SYSC3010

Computer Systems Development Project

Honey, I'm a Smart Home!

Group L1-G2

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1 Introduction

It's no secret that the bees need our help. Environmental organizations around the world have been hard at work ensuring everyone knows about the plight of our bees and other pollinators. Pesticides, deforestation, habitat destruction, disease, and climate change have all had an immense impact on pollinators. While there is no easy solution for such a massive problem, we want to help.

Graham C. Bell has been keeping bees on his farm for 9 years. Through the years, he has seen how his hives thrive and perish. The most notable danger to his hives is the fierce Canadian winter, especially the heavy snowfalls Ottawa is known for. Meia Copeland and Boshen Zhang are eager to help him protect the bees through the winter months. With the HONEY, I'M A SMART HOME! we want to give his bees the best chance to survive the winter and live to pollinate another day.

1.1 Background

The Western Honeybee (*Apis mellifera*) is native to the European continent, brought to North America in the 17th century by settlers as a source of sugar [1]. Italian honeybees (*A. mellifera ligustica*) were the first variety brought to the New World, and are still the most common species kept in Canada and the U.S. today [2]. While adaptable to many different climates, Italian honeybees often struggle in long, cold winters like those of Ottawa, Canada. The swings in temperature from 0°C to -30°C, as well as the heavy snowfalls the region is known for, pose significant risks to the hives. The snow is especially dangerous, as it can clog up the ventilation, increasing humidity in the hive and putting the bees at risk of freezing to death.

The ventilation is located along the bottom board (Figure 1) of a Langstroth hive, the style of hive Graham uses for his Italian bees. This placement makes it very easy for the ventilation to get clogged by snow.

Further, the temperature within the hive is extremely important hive health during the winter months. Too cold, and the bees could freeze. Too warm, and the bees may mistake it for spring and leave the hive early.

Lastly, all hives are vulnerable to pests such as mites, louse, and other vermin. Monitoring all these aspects of the hive would allow the beekeeper to know what needs to be done during the winter months to ensure hive survival.

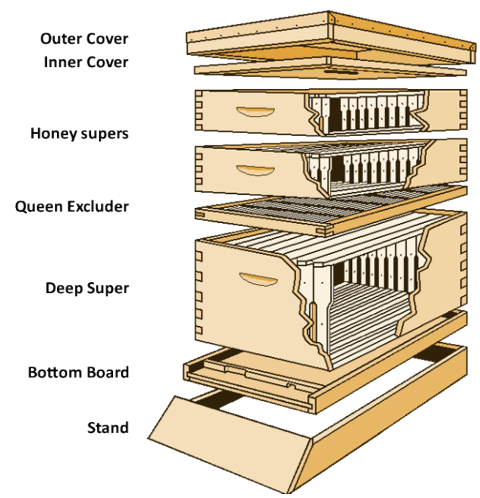

Figure 1: Langstroth hive, the most common style

Some products such as Pollenity's Beebot [3] or the Hive Heart 3.0 [4] only measure environmental factors inside the hive. THE HONEY, I'M A SMART HOME! is a fully modular solution that has sensors inside and outside the hive, and enables beekeepers to remotely tackle danger that may arise due to weather conditions.

1.2 Motivation

The beekeeping hobby has exploded in popularity in recent years alongside gardening and homesteading [5]. Farmers have always been invested in beekeeping, with 80% of all flowering plants pollinated by bees [6]. In Canada and the northern U.S., maintaining hive health through the winter is crucial to having happy and healthy bees, resulting in happy and healthy plants. THE HONEY, I'M A SMART HOME! allows both beginner and experienced beekeepers to monitor their hives without leaving the house, automates de-icing of ventilation, and allows beekeepers to open or close more vents with the touch of a button.

1.3 Project Objective

The HONEY, I'M A SMART HOME! empowers beekeepers with the information and tools they need to keep their hives healthy through the winter months, and to continue monitoring them through the summer.

1.4 Specific Goals

To keep a health hive, the Honey, I'm a Smart Home! will include the following features

MONITOR ENVIRONMENT – Temperature and humidity will be monitored inside and outside the hive

DETECT ICE BUILDUP – Sensors will detect any ice or snow build-up around critical ventilation. Heating strips will be activated to remove ice before it causes problems inside the hive.

ADDITIONAL VENTILATION – Beekeepers will be notified if humidity is high and will be able to remotely open ventilation around the hive, along with fans to enhance air flow.

