

2023_SoAC Project Proposal

Charlie Wilkins final

by Charlie Wilkins

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IOT SMART Beehive
Research Proposal

Charlie Wilkins

<Preferred Supervisor>
Dr Nitheesh Kaliyamurthy

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1. Introduction

The context for this project is that I am a beekeeper and a cyber security student, and I am looking to develop both areas of my life within this project.

I have no industrial partner and I do not intend to have one.

The background reason for doing this project is to develop my understanding of the Internet of things (IOT) and how that relates to computer networks and cybersecurity.

I have been keeping bees for 11 years with my mother and we recognise that having smart beehive technology in our apiaries would allow us to see the data for the individual hives so that we could compare their health status and performance. This would allow us to monitor them from a distance and reduce the requirement to visit the multiple apiary locations and open the hives, therefore reduce the stress on the bees.

I am the right person to do this project because I have IT skills from doing IT courses at school and university, including my HND in cybersecurity and computer networks.

I have been a beekeeper for 11 years and understand the lifecycle of the bee and annual cycle of the colony. I am interested in learning more about bees and am supported in this hobby by my mother who has completed academic modules for the British Beekeepers Association (BBKA) exams and is training to be a Master Beekeeper.

2. Background to the Proposed Research

Introduction: The reason why honey bees are important and the role of technology in making beehives 'smart'.

It has been estimated that insect pollinated crops contribute 1/3rd of the total volume of food eaten by humans [1], and 2/3rd of all types of crops require insect pollination [2]. Honey bees are one of the main pollinators for crops and trees, so the beekeeping industry provides pollination services and also produces honey and hive products such as wax, propolis and Royal Jelly. Statistics for the USA in 2023 recorded 16,814 employees working in the beekeeping industry [3] managing over 3 million honey bee colonies [4] with a turnover of \$624 million. Using technology to reduce the number of man-hours needed to check each hive would reduce costs and improve tasks such as checking to see if the hive was healthy, analysing bee behaviour [5], [6] and trends that help the beekeeper to be more efficient and improve their management of the bees.

The type of data which could be collected from smart beehives includes monitoring of temperature sensors [7], [8] on the inside and outside of the hive. This would show if the hive is properly insulated and how much work the bees are having to do to ventilate the hive [9] to regulate high or low temperatures to maintain the brood at a steady 35°C. Humidity sensors would demonstrate the correct humidity for the brood and the ripening of the honey where the water content of nectar is reduced from 80% so you can tell if the honey is going to be at a low enough water percentage of below 20% for honey storage. There are several different reasons why the weight of a beehive should change over the course of the year. Weight sensors [10] would measure the weight of increasing numbers of bees as the brood nest increased in springtime and diminished in the autumn. As the bees collect nectar the hive gets heavier and sharp increases could indicate a 'nectar flow' when certain plants are in bloom. This would alert the beekeeper that they might need more space to store these resources. As they go into the winter period the hive weight would indicate whether enough nectar has been stored as honey which is essential for their survival in the colder months. At

any time, a sudden reduction in weight might indicate that the hive has 'swarmed' and that a proportion of the bees, led by the queen, have left to start a new colony. It could also indicate that the hive was no longer on the sensor, which could be because it had been knocked over by animals or strong winds, or stolen. Rapid alerting of the beekeeper could save the bees from dying of cold if the hive was on the ground and the lid had been knocked off.

In addition to nectar, bees collect pollen for feeding the brood and the amount of pollen coming into the hive could be independently assessed using hive entrance recordings.

Sound sensors indicate whether the bees are alive and the amount of activity in the hive. Bees communicate through sounds and vibrations of the wax comb which will indicate activities such as when they are regulating the internal temperature by evaporative cooling using water and flapping their wings. In the days before a swarm is issued there is a change in vibrations as they prepare to leave the hive [11], and this could be detected so that the beekeeper can take actions to prevent losing the swarm.

