Made in fulfilment of Design Project
PHY F376

# Wall-following and other behaviour of ants in NetLogo

Project Report
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# Contents

# Introduction

Efficient trail formation from food to nest is a phenomenon observed in various ant species. Ants leave a chemical trail of pheromones behind them, using which the ants behind get a sense of the direction of food (uphill) or nest (downhill).

Ants also have a sense of direction directly towards the food or the nest, depending on where they aim to head.

Ant Colony Optimization (ACO) is an important study since this analysis of complex systems using properties of individual members to find the properties of the system as whole can be used in various models such as traffic, human population movement, et cetera.

# Objectives

1. To implement a working wall-following code for ants weighted by their tendency to approach and be guided towards the wall on their way to their nest.
2. To analyse the system and compare it to experimental data performed with different species of ants.
3. To debug the code to make it as general as possible.

# Methodology

All the simulations were done in NetLogo. Using the previous code of surfaces with different evaporation rates, wall-following was implemented, and the values of evaporation rates were kept the same throughout for a homogeneous medium, so that just the wall-following behavious of ants could be implemented.

For each parameter set to be surveyed, two runs were made and their averages taken. This is because trail formation is sensitive to initial conditions - if the first few ants to reach the food source deviate a bit, the trail may not even be formed.

In the main part of this report, we analyse the primary parameter space of population and distance between nest and food. Using this, we observe the length of the wall being followed by the ant trail when it becomes stable.

All wall-following was done under the command return-to-nest. The cutoff distance was taken by manually checking for the x coordinate on the wall where ants deviate away from the wall to make a straight line towards the food.

# Code

Many different runs of the code were made in progession for the final version which still has immense scope for improvement.
The wall_affinity parameter was implemented in the same way as nest and food scent. It is an exponentially decaying function depending on the turtle's distance from the wall. It is weighted by wall_affinity_mag and dies down as wall_affinity_range.

Implementation of wall-following behaviour starting with the basic code of two surfaces, the progression is as follows.

1. Four wall-affinity parameters, one for each wall - U, D, L, R. Depending on turtle location, it would be attracted to any one wall.
   *Problem* Complexity of having too many parameters and conditions to check for at every run.

2. One wall-affinity parameter, sum of contributions from all walls.
   *Problem* Complexity of too many variables.

3. Set up a grey wall of width wall_width and if the turtle is in that region, follow the wall in the nest direction only.
   *Problem* Turtles tend to remain on the wall. Clustering behaviour.

4. Consider only one wall and make turtles follow nest along it.
   *Problem* Turtles do not reach nest unless nest is on wall.

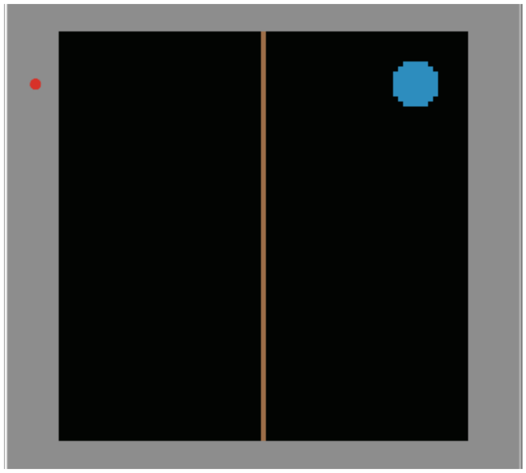
5. Implement a cutoff value of nest scent.
   *Problem* The problem gets hard-coded and some turtles tend to move back and forth near nest.

6. One wall, wall-following at the wall only. Nest is considered to be on the wall.
   *Problem* It is not a general case.

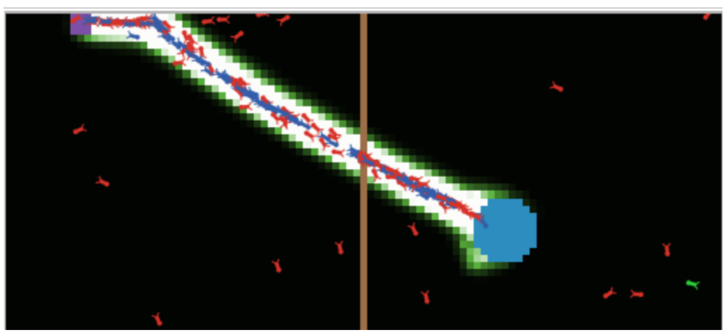
7. Implement one green ant to follow chemical scent only such that trail formation can be confirmed.
   *Problem* Green ant requires different code due to different color and also deviates from trail a lot.

At the end, we have worked with the sixth code as given. The nest was small and on the wall. Trail formation data was collected and the deviation of trail from the wall was noted.

