Artificial Stingless Bee Hive Design Utilizing Embedded Fuzzy-IoT Based Determining Hive Condition and Honey Volume

by

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A research proposal submitted in fulfillment of the requirements for the degree of
Master of Science

Faculty of Electrical Engineering Technology
UNIVERSITI MALAYSIA PERLIS

2024

ACKNOWLEDGEMENT

Firstly, I would like to thanks to my parents and family for supporting me doing this master's program. Indeed, undertaking this project has been a tough endeavor for me. Learning about the behavior of stingless bees in nature provided me with a unique opportunity to acquire knowledge outside of the engineering context. Given this rare occasion, I would like to express my profound gratitude to my supervisor Dr. Bukhari Bin Ilias and my co-supervisor Assoc. Prof. Dr. Norasmadi Bin Abdul Rahim for their support and ongoing assistance with this report, despite the hectic schedule.

I am grateful to the Malaysian Ministry of Higher Education for providing support and funding for my research project under the Fundamental Research Grant Scheme (FRGS/1/2020/TK0/UNIMAP/02/109). The grant greatly assisted in the completion of my master's study by providing a monthly research assistance allowance, paying publication fees for papers, and funding the expenses associated with the master's programme. Also not forgetting the equipment and technical support were provided by the Faculty of Electrical Engineering & Technology at Universiti Malaysia Perlis (UniMAP).

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LIST OF ABBREVIATIONS

CCD	Colony Collapse Disorder
BSF	Black Soldier Fly
PET-G	Polyethylene Terephthalate Glycol
PLA	Polylactic Acid
PVC	Polyvinyl Chloride
IoT	Internet of Things
WSN	Wireless Sensor Networks
MFAAF	Magnetic Field Assisted Abrasive Micro Finishing
SoC	System on Chip
IDE	Arduino Integrated Development Environment
ADC	Analogue to Digital Converter
API	Application Programming Interface
FDA	Food and Drug Administration of United State
FDM	Fused Deposition Modeling
PMMA	Poly(methyl methacrylate)
STL	Stereolithography
CNC	Computer Numerical Control
NaCl	Sodium Chloride
FLDa	Fuzzy Logic Designer app
eFLL	Embedded Fuzzy Logic Library
ANOVA	Analysis of variance
ABS	Acrylonitrile Butadiene Styrene

LIST OF SYMBOLS

%	Percentage
mm	Millimeter
°C	Degree Celsius
RH	Relative Humidity
g	Gram
ΔRa	Surface Roughness
A	Ampere

Reka Bentuk Sarang Lebah Kelulut Menggunakan IoT-Kabur Terbenam untuk Menentukan Keadaan Sarang dan Isipadu Madu

