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BeeSmart Studio

A smart and simple design that allows beekeepers to remotely monitor their hives.

1 Need / Challenge

London Ontario Learning Apiary (LOLA Bees) was facing challenges regarding the health of their bees over the winter. We were tasked with finding a solution to their problem involving remote monitoring of the hives which will make it much easier for our clients to stay up to date on the health of their hives. This challenge led us to our final need statement:

LOLA Bees needs a way to remotely monitor the temperature, humidity, and weight of their hives while optimizing spending to make it easier for beekeepers to manage the health of their hives.

2 Final Design Documentation

In our first client meeting, LOLA Bees discussed with the teams that other than pests and diseases, bee mortality in the winter was generally due to starvation, population loss, and excessive moisture in the hives. It was mentioned that it is difficult to manually monitor the conditions of the hives as it is harmful to the bees to open the hives as it would expose the bees to cold. Hence, they are seeking the ability to monitor these factors remotely which would drastically improve their success over the winter.

The overall design has three main subsystems which cover all of LOLA Bees's objectives, while also considering the constraints. The subsystems are composed of simple syrup paste, insulation, and sensors.

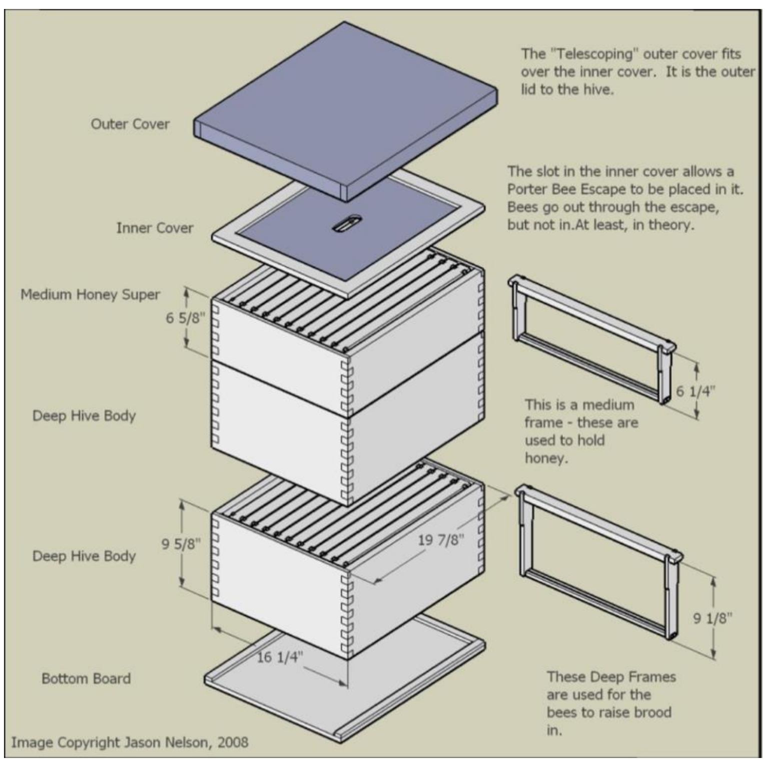

Figure 1: General Beehive Design

When it comes time to winterize the beehives our design requires the beekeepers to make a simple recipe of syrup for the hives. The recipe consists of a 1:1 ratio of water and sugar, where the sugar is completely dissolved in the water by heating the water and adding the sugar to it (Reference [3]). The paste will then be spread on the Inner Cover and Outer Cover (Figure 1). Essentially, the simple syrup is a man-made version of honey (Figure 2). Throughout the design process, we also kept in mind that the simple sugar paste would be adding additional weight to the initial date readings.

