HYBEE: HYBRID BEEHIVE WITH AUTOMATED FLOW FRAME HARVESTING AND COLLECTION, AIR CONDITIONING, AND BEEHIVE ACTIVITY MONITORING SYSTEM

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ABSTRACT

Pulling off the Langstroth frames, removing the wax cap, and draining/crushing the comb are the traditional methods of obtaining honey, all of which disrupt the bee colony. In 2015, artificial flow frame, a revolutionary beehive invention was introduced, allowing the beekeepers to harvest honey without using an extractor or opening the hive with minimal disturbance to the bees. It is operated by a metal rod key to split the comb structure in half, in order for honey to flow. However, there are no in-depth studies regarding the honeybee’s condition and honey yield on the flow frame hives in comparison with its effectiveness on the traditional means. The objective of the research project is to automate the harvest of flow frames without removing the comb in the system while monitoring their behaviors using environmental sensors. The Hybrid beehive monitors the condition of bees inside the artificial flow frame hives using Temperature and Humidity sensors, Accelerometer, to lessen the human intervention by automating the harvesting of the flow frames using Solenoid Valve, Air Compressor, and Weight Sensor. In the initial findings of the system, the hybrid beehive temperature ranges from 30 to 38 degrees Celsius and its humidity ranges from 59 to 83 percent which is optimal temperature and humidity when compared to the 31 to 38 degrees Celsius temperature and 48 to 81 percent humidity of a traditional beehive. The vibration frequency of the hybrid ranges from 108 Hz to 578 Hz is comparable to the traditional hive that ranges from 267 Hz to 536 Hz which indicates. There are parameters that cannot be controlled by the researchers: (a) Weather Changes during the deployment (b) the transition of bees due to the weather changes. There is beeswax bridging between the gaps observed that is a sign of transition of bees taking place to the system. The study can

further the development of knowledge of Electronics Engineers in creating systems to help improve the produce (or products or output) and efficiency in beekeeping and in other livestock.

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INTRODUCTION

1.1 Introduction

Honey collection is difficult due to the threat of bee attacks. Honey gathering is a skill that has been passed down through the generations. Despite the lack of written documents or formal training, they have continued to practice the traditional habit [1]. The centrifuge and split artificial honeycomb were developed over a period of years to reduce the time and labor-intensive process of gathering honey inside the hive without disturbing the colony. In the Philippines, yearly honey production ranges between 50 and 110 metric tons. The honey producing season for the majority of Luzon runs from November through May. In the Visayas, the honey season may begin between September and November, followed by a short drought from December to February, and then reach its peak between March and May. Mindanao will have a year-round honey season characterized by abundant pollen collection [2]. Even though the Philippines is one of the exporters of honey, there are several problems that would affect its production.

European honeybees (Apis mellifera) reside in densely packed nest cavities with only a single entrance, limiting passive ventilation. Individual bees actively ventilate these nests by fanning their wings at the nest entrance when the local air temperature rises above a certain level [3]. During the dry season, bees must aerate more to control the heat inside the hive, and they expend a lot of energy to discharge hot air that is still circulating in the box. Honeybees prefer a temperature of 35 degrees Celsius in their colony. A beehive's optimal humidity level is 60 percent. When humidity levels fall below or rise beyond the optimum of 60%, honeybees, their eggs, honey output, and pest and parasite infestations are all damaged [4]. An efficient ventilation path can be employed to help maintain the quality of air inside the flow hive rather than the bees' self-ventilating.

The buzzing of bees can be deduced from their actions, which include buzzing during flight, foraging, temperature and air regulation, communication, and mating [5]. Vibratory signals serve an important function in honeybee colony formation. It's difficult to decipher the exact significance of certain substrate-borne signals because the mechano-acoustic landscape within the hive appears to be disorderly [6]. Bees use noises to communicate within the hive and listening to them can disclose important information about the colony's health and identify abrupt changes when the hive is threatened. When bees swarm, rob, or lose a queen, they leave a trail of activity that can be linked to forthcoming events inside the flow hive that can negatively affect their wellbeing in the long run and trigger the colony to collapse.

In recent studies conducted in [7], multiple input devices, such as vibration sensors and microphones, are used to indicate different situations with specific challenges that are processed with existing algorithms that can quickly generate real-time results to alert the beekeeper and take preventative measures to keep their bee colony from deteriorating. They demonstrate how to place such sensors in the hive to collect accurate data. The installation requires opening the hive and inserting a microphone between the frames. Eventually, the microphone becomes covered with propolis and is thereby rendered less effective. Interpretation of the bee sounds is left to the beekeeper, or else requires expensive off-line equipment for the needed feature extraction. Sounds captured with an acoustic microphone outside the hive [8], By comprehending and analyzing the data acquired in a flow hive, researchers can create a solution to anticipate when bees are about to leave the hive, robbing when nectar resources are poor, and declining due to the loss of a queen. In this paper, the artificial honeycomb with an automated harvesting system, an air conditioning system for the improvement of the airflow and temperature, and the usage of vibration acquisition system in monitoring the behavior of the bees in terms of vibration frequency.

1.2 Background of the Study

For decades, the Philippine beekeeping industry has been challenging for Filipino beekeepers. The sector is still thriving despite little to no government support in terms of funding, training, and other required policies to help spread the benefits of beekeeping in the Philippines [9]. Recognizing the importance of information transmission will improve and develop healthy beekeeping practices in the country.

In 2015, the Flow Hive, a novel method of honey extraction, was introduced. With this novel method, honey may now be harvested directly from the hive. Honeycomb frames replace the static wax or plastic foundation frames of a typical beehive in the honey super. There is currently less data on the use of artificial honeycomb in the construction of smart beehives, even though dividing the hive can increase harvesting yields since honeybees can devote all of their energies to gathering and storing honey. To obtain honey, flow hives are manually unlocked. However, to preserve and avoid the hive's collapse, certain parameters must be gathered in order to obtain a high harvest flow.

The Flow frame is an alternative way to collect and harvest honey without using the traditional method (i.e., Crushing and Straining, and Centrifugal Extraction). The beekeeper may harvest honey directly from the flow frame by splitting the frames using a metal key, and the honey will flow from the tap [10]. There is currently less data about flow frames in terms of Temperature and Humidity comparison with traditional hives, and in constructing smart beehives. Automating the flow hive will resolve the problem of harvesting the honey at a specific time. A monitoring system would measure the difference of flow hive in traditional Langstroth hive and, an air conditioning system will improve the airflow and temperature inside the hive.

A variety of methods have already been introduced to detect early signs of swarming, robbing activity [11] and loss of queen [12]. A simple microphone can detect frequencies inside the hive, but external factors that might lead to inaccurate signals can lower the percentage of detecting those problems and over time it can be jammed by propolis. Accelerometers could be used instead of microphones to sample hive vibrations [13]. Furthermore, the accelerometers enable more specific information on the general state of the hive. As a result, the vibration analysis generates a large amount of data that can be processed to produce a more comprehensive examination of the hive's health.

1.3 Research Gap

The ideal system for bee monitoring employs an ESP8266 module which can operate several sensors that monitor the needed parameters and connect the system to a cloud server where the data can be stored and visualized via Mobile Application. The Flow Hive needs to be measured by following parameters: Weight, Temperature, Humidity, and Vibration. The weight of flow frames will be monitored using load sensors and the automation will be conducted by electro-pneumatic control that are attached to each frame where the inflatable tube would open the flow frame when load reaches maximum weight. The temperature and humidity sensor would measure the temperature and humidity of the flow hive where it could be compared to the traditional Langstroth hive. An air ventilation system would be developed to improve the airflow and regulate the temperature of the flow hive. Using vibration as data would require an algorithm that generates vibration amplitude as a function of frequency, allowing the analysis tool or the module to determine what is producing the vibration. Fast Fourier transform is an efficient algorithm for computing the discrete Fourier transform (DFT). Thus, developing a system that analyzes and monitors the health and bee activities correlating to the honey production and harvesting efficiency using artificial flow frame versus Langstroth traditional hive.

1.4 Objectives

The research aims to create an Automated Flow Frame Harvest System, Monitoring System with Vibration Acquisition based on Fast Fourier Transform (FFT) and Notification System via Internet of Things (IoT).

1.4.1 Specific Objectives

1. To develop a control mechanism that can automate the harvesting of honey with electro-pneumatic system from the Artificial flow frame based on its weight, improve the air ventilation of the hive by installing 120mm intake fans, and

monitor the activity of bees using MPU6050 vibration sensor and environmental parameters of the bees inside the hive using DHT11 temperature sensors.

2. To analyze the behavior of bees inside the flow frame hive by visualizing the vibration of bees using the FFT algorithm.

3. To develop an IoT-based system with a web and mobile application capable of visualizing data and presenting valuable information about bee activity, temperature and humidity, monitoring control, and beekeeper notifications.

4. To compare the environmental sensor data, vibration frequency data, and yield data of the hybrid beehive to the traditional data

1.5 Significance of the Study

Automated honey extraction and monitoring bee behavior inside the hive are important to the bees and the beekeeper because it lessens the manual labor and can prevent unfortunate scenarios that may happen inside the hive. The decline of the bee population due to health reasons can cause problems since bees are one of the major pollinators of the world's food crops.

The study will introduce innovation in Apiculture and improve the knowledge regarding the use of flow hives as a substitute to the traditional Langstroth hive.

The study addresses the Agriculture, Aquatic, and Natural Resources (Section III) part of the Harmonized National Research and Development Agenda (HNRDA). Goal 12: Ensure Sustainable Consumption and Production Patterns and Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss are addressed in the Sustainable Development Goals (SDG). In the Philippines, Apiculture is a growing industry. The study or similar studies can help bring innovation to the beekeeping industry and give birth to new ideas on how to lessen the difficulty in beekeeping.

1.6 Scope and Limitation

The study focuses on the automated honey extraction of flow hives and improving the temperature inside the hive using a ventilation system. The range of the study will be focusing on one type of Bee which is the *Apis Cerana* (Common species in Southeast Asia). And the setting for data gathering will only be conducted inside a medium-scale bee farm in Luzon (Philippines), wherein the researchers will mainly focus on one beehive. The project study will not extend to the advanced technology due to the financial support of the researchers that may affect the project study. However, the main components of the design will be covered. Honeybee's optimal season for honey collection is from November to May in Luzon. The target deployment of the study is February to give time for the migration of bees inside the flow hive, and it will take around four months until the researchers collect the data. As estimated, the project study is suitable for a whole academic year (one year).

1.7 Definition of Terms

- **Air Conditioning** - Air conditioning refers to the process of altering the temperature, humidity, and overall comfort of an indoor space. It involves the use of mechanical systems or devices to control and regulate the temperature and humidity levels within a building or a confined area.

- **Apiculture -** Also known as beekeeping, is the practice of people keeping bee colonies, usually in man-made hives.
- ***Apis Cerana*** **-** The eastern honeybee, Asiatic honeybee or Asian honeybee, is a species of honeybee native to South, Southeast and East Asia.
- ***Apis Mellifera*** - Apis mellifera is the scientific name for the Western honeybee, which is the most common and well-known species of honeybee. It is a social insect that plays a crucial role in pollination and honey production.
- **Artificial Honeycomb -** A honeycomb made up of plastic.
- **Beeswax** - Beeswax is a natural substance produced by honeybees (Apis mellifera) in the hive. It is a wax-like material that bees secrete from glands on their abdomens and use to build honeycomb cells within the hive. Beeswax has a range of properties that make it valuable and versatile in various applications.
- **BLYNK -** Blynk is a software platform and mobile app designed for the Internet of Things (IoT). It provides a user-friendly interface that allows individuals to control and monitor IoT devices using their smartphones or tablets.
- **Descriptive Statistics** - Descriptive statistics refers to a branch of statistics that involves summarizing and describing the main features or characteristics of a dataset.
- **Dry Season -** One of the two climates in the Philippines from December to May.
- **Electro Pneumatics** - Electro-pneumatics refers to a field of technology that combines electrical control systems with pneumatic components and principles to

achieve desired automation or control functions. It involves the use of electrical signals to control and manipulate pneumatic devices, such as valves, cylinders, and actuators, in order to perform specific tasks or operations.

- **Fanning** - Fanning is a behavior exhibited by honeybees (Apis mellifera) to regulate temperature and control airflow within the hive. It is primarily performed by worker bees and serves several important functions in maintaining hive conditions.
- **Fast Fourier transform (FFT) -** An algorithm for computing a sequence's discrete Fourier transform (DFT) or its inverse (IDFT) of vibrational activity of the honeybees.
- **Flow Hive -** A beehive consists of two boxes made up of artificial honeycomb (top) and Langstroth frames made up of wood.
- **Foraging** - Foraging in bees refers to the activity of honey bees (Apis mellifera) in search of food resources, primarily nectar and pollen. Foraging is a crucial behavior for the survival and productivity of a bee colony.
- **Internet of Things -** Refers to a network of linked devices as well as the technology that enables communication between devices and the cloud as well as between devices.
- **Langstroth Hive** - A Langstroth hive is a type of beehive that was designed by Reverend Lorenzo Lorraine Langstroth in the mid-19th century. It is the most widely used hive design in modern beekeeping and provides a practical and efficient system for managing honeybee colonies.

- **Microcontroller** - A microcontroller is a small computer on a single integrated circuit (IC) that is designed to perform specific tasks and control electronic devices. It is a compact and self-contained computing system that includes a microprocessor, memory, input/output (I/O) ports, and other peripherals on a single chip.
- **Propolis** - Propolis is a sticky, resinous substance produced by honey bees. It is derived from the buds, sap flows, and other botanical sources, such as tree bark and plant resins. Bees collect propolis and use it to seal cracks, disinfect the hive, and protect it from external threats like bacteria, fungi, and other invaders.
- **Swarming** - Swarming is a natural behavior exhibited by honeybees (Apis mellifera) and some other species of bees. It occurs when a colony of bees divides to form two or more separate colonies. Swarming is a way for bees to reproduce and expand their population.
- **Z-test** - The Z-test is a statistical test that compares sample data to a known population mean, assuming that the data is normally distributed. It determines whether there is a significant difference between the sample mean and the population mean, using a test statistic called the Z-score.

Chapter 2

REVIEW OF RELATED LITERATURE

2.1 Conceptual Literature

2.1.1 Apiculture in the Philippines

Beekeeping was practiced in many parts of the Philippines as one of the sources of income and livelihood. Examples of these places are: Lipa City, Batangas, Bicol Region, and Palawan. In Lipa City, Batangas, it is mentioned that beekeeping is one of the most profitable agribusinesses [15]. In the Bicol Region, it is stated that it is dominated by stingless beekeepers. Stingless bees produce the most expensive honey in the local market. Aside from honey, cosmetic products such as moisturizing creams, propolis sprays, hand sanitizers, etc. are being produced from bees [16] [17]. In Palawan, one of their livelihood practices is wild honey hunting and gathering from giant honeybees. When surveyed, researchers found that only 24% of the local community could recognize the giant honeybee [18].

2.1.2 Traditional Beekeeping

An extracting honeycomb machine was assessed and compared to that of the traditional honey extraction method. The machine has a mean extraction rate and efficiency of 69 kg/hr and 86.3%, while the old approach has a mean extraction rate and efficiency of 6.40 kg/hr and 59.1%. These mean values are significantly different from one another at the 5% level of significance. The physicochemical analysis revealed that, with the exception of the ash content and electrical conductivity, the properties of honey extracted using the designed machine produced more desirable results than honey extracted using the traditional method and are within the recommended limits stipulated in international export standards [19].

The research study was conducted that focuses on evaluating different beekeeping practices and establishing a beekeeping calendar in Yamoussoukro's rural western zone in central Côte d'Ivoire. The findings show that there are two types of beekeeping techniques. The first is traditional hunting or honey collection, which has a harmful influence on the ecosystem. The second is the current trend of using Bees are kept in contemporary hives, and honey is collected utilizing bee suits. The new method is both hygienic and environmentally friendly. It also improves the quality and quantity of honey produced. [20]

The research study was conducted in Saudi Arabia that mainly focuses on the profitability and productivity of box hives, which is crucial for encouraging beekeepers to embrace the technology. In conclusion, the productivity gap between box and traditional hives were 42.83%, 7.52%, and 5.34 %, due to labor for bee management, supplemental food, and medication, respectively. According to the study, box hives produced 72 % more honey than standard hives. The average net earnings of beekeepers who use boxed hives produced 33,699.7 SR per year, while traditional hives produced 16,461.4 SR per year. [21]

2.1.3 Flow Hive

2.1.3.1 Sensory properties of yellow pea and macadamia honeys from conventional and Flow Hive extraction methods

In this study, the proponents used the Flow Frame for honey harvesting and conventional honey extraction. They used conventional descriptive analysis for the sensory profiling of the extracted honey. They concluded that the natural sensory properties of honey are more present in the honey that is extracted from the Flow Frame. [22]

2.1.3.2 Increased Honey Yield of Apis cerana Japonica Using Half-Sized Flow Frames in a Traditional Japanese Beehive

The study was conducted in a 2-year setup, the proponents used half-sized flow frames in a traditional beehive. The flow frames are half-sized because the species being studied is Apis cerana Japonica, also known as an Asian Honeybee that is native to the country of Japan. The Asian honeybees reject the plastic flow frame but then accept it when it is coated in beeswax. In the first year of the study, the proponents found out that honey yield in the flow frame was 2.8 times more than the Japanese traditional hive. In the second year of the study, all of the flow frame hives have harvested honey and there are 8 traditional hives that have successful extraction. The annual yield from traditional hive is 56.1 kg and 96.1 kg from the Flow Frame hive. [23]

2.2 Related Studies

2.2.1 Bee Monitoring System

2.2.1.1 Low-cost platform for monitoring honey production and bee's health

In this study, the construction of a low-cost platform for monitoring honey production and bee health in a small colony is described in this work. The suggested system keeps track of the beehive's weight, outside and internal temperatures, humidity, and CO2 concentration. The system can estimate honey output, bee health, and possible pests such as the Aethina tumida beetle, Varroa destructor mite, and others based on the collected data. Unlike other systems on the market that just monitor honey production or bee health, the suggested system examines both and alerts the beekeeper if there is an issue. [24]

2.2.1.2 B+WSN: Smart beehive for agriculture, environmental, and honeybee health monitoring - Preliminary results and analysis

In this study, several UN assessments in recent years have highlighted the growing food supply limitation for Earth's growing human population. As the most significant pollinator insect for a wide range of crops, honeybees are an essential part of the food chain. Protecting the global population of honeybees, as well as allowing them to maximize their productivity, is clearly a major priority. The experiment reported in this paper used heterogeneous wireless sensor networks technology to acquire data from a beehive in an unobtrusive manner, characterizing the colony's conditions and activity. For monitoring the multidimensional circumstances within a living beehive, a variety of sensors were used (including oxygen, carbon dioxide, pollutant levels, temperature, and humidity).

Outside the hive, weather and environmental variables were also monitored throughout the deployment. The data was then analyzed biologically to reveal information about honeybee behavior and health. As a result, an algorithm for automatically determining the status of the bee colony was created. A meteorological analysis was also carried out, leading to the creation of an algorithm for predicting short-term external weather conditions (rain) based on the conditions detected within the hive. The data collected by biological sensors (bees) and physical sensors was found to be influenced by weather conditions. This can be used to increase local weather forecasting accuracy. This algorithm's applications include agricultural and environmental monitoring for accurate short-term forecasts in the beehive's immediate vicinity. [25]

2.2.1.3 System Architectures for Real-time Bee Colony Temperature Monitoring

In this study, sensor data is not transported somewhere for further analysis; instead, it is processed on each individual measurement node, and decisions are communicated to the beekeeper directly. Wireless connections should be used in this technique. It may also be possible to create a separate Web server for each measurement node to allow for remote data access. This strategy can be realized with many Raspberry Pi or Arduino devices, or by creating a custom circuit.

Advantages of this technique include a completely adaptable solution in the event that a specific circuit develops. Each measuring node transfers data individually, and data from only one node can be lost in the event of an error. There is no transfer of raw data; only conclusions are communicated. Disadvantages of this strategy include the need for a power supply for each measurement node. To avoid an unexpected shutdown, each measuring node must be monitored on a frequent basis (e. g., due to battery discharge). Individual SIM cards should be provided for each individual hive if 3G or 4G modems are used. It is sometimes preferable to have all raw data available, rather than just evaluated data. In comparison to wired-based alternatives, the costs of such a system will be higher. [26]

2.2.1.4 Development of a data acquisition system for remote monitoring of environmental variables in the Apis Mellifera beehive

In this research a remote monitoring system generates a basic information system for beekeepers by monitoring internal and exterior temperature, internal and external humidity, brightness, and wind speed in a beehive. The project has three stages: electronic instrumentation from digital and analog sensors that provide information to the system, radio frequency communication to send the hive information to an IoT application for data analysis, and radio frequency communication to send the hive information to an IoT application for data analysis. [27]

2.2.1.5 Implementation of multi-node temperature measurement system for bee colonies online monitoring

This study describes a multi-node temperature measurement system for online monitoring of bee colonies. The adoption of precision agricultural technology and methodologies in beekeeping is proposed in this project. The major purpose of the project is to recognize distinct bee colony stages and prevent colony losses.

