Understanding the foraging behavior of worker ants

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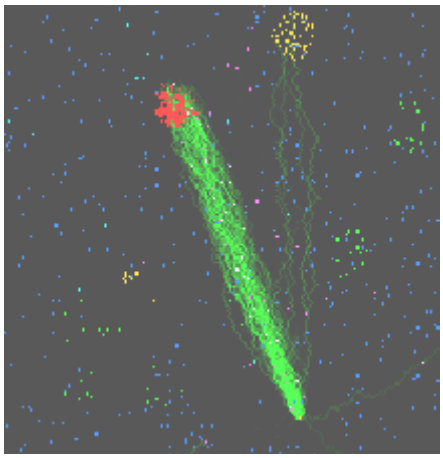
Introduction

The behavior ants exhibit when seeking a path between their colony and a food source is what inspired Marco Dorigio in his PhD thesis of 1992 to propose the first algorithm in Ant Colony Optimization (ACO). The ant colonization optimization algorithm is a probabilistic technique for solving computational problems, which can be reduced to finding good paths through graphs. Over the years, there has been a diversification from the original idea to a wider class of numerical problems. This diversification has led to the emergence of new problems, drawing on various aspects of ant behavior.

Dr Moses and her graduate students have been working on understanding ant foraging behaviors. They have been conducting field experiments with three species of ants native to North America, namely: *Pogonomyrmex Desertorum, Pogonomyrmex Maricopa and Pogonomyrmex Rugosus*. They built a set of Agent Based Models (ABM) to understand how communication behavior and memory of individual ants lead to effective group foraging. Grad student Kenneth Letendre is the architect of these models called an Ant Foraging Simulator (AFS).



Screen shot of AFS.

Field Experiments

The AFS was designed based on field experiments conducted on three species of ants, native to North America. They are *Pogonomyrmex Desertorum* with a colony size of 150, *Pogonomyrmex Maricopa* with a colony size of 250 *and Pogonomyrmex* Rugosus with a colony size of 1000.

In the field experiments, the bait seeds differentiated by their colors are placed at different directions, within a specific radius from the nest of these species of ants. The colors used are red, purple, green and blue. An equal amount of seeds is used for each color; the red seeds are placed in one pile, the same number of purple seeds are divided into 4 piles ;the green seeds are divided into sixteen piles , and the blue seeds are scattered randomly. All seeds are placed within a specified radius from the nest.

The time it takes to collect the bait seeds and other randomly distributed (blue) background seeds are recorded, as well as the amount of seeds collected. From the data collected, a Pile Seed Ratio (PSR) is calculated as the ratio of the number of seeds collected to how long it took to collect them. The PSR is calculated for all the bait seeds and the randomly distributed seeds. A recruitment Ratio (RR) is calculated for each clumped (red, purple and green) distribution as the ratio of that distribution's PSR to the PSR of the randomly distributed seeds. Each

Recruitment Ratio value for the three bait seeds tells us if the ants collected more of the particular bait seed in question as opposed to more of the randomly distributed seeds.

Original Ant Foraging Simulator (AFS) and Ant Foraging Simulator Analyzer (AFSA)

The first version of the AFS I worked with, simulated the field experiments using parameters generated via a Generic Algorithm (GA) that enables the ants to forage for food based on pheromone trails only, we call this *Recruitment*. I designed a program called an Ant Foraging Simulator Analyzer (AFSA) to calculate the PSR and RR from the data generated by the AFS. This program normalizes the RR values which results in negative or positive RR values. Positive RR values indicate the ants collected more of the bait seeds as opposed to the randomly distributed seeds. Negative RR values indicate the ants collected more of the randomly distributed seeds as opposed to the bait seeds.

New Ant Foraging Simulator and Ant Foraging Simulator Analyzer

This summer i had two goals; designing a new AFSA and carrying out data analysis comparing field data to the data generated by the new AFS. This new model was optimized for a colony size of about 100 worker ants and takes a newly discovered ant behavior into consideration called *Site fidelity*, in addition to *Recruitment*. Site fidelity refers to the ability of the ants to remember the location of a food source, using this memory to return to this location to forage for more food. These two new features are what differentiate the new AFS from the first model.

I designed the new AFSA as a desktop application, with a friendly graphical user interface, that can run on any desktop or laptop without the user having to worry about what operating system the computer uses. This new version of the AFSA sorts the runs contained in the AFS output file into separate files on its own before performing any analysis, unlike the previous version. The old AFS did not have this ability, the AFS results had to be sorted manually.

The New AFSA

1. **AFS RAW FILE:**

   From this textbox, the user can browse to the location of the AFS output file, wherever it might be on their local machine.

