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Internet of Things (IoT) Application in Meliponiculture

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Abstract: This paper presents an investigation on the environmental factors affecting meliponiculture (the cultivation of stingless bees on a commercial scale for honey production or pollination) using an internet of thing (IOT) application. Manual collection of data for chosen factors can be sporadic and produce variations from incorrect measurement taking; this can cause complications in producing any important interpretation. The feasibility of online monitoring of bee hive based on IoT application has not been properly explored. For a particular bee hive, the amount of departing and arriving bee was estimated by using non-intrusive sensors of infrared transmitter and receiver. A basic temperature-humidity sensor to monitor the temperature and humidity was placed inside the bee hive. All sensors were integrated with a microcontroller and a Wi-Fi module which sent the data wirelessly to IoT cloud platform where the data was continuously saved, monitored, and can be retrieved anytime. Colonies of Trigona Itama were active throughout the whole period at the experimental site but the daily activity period was intense in the warmer days (over 30 °C) whereas the relative humidity had no significant effect on the flight activities. Intensity of daily flight activity was greatest in December, 2016. Temperature was the most important variable affecting flight.

Keywords: Internet of things, Trigona Itama, climate impact, flight activity, thermogulation

1. Introduction

Malaysian honeys are produced by two main bee genera: Apis and Trigona (stingless bee) [1]. However, stingless bees are different in at least two aspects: they do not sting and smaller in size. There are 32 known species of stingless bees in Malaysia and Trigona Itama is mostly used in meliponiculture [2]. Stingless bees are a large group of bees and usually hive in hollow trunks, tree branches or rock crevices. They are active throughout the whole year (but will be less active in a cooler weather) and store pollen as well as honey in large egg-shaped pots (comb) made of beeswax, typically mixed with various types of plant resin. They will not sting but will defend by biting if their hive is disturbed. In Africa, stingless bees are diverse and are farmed there too. Stingless bee's honey is prized as medicine in many African communities. Bee farmers extracted wild colonies hive in tree trunks before they attached the tree trunk with a hive box called topping at the top of the tree trunks as shown in Fig. 1. A stingless honey bee hive has a funnel shape entrance and was found to be different according to the genus as shown in Fig. 2 [2].

A Typical Stingless Bee Nest

Fig. 1 A typical stingless bee hive with a hive box

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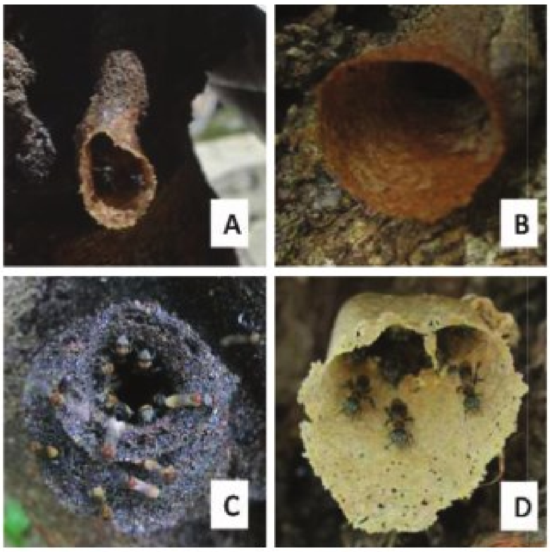

Fig. 2 Shape of the entrance of the stingless bees' hive. A - Funnel shape entrance of T. itama; B – Round ringed entrance of T. itama; C - Entrance in shape of mount (T. thoracica), D - Funnel shape entrance of T. terminata [2]

The ubiquity of advanced Wireless Sensor Network (WSN) and information technologies has been a key enabler networking everyday objects. A collective physical items in a system equipped with "Internet of Things (IoT)" can communicate with each other while integrating the physical world with computer-based system in a more direct way, and greatly improving resources efficiency in addition to alleviating human intervention [3,4].

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If the information on the environment is being collected using the platform of IoT, there are several advantages: reduce effort and time required for monitoring a particular environment, the logging of data allows for reduced likelihood of data being misplaced or lost, and sensor nodes could be placed in critical spots without the need to put personnel in perilous situations [5-7].

