A Real-Time Web-Based Monitoring System for Stingless Bee Farming

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***Abstract*—The low yields in stingless honeybee production have impacted the daily earnings of small size farmers. The IoT-based monitoring system is presented to improve the earnings of stingless bee farmers by helps farmers to gain a better understanding of their farm and boost honey production. The system uses an Arduino Uno ATmega328P and DHT22 sensor to monitor the temperature and humidity inside the hive continuously and transmit the data wirelessly to a server for monitoring and analysis. Furthermore, 30 days of practical monitoring indicates that the system can operate without human intervention and was successfully observed the living condition inside the stingless beehive. Data is collected every 30 minutes for 30 days by the sensor and stored in the cloud. The temperature inside the hive has to be maintain not exceeding 35°C and the humidity level is proposed to be not exceeding 78% to achieve optimal living condition for stingless beehives. The system can be extended with multiple sensors to allow farmers make informed decisions on the condition and activity within the beehive.**

Keywords*—*Stingless bee monitoring, Internet of Things, precision bee farming, temperature and humidity sensors, ThingSpeak

I. Introduction

Stingless bees (Meliponini) mainly live in tropical and subtropical regions and are insects that produce honey and are also known by various names such as sugarbag honey (in Australia), Trigona honey (in Thailand) and Kelulut honey (in Malaysia) [1]. Honey produced by a stingless bee is either eaten directly or used in various traditional medical practices because of its properties of being antioxidant, anti-inflammatory, antibacterial, antiviral, anti-ulcer, antihyperlipidemic, antidiabetic and anticancer [2]. The use of honeybees as a commercial sugar substitute in daily intake has been found to reduce the risk of cardiovascular diseases due to its distinct chemical compounds. In Malaysia, the stingless bee industry is relatively new and thus provides great opportunities for farmers in the agriculture and food commodity sectors to produce honeybee by-products [3]. However, hurdles such as low honey production and inconsistent honey quality cause the price of a stingless honeybee in the market to fluctuate thus slowing down the growth of the stingless bee industry [4]. Therefore, to mitigate the hurdles of low honey production and quality, the activities of the stingless bee colony need to be investigated.

In recent years, a beehive monitoring system has been proposed by many researchers to understand the bee colony activities and quantify the living condition in the beehive such as but not limited to oxygen [5], carbon dioxide [6], pollutant levels [7], temperature [8, 9], and humidity [10]. From the researcher's works [11]–[14], a relationship and correlation between the monitored living conditions and the bee colony's activities have been deduced. Developing the beehive monitoring system is challenging due to the complexity of honeybee colonies [15]. There is various type of data that need to be collected continuously. The types of collected data ranged from colony-related parameters and individual bee-related parameters. The colony-related parameters are the information derived from the behaviour of all bees as a colony (temperature, humidity) meanwhile the individual bee-related parameters are derived from the patterns of a small number of bees (number of bees entering/exiting). The total number and type of sensor (either wired or wireless) deployed are important design metrics in developing a precision honeybee monitoring system. The activity of bees is reported to be affected by temperature and humidity [16] thus analyzing the parameter is decisive. In addition, a self-powered beehive monitoring system is also an important design metric that makes the monitoring system sustainable and operates continuously over a longer period with minimum maintenance cost.

A wireless sensor network (WSN) consists of sensing devices with the ability to compute and communicate wirelessly with each other that form the basic concept of the Internet of Things (IoT). The sensing hardware is equipped with modules comprised of a power unit (batteries and/or solar cells), a sensing unit (sensors), a processing unit, and a transceiver unit (for communication). In [17], a beehive monitoring system (WBee) based on a hierarchical three-level model was developed. The system monitored the temperature and relative humidity using three SHT15 sensors and interconnected it with a weighing scale. In [5], the authors integrated multiple sensors that are particle dust, gas sensors, humidity, and temperature to monitor pollutant levels, oxygen, carbon dioxide, temperature, and humidity. The prototype is deployed over various hives with each sensor collecting data several times per day. Then the data is aggregated using XBee Series 2 Zigbee and transmitted to a server using a GSM/GPRS/3G

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module once every 24 hours. From the data analysis, two main algorithms were developed that is biological and weather prediction algorithms. Other monitoring systems including [18] which used NodeMCU microcontroller, cell sensors and DHT22 temperature and humidity sensors, and in [19] that uses a low-cost platform that can measure inner and outer temperatures, humidity and weight, and carbon dioxide (CO_2) concentration inside the hive to monitor the bee's health.

