Pertanika Proceedings 1 (3): 1 - 8 (2025)

PERTANIKA PROCEEDINGS

Journal homepage: http://www.pertanika.upm.edu.my/

A Conceptual Model of Diagnostic System for Monitoring Stingless Bee Colony Rehabilitation

Yang Lejing[1], Rozi Nor Haizan Nor[1]*, Yusmadi Yah Jusoh[1], Noreha Abdul Malik[2], Wan Nur Asiah Wan Mohd Adnan[3]

[1]Department of Software Engineering and Information Systems, Faculty of Computer Science and Information Technology, Universiti Putra Malaysia (UPM), 43400 Serdang, Selangor, Malaysia
[2]Department of Electrical and Computer Engineering, Faculty of Engineering, International Islamic University Malaysia (IIUM), 53100 Gombak, Selangor, Malaysia
[3]Department of Plant Protection, Faculty of Agriculture, Universiti Putra Malaysia (UPM), 43400 Serdang, Selangor, Malaysia

ABSTRACT

The role of stingless bee colonies in ecosystems is crucial, especially their contribution to pollination. However, these bee colonies face multiple threats, such as disease and environmental changes, which could affect their health and numbers. Therefore, it is particularly important to monitor and maintain these colonies to support the stability of the ecosystem and the sustainable development of agriculture. To address this challenge, this paper proposes a new diagnostic system model designed to monitor and promote the rehabilitation of stingless bee colonies. Model of a diagnostic system for monitoring the stingless bee colony rehabilitation. The system uses a DHT11 sensor to monitor temperature and humidity, a load cell to track the hive's weight, and a force sensor to detect pressure or possible intrusion. Preliminary results show that the system can effectively capture key environmental parameters, providing valuable insights into the rehabilitation process. The findings provide avenues for further research and development of more robust monitoring solutions. This study's key contribution is combining advanced electronic information engineering techniques with ecological knowledge from previous literature. The proposed conceptual framework is an application of technical tools and a comprehensive approach to understanding and protecting these important ecosystem components. The findings highlight the importance of environmental factors for stingless bee rehabilitation and overall colony health. Environmental parameters such as temperature, humidity, and air quality are critical to the survival and development of bee colonies, directly affecting their reproduction, food supply, and disease transmission.

Keywords: Colony rehabilitation, diagnostic system, disease image processing, environment, machine learning, stingless bees

ARTICLE INFO

Article history:
Received: 30 April 2025
Published: 17 July 2025

DOI: https://doi.org/10.47836/pp.1.3.001

E-mail addresses:
yanglejing955@gmail.com (Yang Lejing)
rozinor@upm.edu.my (Rozi Nor Haizan Nor)
yusmadi@upm.edu.my (Yusmadi Yah Jusoh)
norehaa@iium.edu.my (Noreha Abdul Malik)
asiahwan@gmail.com (Wan Nur Asiah Wan Mohd Adnan)
* Corresponding author

e-ISSN: 3083-9475

INTRODUCTION

Meliponini (Apidae: Meliponini) are important pollinators in tropical and subtropical regions and contribute to agriculture and biodiversity (Jaffe et al., 2015; Toledo-Hernandez et al., 2022). They are adaptable, reproducible, and produce economically valuable products such as honey and propolis (Toledo-Hernandez et al., 2022). However, habitat loss, pesticides, climate change, and disease threaten stingless bee populations (Gilbert, 2016; Hashim et al., 2022), requiring ongoing management and protection. To monitor stingless colonies, studies have employed non-invasive methods such as analyzing honey, pollen, and propolis, using techniques such as acoustic signals, thermal imaging, Radio-Frequency Identification (RFID) tags, and others to assess population health and productivity (Anuar et al., 2020; Hrncir et al., 2019; Nunes-Silva et al., 2019). However, these methods are costly and have poor accuracy, so more economical and accurate techniques are needed. This paper proposes a stingless beehive monitoring system that combines sensors, image processing, and machine learning, aiming to provide beekeepers and researchers with immediate and accurate hive health information, promoting early intervention and management optimization. The system adopts a Model-View-Controller (MVC) architecture to efficiently process and manage data (Schneider et al., 2012).