Remote measurement nodes for real-time bee colony temperature readings and a web server for measurement summarization and demonstration to end users make up online monitoring. Constant and real-time temperature monitoring of bee colonies can offer a beekeeper with accurate and timely data and information to aid in the identification of various bee colony states, such as death, brood raising, and brood less. [28]

2.2.2 Temperature Control in Bees

2.2.2.1 Automatic Temperature Control System for a Bee Hive

In this study, the proponents analyzed the physical processes happening inside a beehive during the winter. The proponents also used mathematical models for the parameters: heat transfer, air flow, and air humidity alteration. The data obtained are used to develop an electric heating control scheme with a thermal imaging camera for comparison of data. [29]

2.2.2.2 Flow-mediated self-organization of ventilation in honeybee nests

In this study, it is mentioned that bees self-organize themselves to form "Fanning Groups" where bees gather at the entrance of the nest and fan their wings when the local air temperature surpasses a threshold. In these fanning groups formation, there are bees that are responsible for the inflow and outflow of air, providing ventilation for the nest. The proponents came up with a mathematical model that predicts the temporal stability of these fanning groups and found out that bees break formation and reform depends on the temperature of the hive. [30]

2.2.2.3 Thermal Impacts of Apicultural Practice and Products on the Honeybee Colony

In this study, it is stated that bees spend more energy to maintain homeostasis. It is also stated that honey contributes to the thermal mass inside the beehive. Hence, the extraction of honey may result to loss of thermal mass and bees will spend more energy again to maintain that thermal mass. [31]

2.2.2.4 Self-Powered Smart Beehive Monitoring and Control System (SBMaCS)

In this study, the proponents developed a Self-Powered Smart Beehive Monitoring System using IoT applications with an aim to improve bee colony security and increase honey productivity. The sensors that are used: temperature sensor, humidity sensor, and piezoelectric transducer. The power source of the system may be harvested from motion, vibrations, light, and heat. They used electric fan to provide airflow and thermo-electric heater to provide optimal temperature for the hive. [32]

2.2.3 Internet of Things in apiculture

2.2.3.1 Identifying Beehive Frames Ready for Harvesting

In this study, the proponents designed a harvesting scheduler which uses a low-cost sensor (Round Force Sensitive Resistor) and a mathematical model to reduce honey extraction labor and swarming. Collecting data per frame may be more complex and costlier but it is possible to reduce the complexity and the cost to make room for a consumer-friendly product. [33]

2.2.3.2 The Development of an Efficient System to Monitor the Honeybee Colonies Depopulations

In this study, it is mentioned that reduction of the population of bee colonies are caused by some factors: pesticides, pests, weather, and burglary. The proponents developed a monitoring system where it assesses the population status of bee colonies, evaluates the dangers and prevents loss of population. Two significant features are added in the system: a device that can count forager bees, and sound analysis for hornet detection and other signals that can relate to bee activities. [34]

2.2.3.3 Development of a Heterogeneous Wireless Sensor Network for Instrumentation and Analysis of Beehives

In this study, the proponents used Wireless Sensor Network with IoT application for the monitoring of a beehive. Some of the parameters that are being monitored are: temperature, CO2 build up, pollutants, etc. Weather conditions, hive conditions, and external conditions of the hive are monitored. [35]

2.2.3.4 Internet of Things: Low Cost Monitoring Beehive System using Wireless Sensor Network

In this study, the proponents also used Wireless Sensor Network with IoT application for a beehive monitoring system. The system aims to increase bee productivity and implement sensors to monitor the following parameters: humidity, temperature, and weight. The data acquired will be sent to a third-party platform. [36]

2.2.3.5 A DIY sensor kit, Gaussian Processes and a multi-agent system fused into a smart beekeeping assistant

In this study, a monitoring system (BeeObserver) composed of sensors are recording data regarding the honeybee colonies. Sensors that were used: Digital Temperature Sensor, Single point load cell, humidity sensor, and pressure sensor. All the data acquired are compiled through a mobile application (BOBApp) which the beekeepers can access. The implemented system can detect early signs or situations about incoming diseases which will be notified to the beekeeper. [37]

2.2.3.6 Design and Development of a Smart Weighing Scale for Beehive Monitoring

In this study, the proponents stated that one factor that can affect the strength of a beehive is weight. The proponents also mentioned that weight of the bee colony can affect its productivity, health, and condition. In the weighing system, a high precision analog to digital converter is used with a Zigbee radio for the data transfer. The proponents found out that the system is able to detect changes in the weight of the bee colony. [38]

2.2.3.7 Technical Implementation of IoT Concept for Bee Colony Monitoring

In this study, the proponents stated that the system is an autonomous beekeeping. With an application of IoT, the system can monitor and maintain the bee colony without interfering in its processes. The system can acquire data about frequencies, temperature, and visual data. The beekeeper can acquire the data and use it to do the best possible maintenance needed by the colony. [39]

2.2.3.8 Visual Programmed IoT Beehive Monitoring for Decision Aid by Machine Learning based Anomaly Detection

In this study, the beehive monitoring system is implemented with IoT application and machine learning. The proponents made the system easier to understand so beekeepers that are less knowledgeable in modern technologies can still use the system, acquire data, detect anomalies in the beehive, and lessen the efforts needed to maintain the bee colony. Sensors that were used in the system: Temperature, humidity, air pressure, weight, and gesture sensors. [40]

2.2.4 Vibration in relation with behavior of bees

2.2.4.1 Artificial shaking signals in honeybee colonies elicit natural responses

In this study, the proponents focused on the shaking signal that came from bees. They designed a tool that mimics the shaking signal of the bees. They found out that the shaking signal increases the activity of the worker bees and activate the drones (bees that mate with the queen). [41]

2.2.4.2 Effects of Sinusoidal Vibrations on the Motion Response of Honeybees

In this study, artificial vibrational signals are generated by the proponents with the goal of changing the behavior of the bees. In a certain frequency range that is applied, an increase in motion activity is shown. The proponents stated that the study can be a "path" to have next generation of smart beehives in future beekeeping. [42]

2.2.4.3 Janus: A Combined Radar and Vibration Sensor for Beehive Monitoring

In this study, two sensors are used, a Doppler radar and a piezo-electric transducer on the inside. The RMS powers in the radar and vibration are found to be highly correlated during swarming and robbing activities. [43]

2.2.5 Other Related Studies

2.2.5.1 Comparison of Plastic and Wooden Langstroth hives in terms of some traits

In this study, two kinds of hives are compared, Thermoplastic and Wooden Langstroth. With a total of 23 hives, 13 wooden and 10 plastic, the proponents found out that survivability rate is higher in the plastic hive with a rate of 90% compared to the wooden hive with a rate of 53.85%. Swarm rate and swarm condition are also higher in the plastic hive. Honey yield per honeycomb is also higher in the plastic hive. They concluded that thermoplastic hives are more efficient to use than the wooden Langstroth hive. [44]

2.2.5.2 Impact of the design and material of the hives on honey production of bees

In this study, it is mentioned that the structure of the beehive has an effect on the development and the productivity of the bee colonies. The proponents concluded that reducing the size of the hive has a positive effect on the development of bee colonies. [45]

Chapter 3

METHODOLOGY

3.1 Research Design

3.1.1 Input Process Output of the Study

The inputs of the study are the following parameters: Temperature, Humidity, Vibration, Flow Frame Weight, and Volume of Honey inside the container. There are three data collection processes that were presented in the study. These are Temperature, Humidity Sensing, Vibration Acquisition, Frame Weight Sensing. The data collected will be stored in the cloud server where the ESP8266 is connected. The outputs of the study are Web and Mobile and Web Application real-time display of data, Activation of Air Conditioning System when the temperature is higher than 35.5 degrees Celsius, Blynk notification for Negative Activity, Automation of Harvesting of Flow Frame via electro-pneumatic system, and Collection Notification system.

The Figure 3.1 shows the input, process, and the output of the study. The input of the study consists of Hardware requirements, Software requirements, and Knowledge requirements. Hardware requirements consist of components needed for the system. The Software requirements consist of the programming language and applications needed for the system to work. The Knowledge requirements consist of intellect and skills needed by the researchers to create the system. The Process consists of Hardware Construction, Software Construction, and Testing and Evaluation. Hardware Construction consists of creating the beehive box, assembling the electronic and electropneumatic system in the flow frames, and placing the sensors. Software construction consists of creating the UI on BLYNK IOT App, calibration of sensors, and programming the Arduino and ESP8266. Testing and Evaluation consists of Z-test for the data of temperature and humidity of the traditional and hybrid hive, and vibration data processing through fast Fourier transform algorithm. The output of the study will be a hybrid beehive capable of automated harvesting, air conditioning, monitoring, and notification through application.

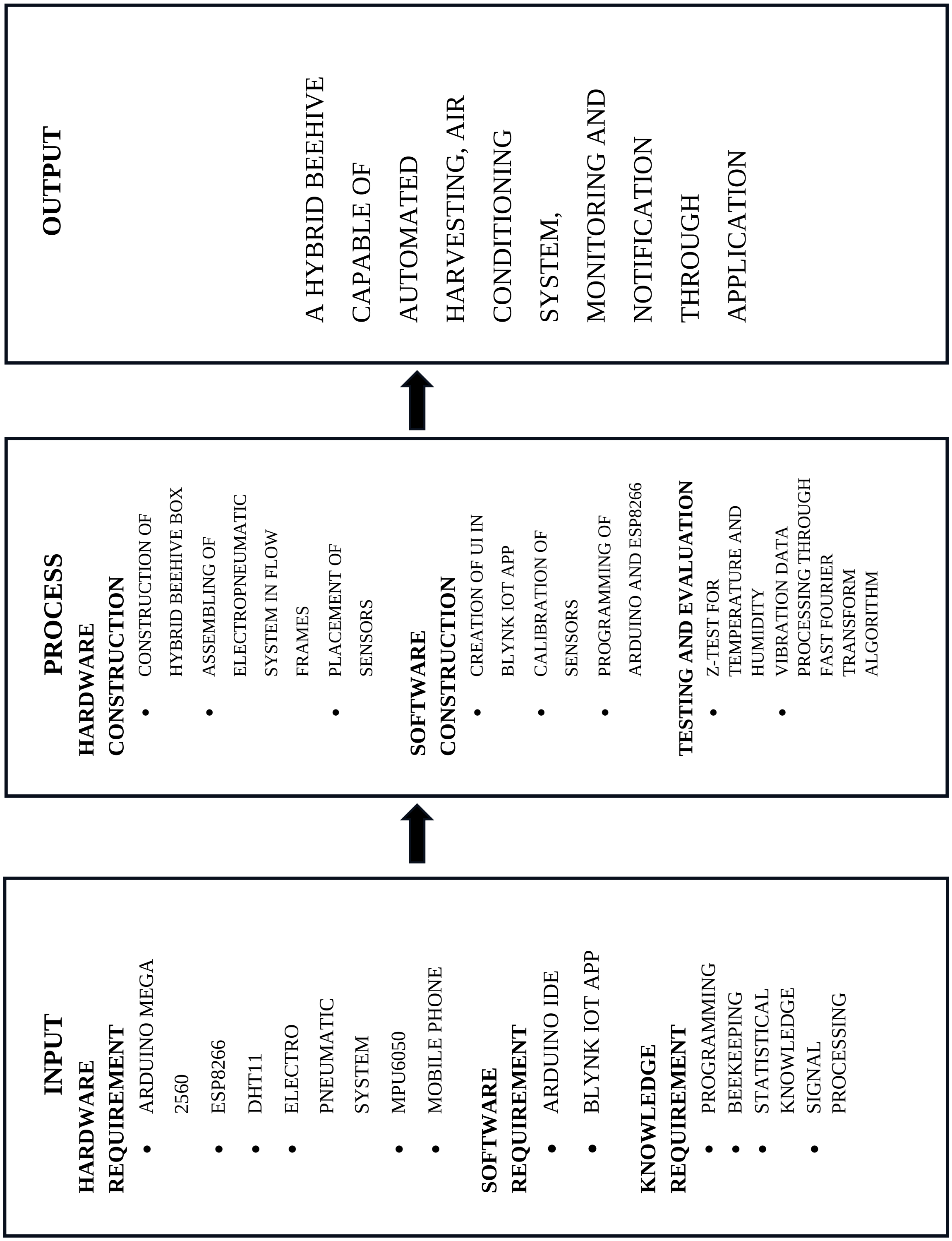


Figure 3.1 Input-Process-Output of the Proposed System

The Systems Block Diagram (Figure 3.2) provided an overview of the interconnections between various devices and illustrated the flow of processes. At the core of this system was the Arduino AT mega 2560 microcontroller, which served as the main controller for multiple sensors. The microcontroller communicated commands and utilized libraries to support each module.

The primary sensors employed in this system included:

1. Loadcell: This sensor measured and stored the weight of the flow frames.
2. MPU6050: An accelerometer that detected and recorded vibrations occurring within the frames.
3. DHT11: This sensor collected and stored temperature and humidity data from the system's interior.

Based on the specific parameters programmed, these sensors would activate the four-channel relay module. The relay module controlled two distinct systems: the air compressor for honey harvesting and the 120mm fans for air conditioning.

In addition to the Arduino AT mega 2560, the system utilized a second microcontroller called the ESP8266. Its primary function was to extract all the data stored by the sensors. This extracted data was then uploaded via the internet, specifically through the Blynk IoT cloud platform.

Once the data reached the Blynk IoT cloud, it underwent processing, sorting, and visualization. The processed data was presented in a visually appealing manner through the Blynk IoT app, accessible on mobile devices. This enabled users to monitor and analyze the data collected by the sensors in real-time.

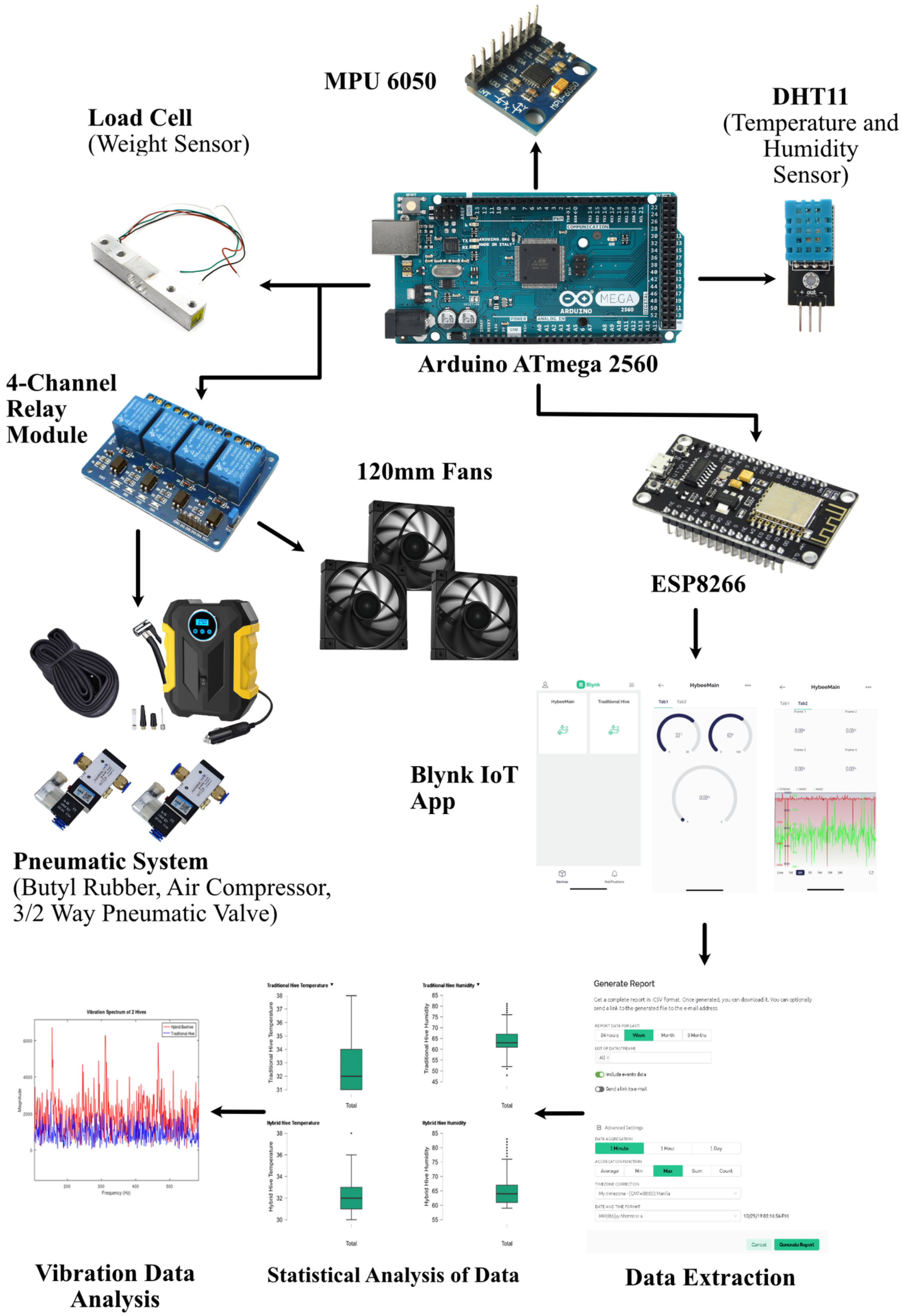


Figure 3. 2 System Block Diagram of the System

3.1.2 Control Mechanism of the Study

3.1.2.1 Air Conditioning System

Figure 3.3 depicts the diagram illustrating the control mechanism of the air conditioning system. The control mechanism was implemented to regulate temperature and humidity within the flow hive. When the temperature of the Flow Frame hive exceeded 38 degrees Celsius, the system would automatically activate the ventilation system and notify the beekeeper through the BLYNK IoT Mobile App that the hive had reached a critical temperature. Once the hive's temperature stabilized, the fan would automatically turn off. Conversely, if the temperature of the flow frame was the same as or lower than that of the traditional Langstroth hive, the ventilation system would not be activated, and the main system would proceed to display the readings in the Mobile Application.

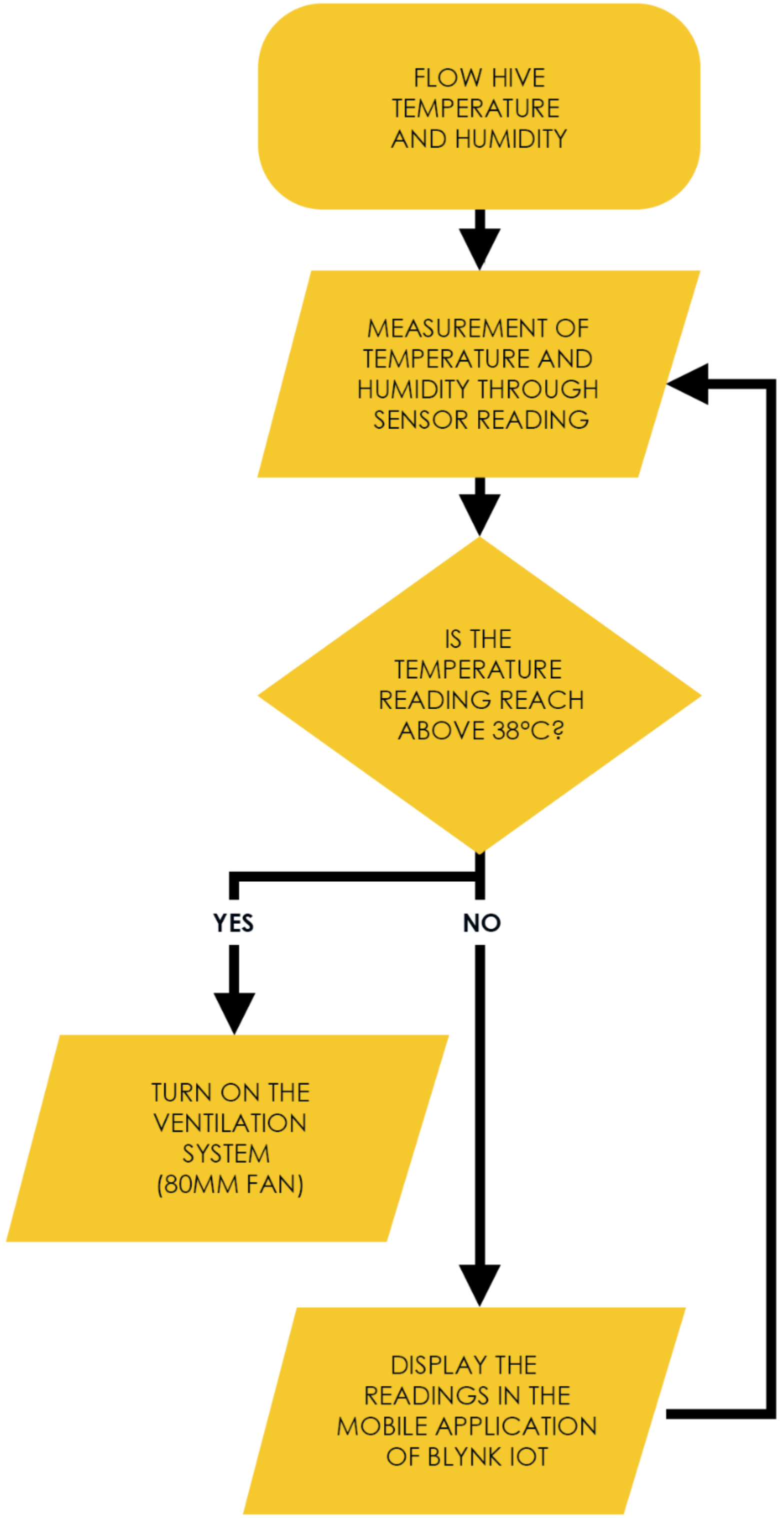


Figure 3.3 Automation of the Proposed System

3.1.2.2 Automated Flow Frame and Collection Monitoring System

The second control mechanism for the system is the Automated harvesting, collection monitoring and notification system. In figure 3.4, the automation of harvesting will occur via weight monitoring of the system. If a flow frame reaches its maximum honey capacity (6 kg total weight = 1kg frame weight + 5kg honey capacity), the system will automatically open the frame via electro-pneumatic control, otherwise the monitoring continues. In Figure 3.5, it shows the harvesting phase of the system. If the honey was extracted in the flow frame (Initial weight of 5kg $\pm$ 5%), the electro-pneumatic control will close the flow frame. If the collection container is full, it will notify the beekeeper that the container is ready for harvest.

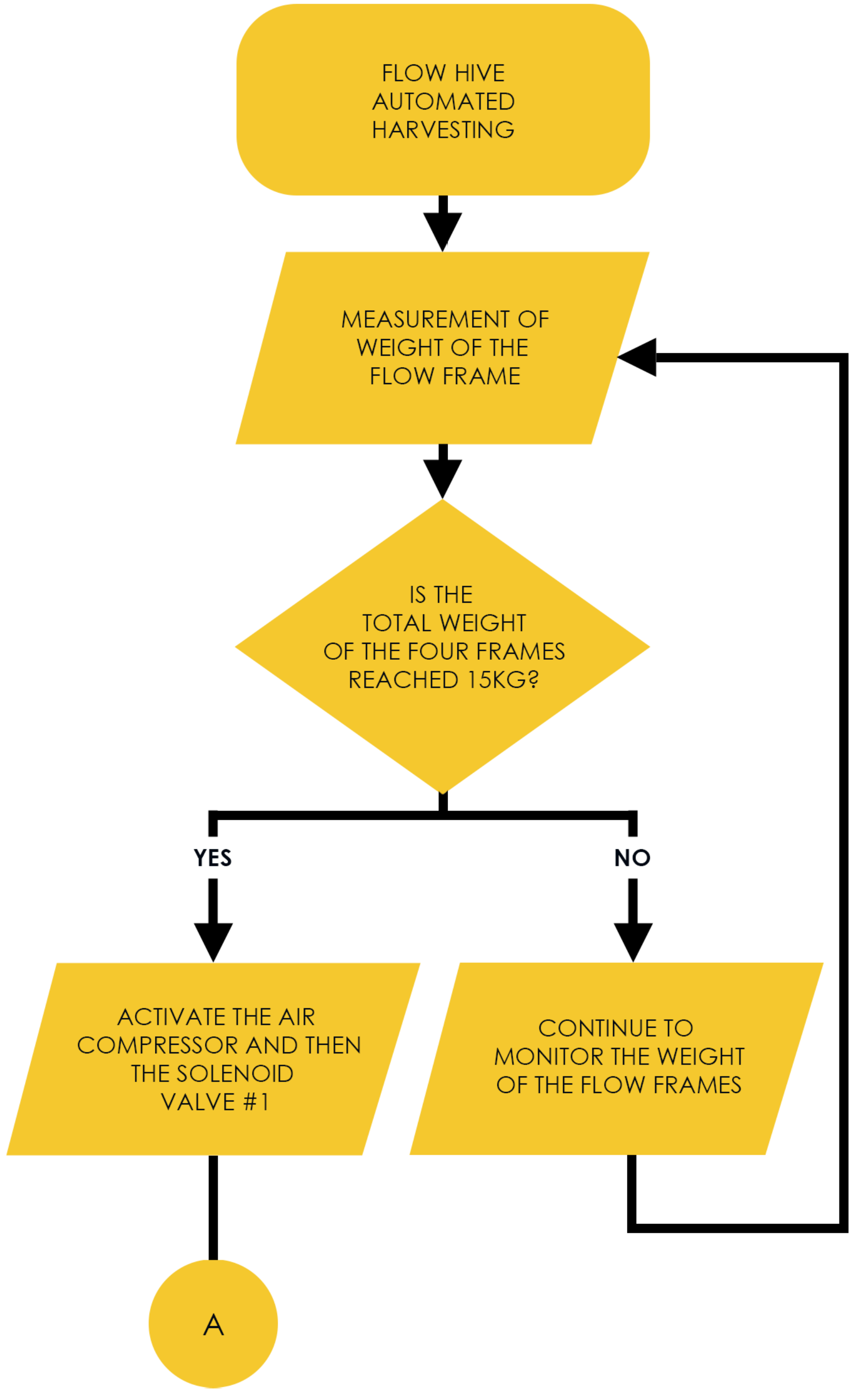


Figure 3.4 Automation of the Proposed System

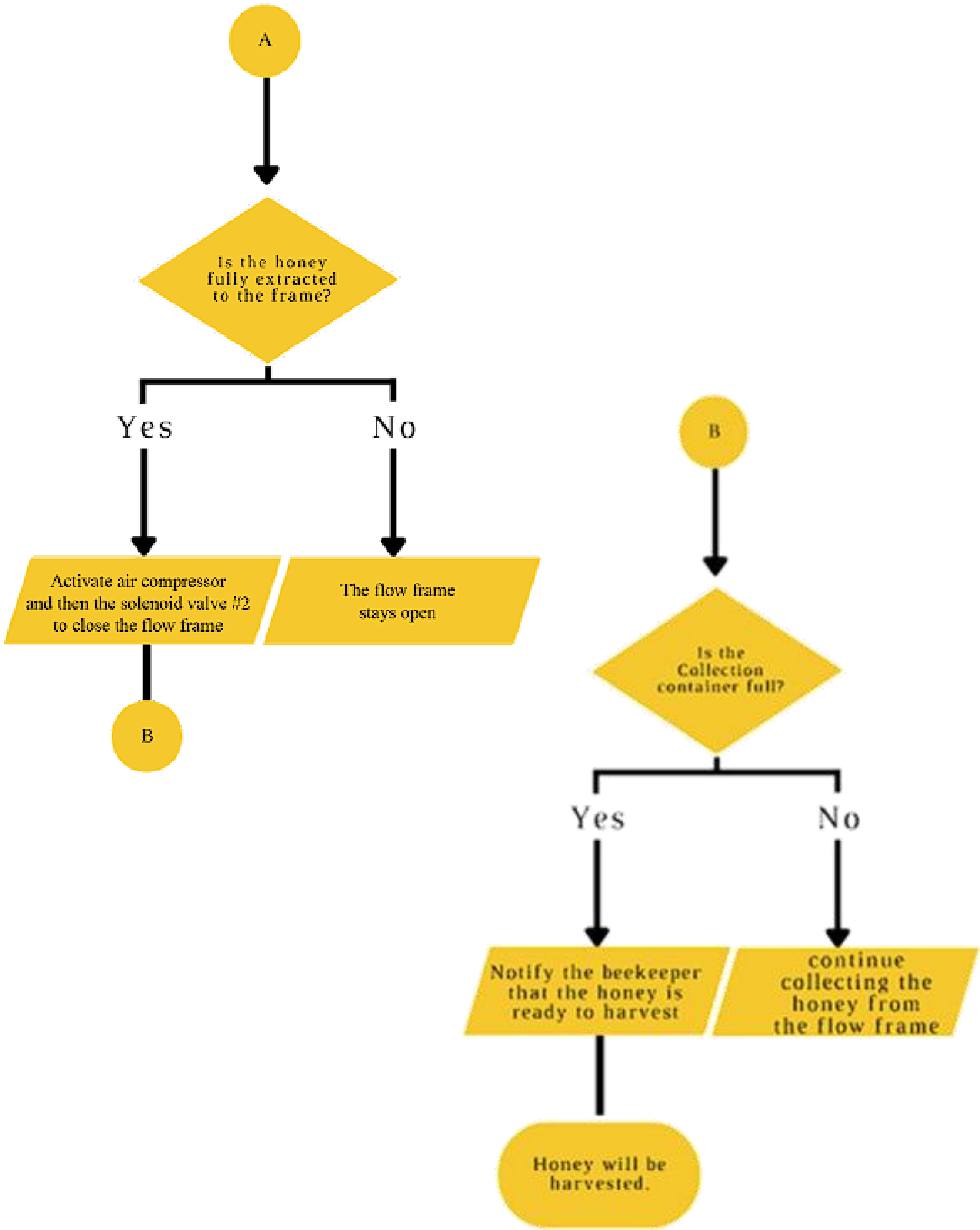


Figure 3.5 Harvesting Phase of the Proposed System

3.2 Research Process Flow

The figure illustrates the flow of the process used by the researchers to create the system. The process began with a literature review to conceptualize chapters 1 to 3 of the study. Following that, the researchers scouted the deployment site and canvassed materials before making the purchases.