This paper proposed a real-time web-based monitoring system for stingless bee farming. The real-time and web-based are chosen for its efficiency, reduction of resources and cost, automation and data-driven solutions. The key contributions of this paper are: (i) provide a solution to farmers using the concept of precision farming (ii) data collection relating to the stingless bee's living conditions, weather, and weight. This paper is organised as follows: Section II describes the proposed design of a stingless bee monitoring system. Section III presents the analysis and discussion of the collected data. Section IV concludes the paper and is followed by a recommendation and future plan.

II. Design of Monitoring System

Fig. 1 presents the framework of the stingless bees monitoring system. The hardware component consists of the Arduino UNO, DHT22 Sensor, and ESP-01S Wi-Fi Module. Meanwhile, the cloud is ThingSpeak, a Web-based system. To measure the temperature and humidity inside the beehive, DHT 22 will be used. The data will be collected by the microcontroller, Arduino UNO because of the serial communication between the microcontroller and ESP-01S Wi-Fi Module enabled data transfer. The data collected will be uploaded to cloud computing, which is ThingSpeak through the ESP-01S. ThingSpeak is an open-source application that enables users to communicate with internet-connected gadgets.

The electronic system uses an Arduino UNO ATmega328P, a low-power consumption Microcontroller that can be programmed using the Arduino IDE open-source software. The ATmega328 on the Arduino UNO comes pre-burned with a bootloader and is equipped with several analogue pins to enable connection with multiple sensors. The DHT22 temperature and humidity sensor come with a dedicated NTC which measures temperature and an 8-bit microcontroller to output both temperature and humidity values as serial data. DHT22 has low power consumption too with a range of 3.3V to 6V and excellent long-term stability. The accuracy of this sensor is relatively high that can be earned at a lower cost. Lastly, the range of the sensor humidity is between 0 to 100% RH with a tolerance of $\pm 2\%$, while the temperature range is between $-40°C$ to $80°C$ with a tolerance of $\pm 0.5°C$.

Wi-Fi module ESP-01S is utilized as the gateway to transfer data wirelessly to the cloud server for analysis as it is more convenient than the Bluetooth module due to the large difference in radio signal range between those two. Bluetooth offers a 10-meter radio signal range, whereas Wi-Fi offers a 100-meter range. The ESP-01S Wi-Fi module is a suitable gateway for mobile and Internet of Things applications with

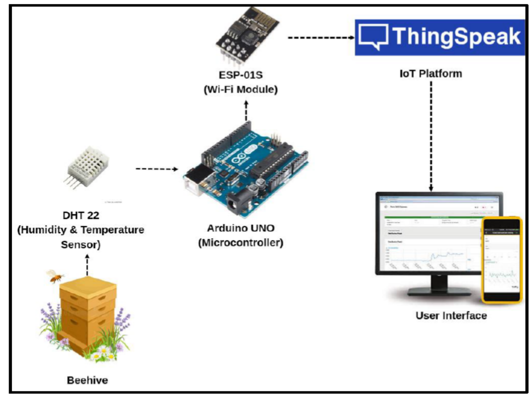

Fig. 1. Framework of the monitoring system.

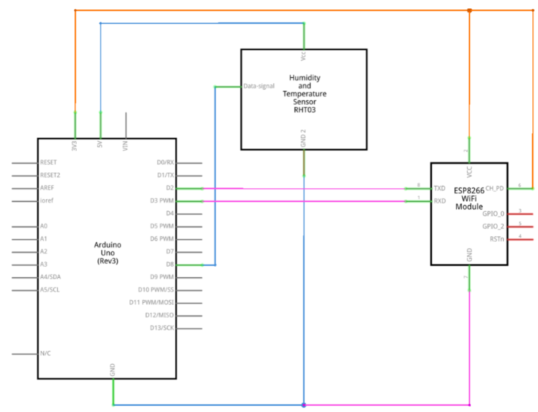

Fig. 2. System schematic diagram.

the lowest power consumption and can be programmed using the user-friendly Arduino IDE programming software. It is an inexpensive Wi-Fi module containing 4MB of flash memory.

