Examining how the Robinson et al’s model ants reacts to changes in their environment.

TRIMURTHY GOVINDAPPA

Intelligence in Animals and Machines (Modelling collective behaviour)

UNIVERSITY OF SUSSEX

Student RegNo: 22316808

Academic year: 2023-2024

Submission Date: 30/11/2023

INTRODUCTION

The Robinson et al work "A Simple Threshold Rule Is Sufficient to Explain Sophisticated Collective Decision Making" in the field of social animal behaviour closely explores how social insects, specifically Temnothorax albipennis, or house-hunting ants, make decisions. The paper proposes a fundamental hypothesis concentrating on collective decision-making during nest site selection scouting ants may employ a simple quality dependent threshold criterion to determine whether to lure nest-mates to a new site or continue looking for alternatives.

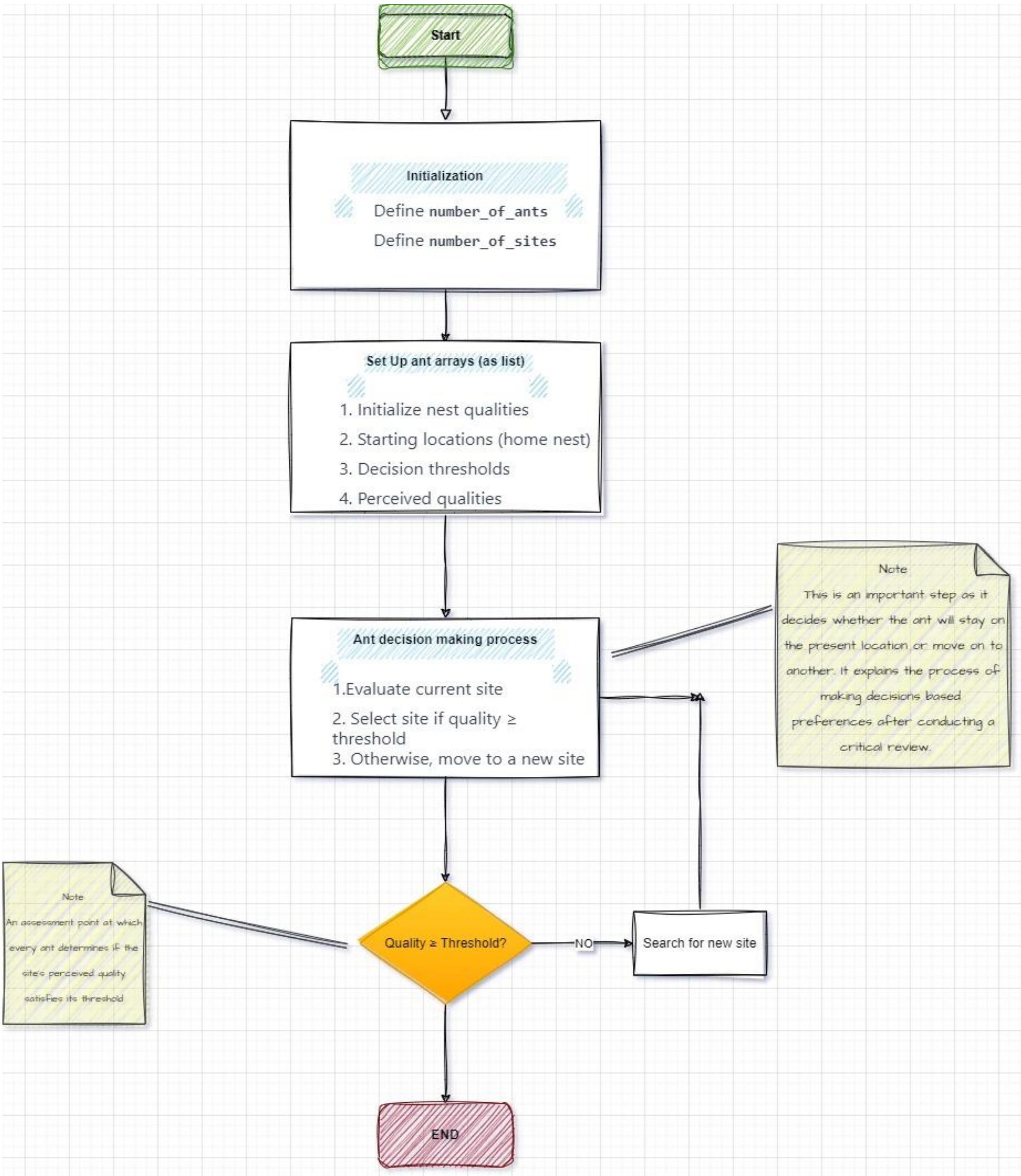
The paper's central premise is the precise balance of simplicity and complexity in these ant's decision-making process. This seemingly simple threshold rule, the authors say could explain patterns in group decision-making found in ants using analytical and simulation models. This report critically examines the proposed rules ramifications, analyzing the methods and evidence presented. We seek to get insights into the processes that govern the ants cooperative actions by decoding the perplexing world of collective decision making in social animals.