CAMERA FEED – Cameras inside and outside the hive will stream a live feed to the web application, where proud beekeepers can show off their bees in the application or cast the feed to other devices.

2 System Design

2.1 System Overview Diagram

The following is a UML deployment diagram of the system.

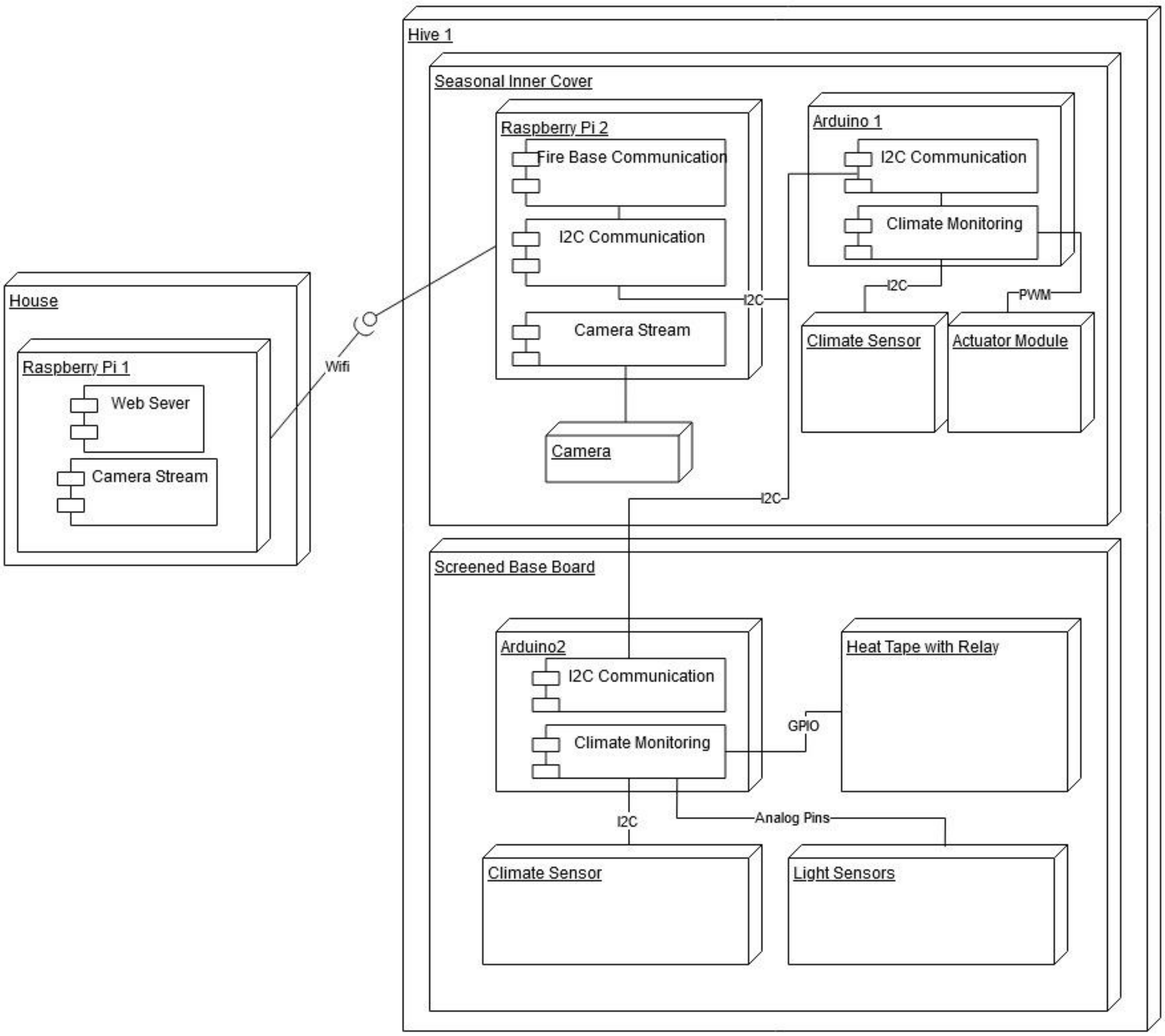

Figure 2: Deployment Diagram

Figure 2 shows the system we plan to build. It is broken into three parts. The first of these parts is in the house. It will consist of a Raspberry Pi running a website and will have access to a firebase account. The second part will be in the seasonal inner cover inside the beehive. It will consist of a Raspberry Pi, an Arduino, a camera, two climate sensors measuring temperature, humidity and pressure, and a motor assembly operating a flapper vent. The third part will be located in the bottom board of the hive and will consist of an Arduino, two climate sensors measuring temperature, humidity and pressure, several light detectors, and a relay board controlling a strip of heat tape.