The initial focus was on creating the automated flow frame, followed by the development of the air conditioning system. The vibration acquisition system was then constructed by calibrating the MPU6050 system. The sensors were integrated into the Arduino Mega 2560, and the data were parsed and transferred to the ESP8266. These data were subsequently sent and stored in the BLYNK IoT Cloud and displayed in the BLYNK IoT Mobile app.

Data extraction was performed in the web app. Once the system was fully assembled, it was deployed at Pia's Bee Farm in Lipa City, Batangas. Sensor data were collected and monitored through the BLYNK IoT App. To validate the environmental sensor, the researchers applied the Z-Test, while the Vibration Signal Processing was conducted using the Fast Fourier Transform.

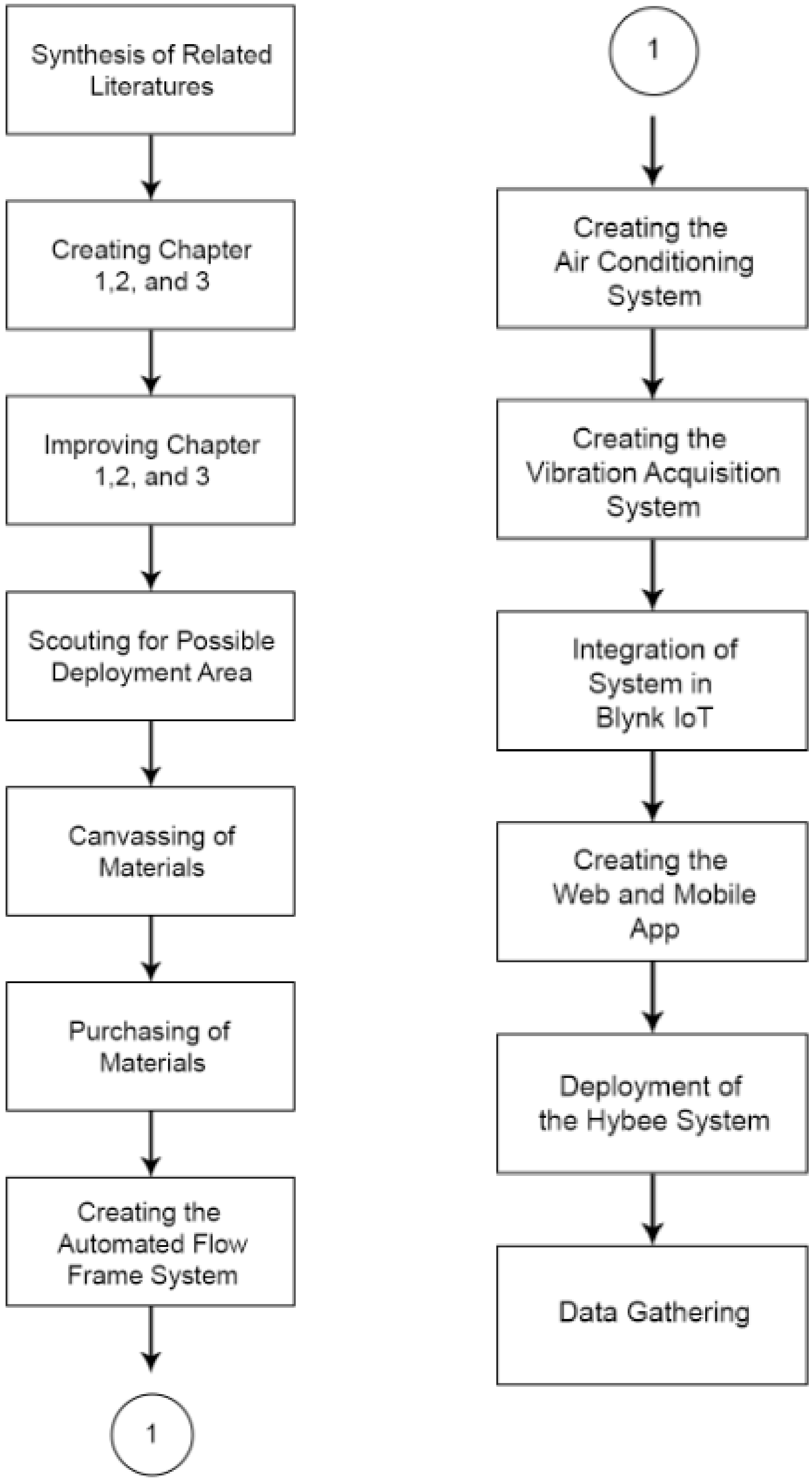


Figure 3.6 Process Flow diagram

3.3 Procedure of the Study

3.3.1 Materials and Equipment

3.3.1.1 Automated Flow Frame System

- Straight Bar Load Cell 20KG & Load Cell Amplifier HX711
- Ultrasonic Sensor Distance Measuring Module HC-SR04
- ESP8266 Wi-Fi IoT Development Board
- Arduino ATmega2560
- 3/2-way electric solenoid valve and 12V air compressor
- Butyl rubber tubes
- Set of artificial flow frame (4 pcs) and acrylic tubes

3.3.1.2 Temperature and Humidity Control System

- DHT11 Temperature and Humidity Sensor Module
- 120mm Fan (2 pcs)
- ESP8266 Wi-Fi IoT Development Board
- Arduino ATmega2560

3.3.1.3 Vibration Acquisition System

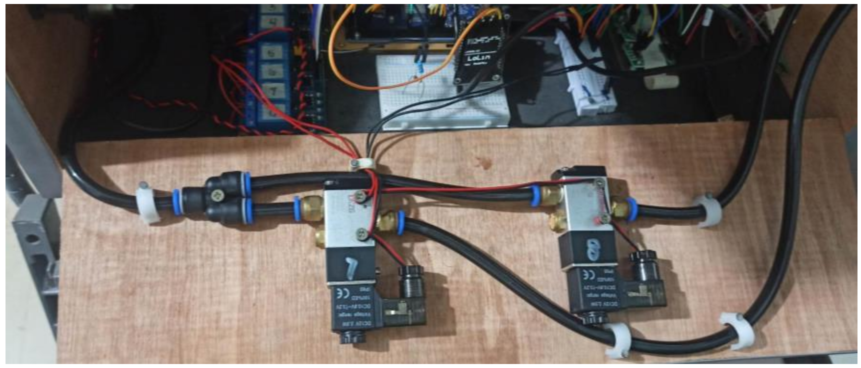
- MPU 6050 Accelerometer module
- Arduino ATmega2560
- ESP8266 Wi-Fi IoT Development Board

3.3.2 Creating the Automated flow frame Harvesting and Collection System

3.3.2.1 Automated Flow Frame Harvesting System

The automation of the system was created using HX711 load sensors and inflatable tubes through an electro-pneumatic system. The load sensors were placed on the frame gap, which measured the weight of the frame. The 20" customized straight tube butyl rubber was inserted into the keys hole, which was inserted into the frames. The automation occurred when the weight of a frame reached the maximum capacity, and the 3/2-way electric solenoid valve triggered the air compressor to inflate the upper straight tube butyl rubber, pushing the comb structures downward and opening it. After some time, it deflated.

When harvesting is almost finished or the collection container is full, the 3/2-way electric solenoid valve will trigger the air compressor to inflate the lower straight tube butyl rubber pushing the comb structures downward closing it, then deflating it after some time when the system extracted 95% of the honey inside the frame.



(a)

(b)

Figure 3.7 Using Pneumatic tubes and Solenoid Valve for the automated honey harvesting system.

3.3.2.2 Honey Collection System

The Honey Collection occurred once the honey had reached a sufficient weight in the flow frame. The process started with the bees continuously collecting honey. A network of butyl rubber tubes was inflated by an air compressor when the flow frames reached the desired amount of fullness. As a result of the split comb structures being broken, the honey started flowing through the PVC pipes down to the collection container box. The collection container had a 9-liter capacity and an ultrasonic sensor installed. The air compressor would turn on when the container was nearly full of extracted honey. This would inflate and close the split comb structures to stop the flow. Additionally, the system would notify the beekeeper that the container was full and ready to be harvested.

Figure 3.8 Butyl rubber is used for the opening and closing of the flow frame for honey harvesting.

3.3.2.3 Electro-Pneumatic Control

The harvesting of honey from the Flow Frame was done by using inflatable tubes (with the right amount of air pressure) through electro-pneumatic control. (a) A portable vehicle air compressor with a 150-psi maximum pressure output is used in the pneumatic inflator for the rubber butyl tubes. The calibrated psi used for the network of four butyl rubber tubes is only capable of 10 psi, according to extensive testing. The compressor runs at a 120W power rating, 12V voltage, and 10A amperage. The system displays minimal power consumption due to the component's rare usage, which normally only happens 3-5 times per year depending on the intensity of the local honey flow. (b) A 3/2-way solenoid valve is the designated airflow control component in the system. The network of rubber butyl tubes that need to be inflated is effectively targeted by this valve, which successfully directs the airflow there. (c) The four-channel relay module functions as an electronic board with the ability to control loads with high voltage and high current. By managing multiple components, it plays a significant part in automating the honey gathering process. These include the power on/off and trigger controls for the air compressor, two 120mm fans for air conditioning, two 3/2-way solenoid valves for controlling airways, and more. (d) The rubber-based butyl rubber tube functions as an inflating tube with a bulb mechanism. It makes it easier for the system to open and close the flow frame. The building and dismantling of the honeycomb structure are made possible by inflating and deflating the upper and bottom keyholes. (e) The electro-pneumatic system makes use of the pneumatic nylon hose as an air path. Its nylon construction makes it possible to move pressurized air from the air compressor to the solenoid valves and then to the butyl rubber tubes. (f) The electro-pneumatic fittings, which are made of brass parts in a variety of shapes, are essential to the system's operation. They make it possible to attach the butyl rubber tube to the flow frames and the pneumatic nylon hose to the solenoid valve. The fittings have an 8mm hole diameter and a

1/8" thread size. Teflon tape is placed to the threads in order to provide a solid seal and avoid air leakage.

Figure 3.9 (a) Air Compressor, (b) 3/2-way Electric Solenoid Valve, (c) 4-Channel Relay Module, (d) Butyl tube, (e) Pneumatic Pipe, (f) Pneumatic Fittings

This study used Festo FluidSIM to develop a streamlined pneumatic control representation to evaluate the control mechanism used in inflating the inside rubber tubes. In particular, the relay was controlled by commands sent by the Arduino AT mega 2560, which in turn activated the 3/2-way solenoid valve that inflated the butyl rubber tubes. Pistons were used in the schematic to represent these rubber tubes metaphorically. The relays were programmed with a 5-second time delay to replicate the wait before the solenoid valve closed.

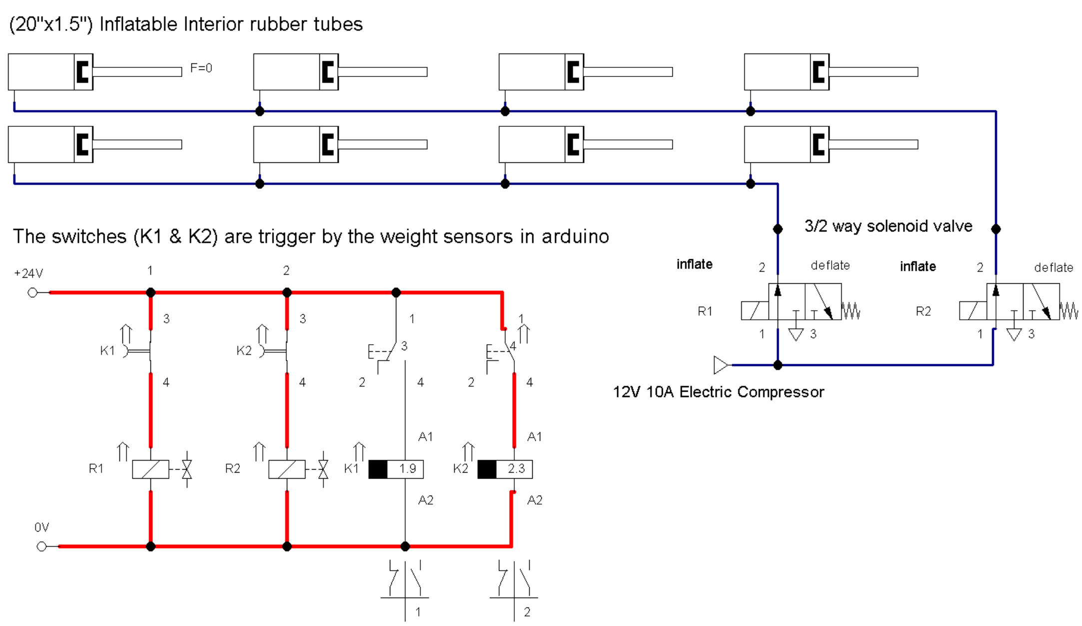


Figure 3.10 Schematic Diagram for Electro-Pneumatic Control

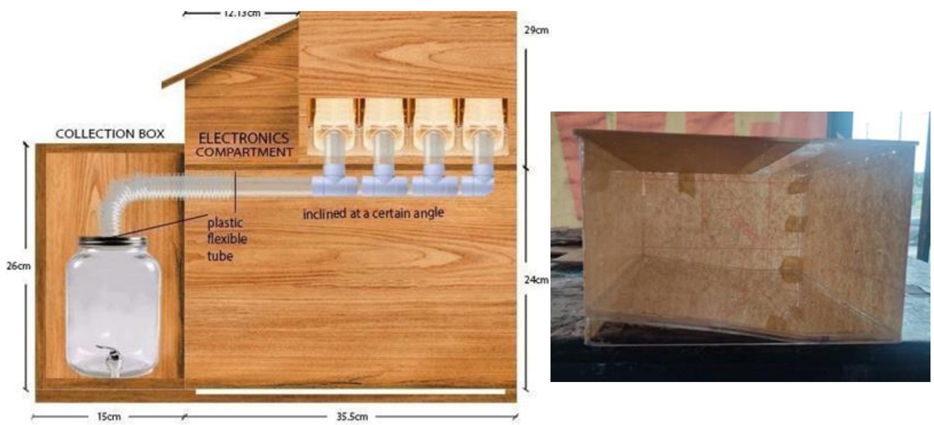
3.3.2.4 Honey Flow and Flow Frame Harvesting

The selection of materials for the system was carefully done with food safety in mind. The choice of 25mm acrylic tubes was based on the fact that acrylic material is generally recognized as safe for food contact, especially when used as containers, utensils, or tubes for food processing and storage. Acrylic is known for its transparency, which allows for easy visibility of the contents. Its smooth surface also facilitates convenient cleaning and maintenance, making it suitable for food-related applications.

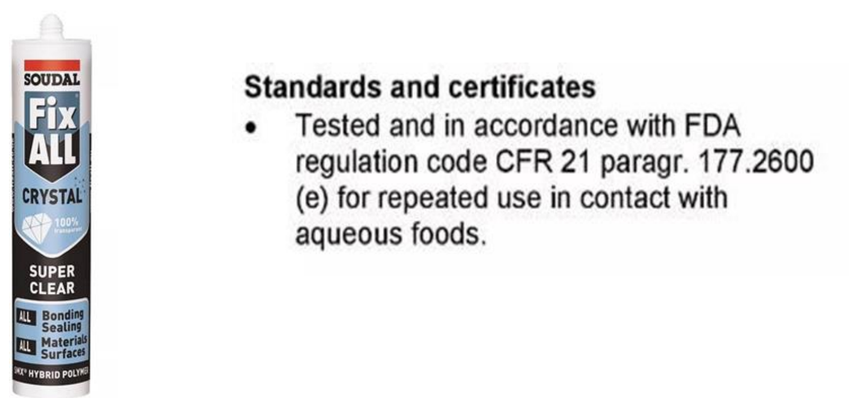
However, it is important to note that PVC connectors are not recommended for direct contact with food. In the system design, the PVC materials were used solely as connectors between the acrylic tubes, which directly flow into the honey storage container. This design choice helps mitigate the risk of direct food contact with PVC.

To ensure a secure and food-safe connection, the researchers utilized a food-grade sealant called Soudal - Fix All Crystal. This sealant is approved by the FDA and certified for repeated use in contact with aqueous foods. Food-grade sealants are commonly applied to create a barrier between surfaces, ensuring hygiene and preventing contamination. In this case, the food-grade sealant was applied at each corner of the honey container to prevent any leakage during honey production and storage, further ensuring food safety.

(a) (b) (c)



(d)



(f)

Figure 3.11 (a) 25mm Acrylic tubes (b) 25mm PVC Elbow Connector (c) 25mm PVC Tee Connector (d) Acrylic Design with food grade sealant (f) Test Report (FDA Specification)

When the Flow Frame was open for harvesting, the honey flowed through a series of connected acrylic tubes leading to a container.

3.3.3 Creating the Temperature and Humidity Monitoring and, Air Ventilation System

The design of the beehive roof was specifically developed to minimize and mitigate any disruptive effects of air exhaust on the bees. To achieve this, a regulation was implemented to control the speed of the 120mm exhaust fan, utilizing a low amperage setting. Additionally, the fan was positioned at a distance of three inches away from the top box to minimize direct airflow disturbance to the bees.

To ensure the safety of the bees while maintaining proper air circulation within the hive, mesh covers were strategically installed to prevent the bees from entering the fan area. These mesh covers allow for adequate airflow without compromising the well-being of the bees.

In order to maintain optimal conditions within the hive, an air conditioning system was integrated. The activation of this system was contingent upon the temperature reading from the dht11 sensor within the hive exceeding 38 degrees Celsius. This temperature threshold was chosen to ensure that the bees are not exposed to excessively high temperatures, which can be detrimental to their health.

Recognizing the natural tendency of hot air to rise and cold air to sink, the airflow was directed from the bottom of the hive, ascending through the various boxes, and ultimately exiting through the roof. This design allows for efficient air circulation and temperature regulation within the hive, promoting a comfortable and suitable environment for the bees' well-being.

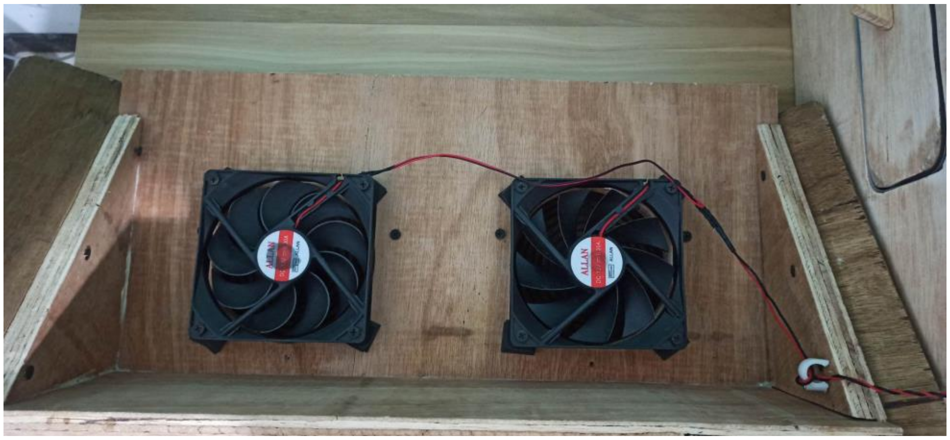


Figure 3.12 Design for Air Ventilation System

3.3.4 Creating the Vibration Acquisition System with BLYNK IoT

3.3.4.1 Vibration Signal Extraction

The vibration sensor was installed at the entrance of the hive where honeybees routinely went in and out, harvesting pollen and honey. As the bees went about their business, the sensor picked up vibrations from them, creating their normal pattern, which was based on a healthy living frequency. Within the data collection that took four months, the frequency pattern was interpreted when there was exponential decay or growth on the initial healthy pattern. This suggested various difficulties or alerts if the colony was in danger based on events taking place within the colony.