LITERATURE REVIEW

Recent research has focused on managing and conserving bees and stingless bees. Bilik et al. (2021) developed a real-time visual diagnostic system to monitor bee colony health; Jaffe et al. (2015) explored management practices to optimize stingless bee culture in Brazil; Rosli et al. (2022) proposed a honeycomb monitoring system based on the Internet of Things (IoT). Schneider et al. (2012) used RFID to assess the impact of pesticides on bees. Ismail (2016) reviewed the challenges of beekeeping in Malaysia and recommended developing industry standards; Hadjur et al. (2022) explored the application of IoT in precision beekeeping. As bee populations decline, technological innovation offers a solution. Miskon et al. (2022) developed a stingless bee monitoring system based on LoRa (Long Range) to monitor bee colony health in real time. Zaman and Dorin (2023) proposed a hive health monitoring framework. Radaeski and Bauermann (2021) studied the effects of plant resources on bee colonies. Becher et al. (2013) proposed a system model to study the mechanism of bee colonies coping with stressors. Anuar et al. (2023) developed a Firebase-based IoT system to monitor honeycomb status; Jailis et al. (2022) built a honeycomb monitoring system with Arduino and DHT22 sensors. These technologies drive advances in stingless bee farming and contribute to sustainable development. Research has recently focused on using advanced technologies to improve hive management and bee behavior monitoring. Anuar et al. (2021) developed an integrated wireless system to monitor colony environmental changes and their effects on behavior; Aumann et al. (2021)

proposed Janus sensor to accurately identify bee activities; Braga et al. (2020) use machine learning to analyze honeycomb states and predict risks; Cecchi et al. (2020) used sensors to reveal the relationship between bee colonies and their environment. The convergence of technologies has also facilitated the development of colony monitoring systems. Cunha et al. (2001) proposed an Internet-based system to track the impact of environmental factors on bees in real time. Edmund and Rahman (2021) developed an intelligent stingless beehive monitoring system; Cota et al. (2023) designed low-cost IoT systems; Jiang et al. (2016) designed a system based on a wireless sensor network (WSN) to accurately monitor the relationship between bee activities and the environment.

FINDINGS

Conceptual Stingless Bee Colony Rehabilitation Monitoring and Diagnosis System Model

Developing a stingless colony rehabilitation monitoring system, with electronic information technology and ecological research, aims to provide beekeepers and researchers with tools to assess colony health and rehabilitation progress. Stingless bees are important native pollinators in tropical ecosystems and are critical for maintaining biodiversity and ecological services (Toledo-Hernandez et al., 2022). However, external factors such as invaders, food, climate change, and internal factors such as queen and larval health put global stingless bee populations at risk of decline (Lail, 2021; Miskon et al., 2022). Therefore, monitoring and protecting stingless bee colonies is crucial. Colony health is affected by temperature, humidity and air quality. Precise temperature and humidity control are essential for larval health and colony functioning. Hive ventilation helps manage these environmental factors to ensure colony health. Understanding the relationship between these factors and colony recovery is critical to the persistence and robustness of stingless bees. This model shows the relationship between environmental factors and the recovery of a stingless colony (Figure 1).

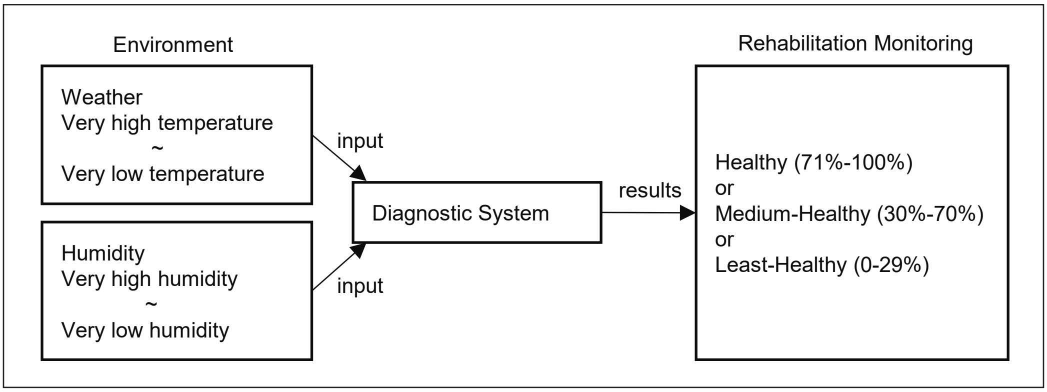

Figure 1. Diagnostic model of environmental aspects for monitoring the stingless bee colony rehabilitation

A Model View-Controller (MVC) architecture was developed to integrate user interaction, knowledge acquisition and expert decision process to enhance stingless bee monitoring and recovery. The diagnostic module allows users to intuitively judge colony health problems, such as queen bees, worker bees, temperature and humidity, and provide corresponding solutions. The system is integrated through sensor nodes, image devices, and machine learning models to process data in real time and provide feedback to beekeepers (Jaffe et al., 2015). The system combines sensors, image processing and machine learning to create a comprehensive colony monitoring and diagnosis model that helps detect anomalies on time and provides scientific evidence. This is the diagnostic model system (Figure 2).