Figure 2: Simple Syrup Paste in a Hive

The second part of the design is insulation. The insulation will be made using a Styrofoam frame wrapped all around the outside of the hive. The reason our team is using the Styrofoam insulation boards is to be able to easily cut them and create a box out of them so they can perfectly fit the hive. Not to mention the beekeepers can easily remove them when spring comes. These boards can be bought from any hardware store including the rope. Since snow collects at the bottom of the hives, the insulation boards need to block the cold air and water from entering the hive. Therefore, the Styrofoam boards will cover the whole hive from top to bottom (Figure 3). The insulation boards will also include breathing holes on the sides for ventilation. The reason we will not glue the boards together is that it is hard to store them over the summer. When they are kept together by a rope you can dismantle and reuse the boards easily for the next Winter season. The goal for this section of the design is to help prevent the cold air from entering the hive. After some research from the team, we found that bees cannot survive temperatures under 7 degrees Celsius.

Figures 3 & 4: Styrofoam boards around the hive (Reference [6] & [7])

The design also relies on sensors to read data on the hive, this data can be broken up into three different parts: weight, temperature, and humidity, these three types of data allow a comprehensive monitoring system to be built. All the sensors work similarly and send their data to the same place.

Weight is one of the three types of data the design tracks. This is done through several load sensors (Figure 4). Four load sensors are attached to bee-safe wood and are placed underneath the bottom board of the hive (Figure 1). These load sensors allow our system to track the overall weight of the hive, which must not lose more than 60lb for the bees to remain healthy. As the bees progress through the winter, they begin to consume the stores of food they collected over the fall. The rate at which they consume the stores is reflected in the overall weight of the hive, as it is expected that they can consume anywhere from 40lb to 90lb of honey. The sensors from our design allow the client to see current and historic hive weights, analyzing honey consumption easy for the client. The sensors work by combining four load sensors which measure the resistance across the four cells. These sensors can be bought in a packet of 4 from amazon for a cost of thirteen dollars (Table 1).

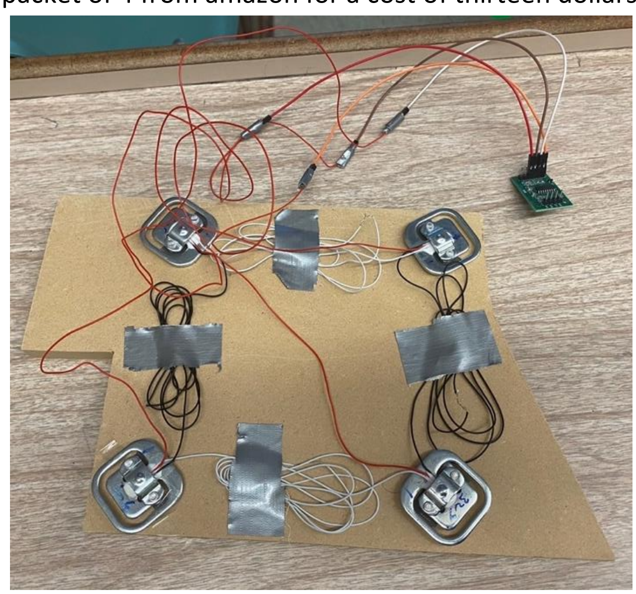

Figure 5: Four load sensors – measures the weight of the hive

The next sensor in the design implementation is a combined temperature and humidity sensor, these sensors are critical as it monitors the hives' temperature fluctuations and the overall humidity of the hive. The temperature of the hive must be kept within a specific range for the hive to remain healthy. These sensors along with the insulation create an optimal situation for the hive, as the insulation keeps the hive warm, and the sensor allows the client to see when the hive needs additional warmth. The humidity offers insight into the condition of the hives, too high means there is an extra movement within the hive and moisture needs to be removed, and too little means the hive is not operating properly and indicates issues with its function.

All the sensors are connected to the same ESB micro controller which will write to the SD card. The two different sensors have their code to send the data to the SD card. One for the temperature and humidity sensors (Figure 6) which is coded in the Arduino. The second code is for the weight sensors (Link 1).