2. **AFSA Output File:**

   From this textbox, the user can browse to any location on their local machine where they want the results of the AFSA analysis written too.

3. **Calculate Means and Standard Deviations:**

   This is a check box which if checked, tells the program to also include calculations for the Mean and Standard Deviations of the normalized Recruitment Ratios, in its analysis results.

4. **Sort AFS Files**

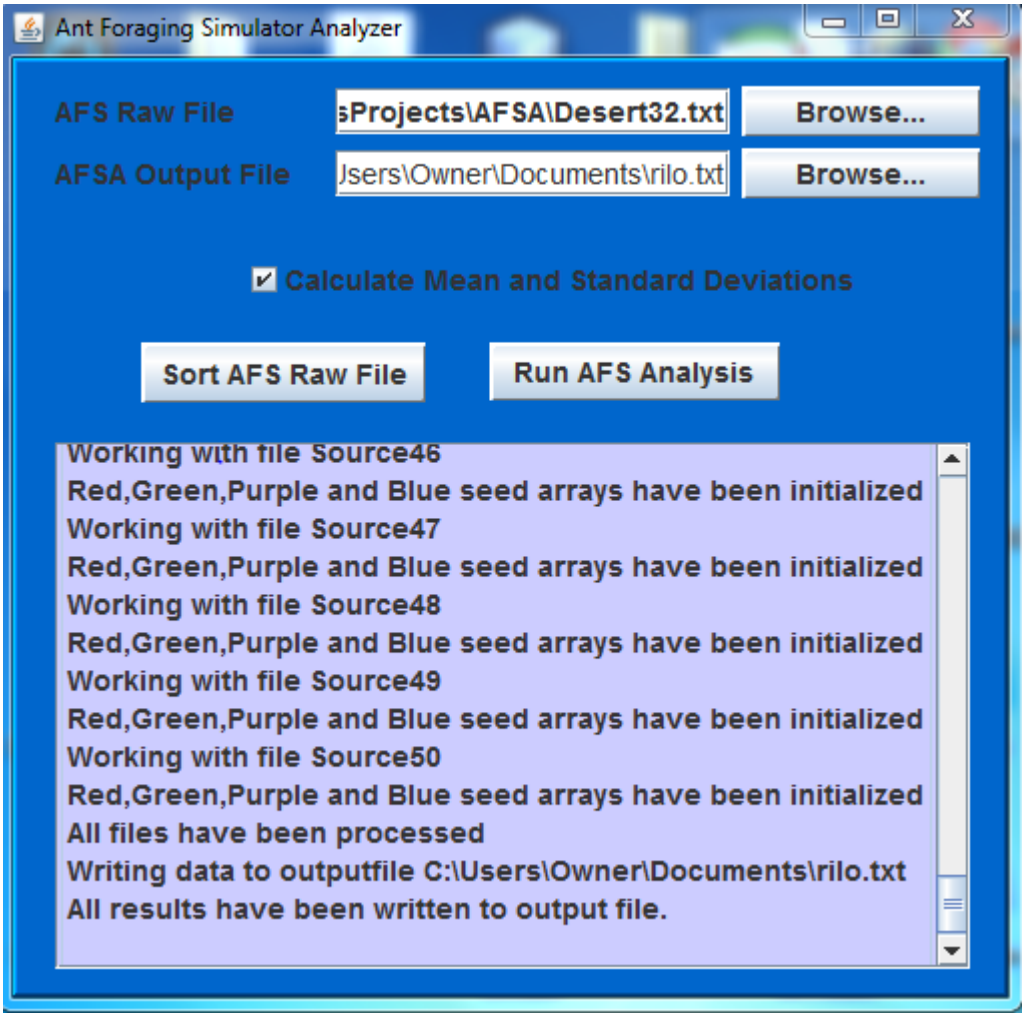
   This button triggers the function in the program that sorts all the data in the raw AFS output file into separate files. The AFSA creates a file for each run and stores the data for that run in the created file. The name for each created file is stored in another file, which it reads from later, when it's ready to analyze the data. Once it's done with sorting it lets the user know by outputting a message to the Output pane.

5. **Run AFS Analysis:**

   This button triggers the analysis of the AFS data once it has been sorted out.

6. **Output Pane:**

   This serves as a window where the program outputs any message it has for the user; it also helps the user keep track of the status of the work being done by program.