In this report, we are experimenting with the decision making model of ants by introducing a new nest site, changing nest qualities, and tailoring the travel times to reach each site. We aim to see if ants still pick the best home even when we give them more options and change how far they have to travel. This will help us figure out if ants always go for the best nest site or if the time taken to discover a nest matters too. Our goal is to learn more about ants decision making as a group and what that can tell us about how they behave.

METHODS

Model Description:

The goal of the simulation model is to simulate how ants make decisions when deciding potential nest sites. In the model, each ant agent evaluates the quality of sites independently based on a threshold rule. The steps involved are as follows:



STEPS INVOLVED EXPLAINED:

1. First, we create a virtual world in which specific spots are marked as possible new homes and given a quality score each.

2. Next, we add the virtual ants, each with their own idea of the best nest site.

   Set number_of_ants, number_of_sites.

   Define nest_quality for each site.

   Initialize ants array with location (start at home nest), threshold, and site quality

3. every ant examines a location individually. If everything meets its requirements, it decides to move in.
4. If the first site isn't good enough, the ant investigates a different, randomly chosen one.

Ant Decision Process (Repeat for each ant) While not_selected_a_site:

Evaluate current site:

If perceived_quality >= threshold, select site.

If site not selected, move to new site based on transition probabilities.

Note down selected site.

5. This continues until all of the ants have chosen a location.
Output: Return site selection statistics for the colony.

Perquisites of Robinsons model:

The perk of using this model is that it uses simpler rules for each ant to make decision on choosing a nest site. This is because real ants seem to use a similar method. Real ants don't compare all the available homes but instead pick the first site that meets their personal requirements. The same behaviour is also reflected in the model. This model is simpler than the other models, where ants compare a lot of different homes for example the Visscher PK. (2007)'s model ("Group decision making in nest-site selection among social insects”) which is less effective due to its increased complexity and cognitive demands on individual ants. So, the Robinson's model is easier to manage and understand simplifying the complex matrices and calculations. This approach satisfies the paper's findings, as it reinforces the importance of each ant's individual choice in the group's overall decision. By focusing on these individual thresholds, we can easily understand how multiple simple decisions lead to the complex group behaviour without requiring complex calculations.