The bottom board system's function is to take climate measurements inside and outside the hive as well as detect ice build up on the hive's exit. It is responsible for triggering a relay that will power a heater to melt the ice away from the exit. The ice build-up detection will be performed with a series of light detectors embedded into the board. All the information from this sub system is sent back to the Raspberry Pi over a shared I2C bus.

The inner cover system's function is to collect data from the base board system, take climate measurements inside and outside the hive, as well to regulate the humidity of the hive with a flapper valve operated by a servo. The servo will be operated by an Arduino using a PWM signal. This Arduino will also be responsible for operating the climate sensors over a I2C bus that is not shared with the base board. This I2C bus will use the softI2C library [7] to give our Arduinos more connectivity. The Arduino will send its information back to the Raspberry Pi located in the inner cover over the I2C bus shared with the base board. The Raspberry Pi located in the inner cover will receive data from both the Arduinos and make decisions over whether to activate the heat strip or the flapper valve. This Raspberry Pi will also control a camera situated above the hole in the inner cover. The Raspberry Pi will also send the camera feed to the Raspberry Pi in the house as well as upload the sensor data to firebase.

The house subsystem will be composed of only a Raspberry Pi and will perform the tasks of; running the web server, running the video feed and correlating the data into grafts so more complex predictions can be made with it. This Raspberry Pi will use firebase to get the information from the previous subsystem and will be connected to ethernet.

The system has been broken down into different subsystems so that they can be developed, tested and operated separately. This approach is used to keep components that cost the most in safer environments. For instance, the Raspberry Pi in the house will be the most powerful Pi as it has the most demanding job running the website. It could be located anywhere but its position inside the house allows it to be kept safe from the elements. This contrasts with the Arduino and subsystem in the bottom board. These will be the cheapest components as they are in an area of higher risk.

The separated approach also allows us to scale the number of hives being monitored. The Raspberry Pi in the house acts as a central hub to access the information from the Raspberry Pis in the top of the hives.

2.1.1 Communication Protocols

As can be seen in the deployment diagram, we will be using a number of different protocols and interfaces throughout this project. These include I2C, analog and digital GPIO as well Wi-Fi and ethernet.

The communication method we will be using to communicate between nodes is firebase. We will most likely need a category for 4 different temperatures, humidity, and pressures. A category for the status of the flapper valve, and the status of the heater. As well we will need a category for whether ice is detected or not.

2.2 Component Details

2.2.1 House Raspberry Pi

This Raspberry Pi will communicate with the rest of the system using ethernet and firebase. This Pi will have to be fast to run the web GUI as well the video stream.

2.2.2 Web Interface

This interface will be accessible by a mobile phone web browser or a computer. It will access firebase to show the data the sensors have collected over time. This will also be where the video stream will be accessible from and where the video casting is controlled from.

2.2.3 Seasonal Inner Cover Raspberry Pi

This Raspberry Pi will communicate with the House Raspberry Pi using Wi-Fi firebase and a device ID. This Raspberry Pi will periodically check the 2 attached Arduinos to get sensor data and update the status of the heat tape and flapper valve. This Pi will most likely have to be waterproofed, and bee proofed. We are thinking of accomplishing this with a 3D printed case that will move the fan intake outside the hive. This Pi will communicate with the two Arduinos over I2C.

2.2.4 Seasonal Inner Cover Arduino and Sub System

This Arduino will be connected to the Seasonal Inner Cover Raspberry Pi over I2C. It will connect on a separate I2C bus to two temperature sensors, most likely a BMP180. It will also use PWM to control a servo Flapper valve. Figure 3 demonstrates a rough outline of this systems set-up.

