**CAP 6675 Fall 2017 – Homework 3 Report**

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**Introduction**

This document describes the question, hypothesis, experiment, results, and conclusions from our modifications of the stigmergic ant colony model. In the unmodified, original model, ant agents randomly wander around in search for food. Once an ant finds food, it takes it back to the nest and emits a pheromone trail on its return path so that other ants can trace it to the food source. The pheromone dispersion and evaporation rates can be set by the original model. We investigated the effect of task allocation mechanisms on food retrieval efficiency.

**Investigation: Task Allocation**

*a. Question*

In a real ant colony, ant agents specialize in food foraging and brood care tasks. Thus, ants must continuously decide which task they will do, and the colony is better off if task allocation of all ants adapts to various stimuli. Task allocation in ants is affected by experience (Ravary et. al., 2007), and so our question is: “How do different changes in ant thresholds for performing certain tasks affect the ability of the colony to manage the balance between two tasks, foraging and brood care?”

*b. Hypothesis*

Given two tasks, an ant’s *threshold* is how much more likely it is to perform one task over another. We considered two factors: the threshold an ant is born with and how that threshold changes over time. Whatever these thresholds are, the best outcome for an ant colony is to allocate the fewest ants to the foraging task that results in the greatest amount of food brought to the nest. In other words, the best outcome maximizes the food retrieved per foraging ant. We hypothesize that a random initial threshold distribution over all ants and allowing experiences to change these thresholds at a flat rate over time will result in the maximum level of food gathered per forager ant. The rationale behind this hypothesis is that a random initial threshold scheme will make all the ants different and therefore specialize in varying degrees in either foraging or brood care. The flat rate threshold adaptation scheme will allow ants to choose their task according to food availability. If too few ants are foraging, then more ants that probabilistically try to forage will succeed, experience a decreased threshold for foraging, and continue to forage, increasing food input. If too many ants are foraging, then some will fail, experience an increased threshold for foraging, and fall back to brood care, increasing food per forager in both cases.

*c. Experiments*

We tested our hypothesis by implementing a NetLogo model of the stimergic ant colony where the top half of the view represents the outside world and the bottom half represents the interior of the nest. The nest has one entry/exit point from which there are paths into the nest or into the outside word that the ants can travel on. If an ant chooses to forage, it retrieves food from the outside world according to the original ant model and deposits it at the nest entrance. If an ant chooses to do brood care, it searches for food inside the nest and brings it back to the nest entrance/exit. In the real world, ants care for larvae when doing brood care (Locher et. al., 2009), but for simplicity, we implemented a secondary food searching task and called it “brood care”. If an ant does not find food after a certain amount of time, it gives up and returns to the nest entrance.

Upon returning to the nest entrance, a successful forager increases its foraging points and decreases its brood points, and a successful brood worker increases its brood care points and decreases its foraging points. Increases in an ant’s foraging or brood points also contribute to colony foraging and brood sums, respectively, but unlike ant points, colony sums never decrease. (An ant that has given up on its task experiences no change in points and contributes nothing to colony totals.) After reaching the nest entrance, the ant probabilistically chooses its next task based on two probabilities: colony need and resistance.

Colony need is a threshold equal to colony brood points divided by the sum of colony brood points and colony foraging points. It encourages ants to adopt the task that is garnering relatively fewer points for the colony. Therefore, the probability of the ant choosing to forage is given by the following:

Let B = colony brood points sum

Let F = colony foraging points sum

Pr(forage) = B / (B + F)

Pr(brood) = 1 – Pr(forage)

Specialization is a second threshold which determines the probability that an ant chooses the task with which it has had more success, regardless of colony need. If an ant has more experience foraging, then its probability of “resisting” colony need and sticking to foraging (its specialty) is greater. This ant’s resistance is determined by its foraging bucket, which is its relative ranking among all foragers (where higher rank means more relative foraging experience). Foragers with the same amount of foraging points have the same ranking. Foraging bucket N, which contains the group of ants with the most foraging points, has a maximum resistance threshold MR. MR is set by a slider in our NetLogo model. The probability that an ant in foraging bucket I (where I is in the range [1, N]) resists colony need and chooses to forage is given by:

Pr(resist) = (MR / N) \* I

The resistance to colony need of ants specializing in brood care is computed similarly using brood care buckets. Therefore, as an ant gains foraging (or brood care) points, it ascends to higher buckets with greater resistance to colony need, resulting in ant specialization.