Screen shot of the new AFSA

Data Analysis

The second goal this summer was to identify which strategy the ants used to forage for food. To do this, Dr Moses decided that I should run two sets of simulations based on four scenarios and then compare the results of the simulations to field data that had been collected by her team, using Minitab 15 to run an ANOVA test.
The four scenarios i ran the simulations under are:

a) Recruitment only

   In this scenario, the model ants forage for food using pheromone trails only.

b) Site Fidelity only

In this scenario, the model ants forage for food using their ability to remember the location of a food source.

c) Both

In this scenario, the model ants use both recruitment and site fidelity to forage for food.

d) None

In this scenario, the model ants use neither recruitment nor site fidelity to forage for food. Instead they search randomly for food.

The bait seed piles were set to 32 seeds for each pile, all distributed according to the method used in field experiments. The first set used a random background seed distribution and the second set used a power law distribution for the background seed distribution. In a random background seed distribution, the background seeds (i.e. natural food) are randomly distributed but not in piles. With power law distribution the background seeds are both distributed randomly and in piles.

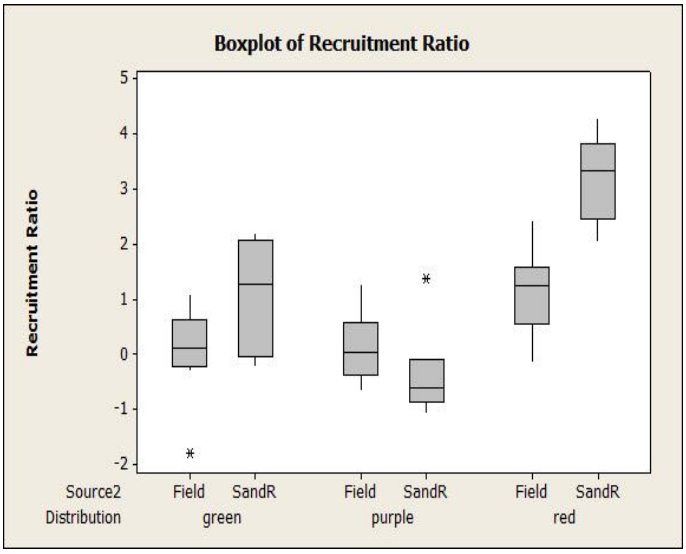
Results for random background seed distribution

I performed an ANOVA test (Analysis of Variance) using Minitab 15 on each individual scenario model result, in each of the two sets. The table below summarizes the results each of the scenarios under the first set.

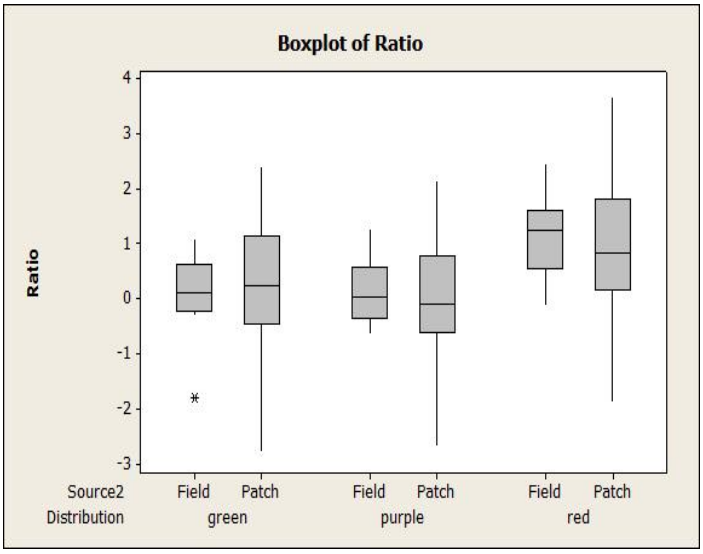
Scenario	P-Value
Site Fidelity only	0.762
Recruitment only	0.038
Both(i.e. Recruitment and Site Fidelity)	0.002
None(i.e. neither Recruitment or Site Fidelity)	0.032

For each scenario, the null hypothesis is that the ants use these behaviors to forage for food. Both, Recruitment only and None have P-Value less than 0.05, this tells us our assumption that they are the strategy used by the ants for foraging is false. Site Fidelity only has a P-Value that is greater than 0.05 which confirms our assumption in this scenario that site fidelity is the strategy used by the ants to forage. A graphical representation of the above results is presented using box plots on the next page.

