begin{cases} 0 & \text{if illegal move} \\ 1 & \text{if move closer to } P_t \\ 2^f & \text{if move away from } P_t \end{cases} \qquad \alpha \text{ is the normalization factor} \tag{3}$$

2 Implementation

a. ***Leave empty. Refer to script bayesfilter.py***

3 Experiment

a. The standard deviation of our belief state is a good measure of its uncertainty, since having a low std will concentrate the probability mass function (PMF) in a small range of X_t and therefore increase our certainty of the whereabouts of the ghost(s) in a specific region around the mean X_t. While having a high standard deviation leads to a more spread out PMF over the maze grid and thus no concentration of probabilities in a certain region, which means our certainty is low.

b. In order to measure the quality of the belief state, we can compare it to the true location of the ghost, so we use the Manhattan distance between the expected X_t position of the ghost(Center of mass of the belief state or the PMF) and the ghost's real position in the maze. If this distance is low then our belief state is of good quality. And when this distance is high then our belief state has a low quality.

c. Our experimental protocol:
- We runs the code 10 times for each ghost type with and without walls.
- We took different seeds for each run (from 1 to 10).
- We make over 70 times step or more per run.
- We plot for each maze and ghost type the quality and the uncertainty on the same graph, both are Manhattan Distances and thus can be compared to each other in the same plot. See Figures 2 to 7 on pages 3 to 5.

d. The transition model parameter plays an important role in Pacman's belief state and also on the ghost's behavior. The confused ghost (f = 0) wanders aimlessly in the maze with no specific direction, and Pacman is also clueless about the destination of the confused ghost, this is why we observe a high uncertainty for Pacman especially without walls.
For the afraid ghost (f=1), he is trying to get away from Pacman but not in a fast and direct manner, this is why he will eventually reach the bottom right corner of the maze, and Pacman has a better certainty about the whereabouts of this ghost.
Uncertainty of Pacman is the lowest for the scared ghost (f=3), because this ghost is mostly always running away from Pacman and when ghost reaches the bottom right corner of the maze it could only move one step towards Pacman and back to the corner in an endless cycle.
Walls reduce the quality of Pacman's belief state because the ghost could be on the other side of the walls. And sometimes Ghost can be stuck on open corners avoiding to get closer to Pacman.

	Uncertainty		*Quality*	
Confused with wall	3,8	*MID*	3,5	*MID*
Confused without wall	5	*HIGH*	4	*MID*
Afraid with wall	2,5	*LOW*	5,3	*LOW*
Afraid without wall	2,5	*LOW*	3,4	*MID*
Scared with wall	1,5	*LOW*	6	*LOW*
Scared without wall	1	*LOW*	1	*HIGH*

Figure 1: Measures fluctuating around these value

e. The sensor variance increases the uncertainty of Pacman's belief state, when we raised the sensor variance to as much as 10, we saw that our belief state had a widely spread out distribution and thus a bigger standard deviation. This is mainly because that the range of the rusty sensor noise that was [-2:2] as discussed in **1.a** turns into [-20:20] which is really bad localization attempt of the ghost.

f. We would definitely use the center of mass of the belief state mass distribution (expected position) to fix a destination for Pacman (the prediction of the position of the ghost). In the simple case without walls inside the maze, Pacman would locate himself and locate the prediction of the first ghost then Pacman would define a route towards this location, then at the following time step, after one move for Pacman, the destination would change and Pacman would have to update his route towards the new found destination. Assuringly, Pacman's route will not change drastically only micro adjustments as the ghost's predicted positions' change is continuous along the maze.

g. ***Leave empty.***

Figure 2: Plot of uncertainty and quality for confused ghost with wall (seed = [1;10])