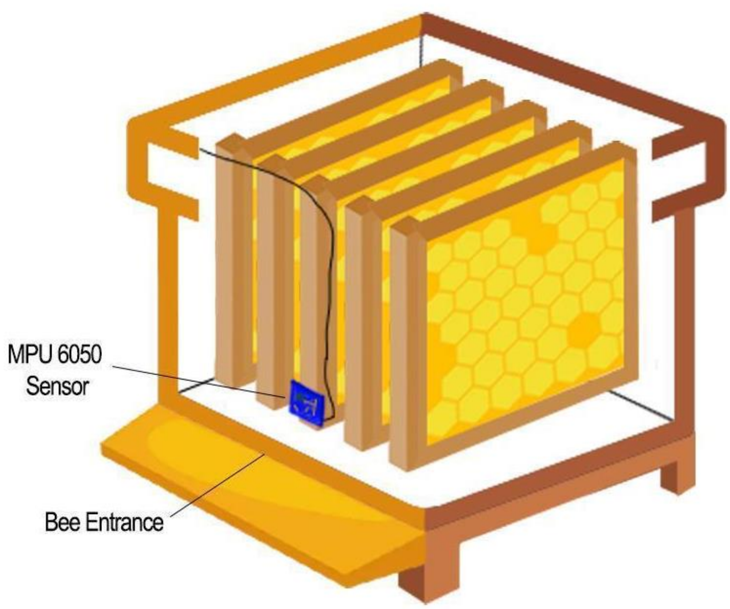


Figure 3.13 Initial Placement of MU 6050 Sensor

3.3.4.2 Vibration Signal Processing and Display in Application

The ESP8266 managed the data collected by the MPU 6050 Accelerometer sensor by collecting all frequencies and uploading it to the cloud, where it was visualized in graphs and clearly plotted real-time events in the mobile and online application. The ESP8266 used the Arduino IDE Library in conjunction with the Arduino ATmega2560 to easily program and synchronize the flow frame system's control mechanism.

3.3.5 Implementation of IoT in the system

3.3.5.1 Calibration of Sensors

The default program compatibility offered in the installed library from the Arduino IDE libraries was used to calibrate all the sensors. Specific parameters needed to be met in order to create the system. The weight sensor needed to be calibrated in accordance with the maximum frame weight (1 kg total weight = 4 kg frame weight + 3 kg honey capacity) since the automation was activated once the frame reached maximum capacity. The ultrasonic sensor needed to be calibrated in accordance with the maximum capacity of the collection container (9 Liters) since the system notified the beekeeper if the collection container was full. The temperature and humidity sensor needed to read 34.5 to 35.5 + 5% degrees Celsius and 60% + 5% humidity. Any changes in temperature and humidity operated the air conditioning system. If the temperature and humidity stabilized, the air conditioning system automatically turned off. The vibration sensor was calibrated to 100 to 1 kHz. The signal that was displayed was the average vibration signal per day. If the average signal observed was lower than 300 Hz, the system notified the beekeeper that the hive had low activity.

3.3.5.2 Integration of Sensors to BLYNK IoT Cloud

The sensors utilized in the system were connected to the Arduino Mega 2560 Board, which served as the central control unit. The Arduino Board facilitated the communication and data acquisition from the sensors. The Arduino Board, in turn, was connected to the ESP8266 module, enabling the transmission of data from the Arduino to the BLYNK IoT platform.

The ESP8266 module acted as a bridge between the Arduino Board and the BLYNK IoT. It established a connection to the internet and facilitated the direct upload of data gathered by the sensors to the BLYNK IoT platform. This setup ensured that the sensor data were seamlessly transmitted to the BLYNK IoT for monitoring and analysis.

Overall, the Arduino Mega 2560 Board, along with the ESP8266 module, enabled the real-time transfer of sensor data to the BLYNK IoT platform, allowing for remote monitoring and analysis of the collected information.

3.3.5.3 Creating a Mobile Application

The researchers used the BLYNK IoT App for the development of Mobile and Web applications. BLYNK IoT is an online platform that enables the creation, deployment, and monitoring of IoT-based projects. Using the IoT Cloud, the researchers added a set of variables that corresponded to their monitoring system, including Weight Sensing, Temperature, Humidity, and Vibration. For the device, the ESP8266 was integrated into the IoT Cloud using the Wi-Fi credentials.

The key features of the IoT Cloud online platform included the Dashboard. The researchers designed their own User Interface (UI) to precisely display the real-time data from the beehive monitoring system. The system also implemented data logging to Google Sheets via ESP8266 for recording and storage of the collected data.

3.3.6 Power Management of the Whole System

The table was comprised of components accompanied by their respective voltage and current ratings. This facilitated the estimation of the maximum power consumption, taking into consideration the power-saving features implemented on each module. The main power source was a switch power supply, which was supplemented by the utilization of buck converters to supply the sensor and components with voltages ranging from 5V to 3.3V.

Table 3.1 Power Specification of Hardware Components

Component	Voltage (V)	Ampere (A)
Switch Power Supply Driver Adapter	12V	15A
Tire Inflator Portable Air Compressor	12V	10A
3V110-06 3 Port 2Position Pneumatic Valve Electric Magnetic	12V	0.2A
5V 5A DC-DC Converter	5V	5A
Arduino AT mega 2560	5V-12V	20mA (I/O pin) 50mA (3.3V pin)
ESP8266 Wi-Fi Module	3.3V-12V	70mA
DHT11 Temperature-Humidity Sensor	3V-5V	2.5mA
HC-SR04 Ultrasonic Sensor Module	5V	15mA
HX711 Load Sensor	5V	1.5mA
MPU6050 Accelerometer Module	3V-5V	10µA-500µA

3.4 Statistical Analysis

3.4.1 Temperature and Humidity

The temperature and humidity of the hybrid beehive was compared to the traditional hive. These two parameters were compared using z-test: Two samples for means to compare the overall condition of both hives. 50 samples were tested out of 1400 10-min interval data points to prove if the temperature and humidity of the hybrid hive has no significant difference with the traditional hive.

$$t = \frac{|\mu_a - \mu_b|}{\sqrt{\frac{(\sigma_a)^2}{\eta_a} + \frac{(\sigma_b)^2}{\eta_b}}}$$

Where:

t = t-value;

μa = mean of the samples in set-up A;

μb = mean of the samples in set-up B;

σa = standard deviation of the set-up A;

σb = standard deviation of the set-up B;

n_a = sample size of set-up A; and

nb = sample size of set-up B.

3.4.2 Vibration

The behavior of both hives was assessed by conducting vibration analysis of the colony using the Fast Fourier Transform (FFT). This analytical technique allowed for the visualization of the vibration spectrum and activity within the hive. By applying the FFT to the collected vibration data, researchers were able to gain insights into the behavior and activity of the colony, as different hive conditions and activities correspond to distinct vibration frequencies.

3.5 Project Work Plan

Table 3.2 Gantt chart from June 2022 to July 2023

Objectives	Months													
	2022							2023						
	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
CREATING THE PAPER	Construction of Chapters 1,2, and 3												Construction of Chapters 4 and 5	
HARDWARE DEVELOP-MENT		Canvassing and buying of materials		Building the automation and air conditioning system		Construction of vibration acquisition system								
SOFTWARE DEVELOP-MENT				Integrating the automa-tion, temperature, and humidity sensors in IoT cloud		Integrating the vibration acquisition system in the IoT cloud and creating the cloud remote app.								
TESTING AND DEVELOP-MENT			Surveying for a potential deployment site				Initial testing of the system	Final dry run of the system	Deployment					
GATHERING OF DATA										Gathering and visualizing the data				
FINAL ASSES-MENT														Final Defense

Chapter 4

RESULTS AND DISCUSSIONS

This chapter presents the project's technical description, project structure, interpretation of data and analysis of findings relative to the tests conducted.

4.1 Project Technical Description

The hybrid beehive system consists of four major parts: the pneumatic control system, the honey collection system, the air-cooling system, and the monitoring and notification system. The pneumatic control system is built using two 3/2-way pneumatic solenoid control valves, a digital air compressor rated at 12V and 10A, four load cell sensor and an HX711 driver amplifier for weight sensing, and a 4 Channel relay module low-level trigger. The weight received on load cells is amplified by the HX711 module, converted to digital signals, and transmitted to the Arduino Mega 2560 microcontroller. When the weight reaches an approximate of 80 percent of the projected total weight, the Arduino then triggers the relay module to activate the three consecutive components simultaneously to perform opening and closing the artificial flow frame: air compressor power, solenoid valve power/trigger, and air compressor trigger. After the pneumatic control system is activated, the honey will flow freely through the acrylic tubes and down to the honey collection system equipped with the HC-SR04 ultrasonic sensor. The dimensions of the box are 9x12x6 inches, which can hold up to 10 liters of honey, and to control overfilling, the maximum height or level for honey is calibrated to 5 inches as a safe distance with the sensor. The air-cooling system is established using the DHT11 as a temperature and humidity sensor. The Arduino microcontroller receives the values obtained by the DHT11 sensor and sends a signal to DC brushless fans when it reaches

38 °C and deactivates after reaching 34 °C. The monitoring and notification system are the application of the Internet of Things to the system. The MPU6050 accelerometer will record the vibration emitted by the colony for the analysis of the behavior of bees inside the system. The Arduino Mega 2560 was connected to the NodeMCU ESP8266, which will display the data through the Blynk IoT app and log it to Google Sheets.

4.2 Project Structural Organization

4.2.1 Hardware System

4.2.1.1 Pneumatic Control System

The pneumatic control system comprises an air compressor, pneumatic tubes, and flow frames. This system is activated when the weight of a flow frame reaches a specific value. Once activated, the air compressor turns on and inflates the butyl rubber tubes (depicted in Figure 4.2), which are responsible for opening and closing the flow frame.

As shown in Figure 4.1, the Pneumatic Control System consists of several components. Firstly, there is the pneumatic pipe, which plays a significant role in the system. The portable air compressor generates air that travels through this pipe until it reaches the butyl rubber located inside the artificial flow frame. Next, the solenoid valve is a device responsible for controlling the airflow within the system. It also facilitates the retraction and extraction processes of the flow frames. Furthermore, the pneumatic fittings stabilize the pneumatic pipes connected to the solenoid valve, preventing any air leaks.

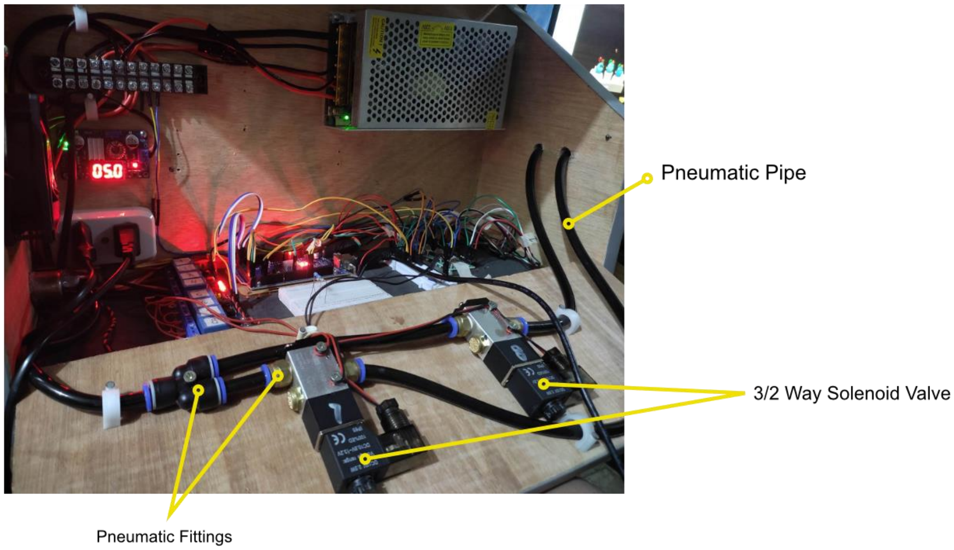


Figure 4.1 Pneumatic Pipe connected to 3/2-way Solenoid Valve to pneumatic fittings.

Figure 4.2 Electro-Pneumatic System connected to the flow frames

4.2.1.2 Honey Collection System

The Honey Collection System consists of 25 mm acrylic tubes, which function as the passageway for honey, facilitating its flow from the artificial flow frames to the acrylic container. The purpose of using two

25mm PVC Elbows and three PVC Tee connectors is to combine the four (4) acrylic tubes, allowing for simultaneous honey harvesting. Additionally, the Honey Storage Box is made up of two (2) parts. In Figure 4.3, the upper portion is shown, where the acrylic container for honey storage is placed. This honey container has a capacity of up to 10 liters of honey. On the other hand, the lower part of the Honey Storage Box is designated for the placement of a portable air compressor.

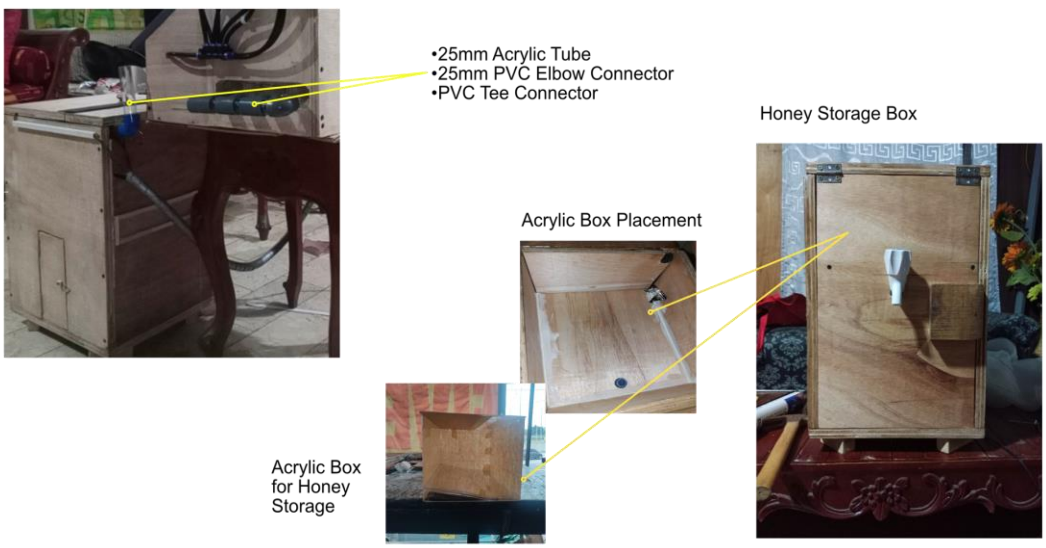


Figure 4.3 Honey Acrylic box and acrylic tubes

4.2.1.3 Air Cooling System

The Air-Cooling System consists of a temperature sensor and 120mm fans. These fans will be activated if the temperature inside the hive reaches 38°C.

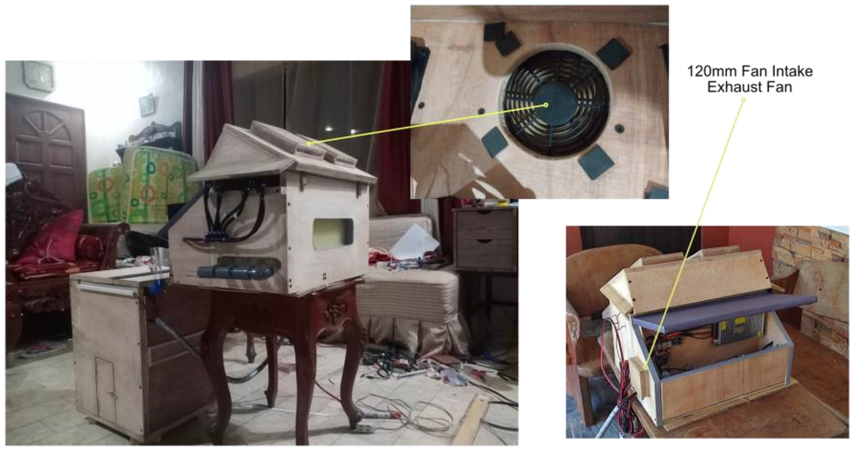
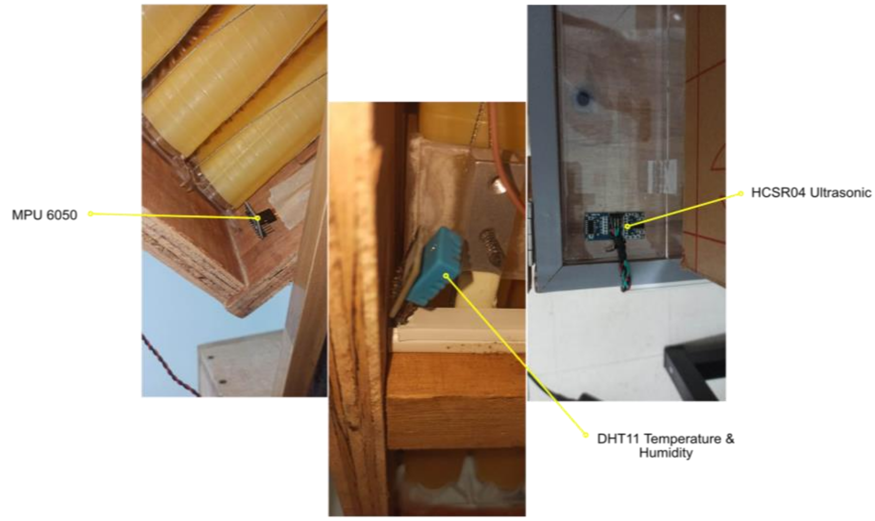


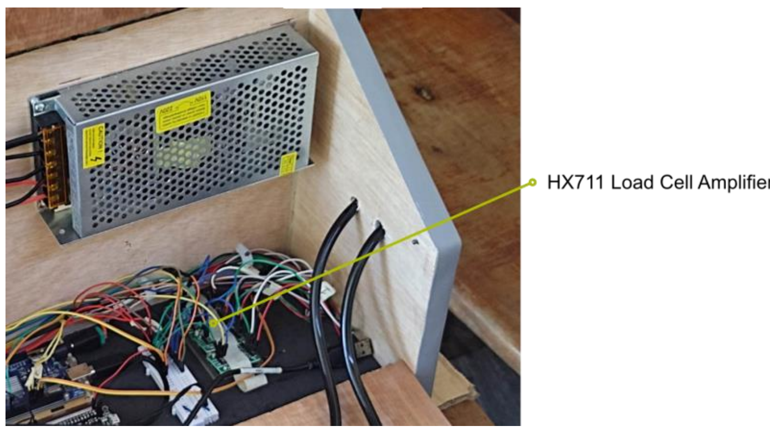
Figure 4.4 The Fans and their placement on the system

4.2.1.4 Monitoring System

The monitoring system is composed of 4 individual load cells connected to HX711 load cell drivers, MPU6050 Accelerometer, HCSR04 Ultrasonic Sensor, and DHT11 Temperature and humidity sensor. The sensors are calibrated to gather accurate readings of the hybrid beehive system.



(a)



(b)

Figure 4.5 (a) placement of MPU6050, HC-SR04 Ultrasonic and DHT11 in the system, (b) HX711 Load Cell Amplifier inside the Electronic box

4.2.2 Monitoring System Connection, Data Display, and Data Logging

The system is integrated with the Internet of Things application using a NodeMCU ESP8266. The data from the Arduino Mega2560 was transferred to the NodeMCU ESP8266 which displays it to the Blynk IoT App and logs it into csv format. The interval for the data logging can be set in 1 second, 1 minute, or 1 hour. The Blynk IoT display is set to 2 seconds to efficiently display the data.

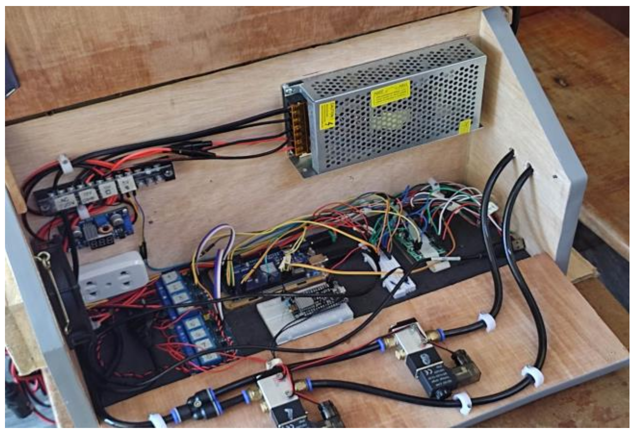


Figure 4.6 NodeMCU ESP8266 connected to Arduino Mega 2560

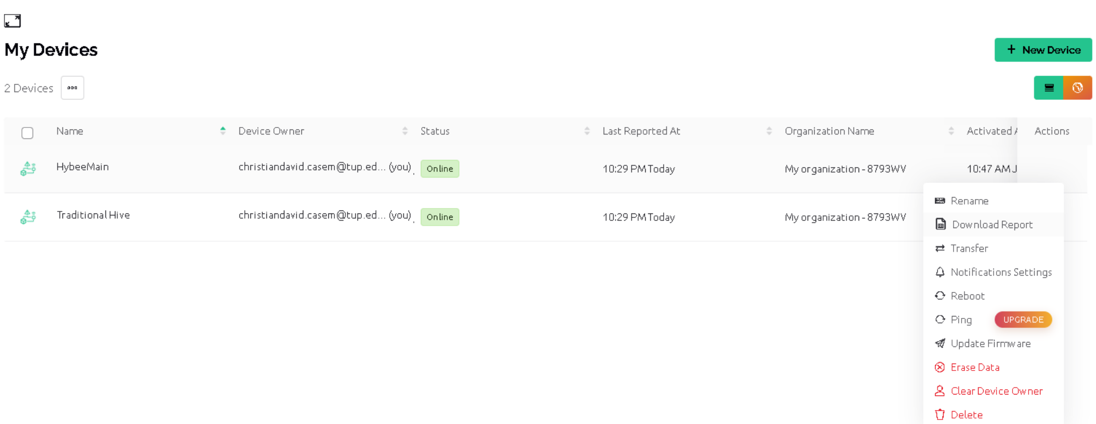


Figure 4.7 Data Logging of the System

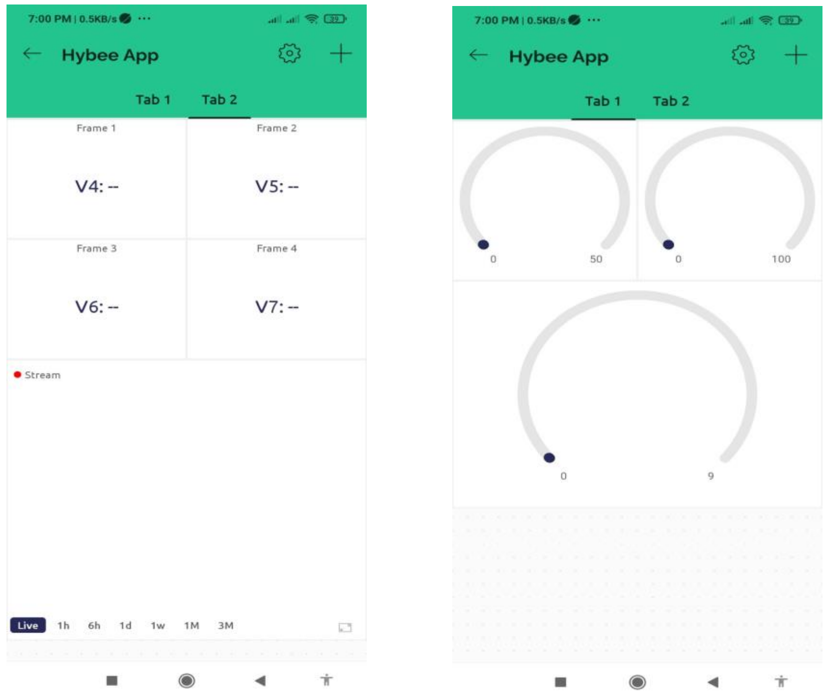
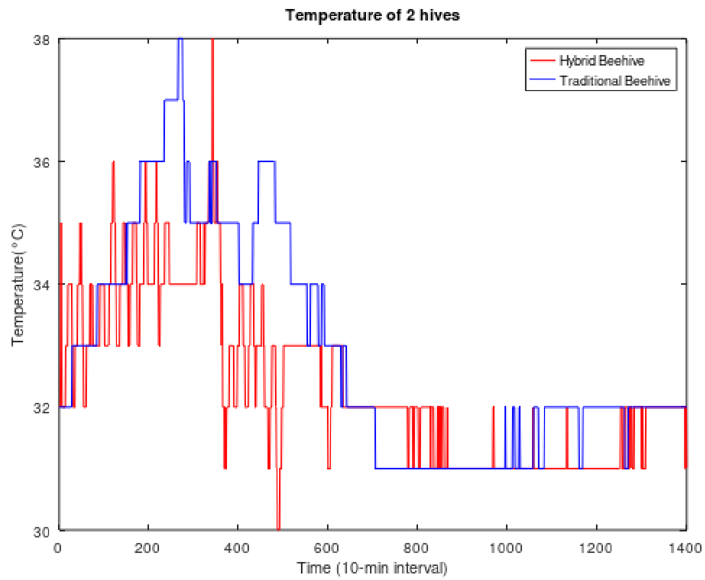


Figure 4.8 Blynk Application User Interface

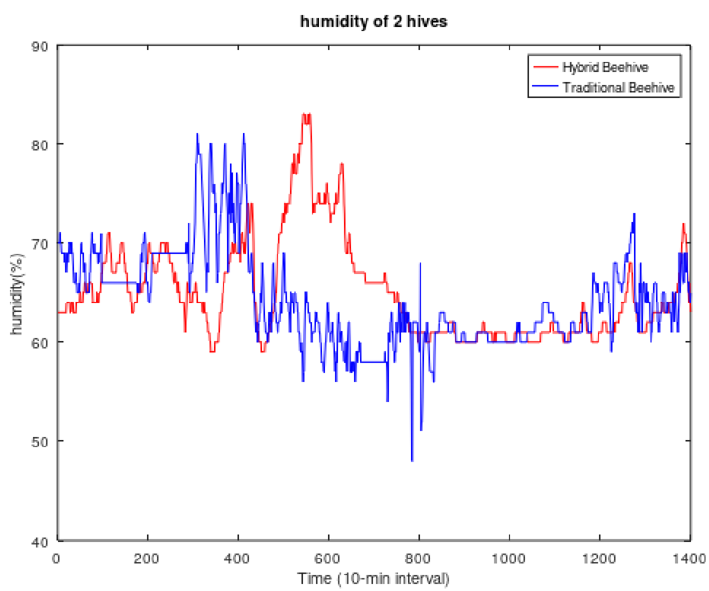
4.3 Statistical Analysis and Data Interpretation

4.3.1 Temperature and Humidity

Value interpretation reveals the difference between the temperature and humidity of the hybrid and traditional hive. The value of temperature and humidity in the hybrid beehive ranges from 30 to 38 degrees Celsius and 59 to 83 percent humidity, while the traditional beehive ranges from 31 to 38 degrees Celsius and 48 to 81 percent humidity. In figure (a), it shows that the temperature of the traditional and hybrid beehives reached 38 degrees Celsius. In a ten-minute interval, the traditional hive stayed around 10 minutes before the temperature went down to 37 degrees Celsius, while the hybrid beehive regulated the temperature of the hive to 36 degrees Celsius in a ten-minute interval. The z-test reveals that there is no significant difference between the temperature and humidity between the traditional and hybrid beehive as the critical value computed for two-tailed z-test is equal to the z-tabular value 0.05 significance level.