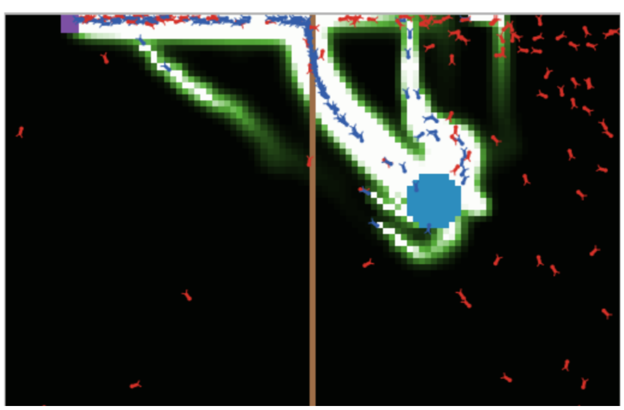
Setups of some codes are shown below.



*Code 3 - grey wall*



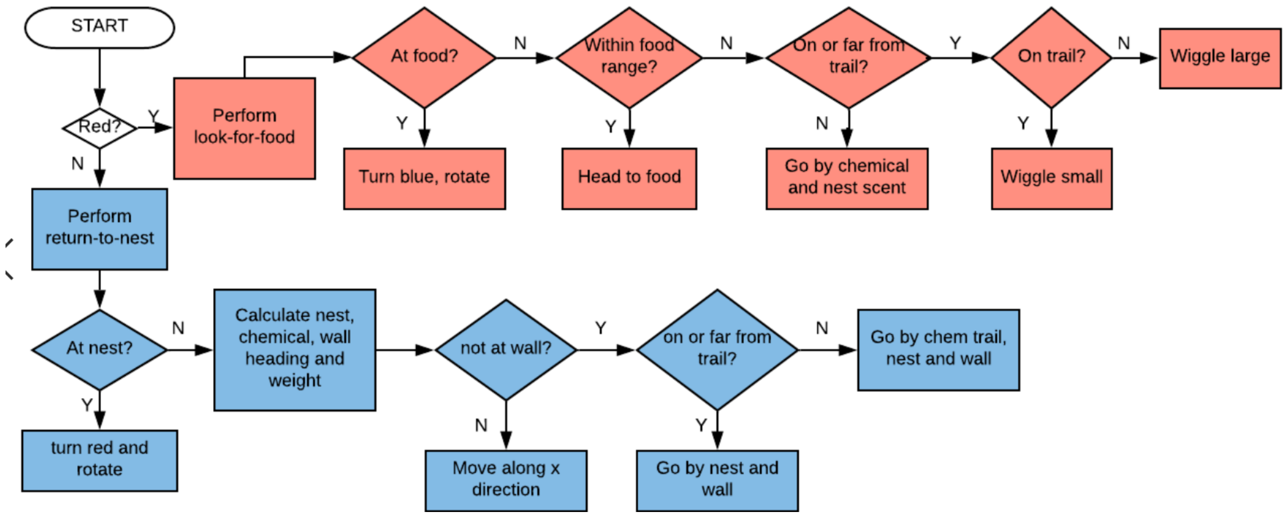
*Code 7 - green ant*



*Code 6 - implemented*

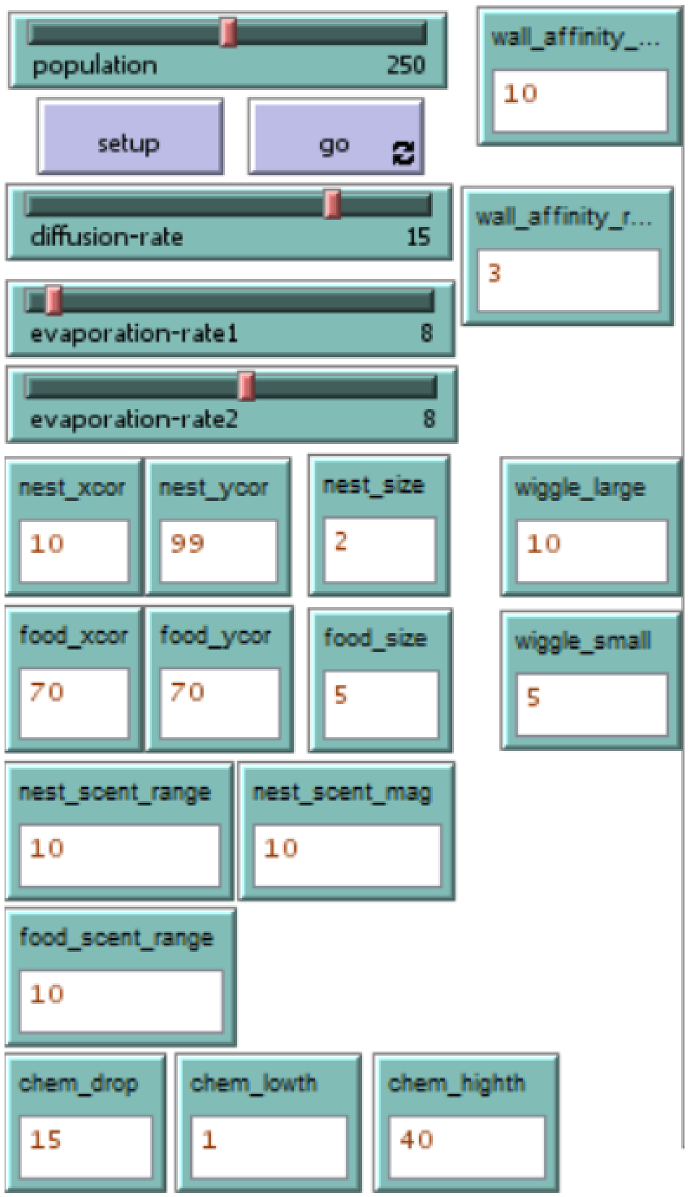
A flowchart of the code is given below. The changes are implemented in the return-to-nest part given in blue (for blue ants in the simulation).