Result of the code before experimentation

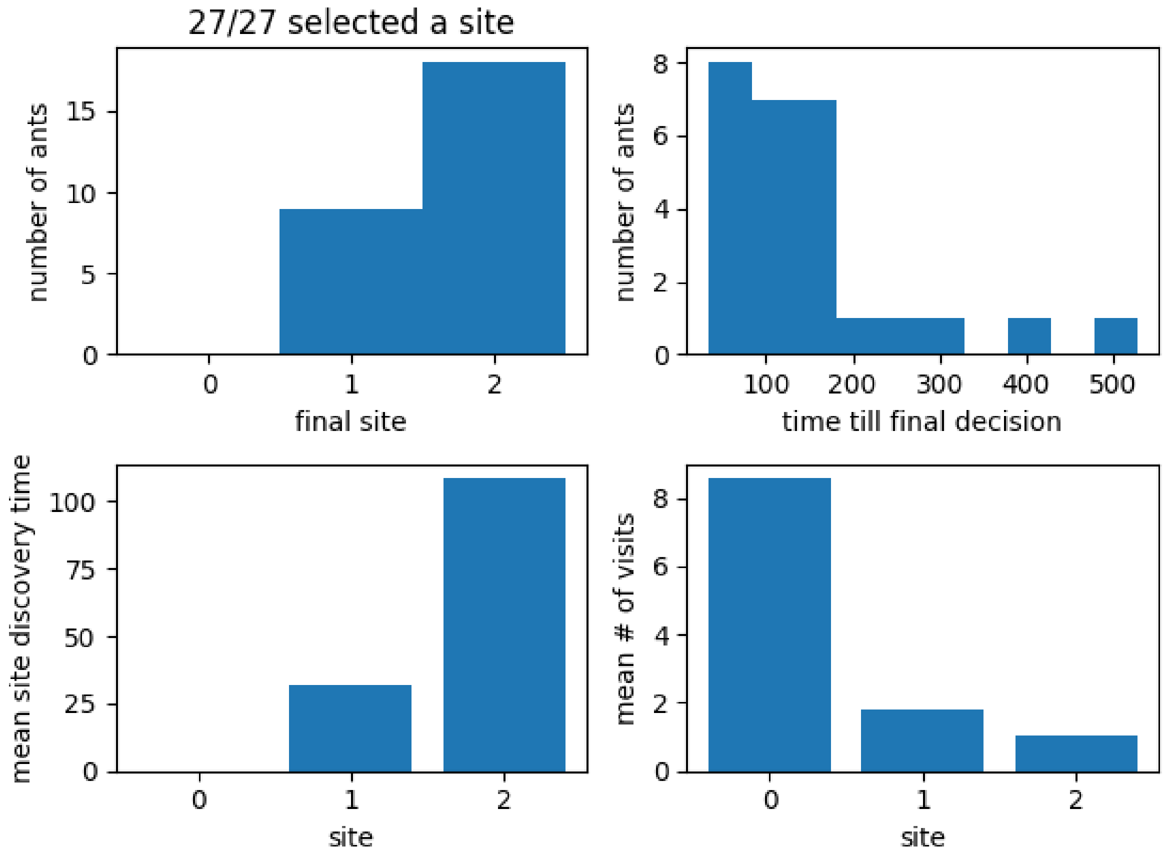


***Figure 1**: Output of the code before experimentation*

Code summary:

The output is obtained when the default source code is run, for the variables like,

The number of ants 'n' is set to be 27, the variables governing the ant's threshold are threshold_mean and is set to 5, the threshold_stddev is set to be 1.

As per the given code, in the overall of 3 nest sites (including the home nest) the quality of home nest is set to '-np.inf' which is the negative infinity, eliminating the probability of ant's choosing their current/home site. And the quality of poor nest is set to 4, while the quality of best nest is set to 6. The qual_stddev is set to np.array([1,1,1]) as per the sourcecode for similar factors involving in choosing a site. The mean time to get between each nest is established by the variable time_means which is set to np.array([1,36,143], [36,1,116], [143,116,1]) and time_stddevs is set to time_means / 5.

The probability of ants visiting each site from each other is set by variable 'probs', where probs = np.array([0.91, 0.15, 0.03], [0.06, 0.8, 0.06], [0.03, 0.05, 0.91])

```
n = 27
threshold_mean = 5
threshold_stddev = 1
quals = np.array([-np.inf, 4, 6])
```

```
qual_stddev = np.array([1, 1, 1])
time_means = np.array([[1, 36, 143], [36, 1, 116], [143, 116, 1]])
time_stddevs = time_means / 5
probs = np.array([[0.91, 0.15, 0.03], [0.06, 0.8, 0.06], [0.03, 0.05,
0.91]])
```

Explanation of the results (*Figure 1*)

The first graph on the top left depicts, out of 27 ants' predominant number of ants (more than 15) chose the second site of which the quality was set high and far fewer ants chose nest 1.

From the second nest on the top right establishes the relation between the number of ants and the time taken to make a final decision. This depicts that most ants took very less time in deciding.

From the graph on the bottom left, it is evident that most ants took a lot of time to discover sight 2 whereas ants took less number time to discover site 1.

The graph on the bottom right establishes the relation between the mean number ants' visit to each site. It suggests that the greatest number of ants visited site 1 first as the time taken to reach site 1 was comparatively less than that of site 2.