Significant IoT applications of *Apis* genus bee monitoring have been observed around the globe [7-15]. Some of the important findings stated that the occurrence of the pesticide abuse around the beehives in the radius of up to 3 km is usually reflected as a huge number of death bees and changes beehive local climate [16]. Under WSN automated monitoring, honey bees (not stingless bee) are most active when the daily average ambient temperature is higher than 25 ℃, and the average ambient relative humidity is between 60 %RH and 70%RH [7].

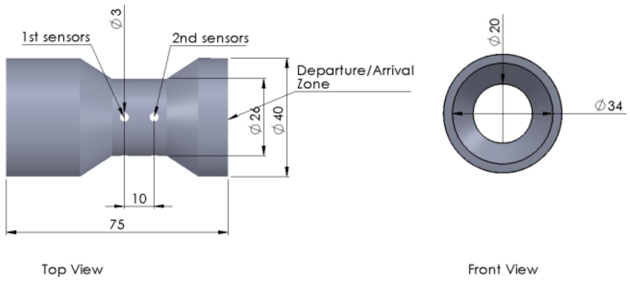
Various thermal patterns have been discovered related to hive conditions which potentially trigger absconding conditions [10]. Overheating and high humidity are major concerns for beehives as they have adverse effects on the condition of the brood (bee larvae) and adult bees, as well as reducing the quality and stability of the hive's wax combs [13,14]. In an adaptation study, bee colonies were able to thermoregulate in hive box modifications to deter a harmful predator in a Mediterranean climate, thus indicating that it is safe to use open-screened bottom board bee hives [15]. The success of the applications is due to the advancement of wireless sensors node technologies [7,8,10,13-15], sensor and actuator technologies [9,12], and miniaturization of devices based on MEMS [11].

The monitoring of stingless bee activities is a way to understand the survival determinant and dispersal adaptation of the stingless bees for large-scale honey productions and future crop pollination success [1, 17-22]. However, the traditional methods pose some challenges such as direct human observation and intervention which can be viewed as too subjective, intrusive, and time consuming. Moreover, human health and safety risk is at stake, if overnight observation is considered. Furthermore, the time span of study is normally limited and irregular due to the weather which could miss some important data. Although much information has been obtained on the conditions of stingless bee, investigation on the behavior of the stingless bee combined with the population size and the amount of honey productions has not been carried out in a systematic manner and extensively on IoT platforms.

This paper focuses on the introduction of IoT in Meliponiculture where the hive's climate condition and activities of Trigona Itama are studied. The main designs and outcome of the sytems are also presented. We also aimed to discuss the influence of climate on stingless bee activities using an IoT application. The data was collected between 5th December 2016 and 9th April 2017 (125 days).

2. Methodology

A Trigona Itama bee has a body size between 3.0 to 7.5 mm, dominantly blackish body and with one weak tooth on the mandible. The amount of Trigona Itama bees is estimated by using two pairs of infrared light transmitters (LEDs) and receivers (photodiodes). To realize the use of the non-intrusive sensor, an extension funnel was developed using a 3-D printer. Fig. 3 (a) shows a SolidWork illustration of the funnel. These sensor pairs are placed in arrays at the middle area of the extension funnel which are attached to the entrance of the Trigona Itama stingless bees' hive as shown in Fig. 3 (c). For each pair, the infrared light transmitter and receiver were inserted into vertical through holes on the circumference of the extension funnel. The infrared light transverses through the stingless bee path perpendicularly from the transmitter to the receiver (direct incident). The schematic diagram of the bee counter system is shown in Fig. 4. For each pair, when the infrared light is obstructed by a bee, no current flows through the photodiode and a HIGH input signal is sent to the Arduino analog input. The bee counter system works by recognizing a departing bee when the first Arduino analog input is HIGH followed by the second Arduino analog input and then, value "1" is added to the current total count. Meanwhile, an arriving bee is detected when the second Arduino analog input is HIGH followed by the first Arduino analog input and then, the current total count is added with value of "-1".