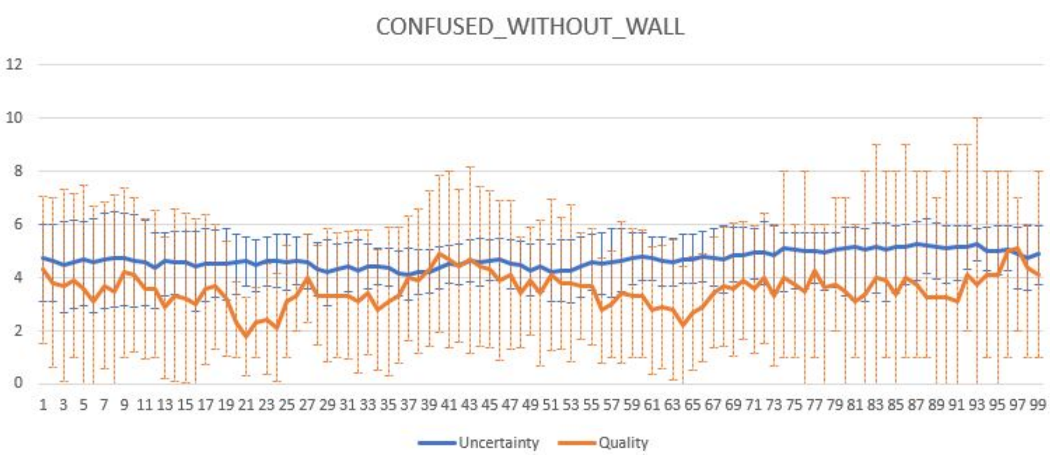

Figure 3: Plot of uncertainty and quality for confused ghost without wall (seed = [1;10])

Figure 4: Plot of uncertainty and quality for afraid ghost with wall (seed = [1;10])

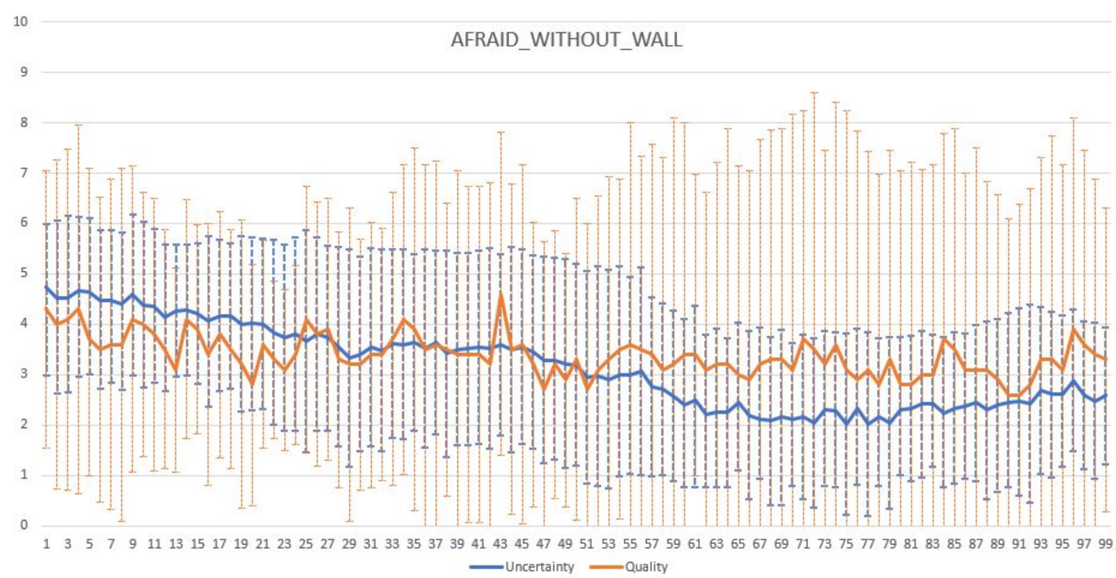

Figure 5: Plot of uncertainty and quality for afraid ghost without wall (seed = [1;10])

Figure 6: Plot of uncertainty and quality for scared ghost with wall (seed = [1;10])

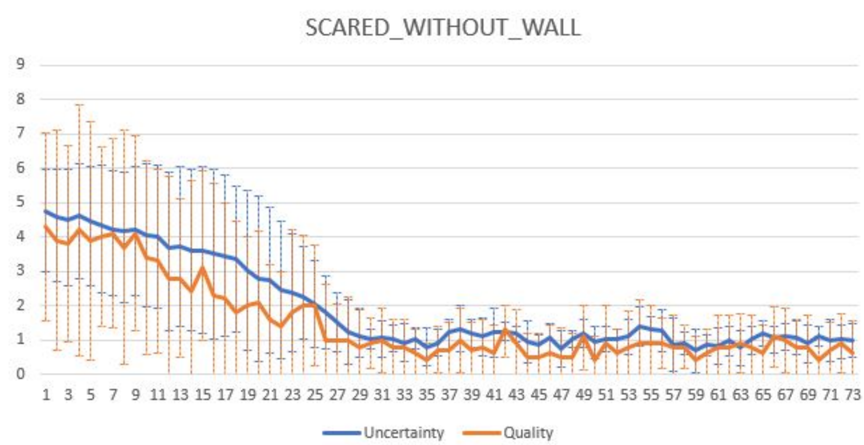

Figure 7: Plot of uncertainty and quality for scared ghost without wall (seed = [1;10])