

"Ants Gone Wild"

-- Simulating Semiochemical-Induced Ant Aggression

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NECSI One-Week Complex Systems Course

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Background

Ant colonies have been of considerable interest with regard to complex systems, because of the ease by which they can be studied. Much work has been done on foraging behavior in ants, including the construction of cellular automata-based models, with success in demonstrating the emergence of complex behaviors from simple rules (Mitchell 1997).

Although foraging behavior is well-studied with respect to ant colonies, perhaps less well-explored is aggression. Ants fight in order to monopolize a food resource or to protect their nest. This aggression may be directed toward other insects attempting to steal their food, as well as toward ants belonging to a different nest. Ants of the same species are able to recognize others of their own species by means of detecting a pheromone. Some kinds of ants are quite aggressive in protecting their nest or food resources.

Another form of aggression that can be exhibited is that directed toward others in the same colony. A recent study showed that ants can be incited to in-fighting behavior by compounds (known as semiochemicals) in secretions from insect social parasites such as the wasp *I. eumerus* and butterfly *M. rebeli* (Thomas et al 2002). The larvae and pupal stages of the wasp *I. Eumerus* (which inhabit colonies of the ant *M. schencki*) secrete such chemicals, disrupting the ant colony and allowing them to infiltrate and exploit the rich resources within the ant nests. The active chemicals were purified and found to represent a cocktail of at least 6 compounds, three alcohols and three aldehydes. These secretions were potent enough to immobilize up to 80% of an ant colony, and the chemicals could persist and provoke aggression up to 50 days after secretion.

In addition to aggression induced by chemical exposure, the agitated ants further release an alarm signal known as the alarm pheromone (Hughes and Goulson, 2001), which triggers more agitation and violence in other ants. Although an individual alarm pheromone signal appears to fade on the order of seconds, the overall chaos in the ant colony can last for hours to days.

It has been suggested that this phenomenon may find application in pest control (Thomas et al., 2002). Standard chemical pesticides used to kill insects do not depend much on interactions between targets, and can be described with a more linear model. In contrast, the use of chemicals that incite aggression between ants would be expected to take advantage of interactions between ants, perhaps leading to greater effectiveness. Understanding complexity in the collective dynamic response of a population of ants to these agents, is therefore of importance. With this in mind, our objective was to model survival in an ant colony in response to addition of chemical agents that induce in-fighting. Here we use an agent-based simulation to study the dynamics of this process.

Model Design

We used a JAVA-based platform to build the model. The program is composed of two parts -- the simulation of ant colony response to chemical stimulus and the visualization component. One aim of the simulation is to search parameter space for values that optimize ant elimination.

Assumptions and Rules

1. A variable number of ants (N) exist on a grid of 50 x 50 squares. The grid spatially represents the ant colony.
2. Ants perform a random walk within the grid, taking 1-step in either of four directions per time-step. The simulation runs for 500 time-steps.
3. The semiochemical is applied to a restricted area of variable size (A).
4. The semiochemical is placed on the grid at one spot of variable location (L).
5. At the start of the simulation, all ants are in an un-agitated state.
6. If an ant encounters the semiochemical during its random walk, it changes to the agitated state with a probability of P , and turns around and resumes the random walk.

7. Once agitated, the ant will attack any ant encountered during its random walk.
8. One encounter causes both ants to record 1 "hit" and then continue their random walks.
9. An ant dies once it registers 3 hits.
10. Each ant remains agitated for a duration Tagitation.
11. Once agitated, each ant also lays alarm pheromone along its path for duration Tagitation.
12. The alarm pheromone remains active for a fixed duration Talarm.
13. If an agitated ant encounters chemical or alarm pheromone, its Tagitation counter is reset.
14. An ant disappears from the grid if it dies.

Table 1: Variable Parameters and Default Values

<u>Parameter Name</u>	<u>Default Values</u>
Surface area of initial chemical (A)	64 squares
Location of chemical (L)	Center of grid
Probability of agitation (Pagitation)	70% upon contact of chemical or pheromone
Duration of agitation (Tagitation)	10 time-steps
Number of ants in colony (N)	250
Duration of activity of alarm pheromone (Talarm)	10 time-steps

Results of Simulation

The simulation was run with set default parameters (see Table 1). Fig. 1 shows a screen shot of results of this simulation.

