Gathering of the Hive:
Investigating the clustering behaviour of honeybees through art and swarm robotics

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Abstract

In the *Gathering of the Hive* project, the societal and ecological implications, as well as technological possibilities of swarm robotics are explored through artistic methodology applied to Artificial Life. These matters are examined through an algorithm inspired by the clustering behaviour of honeybees applied to a swarm of Thymio robots interacting in a physical, changing environment. This work is a part of the ongoing FELT[1] project (Futures of Living Technologies), which explores artificial life systems through art and technology.

Introduction

A self-organizing clustering behaviour is most commonly found in social bees, and occurs when weather conditions are sub-optimal (Crailsheim, et al. 1999). These clusters are formed through mutual, collaborative, interactive behaviour within groups of bees. A combination of factors play into the movement of the individual bee, but gives a collective result in tightly formed clusters around areas with ideal conditions for the group as a whole, a living behavioural system.

Working through artistic practice gives a flexibility and open-endedness to the collaborative process, opening up to new ideas emerging from unexpected places. With the theoretical entrance point of System Aesthetics, developing art in regards to the way things are done (Burnham, 2015) – be that by human, robot or bee – artistic and technological strategies are used to examine this clustering and reflect around the implications of its technological application. Using this behavioural pattern towards programming a swarm of robots, algorithmically set to exhibit traits of this natural living system, we explore the artistic potential and concerns central to that of Artificial Life (Penny, 2017). By looking at not only the behaviour of bees in-amongst themselves, but towards and in interaction with their environment, ecological perspectives, also come into play. In the condition of the Anthropocene (Wark, 2016), where natural and human forces intertwine – man-made technologies increasingly possess properties of life and the planet is irreversibly altered by the actions of humans – what role can these technological systems drawing on natural mechanisms play? This is explored through a combination of artificial life, artistic production and research. This work is a part of the ongoing FELT[1] project (Futures of Living Technologies), carried out at the Living Technology Lab (Berg, et. al. 2019; Hansen, et al. 2018) at the Oslo Metropolitan University (Oslo, Norway).

Algorithm

The algorithm taken as an entrance point in this project comes from Schmickl and Hamann (Schmickl and Hamann, 2011) studies of the collective behaviour of honeybees, where they developed an algorithm for clustering behaviour designed for implementation into a robot swarm. Essentially the algorithm, named BeeClust, performs the following steps:

- The honeybees roam around randomly until encountering a wall, or another honeybee.
- When they encounter a wall, they turn around, and continue roaming.
- If they meet another honeybee, they read the sensor measurement and stay idle for a time proportional to the sensor value.

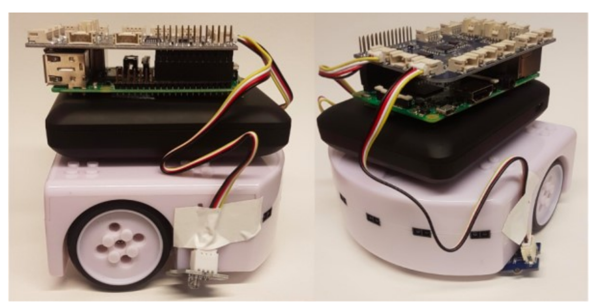

Figure 1: Technological set-up of the thymio robots

This will cause the honeybees to cluster around the focused area, where their sensor values stay high (Schmickl and Hamann, 2011). Being an algorithm designed with swarm robotics in mind – optimal result depends on the collaborative effort of multiple actors – the amount of robots present would become an important point of investigation (Navarro and Matía, 2013).

[1] https://sites.google.com/view/feltproject

Implementation

The BeeClust algorithm was developed in Python, stored on a Raspberry Pi 3 Model B. The Raspberry Pi is connected to a Thymio II[2] robot, and used as a controller for the robot's actions, and to read the sensor values. A power bank is used to supply the robot and the Raspberry Pi with power.

The Thymio II has sensors in the front, five sensors facing forwards and two facing downwards. These infrared sensors can detect nearby objects, and colour range ranging from black to white. These sensors are not precise enough to detect small environmental changes, thus external sensors were implemented, to read the light intensity of the projection. The GrovePi[3] is a shield to Raspberry Pi that can easily be connected to sensors provided by the same company. The used sensors can measure light changes in different environmental conditions precisely. The GrovePi reads sensory values and converts the signal to analogue, providing Raspberry Pi the ability to read analogue signals, and enables us to work with intensity, rather than binary on/off values. The robot setup is depicted in Fig. 1.

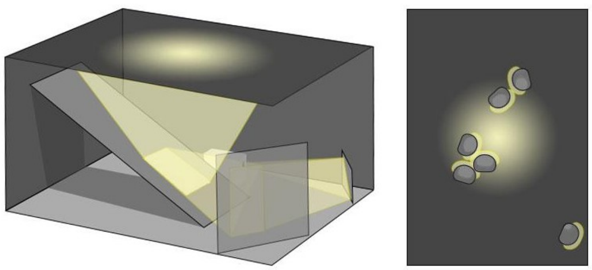

Figure 2: Model of rear-lit set-up (left), and model of bees clustering in relation to light-gradient (right)

Figure 3: Thymios clustering on the projected gradient.

Designing the Environment

When designing the environment for the Thymio robots to roam, the goal was to make a dynamic environment, where the source of optimal 'heat' would be in a changing condition, thus affecting the clustering performance of the bees. The way bees use the sun to triangulate the location of food sources in relation to their hive, was used as inspiration for the design (Evangelista, et al. 2014). Instead of a food source being the site of aggregation, this would be a simulated 'Sun' in the form of a pulsating white-to-black gradient projected onto a semi-transparent surface the robots were to move on. Aided by mirrors built into a box, this rear-projection would make possible a system for the robots to move, cluster, and re-cluster as the 'Sun' goes its way across the surface. Thus making practical use of the behavioural pattern in the form of a robot artistic performance in a visually perceivable way, also for the spectator. A setup is shown in Fig. 2, and an example of the swarm robotics art performance is shown in Fig. 3. This follows as a continuation of previous work on the project called *Pheromone Performance with Swarm Robotics*, A short introductory video to this can been seen through the following link: http://y2u.be/hA_YsC6mLP0

Conclusion and Further Work

Our work on the implementation and application of the BeeClust algorithm has resulted in a system capable of making use of, and highlight the distinctive pattern of honeybee clustering. Using clearly defined principles, the ongoing systematic process the robots conduct in this artistic performance carry its own possibilities and limitations. By using technology in unexpected ways, such as a light-led robot performance, artistic practice can provide new perspectives towards technological development. One could, for example, imagine similar principles used by robot swarms to cluster around lost people at sea through the lead of body temperature.

The arts opens up to an expanded use of the strategies and mechanisms set forth in this project and in artificial life in general, giving room to imagine robots and artificial living systems 'programmed' towards other parts of society. In future work this will be further explored through art exhibitions and workshops where an audience is invited to learn about and explore principles and possible execution of artificial life – Further reflecting over its biological and ecological roots and technological potential, in the current state where these seem to become increasingly entangled.

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[2] https://www.thymio.org/en:thymio

[3] https://www.dexterindustries.com/grovepi/