Bee Hive Simulation*

Mariana Brandão (86893)
Instituto Superior Técnico
mariana.brandao@tecnico.ulisboa.pt

Daniela Carvalho (92443)
Instituto Superior Técnico
daniela.carvalho@tecnico.ulisboa.pt

Maria Costa (93399)
Instituto Superior Técnico
mcarmoccosta2000@tecnico.ulisboa.pt

ABSTRACT

Bees play a key role in our natural environment and are the biggest contributors to an ecosystem's biodiversity. Not only are they responsible for that sweet sugary substance called *honey*, but they are also responsible for pollination, keeping ecosystems worldwide alive and thriving.

Bees carry pollen between different plants and the hive. This results in the spread of pollen between plants of different sexes, which fertilises them, or even between different parts of the same plant, which also helps in reproduction.

A hive of bees encompasses different types of interactions among the different bees. Even though they all work towards the same goal, to grow the hive and produce honey, their different roles play a big part in the hive's maintenance and survival. Besides that, exterior factors to the colony must be taken into account as they influence the bees' behaviour.

The importance of bees to our food supply is also unquestionable. Without bees, our world would be much less colourful, our ecosystems wouldn't be as rich and diverse, and our dinner tables would be very empty. Therefore, we want to explore the survival of a beehive simulation for one year, having changes in the exterior factors influence the actions of our agents, and, subsequently, the production of honey and their survival.

KEYWORDS

Bees; Hive; Autonomous Agents; Multi-Agent; Simulation

1 INTRODUCTION

When confronted with the challenge of having a project related to Autonomous Agents and exploring the cooperation between them, one of our first associations was comparing these agents to a colony of bees, which are Nature's most famous effective collaborators.

As we all know, there are different roles bees take up while working in a hive, such as the queen bee, pollinators, and honey-makers. In our system, these three different roles will have to collaborate with each other in order to produce honey and help the hive survive the external adversities of each season for one year.

After searching for similar work projects, we did not find anything closely related to the specifications of our project, apart from an Ant *PettingZoo* Environment that might be useful.

With this Multiple Autonomous Agents System, we aim to better understand these Artificial Intelligence concepts, explore how we can simulate the cooperative interactions between bees and the environment, and raise awareness of the importance and complexity of these tiny insects for our biodiversity.

2 APPROACH

Here we will explain how the environment is to be designed, the architecture of the system, and its different agents.

2.1 External Environment

Our environment will include several external factors, which will impact the way the agents act. The agents will have to react to these factors and take them into account to reach their goal of efficiently producing honey so that the hive survives the year.

These external factors will include:

- The amount of flowers outside and their distance to the bee hive. The further the colony is from a certain flower, the longer it would take a bee to get there;
- The existence of rain, which will make it more difficult for the bees to collect pollen since it doesn't allow them to leave the hive;
- The existence of flowers with pesticides, substance which kills the bees;

The different seasons of the year will impact the surroundings of the bee hive (like the amount of flowers and the probability of rain) differently as we explain further down.

To help us design the environment, we found an Ant *PettingZoo* Environment that can be viewed at [1]. This uses another library called PettingZoo available at [4].

We also want to display the passing of time and the seasons in our simulation. To achieve this, we will have the season, weeks, and respective weather (Sunny or Rainy) visible to the viewers.

2.2 System's architecture

Like previously mentioned, the bees will be be our Autonomous Agents and will interact and cooperate between themselves so that the hive survives through the adversities of the seasons and long after their life-span.

For this project, we want the bees to collect enough honey during the warmer seasons to survive during the winter. We will have three types of bees: the queen, and the two types of workers (pollinators and honey-makers).

During the year, the two groups of worker bees (the honey producing and the pollen collectors) will be performing their respective set of tasks, producing honey to last through the winter. The pollinators are responsible for leaving the hive and flying to the flowers, collecting pollen, which is put in a pile. They will also be responsible for the pollination and reproduction of the flowers. Since they are Rational Agents, they will spread throughout the exterior so that they don't all decide to visit the same flower, wasting time.