Temperature_Humidity_Readout | Arduino 1.8.20 Hourly Build 2021/12/20 07:33

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Temperature_Humidity_Readout

```
/*
 * Created by ArduinoGetStarted.com
 *
 * This example code is in the public domain
 *
 * Tutorial page: https://arduinogetstarted.com/tutorials/arduino-temperature-humidity-sensor
 */

#include "DHT.h"
#define DHTPIN 2
#define DHTTYPE DHT22

DHT dht(DHTPIN, DHTTYPE);

void setup() {
  Serial.begin(9600);
  dht.begin(); // initialize the sensor
}

void loop() {
  // wait a few seconds between measurements.
  delay(2000);

  // read humidity
  float humi  = dht.readHumidity();
  // read temperature as Celsius
  float tempC = dht.readTemperature();
  // read temperature as Fahrenheit
  float tempF = dht.readTemperature(true);

  // check if any reads failed
  if (isnan(humi) || isnan(tempC) || isnan(tempF)) {
    Serial.println("Failed to read from DHT sensor!");
  } else {
    Serial.print("Humidity: ");
    Serial.print(humi);
    Serial.print("%");
```

Figure 6: Code for Temperature/Humidity sensors

Link 1: Code
https://github.com/HikaruSadashi/1050-winter-project

3 Testing and Validation

3.1 Objectives (and Functional Capabilities)

#	Objective	Assessment	Evidence
1	Remotely monitor hives	Met	The design incorporates the ESP32 which is a microcontroller that has support (and hardware) for Bluetooth and Wi-Fi which can remotely send data over nearby Wi-Fi networks. This allows the user to really access the data from everywhere if the hive is close to nearby networks.
2	Maintenance and repair friendly	Met	In terms of physical design there is a lot of room for repair and maintenance over time because of how the circuity is setup. It's all using jumper wires that are easily swappable. Also, the circuit runs on 5 volts standard voltage for Arduino which is very well supported.
3	User friendly experience	Met	The design is user friendly because it exports formats typically used such as excel sheets. The code also has exception handling, so error messages are easier to deal with. The Arduino also overwrites old data when new data is needed so all the user has to do is plug in the SD card and copy the .csv files.
4	Notify the user when values are above or below certain thresholds	Not met	This objective was not met since the constraint of no electricity/Wi-Fi and the budget set us back. All we could accomplish is collecting the data on the SD card which the clients can collect after a few weeks to check how the hives are doing. They would have to manually see if the temperature/humidity data are below or above the threshold and the same goes for the weight data points.
5	Reliably save data to the SD card	Met	Running the code immediately starts data logging and writing data to the SD card is inserted. This includes data from the load sensors (for weight) & for temperature and humidity. The data is written in the CSV format which allows users to just load the SD card and edit it in excel charts. Also, the microcontroller uses the internal clock to track the time and sensor data which make up the data table saved.

3.2 Testing and Validation: Constraints

#	Constraint	Assessment	Evidence
1	Budget of approximately $50 per hive	Met - exceeded	The cost per hive for our design is $48.50 (Table 1), this meets our clients wishes of a total cost per hive of $50. This design can be repeated for several hives for the same total cost, making our design applicable to the client's needs. By having a total cost per hive with no upfront additional cost, our design no longer needs to worry about the constraint for cost.
2	Electronics and hive must withstand winter temperatures	Met	Styrofoam insulation can withstand temperatures up to -50 degrees Celsius (Reference [1]), this is critical for keeping our components and hive warm. It's important that the components of the monitoring system are kept warm, but more importantly, the hive core temperature should be kept above 7 degrees Celsius (Reference [4]). As that is the temperature of bee death. Our design components also work well above 7 degrees Celsius. The Styrofoam insulations offer enough protection for both the hive and components with a temperature threshold of –50 degrees Celsius.
3	Hive must be bee safe	Met	The main goal of the design is to protect the hives health above all else. Therefore, the design incorporates several measures to maintain hive integrity. The design is made of natural materials that are safe for beehives, such as wood, as well as sealed wiring. The design can be compared to a John Naylen Sorrell's family beehive's monitoring system (Figure 3). The materials are the same for both systems as well as the monitoring style. This makes it evident that the materials and system we have designed is safe and effective for beehives, as the Naylen Sorrell family's system closely resembles our own. The Naylen Sorrell monitoring system has effectively monitored hives for several winters; thus, our design should also maintain bee health.