The schematic diagram of the system is shown in Fig. 2. The Arduino UNO board can be powered up by a USB connection or with an external power supply. The external power supply comes from either battery or an AC-to-DC adapter with a 2.1 mm centre-positive plug. Battery leads can be put into the POWER connector's GND and Vin pin headers. The board may be powered by an external source ranging from 6 V to 20 V. However, if supplied less than 7 V, the 5 V pin will cause the board to become unstable due to insufficient power. When more than 12 V is supplied, the voltage regulator may overheat and damage the board. There is a total of 14 digital I/O pins that can be used as an input or output. To connect the DHT22 temperature and humidity sensor to the board, only need to connect the data pin to the digital pin on the board. The VCC and GND pins for both the sensor and board will be connected. The maximum number of sensors that can be connected to the board is 14 sensors. The ESP-01S Wi-Fi module has a total of 8 pins on it. However, connecting the Wi-Fi module to the Arduino UNO board only requires 5 pins. That is the GND, VIN, ENABLE, TX, and RX. As the Wi-Fi module is powered strictly to 3.3 V, voltage beyond that will damage the module.

Fig. 3. Arduino IDE development interface.

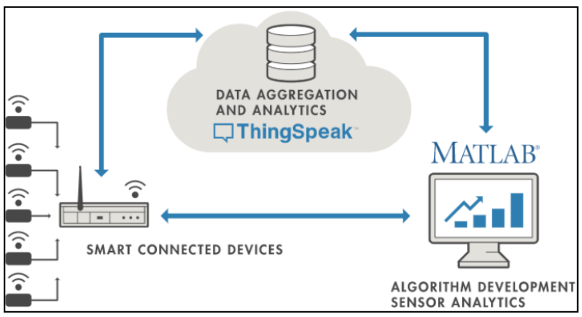

Fig. 4. ThingSpeak IoT Platform.

The Arduino IDE will be used to write and upload programming codes on the microcontroller and the ESP8266 Wi-Fi module. The Arduino IDE Development Interface is shown in Fig. 3. It is an open-source programming tool that is used to write codes for the Arduino Module. The software compiles the sketches and uploads it on the Arduino board. The software is also available in various operating systems such as MAC, Windows, and Linux. The programming tools support both C and C++ languages to write the sketches. Besides, the Arduino IDE is a user-friendly software that can be edit, compile, and upload codes easily. The code written is converted into a set of instructions that can be read by the Arduino hardware.

The temperature and humidity levels sensed by the DHT22 sensor will be transmitted to the ThingSpeak database. ThingSpeak is an IoT platform which can analyse data as shown in Fig. 4. The ThingSpeak cloud computing is equipped with the mathematical tool to analyse the data received. Users can create a channel to monitor the data retrieved and available for commercial and non-commercial projects. Data collected from smart devices such as the Arduino UNO and Raspberry Pi were stored on the ThingSpeak database which runs a MATLAB function that can be used to develop an algorithm for further data interpretation and analysis. To start using ThingSpeak, users need to have a ThingSpeak account or an existing MathWorks account.

III. Analysis of Monitoring Results

The prototype of the stingless bee monitoring system was deployed in Kampung Tagaroh, Kota Marudu, Sabah, Malaysia from 24/04/2022 to 24/05/2022 as shown in Fig. 5 and Fig. 6. Data is collected every 30 minutes for 30 days by the sensor and stored in the cloud. The collected data can be seen in Fig. 7. The data are presented as graphs, with time on the X-axis, and temperature, relative humidity, and weight, respectively on the Y-axis. Throughout the 30 days of prototype deployment, weather conditions were recorded daily. There are 15 days where the weather is sunny, on day $25^{th}, 26^{th}, 29^{th}, 30^{th}$ of May and $1^{st}, 2^{nd}, 3^{rd}, 4^{th}, 5^{th}, 6^{th}, 7^{th}, 8^{th}, 10^{th}, 11^{th}, 12^{th}$ of June. Meanwhile, the other 15 days are when the weather is cloudy. On sunny days, the maximum temperature can exceed over 35°C while on cloudy days the maximum temperature is less than 35°C. For both sunny and cloudy days, the lowest temperature recorded is approximately within 23°C to 27°C.