Depending on whether the ant is near a trail or not, its heading is weighted differently.



# Data

Optimum values of other parameters were found through trial-and-error. A snapshot of the values is shown below.



## Population

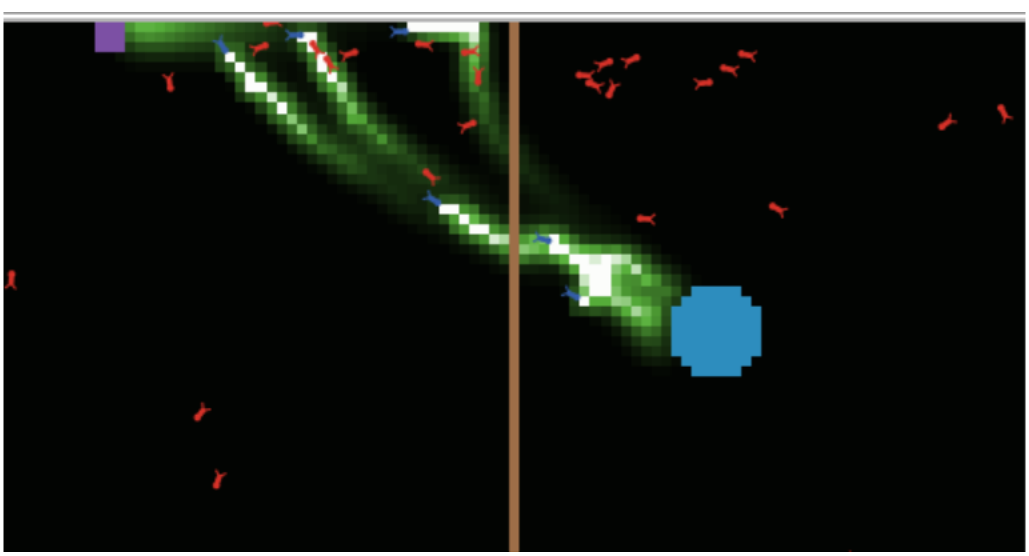
Changing the value of population on the slider from 50 to 320 ants, we observe a trail at 100 ants for the given set of values. The data is shown below.

| Populatior | Cutoff1 | Cutoff2 | Net Cutoff |
|---|---|---|---|
| 50 | 0 | 0 | 0 |
| 80 | 0 | 0 | 0 |
| 90 | 0 | 0 | 0 |
| 100 | 20 | 18 | 19 |
| 120 | 17 | 21 | 19 |
| 140 | 18 | 19 | 18.5 |
| 160 | 19 | 21 | 20 |
| 180 | 21 | 22 | 21.5 |
| 200 | 32 | 36 | 34 |
| 220 | 34 | 38 | 36 |
| 240 | 34 | 39 | 36.5 |
| 260 | 42 | 34 | 38 |
| 280 | 36 | 35 | 35.5 |
| 300 | 27 | 39 | 33 |
| 320 | 36 | 39 | 37.5 |

