Modeling of Honey Bee Behavior

Bhargav Singaraju (Author)
Electrical & Computer Engineering
Rutgers School of Engineering
Piscataway, NJ, USA
brs110@scarletmail.rutgers.edu

Dr. Richard Martin
Electrical & Computer Engineering
Rutgers School of Engineering
Piscataway, NJ, USA
rmartin@scarletmail.rutgers.edu

***Abstract*—in this paper, we describe the Bee Cognitive & Behavioral model and its implementation using Pygame. The purpose of experimenting on honey bees is to understand how they react when exposed to RF transmissions. This paper specifically tries to understand the movements of honey bees so that researchers can understand the impact of external stimuli. This simulation shows that the bee was able to figure out the general proximity of the feeder in about an hour.**

Keywords—Radio Frequency (RF) Transmissions

I. Introduction

There are many examples of devices that emit Radio Frequency (RF) signals. Some of those devices are cellphones, sonars, GPS systems, street cameras, FM/AM Radio and many more (SCHNIER, 2006). In fact, the amount of RF (Radio Frequency) signals that honey bees are exposed to daily is enormous and some studies show that it is harmful towards them because RF transmissions significantly reduced the percentage of hatched queens in a colony (Apicultural State Institute, 2019). Because there are fewer queens born in a colony, this means that there was less mating in hives that were affected by RF since queens are born through mating. To understand more about the why there might be less mating in colonies, there must be a greater understanding on the behavior of honey bees. As a way to understand more about their behavior, this paper aims to understand how bees react to stimuli through a model using Pygame.

II. Background

A. Bee Cognitive & Behavioral Model

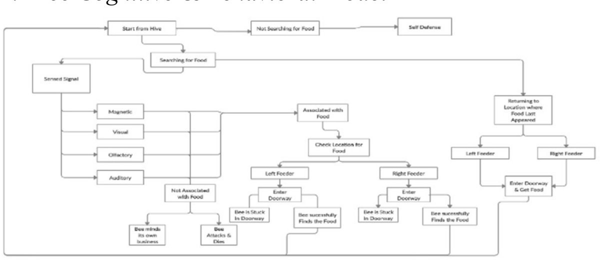

Figure 0: An Image of the Bee Simulation Model

This model above exemplifies most of the possibilities that a bee is given if it would like to move in an environment. The model allows researchers to categorize actions taken by a honey bee depending upon the stimulus. The purpose of designing such a model stems from the thought that the sample size of honey bees that reach our experimental platform might be inaccurate because there are many honey bees in nature but only a few end up on our experimental platform. This is because honey bees may be lost from multiple stimuli such as magnetic, visual, olfactory and auditory. The assumption behind this model is that honey bees can come from surrounding hives to the experimental platform in order to get food. The experimental model allows for researchers to predict how a honey bee can make it to our visual setup. To the left of the model are stimuli which a bee can sense and to the right are the actions that it will take based on the input. This cognitive & behavioral model is set up like a state machine such that each and every bee that fails to reach our experimental setup is assumed to start back at square 1 (in Figure 0). In other words, this is an indication for the bee to start back at the hive if the honey bee cannot reach its destination.

B. Simulating Bee Model using Pygame

This part of the project is to create the simulation of the Cognitive & Behavioral Model using Pygame in order to understand how a bee might respond in an experimental setup. In the simulation, the yellow square represents the bee and the red squares represent the feeders. The diagram below outlines how the feeder looks like in the simulation.

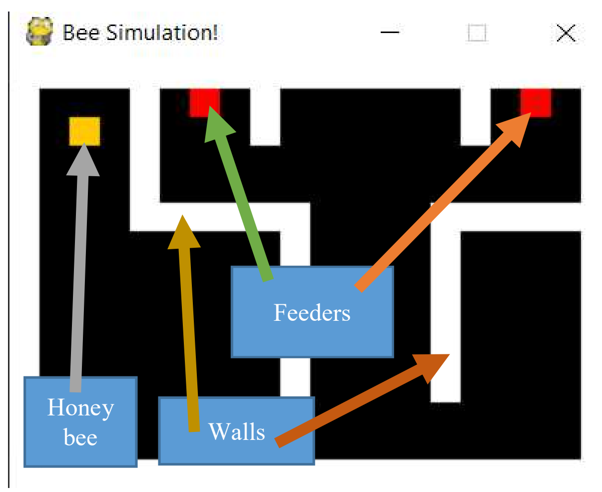

Figure 1: Simulation Model

The simulation above (in Figure 1) is a 2-D projection of the platform in the image below:

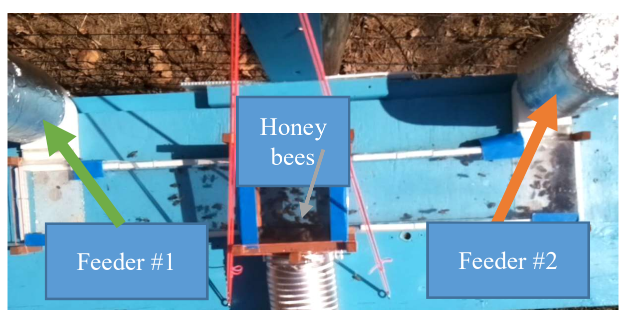

Figure 2: Experimental Bee Platform from Live Video

III. Modeling Bee Behavior

This experiment was simulated by having the bee find the shortest path to the feeder. To find a path to the feeder, I used the distance formula to find the distance between the honey bee and the feeder closest to its location. In this simulation, there was also a calculation of the angle between the bee and the feeder. The angle was used to figure out where the bee should move and the distance was used to find out how far the bee would need to move in order to make it to the feeder. Shortest Path Algorithm is used since the bee is trying to reach its destination in the short amount of distance. Since it is using the shortest path, it might take a longer duration to reach its destination.