EXPERIMENTATION/IMPLEMENTATION

Experiment 1: Adding new nest site

To experiment with this setup, I tailored our original model by adding a new nest site. The new nest was assigned with the best quality score compared to the other nests to examine the ants' behaviour while choosing nests. Other variables were altered as per the requirement of our alteration. After that, the simulation was run several times, which enabled us to see the following differences in the ants' decisions after the addition of this new nest site.

The variables that were altered are as follows:

```
probs = np.array([[0.76, 0.08, 0.08, 0.08],
                  [0.10, 0.82, 0.05, 0.05],
                  [0.09, 0.05, 0.82, 0.05],
                  [0.05, 0.05, 0.05, 0.82]])
```

```
time_means = np.array([[1, 46, 46, 56],
                       [46, 1, 80, 90],
                       [40, 80, 1, 90],
                        [56, 90, 90, 1]])


quals = np.array([-np.inf, 4, 6, 8])
```

```
qual_stddev = np.array([1, 1, 1, 1])
```

```
threshold_mean = 7
threshold_stddev = 1
```

```
ax1.hist(accepts, bins=[-0.5, 0.5, 1.5, 2.5, 3.5]) #increased the length of X axis in the output summary by 1 unit.
```

EXPERIMENTAL RESULTS:

When the simulation was run several times after the addition of new nest, the following outcomes were observed (Figure 2)

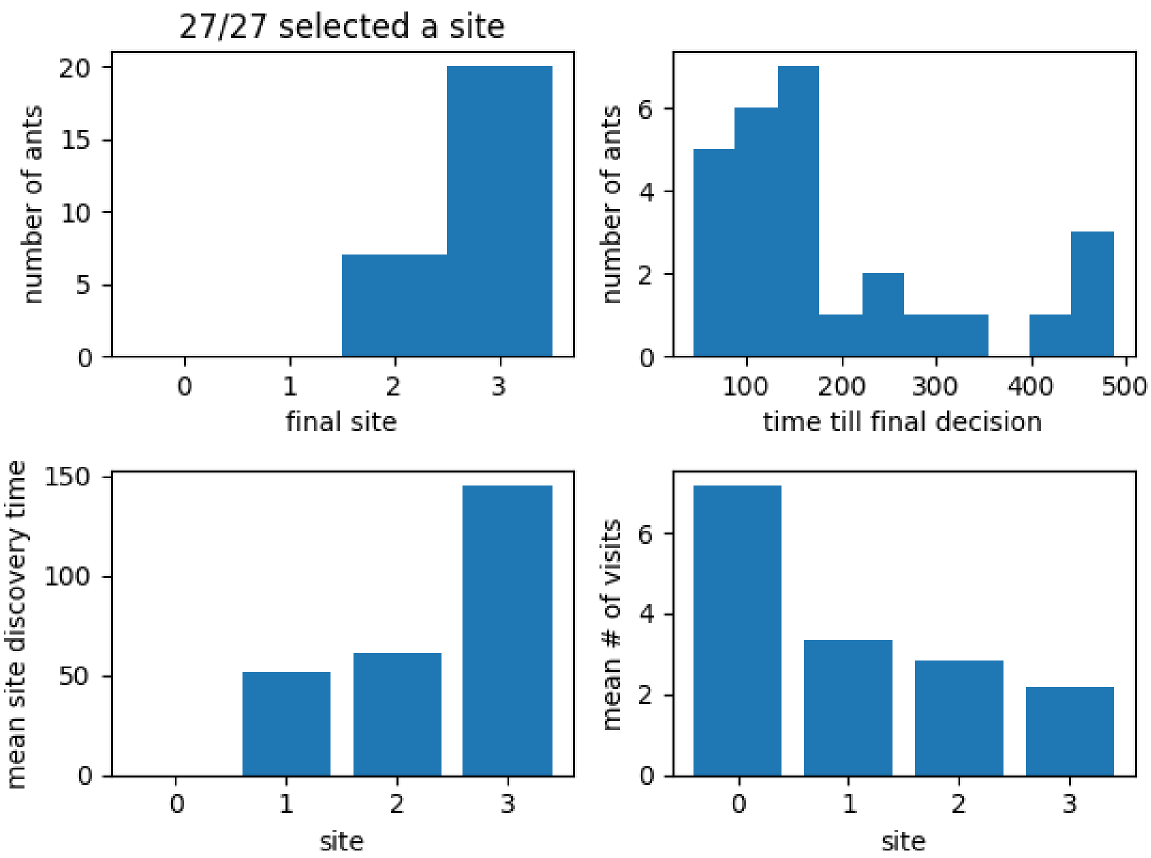


Figure 2. Experimental results after addition of a new site

The experimental outcomes (figure 2) depict that predominant number of ants (nearly 20 out of 27 ants) chose the new site that was added. So, it is evident that the ants chose the best site (with highest quality) in this case our newly added site.