*Bees act as Multiple Autonomous Agents that collaborate in order to produce honey

AASMA Project, IST, 2022, Lisbon, Portugal

https://doi.org/

In order to have these agents efficiently search for flowers, we'll implement a algorithm that contains Path Integration (PI), based of the work here [2], which is a non-pheromone based algorithm.

The honey-makers' job is to take pollen from the pile and create honey from it, which is a task that takes a certain amount of time.

Each season will have different conditions, which include rain, quantity of flowers, and pesticides to make the system more accurate and to let us explore the agents' reactions to set-backs. For instance, a flower with pesticide will kill a bee, and during the rain the bees are not allowed out. Besides this, the bees will also have have a lifespan to better replicate reality.

To populate the hive with more agents, the queen is considered "immortal" and will be replacing the worker bees that die. The available honey will be consumed by the queen to create new bees. Thus, if there is no honey, the bees that die will not be replaced and the colony's size will decrease.

During the Winter season, all bees will consume the honey in order to survive, testing if the hive can make it through this tougher season with the previously produced and stored honey.

2.3 Empirical evaluation

For the challenges that the bees might face during the year, we will have rainy days like mentioned above. A day has a different probability of being "Rainy" depending on the season. During Spring, we will start with a chance of 15% rain; in the Summer there will be 5%; in the Autumn there will be a chance 50%; and in the winter it will be 100%.

There will also be a chance that a flower has pesticides of 20% and if a bee unknowingly goes to get pollen from that flower, it will die.

The bees must be the ones to pollinate the flowers, so after getting the pollen from a flower, in the Spring, this action will originate 2 new flowers; in the Summer, only 1 new flower, and in the Autumn, it won't create any new flowers.

The working bees will have a lifespan of between 6 to 12 weeks, this number will be random, to better emulate real life bees.

Some of the values of our metrics are susceptible to being changed after we start implementing since we are curious to study how they might affect the outcome of the system and the bees' survival. These changes will also be very important for our experimental analyses and findings.

Our goal is to achieve a bee hive that withstands all these challenges and remains alive for a whole year.

3 CONCLUSIONS

To conclude this proposal, we hope to get a better understanding on the cooperation between these complex agents that help make the world as we know it. Bees play a huge role in biodiversity and flora's maintenance, being therefore crucial in our planet. However, their numbers are dangerously declining due to climate change [3], compromising the good functioning of plants' reproduction. Besides raising awareness to said problem, we believe these agents' interactions and roles would serve as good models in a system as required by the project specifications.

A ACKNOWLEDGMENTS

We would like to acknowledge and thank the Save the Bees movement for bringing awareness to the worrying and increasing problem that we face nowadays.

U.S. National Agricultural Statistics have shown that since 1947 until 2008, in the US, there has been a decline from about 6 million hives to 2.4 million, a 60 percent reduction.

REFERENCES

[1] Chorsch. 2021. Ants' PettingZoo: A custom pettingzoo environment that simulates a very simple ant colony. (2021). https://github.com/chorsch/ants

[2] Nyree Lemmens, Steven De Jong, Karl Tuyls, and Ann Nowé. 2007. Bee behaviour in multi-agent systems: A bee foraging algorithm. In *Proceedings of the 7th ALAMAS Symposium*. Citeseer, 126–138.

[3] Peter Soroye, Tim Newbold, and Jeremy Kerr. 2020. Climate change contributes to widespread declines among bumble bees across continents. *Science* 367, 6478 (2020), 685–688. https://doi.org/10.1126/science.aax8591 arXiv:https://www.science.org/doi/pdf/10.1126/science.aax8591

[4] J. K Terry, Benjamin Black, Nathaniel Grammel, Mario Jayakumar, Ananth Hari, Ryan Sulivan, Luis Santos, Rodrigo Perez, Caroline Horsch, Clemens Dieffendahl, Niall L Williams, Yashas Lokesh, Ryan Sullivan, and Praveen Ravi. 2020. PettingZoo: Gym for Multi-Agent Reinforcement Learning. *arXiv preprint arXiv:2009.14471* (2020).