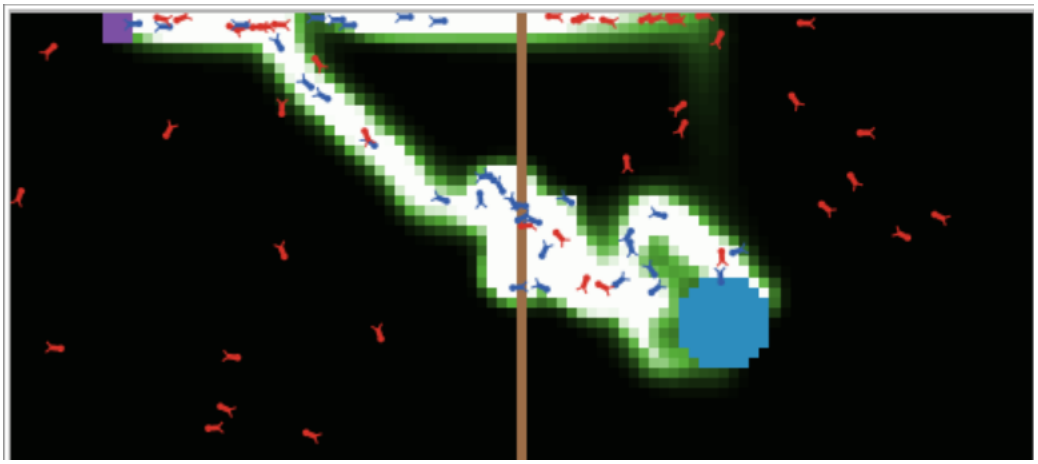
And the corresponding graph is plotted. Here, we can observe an increase in the length of the wall along which ants move till the nest, as the population increases. However the increase is not monotonic. After some time, it saturates.

A likely reason is that there are already enough ants to ensure that the trail is strong and does not evaporate fast. More ants do not make a distance to the trail formation as such, nor is there any optimization by moving along more of the wall.

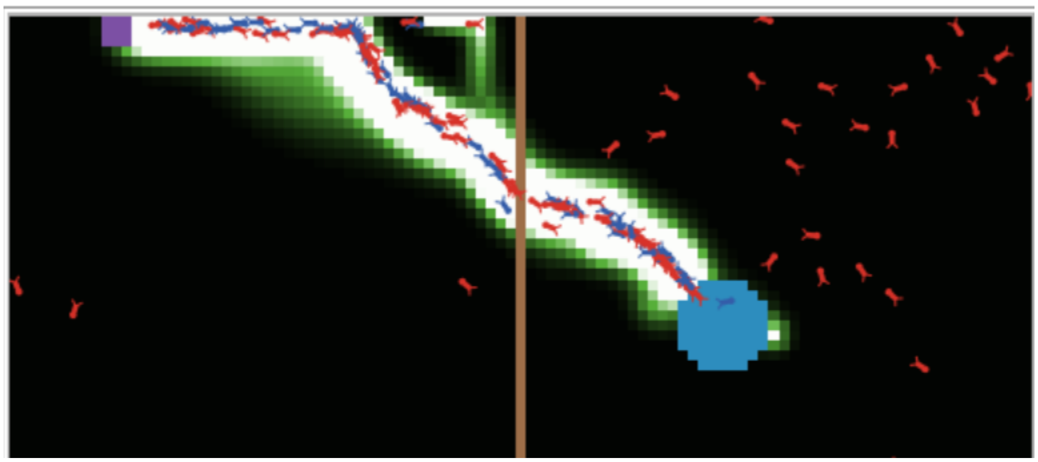
Snapshots of a few populations are shown.



*50 ants*

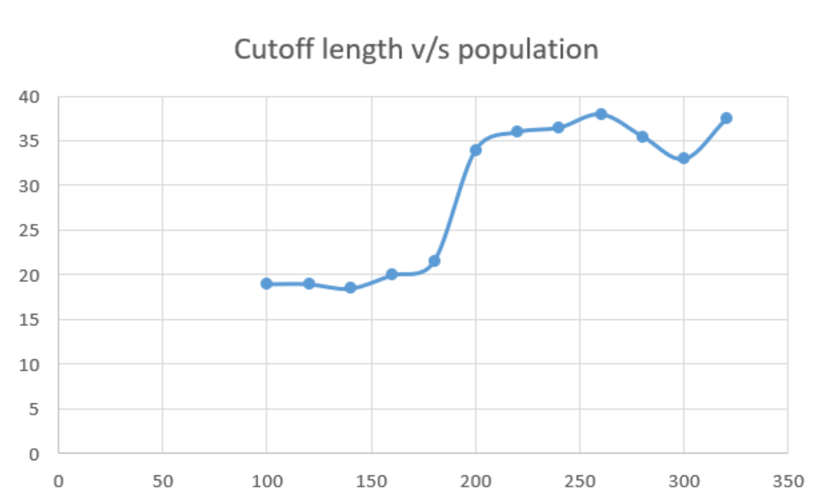


*100 ants*



*200 ants*

A graph of cutoff as a function of population is shown.



