A Comprehensive Study of Ant Behavior in Competitive Nest Environment

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1 INTRODUCTION

When ants forage for food in the nature, they show one of the three behaviors. First, they may walk randomly, which means they forage without any prior information of food source. Second, they may use site fidelity, which means they go for the food location which is previously known to them. Third, they can communicate with each other using pheromone. The ants can follow a pheromone trail of other ants in order to reach a known food source.

In this experiment, we will simulate and observe ants' performance in two different modes using different level of pheromone. As we will observe the behavior only with different rate of pheromone use, we will keep the site fidelity rate as a constant.

1.1 CPFA

The Central Place Foraging Algorithm (CPFA) is the most basic foraging algorithm consists of only one nest and several ant-bots in the simulator. It was previously described by Hecker and Moses. In this algorithm, the is a single and central nest in the simulator arena and all the ant-bots belong to that nest. All ant-bots return to that nest and also bring resources to that nest.

1.2 MPFA

In Multiple Place Foraging Algorithm (MPFA), there are multiple nests instead of a central nest. While returning to nest after collecting seed, the an-bots search for the closest nest and return there. In the static MPFA, the position for each nest is fixed. Usually in MPFA, there are four nests distributed uniformly in the simulation arena.

In MPFA, the nests cooperate with each other. Which means, no ant-bot belongs to any specific nest. Instead, any ant-bot may return with or without any resources regardless of which which nest was its origin. In this study, we will use static MPFA with two nests.

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1.3 CCPFA

In this study I implemented a novel ant foraging algorithm called Competitive Central Place Foraging Algorithm (CCPFA). This algorithm is similar to static MPFA. However, in this algorithm, instead of cooperating with each other, the nests compete with each other.

Initially, each ant-bot belong to specific nest. When the ant-bots search for resources in the arena, they get out of the nest and come back to their own nest afterwards. No matter how close they are from another nest, the ant-bots are not allowed to return or take resources to other nest.

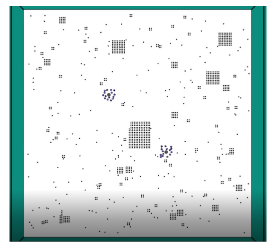

Fig. 1. This is a snapshot from the ARGoS simulator. There are two black large circles which indicate the nests located diagonally in the arena. There are fifteen blue colored and around each nest. A total number of 1024 seeds (small black circles) are scattered across the 20*20 arena. The seeds are distributed using the power law distribution.

1.4 ARGoS Simulator

ARGoS is a multi-physics robot simulator. It can simulate large-scale swarms of robots of any kind efficiently. In this experiment, I used ARGoS as my simulator. Fig 1 shows a snapshot of the ARGoS simulator at the initial state.

2 METHODS

The primary objective of this experiment is to observe and compare ant foraging behavior between static MPFA and CCPFA. In order to keep it simple, I customized the simulation arena of static MPFA. The new simulation arena dimensions are 20*20 and it contains only two nests (nest A and nest B) located diagonally in the arena. There are thirty ant-bots, initially fifteen for each of the nests.

For CCPFA, the initial arena size and the number of bots were same. I varied the pheromone laying probability from 1 to 19 and ran 10 simulations for each probability for both static MPFA and CCPFA. For each run, there were 1024 power law distributed seeds. Each simulation was of 90 minutes with 32 ticks per second. Fig 1 shows the initial state of simulator.

From Fig 1, we can see the initial condition of the ant-bots in the simulator. As we start simulating from there, we can monitor the activity of ant-bots over the time. Finally, when the simulation is complete, we can collect the result from the simulator log.

3 RESULTS

With the simulation, I found some interesting results for both cooperating and competitive behavior.

3.1 Static MPFA

Fig 2 shows the cumulative score of static MPFA. In general, the score is higher when the ants use more pheromone. However, we can see from the graph that, the scores do not show constant downtrend. This happens due to the distribution of seed. The standard deviation bar in the middle does not show any pattern.

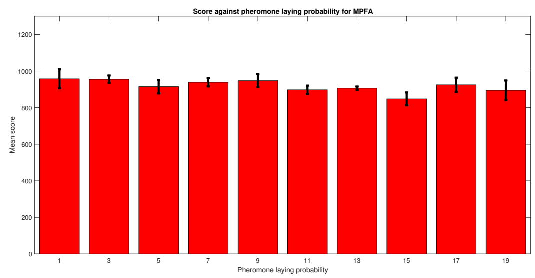

Fig. 2. The plot shows the effect of pheromone laying probability on the total score for MPFA. The x-axis represents the probability of pheromone laying from 1 to 19. The y-axis is the cumulative score from nest A and nest B. The bar in the middle is the standard deviation range of 10 simulations. The histogram trend shows that, the ants tend to collect more seeds when they use more pheromone.

3.2 CCPFA

Fig 3 shows the results for the CCPFA. From the figure we can see that, the seed collection is most for pheromone laying probability 5 and 7. Also, as the ant-bots use less pheromone, they tend to collect less seeds. The standard deviation bar in the middle does not show any pattern.

