**4. Computational Evaluation**

In this section, we use a related path planning frame work [Masters and Sardina, 2017] to test and evaluate our two models that introduced in section 3. There are two goals in this experiment: on the one hand, we use this experiment to test the deception and its performance of our model by comparing with honest baseline and other’s work; on the other hand, the similar experiment is used to measure the cost by comparing with optimal model. Both items are key indexs for a successful deceptive path planning model.

**4.1 Experiment Design**

In Section 3, there are two models: heuristic model and entropy model. To evaluate path planning algorithms and visualize the performance of algorithms, both models are implemented by using the P4 framework. At the same time, we implement the ambiguity [Yue Yang, Zhengshang Liu, Peta Masters, Tim Miller] model and astar model as a control group.

**Independent variables** The details and characters of four models that we implement in experienment are:

1. Dummy Agent, which use Astar algorithm to find an optimal policy in a given problem. This agent can be thought as an honest model with lowest cost.
2. Original Model, which is a successful deceptive path planning model by using reinforcement learning. But this model uses multiple Q-Tables to deal with multiple reward functions.
3. Heuristic Model, which is a reinforcement learning method that using only one Q-Table. Reward shaping technology is applied in this model.
4. Entropy Model, which the core idea is using q-value to calculate the entropy of every possible move, is using q-value to calculate the entropy of every possible move.

**Measurements**

There are three measures on these four models.

1. The proportion of exposed paths. This means the probability that the real destination is exposed at different density stage. This measurement uses the location of final exposed point and map environment to estimate the probability.
2. The probability of the real goal against the density. This measure gives a probability for each given goal to guess if the goal is the real goal. This measurement is based on the naïve intention recognition algorithm by implemented the notion of cost difference in path-planning problem.

Both (1) and (2) are used to measure the deception of the models.

1. The total cost of each path. This is another important aspect of the model, we desire an excellent deceptive model with low cost.

One more thing need to explain is ‘density’. The node at density = x%, means the node at position = (x%\*length (Path)). During this experiment, density can be defined as the percentage of the path that exposed to observers. It ranges from 0 to 100%. For example, desity equals 100% means the agent reached the desitination, and all of path is exposed. Usually, the higher density that the model performs deception, the more deceptive it is.

**Experiment Parameters**

We test our models on three different maps:

1. The map without any obstacles
2. The map with three large obstacles
3. The map with some random but smaller obstacles

All of three maps are the same size (49\*49) and have one real goal and a number of feak goals. But for each map, we set 11 different location of goals. Therefore, there are 33 kinds of map totally. Every model is evaluated on the 30 maps. For each result, we recorded the Measurements (1) and Measurements (2) for every 10% density. For Measurement (3), we only care the cost of the total generated path.

**4.2 Result**

The Figure 1 shows the proportion of exposed paths, the x-axis is density and the y-axis is the probability that real destination is exposed at each state of the generated path. In general, the lower the y value is, the better capacity of deception. For this metric, it is obvious that the Orginal method performs best, then our Entropy model, next is the Heuristic model. There are three conclusions that can be acquired from Figure 1: (1) Even though the performance of the Entropy model and Heuristic model are worse than the Original model, these two models still performs much better than the dummy agent, which proves the Heuristic and Entropy model is deveptive. (2) For both Heuristic and Entropy model, they perform well on lower density. (3) The reason that why the performance of our models is worse than Original model is that we use single Q-table to deal with multiple reward, this action hides more environment information to agent, therefore, the strategy may perform worse.

The Figure 2 presents the probability of the real goal against the density. The x-axis is the density, and the y-axias means the probability of heading to the real goal. The smaller y value, the better of deception. There is an important check point on y-axias is 50%. Because when the probability of the real goal larger than 50%, it means the probability to real goal is larger than the probability to any other fake goals. When an observer makes a decision which is same as 70% or 90%, it will always choose the correct real goal. By analysising the result that under y=0.5, we summarize that the entropy model performs the best, the the original model and heuristic model. We can come to similar conclusion with Figure 1. However, in this evaluation metric, the Heruritic model and Entropy model show more competitive performance. Our Entropy model even is the most deceptive model in this metric.

The Figure 3 reveals the cost of each model. Because Dummy model is based on Astart algorithm which leads to optimal path, the Figure 3 cancluate the cost ratio of each model by comparing the cost with the cost of Dummy model. The capacity of the deception is not the only aspect in our problem since a very skewed path which lingering among fake goals can be very deceptive but very cost expensive as well. In our experiment, the Entropy model and the Original model share similar cost while the cost of Heuristic model is smaller than these two models. This proves that even though Heuristic model shows less deception, it can be implemented in the situation where requiring low cost.

Figure 1 Proportion of Exposed Paths against Density

Figure 2 Average Probability of the Real Goal

Figure 3 Cost Ratio