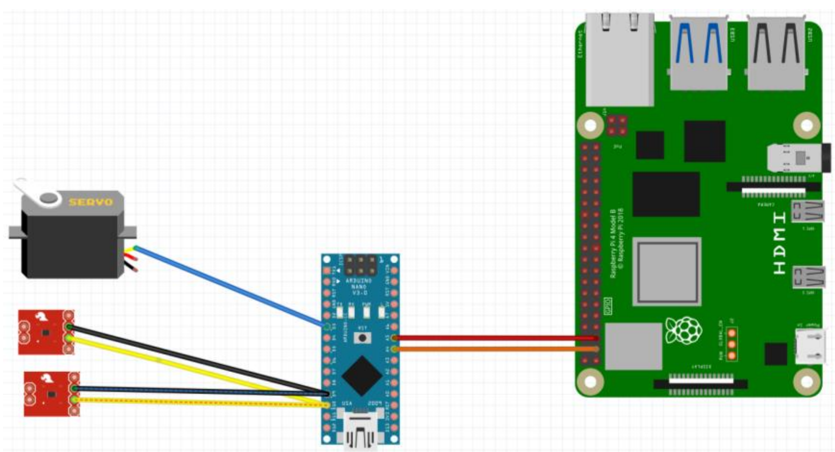

Figure 3: Seasonal Inner Cover Arduino and Sub System

2.2.5 Servo Flapper Valve

This flapper valve will use a MG 996R servo to actuate a 3D printed Flapper valve. A main concern with this is preventing bees from gluing up the surface. Special attention will be given to the point where the flapper will mate with the housing to make it appear as a seamless object. Figure 4 shows a cut away of the valve we plan to make. The figure also shows how it will actuate.

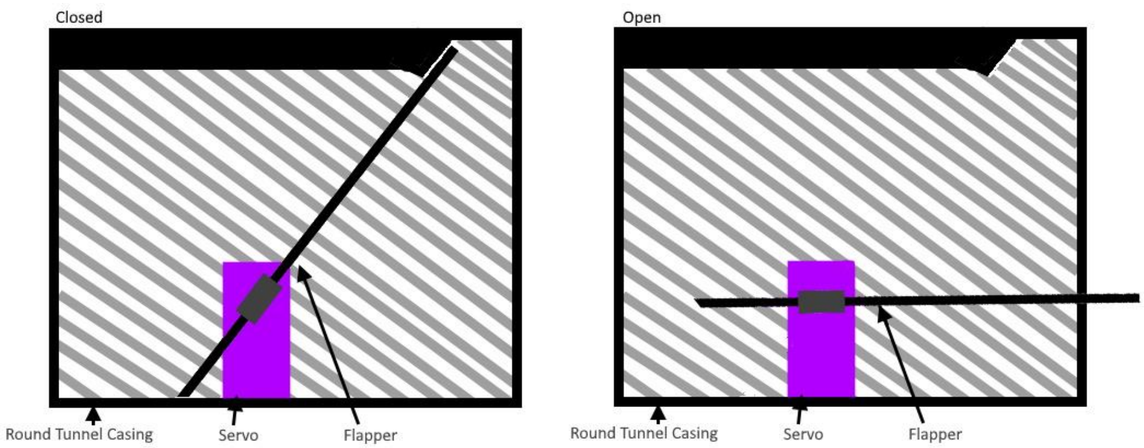

Figure 4: Cut Away of Servo Flapper Valve

2.2.6 Baseboard Arduino and Sub System

The Arduino in this system will communicate with the Seasonal Inner Cover Raspberry Pi over I2C. This Arduino will also have two BMP180 temperature sensors as well as it will utilise the analog in pins to measure the resistance of an array of photoresistors. One of the Arduino digital out pins will be connected to a relay board. Figure 5 demonstrates a rough outline of this systems set-up.

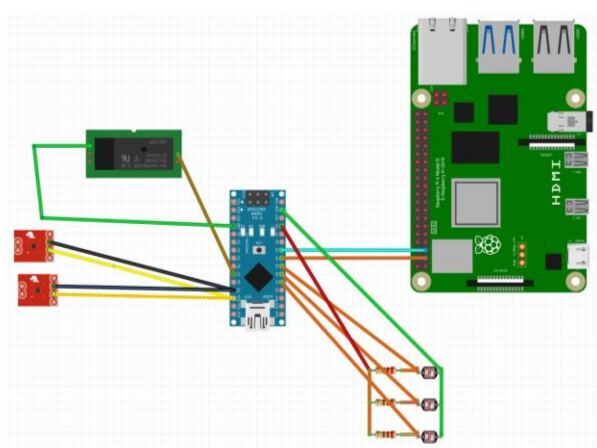

Figure 5: Baseboard Arduino and Sub System

2.2.7 Baseboard Relay Board and Heater

This system will use heat tape and a generic relay board to melt snow on a hive's entrance. A relay will be used due to the high current nature of heat tape.