Data Analytics

Importance of Data: the more information to which you have access creates a better understanding of how to manage the bee colony. When you can collect significant quantity of data it can be analysed to gain insights which inform decision making. Technology can be used to assist this process.

The following is a list of automated hive control monitoring and data analysis from the literature research [12], [13], [14], [15] which could include:

Decision-making support: The use of AI or machine learning over multiple years could start to pick up trends which would be useful for you to know as a beekeeper.

Alerts and Notifications: Customisable notifications and alerts could allow a real time response to situations in the hive, rather than turning up too late, ie after the hive has swarmed or starved from lack of resources.

Temperature Alerts: It is essential to know the temperature within the hive so that you are aware if the bees are overheating if the hive is in too much sunlight, or if it is too cold.

Humidity Alerts: These are useful so you know if they are struggling to find enough water to maintain the humidity inside of the hive, or are actively ripening honey and producing water vapour as a waste product which must be expelled from the hive.

Environmental monitoring: Understanding the environment in which the bees are flying provides data for their management and includes ambient temperature, humidity, wind speed, solar radiation, and pollen count. Weather data [16] will help predict foraging behaviour and enable optimal placement of the hive.

Security: The security options include cameras on hives to provide threat detection. Vandalism protection could be done by using cages over the hives which are difficult to remove and have sensors that trigger remote detection. The main animals which attack hives within the UK are badgers although other livestock such as cows could accidentally knock the hive over. Bees are at risk from other bees robbing their hive if they are weak or diseased, this is possible to detect with video recording software [17].

Sound Anomalies: These can indicate many different situations including external threats from an animal attacking the hive to a person trying to vandalise the hive. Internal sound recordings would indicate the activity within the hive ranging from almost stillness during a cluster in the winter to frenzied excitement as a swarm is about to leave.

Hive Connectivity: With hive networking it would be useful to link data from all the hives in various locations to send data to the website or storage location for the data.

Central Control Hub: A central control hub would be useful to be able to see all the data from the smart hive technology in one location.

Remote Communication: Remote communication is necessary to integrate software and hardware.

Remote Hive Management: This could include remote food release that opened a mechanical gate and allowed access additional food for the bees (sucrose or fondant) if the hive weight had dropped to a dangerous level. The width of the entrance could be reduced in adverse weather or if the colony was under threat from wasps or hornets, or closed in the evening if the hive was to be moved the next day.

Remote Hive Inspection: Remote cameras can be used to look at the frames and assess the health of the bees [18], for example looking for bacterial disease and varroa mite infection [19] and from there you can decide if you need to inspect the hive in person. This reduces the number of physical inspections required and saves time.

Pest Control Activation: Honey bees are susceptible to several diseases and require routine treatments. These are in different forms; medicated syrups that the bees walk through or vaporised crystals. Depending on the type of medicine the pest control activation will be different but could be remotely delivered in each hive as required.

Data Sharing

Collaborative Beekeeping: The contribution from each beekeeper could be 20 to 30 hives, but if 10 beekeepers collaborate that would be 300 hives sending data. Collecting collaborative data increases the accuracy of analysis.

Research Contribution: Collaboration increases the data for research, which would improve understanding and enable better health awareness and increased productivity.

Data-Driven Decisions: Data driven decisions consist of informed high management, predictive analysis, and improve productivity. A combination of these things enables the beekeeper to be efficient [20].

Real-World Applications

Commercial Beekeeping: On large scale operations for commercial beekeeping to enhance productivity a couple of smart hives could be used within a large apiary. For example a one acre farm field with 100 hives in a grid formation could have a smart hive in each corner, allowing assessment of the quality of the field for commercial farming. A few smart hives would reduce costs in physical labour and fuel.

Hobby Beekeeper: Accessibility is important to hobby beekeepers who may be working during the week and unable to check their bees apart from weekends when the weather may not be suitable. Smart hives would augment the physical inspections, allow regular virtual inspections despite the weather or availability of the beekeeper, and provide a learning tool for hive management.