Observations

After running the simulation, we noticed that, after some time, ants do not come into contact with the chemical very often. We attribute this to the fact that, after ants were infected and spread out, they die, creating a void around the chemical without ants. Since the ant movement is modeled by random walk, it takes a while for the surviving ants to be in contact with the chemical. This suggests that we need to vary the parameters in the program to find the best placement of chemical to maximize its effective use as a pesticide.

Further Explorations

The different parameters of the program can be changed to model reality better. We can also enhance this simulation by adding the pheromone-based foraging behavior of ants. Johnson (2001) has explored this food foraging behavior. By combining our simulation with Johnson's, we can get a model a more complex situation. We can also add obstacles in the environment to see how physical partitioning of the environment affect both ant foraging and pesticide use.

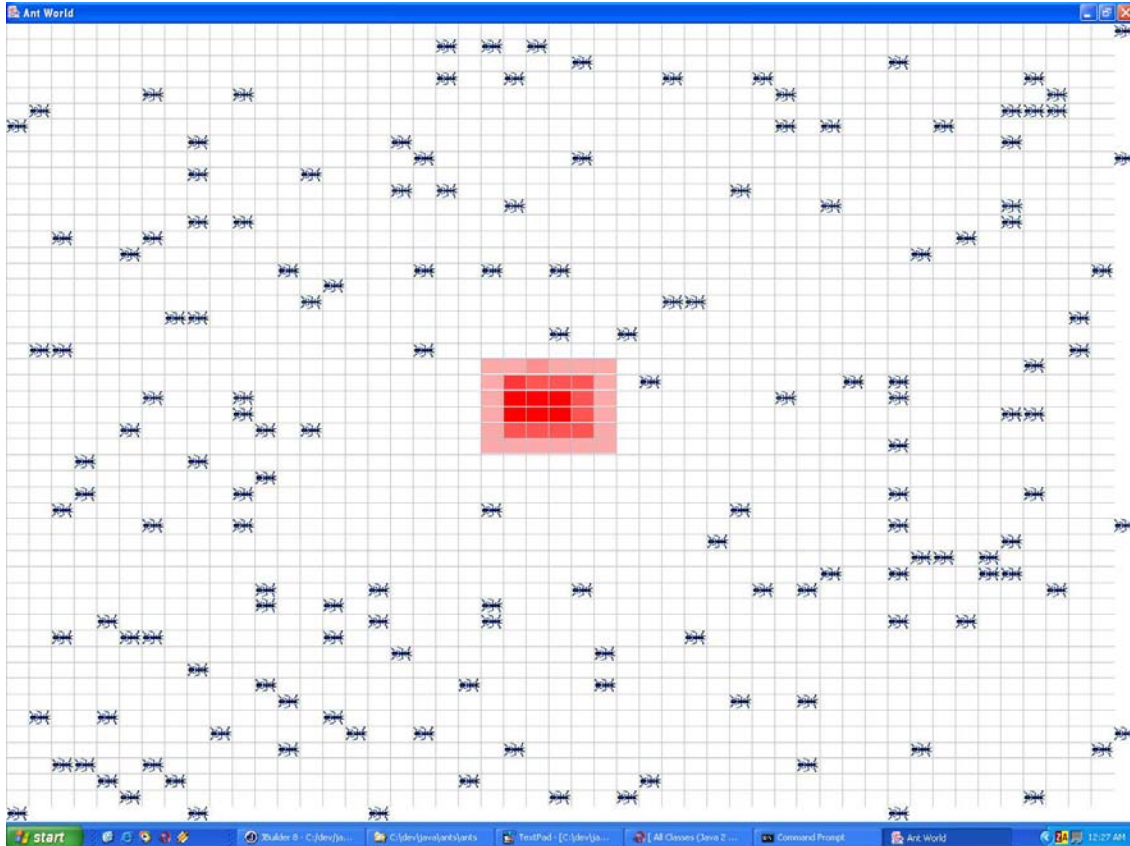


Fig. 1: Screen shot of simulation with default parameters.

Ants are depicted on a 50x50 square grid in the unagitated state. Agitated ants are depicted as butterflies. The semiochemical is depicted as a gradient of red, with increased intensity representing increased amount of chemical in a particular square. The alarm pheromone is depicted using the same color gradient (as it has an identical effect as the semiochemical in this model).

References

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