2.3 Use Cases

A few major use cases in our project are the ability to check sensor values, automatically operate the flapper valve and automatically operate the heater.

2.3.1 Use Case 1: Check Sensor

The Check Sensor use case as seen in Figure 6 will get sensor data from firebase and display it on the house Raspberry Pi's web interface. The data is asynchronously getting transmitted from the sensor in the hive to firebase and then to the web sever.

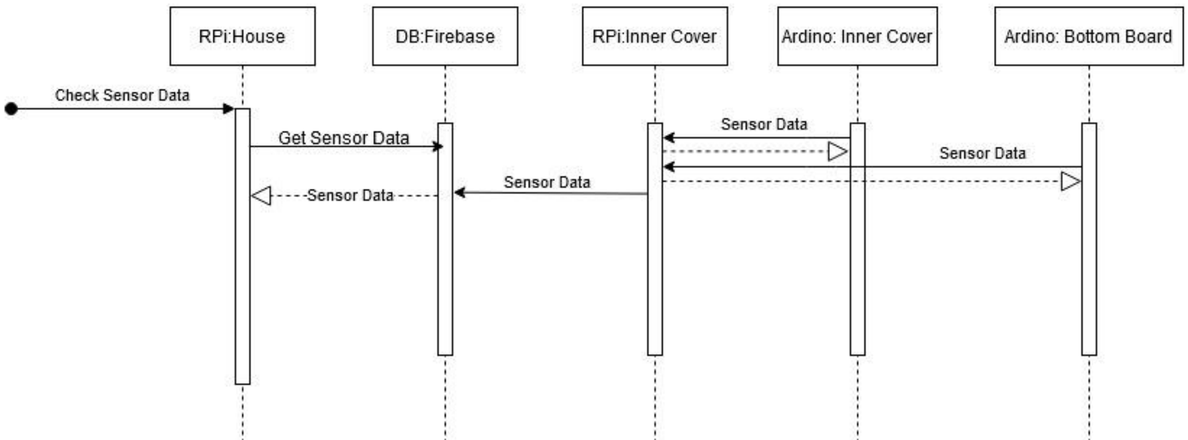

Figure 66: Check Sensor Sequence Diagram

2.3.2 Use Case 2: Automatically Update Flapper

The Automatically Update Flapper use case as seen in Figure 7 will take in sensor data from the Arduinos and determine if the humidity is too high. If the humidity is too high, it will open the flapper.

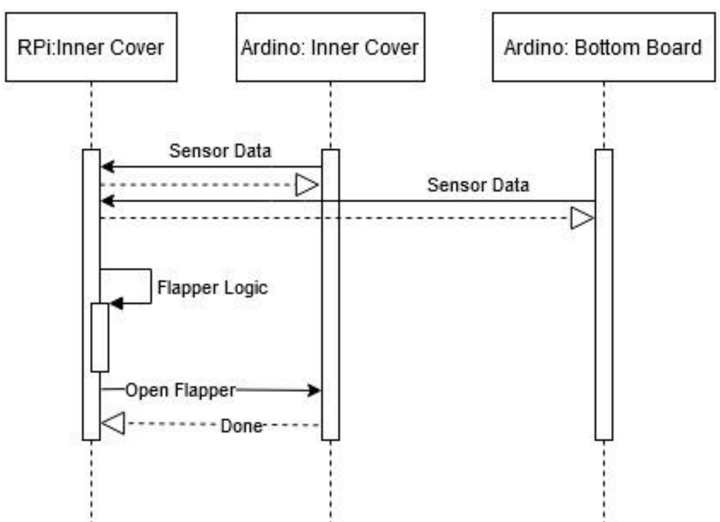

Figure 77: Automatically Update Flapper Sequence Diagram

2.3.3 Use Case 3: Automatically Update Heater

The Automatically Update Heater use case as seen in Figure 8 will take data from the light sensors and determine if the heater needs to be run to de-ice the exit of the hive.