Experiment 2: Increasing the number of ants.

The only variable that was supposed to be tailored was ‘n’ (number of ants)

```
n = 1000
```

When the simulation was run several times after the variable ‘n’ was drastically increased from 27 to 1000, to the previously set up experimental conditions the following outcome was observed (Figure 3)

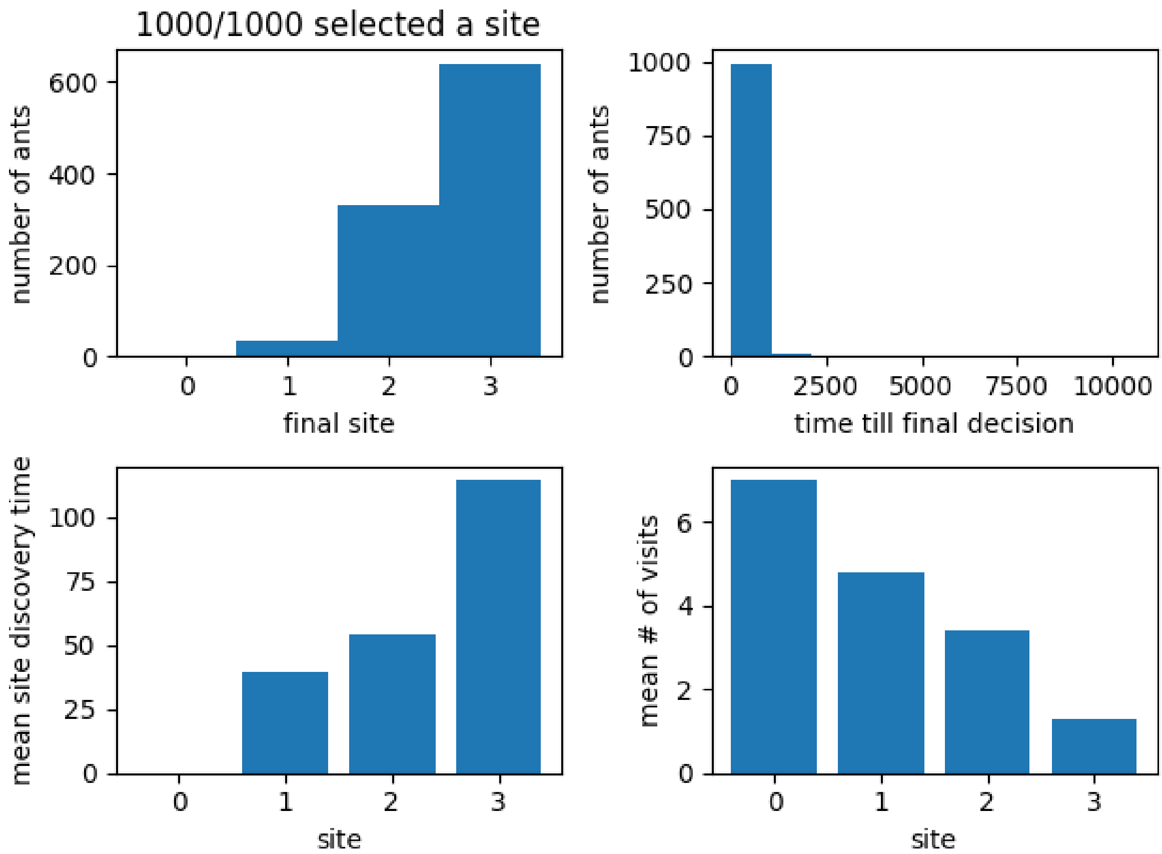


Figure 3: Outcome of the experimental set up for thousand ants

The outcome suggests, despite increasing the number of ants dramatically, it was seen that most ants still chose the best available nest (in this case the newly added nest with the best quality. While least number of ants chose the poor quality nest and moderate number of ants chose site 2. It is hence evident that the outcome of ants’ decision was in the order of increasing quality.