(a)

(b) (c)

Fig. 3 (a) Extension funnel drawn using SolidWorks Bee hive entrance (b) before and (c) after the bee counter extension funnel is attached

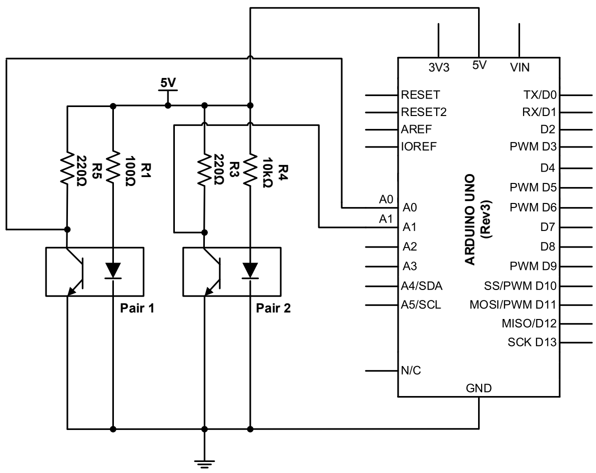
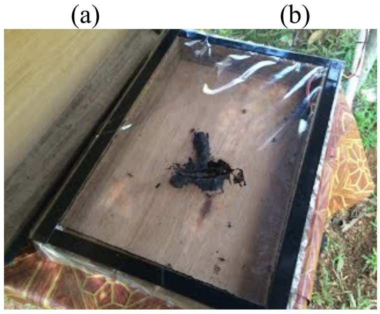


Fig. 4 Schematic diagram of the bee counter system

Fig. 5 shows a DHT11 basic temperature-humidity sensor that is used to monitor the temperature and humidity inside the containment box (topping). The DHT11 board is covered in Polytetrafluoroethylene (PTFE) tape. PTFE allows water vapor to pass back and forth while protecting the sensor from stingless bee's wax or propolis as shown in Fig. 5.

The bee counter system and the DHT11 sensor were integrated with Arduino microcontroller. Arduino microcontroller sends the data to ThingSpeaks (an IoT third party gateway provider) via ESP8266 Wi-Fi Module and a Wifi router every 40 s as shown in Fig. 6. Thus, humidity, temperature, and bee counts can be recorded and displayed on the graphs published through ThingSpeak. ThingSpeak is an IoT analytics

(a) (b)



(c)

Fig. 5 (a) DHT11 sensor (b) DHT11 sensor covered in PTFE (c) DHTT sensor inside the topping and on the inside corner