(a)



(b)

Figure 4.9 (a) Temperature of the two hives, (b) Humidity of the two hives

Table 4.1 50 points of data used for the Z-test

	Hybrid Hive		Traditional Hive	
	Temperature (°C)	Humidity (%)	Temperature (°C)	Humidity (%)
1	32	67	32	70
2	32	67	32	70
3	33	67	32	70
4	35	67	32	70
5	33	67	32	71
6	32	67	32	70
7	32	67	32	70
8	32	68	32	69
9	32	68	32	69
10	32	68	32	69
11	32	68	32	69
12	32	68	32	69
13	32	68	32	69
14	32	68	32	69
15	33	68	32	69
16	33	69	32	68
17	33	69	32	69
18	33	70	32	68
19	33	70	32	67
20	34	70	32	67
21	34	70	32	68
22	34	70	32	69
23	34	70	32	68
24	34	69	32	69
25	34	69	32	69
26	34	68	32	70
27	34	68	32	70
28	34	67	32	70
29	33	67	33	69
30	33	67	33	69
31	32	67	33	70
32	32	66	33	69
33	32	65	33	69
34	32	65	33	68
35	32	65	33	67

	Hybrid Hive		Traditional Hive	
	Temperature (°C)	Humidity (%)	Temperature (°C)	Humidity (%)
36	33	65	33	66
37	33	65	33	66
38	33	65	33	66
39	33	65	33	66
40	33	64	33	67
41	33	64	33	66
42	34	63	33	66
43	34	63	33	65
44	34	63	33	65
45	34	63	33	65
46	34	63	33	65
47	35	64	33	66
48	34	64	33	65
49	35	64	33	66
50	34	64	33	67

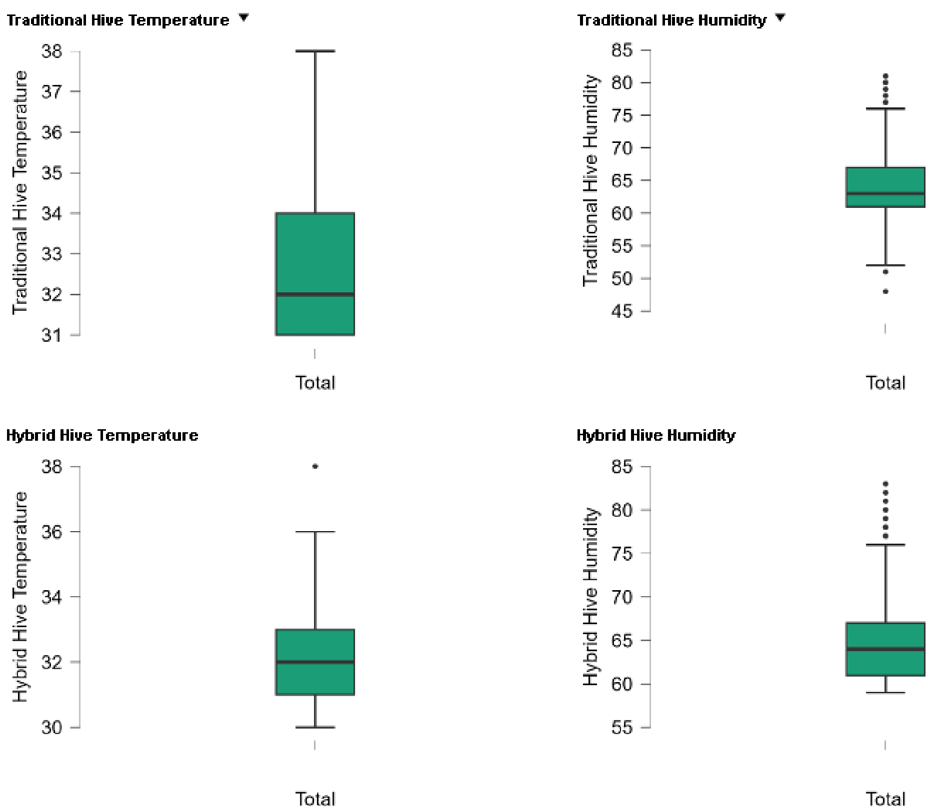


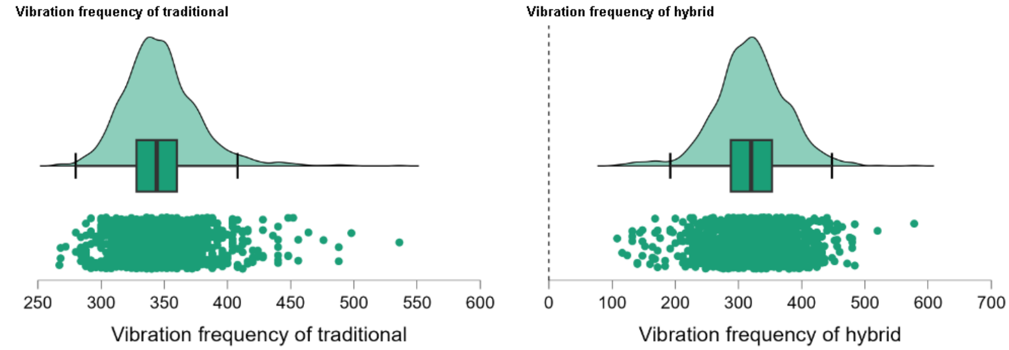
Figure 4.10 Box Plot of Humidity and Temperature of Traditional and Hybrid Hive

Table 4.2 Z-test result for temperature and humidity in traditional and hybrid hives

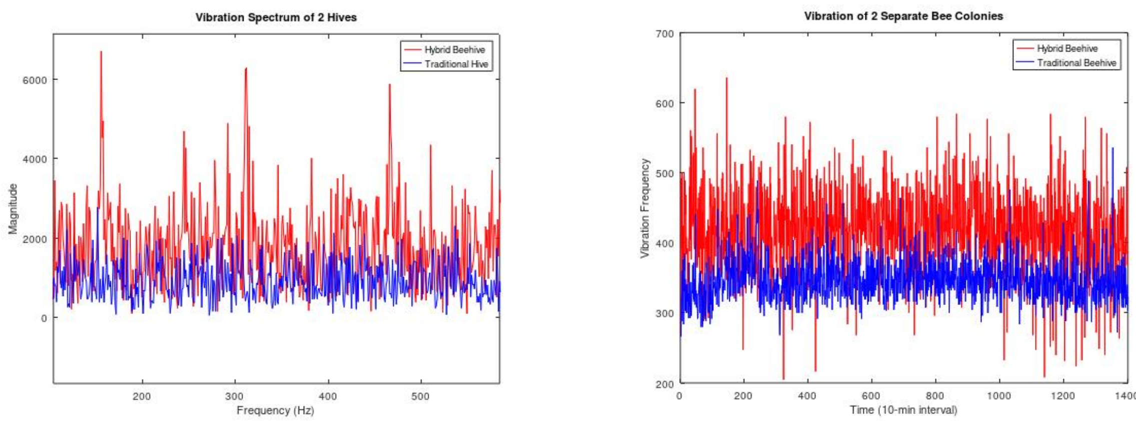
Parameters	No. of Samples	Mean	SD	Z- score	Two-tailed Z-test (df = 98, α = 0.05)	
					Critical Value	p-value
Traditional Hive Temperature	50	33.714	0.6124	-3.2788	1.960	0.0014435
Hybrid Hive Temperature	50	33.265	0.7296			
Traditional Hive Humidity	50	66.306	2.220	2.56	1.960	0.0119818
Hybrid Hive Humidity	50	65.224	2.143			

4.3.2 Vibration

The vibration frequency of the hybrid beehive ranges from 108 Hz to 578 Hz, which is comparable to the traditional hive, which ranges from 267 Hz to 536 Hz. As observed in figure 4.11 (b), by applying a Fast Fourier transform to the vibration data, higher fluctuations can be observed in the hybrid beehive when compared to the traditional hive. The transition of the colony to the hybrid beehive can be interpreted as this. The frequency distribution emitted by bees inside the colony is shown in Figure 4.11 (a). As observed in the graph, the raincloud plot is more concentrated at 300 Hz to 400 Hz in both hives which is the normal vibration frequency of a traditional hive. There are also vibration frequency plots in 100 Hz.



(a)



(b)

Figure 4.11 (a) Vibration Data observed in Raincloud plot **(b)** Analysis of Vibration Frequency using Fast Fourier Transform in Traditional and Hybrid Hives

Table 4.3 Mean and Range of Vibration Data for Traditional and Hybrid Hive Mean and Range of Vibration Data for Traditional and Hybrid Hive

Descriptive Statistics ▼

	Vibration frequency of traditional	Vibration frequency of hybrid
Valid	1400	1400
Mean	346.764	320.126
Minimum	267.000	108.000
Maximum	536.000	578.000

4.3.3 Yield

There are parameters that cannot be controlled by the researchers. The Honey flow season in the deployment area coincides with the deployment date, however the weather from February to May is not optimal for the honey production of the bees. It also affected the transition of the bees from brood box to flow frames, delaying the bees in using the flow frames for the storage of honey. There is progress regarding the transition of bees to the hybrid beehive. The bees are preparing the flow frames for honey storage by using their beeswax in bridging the gaps between the flow frame cells, which completes a honeycomb structure as observed in Figure 4.12.

Figure 4.12 Reconstructing the gaps with beeswax in preparation for honey storage

4.3.4 Projection of Honey Yield and Return of Investment

Table 4.4 Return of Investment of 2 Set-ups

Setup	Initial Investment	Annual Projected Yield (Kg)	Yield Income	Power Consumption Rate (If Applicable)	Electricity Cost Per year	Return of Investment
Hybrid Hive (4 Flow Frames)	23,818 Php	48.9	4890 Php	3.54353 W	355.19 Php	5.21 years
Traditional Hive	15,000 Php	30	3000 Php	-----	-----	5 years

Yield Income: 1 peso of per gram of honey

Annual Projected Yield of Traditional Hive in the Philippines (APY): 30 kg

Power Consumption Rate of the Hybrid Hive: 3.54353 W

kWh cost in the Philippines (2023): 11.4929 Php

Traditional Yield in RRL: 56.1 Kg

Flow Frame Yield in RRL: 96.1 Kg

For Traditional Hive:

$$Return\ of\ Investment\ Period_{Trad} = \frac{Production\ Price}{Yield\ Income}$$

$$Return\ of\ Investment\ Period_{Trad} = \frac{15000}{3000} = \mathbf{5\ years}$$

For Hybrid Hive:

$$Annual\ Prokected\ Yield\ for\ Hybrid\ Beehive$$
$$= \left[1 + \left(\frac{Flow\ Frame\ Yield\ in\ RRL}{Flow\ Frame\ Yield\ in\ RRL + Traditional\ Yield\ in\ RRL}\right)\right] * APY$$

$$Annual\ Prokected\ Yield\ for\ Hybrid\ Beehive = \left[1 + \left(\frac{96.1}{96.1 + 56.1}\right)\right] * 30 = \mathbf{48.9\ kg}$$

$$E(kWh) = P(W) \times \frac{t(hr)}{1000}$$

$$E(kWh) = 3.54353 \times \frac{24}{1000} = 0.085\ kWh$$

$$Cost\left(\frac{peso}{year}\right) = E\left(\frac{kWh}{day}\right) \times Cost\left(\frac{peso}{kWh}\right) * 365\ days$$

$$Cost\left(\frac{peso}{year}\right) = 0.085\ kWh \times 11.4929 * 365\ days = 355.19\ Php$$

$$Return\ of\ Investment\ Period_{Hyb}$$
$$= \left[\left(\frac{Production\ Price}{Yield\ Income}\right) * \left(\frac{Electricity\ Cost\ Per\ Year}{Yield\ Income}\right)\right]$$
$$+ \left(\frac{Production\ Price}{Yield\ Income}\right)$$

$$Return\ of\ Investment\ Period_{Hyb} = \left[\left(\frac{23{,}818}{4890}\right) * \left(\frac{355.19}{4890}\right)\right] + \left(\frac{23{,}818}{4890}\right)$$

$$Return\ of\ Investment\ Period_{Hyb} = [4.87 * 0.07] + 4.87 = \mathbf{5.21\ years}$$

The cost analysis was conducted to ascertain the investment return for both traditional and hybrid hives. The analysis conducted by Ishii et is the foundation for the hybrid system's projected annual production. According to al. (2021), the yield for the conventional hive is 59.1 kg, whereas the yield for the 4-frame flow frame hive is 96.1 kg. The researcher was able to determine the proportion of the flow frame hive's yield compared to that of the traditional hive using the result of flow frame yield over the total of traditional and flow frame yield. She then used this information to project the system's annual yield, using the yield of one hive in a perfect Philippine setup, which was 30 kg, to arrive at 48.9 kg.

The cost of honey produced in the Philippines is one peso per gram at retail. The hybrid hive requires a down payment of 23,818 pesos, compared to 15,000 pesos for the standard hive. In five years, the typical hive will get its money back. Electricity usage was considered while calculating the hybrid hive's investment return as one of the factors required to sustain the hive. In 5.21 years, the hybrid beehive's investment will be recovered. The higher predicted production of the hybrid beehive will assist it to compete with the regular hive even though it takes a longer time to recoup its investment.

Chapter 5

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary of findings, conclusions, and recommendations relative to the results conducted during the duration of this research.

5.1 Summary of Findings

The researchers were able to design an automation system for the flow frames, create an air ventilation system for temperature regulation, and incorporate the Internet of Things application into the system. The temperature and humidity of the hybrid and traditional hives have no significant difference; however, due to the improved ventilation system of the hybrid beehive, it took less time to regulate the temperature when compared to the traditional hive. The behavior of the bees was assessed in both traditional and hybrid beehives. There's no significant difference in the data when observed; however, when applying the fast Fourier transform to the vibration readings, the hybrid beehive has a higher magnitude when compared to the traditional beehive due to the behavior of the bees during the transition period from brood box to hybrid hive. There are parameters that the researchers cannot control during the deployment such as the frequent raining from February to May, which is supposed to be the honey flow season in San Salvador, Lipa City, Batangas; and the transition of the bees from brood box to flow frames. The flow frames were observed to be prepared by the bees due to the beeswax that they bridged in each cell, which resembles their honeycomb structure.

5.2 Conclusions

Based on the results and findings of the research, the following conclusions were inferred:

1. The researchers have successfully developed an automated system for the harvesting of the flow frames using electro-pneumatic system, improve the air ventilation of the hive using 120mm intake fans that activates when the hive reaches 38 degrees Celsius, and a beehive activity and environmental monitoring system using MPU6050 accelerometer and DHT11 temperature and humidity sensor.
2. The researchers were able to analyze and compare the behavior of bees in the hybrid hive and the traditional hive. Although there are no differences observed in descriptive statistics, the vibration spectrum of the data revealed that the hybrid beehive has a higher amplitude when compared to the traditional hive, which signifies their behavior towards transitioning from brood box to flow frame hive throughout the deployment phase.
3. The researchers were able to create the system to become IoT-based with mobile application by using NodeMCU ESP8266, which caters the connection of the system to the Blynk IoT App. The Blynk IoT app can visualize the data that the ESP8266 sends to the cloud and can also notify the beekeeper when the hive reaches critical temperature.
4. The hybrid and traditional beehives have no significant differences observed when it comes to environmental parameters. The behavior of bees inside the hybrid beehive was observable to be more active compared to traditional hive when observed in vibration spectrum due to the transition of the bees from traditional hive to flow

frame hives. Using the standard techniques of beekeeping, the researchers were able to develop a more intricate monitoring system for the beekeepers to observe the hive. There are factors that cannot be controlled by the researchers, such as the bees' transition, forage, and weather conditions in the area; however, beeswax is observed that bridged the gaps between the flow frame cells which indicates the transition of the bees to flow frames.

5.3 Recommendation

The following recommendations are made by the researchers, partner beekeeper, and the UPLB bee program based on their analysis of data and their review towards system:

1. Create multiple hybrid hive systems and deploy it in multiple sites in the Philippines to make the study more noble and prove the efficiency of the flow frame system in the country.
2. To ensure a smooth transition for the bees, it is important to deploy the system in an area with abundant forage and a consistent honey flow season. The climate of the deployment area should be optimal for the bees to produce honey.
3. Create a separate system for monitoring and harvesting, as it is convenient to use in monitoring the hive environmental parameters and behavior.
4. Create the system more compact and detachable as it took ⅓ of the whole hybrid hive.

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ANNEX I

HYBEE
BILL OF MATERIALS

Annex I Bill of Materials

BILL OF MATERIALS

	Electro Pneumatic System				
	MATERIALS	**QTY.**	**UoM**	**AMOUNT**	**TOTAL**
1	Electric Solenoid Valve 3/2-way Pneumatic Air Control	2	pc/s	347	694
2	Portable Air Compressor Pump	1	pc/s	307	307
3	PK 8mm Pneumatic Fitting Ppe Connector Tube	2	pc/s	32	64
4	PC 8mm Pneumatic Fitting Ppe Connector Tube	4	pc/s	21	84
5	PY 8mm Pneumatic Fitting Ppe Connector Tube	1	pc/s	22	22
6	1/8 mm Exhaust Fitting Pipe Connector Tube	2	pc/s	20	40
7	1/8 PLF mm Fitting Pipe Connector Tube	8	pc/s	31	248
8	Pneumatic Pipe Tube Hose 8mm	6	pc/s	41	246
9	Acoustic Foam	12	pcs	27.75	333
				TOTAL	**2 038**

	Electronic System				
	MATERIALS	**QTY.**	**UoM**	**AMOUNT**	**TOTAL**
1	Arduino AT mega 2560	1	pc/s	749	749
2	ESP8266 Wi-Fi Module	1	pc/s	235	235
3	Switch Power Supply Driver Adapter	1	pc/s	500	500
4	Relay Module 4-Channel	1	pc/s	187	187
5	DHT11 Temperature and Humidity Sensor	1	pc/s	89	89
6	HC-SR04 Ultrasonic Sensor	1	pc/s	67	67
7	MPU 6050 Accelerometer Module	1	pc/s	84	84
8	Load Cell Sensors and Drivers	4	pc/s	200	800
9	DC-DC Converter 5V 5A	1	pc/s	105	105

Electronic System					
	MATERIALS	**QTY.**	**UoM**	**AMOUNT**	**TOTAL**
10	80mm fans	2	pc/s	65	130
11	120mm fans	2	pc/s	75	150
12	Wi-Fi Router	1	pc/s	1 500	1 500
13	Small Breadboard	1	pc/s	49	49
14	Jumper Cable/Wires	3	set/s	50	150
15	Car Charger adaptor	1	pc/s	25	25
16	Extension Socket	1	set/s	54	54
17	Royal Cord	10	meter	50	500
18	Plug	1	pc	15	15
19	Speaker wire	6	meter	25	150
20	BLYNK IoT subscription	12	month	340	4080
				TOTAL	**9 619**

HYBEE Box					
	MATERIALS	**QTY.**	**UoM**	**AMOUNT**	**TOTAL**
1	Flow Frames	1	set/s	4 000	4 000
2	Butyl Rubber Tubes	8	pc/s	95	760
3	Acrylic Pipes	2	pc/s	127	254
4	Acrylic sheet	1	pc/s	150	150
5	Acrylic box (customized)	1	pc/s	1 500	1 500
6	PVC Connectors	5	pc/s	30	150
7	Food-Grade Sealant	1	pc/s	538	538
8	Plastic Faucet	1	pc/s	100	100
9	¾” Plywood	1	pc/s	1 300	1 300
10	Wood glue, screws, and small hinges	1	set/s	250	250
11	Waterproof Cloth	1	yard	45	45
12	Velcro	3	yard	27	81
13	Nylon mesh (1.5mx1m)	1	pc/s	33	33

HYBEE Box					
	MATERIALS	**QTY.**	**UoM**	**AMOUNT**	**TOTAL**
13	Waterproof Tape seam	4	pc/s	16	64
14	Spiral Cable Organizer	2	pc/s	27	54
				TOTAL	**9 161**
OVERALL TOTAL					**20 818**