## Distance

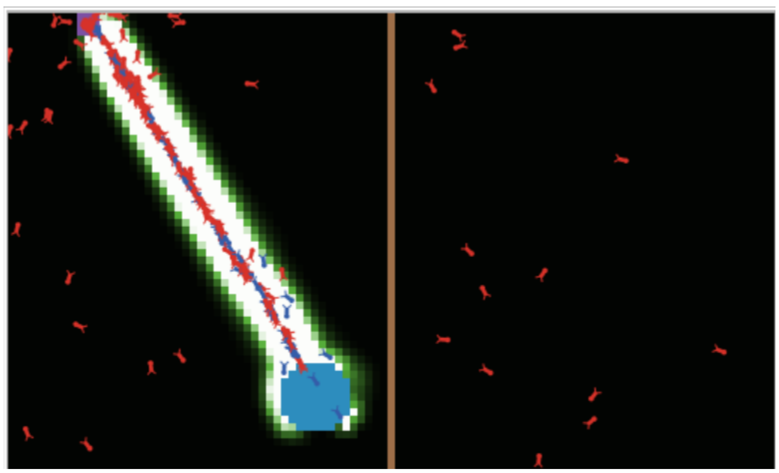
The population was kept constant at 250 ants. The x and y values were changed separately to observe the cutoff of and trail at the wall.

### Moving food in the x-direction

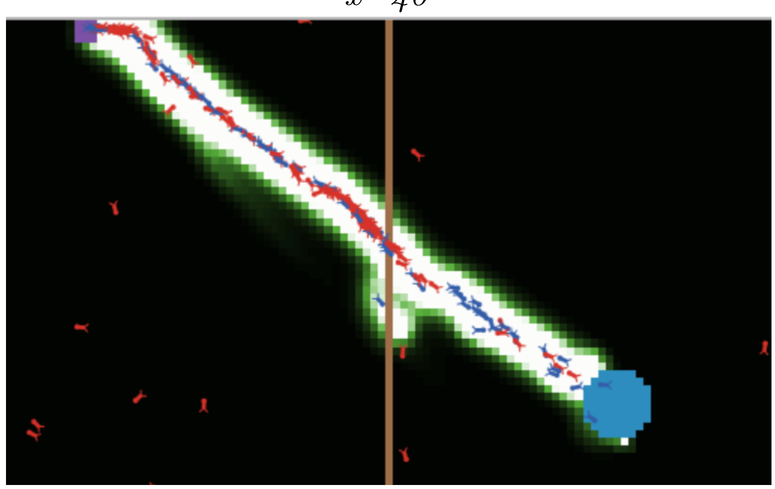
When the food source was kept at constant y coordinate (50) and the x coordinate was changed, cutoff started only at 80 and then increased.

| Food x | Food y | Distancexy | Cutoff1 | Cutoff2 | Cutoff |
|---|---|---|---|---|---|
| 20 | 50 | 50.009999 | 0 | 0 | 0 |
| 40 | 50 | 57.45433 | 0 | 0 | 0 |
| 80 | 50 | 85.445889 | 16 | 16 | 16 |
| 90 | 50 | 93.813645 | 19 | 20 | 19.5 |
| 100 | 50 | 102.47439 | 20 | 20 | 20 |

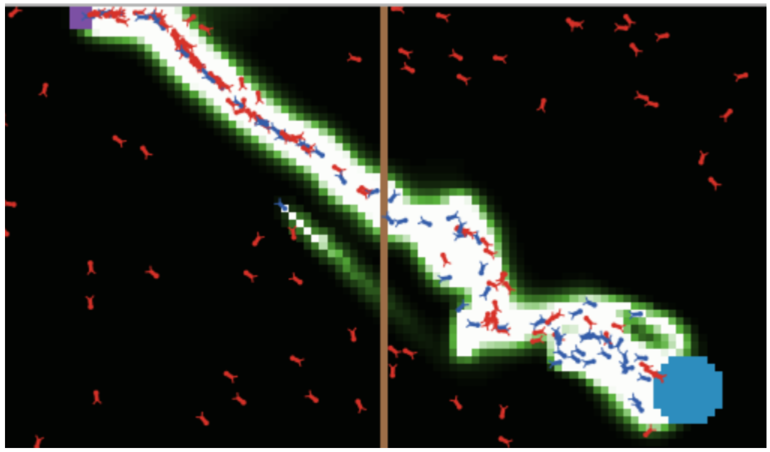
The simulations are shown below.