#	Constraint	Assessment	Evidence
4	Reliably monitor sensor data and save it to SD card	Met	The design can monitor the data and download it to an SD card which is installed with the rest of the sensors, this is possible do the code written, which allows the sensors the communicate with our Arduino and ultimately the SD card. The code (Link 1) allows this process to happen. Once the sensors are calibrated, the design allows for optimized data uptime, as one SD card can be replaced with another SD card, so data is always being monitored.
5	Weight can't drop below 60lb	Met	With the designs comprehensive monitoring system, the client will be able to access weight data points of the hives via the SD card system. The load cells allow the data on the hives weight to be downloaded, once downloaded, the client can analyze the data. For example, they will be able to see if the hive's weight has dropped 60lb or more.

Figure 7: Naylen Sorrell Family Beehive

4 Comparison

4.1 Comparison 1

The Digital Beehive / Description / Link (as applies):

The Digital Beehive (Reference [5]): https://makezine.com/projects/bees-sensors-monitor-hive-health

Practicality Comparison	• Our design is much more affordable, making it easier to deploy multiple units at once • Our design saves the monitoring data to an SD card and uploads it to the user's device, allowing it to have redundancy whereas the Digital Beehive only uploads the data to the internet which is an issue as our clients do not have Wi-Fi at the bee site • The Digital Beehive saves the data in graphs rather than a spreadsheet like our design, as the clients specified, they would like their information in a spreadsheet format
Comparison of Strengths	• The Digital Beehive has an organized compact enclosure to keep the electronics safe from the natural elements • Our design is more reliable than the digital beehive as it continued to work after calibration and during testing whereas the digital beehive had their temperature and humidity sensor fail • The Digital Beehive consists of a more sustainable power source which doesn't have to be maintained as much as a portable battery • Our design is based off a team member's current beehive monitoring system which has been active for years on end with no issue, this ensures a long-life span and effectiveness of our design
Comparison of Weaknesses	• The Digital Beehive's temperature & humidity sensor failed. It was also placed inside the hive where the bees might wrap the sensor with propolis • The alternative uses solar panels that are very inefficient and rely on a clear sky, which is highly unlikely on a Canadian winter day. They also cost a lot, which won't meet the $50 per hive budget • For our design, the clients will have to visit the hives regularly to access the data in winter, while they can access data more easily by using the alternative
Other Comparisons	• The alternative has a cleaner design

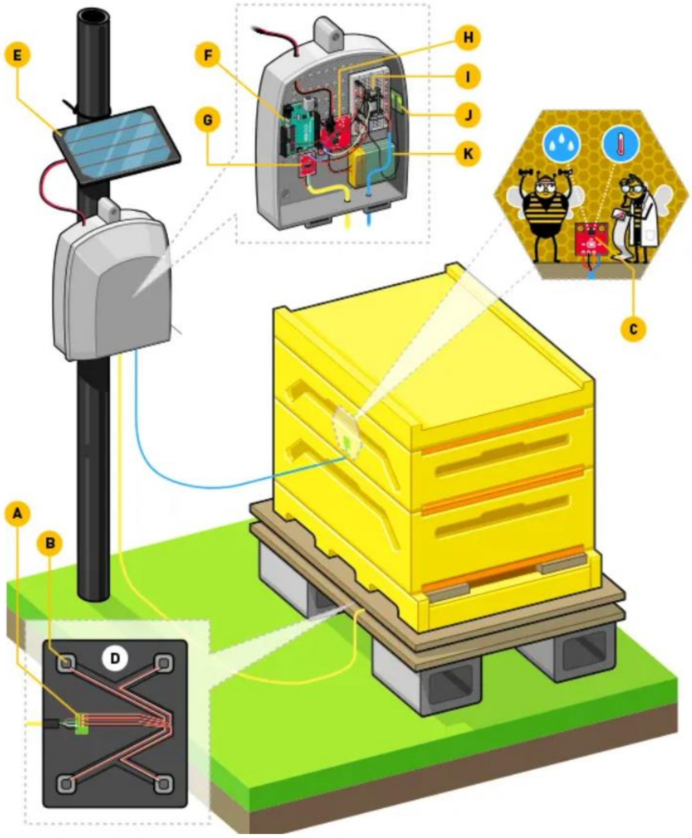

Figure 8: The Digital Beehive (Reference [5])

