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IOT SMART Beehive

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1. ABSTRACT

Beekeeping is the ancient art of managing bees.
For thousands of years humans have valued the products from the hive; honey, beeswax, propolis and Royal Jelly and in return have managed bee colonies, providing the bees with a straw skep or modern wooden/synthetic hives. The bees are semi-domesticated in this symbiotic relationship, so it is the responsibility of the beekeeper to ensure that the bees are healthy and able to maintain the homeostasis of the colony in the hive.
This means ensuring that they are not overheating in the summer or too cold and damp in the winter, that they have sufficient stores and are not endangered by animals. It is impossible for the beekeeper to do this unless they are able to monitor the hives and measure parameters such as the humidity and temperature within the hive.

The aim of this project was to evaluate systems which record these parameters within a beehive – the concept of the 'smart beehive' [1].

Methods used: the project used a pre-production smart beehive system from a small start-up company called HiveBeat. This is not yet in production, so the research project provided an opportunity to Beta-test their equipment consisting of tags and controllers in conjunction with controller configuration software to connect the tag through home Wi-Fi.

Key Findings: The HiveBeat system worked well but there was a problem with the range achieved with radio wave technology. This was fine for the very close home apiary but not sufficient to reach the apiary next door. This defeats the object of remote hive monitoring and illustrates the requirement to select the correct technology for the job. Data from 8 sensors every 30 minutes between January and April 2024 allowed for more effective temperature and humidity management, allowing for significantly improved hive population health.

Recommendations include the need to identify an alternative technology for recording hive parameters which increases the range between controllers and tags so that the monitoring is truly remote. There are small changes in the HiveBeat system which would improve the data processing and user interface to exponentially improve the utility of the system.

Summary: this project has demonstrated that there is a very useful role for smart hive monitoring, but this is reliant on choosing suitable technology which meets the requirements of the beekeeper in their responsibility to support homeostasis within the beehive.

2. AIMS & OBJECTIVES

Aims
1. Create a system which will record parameters within a 'smart beehive'.
2. Learn about software integration through IOT to hardware sensors.

Objectives
1. Research the use of remote monitors, hardware and software integration.
2. Install and set up the software integration and hardware sensors.
3. Trial the equipment and record data.

3. BACKGROUND

The Internet of Things. The Internet of Things (IoT) is a collection of hardware and software designed to connect and communicate through the Internet. This enables a more efficient, reliable and faster system with a higher capacity than could be achieved by a human.

Smart Technology can be connected to the Internet and can have multiple different components. Smart technology can make normal connections work, faster and more efficiently and allows the analysis and interpretation of bulk data.

Beekeeping. Bee colonies are super-organisms made up of tens of thousands of bees living in a highly structured society. Bees communicate with one another through chemical messages (pheromones), vision, sound and vibration. The health of the hive is influenced by environmental factors such as ambient temperature and the availability of resources.

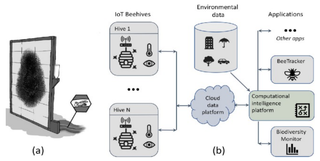
4. CONCEPT OF SMART BEEHIVES

The concept of smart beehives is applying 21st-century devices to a historical craft. Smart Beehives help to achieve efficiency for:
- Optimised bee welfare.
- Optimised honey production.
- Optimised economic success.

Technology can be used to create a complex system for collecting and processing data to achieve optimisation.

5. RESEARCH

The research for this project focused on the headings of **Connectivity, Data Processing** and **User Interface.**



Ref 2: a) Schematic prototype of a smart beehive. b) Conceptual setup with data collection at IoT nodes, use of other (open) data, data storage and computational services.

Connectivity
The method by which the information is transmitted from the sensor/device to the internet depends on the hardware used and the access available.
Methods include direct physical connection to the internet via ethernet cable via a gateway/router, WiFi, Bluetooth, Cellular, ow-power wide-area networks (LPWAN) , satellite communication.

Beehive monitoring solutions must consider:
- Power consumption
- Range
- Bandwidth

Other options include low-power wide-area networks (LPWAN) or even satellite communications.

LoRa[3] is an RF modulation technology for low-power, wide-area networks (LPWANs) suitable to increase the range. Noting that it would also need to be weatherproof and not harmful to the bees.
Choosing which connectivity option is best comes down to the specific IoT application, but they all accomplish the same task: getting data to the cloud.
Other technologies include Sigfox 0G Technology which is a low power wide area network (LPWAN) dedicated to Massive IoT data with opened Standard.