ABSTRAK

Pemeliharaan lebah kelulut memberi peluang dan cabaran, dengan kerentanan sarang dan suhu sekitar menjadi ancaman serius terhadap pertumbuhan koloni dan pengeluaran madu. Penyelidikan ini mengatasi cabaran tersebut dengan membangunkan reka bentuk sarang tiruan yang menggabungkan teknologi IoT dan logik kabur untuk tentukan keadaan sarang dan pengeluaran madu. Kajian ini bermula dengan reka bentuk sarang tiruan untuk mengurangkan cabaran diatas. Dengan menggunakan bahan seperti Polietilena Tereftalat Glikol (PET-G), komponen dicetak 3D, dan Polivinil Klorida (PVC), sarang tiruan bertujuan untuk menyediakan persekitaran yang selamat dan kondusif bagi koloni lebah kelulut. Sebanyak lima teknik insulasi dilaksanakan pada sarang tiruan untuk mencapai suhu maksimum yang pernah direkodkan, iaitu 39.4°C. Koloni tiruan yang dilindungi dengan tanah liat menunjukkan penyimpangan piawai kelembapan yang paling kecil, dengan ukuran 0.46. Walau bagaimanapun, memandangkan hubungan yang lebih besar antara suhu dan keselamatan lebah, sarang tiruan aluminium gelembung muncul sebagai pilihan yang lebih baik, disebabkan perbezaan suhu purata tertinggi iaitu 6.4°C di antara bahagian dalam dan luar. Selain itu, integrasi kemampuan IoT (Cayenne myDevice dan ThingSpeak) memudahkan pemantauan secara langsung terhadap parameter sarang seperti suhu, kelembapan, dan berat kompartmen madu. Pengesahan sensor memastikan ketepatan dan kebolehpercayaan dalam pengumpulan data, sementara eksperimen insulasi haba bertujuan untuk mengekalkan keadaan sarang yang optimum, penting untuk kesihatan koloni dan pengeluaran madu. Pelaksanaan logik kabur membolehkan data yang dikumpulkan meramalkan keadaan sarang dan jumlah madu. Selepas pelaksanaan berjaya Logik Kabur Terbenam pada NodeMCU ESP8266, perbandingan dibuat dengan Logik Kabur menggunakan MATLAB. Piawai penyimpangan untuk keadaan sarang dan jumlah madu kedua-duanya kurang dari 0.5, dan kesilapan peratusan purata berada di bawah 1%. Hasilnya, sistem ini menunjukkan dispersi minimal dan ia baik digunakan dalam kajian ini. Bagi menilai keberkesanan sistem logik kabur, yang menggunakan dua output (Keadaan Sarang dan Jumlah Madu) dan tiga input (Berat, Suhu, dan Kelembapan), ujian ANOVA dan plot kotak dilaksanakan. Variasi yang ketara dalam kelembapan dalaman dapat diperhatikan berkaitan dengan kedua-dua keadaan sarang dan jumlah madu. Sebaliknya, suhu kompartmen bervariasi secara ketara hanya dengan jumlah madu, sementara suhu dalaman bervariasi secara ketara hanya dengan keadaan sarang. Secara keseluruhan, penyelidikan ini menyumbang kepada kemajuan amalan pemeliharaan lebah kelulut dengan menyediakan peternak lebah dengan alat dan teknologi untuk meningkatkan pengurusan sarang dan mengoptimakan pengeluaran madu. Dengan memanfaatkan IoT dan logik kabur, peternak lebah dapat membuat keputusan yang berasaskan maklumat dan memaksimumkan hasil madu, akhirnya memastikan kelestarian dan pertumbuhan koloni lebah kelulut.

Artificial Stingless Bee Hive Design Utilizing Embedded Fuzzy-IoT Based Determining Hive Condition and Honey Volume

ABSTRACT

Stingless bee beekeeping presents both opportunities and challenges, with hive vulnerabilities and surrounding temperature posing significant threats to colony growth and honey production. This research addresses these challenges by developing an innovative artificial hive design incorporating IoT technology and fuzzy logic to optimize hive conditions and honey production. The research begins with the design of artificial hives on mitigating these threats through. Utilizing materials like Polyethylene Terephthalate Glycol (PET-G), 3D-printed components, and Polyvinyl Chloride (PVC), the artificial hive aims to provide a safe and conducive environment for stingless bee colonies. A total of five insulation techniques were implemented at artificial hives to achieve the maximum temperature ever recorded, which was 39.4°C. The clay-insulated artificial colonies exhibited the smallest standard deviation of humidity, measuring 0.46. However, given the greater relationship between temperature and bee survival, the bubble aluminium artificial hive emerges as the more favourable choice, due to its highest average temperature differential of 6.4°C between the interior and exterior. Furthermore, the integration of IoT (Cayenne myDevice and ThingSpeak) systems facilitate real-time monitoring of hive parameters such as temperature, humidity, and weight of honey compartment. Validation of sensors ensures accuracy and reliability in data collection, while heat insulation experiments aim to maintain optimal hive conditions, crucial for colony health and honey production. The implementation of fuzzy logic enables the collected data to forecast hive conditions and honey volumes. Following the successful execution of Embedded Fuzzy Logic on NodeMCU ESP8266, a comparison was made with Fuzzy Logic using MATLAB. Standard deviations for hive condition and honey volume are both less than 0.5, and average percentage errors are below 1%. As a result, the system exhibits minimal dispersion and it's good to use in this study. In order to assess the effectiveness of the fuzzy logic system, which utilised two outputs (Hive Condition and Honey Volume) and three inputs (Weight, Temperature, and Humidity), ANOVA tests and box plots were implemented. Significant variations in internal humidity can be observed in relation to both the condition of the hive and the volume of honey. On the contrary, compartment temperature varies substantially only with honey volume, while internal temperature varies substantially only with hive condition. Overall, this research contributes to the advancement of stingless beekeeping practices by providing beekeepers with tools and technologies to enhance hive management and optimize honey production. By leveraging IoT and fuzzy logic, beekeepers can make informed decisions and maximize honey yields, ultimately ensuring the sustainability and growth of stingless bee colonies.