Experiment 3: Modifying time intervals.

In this experiment, I changed the code to make one of the nest sites much harder to get to. Before altering the code (Code 1), it didn't take the ants too long to travel between them as all the nest sites were pretty close to each other.

Code 1:

```
time_means = np.array([[1, 46, 46, 56],
                       [46, 1, 80, 90],
                       [40, 80, 1, 90],
                       [56, 90, 90, 1]])
```

But now I cnaged the dode(Code 2) so that getting to the last nest would take a lot more time than others. This way, we can see if antss still pick the faraway nest when it's a lot harder for them to reach it.

Code 2:

```
time_means = np.array([[1, 46, 46, 150],   # Increased the time taken to reach final site from site 1
                       [46, 1, 80, 150],   # Increased the time taken to reach final site from site 2
                       [40, 80, 1, 150],   # Increased the time taken to reach final site from site 3
                       [150, 150, 150, 1]]) # Increased the time taken to reach all other sites from the final site
```

Outcome: After running this simulation the following result was observed. (figure 4)

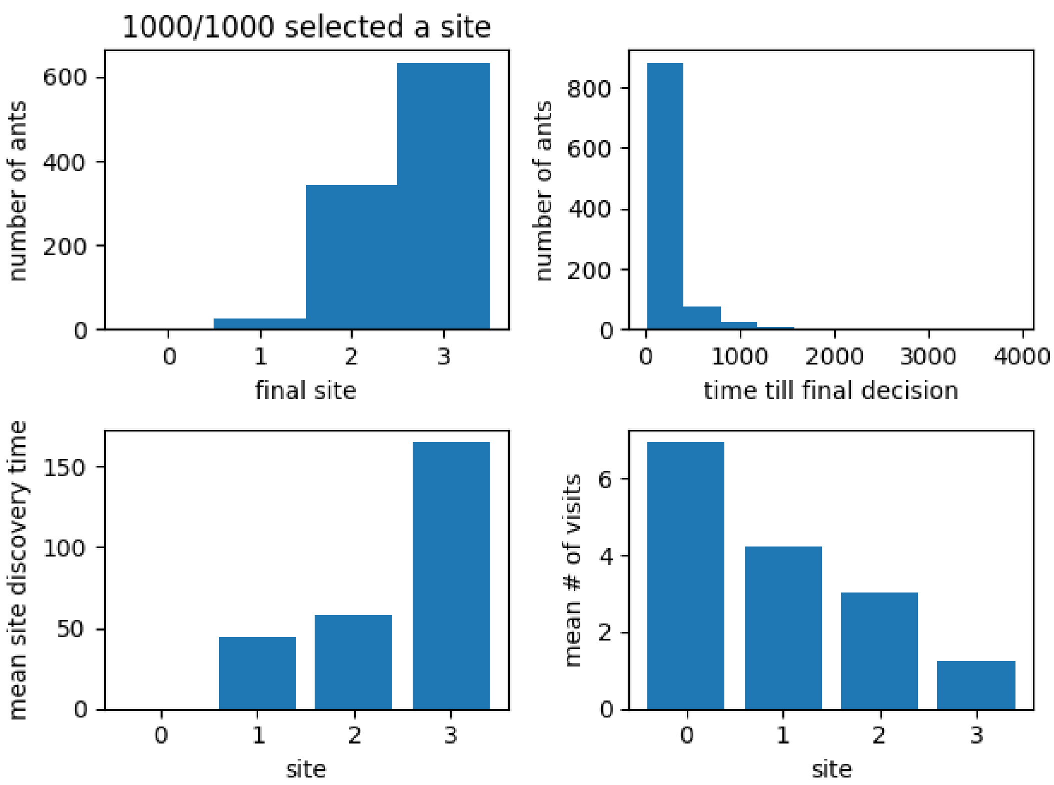


figure 4: outcome of experiment 3

Interestingly, despite making the final site much harder to reach by increasing the travel time, the ants still chose it. Even though reaching this particular site took much time than others. So we can conclude that for the ants, the quality of the nest is more important than how long it takes to get there.

They consistently picked the best nest available, showing that their decision making focuses predominantly on the quality of the site, rather than the effort needed to reach it.