ANNEX II

HYBEE
PROGRAM CODES

Annex II Program Codes

HYBEE ARDUINO CODE

```
#define ARDUINOJSON_ENABLE_COMMENTS 1
//Arduino to NodeMCU Lib
#include <SoftwareSerial.h>
#include <ArduinoJson.h>
//dht11
#include <DHT.h>
//HCSR04
#include <EasyUltrasonic.h>
#define TRIGPIN 5 // Digital pin connected to the trig pin of the ultrasonic sensor
#define ECHOPIN 6 // Digital pin connected to the echo pin of the ultrasonic sensor
EasyUltrasonic ultrasonic;

//Initialise Arduino to NodeMCU (10=Rx & 11=Tx)
SoftwareSerial nodemcu(10, 11);

//MPU6050
#include<Wire.h>

const int MPU_addr=0x68;
int16_t AcX,AcY,AcZ,Tmp,GyX,GyY,GyZ;
int minVal=265;
int maxVal=402;
```

```
double X; double Y; double Z;


//Initialisation of DHT11 Sensor

#define DHTPIN 3

DHT dht(DHTPIN, DHT11);

#include "HX711.h"

//RELAY1------------//52//50//48//46

int FAN1 =52 ;


//RELAY2

int POWCOM = 50;

//RELAY3

int COMP = 48;

//RELAY4

int TEMPFAN = 46;

//RELAY7

int BAG1 = 49;

//RELAY8

int BAG2 = 47;


int i = 0;

int j = 0;

int l = 0;
```

```
const int pinData1 = 22;
const int pinData2 = 23;
const int pinData3 = 24;
const int pinData4 = 25;
const int pinClk = 26;

HX711 scale1;
HX711 scale2;
HX711 scale3;
HX711 scale4;

float calibration_factor = 137326;
double temp =0; double hum =0; double col =0;
double viby =0; double m1 =0; double m2 =0;
double m3 =0; double m4 =0;
//--timer--
unsigned long previousMillis = 0;
unsigned long interval = 5000;

void setup() {
  Serial.begin(115200);
```

```
dht.begin();
ultrasonic.attach(TRIGPIN, ECHOPIN);
Wire.begin();
Wire.beginTransmission(MPU_addr);
Wire.write(0x6B);
Wire.write(0);
Wire.endTransmission(true);

scale1.begin(pinData1, pinClk);
scale1.set_scale();
scale1.tare();  //Reset the scale to 0
long zero_factor1 = scale1.read_average();

scale2.begin(pinData2, pinClk);
scale2.set_scale();
scale2.tare();  //Reset the scale to 0
long zero_factor2 = scale2.read_average();

scale3.begin(pinData3, pinClk);
scale3.set_scale();
scale3.tare();  //Reset the scale to 0
long zero_factor3 = scale3.read_average();
```

```
  scale4.begin(pinData4, pinClk);
  scale4.set_scale();
  scale4.tare();  //Reset the scale to 0
  long zero_factor4 = scale4.read_average();

  nodemcu.begin(9600);
  delay(2000);

  pinMode(BAG1, OUTPUT);
  pinMode(BAG2, OUTPUT);
  pinMode(FAN1, OUTPUT);
  pinMode(TEMPFAN, OUTPUT);
  pinMode(COMP, OUTPUT);
  pinMode(POWCOM, OUTPUT);
  Serial.println("Program started");
}
void loop() {
 unsigned long currentMillis = millis();
 if (currentMillis - previousMillis >= interval) {
    previousMillis = currentMillis;

  StaticJsonDocument<400> doc;
```

```
//Obtain Temp and Hum data
hum = dht.readHumidity();
temp = dht.readTemperature();
Serial.print("Humidity: ");
Serial.println(hum);
Serial.print("Temperature: ");
Serial.println(temp);

//relay for airconditioning
if (temp < 38.5) {
  digitalWrite(TEMPFAN, HIGH);
}
if (temp > 38.5){
  digitalWrite(TEMPFAN,LOW);
}

//honeyqty
float sonred = ultrasonic.getPreciseDistanceCM(temp, hum);
float tank = 12;
float gap = tank - 2;
float TEMP1 = sonred - 2;
float ACTLVL= gap - TEMP1;
float col = ACTLVL / gap * 8.5;
```

```
Serial.print("Collection: ");
Serial.println(sonred);
Serial.println(TEMP1);
Serial.println(ACTLVL);
Serial.println(col);

//Vibration
Wire.beginTransmission(MPU_addr);
Wire.write(0x3B);
Wire.endTransmission(false);
Wire.requestFrom(MPU_addr,14,true);
float Acx=Wire.read()<<8|Wire.read();
float Acyy=Wire.read()<<8|Wire.read();
AcX = Acx ;
float Acy = Acyy ;
float AcZ=Wire.read()<<8|Wire.read();
int xAng = map(AcX,minVal,maxVal,-90,90);
int yAng = map(AcY,minVal,maxVal,-90,90);
int zAng = map(AcZ,minVal,maxVal,-90,90);
viby= RAD_TO_DEG * (atan2(-xAng, -zAng)+PI);
Serial.print("AngleY= ");
Serial.println(viby);
Serial.print("RawY= ");
```

```
Serial.println(AcY);
Serial.print("RawX= ");
Serial.println(Acy);
Serial.print("RawZ= ");
Serial.println(AcZ);

//Frames--------------------
scale1.set_scale(calibration_factor);
float m1 = (scale1.get_units());
Serial.print("M1: ");
Serial.println(m1);
scale2.set_scale(calibration_factor);
float m2 = (scale2.get_units());
Serial.print("M2: ");
Serial.println(m2);
scale3.set_scale(calibration_factor);
float m3 = (scale3.get_units());
Serial.print("M3: ");
Serial.println(m3);
scale4.set_scale(calibration_factor);
float m4 = (scale4.get_units());
Serial.print("M4: ");
Serial.println(m4);
```

```
//relay for weight
float weight = m1 + m2 + m3 + m4;

if (weight < 1.01){
digitalWrite(BAG1, HIGH);
digitalWrite(BAG2, HIGH);
digitalWrite(POWCOM, HIGH);
digitalWrite(COMP, HIGH);
i = 0;

if (weight < 1.01 && j == 1){
  j = 0;
  digitalWrite(POWCOM, LOW);
  delay(500);
  digitalWrite(BAG2, LOW);
  delay(1000);
  digitalWrite(COMP, LOW);
  delay(5000);
  digitalWrite(BAG2, HIGH);
  delay(1000);
  digitalWrite(COMP, HIGH);
  delay(500);
  digitalWrite(POWCOM, HIGH);
```

```
  delay(500);
 }
}
if (weight > 20){
 i = i + 1;

 if ((weight > 20) && i == 1){ //opening
  digitalWrite(POWCOM, LOW); delay(500);
  digitalWrite(BAG1, LOW);        delay(1000);
  digitalWrite(COMP, LOW);        delay(5000);
  digitalWrite(BAG1, HIGH);        delay(1000);
  digitalWrite(COMP, HIGH);        delay(500);
  digitalWrite(POWCOM, HIGH); delay(500);
  j = j+1;
 }
}

 //Assign collected data to JSON Object
 doc["humidity"] = hum;
 doc["temperature"] = temp;
 doc["Collection"] = col;
 doc["y"] = AcY;
 doc["f1"] = m1;
```

```
  doc["f2"] = m2;
  doc["f3"] = m3;
  doc["f4"] = m4;
  doc["x"] = Acy;
  doc["z"] = AcZ;
  //Send data to NodeMCU
  nodemcu.print(serializeJson(doc, nodemcu));
 }
}
```

HYBEE ESP8266 to BLYNK Code

```
#define BLYNK_PRINT Serial
#include <ESP8266WiFi.h>
/* Fill-in your Template ID (only if using Blynk.Cloud) */
#define BLYNK_TEMPLATE_ID   "TMPLxXF12mgf"
#define ARDUINOJSON_ENABLE_COMMENTS 1
#include <SoftwareSerial.h>
// ArduinoJson - Version: 5.13.5
#include <ArduinoJson.h>
#include <ArduinoJson.hpp>
SoftwareSerial nodemcu(D6, D5);
#include "BlynkSimpleEsp8266.h"
```

```
// You should get Auth Token in the Blynk App.
// Go to the Project Settings (nut icon).
char auth[] = "k3XzPLnyPBiAe75nJ80zJN_zeKwEFtbz";


// Your WiFi credentials.
// Set password to "" for open networks.
char ssid[] = "TUP-Hybrid Beehive";
char pass[] = "Hyb33_TUP";


float h;  float t;  float temp;  float hum;  float m1;
float m2;  float m3;
float m4;  float AcX;  float Acy;  float AcZ;  float col;
BlynkTimer timer;
void setup()
{
  // Debug console
  Serial.begin(9600);
  nodemcu.begin(9600);
  while (!Serial) continue;
  Blynk.begin(auth, ssid, pass);
  timer.setInterval(5000L, sendSensor);


}
void sendSensor(){
```

```
    Blynk.virtualWrite(V2, hum);
    Blynk.virtualWrite(V1, temp);
    Blynk.virtualWrite(V3, col);
    Blynk.virtualWrite(V8, AcX);
    Blynk.virtualWrite(V4, m1);
    Blynk.virtualWrite(V5, m2);
    Blynk.virtualWrite(V6, m3);
    Blynk.virtualWrite(V7, m4);
    Blynk.virtualWrite(V11, Acy);
    Blynk.virtualWrite(V12, AcZ);
    if(temp > 38)
    {
      Blynk.logEvent("temp_alert","The colony reached
                                 critical temperature");
    }
    if(col > 5)
    {
      Blynk.logEvent("col_full","The honey container is full.");
    }
}
void loop()
{
  Blynk.run();
  timer.run();
```

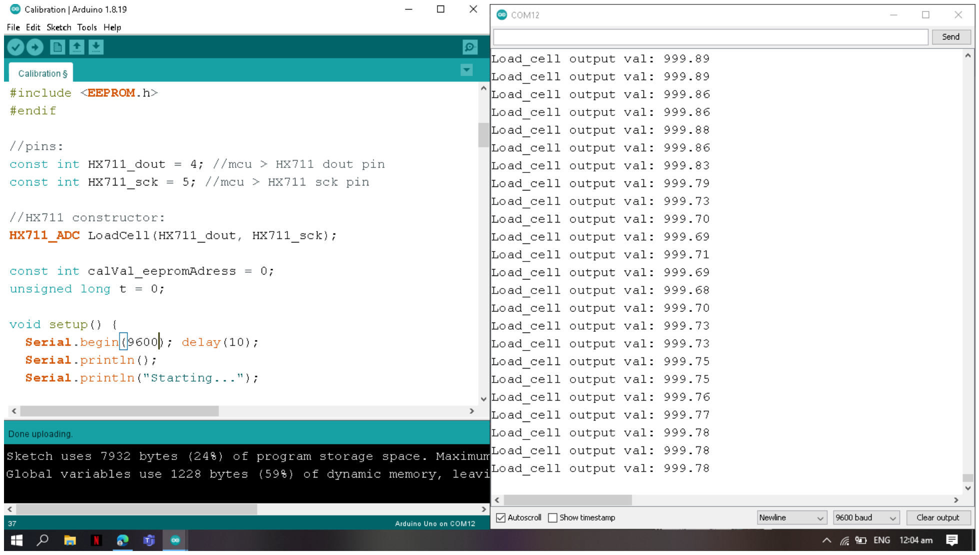
```
if (nodemcu.available() > 0)
{
  Serial.setTimeout(5000);
  StaticJsonDocument<400> doc;
  DeserializationError error = deserializeJson(doc,
                    nodemcu.readString());
    if (error) {
      Serial.print(F("deserializeJson() failed: "));
      Serial.println(error.f_str());
      return;
    }
  hum = doc["humidity"];
  temp = doc["temperature"];
  col = doc["Collection"];
  AcY = doc["y"];
  m1 = doc["f1"];
  m2 = doc["f2"];
  m3 = doc["f3"];
  m4 = doc["f4"];
  AcX = doc["x"];
  AcZ = doc["z"];
  Serial.println(hum);
  Serial.println(temp);
  Serial.println(col);
```

```
    Serial.println(AcY);

    Serial.println(m1);

    Serial.println(m2);

    Serial.println(m3);

    Serial.println(m4);

    Serial.println(Acy);

    Serial.println(AcZ);  }

}
```

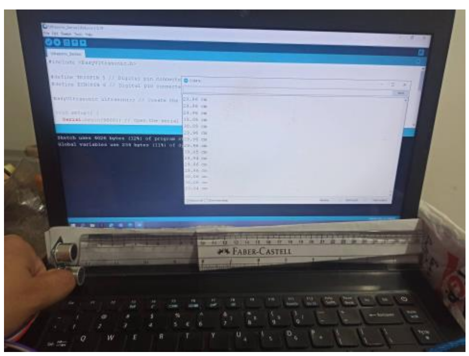
ANNEX III

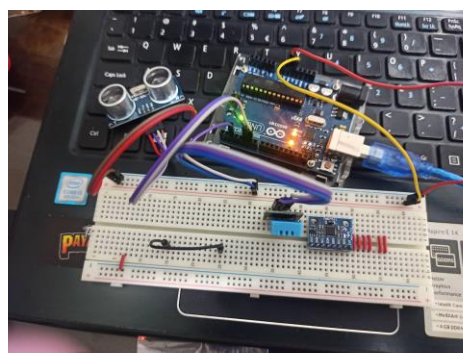
PROGRESS DOCUMENTATION

Load Sensor Calibration and Testing

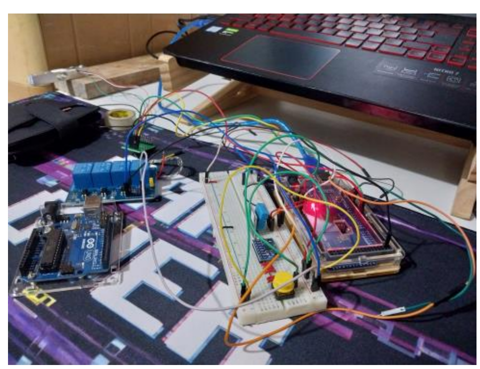


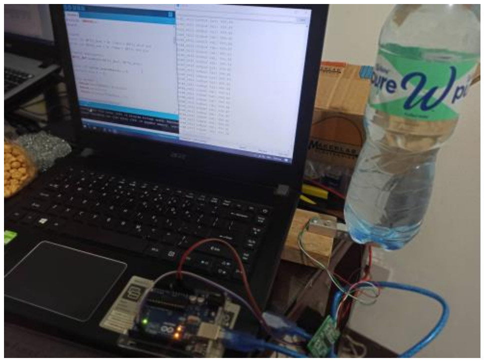
Testing of Arduino and Ultrasonic Sensor HC-SR04 Calibration

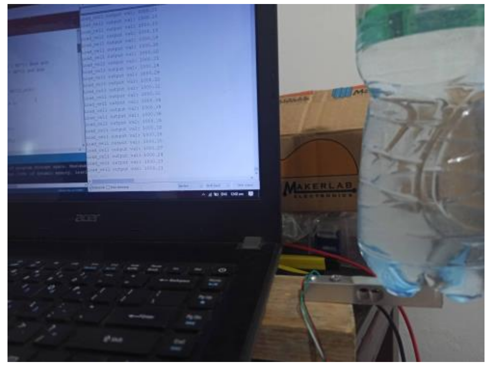




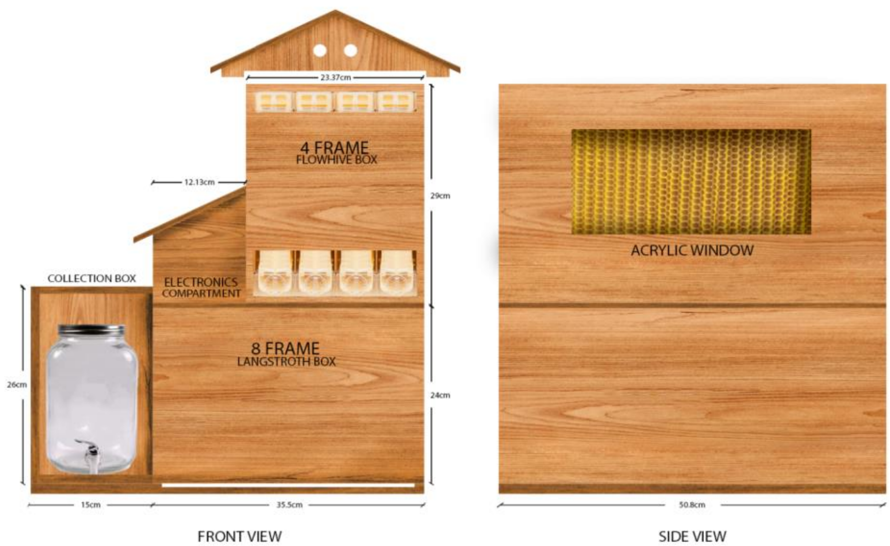
Programming and Testing of Temperature, Humidity, Vibration and Weight Sensors.







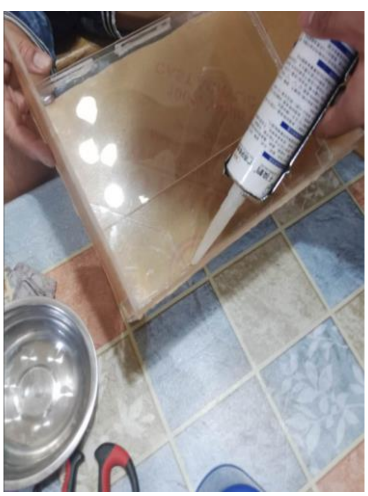
Design and Placement for the Flow Hive, Langstroth, Electronic Component, and Collection Box.

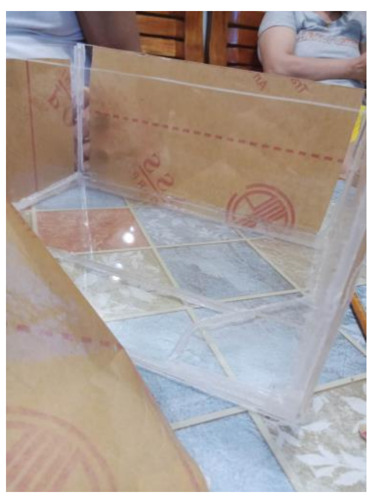


Actual 4-Frame Flow Hive and 8-Frame Langstroth Box.

Cutting of Acrylic Sheet to Create the Acrylic Container (Storage Box)

Acrylic Container Assembly for Honey Collection using Food Grade Sealant

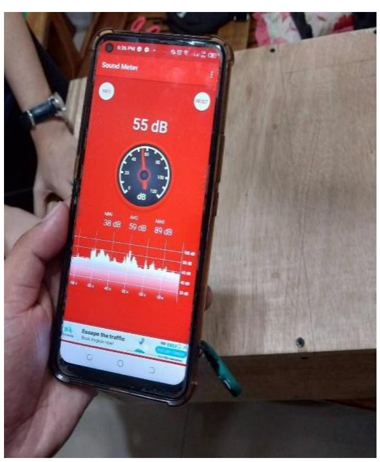


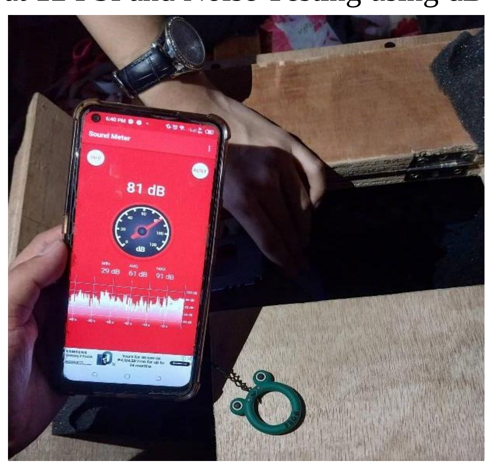


Air Compressor Box Assembly using Acoustic Foam for Soundproofing to Avoid Disturbance for the Bees.

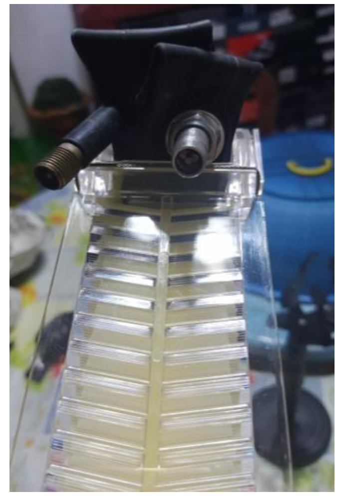


Air Compressor Testing at 12 PSI and Noise Testing using dB Meter.

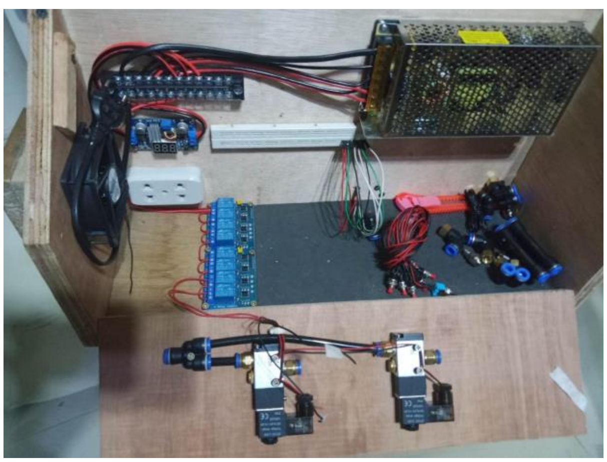


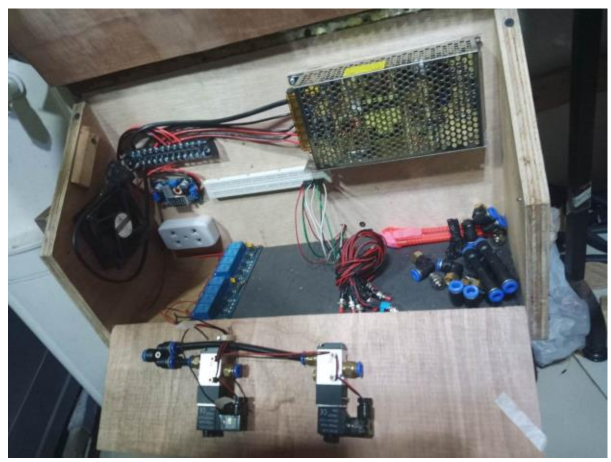


Customized Butyl Rubber Installation for the Automated Harvesting System of the Flow frame using Pneumatic System.

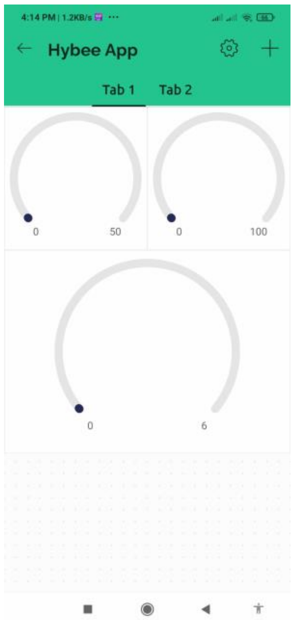


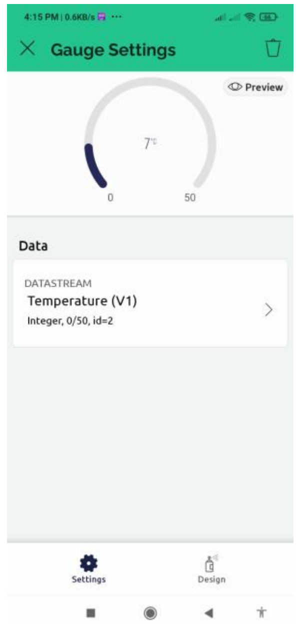
Finalization of Component Placements for the Electronic Compartment Box.