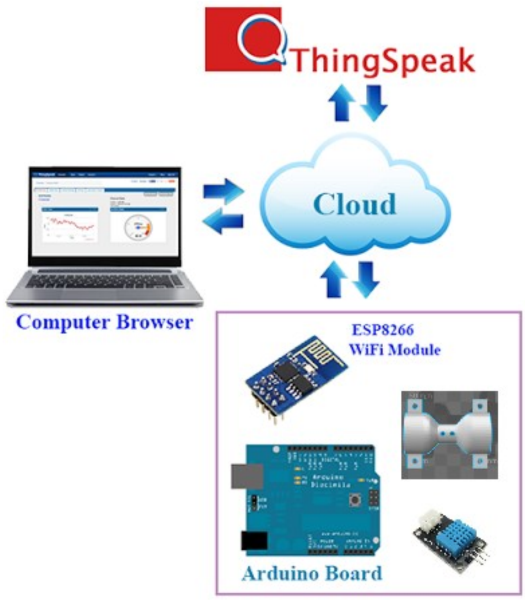


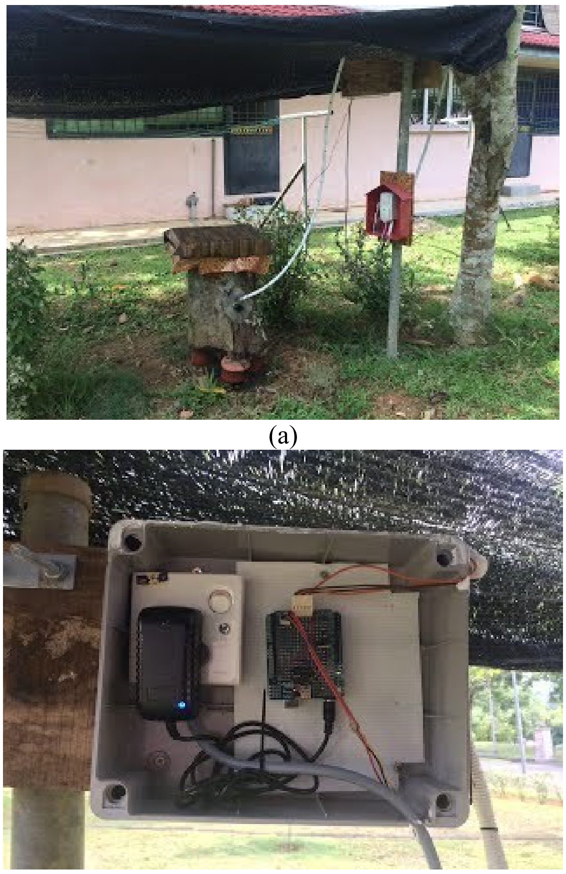
Fig. 6 Arduino and ESP8266 monitoring device with ThingSpeak

platform service that allows aggregation, visualization, and analysis of live data streams in the cloud. ThingSpeak provides instant visualizations of data posted by devices to ThingSpeak. ThingSpeak's widgets allows website integration which displays temperature, humidity, and bee counter on graphs.

The system was deployed behind the XC3 building, a residential college of Dato'Onn Jaafar, at Universiti Teknologi Malaysia as shown in Fig. 7. It was installed there because the location was surrounded with forests which are rich in wildflowers and trees with natural plant resins. Fig. 7 also shows the Arduino microcontroller and the ESP8266 Wi-Fi Module being placed inside a box and on a pole. The pole was cemented into the ground so that it will be stable even when there is a storm.

3. Results and Discussion

Tests were performed between 5th December 2016 and 9th April 2017 (125 days), 24 hours, and every 40 seconds. The graphs in Fig. 8 shows the temperature and humidity of the hive for 125 days. It can be seen that the maximum and minimum temperature are around 48 °C and 20 °C, respectively. High temperature fluctuations over 35 °C were recorded between 12 pm and 3 pm. These extreme temperature conditions only happened for a short period of time (i.e. less than 10



(a) (b)

Fig. 7 (a) A photo of the experimental setup behind building XC3 (b) Micro-controller and WiFi modules inside the system box

minutes) and when the rays of sun streaming down through the trees' leaves directly to the topping (top cover of the hive). Higher average temperature was observed in the month of December, 2016. This was due to the fact that the hot season had not ended until January 2017.

Fig. 8 also shows the relative humidity in the bee hive. The relative humidity oscillates between 70% and 85% for 125 days. The relative humidity is not fluctuating due to external factors and was stable within the hive. The relative humidity tells us how close the air is to being saturated. If the relative humidity is 100%, then the air in the hive is saturated. Relative humidity is inversely related to the temperature in the hive, as compared between the graphs in Fig. 8. The relative humidity is higher before and during sunrise (18:00 hour and 09:00) and lower before and during late afternoon (09:00 hour and 17:00).

In the case of low hive temperature, the bees heat up the brood combs by performing mass incubation. In addition, the hive was insulated by covering it with cerumen. 35,000 bee individuals departing for foraging from the hive was recorded as shown in Fig. 9, especially when the temperature was over 30 °C, to reduce overheating, apart by accelerated and aligned fanning of bees in the hive (social thermogulation).

Colonies of Trigona itama were active throughout the investigation at the experimental site but the daily activity period was intense in the warmer days. The intensity of daily flight activity was greatest in December, 2016. Temperature was the most important variable affecting flight activity. The temperature impose onsets on activity, with flight occurring up to departing bees, between 600 and 800 individuals per second as shown in Figure 10 between December 2016 and January 2017. Relative humidity is inverse relationship with the temperature and had no significant effect to the daily activity. Moreover, the intensity of arriving bees, between -600 and -800 individuals per second was also recorded in the period or warmer days. The bee colonies control the amount of excessive water and strong temperature by regulating the relative humidity. The bee colonies were able maintain the relative humidity below 100% most of the time, thus preventing the deposition of water vapors inside the bee hive. Strong relationships were found between the intense flight activities (departing and arriving) and temperature as shown in Fig. 10. In between the months of February 2017 and April 2017, less intense flight activities were recorded because of the cessation of foraging activities during rainy days.