Data Processing
Data processing describes the reception, storage and analysis of the data received. At the simplest level, processing is just a representation of data which may be as simple as a graph of hive temperature. More complex processors correlate multiple data sources, for example comparing the internal hive temperature with external ambient temperature to illustrate the work the bees are doing to raise the temperature of the cluster in winter or cool the hive in summer. Data processing can be used to interpret the humidity index as a measure of hive cooling or honey ripening and processing data from video recordings of the activity level of bees at the entrance to the hive could indicate if they are ventilating the hive or preparing to swarm.

User interface
Any user interface must be suitable for the environment. Challenges presented by beekeeping include that many beekeepers wear sting-proof gloves, which limit dexterity. The beekeeping environment is sticky because of the honey, wax and propolis (an antiseptic, substance produced by the bees from plant resins which they use to seal any gaps and stick surfaces together; 'bee glue').
Hive equipment can be heavy and awkward, all of which makes it difficult to use delicate electronic equipment.
The user interface must provide the information in a format which is easily understood and simple to use. Practical applications could include automated sensors to detect robbing which is when other bees or wasps attack the hive to steal honey. This could use video motion detectors at the hive entrance to detect frenetic activity. At the simplest level this would send an alert notification to the beekeeper who would then travel to the apiary and reduce the size of the hive entrance, making it smaller and easier for the resident colony to defend. An automated system would allow the beekeeper to remotely adjust the entrance. Being able to do this remotely, without having to travel to the apiary, is time efficient and could make the difference between rescuing a colony or not. The next level would be AI interpretation of the scenario using predictive algorithms and automated closing of the entrance space via predefined rules

6. DESIGN & IMPLEMENTATION

The research project required the trial of hardware sensors, connection to controllers[4] and review of the data produced. The equipment was purchased from a start-up company in Yorkshire called HiveBeat.

The founder of HiveBeat is a cybersecurity professional with an interest in Natural Beekeeping which is keeping bees in traditional environments such as skeps and tree hollows. It is not possible to see what is happening with the bees in the same way as modern hives with removable frames, so he created this system to allow remote monitoring.

The system consists of sensors which detect temperature, humidity and motion. The connection to the controllers was 2.4GHz radio wave and then Wi-Fi was used for IoT connection for data processing and data analysis.

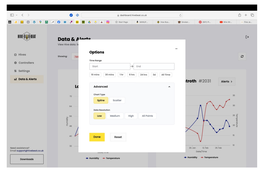
7.RESULTS & DISCUSSION

Sensors. The sensors were high quality, robust and custom made. They measured humidity, temperature and hive movement. The Sensors had a plastic to clip on the outside to protect from wax, propolis and honey. Cut-out at one end for the arial. They were attached to the top bar of the frames with a glue strip. This is a single-use method which required the frame to be clean and taken out of the hive to perform this task.

Connectivity. The sensor connects to the controller with Lower power radio frequency - 2.4Ghz wavelength. Controllers connect to the secure server by Wi-Fi. The controller software is downloaded from the HiveBeat website onto a computer. This only runs on a Windows computer. Radio wave technology has a relatively short range and can be blocked by physical obstructions such as tree.

Data Processing
The data received from the sensors was sent directly from the controller and then to the HiveBeat server. This ensured that the system was secure, and the information encrypted. The next step was to log into the HiveBeat website to see data from controllers and paired sensors. The data was presented graphically and in near real-time to illustrate changes within the hives.
The HiveBeat system has an excellent alerts feature which allow a quick response to situations such as the hive being knocked over, or a sudden drop in temperature might indicate that the lid had been blown off.
This feature could literally save the colony.

User interface
Graphical data pre-set options: Time data was set for 10 or 30 minutes, 1, 6, 24 hours, 3 days, or all time. The Chart types were scatter or lines and the data resolution was low-high or all points. Data was sent from the sensor every 30 minutes.

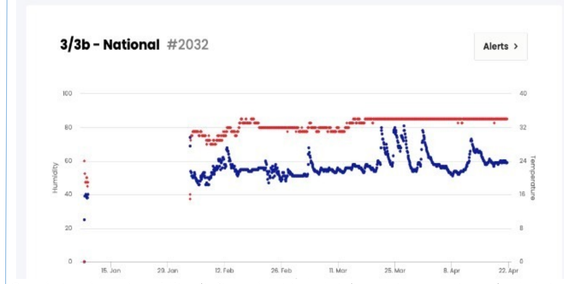


The time frames were only available for selected pre-set. **3 days** did not give enough data to see the trends. **All points** showed when the tags were being set up a month before we received them. There was therefore a lengthy period of no transmissions and the data we wanted was compressed.
It would be helpful if it was possible to set the time frame in terms of both the length of the period and the start date of the data represented.