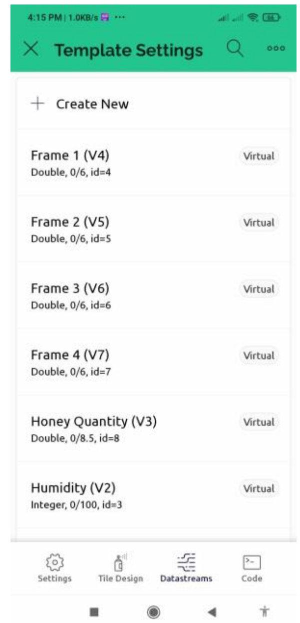


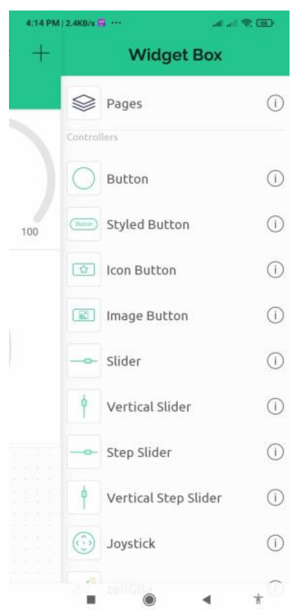


Creating the User Interface of Mobile Application using Blynk IoT



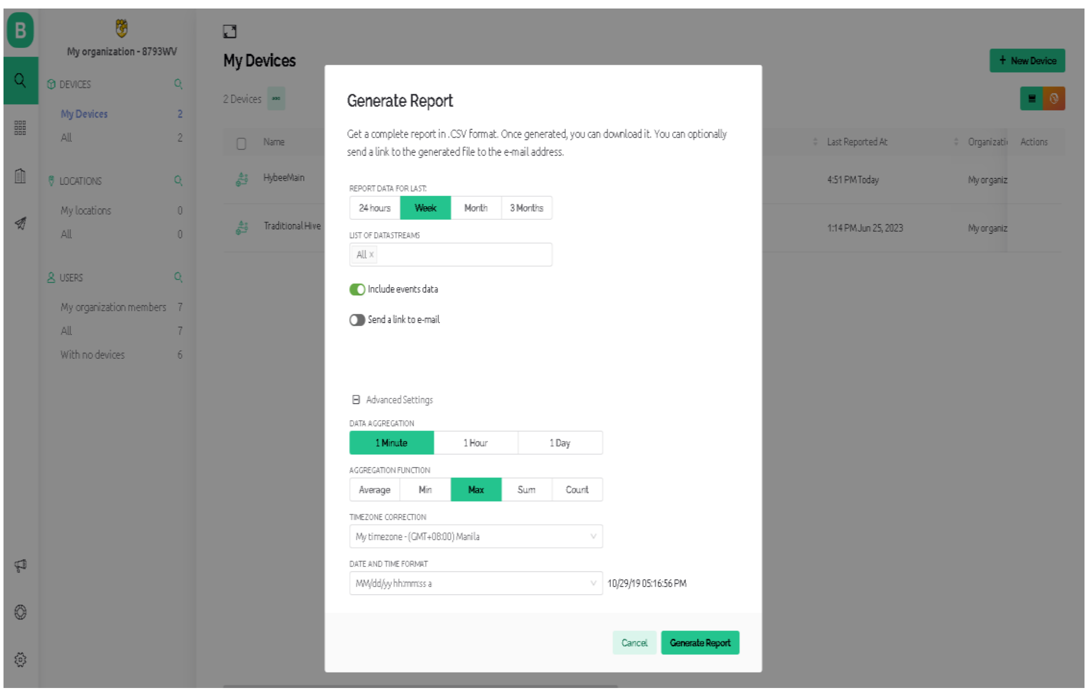




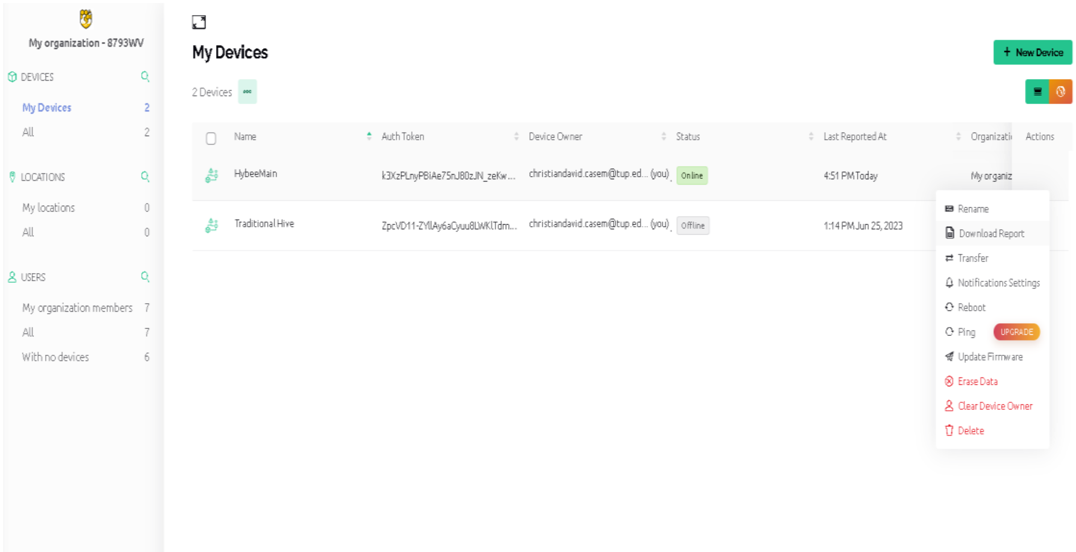


Final Testing and Functional Prototype of the Hybrid Beehive

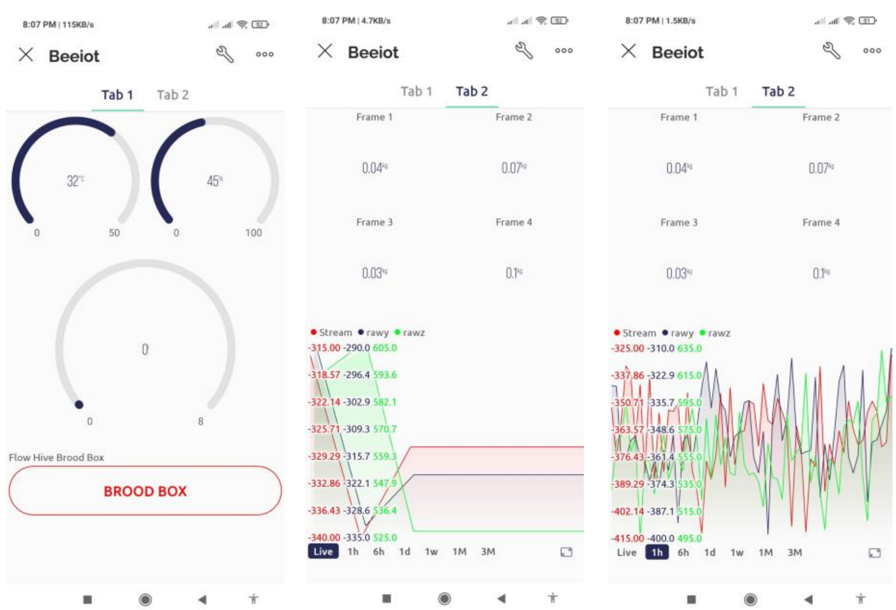
Weekly Data Gathering Setup in Blynk IoT



“My Devices” Setup of Blynk IoT



Final User Interface Design of the Blynk IoT App and Initial Data Gathering.



ANNEX IV

PROPONENTS INFORMATION

Annex IV Proponents Information

CHRISTIAN DAVID CASEM

B S   E L E C T R O N I C S   E N G I N E E R I N G

Address: Bacoor City, Cavite | +63 939-346-4156 | christiancasem005@gmail.com

CAREER OBJECTIVE

A competent member with knowledge in programming and data analytics, has strong work ethic and motivation to finish tasks efficiently, and has the ability to thrive under pressure.

TECHNICAL SKILLS

- CAD Tool (AutoCAD, Sketchup)
- Statistics Tool (JASP, Excel)
- R programming
- Python Programming
- App Development(Android Studio, Flutter)
- HTML 5
- CSS 3
- Unity Engine
- Video Editing

SOFT SKILLS

- Work Management
- Excellent Communcation Skill
- Adaptability
- Time Control
- Team Player

CHARACTER REFERENCE

Engr. Villamor M. Amon
ECE Faculty, thesis adviser
TUP - Manila
villamoramon@gmail.com
+63 961-288-5115

WORK EXPERIENCE

DAI-ICHI ELECTRONICS MANUFACTURING CORP.
Cadet Engineer **Aug-Oct 2022**

- Documentation of Manufacturing Process in Cone and Damper Department
- Supervised Designing of Speaker Circuit Boards using AutoCAD

CREOTEC PHILIPPINES INC.
K-12 Work Immersion Intern **2017**

- Circuit Soldering
- Circuit Connectivity Testing
- Circuit Assembly

EDUCATION HISTORY

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
BS Electronics Engineering **2018-2023**

Campus Organizations

- Former Technical Committee and Emcee, Institute of Electrical and Electronics Engineers (IEEE) TUP Manila Student Branch | 2020-2021
- Member, Organization of Electronics Engineering Students (OECES) TUP Manila

UNIVERSITY OF PERPETUAL HELP - MOLINO
Senior High School **2016 - 2018**

- Science, Technology, Engineering and Mathematics track (STEM)- Graduated with Honor

CERTIFICATION & TRAININGS

Master IP Addressing and Subnetting for CCNA (2022)

- Mnet IT Solutions
- Fundamentals of IP Addressing

Cisco Routing Basic (2022)

- MNET IT Solutions
- General Router Configuration in Cisco Packet Tracer
- Static Routing

I certify that the written information is true and correct.

Christian David C. Casem
Applicant

KENT NICKLAUS BANTINAN

BS ELECTRONICS ENGINEERING

Address: Bacoor, Cavite

+63 966-1767-499

kenbantinan@gmail.com

CAREER OBJECTIVE

A responsible, hardworking, and willing to learn graduate of BS Electronics Engineering from Technological University of the Philippines - Manila. Looking for an opportunity to practice and develop new skills.

TECHNICAL SKILLS

- Basic Layout (Cadence Virtuoso)
- Soldering and breadboard making
- NI Multisim, MATLAB
- Basic C++ Programming
- Computer technical expertise, building and maintenance
- Reading instruments
- MS Office (Word and Powerpoint)

SOFT SKILLS

- Time management
- Proactivity
- Interpersonal skills
- Work ethic
- Flexibility

CHARACTER REFERENCE

Engr. Villamor M. Amon
ECE Faculty, thesis adviser
TUP - Manila
villamoramon@gmail.com
+63 961-288-5115

WORK EXPERIENCE

DAI-ICHI ELECTRONICS MANUFACTURING CORP.
Cadet Engineer **Aug-Oct 2022**

- Quality Testing/Assurance of woofers, subwoofers, and different parts of a speaker
- Power/Life Testing of woofers, subwoofers, and tweeters
- Technical works like soldering, assembly and disassembly, documentation, and machine operated stations

EDUCATION HISTORY

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
BS Electronics Engineering **2018-2023**

Campus Organizations

- Member, Organization of Electronics Engineering Students (OECES) TUP Manila

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
Senior High School **2016 - 2018**

- Science, Technology, Engineering and Mathematics track (STEM) - Information Technology Specialization

CERTIFICATION & TRAININGS

- Cisco Routing Basics (6-hour free online course on MNET-IT)
- Master IP Addressing and Subnetting for CCNA (15-hour free online course on MNET-IT)
- Spreadsheet Fundamentals(DataCamp Online) - Data Analysis in Spreadsheets

I certify that the written information is true and correct.

Kent Nicklaus R. Bantinan
Applicant

JOHN MARCO BUENAVISTA

BS ELECTRONICS ENGINEERING

Address: Floridablanca, Pampanga | +63 999-874-8440 | jmarcobuenavista@gmail.com

CAREER OBJECTIVE

An electronics engineering student who is highly motivated and aspiring network engineer with a passion for designing, implementing, and maintaining robust network infrastructures.

TECHNICAL SKILLS

- IC Designing (Cadence Virtuoso)
- Basic Knowledge in Cisco Packet Tracer
- Basic Knowledge in GNS3
- NI Multisim & MATLAB
- Computer Literate (Software and Hardware)
- Proficient in Microsoft Office (Word and Power Point)

SOFT SKILLS

- Time management
- Decision-Making
- Teamwork
- Work ethics
- Adaptability & Flexibility

CHARACTER REFERENCE

Engr. Villamor M. Amon
ECE Faculty, thesis adviser
TUP - Manila
villamoramon@gmail.com
+63 961-288-5115

WORK EXPERIENCE

DAI-ICHI ELECTRONICS MANUFACTURING CORP.
Cadet Engineer **Aug-Oct 2022**

- Quality Testing/Assurance on Line Source Production. Tweeter Bridge assembly and Testing.
- Technical works such as soldering, wiring management, and repairing.

EDUCATION HISTORY

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
BS Electronics Engineering **2018-2023**

Campus Organizations

- Member, Organization of Electronics Engineering Students (OECES) TUP Manila

L A CONSOLACION COLLEGE - MANILA
Senior High School **2016 - 2018**

- Science, Technology, Engineering and Mathematics track (STEM)- Graduated with Honor

CERTIFICATION & TRAININGS

Master IP Addressing and Subnetting for CCNA

- Mnet IT Solutions (Online) Completed on May 2022: Credential ID 632404752583223112168

MNET Cisco Routing Basics (Online Course)

- 6-Hours of Cisco Routing Basics Completed on May 2022

Unleashing the Power of Data (Webinar & Workshop)

- SAP Analytics Cloud Workshop (Online) Completed on April 13, 2023

I certify that the written information is true and correct.

John Marco P. Buenavista
Applicant

LUCIA MERTELLA MARALIT

B S ELECTRONICS ENGINEERING

Address: Las Piñas City

+63 956-584-9708

luciamertellam@gmail.com

CAREER OBJECTIVE

An engineering student with strong problem-solving skills and a dedication to continuous learning, seeking an opportunity to apply technical knowledge and contribute to innovative projects.

TECHNICAL SKILLS

- Knowledgeable in programming languages such as HTML, Python, C++, and MATLAB
- Proficient in using simulation software such as NI Multisim, TinkerCAD and Proteus
- Proficient in Microsoft Office
- Basic knowledge in Adobe Photoshop

SOFT SKILLS

- Adaptability
- Problem-solving
- Attention to detail
- Teamwork
- Self-Awareness

CHARACTER REFERENCE

Engr. Villamor M. Amon
ECE Faculty, thesis adviser
TUP - Manila
villamoramon@gmail.com
+63 961-288-5115

Engr. Romnick U. Cartusiano, ECT
Engineer II
Las Piñas, Office of the City Engineer
cartusiano.romnick@gmail.com
+63 956 8553 875

WORK EXPERIENCE

DAI-ICHI ELECTRONICS MANUFACTURING CORP.
Cadet Engineer **Aug-Oct 2022**

- Quality assurance report of speaker units and documentation
- Technical works such as soldering, Clio SPL (Sound Pressure Level) testing, DCR, and Speaker Assembly

EDUCATION HISTORY

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
BS Electronics Engineering **2018-2023**
Campus Organizations

- Former Technical Committee, Institute of Electrical and Electronics Engineers (IEEE) TUP Manila Student Branch | 2020-2021
- Member, Organization of Electronics Engineering Students (OECES) TUP Manila

STI ACADEMIC CENTER - LAS PIÑAS
Senior High School **2016 - 2018**

- Science, Technology, Engineering and Mathematics track (STEM)

CERTIFICATION & TRAININGS

Master IP Addressing and Subnetting for CCNA

- Mnet IT Solutions (Online) Completed on May 2022: Credential ID 6320672525832231121 68

Data Science Foundations

- Great Learning (Online) Completed on March 2023

Data Literacy Fundamentals

- DataCamp (Online) Completed on April 14, 2022:
  - Data Science for Everyone (April 04, 2022)
  - Machine Learning for Everyone (April 07, 2022
  - Data Visualization for Everyone (April 12, 2022)
  - Data Engineering for Everyone (April 14, 2022)
  - Cloud Computing for Everyone (April 14, 2022)

Spreadsheet Fundamentals Track

- DataCamp (Online):
  - Data Analysis Spreadsheet completed on April 18, 2022
  - Intermediate Spreadsheet completed on July 18, 202

I certify that the written information is true and correct.

Lucia Mertella I. Maralit
Applicant

MARVIN BRAZAL

BS ELECTRONICS ENGINEERING

Address: Quezon City
+63 907-169-3229
brazal.marvin14@gmail.com

PROFILE INFO

A competent team player and leader who pursues results without bias. I'm always eager to take on new challenges and motivated to make things done.

TECHNICAL SKILLS

- Eda tool IC Designing (Cadence Virtuoso)
- PCB and breadboard making
- NI Multisim, Proteus, MATLAB
- Programming C++
- Computer technical expertise, building and maintenance
- Graphic Designing-Photoshop
- Sony Vegas Video Editing

SOFT SKILLS

- Time management
- Proactivity
- Interpersonal skills
- Work ethic
- Flexibility

CHARACTER REFERENCE

Engr. Villamor M. Amon
ECE Faculty, thesis adviser
TUP - Manila
villamoramon@gmail.com
+63 961-288-5115

Kaiser Andrei Gurne
Project Engineer
Trends & Technologies Inc.
kaisergurne@gmail.com
+63 968-544-2086

WORK EXPERIENCE

DAI-ICHI ELECTRONICS MANUFACTURING CORP.
Cadet Engineer **Aug-Oct 2022**
- Quality Testing/Assurance of crossover circuit boards, ribbon tweeters, and woofer speakers.
- Technical works such as soldering, PCB assembly, machine operated stations, and documentation.

QUEZON CITY HALL- ENGINEERING DEPARTMENT
K-12 Work Immersion Intern **Sept 2017**
- Rendered 80hrs of On-the-job Training | STEM track
- Observation of City building planning, sorting and printing of blueprints, and encoding of data.

EDUCATION HISTORY

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES
BS Electronics Engineering **2018-2023**

Campus Organizations
- Former Vice Chairperson for Operations, Institute of Electrical and Electronics Engineers (IEEE) TUP Manila Student Branch | 2020-2021
- Member, Organization of Electronics Engineering Students (OECES) TUP Manila

LAGRO HIGH SCHOOL
Senior High School **2016 - 2018**
- Science, Technology, Engineering and Mathematics track (STEM)- Graduated with Honor

CERTIFICATION & TRAININGS

Master IP Addressing and Subnetting for CCNA
- Mnet IT Solutions (Online) Completed on May 2022: Credential ID 631913552583223112168

Data Literacy & Spreadsheet Fundamentals
- DATA CAMP (Online) Completed on July 17, 2022

I certify that the written information is true and correct.

Marvin S. Brazal
Applicant

ANNEX V

HYBEE

USER'S MANUAL

Annex V User's Manual

HYBEE USER'S MANUAL

HYBEE User's Manual, a comprehensive guide to the innovative world of beekeeping management. This manual aims to guide you to the features, and benefits of hybrid beehive boxes, empowering you to revolutionize your beekeeping practices.

Section 1: Setup

1. Connect the Power Plug
    - Locate the power plug of the beehive box.
    - Insert the power plug into a compatible socket.
2. Initialize the Relay
    - Wait for the relay to initialize/boot. The user should hear a click sound indicating that the system is already running.
3. Connect the Compressor
    - Locate the auxiliary power outlet behind the electronic box.
    - Connect the compressor to the auxiliary power outlet securely.

Section 2: App Installation

1. Download the BLYNK IoT Application
    - Open the Google Play store/App Store on your mobile device.
    - Search for "BLYNK IoT" and select the official app.
    - Download and install the Blynk IoT app on your device.
2. Account Invitation and System Access.
    - The system's admin will send an invitation to your Blynk Account.

- Make sure that you have a Blynk Account ready for this step.
- Accept the invitation from the admin sent through your email to gain access to the UI of Blynk IoT app.

3. Check System Status
   - Open the Blynk IoT app on your mobile device.
   - Navigate both “HybeeMain” and “Traditional Hive” section.
   - Verify if the system is online and functioning properly. If the system is not working, the UI will display “Offline” for both sections.

Section 3: Monitoring Notifications and Harvesting

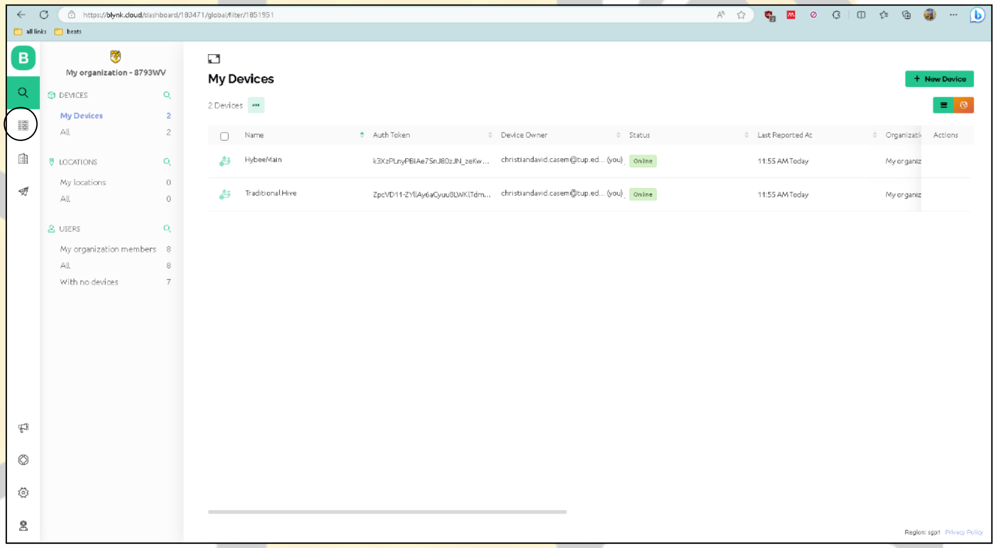
1. Notifications
   - While using the hybrid beehive system, ensure that you keep an eye on the Blynk IoT app for any notifications.
   - The app will notify the user when it’s time for harvesting or any relevant updates such as temperature and bee activity.
2. Honey Extraction
   - Prepare the honey storage box to collect the harvested honey.
   - Locate the faucet in the storage box of the hybrid beehive system.
   - Open the faucet and collect the honey in the container.

Note: Use caution when handling the honey and ensure proper hygiene practices are followed.

How to setup the BLYNK IOT webapp to the system.

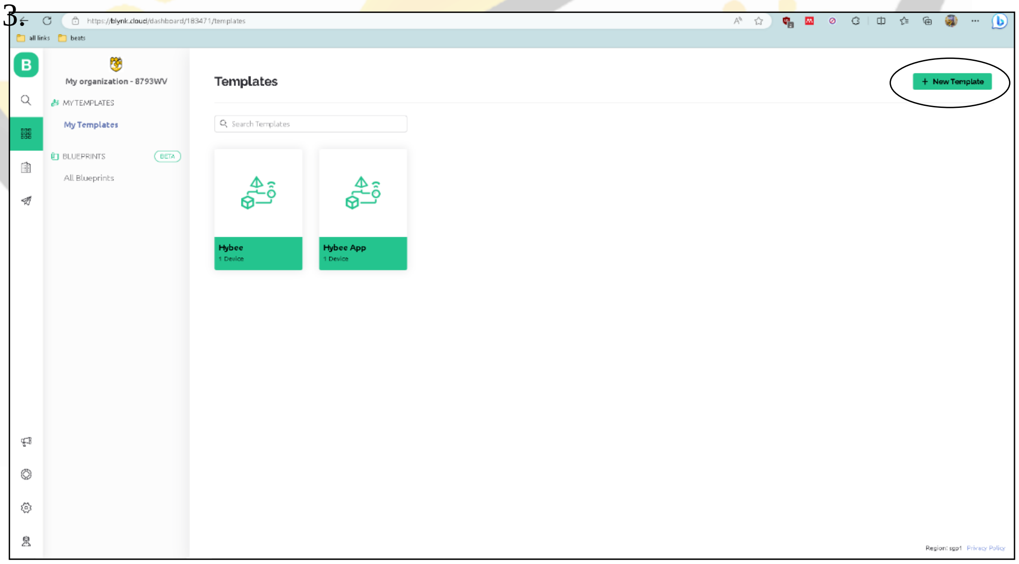
Section 1: Create Template.

1. Click the TEMPLATE button.



2. Click NEW TEMPLATE to create a Device ID for the webapp and mobile app.

3.



4. Set the name of the template then set the hardware to ESP8266 when you are using the board in your system and set the connection type to Wi-Fi.

5.

6.

7.

8.