4. Summary

In this study, an IoT application of Trigona Itama stingless bee hive condition and flight activities monitoring was demonstrated. Stingless bee cultivation is quickly becoming popular nowadays in Malaysia. There were many investigations on stingless bee. Even so, there is still no utlilization of IoT application in stingless bee studies. Therefore, the system in the current work will be a platform for future development of the problem. This

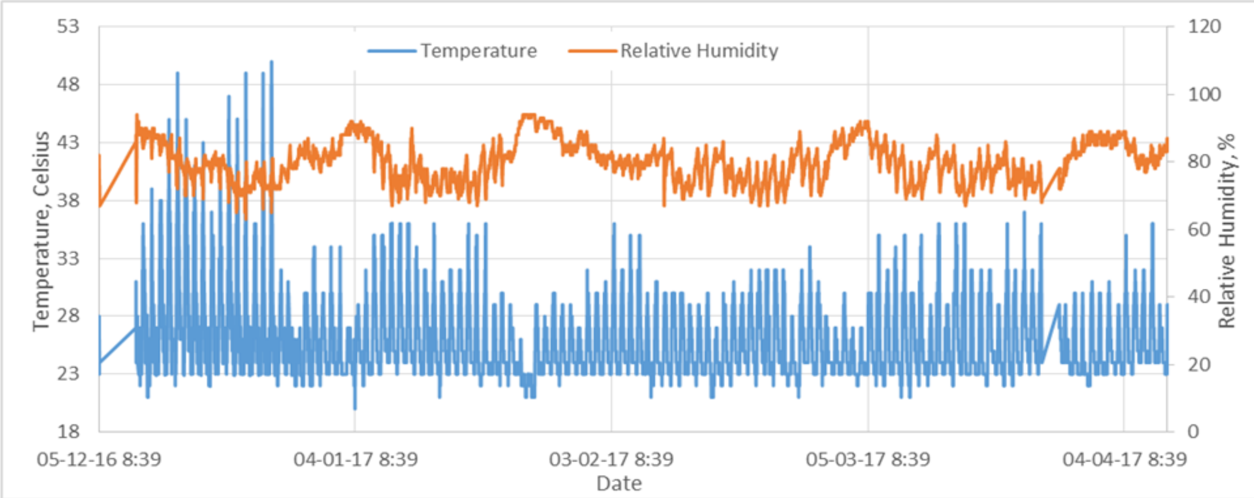


Fig. 8 Temperature and relative humidity within the beehive

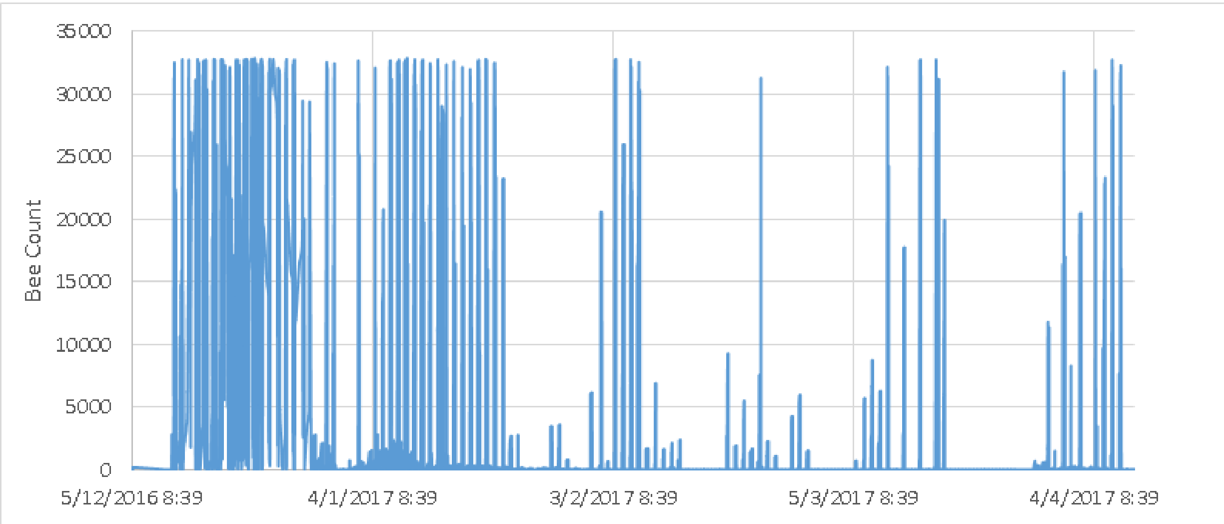


Fig. 9 Bee counts between 5th December 2016 and 9th April 2017 (125 days), 24 hours, and every 40 second