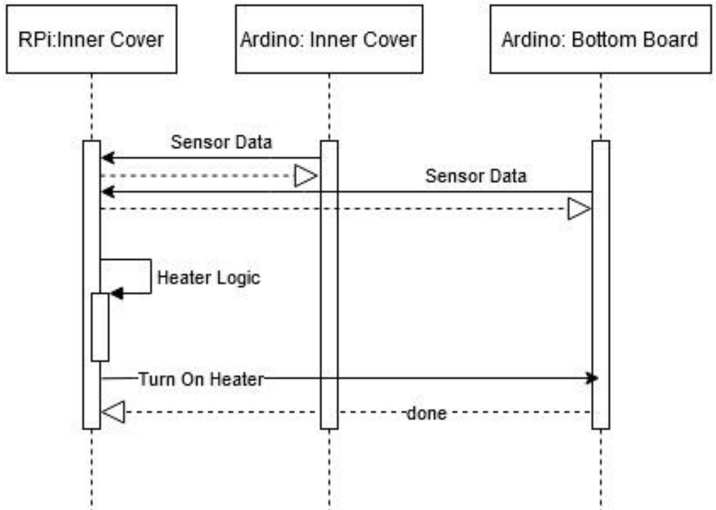

Figure 88: Automatically Update Heater Sequence Diagram

3 Work Plan

3.1 The Project Team

Our group is composed of 3 talented individuals. Graham C. Bell is a third-year student living on his family's hobby farm. As a beekeeper, he is familiar with the practical problems of beekeeping. He has a passion for hardware and system design, with lots of professional and specialized equipment that will greatly reduce the difficulty of implementing this project. Meia Copeland is a fourth-year student with a lot of rich working experiences. Through her various internships and co-op terms, she has developed many skills in professional software development, which the team will leverage to build out a solid framework and organize the work in a professional way. Boshen Zhang is a third-year student, with an internship from the past summer under his belt. He will provide support at the web and communication level. He is eager to learn from his teammates and further develop his skills. The team is excited to work on a project that will have real-life benefits for Graham's bees, and to learn all kinds of new technologies along the way.

3.1.1 Roles and Tasks

Each team member will both work to their strengths, while also participate in activities that are unfamiliar to them. With his own studio, Graham will be the primary contributor to the hardware required by the project, and support members that take on some hardware responsibilities. Boshen will use his knowledge of web and cloud architecture to engage in website creation and database management. Meia is eager to learn more about setting up web servers and working on hardware and will offer support with any software-related activities.

Table 1 - Tasks assigned to members

Task	Primary	Secondary
Set up RPis to be remotely accessible	Graham	Boshen
Create web server on RPi	Meia	Boshen
Connect RPis to database	Boshen	Meia
Set up sensors	Meia	Graham
Create ventilation system with Arduinos	Graham	
Design and create website	Boshen	Meia
Camera stream	Meia	Boshen
Attach system to beehive	All	All
Design protective cases for systems inside Beehive	Graham	Meia

3.1.2 Teamwork Strategy

At the very beginning of the project, all members of the team met each other and the bees at Graham's farm. Everyone is located in Ottawa which is an advantage because there is no time zone differences and enables us to communicate easily. The project will follow an Agile approach to development, and use the Kanban board, Trello, to track tasks. In addition, Github will be used to write, track, review and merge code. Communication will be done in the group Slack channel. Frequent exchanges of questions, keeping in touch, and meeting when appropriate are all recommended.

3.1.3 What we will need to learn

- Setting up RPi as a web server
- Using VPN and remote access software to control RPi remotely
- Connecting Arduinos to RPi
- Creating web sites and connecting them to a database
- 3D printer utilization
- Implementing and adjusting the whole system
- Various hardware connections and operations

3.2 Project Milestones

Table 2 - Project milestones for winter semester

Milestone	Description	Date
RPi Server Setup	Set up RPi as server to host web page and send/receive information from sensor RPi.	Week Feb 13
VPN setting	Set up the VPN and remote access to RPis on Graham's farm so that all team members can access the same RPi and work on it.	Week Feb 13
Detect Environmental factors	Detect temperature and humidity inside the hive using SenseHat or other sensors.	Week Feb 27
Adjust environmental factors	Remotely adjust the environmental temperature and humidity using heat and ventilation system.	Week March 6

Cameras	Set up cameras to monitor inside and outside of the hive. Camera feed on web page feed should be castable (i.e. Chromecast, AppleTV).	Week March 13
Weather/Bee-Proof hardware	Create covers for all electronics to water-, weather- and bee-proof them.	Week March 25