5 Potential Improvements

If this project were to be repeated, a potential improvement our team would make would be to order our materials earlier. We didn't place our order until Week 20 of the design process, giving us only two weeks to create and test the prototype before presenting it at the design showcase. Our team could have spent significantly more time testing and enhancing our design if we had ordered just two weeks earlier (Week 18). We finished our prototype the week before it was due, and we were not able to conduct numerous rounds of testing as we did for the Fall project. Because of this setback, we were unable to meet our objective of notifying the client when values were above or below certain thresholds. This hampered our team's progress and prevented us from achieving the desired result or providing the greatest design for our client.

Furthermore, with more time, our team would've liked to further enhance our design with the development of an app. This idea came up during our original brainstorming session, but we didn't have enough time to put it into action. The software would have provided regular updates to the clients' phones about the hives and bees' health. Although our current system also allows for remote monitoring of the hives, the app would have made it easier for the clients to use. If done correctly, it would have been a simple-to-use platform that would have made the beekeepers' tasks considerably easier by allowing them to be updated from anywhere.

Overall, our final prototype would have been considerably stronger and easier to use if we had adjusted our timeline or had more time.

6 References

[1] Engineering ToolBox, 2005. *Insulation Materials - Operating Temperature Limits*. [online] Available at: https://www.engineeringtoolbox.com/insulation-temperatures-d_922.html [Accessed 31-03-2022]

[2] Papiewski, J., 2018. *How Does a Styrofoam Cooler Keep Things Cold?* [online] Available at: https://sciencing.com/styrofoam-cooler-keep-things-cold-18521.html [Accessed 31 March 2022].

[3] GloryBee. 2016. *Sugar Syrup Recipe For Beekeepers*. [online] Available at: https://glorybee.com/blog/sugar-syrup-recipe-for-beekeepers/ [Accessed 2 April 2022]

[4] Carolina Honey Bees, 2021. *How do Bees Survive Winter?.* [online] Available at: https://carolinahoneybees.com/honeybees-survive-winter/ [Accessed 2 April 2022]

[5] Seidle, N., 2015. *The Internet of Bees: Adding Sensors to Monitor Hive Health* [online] Make: DIY Projects and Ideas for Makers. Available at: https://makezine.com/projects/bees-sensors-monitor-hive-health [Accessed 3 April 2022].

[6] Beemaster.com. 2011. *How to best secure Styrofoam sheets for side insulation?*. [online] Available at: https://beemaster.com/forum/index.php?topic=35642.0 [Accessed 3 April 2022].

[7] The Home Depot. n.d. *Owens Corning formula ¼ in. x 4 ft. X 50 ft. R-1 fanfold rigid foam board insulation sheathing 21um*. [online] Available at: https://www.homedepot.com/p/Owens-Corning-FOAMULAR-1-4-in-x-4-ft-x-50-ft-R-1-Fanfold-Rigid-Foam-Board-Insulation-Sheathing-21UM/100320301 [Accessed 3 April 2022].