kind of application is important for the adaptation of the stingless bees for upcoming honey production and crop pollination success. It will overcome the problem of direct human observation and intervention which can be viewed as too subjective and time consuming. Conventional studies also put human health and safety are at risk if overnight observation is conducted. Moreover, with the advancement of IoT, the time span of study is virtually unlimited and regular regardless of weather conditions.

IoT made use of the ESP8266 Wi-Fi Module. The utilization of this module increased the reliability of collected data that has been sent. In order to detect the flight activities of the bees, a non-invasive infrared sensors had been developed. The important factors that influenced stingless bee activities such as temperature and humidity had been measured using the DHT11 sensor.

Therefore, data from these parameters was collected. Collected sensors data went through another three processes which was sending, saving and showing. Tests showed that the system can systematically record essential information such as temperature, humidity, and flight activities which are vital parameters to perform the analysis. Colonies of Trigona Itama were active throughout the experiment but the daily activity period was intense in the warmer days (over 30 °C) whereas the relative humidity had no significant effect on the flight activities. The intensity of daily flight activity was greatest in December, 2016. Temperature was the most important variable affecting flight.

IoT application had proven that it can seamlessly monitor stingless bee conditions and from the analysis, we can understand the climate impact on the stingless bee activities within 125 days. The same system can be replicated and expanded to other hives creating a network of online monitoring of many stingless bee hives. With the availability of internet and online at all time, low-cost smart sensor node development enabled devices to be connected easily and the corresponding information can be accessible globally.

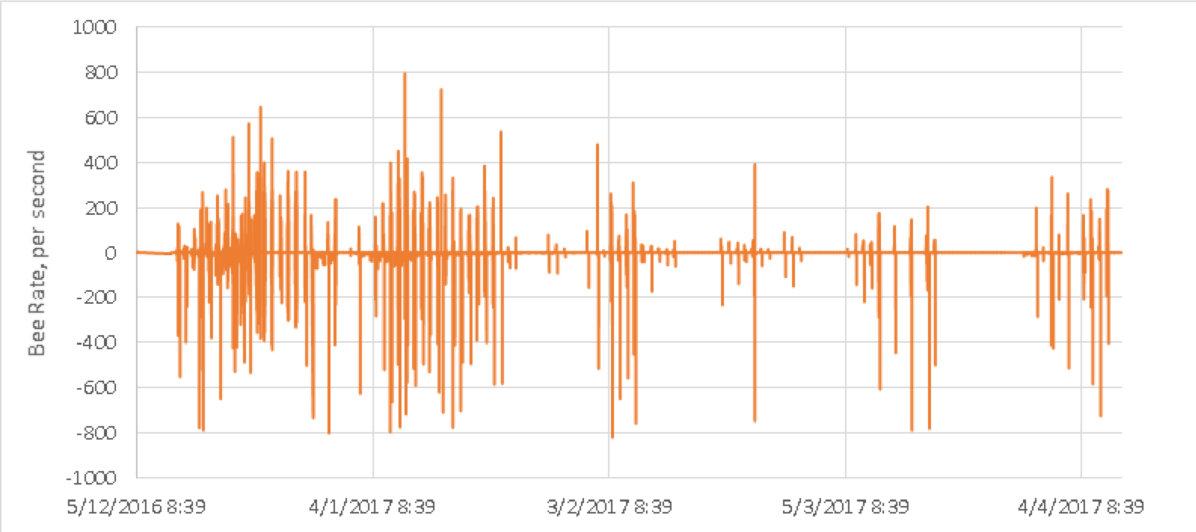


Fig. 10 Bee rate per second between 5th December 2016 and 9th April 2017 (125 days)

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