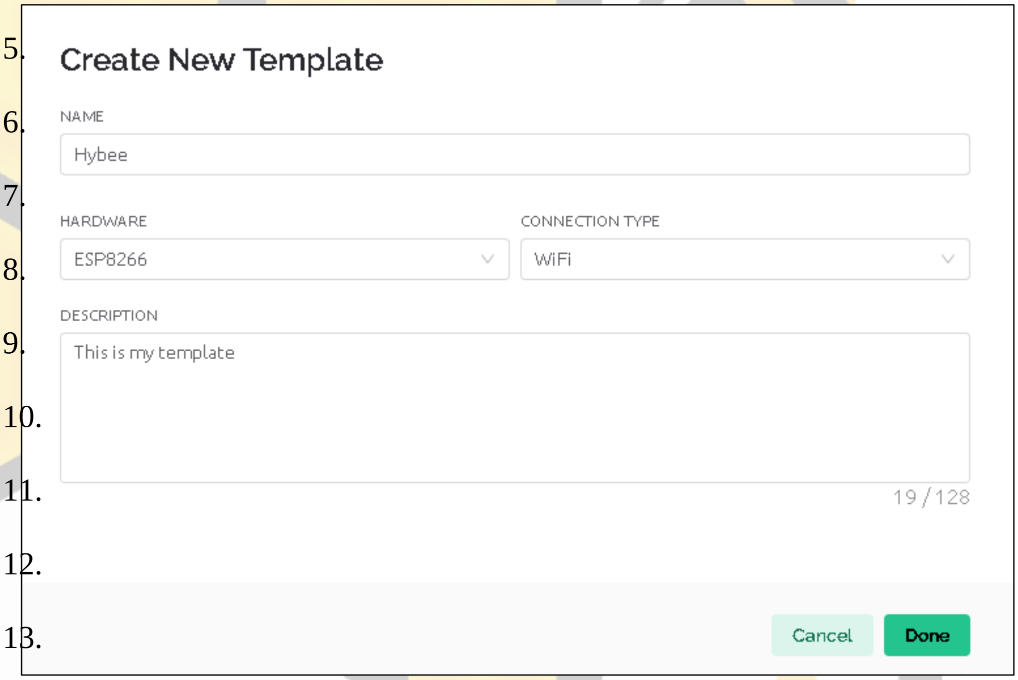
9.

10.

11.

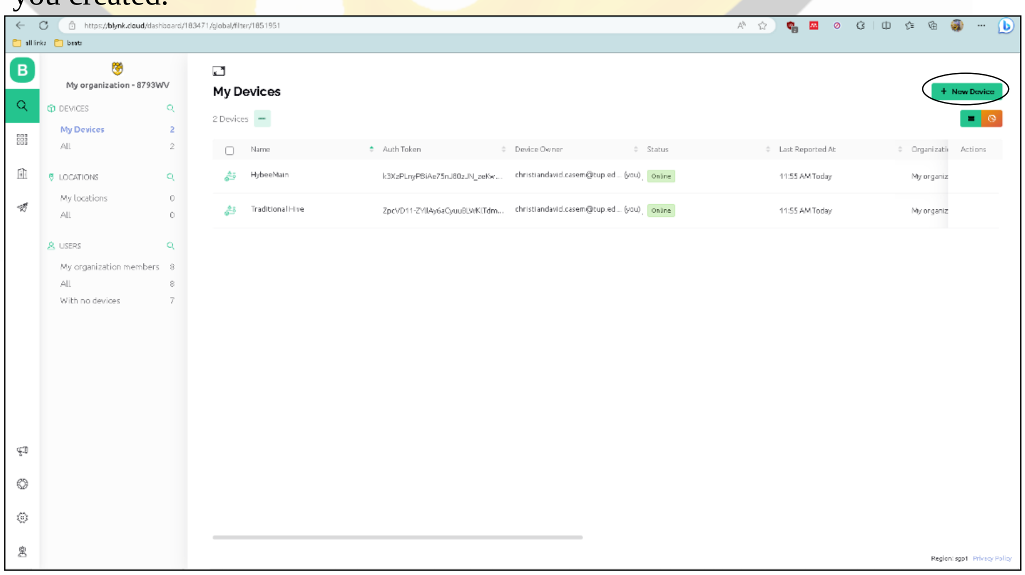
12.

13.

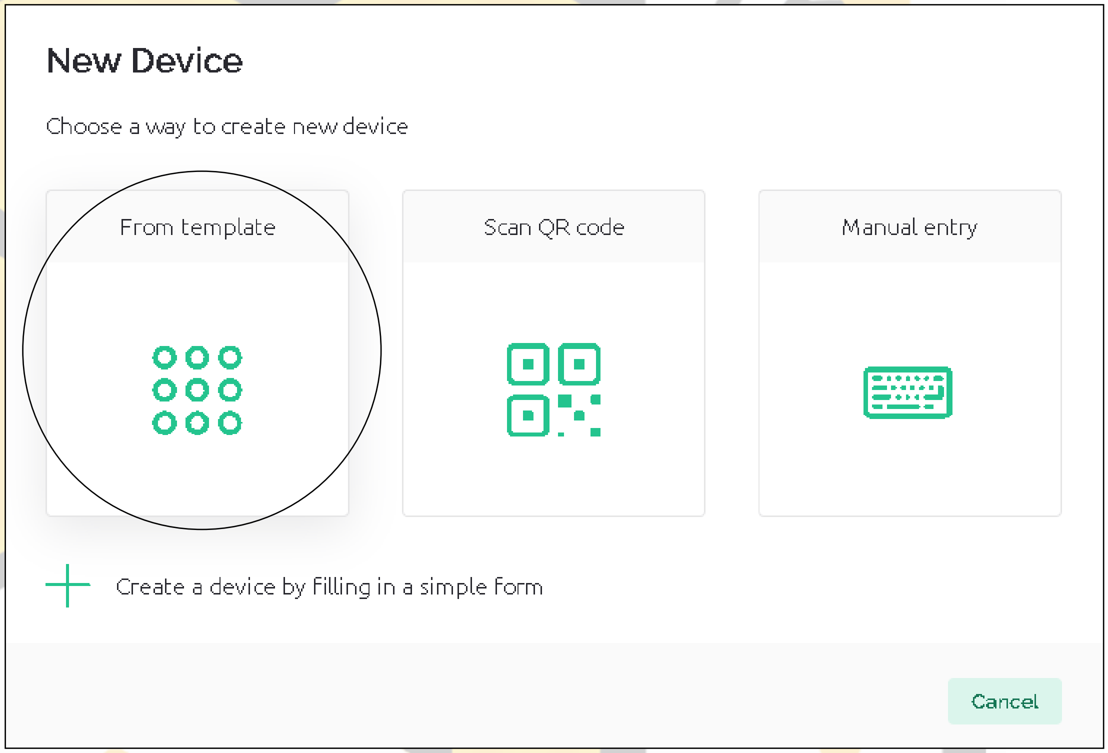


Section 2: Setup New Device

1. Go back to MY DEVICES and click NEW DEVICE to add the template you created.



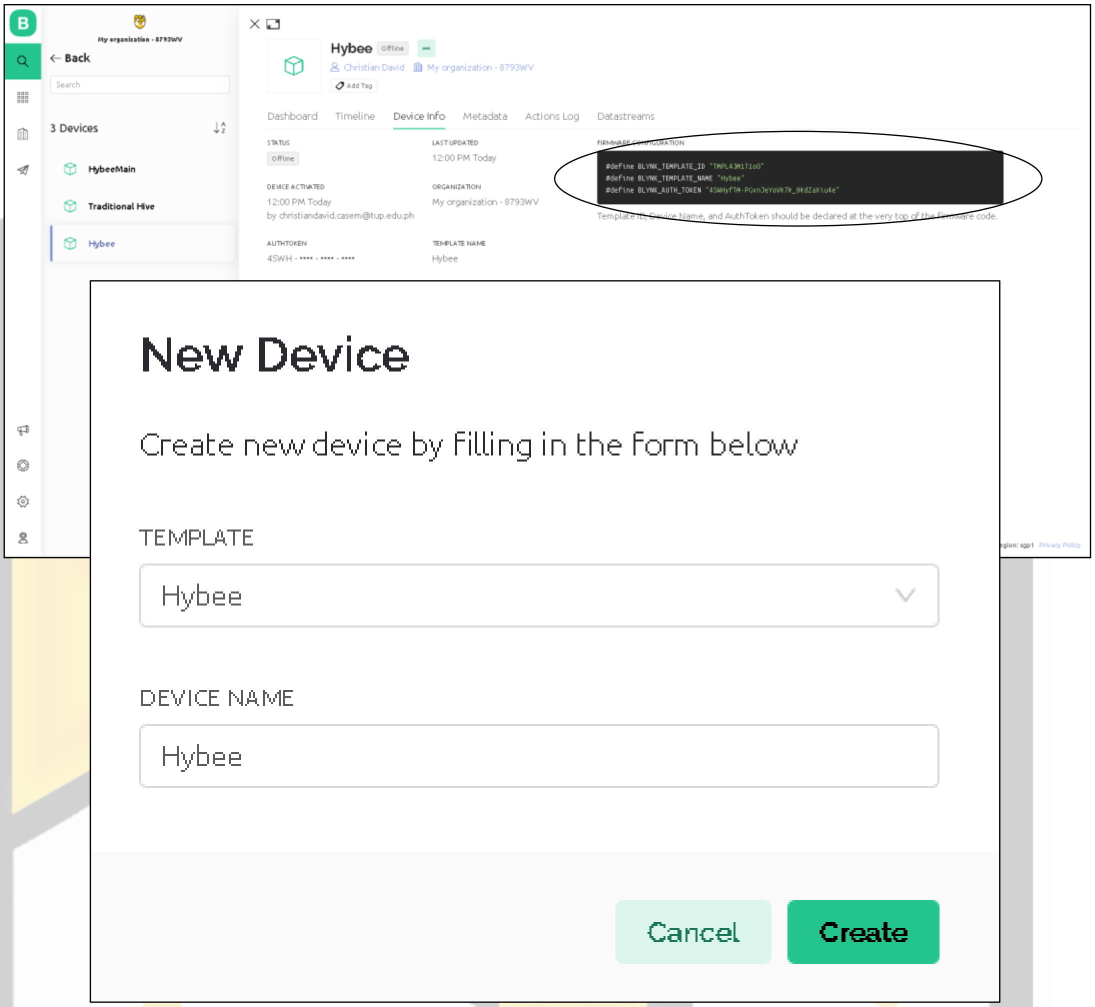
2. Select FROM TEMPLATE then select the template for the system you created.



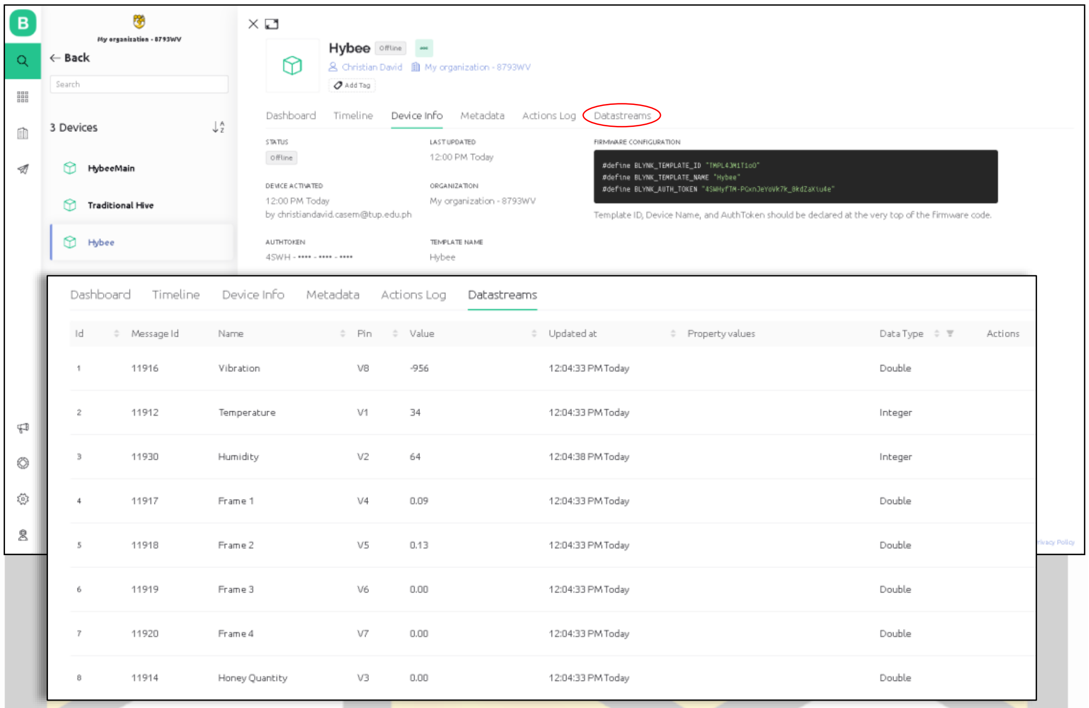
3. Type the name of the device.

Section 3: Configurations

1. Copy the FIRMWARE CONFIGURATION to the code of ESP8266



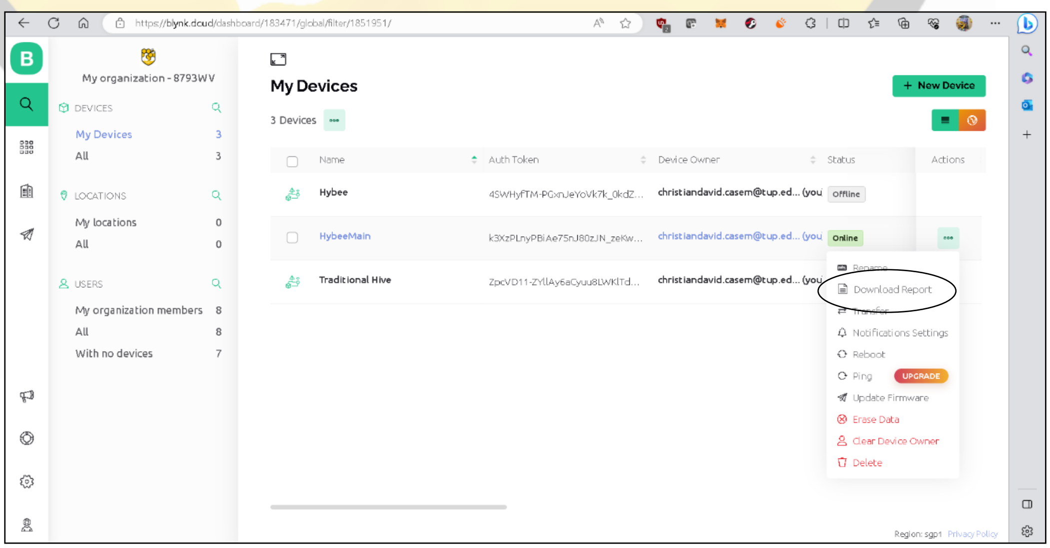
2. Click the DATASTREAMS to set the parameters that will be displayed by the device.



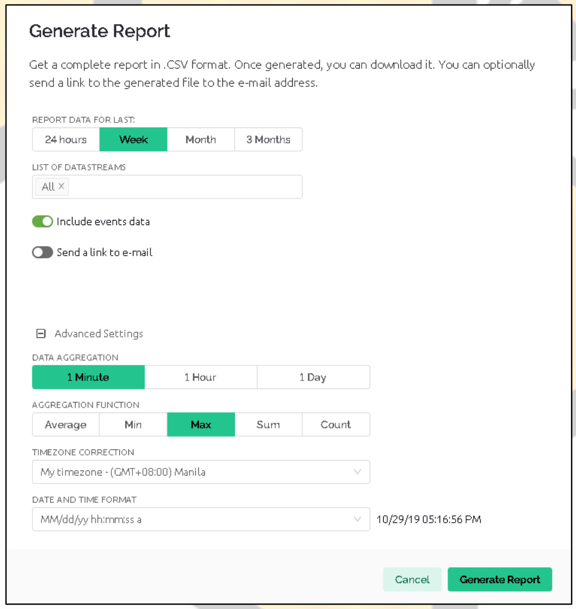
Id	Message Id	Name	Pin	Value	Updated at	Property values	Data Type	Actions
1	11916	Vibration	V8	-956	12:04:33 PM Today		Double	
2	11912	Temperature	V1	34	12:04:33 PM Today		Integer	
3	11930	Humidity	V2	64	12:04:38 PM Today		Integer	
4	11917	Frame 1	V4	0.09	12:04:33 PM Today		Double	
5	11918	Frame 2	V5	0.13	12:04:33 PM Today		Double	
6	11919	Frame 3	V6	0.00	12:04:33 PM Today		Double	
7	11920	Frame 4	V7	0.00	12:04:33 PM Today		Double	
8	11914	Honey Quantity	V3	0.00	12:04:33 PM Today		Double	

Section 4: Extraction of Data from the Webapp

1. In setting up the webapp, click the ellipsis (…) button then click download report.



2. In this part, you can generate the saved data sent from the device to the BLYNK IOT Cloud. You can set the interval of the data for the analysis of the parameters needed to be observed.



ANNEX VI

DUPLICATION
PROCEDURES

DUPLICATION OF THE SYSTEM:

Materials:

- ¾” Plywood
- Nylon mesh
- Load Cell Sensors and Drivers
- 120mm and 80mm fans
- 3/2 Electro-pneumatic solenoid valve
- Jumper Cable/Wires
- 5V 5A DC-DC Converter
- Arduino AT mega 2560
- ESP8266 Wi-Fi Module
- DHT11 Temperature and Humidity Sensor
- HC-SR04 Ultrasonic Sensor
- MPU 6050 Accelerometer Module
- Small Breadboard
- Extension Socket, cord, and plug
- Car charger adaptor
- Wood glue, screws, and small hinges
- Switch Power Supply Driver Adapter
- Tire Inflator Air Compressor
- Butyl Rubber Tubes
- Acrylic Pipes, Acrylic Sheet, and PVC Connectors
- Flow Frames
- Acoustic Foams
- Small Wi-Fi Router
- Waterproof Cloth
- Velcro
- 4-Channel Relay Module
- Plastic Faucet
- Pneumatic Tubes and fittings
- Silicone Tube
- Food-Grade Sealant
- BLYNK IoT Application

Procedures:

- The Hybrid Beehive consists of four parts: The flow frame box, the traditional Langstroth Box, the electronic component box, and the collection/compressor box.
- For all the boxes, use ¾” Marine Grade Plywood.

Flow frame box:

1. For the Flow Frame box, construct a 50.8cm x 23.37cm x 29cm box. Make a hole for the acrylic window, acrylic pipes, car adapter, and extension cord.

2. Inside the box, place a 1-and-a-half-inch wood thick for the mounting of load cell sensors.

3. Create a see-through window using ¾” spare wood to be placed on top of the box. The middle part of the window is covered with nylon mesh so that the user can still see inside the box.

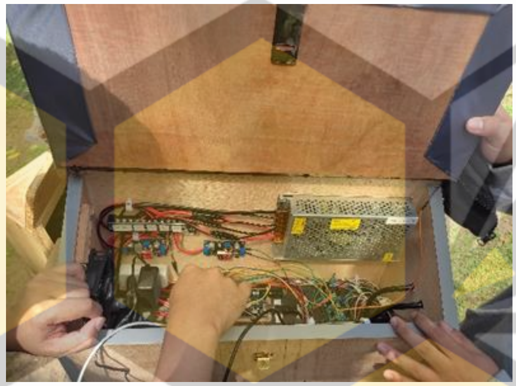
4. Create a triangular roof made from plywood and make holes for the 120mm fans.

ELECTRONIC COMPONENT BOX

1. For the Electronic Component Box, construct a box beside the Flow Frame box with dimensions 50.8cm x 12.13cm x 29cm with a slanting and turning cover using hinges.
2. In the Electronic Component Box, mount the solenoid valves in the turning cover, mount the power supply, extension socket, DC-DC Converter in the wall area of the box. Mount the Arduino ATmega2560, Load Cell Drivers, 4-Channel Relay Module in the middle surface of the inside box.

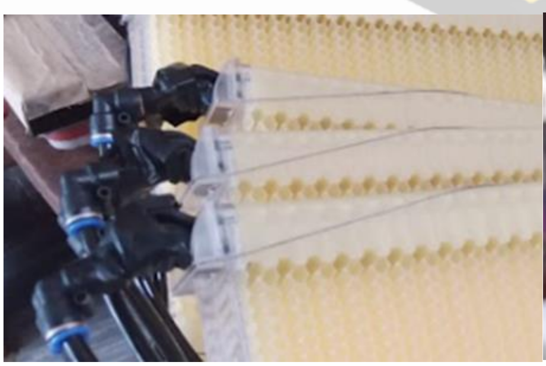
3. Mount the ESP8266 Wi-Fi module to the breadboard and place it near the other components on the surface inside the box.
4. Mount the Load Cell sensor in the wood inside the box. Mount the 80mm fan in the electronic component box to avoid overheating.

5. Calibrate the sensors: Ultrasonic Sensor, Temperature and Humidity Sensor, Load Cell Sensor, Accelerometer Module.
6. Make the Circuit: Connect wires to the components for longer reach, make a small hole in the side of the flow frame box, and insert the wires from the load cell. Start the wiring and setup of the Arduino AT mega, ESP8266, 4 Channel Relay Module, Solenoid Valves, Load Cell Drivers to the correct supply of their voltages.



7. Also Connect the 120mm fans from the roof for the temperature regulation in the flow frame box.

8. Place a pair of butyl rubber in the keyhole of the flow frame box. Place the fittings with the pneumatic tubes in the opening of the butyl rubber.
9. Mount the other fittings outside the flow frame box and connect it to the solenoid valve.

10. Mount the flow frames on top of the Load Cell Sensors.

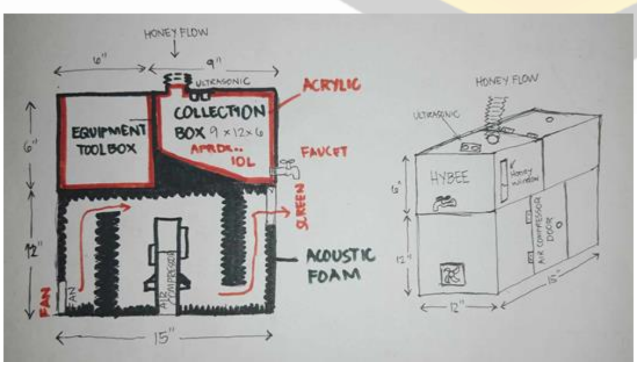
11. Place acrylic pipes on the bottom part of the flow frames for the harvesting. Connect them using a PVC elbow and tee connector. At the end of the pipe, place a silicone tube.
12. Setup a database and connect the system in the BLYNK IoT app for the sensor readings.

TRADITIONAL LANGSTROTH BOX

1. For the **Traditional Langstroth Box**, create a box for the bottom part of the hybrid beehive with dimensions 50.8cm x 35.5cm x 24cm. Create a small opening for the entrance and exit of the bees.
2. Place the Flow Frame box on top of the Traditional Langstroth Box.

HONEY STORAGE/COMPRESSOR BOX

1. For the **Honey Storage/Compressor Box,** create a box with dimensions 15” x 12” x 18”. Divide the top and bottom part of the box for the storage and the compressor with another 80mm fan.



2. At the bottom part of the box, place acoustic foam on all surfaces of the box for soundproofing then mount the air compressor

3. At the top part of the box, create an acrylic storage with a slanted base, with dimensions 23.2cm x 30cm x 14.8cm. Make a hole near the edge of the slanted base. Also make a hole at the top-right part of the acrylic storage for the honey flow and place an acrylic pipe

4. Mount the ultrasonic sensor for monitoring of harvest.

5. Make a hole also in the middle part of the box and place a PVC pipe matching the location of the hole in the acrylic box

6. Place a food-grade sealant on all the corners and the side of the hole of the PVC pipe.

7. Place the faucet outside the box in the hole made earlier.

8. Connect the air compressor to the solenoid valve.
9. Make a partition behind the acrylic box and place the Wi-Fi router for the Internet connection of the system.

10. The other end of the silicone tube is connected to the acrylic pipe in the acrylic storage.
11. Plug in the Wi-Fi and the system, then upload the code in the Arduino AT mega 2560 (reset if needed).
12. Check the wiring and readings.