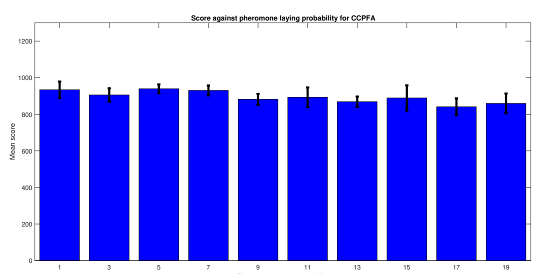

Fig. 3. The plot shows the effect of pheromone laying probability on the total score for CCPFA. The x-axis represents the probability of pheromone laying from 1 to 19. The y-axis is the cumulative score from nest A and nest B. The bar in the middle is the standard deviation range of 10 simulations. The histogram trend shows that, the ants tend to collect more seeds when they use more pheromone.

3.3 Comparison

The comparison figure (Fig 4) shows a very interesting and obvious behavior of the nests. We can see that, the seed collection is high almost always when the nests cooperate with each other.

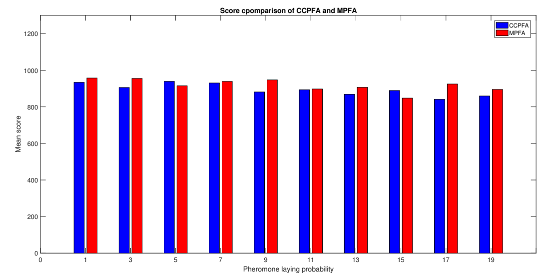

Fig. 4. The plot shows comparison between two foraging behavior. The 1st(blue) bar is the score of CCPFA and the 2nd(red) bar is the score of MPFA. It is clear from the comparison that, the ant-bots tend to collect more seeds when the nest cooperate with each other.

3.4 Score difference between nests

Fig 5 shows the average score difference between nest A and nest B for different pheromone laying probability. From the plot we can see that, when the nests compete, the average score difference is high. On the other hand, when the nests cooperate with each other, they tend to have little difference with each other.

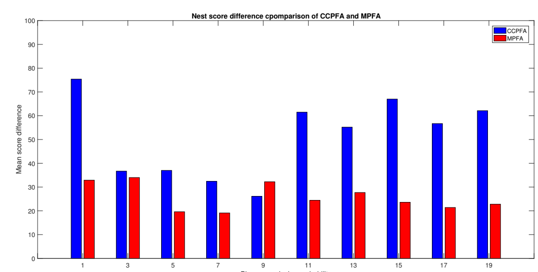

Fig. 5. The plot shows the average difference of seed collection between nest A and nest B in both static MPFA and CCPFA. From the plot, it is clear that the difference is high when the nests fight with each other. On the other hand, when the nests cooperate, the difference is very little.

3.5 Detailed Result

The full result of all the simulations can be found in the URL [1].The spreadsheet contains scores from all 10 simulations, score breakdown of nest A and nest B, mean and standard deviation of both static MPFA version and the competitive CPFA version. All the simulations are 90 minutes long, have two diagonally positioned nests with fifteen ant-bots each with a total of 1024 power law distributed seeds.

[1]https://drive.google.com/file/d/0B3hz873ppjF_clhaemFJTmstQTQ/view

3.6 Simulation video

I have captured six simulation videos (three for competitive CPFA and three for static MPFA) varying the pheromone laying probability for better understanding. All the simulations are 90 minutes long, have two diagonally positioned nests with fifteen ant-bots each with a total of 1024 power law distributed seeds. URLs to those videos are:

(1) Competitive CPFA with pheromone laying probability 1 [2]
(2) Competitive CPFA with pheromone laying probability 3 [3]
(3) Competitive CPFA with pheromone laying probability 19 [4]
(4) Static MPFA with pheromone laying probability 1 [5]
(5) Static MPFA with pheromone laying probability 3 [6]
(6) Static MPFA with pheromone laying probability 19 [7]

4 LIMITATIONS AND FUTURE WORKS

There are some limitations of this study. In some of experiments there were no certain patterns. Also each experiment was ran ten times. I think we will be able to find some more fine grained statistics if we run more than ten times.

In future, we can go for field experiments to see what actually happens in the nature. Instead of using the power law distribution, we can forcefully place the seeds in different (i.e. in the middle, skewed to one nest, across another nest) places to observe ant behavior. Afterwards we can model them in the simulator and run more experiments. We can also change other parameters like the site fidelity and experiment more.

5 CONCLUSIONS

In this study, I compared the performance of ant-bots between static MPFA and CCPFA. From the results it is clear that the ant-bots score better when they use more pheromone for both of the algorithms. It is also clear that, the nests perform better when they cooperate each other. However, there are many other scopes where we can experiment later on.

[2] https://www.youtube.com/watch?v=ADDr_RfeeXc
[3] https://www.youtube.com/watch?v=njfmluQs0vI
[4] https://www.youtube.com/watch?v=0m_5_DGzBd0
[5] https://www.youtube.com/watch?v=dOEUeVbaxu4
[6] https://www.youtube.com/watch?v=Gwj1EkmZsVs
[7] https://www.youtube.com/watch?v=1OgNxdVDhNU