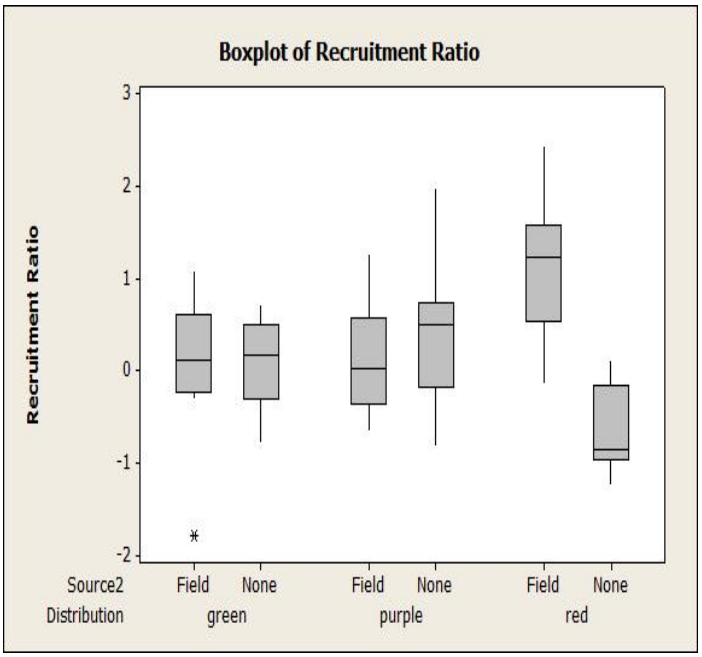
1.) Field data vs. Both model.



2.) Field data vs. Site Fidelity only model.



3.) Field data vs. None model.



4.) Field data vs. Recruitment only model.

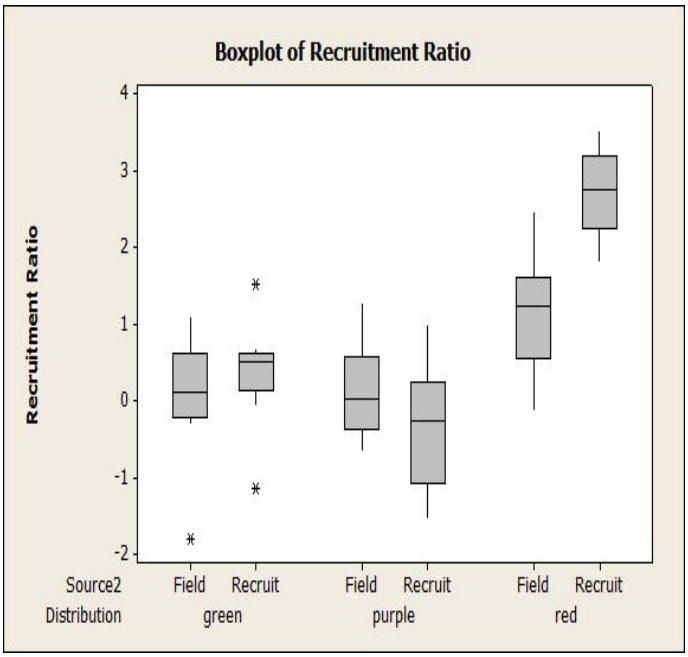


Figure 1: Recruitment Ratios (RR) of the field data versus the Recruitment Ratios (RR) calculated from the models under the four different scenarios. The Site Fidelity only box plot shows how close the model data is to the field data for all three bait seeds unlike the rest which have a very high difference when it comes to the red seed distribution.

Results for the Power Law Distribution

The table below shows the resulting P-Values for each of the four scenarios using a power law distribution for the background seeds.

Scenario	P-Value
Site Fidelity only	0.991
Recruitment only	0.445
Both(i.e. Recruitment and Site Fidelity)	0.449
None(i.e. neither Recruitment or Site Fidelity)	0.000

The resulting P-Value for the None scenario is less than 0.05 which indicates that we can safely assume that the ants don't randomly forage food. The remaining P-Values are over 0.05 which indicates the ants could be using site fidelity, recruitment or both to forage.

Conclusion

For this research project I created an analysis tool (the AFSA) with a graphical user interface to analyze data from the Ant Foraging System. I used this tool to test which behaviors encoded in the AFS are consistent with observed foraging behaviors of real ants. Real ants in the field experiments were simultaneously searching for bait food and natural background food. Because we don't know what those background distribution looks like, we ran our simulations with both a random and a powerlaw distributed set of background seeds. Given randomly background food, only the site fidelity model is indistinguishable from the field data. Site fidelity also has the highest p-value for the simulation with powerlaw distributed background seeds. This provides support for the hypothesis that the real ants use a site fidelity strategy to forage for food.

References

Letendre, Kenneth. "SIMULATING THE EVOLUTION OF RECRUITMENT BEHAVIOR IN FORAGING ANTS." Diss. University of New Mexico, 2010. Print

Lang, Daniel Y. "Chapter 15: Event Driven Programming" *Introduction to Java Programming*. 7th ed. Prentice Hall, 2008. Print. Brief Edition.

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