Data preparation involves collecting and processing data on variables required for monitoring a stingless colony, such as temperature, humidity, and hive weight. It is necessary to select the appropriate sensor and data acquisition system to ensure the data's accuracy, reliability and real-time, and to store and back up the data. Hive health was assessed by the degree of pollen expansion: healthy hive pollen expansion 71%–100%, moderately healthy hive pollen expansion 30%–70%, and least healthy hive with less than 30% expansion and low activity (Ramli et al., 2021). This module shows the rehabilitation monitoring of the proposed system (Figure 3).

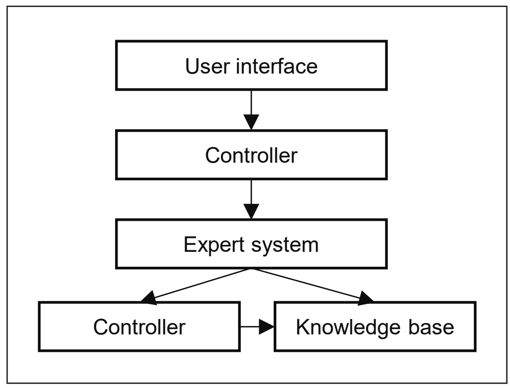

Figure 2. Diagnostic module for the proposed system

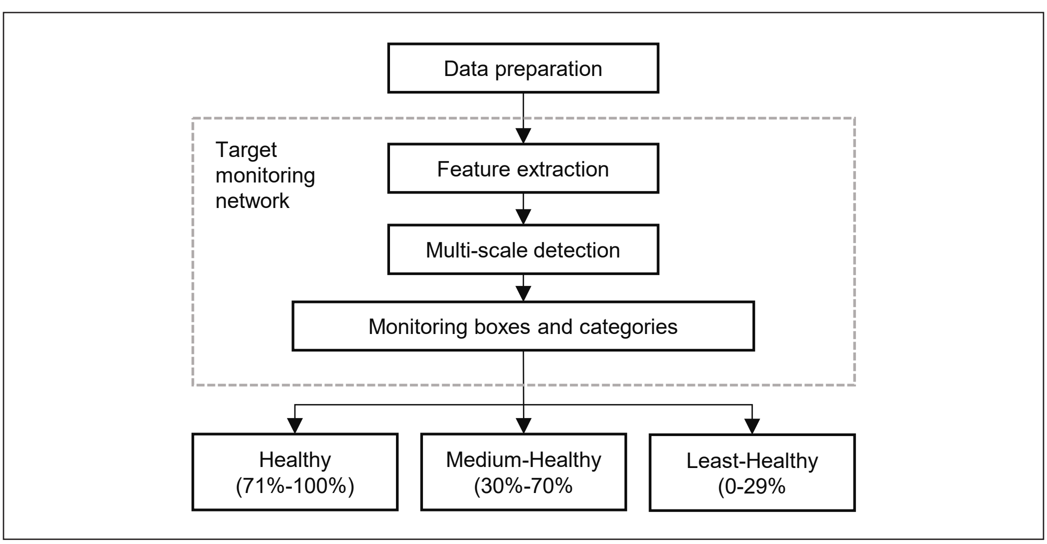

Figure 3. Rehabilitation monitoring module for the proposed system

The diagnostic system is designed to be simple and effective. It uses a DHT11 sensor to monitor the hive's temperature and humidity (Figure 4), a weighing sensor to track its weight to provide nectar and honey data, and a force sensor to detect abnormal pressure changes to indicate intrusion or structural problems.

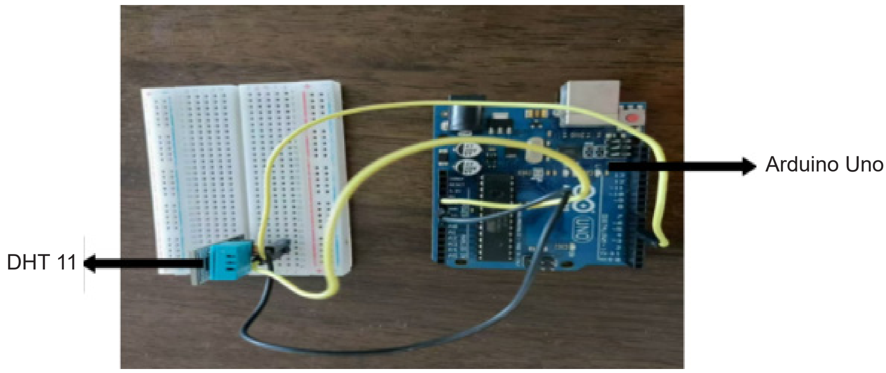

Figure 4. The DHT11 sensor circuit prototype

RESULTS

The diagnostic system effectively captures environmental parameters such as temperature, humidity, weight and pressure to provide data support for colony health. The study demonstrated the ability of the system to help beekeepers maintain sustainable bee colonies, and the future should optimize sensor integration and explore more environmental factors. The model combines sensing technology, machine learning and data evaluation to drive technological advances in beekeeping and support sustainable agriculture.