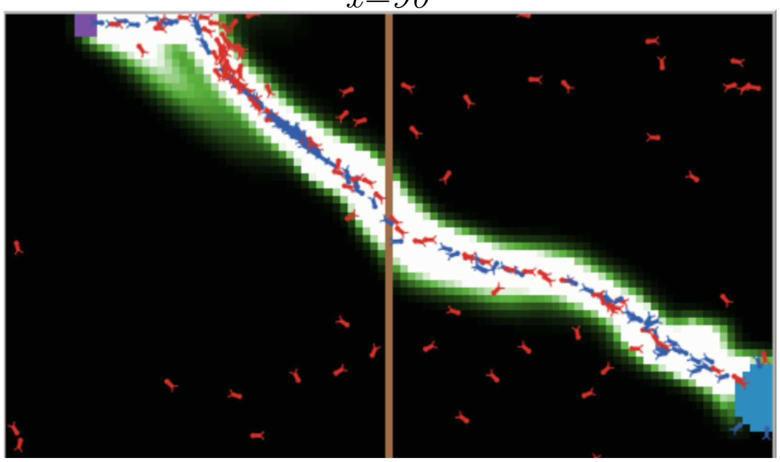
*x=40*



*x=80*

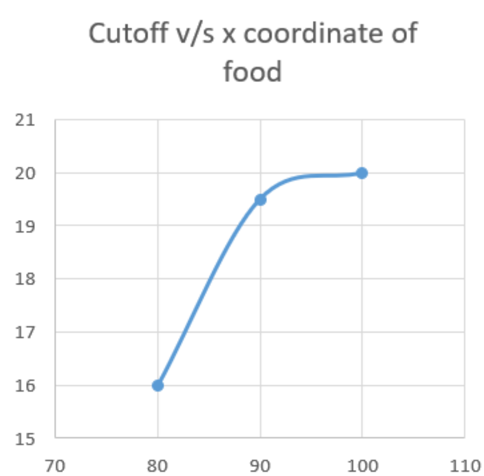


x=90



x=100

Clearly the cutoff increases with distance.
Increase of x beyond 100 was not possible as 100 is maximum x coordinate of our simulations.

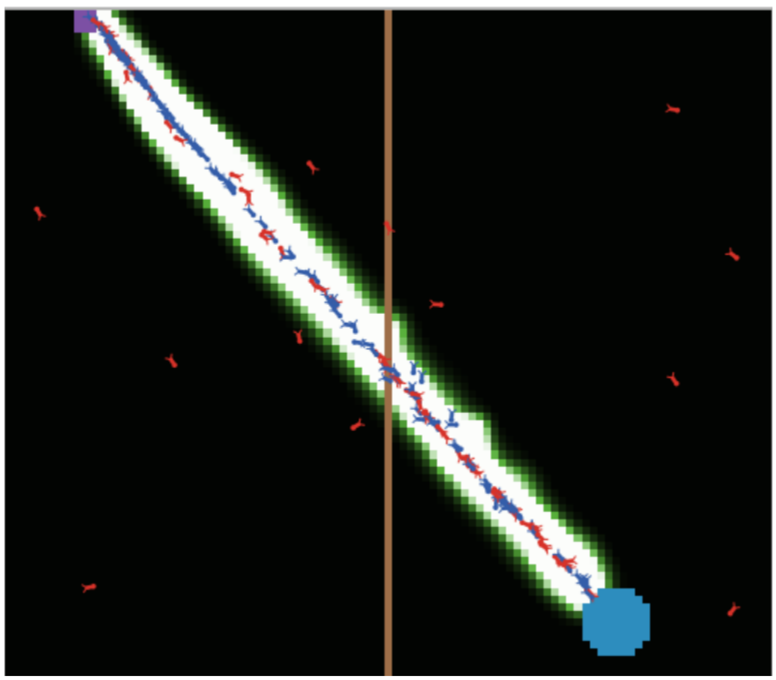


**Moving food in the y-direction**

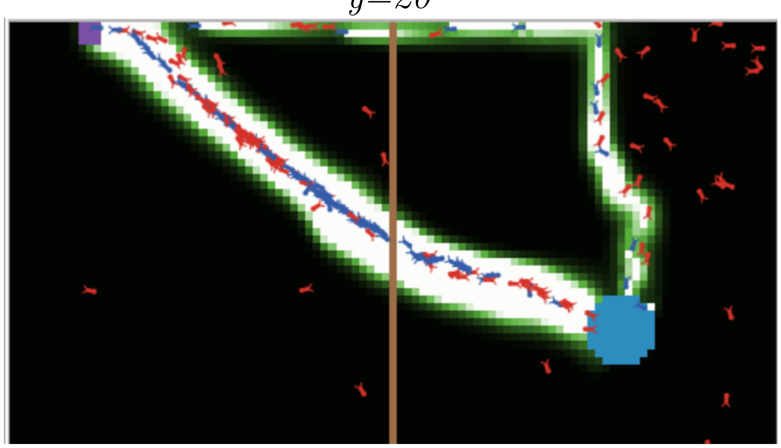
When the food source was kept at constant x coordinate (70) and the y coordinate was changed, we observe the following.