CHAPTER 1 : INTRODUCTION

1.1 Research Background

Stingless bee honey has grown in popularity in recent years due to it is commonly reported that the mineral content of honey correlates to the nutritional value of honey [1]. Stingless bees have reduced vulnerability to diseases and parasites, making them a more sustainable option for honey production [2]. The relatively simple management of stingless bee farming has contributed to its growing popularity among beekeepers. As implied by its name, this bee does not sting making it easier to collect honey, pollen, and propolis as opposed to the extraction of honey from common honey bees, which needs the use of protective gear and training [3].

Kelly et al. [4] discovered that meliponiculture in Kelantan, Malaysia utilised two types of traditional hives, including hollow tree trunks and artificial wood boxes. However, beekeepers frequently experience Colony Collapse Disorder (CCD) on stingless bee colonies using traditional hive. This is because the traditional stingless bee hives are typically crafted from wood trunk, which are potentially vulnerable to invasion due to its perforated structure. Furthermore, temperature and humidity also can cause CCD due if not monitor carefully.

Therefore, this research focuses on design of artificial stingless bee hives specially to prevent from CCD occurred in bee colonies. In addition, this hive is equipped with IoT systems that allow the beekeeper to monitor the hive's condition from anytime. Among the parameters considered in IoT systems are the honey compartment's weight, its internal temperature and humidity, and its external temperature and humidity. To assure the experiment's success, a smart beehive the success of this experiment in preventing CCD, a fuzzy logic algorithm based on IoT system data will be developed to anticipate the condition of the hive and the optimal time for honey harvesting.

1.2 Problem Statement

Originally, beekeepers used wooden blocks that were then equipped with a compartment known as super honey to facilitate honey production. At first glance, producing stingless bees appears to be quite simple, which inspires many to give it a try. Nonetheless, farmers are likely to face a huge of challenges that slow down stingless bee growth. The main issues are when the traditional hive looks perforated and dangerous, it can be caused by a variety of hazard including as predator’s attack, parasites invasion, extreme hive’s temperature and unstable hive’s humidity.

Additionally, stingless bees have several predators and parasites like any other species. Among the predators that will attack these stingless bees are lizards, spiders, ants, wasps, assassin bugs, beetles, and phorid flies [5]. The study conducted by Jaapar M et al. [6] identifies predators and parasites for stingless bees Heterotrigona Itama. The predators of Haterotrigona Itama are Robber flies (Asilidae), Ants (Formicidae), Lynx Spiders (Oxyopidae), and Jumping Spiders (Salticidae), whereas the parasites are the Leafcutting Bee (Megachilidae) and Sap Beetle (Nitudilidae). Megachile Disjuncta, or "Lebah Tapir" in Bahasa, is a parasite that is frequently encountered by stingless beekeepers in Malaysia, and this is very dangerous for the stingless bee colonies. Additionally, there have been reports of parasite attacks, Black Soldier Fly (BSF), and beetles There have been reports of parasite attacks, Black Soldier Fly (BSF), and beetles affecting the production of over 70% of 411 stingless bee farmers in 2016 [7].

The rise in global average temperatures has significant implications for various ecosystems, including beehives. As global warming intensifies, it becomes increasingly challenging to maintain optimal conditions within beehives. According to earlier research, the temperature within beehives should not exceed 38°C and below 22°C to minimise pupae death inside brood cells [8]. Honey pots are composed of beeswax and may melt at high temperatures [9]. If this occurs, the honey floods the honey compartments, impairing the output and quality of the honey.

Another critical factor to consider is the mass of the beehive when determining the performance of the stingless bee colony. However, the characteristics are difficult to precisely measure since the traditional stingless beehive is constructed entirely of thick and heavy wooden blocks, making it impossible to detect even a little variation in measurement using a load cell sensor.

Moreover, the beekeeper faces the inconvenience of having to determine the fullness of the honey pot by opening the hive's topper or cover, which is made more difficult by the variable quantity of honey. Furthermore, the purpose of inspecting the honey pot is to verify that the honey has gone through the process of evaporation inside the hive, resulting in a decrease in moisture content. This is achieved by allowing a month to pass before harvesting [10]. However, this phase may interfere the activities of stingless bee colonies within the hive and could delay honey harvesting. [11].

1.3 Research Objective

This research aims to develop an artificial stingless bee hive that capable of preventing the degeneration of bee growth and monitoring the hive's condition regardless of its location. The following are more specific objectives:

a) To develop an artificial hive for stingless bees into sturdier and more robust, as well as a heat-resistant hive to provide comfort and safe for the bees.

b) To implement an IoT on artificial hive in order to provide real-time monitoring and data collecting regardless of where the hive is located.

c) To analyse the of artificial hive using embedded fuzzy logic to determine whether the hive is in good condition and the honey is ready to be harvested.