3.3 Schedule of Activities

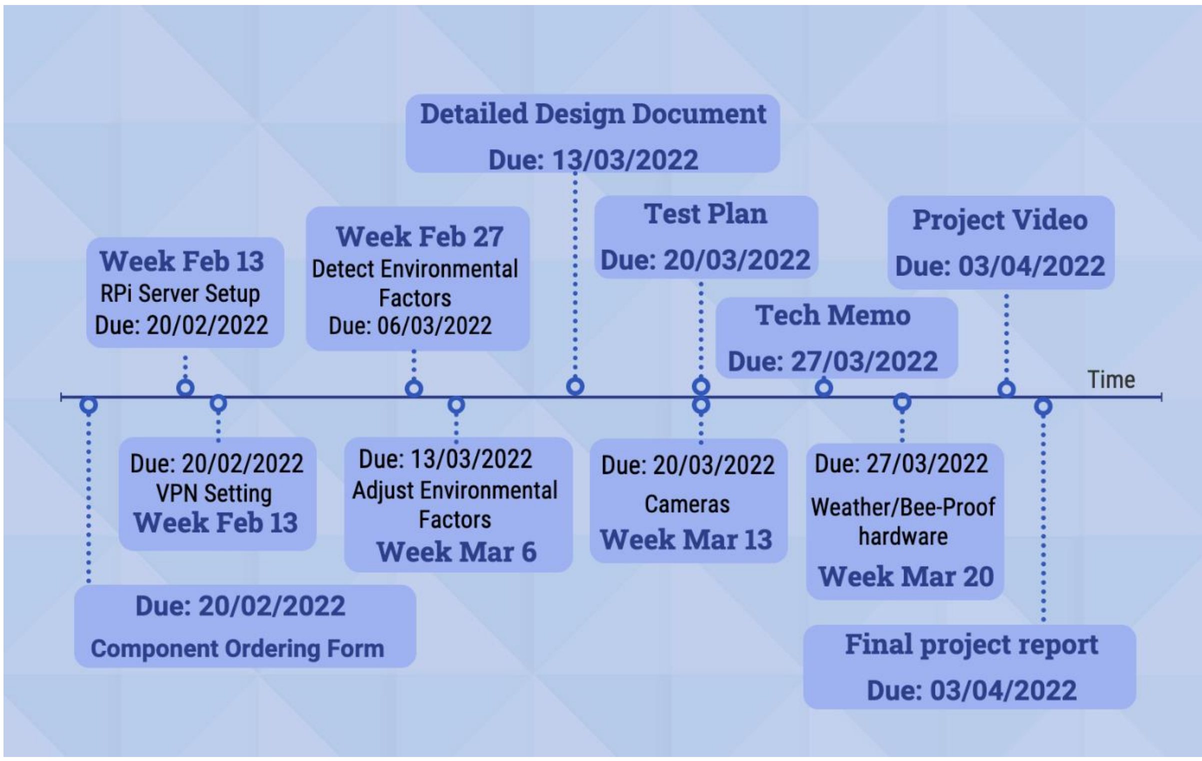

Figure 9 - Gantt chart of activities for the winter term

4 Project Requirements Checklist

Table 3 - Requirements checklist for each stage of the project

	Requirement	Activities
1	Setup server to host website	- Setup RPi as server - Pull information from the Firebase DB to present to beekeeper - Create website to present data and activities in a clean and intuitive format.
2	Monitor environmental factors	- Connect digital thermometer to RPi in hive - Connect humidity detection unit - Feed data to Firebase DB at regular intervals
3	Adjust environmental factors	- Adjustable heater around hive for de-icing - Vents that can be opened and closed in hive walls
4	Cameras	- Connect camera in hive - Stream camera feed over internet - Host camera stream on website

- Allow for casting of camera stream to other devices

4.1 Stretch Goals

The following are goals that would be excellent additions to current plans, and can be worked on if time and budget allows.

Table 4 - Additional goals if time allows

	Requirement	Activities
1.	Battery operation	- Connect battery to allow for operation during power outages
2.	Solar power	- Extend battery to allow for charging using solar power - Run system off solar power
3.	Multiple hives	- Connect multiple hives to system

5 Additional Hardware Required

In this project we are expecting to permanently install hardware into beehives. For this reason, we will not be using any rented hardware from the school. Graham will be personally purchasing any needed hardware. BMP180 temperature and pressure sensors [8] will likely be purchased. Further hardware is already in Graham's possession.

6 References

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