3. Aims & Objectives

Aims

1. Create a system which will record parameters within a beehive – a 'smart beehive'.
2. Learn how to run a project.
3. Learn about software integration through IOT to hardware sensors.

Objectives

1. Research the use of remote monitors, understand the hardware and software integration.
2. Plan the project delivery.
3. Understand and set up the software integration and hardware sensors.
4. Trial the equipment, test and adjust. Record data.
5. Analyse the project outcomes and deliver the report.

4. Methodology

4.1 Research Methodology

Research the background.

Review what other systems are available on the market.

Build the prototype connecting the hardware sensors to the software.

Collect data.

Analyse results.

Conclude efficacy, and make adjustments and recommendations for future development.

4.1.1 Philosophy

I am using positivist philosophy, deductive approach (testing a theory), using precise and highly specific data and generalising from the sample to the population.

Methods are software development and experiments, using a highly structured approach, collecting qualitative data in large amounts to allow generalisation of the sample size to the population and the researcher is independent of the results.

4.1.2 Approach

Deductive.

This is a practical project where data can be collected and analysed.

4.1.3 Strategies

1. Literature review
2. Experiment
3. Software development

The literature review is necessary to see what information is already known, what problems need to be solved and what other solutions have been proposed.

The Experiment will show whether the equipment can be used to detect the data required.

The software development will enable this to become a system which can be used by beekeepers and is user-friendly. It will also show if the system actually serves a useful purpose in making the beekeeper more efficient and looking after the bees.

4.1.3.1 Literature Review

4.1.3.2 <Strategy 2>

4.1.3.3 <Strategy 3>

4.1.4 Risks & Limitations

External factors which could prevent the project from being a success include:

- The availability of suitable equipment such as sensors (cost, environmental suitability, availability)
- Incompatible software.
- Factors in the beehive which prevent the recording of accurate data.

I will attempt to prevent this from happening by:

- Careful planning and thorough research.

- Initial pilot experiments with the equipment.

If things do go wrong, I plan to work around this by beginning with simple measurements which will test the validity of the proposal and then make incremental changes to add complexity as each element is proved.

Limitations on the project:

- Cost and availability of equipment.
- The activities of the bees are seasonal, so some behaviours are limited to specific times of the year.

These will be handled by careful planning and timeline analysis.

4.1.5 Ethical Issues

There are no ethical issues related to this research. The bees will be handled by experienced beekeepers and will not come to any harm.

Potential of physical, mental, or reputational harm to the researcher, any industrial partners, any participants, or to the university: The normal risks of handling bees will be mitigated by careful planning, and supervision from an experienced beekeeping mentor. Full beekeeping protective clothing will be worn when handling the bees.

4.1.6 Validity, Reliability & Generalisability

4.1.6.1 Validity

This is a good way to investigate this problem because research [21] has demonstrated that the use of technology to monitor the bees through a smart beehive is efficient for the beekeeper and improves the care of the bees.

4.1.6.2 Reliability

Once the equipment has been set up, the results should be reproducible by a different researcher. The aim is that the smart equipment can be used by non-technical beekeepers. The IOT element should enable the usability and repeatability.

4.1.6.3 Generalisability

The pathway will be proven with a simple measurement such as the weight of the hive, but other parameters could be added in in due course. Over the course of a year, the bees will exhibit all the different behaviours and the data would reflect these changes over time.

Once proven, the pathway can be applied to other bees in other locations at other times.

4.1.7 Data Evaluation Methods

4.1.7.1 Data Collection

The types of data I will collect are initially measurements of weight and temperature.

These require sensors to monitor the hive and feed back to an information hub.

The data will then be analysed and interpreted with my knowledge of beekeeping, assisted by my beekeeping mentor if required.

No survey is required.

The minimum amount of data will depend on the accuracy of the sensors which will be determined in the next stage of the project.

The data from a single hive may be inaccurate so it would be sensible to monitor several hives at the same time. This would exponentially increase the amount of data that could be collected in the timeline of the research project.