ACKNOWLEDGEMENT

We sincerely appreciate the support and provision of essential resources from Universiti Putra Malaysia (UPM) and the Faculty of Computer Science and Information Technology (UPM), which significantly contributed to the development of this project.

REFERENCES

Anuar, N. H. K., Yunus, M. A. M., Baharudin, M. A., Ibrahim, S., Sahlan, S., Hashem, M. Y. B., & Siddique, M. A. (2023). Data management system of IoT for stingless bee monitoring. *AIP Conference Proceedings 2795*(1), Article 030004. https://doi.org/10.1063/5.0121003

Anuar, N. H. K., Yunus, M. A. M., Baharudin, M. A., Ibrahim, S., & Sahlan, S. (2021). Embedded wireless stingless beehive monitoring and data management system. In *2021 IEEE International*

Conference in Power Engineering Application (ICPEA) (pp. 149-154). IEEE. https://doi.org/10.1109/ICPEA51500.2021.9417758

Anuar, N. H. K., Yunus, M. A. M., Baharudin, M. A., Ibrahim, S., & Sahlan, S. (2021). Embedded wireless stingless beehive monitoring and data management system. In *2021 IEEE International Conference in Power Engineering Application (ICPEA)* (pp. 149-154). IEEE. https://doi.org/10.1109/ICPEA51500.2021.9417758

Aumann, H. M., Aumann, M. K., & Emanetoglu, N. W. (2021). Janus: A combined radar and vibration sensor for beehive monitoring. *IEEE Sensors Letters, 5*(3), Article 1500204. https://doi.org/10.1109/LSENS.2021.3056870

Becher, M. A., Osborne, J. L., Thorbek, P., Kennedy, P. J., & Grimm, V. (2013). Towards a systems approach for understanding honeybee decline: a stocktaking and synthesis of existing models. *Journal of Applied Ecology, 50*(4), 868-880. https://doi.org/10.1111/1365-2664.12112

Bilik, S., Kratochvila, L., Ligocki, A., Bostik, O., Zemcik, T., Hybl, M., Harok, K., & Zalud, L. (2021). Visual diagnosis of the varroa destructor parasitic mite in honeybees using object detector techniques. *Sensors, 21*(8), 2764. https://doi.org/10.3390/s2108276.

Braga, A. R., Gomes, D. G., Rogers, R., Hassler, E. E., Freitas, B. M., & Cazier, J. A. (2020). A method for mining combined data from in-hive sensors, weather and apiary inspections to forecast the health status of honey bee colonies. *Computers and Electronics in Agriculture, 169*, Article 105161. https://doi.org/10.1016/j.compag.2019.105161

Cecchi, S., Spinsante, S., Terenzi, A., & Orcioni, S. (2020). A smart sensor-based measurement system for advanced bee hive monitoring. *Sensors, 20*(9), Article 2726. https://doi.org/10.3390/s20092726

Cota, D., Martins, J., Mamede, H., & Branco, F. (2023). BHiveSense: An integrated information system architecture for sustainable remote monitoring and management of apiaries based on IoT and microservices. *Journal of Open Innovation: Technology, Market, and Complexity, 9*(3), Article 100110. https://doi.org/10.1016/j.joitmc.2023.100110

Cunha, R. S. D., Saraiva, A. M., Cugnasca, C. E., Hirakawa, A. R., Imperatriz-Fonseca, V. L., & Hilário, S. D. (2001). An internet-based monitoring system for behaviour studies of stingless bees. *Proceedings of the Third European Conference of the European Federation for Information Technology in Agriculture, Food and the Environment 1*, 279-284.

Edmund, C., & Rahman, M. A. (2021). Smart stingless beehive monitoring system. In R. Alfred, H. Lida, H. Haviluddin & P. Anthony (Eds.) *Computational Science and Technology: 7th ICCST 2020* (pp. 537-549). Springer.