| | | | | | |
|---|---|---|---|---|---|
| 80 | 90 | 70.5762 | 77 | 76 | 76.5 |
| 80 | 80 | 72.532751 | 82 | 82 | 82 |
| 80 | 70 | 75.769387 | 42 | 78 | 60 |
| 80 | 60 | 80.131143 | 33 | 19 | 26 |
| 80 | 40 | 91.547802 | 15 | 14 | 14.5 |
| 80 | 20 | 105.55094 | 12 | 12 | 12 |

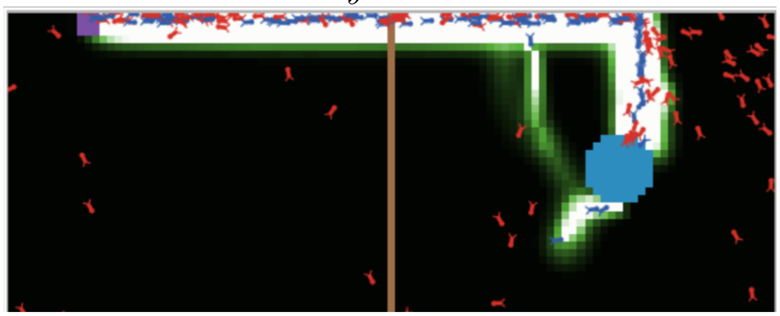
The cutoff decreases with distance in this case. This is because the food is going further away from the wall. Hence it relies more on nest scent and chemical trail than wall-affinity.
Some simulations are shown below.



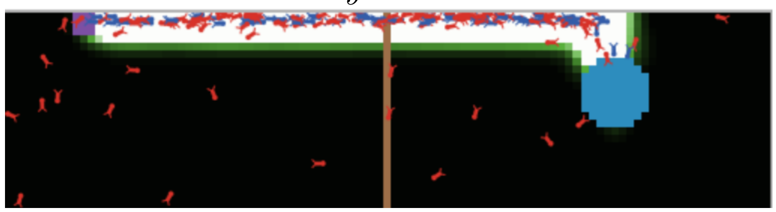
*y=20*



*y=60*

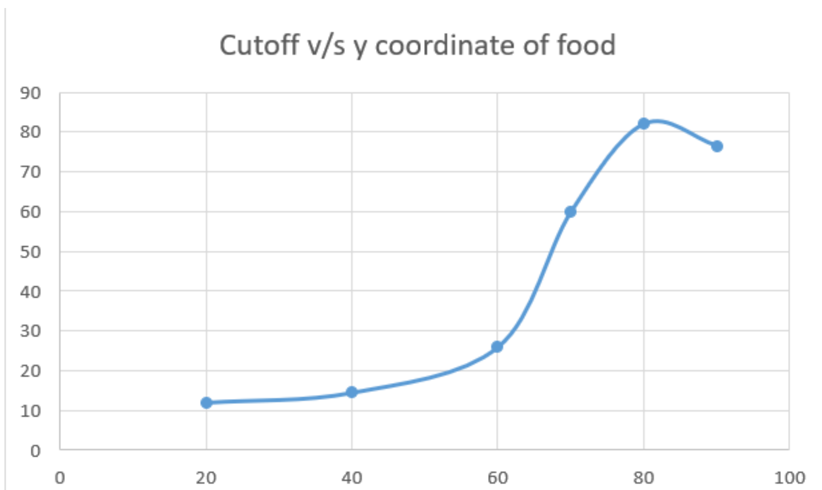


*y=80*



*y=90*

The graph is shown below.