4.1.7.2 Data Evaluation

How will you evaluate your data? What statistical analysis techniques will you use?

TBC

If you are performing an experiment then what are your experimental hypotheses and what level of statistical significance will you use?

TBC

I will present your data by graphical representation of weight and temperature with observational interpretation of the activity of the bees at that time.

4.2 Development Methodology

4.2.1 Software Development Methodology OR Other Relevant Major Methodology

The software development I will be using is remote sensors and monitoring using IOT software because this is most suitable for an IOT project.

4.2.2 (Optional) <Any Other Relevant Subsidiary Methodologies>

At this point, I do not believe there are other methodologies needed for this project.

5 Resources and Planning

The resources I am going to need are access to beehives, access to suitable monitoring and measuring equipment, and suitable hardware and software equipment.

5.1 Hardware Resources

The hardware required is monitoring equipment: initially weight and temperature sensors. This will need to connect through the IOT to a normal PC.

Technical Issues to consider include sensor reliability, connectivity problems and power supply.

5.2 Software Resources

Software I will need is the measuring devices can function and communicate, and then send the data over the network to storage location or website.

5.3 (Optional) Information Resources

At this point, I do not need any external data to which I don't have access.

5.4 (Optional) Human Resources

In this research project, the use of human resources is limited to the requirement for an experienced beekeeper mentor who has access to the beehives and will collaborate in the monitoring. This is my mother.

5.5 Project Plan

The timeline for the major project is as shown in the chart.