Fig. 5. Deployment site.

Fig. 6. Actual System Deployment.

The graph of relative humidity increases and decreases steadily at the beginning of deployment. However, after 8^{th} of May, the humidity starts to rise noticeably due to the rainy and cloudy days. When it is raining, the hive gets wet, and the wood used to build the hive absorbs the rainwater. Thus, the humidity inside the hive keeps on increasing and did not reduce. The initial weight of the hive is 40.80 Kg and after

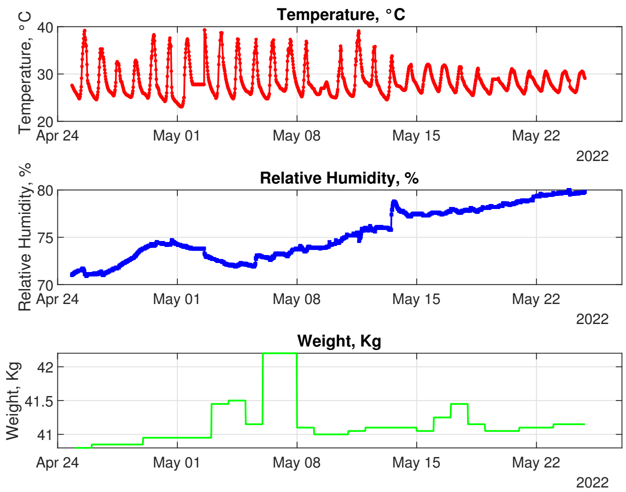

Fig. 7. Data collected over 30 days of deployment.

30 days, the weight increased to 41.15 Kg, which is an increase of 0.35 Kg. From the graph of weight, it shows that there were 3 different days when the weight suddenly rose. Due to the rainy and cloudy days, when the rainfalls, the hive gets wet and absorbs the rainwater thus significantly increasing the overall weight of the hive. The weight does reduce back to normal after few days during the sunny day.

According to [20], stingless bees, especially the pupae, can die at temperature as high as 38°C. Hence, reducing the number of stingless bees and thus reducing the overall honey production inside the hive. The stingless bee has a brood cell area within the ideal temperature of 31°C and 32°C. From the data, during the sunny days, the observed temperature is exceeding 35 °C for most of the days while the humidity is within 71% to 75%. The recorded temperature is beyond the ideal temperature thus it is not an optimal living condition for the stingless bee hives. On the other hand, during the cloudy days, the recorded temperature is ranging between 32°C to 26°C which is approximately the ideal reported temperature but the humidity shown to be built up from 76% to as high as 80%. For now, to the extent of our knowledge, there are no ideal humidity have been reported yet. But high humidity can also disrupted the optimal living condition of the stingless bee.

IV. Conclusions

A real-time web-based monitoring system for stingless bee farming was presented. The system can collect the temperature and humidity inside the hive continuously and transmit the data wirelessly in ThingSpeak which provides access to MATLAB to visualized and analyze the data. The system has a low power consumption to guarantee the longevity of deployment and consist of multiple analogue pins for future scalability. The experiment shows that the temperature and humidity inside the hive is affected by the surrounding conditions and thus reflect the microclimate of the stingless beehive. The temperature inside the hive has to be maintain not exceeding 35°C and the humidity level is proposed to be not exceeding 78% to achieve optimal living condition for stingless beehives. Despite the variations in temperature and humidity, the weight of the hive recorded an increase of 0.35 Kg for the duration of 30 days. In the future, the hive's roof is proposed to be waterproof and additional sensors with larger window of data will be implemented to automate the living condition of the stingless bees.

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