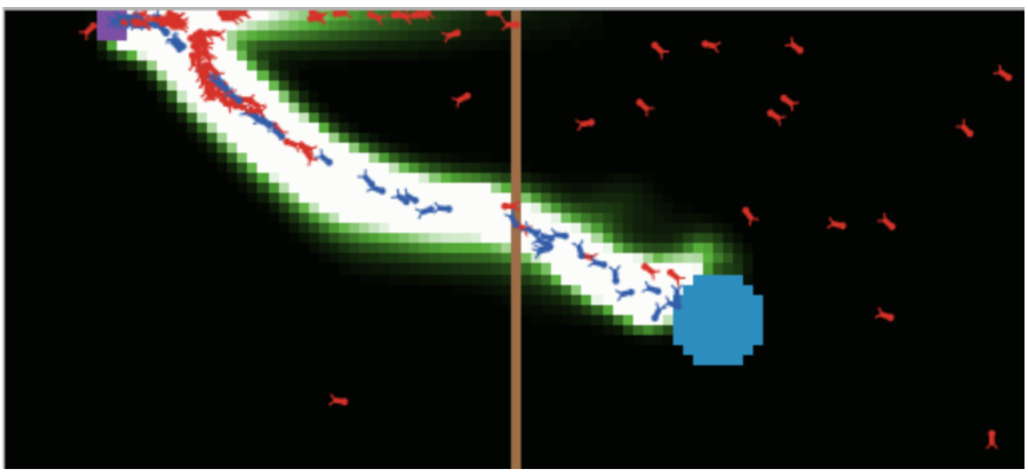


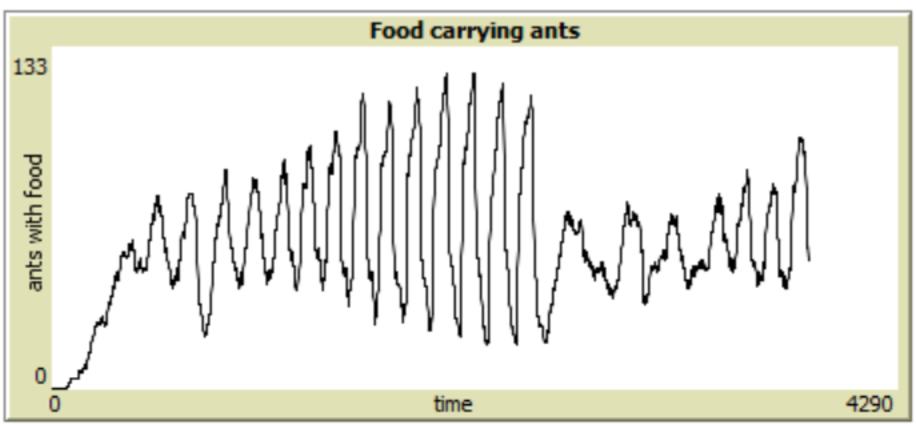
# Difficulties Encountered

The main issues faced are elaborated here.

### Clustering

The ants tend to move in a group which grows in time. If the group gets too large it breaks off, to form a group again. Spikes in food-carrying-ants v/s ticks (time) shows this clumping behaviour very well. One such run is shown for population 150.



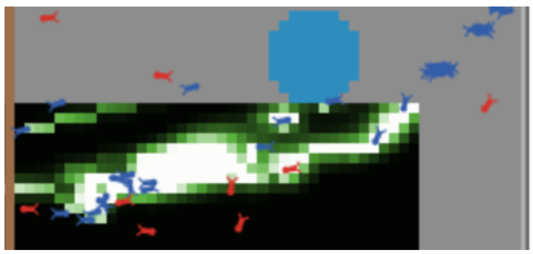



In the graph, the size of the peaks keep growing till there is just one huge clump. It suddenly breaks off as we can clearly see, and starts reforming. It breaks due to the fact that all ants are together and trail is not being reinforced.

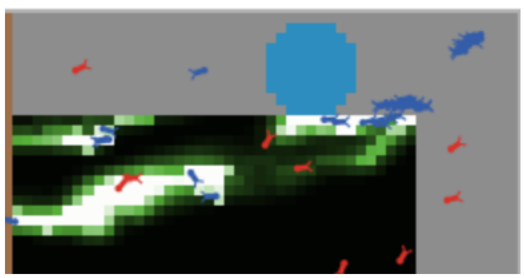
*Efforts to reduce clumping* Changing parameters did not help much, although increasing diffusion helped a bit.
Clumping is more only for lower populations that have a distinct trail. For higher populations, due to the larger number of ants, trail is already re-in-forced continuously. *Possible reasons for clumping* Clumping could be caused because one ant could be heavily influenced by the chemical trail left by the neighbouring ant.

#### Clumping

In previous runs of the code, some ants would get "confused" about which direction to follow and would wiggle in the same spot. Other ants would come join them. One such example is shown below.



*A few clusters formed.*



*A few ticks later. Clusters move together.*

#### Trail formation

Visually it is easy to see whether a trail has been formed or not, but it is harder to classify with data. Effort was made to implement a green ant to only follow the trail, but was not carried out further.

# Further Considerations

Some things that can be worked on further.

1. To analyse the phenomenon of clustering, and methods to reduce it.
2. To characterise trail formation objectively.
3. To make a more general model for wall-following and observe the phenomenon of edge-cutting which is something well-observed in ant trails.

# References


1. Oettler, Schmid, Zankl, Rey, Dress, Heinze.(2013)*Fermat's Principle of Least Time Predicts Refraction of Ant Trails at Substrate Borders*
   doi:10.1371/journal.pone.0059739

2. Pratik Mandrekar, Toby Joseph (2014)*When to Cut Corners and When Not to*
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3. Tisue, Wilensky. (2004) *NetLogo: Design and implementation of a multi-agent modeling environment*

4. Dorigo, Stutzle (2004) *Ant Colony Optimization*
   The MIT Press