A. Observational Remarks from Live Video of Honey Bees

I was able to observe these statements after looking at live bee video taken on September 22, 2019 from 12:08 PM to 1:08 PM. The video that I was looking at is similar to Figure 2. There were a couple of honey bees that were wandering around the experimental feeder looking for cracks in order to access the inside of the platform. Honey bees exhibit this type of behavior in order to find of way to get into the feeder so that they would have an easier time finding the food. I observed that 2 bees from the center of the tunnel made it to the direction of the feeder in less than 10 seconds. I saw that there were a lot of honey bees that were stuck in the tunnel. I saw that for every couple of inches away from the tunnel in the direction of either of the two feeders that the amount of honey bees steadily decreased in number. Since there were less honey bees at the feeder itself at a given point in time compared to the number at the tunnel, it stands to reason that honey bees find this maze to retrieve food very challenging. It was also observed that once a bee finds the food, the bee doesn't try to fight with other bees for that food. That is, bees don't categorize the food from the feeder as theirs but instead as free food for all bees.

B. Observational Remarks from the Bee Simulation

The honey bee in the simulation displays Brownian motion which is random, uncontrolled movement of particles in an area as they constantly collide with other particles (Advances in Applied Mechanics, 2012). The particles in the definition refer to honey bees. The other particles in the definition refer to the walls. In this simulation, the honey bees move in the direction of the food based on the shortest path possible. The initial movement of the bee, however, does not consider that there might be road blocks on the path to the food. This simulation allows us to observe whether the bee would find its way around those road blocks. A picture of how the simulation looks like is represented by Figure 1. It was observed that the bee initially found the closest possible spot before hitting a wall, which is an accumulation of white shaped blocks as represented in Figure 1. Once the bee collides with the wall, this is when the Brownian motion of the bee comes into play. In this situation, the bee is unsure of its next move despite having impulses such as the scent of the food that inform the bee such that the food is in a particular direction. Therefore, the bee in this simulation moves in a random direction until it can find a path to get to the food. It was observed that most of the bees did not ever find the food but had, in fact, been able to get in the right direction in a limited time. This simulation was run in two hours intervals to study the behavior.

C. Compare & Contrast Bee Behavior from Video and Simulation

The simulation of bees moving towards the feeder in this research report is similar to how they move in real life since in real life the bee tries to move to the feeder based on how far the feeder is from the bee and in the video the bee tries to move to the feeder based on its distance from its destination. The motion is also similar since the bee in the simulation is exhibiting Brownian motion after collusion as it is depicted in the video. The motion of the bee is different in the simulation than in live video because the determination of bee in the simulation depending on how long the simulation is run for is much greater than the determination of the bee in the live video. This is because the bee is a living organism that needs to maintain homeostasis unlike the computer simulation. Also, there were only bees in this simulation but on the field there might be a possibility for other organisms other than bees to be competing against each other for food.

IV. Conclusions

After running the simulation, it was noted that the bee tended to figure out the general proximity of where its destination was but would often get stuck as it approached the exact coordinates of the feeder. To minimize the probability of the bee getting stuck, it was considered that increasing the randomization of the bee could increase the probability of the bee finding the feeder. That is, randomizing the movement of the bee at every moment that the bee tried to move. This idea helped to an extent since some possibilities of the bee getting stuck were eliminated; however, the bee would still be moving in directions that were completely random. It was concluded after this research that the bee would need a considerable duration of time in order to reach the feeder.

V. Further Research Ideas

It would be possible to use Minimal Squares Algorithm and the Shortest Path Algorithm in order to further improve the probability of the bee reaching the feeder. My impression is that by increasing the bee count in the simulation that this would increase the probability of the bee reaching the feeder faster. Some ideas to consider for future research into this project:

- Could it be that some of the bees never reach the feeder?
- Could RF lead to some extra sense which might point the bees in the correct direction?
- How does communication between honey bees help increase the number of bees that make it to the feeder?

Bees are known to have magnetic sensing and if the waves coming out of the solenoid happen to be magnetic waves then maybe the bee might have an easier time finding its destination through magnetic sensing.

Acknowledgment

I thank Dr. Rich Martin for his tireless efforts in advising me on this project. I would like to thank WINLAB for

providing their resources to me in order to successfully complete this research project.

References

[1] Advances in Applied Mechanics. (2012). Brownian Motion. Retrieved from https://www.sciencedirect.com/topics/chemistry/brownian-motion

[2] Apicultural State Institute. (2019, April 15). Effects of radiofrequency electromagnetic radiation (RF-EMF) on honey bee queen development and mating success. Retrieved from https://www.emfdata.org/en/studies/detail?id=509

[3] SCHNIER. (2006). EMF: 2. What are the sources of exposure to radio frequency (RF) fields?. Retrieved from https://ec.europa.eu/health/scientific_committees/opinions_layman/en/electromagnetic-fields07/l-2/2-exposure-radio-fields.htm