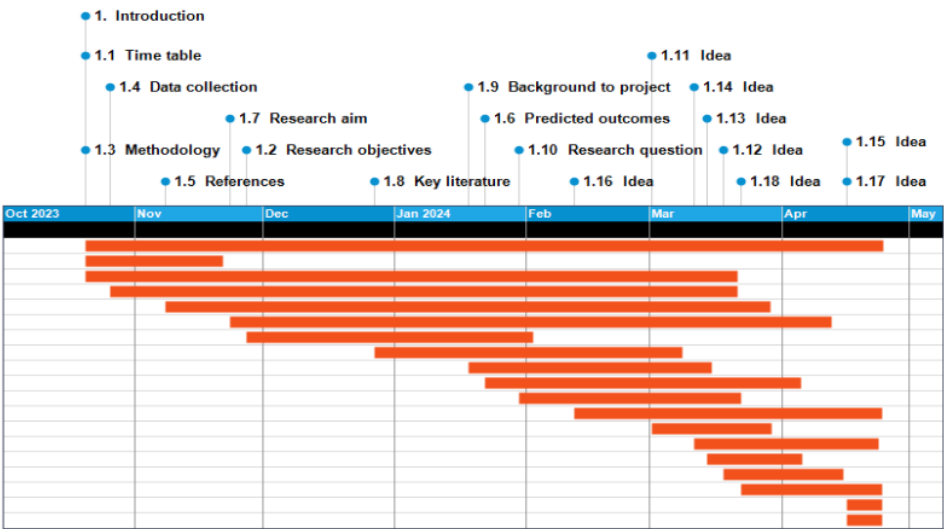


Figure 1: Project timeline

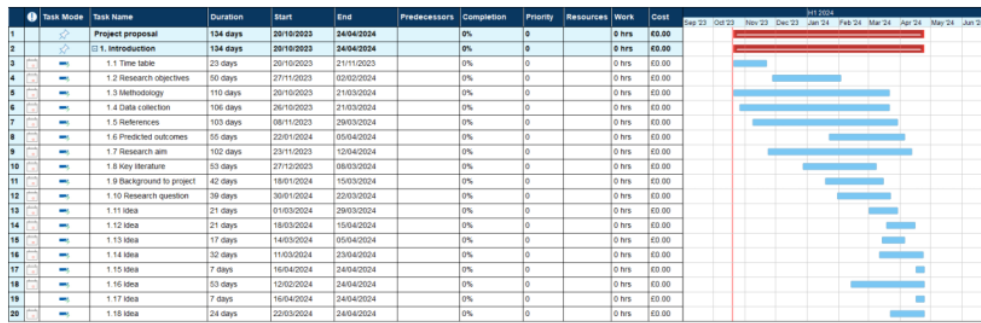


Figure 2. Breakdown of project phases

The next section in my project will be to read a lot of literature reviews and increase my understanding of the internet of things, smart beehives, and the networking between them. I will start my dissertation and once I have enough knowledge of the equipment, I will need to buy the hardware and the necessary software to connect with it. Once I have built the smart beehive I will record the successes and difficulties creating the product and then record data to prove the processes and provide enough evidence to achieve my aims and objectives.

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

74/100

PROJECT PROPOSAL – ACCA6020 INDEPENDENT PROJECT

Student Charles Wilkins (2104032)

Mark

74

Intro / A&O (400 words)		
Project title; Identification of a specific problem to be investigated; Well-defined aims and SMART objectives; Explaining why this project is worth doing; Discussion of what the project needs to do in order to be a success; Description any deliverables that will be produced at the end of the project	20	14
The integration of IoT technology into beehives for monitoring purposes clearly identifies the specific problem. Additionally, the project highlights a personal connection by highlighting the importance of efficiency, reduced stress on bees, and potential cost savings. While the		

aims and objectives are well-defined, there is room for improvement in terms of specificity and the inclusion of measurable factors that will guide potential research and development. The discussion about the project's success criteria is unclear, briefly mentioning data recording and analysis without providing sufficient detail. Similarly, with deliverables there is an opportunity to elaborate on them, enhancing the details for a more comprehensive project proposal.		
Background to the Project / Literature Review (400 words)		
Description of how the work to be done by in the project relates to the work identified in the literature review; Discussion of any ethical issues raised by the project Identifying what has already been done within the field; Topic familiarity; Brief literature review using appropriate sources – 6-8 journal papers and book chapters rather than just websites; Selection of relevant models & concepts The project establishes a connection with existing literature, particularly in the realms of technology and beekeeping. Although ethical considerations are briefly touched upon, a more comprehensive discussion in this regard would be advantageous. The literature review is evidenced by references to several	20	15

relevant sources. The discussion delves into appropriate concepts concerning smart beehives and IoT technology. However, it would have been beneficial to see some initial recommendations based on the reviewed literature.		
Project Design (500 words)		
Clear statement of which development methods are to be used and why they are appropriate; Clear statement of which tools are to be used and why they are appropriate; Clear description of how data collected will be analysed The document lacks some details regarding the methods employed in the project. While tools such as remote sensors and IoT software are mentioned, it is missing the explanations about their roles within the project. Additionally, the document falls short in providing a clear description of the data analysis methods utilized. To maximise this area, it is recommended to explicitly state the development methods, elaborate on the functionalities of mentioned tools, and provide a detailed account of the data analysis methods employed.	30	21
Resources / Planning (200 words)		
List of any deliverables; Clear	15	11

diagram showing both timing and resource use; Completed ethics form; Limited and relevant appendices. The document acknowledges deliverables but lacks detailed elaboration on their nature and scope, necessitating a more comprehensive description for clarity. A clear diagram illustrates project timing and resource allocation, providing transparency in understanding resource utilization. Ethical considerations are briefly mentioned, prompting the need for a more thorough discussion to address potential implications. Delving into ethical challenges and proposing strategies ensures adherence to standards and guidelines. Overall, enhancing detail in deliverable descriptions, utilizing visual aids, and deepening ethical discussions will fortify the project's comprehensibility, transparency, and ethical integrity.		
Document Presentation		
Correct spelling, grammar and punctuation; Flow of narrative/fluency; Coherence; Word processed; Correct use of referencing with bibliography; Strict word limit Overall, the report is presented correctly, with a	15	13

few minor errors. The narrative flows logically, and the ideas are consistently presented. The content is coherent and follows a logical sequence, with evidence of proper citations and references being used.		
TOTAL	100	74

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