The alert feature detected movement and changes in temperature. This could be because the Tag had slipped or because the bees were unable to maintain their temperature (homeostasis). This might be because they had insufficient stores in the winter or because a woodpecker had made a hole through which cold air was entering. In the summer, the hive might be too hot because it was overheating in direct sunlight, because the bees did not have access to water to provide evaporative cooling or the beekeeper had left the entrance shut by mistake and the bees were 'cooking' inside the hive. The alert feature could make the difference between a colony surviving or not, and provides reassurance for the beekeeper at a distance, without having to disturb the bees.

8. ANALYSIS OF PRACTICAL APPLICATION & DEPLOYMENT

Sensors. The sensors were good at collecting the data, reliably recording a data point every 30 minutes. They were small, easily placed in the hive, noting the adaptation to use string rather than single-use glue strip. The arial stuck up above the level of the top bar so there was no space for arial, which was bent horizontally. We used string to lower the tag further into the hive to prevent damage to the arial. The cut-out of the plastic cover had to be positioned the right way up so that it did not damage the arial. Bees propolise or build comb around objects in the hive which held them in place. During the initial set up controllers ping every 30 seconds for 30 minutes. This ensures that the sensor is in the correct position and activated. However, this can be used only once and is not repeatable. It also requires computer to be available during the set-up process which adds complexity to the set-up in a remote apiary.
The sensor set-up worked perfectly in the home apiary - only 20m from the house, with the controller connected to power source and home internet.
Out-apiary out of Wi-Fi range - computer taken to the apiary and hot-spot to phone.
After the tags were activated a connection failure was noted but the system had been initialised and only had 30 minutes of regular transmission. With hindsight, I should have activated just one controller at a time so as not to make this mistake for the rest of the tags.



Graph to show humidity (left scale, blue dots) and temperature (red dots, right scale). This shows that the colony gradually warmed up over the first weeks in February and then was able to maintain a steady 33^{0}C once the brood was laid arund 18th March.

Connectivity. The radio frequency range too short to be able to monitor hives at a distance but useful to remotely monitor the close hives in the home apiary. The system requires the controller to be close to the sensor, but controller must be within WiFi range and attached to a power source. During the Out-apiary set-up I tried all options to increase the controller range including using a 4m power cable, a Wi-Fi extender in the garage, and mounting the controller on a 6ft pole. The problem was that the line-of-sight for low frequency radio waves is easily obstructed by vegetation and although we achieved Intermittent contact with two of the sensors there was no reliable data transmission.

Data processing. The data received from the sensors was sent directly from the controller and then to the HiveBeat server.
This ensured that the system was secure, and the information was encrypted.
I was then able to log into the HiveBeat website and see the data from our controllers. The data was presented graphically and in near real-time to see any changes in the hives.
Current data management optimizes the graphical representation to fill the graph on the screen. This makes direct comparison between adjacent hives difficult. This is essential to see if one hive is struggling and might require an intervention.

User interface. During the initial set-up of controllers and tags on the website there were some problems with importing the data for each hive which had to be retyped multiple times. However, support engineer assistance was available from HiveBeat. We were Beta testing for the company and provided feedback on these processes. The graphical data pre-set options could be improved; it would be helpful to be able to customize the ranges when looking at different aspects. The scatter or line charts were useful for assessing trends vs looking at specific data points. An ability to fix the data range would allow direct comparison of hives.

9. CONCLUSIONS

This project demonstrated that smart hives provide a step-change in ability of beekeeper to monitor hives at a distance and increase efficiency.
The key learning points were:
- Hardware equipment must be reliable and able to perform the task.
- The more features within the hardware, connectivity, and data, the more the complexity of the system and the higher the cost.
- This system was designed to be affordable but there is always a trade-off with functionality.

10. REFERENCES

1. Braun, Andrew. What You Need to Know About the Internet of Bees. March 16, 2020. https://www.iottechtrends.com/internet-of-bees/. [Online].
2. Sangiovanni, Mirella & Schouten, Gerard & Heuvel, Willem-Jan. (2020). An IoT Beehive Network for Monitoring Urban Biodiversity: Vision, Method, and Architecture. 10.1007/978-3-030-64846-6_3. [Online].
3. LoRa. https://lora-developers.semtech.com/documentation/tech-papers-and-guides/lora-and-lorawan/ [Online].
4. How an IoT system actually works. www.leverege.com [Online]. https://www.leverege.com/iot-ebook/how-iot-systems-work.

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This project has been produced by Charlie Wilkins for the BSc (Hons) Computing (Computer Networks and Cybersecurity).

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