7 Appendix A – Examples of Design Documentation

Table 1: Materials and cost

Material	Price ($)
Load sensor (x4)/2	12.98/2.00 = 6.50
ESP32	15.00
Temp/humidity sensor (x1)	16.00
SD card	11.00
Total Price	**48.50**

7.1 Flowchart

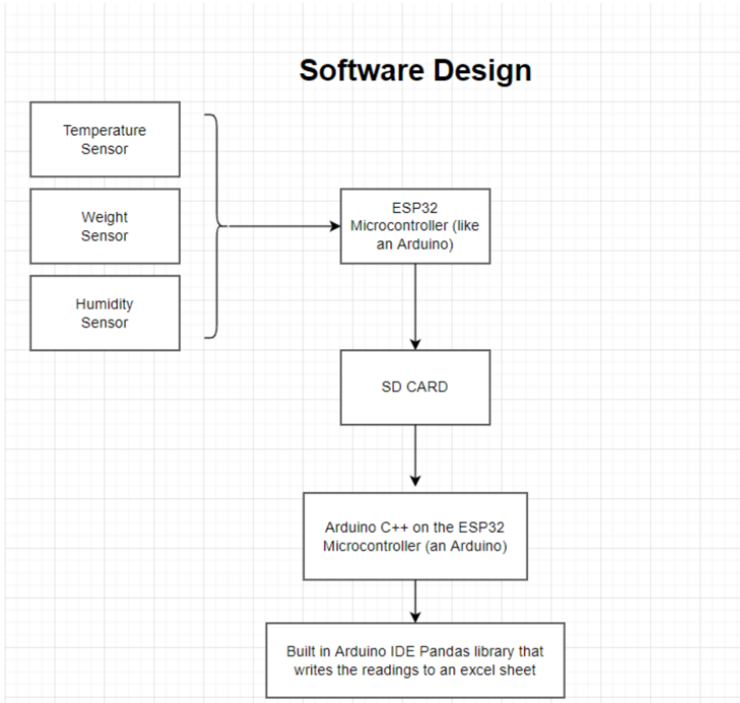

Figure 9: Software Design flow chart

7.2 Prototype images

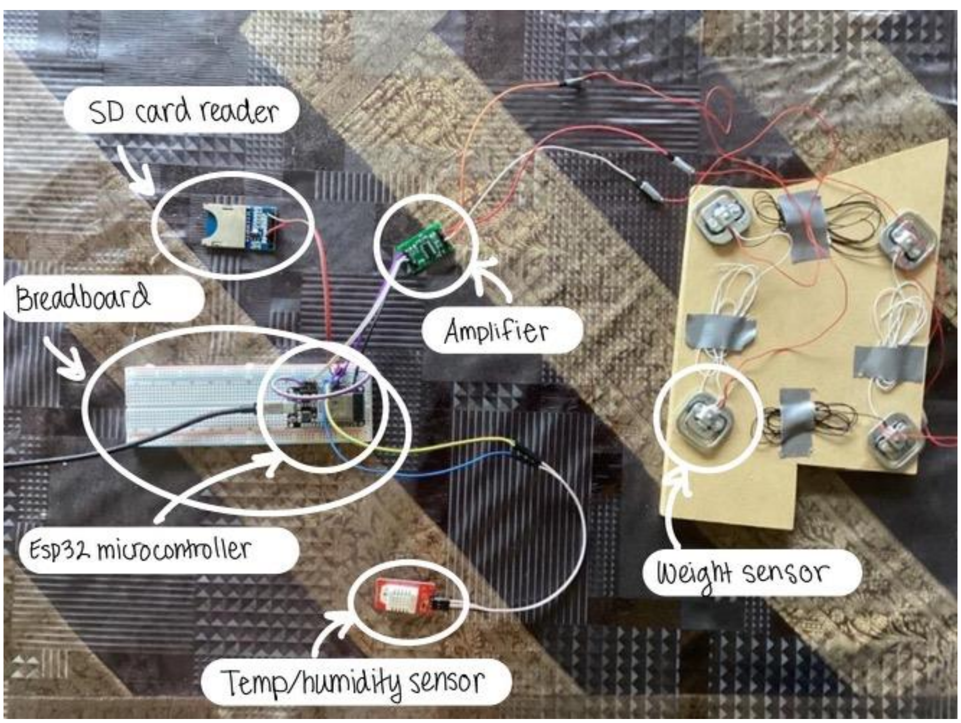

Figure 10: Final prototype