1.4 Research Scope

The project's scope is determined by various constraints that collectively shape the framework in which the research is conducted:

a) This study focuses on Heterotrigona Itama, a species of stingless bee commonly found in Southeast Asia.

b) The research is conducted in Robotic Lab, Faculty of Electrical Engineering Technology, Universiti Malaysia Perlis, Perlis, Malaysia,

c) The research parameter are the compartment weight, internal temperature, external temperature, internal humidity and external humidity of artificial hive.

d) The material of Artificial Hive will be made from 3D-Printed Polyethylene Terephthalate Glycol (PET-G) and Polyvinyl Chloride (PVC).

e) This project uses fuzzy logic to assess hive conditions and honey volume based on mass, temperature and relative humidity.

1.5 Summary

The study explores the advancement of artificial hives designed for stingless bees, with a particular focus on the Heterotrigona Itama species that is prevalent throughout Southeast Asia. The study focusses on the challenges associated with traditional wooden hives in stingless bee farming, including their vulnerability to predators, parasites, extreme temperatures, and humidity fluctuations. This is in response to the increasing popularity and sustainability of stingless bee farming, which is attributed to their reduced susceptibility to diseases and the ease of collecting honey.

In order to address these difficulties, the research project seeks to develop a sturdier and heat resistant artificial beehive by utilising 3D-printed materials such as PET-G, PVC and some of the heat resist materials and methods. The project also incorporates an Internet of Things-based monitoring system to deliver real-time data on hive parameters, including as internal and internal of temperature and relative humidity, and the mass of the honey compartment. The system employs fuzzy logic to determine the condition for hive and the honey volume, to minimising the risk of Colony Collapse Disorder (CCD) and guaranteeing the efficiency of bee colonies.

The research is carried out in the Robotic Lab at the Faculty of Electrical Engineering Technology, Universiti Malaysia Perlis, and aims to provide a geographical perspective on the influence of regional conditions on populations of stingless bees. The study focusses on analysing important elements necessary for maintaining healthy artificial hive habitats and implementing cutting-edge technologies to improve beekeeping practices.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

Researchers, notably in the region of Southeast Asia, have grown an attraction in stingless bees in recent years. Several research were undertaken to assess the influence of stingless beehive behaviour on colony health and honey production. This research is critical for maintaining the health of stingless bees on farms. This will prevent stingless bees from foraging further from their wild hives in the jungle, while also increasing their honey production.

Before making any preparations for this project, it is necessary to conduct study regarding the features for stingless bees. Therefore, a comprehensive analysis was conducted on previous studies about the morphology of stingless bees, the structure of their hives, the death rates of stingless bees, as well as their predators and parasites. These studies can assist in the identification of stingless bees in greater detail. Besides, in order to safely transfer stingless bee colonies from traditional hives to artificial hives and to prevent colony collapse during the colony transfer procedure, colony division methods are also studied.

In addition, the research is conducted on the creation of artificial hives without the use of wooden logs, which might lead to extensive deforestation. These investigations also indicate that it is compatible with the sensors that will be employed, such as DHT22 and load cells. Simultaneously, methods for mounting sensors on artificial nests were explored in order to determine where and how sensors would be installed on artificial hives.

Next is a study on the implementation of the IoT system, which will enable beekeepers to monitor the condition of the hive without having to approach it or open it. These analyses facilitate the selection of the most suitable IoT platform for this project and its implementation.

Last but not least, Studies on the use of fuzzy logic to beehives have been conducted. The use of fuzzy logic to standard beehives constitutes the first research article. This article is analysed to see if the input and output are most suitable for use in developing a fuzzy logic algorithm for detecting the status of the hive. Afterwards, several publications on applications of fuzzy logic were reviewed to determine how to evaluate the performance of an embedded fuzzy logic.

2.2 Stingless Bee

Meliponini is the family of stingless bees, and Melipona, Trigona, and Heterotrigona Itama are subfamilies of this family [12]. Regular honeybees use stinging for defence, while stingless bees use biting when disturbed [13]. A solitary nest of stingless bees, referred to as Trigona bees, can accommodate colonies consisting of thousands of individuals. In a bee colony, there are various hierarchical levels inside a bee colony, including the queen, male bees, worker bees, and baby bees [14]. Cultivating stingless bees is simple and does not require a large financial investment.