For initial ant thresholds, we set thresholds of all ants to either 75% forage (and 25% brood care), a random percentage, and or 50% forage (and 50% brood care). For threshold change schemes, we experimented with no threshold change (thresholds remain the same throughout the simulation), flat change (thresholds change by a fixed amount after every task attempt), and graduated change (earlier experiences contribute more to threshold changes than later experiences). For each initial threshold/change threshold scheme combination, we measured average food retrieved per forager ant over time, the average percentage of ants that chose to forage over time, and the average percentage of successful foragers over time. For all experiments, we used a pheromone diffusion-rate of 5, a pheromone evaporation rate of 7, and an ant population of 1000. Also, in all experiments, the nest-size is 35 (half of the 70 x 70 view), the maximum number of time steps before an ant “gives up” on its current task is 300, the food amount is 10, and the return-speed of ants to the nest entrance/exit is 2.

We repeated this experiment for three maps to vary the relative difficulty of brood care and foraging. All maps contain three paths into the foraging area and three paths into the nest interior. The end of each path contains an approximately equal amount of food. All nest paths are equal in length and all foraging paths are equal in length. The first map (Figure 1) contains short foraging paths and longer nest paths, making foraging an easier task than brood care. The second map (Figure 2) contains foraging paths that are equal in length to the nest paths, so the brood care and foraging tasks are approximately equal in difficulty. The third map (Figure 3) contains foraging paths that are longer than the nest paths, making foraging the harder task.

The hypothesis is confirmed if random initial threshold and a flat threshold change scheme resulted in the highest food per ant cumulative value for all three maps.

*d. Results*

Tables 1-3 show the results on maps 1-3, respectively, of each combination of threshold initialization and threshold change scheme.

Table 1 Map 1 - Foraging is easier than brood care (max-Resistance 20%, 50%, 80%)

|  |  |  |  |
| --- | --- | --- | --- |
| Initial Foraging Threshold | Threshold Change Scheme | Avg. % ants that are foragers | Avg. % foraging done by forager ants |
| 75% forage | No change | 41.9, 49.1,50.7 | 91.6, 99.7,100 |
| 75% forage | Flat change | 52,87.3,59.7 | 35,78.9,100 |
| 75% forage | Graduated change | 70,65,50 | 97.6,99.8,99.8 |
| Random % forage | No change | 27,40,45 | 64,70,90 |
| Random % forage | Flat change | 58,74,62 | 47,64,100 |
| Random % forage | Graduated change | 43,70,56 | 68,90,98.4 |
| 50% forage | No change | 16,38,27 | 15,37,60 |
| 50% forage | Flat change | 77,72,58 | 83,68,100 |
| 50% forage | Graduated change | 22,60,59 | 39,53,100 |

Table 2 Map 2 - Foraging and brood care are equally difficult

|  |  |  |  |
| --- | --- | --- | --- |
| Initial Foraging Threshold | Threshold Change Scheme | Avg. % ants that are foragers | Avg. % foraging done by forager ants |
| 75% forage | No change | 50,50 … | 100,100 … |
| 75% forage | Flat change | 51,99,57 | 42,100,100 |
| 75% forage | Graduated change | ,95,61 | ,100,100 |
| Random % forage | No change | 41,48,52 | 69,75,97 |
| Random % forage | Flat change | 95,88,62 | 96,83,100 |
| Random % forage | Graduated change | 65,71,62 | 80,89,99 |
| 50% forage | No change | ,46, | ,48, |
| 50% forage | Flat change | ,71, | ,62, |
| 50% forage | Graduated change | ,68, | ,61, |

Table 3 Map 3 - Foraging is harder than brood care (maximum Resistance 20%,50%,80%)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Initial Foraging Threshold | Threshold Change Scheme | Avg. food retrieved per forager ant | Avg. % ants that are foragers | Avg. % forager ants that are successful |
| 75% forage | No change |  |  |  |
| 75% forage | Flat change |  |  |  |
| 75% forage | Graduated change |  |  |  |
| Random % forage | No change |  |  |  |
| Random % forage | Flat change |  |  |  |
| Random % forage | Graduated change |  |  |  |
| 50% forage | No change |  |  |  |
| 50% forage | Flat change |  |  |  |
| 50% forage | Graduated change |  |  |  |

*e. Conclusions*

This is what we conclude…

This is the knowledge we contribute…

**References**

Locher, G. D. A., Giannotti, E., & Tofolo, V. C. (2009). Brood care behavior in Ectatomma brunneum (hymenoptera, formicidae, ectatomminae) under laboratory conditions. *Sociobiology*, *54*(2), 573–587.

Ravary, F., Lecoutey, E., Kaminski, G., Châline, N., & Jaisson, P. (2007). Individual Experience Alone Can Generate Lasting Division of Labor in Ants. *Current Biology*, *17*(15), 1308–1312.