Thoughts on the results

In my experiment, I set out to explore how ants decide on their nesting sites when the conditions change. From previous studies, like those by Robinson and his team, we know that ants usually follow a simple rule to choose the best nest they can find. I tested this by altering three things in my ant model. First I added a new nest, increased the number of ants, and then made one nest more difficult to reach. It was clear that most of the ants chose the new, nest with highest quality score that I added. when I offered it to them to observe how they would respond. This result demonstrated the ants strong preference for high quality nests.

Then, I was curious about the impact of a larger number of ants on their decision making. So I increased the number of ants from 27 to 1000. Interestingly, even with more ants involving in the decision making process, the majority of ants still chose the best nest. This indicated to me that the preference for higher quality nests isn't affected much by the number of ants making the choice.

Lastly, I was interested to see how ants' decision would be influenced by the effort put in discovering the site, specifically in terms of travel time. I increased the difficulty of ants discovering the final best site by increasing the time taken to reach the final site. Interestingly, the ants kept choosing the best nest even though it was getting harder to get to. This proved to me that the ants care more about the nest's quality than the efforts put in.

I learned a lot about the ants' decision-making process from my experiments. regardless of multiple options or the effort needed to get there, they always seem to put the quality of the nest before other factors. This straightforward approach to decision making may even find wider uses in fields such as robotics or studies of collective behaviour. In future studies, it would be interesting to see how ants choose their nests in response to dangers from other ant colonies or predators. Even real ants could be used in similar controlled environment experiments to see if their behaviour agrees with our programming model

References

Robinson, E. J., Franks, N. R., Ellis, S., Okuda, S., & Marshall, J. A. (2011). A simple threshold rule is sufficient to explain sophisticated collective decision-making. PLoS ONE, 6(5), e19981.

Visscher PK. (2007) "Group decision making in nest-site selection among social insects." Annual Review of Entomology, 52, 255-275.

APPENDICES

Code used:

```
import numpy as np

import PlotSummaryDataRobinson as psdr

import OutputRobinsonDataExcel as orde

import RobinsonCode as rc

# ExampleUsingRobinsonCodeNew

# this sets the name of the outp[ut file. It stores the data for each of

# your tests so you'll need to call it something that indicates what

# experiment it is

# output_file='RobinsonTestExperimentTest1.mat'


output_file_xls = 'RobinsonTestExperimentTest1.xlsx'


# these parameters are for the first experiment

# probabilities of visiting each site from each other

#probs = np.array([[0.91, 0.15, 0.03], [0.06, 0.8, 0.06], [0.03, 0.05, 0.91]])


probs = np.array([[0.76, 0.08, 0.08, 0.08],

                [0.10, 0.82, 0.05, 0.05],

                [0.09, 0.05, 0.82, 0.05],

                [0.05, 0.05, 0.05, 0.82]])

#  original mean time to get between each nest

#time_means = np.array([[1, 46, 46, 56],

 #                 [46, 1, 80, 90],

  #                [40, 80, 1, 90],

   #               [56, 90, 90, 1]])

#modified mean time to get between each nest.

time_means = np.array([[1, 46, 46, 150],   # Increased the time taken to reach final site from site 1
```

```
            [46, 1, 80, 150],   # Increased the time taken to reach final site from site 2
            [40, 80, 1, 150],   # Increased the time taken to reach final site from site 3
            [150, 150, 150, 1]]) # Increased the time taken to reach all other sites from the final site

# standard deviation of time to get between each nest
time_stddevs = time_means / 5

# mean quality of each nest. Note home is -infinity so it never gets picked
quals = np.array([-np.inf, 4, 6, 8])

# standard deviation of quality: essentially this controls
# how variable the ants assessment of each nest is. This is currently set
# as in the 1st experiment where the variability is the same for each nest
qual_stddev = np.array([1, 1, 1, 1])
# However, if you want to change is so nests perceived w different accuracy
# you could do eg qual_stddev = [1, 1, 4]

# set the number of ants
n = 1000

# these govern the ant's threshold
threshold_mean = 7
threshold_stddev = 1

current_time, discovers, visits, accepts, Ants, rnd_seed, preqtimes, preqdiscovers, preqvisits, preqaccepts = \
    rc.RobinsonCode(n, quals, probs, threshold_mean, threshold_stddev, qual_stddev, time_means, time_stddevs, [], [])
```