Gilbert, N. (2016). Global biodiversity report warns pollinators are under threat. *Nature News 2016*, Article 19456. https://doi.org/10.1038/nature.2016.19456

Hadjur, H., Ammar, D., & Lefèvre, L. (2022). Toward an intelligent and efficient beehive: A survey of precision beekeeping systems and services. *Computers and Electronics in Agriculture*, *192*, Article 106604. https://doi.org/10.1016/j.compag.2021.106604.

Hashim, S., Nassir, C. M. N. C. M., Zarim, M. H. A., Kamaruzaman, K. A., Halim, S. A., Mohamed, M., & Mustapha, M. (2022). The cerebral plasticity prospect of stingless bee honey-polyphenols supplementation in rehabilitation of post-stroke vascular cognitive impairment. In P. Sanchetee (Ed.) *Post-Stroke Rehabilitation* (pp. 103135). IntechOpen. https://doi.org/10.5772/intechopen.103135

Hrncir, M., Maia-Silva, C., Silva Teixeira-Souza, V. H. D., & Imperatriz-Fonseca, V. L. (2019). Stingless bees and their adaptations to extreme environments. *Journal of Comparative Physiology A, 205*(3), 415-426. https://doi.org/10.1007/s00359-019-01327-3

Ismail, W. I. W. (2016). A review on beekeeping in Malaysia: History, importance, and future directions. *Journal of Sustainable Science and Management, 11*, 70–80.

Jaffe, R., Pope, N., Carvalho, A. T., Maia, U. M., Blochtein, B., Carvalho, C. A. L. D., Carvalho-Zilse, G. A., Freitas, B. M., Menezes, C., Ribeiro, M. D. F., Venturieri, G. C., & Imperatriz-Fonseca, V. L. (2015). Bees for development: Brazilian survey reveals how to optimize stingless beekeeping. *PloS one, 10*(3), Article e0121157. https://doi.org/10.1371/journal.pone.0121157.

Jailis, B. A., Kiring, A., Yew, H. T., Barukang, L., Farm, Y. Y., & Wong, F. (2022). A real-time web-based monitoring system for stingless bee farming. In *2022 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET)* (pp. 1-5). IEEE. https://doi.org/10.1109/IICAIET55139.2022.9936841

Jiang, J. A., Wang, C. H., Chen, C. H., Liao, M. S., Su, Y. L., Chen, W. S., & Chuang, C. L. (2016). A WSN-based automatic monitoring system for the foraging behavior of honey bees and environmental factors of beehives. *Computers and Electronics in Agriculture, 123*, 304-318. https://doi.org/10.1016/j.compag.2016.03.003

Lail, M. Y. I., (2021). *Movices architecture for meliponiculture diagnostic application system development* [Unpublished master thesis]. Universiti Putra Malaysia.

Miskon, M. T., Razak, M. A. A., Jaafar, H., Hassan, N., & Mahmood, R. (2022). A lora-based testbed development for stingless bee monitoring system. *TEM Journal*, *11*(2), 712.

Nunes-Silva, P., Hrncir, M., Guimarães, J. T. F., Arruda, H., Costa, L., Pessin, G., Siqueira, J. O., Souza, P. D., & Imperatriz-Fonseca, V. L. (2019). Applications of RFID technology on the study of bees. *Insectes Sociaux, 66*(1), 15-24. https://doi.org/10.1007/s00040-018-0660-5

Radaeski, J. N., & Bauermann, S. G. (2021). Contributions to melissopalynology studies in southern Brazil: pollen analysis in the honeys from Apis mellifera, Tetragonisca angustula, Melipona quadrifasciata quadrifasciata, Scaptotrigona bipunctata, Plebeia remota and Plebeia droryana. *Palynology, 45*(3), 477-486. https://doi.org/10.1080/01916122.2020.1869113

Ramli, M. F., Harun, A., Ismail, R. C., Ndzi, D. L., Turner, J., Farook, R. S. M., & Murad, S. A. Z. (2021). Design and development of stingless beehive air pollutant monitoring system. *International Journal of Nanoelectronics & Materials, 14*(Special Issue), 265-278.

Rosli, H. A., Malik, N. A., & Ahmad, Y. A. (2022). IoT based monitoring system for stingless bees colony in IIUM. *Journal of Physics: Conference Series, 2312*(1), Article 012088. https://doi.org/10.1088/1742-6596/2312/1/012088

Schneider, C. W., Tautz, J., Grünewald, B., & Fuchs, S. (2012). RFID tracking of sublethal effects of two neonicotinoid insecticides on the foraging behavior of Apis mellifera. *PloS one, 7*(1), Article e30023. https://doi.org/10.1371/journal.pone.0030023.

Toledo-Hernandez, E., Pena-Chora, G., Hernandez-Velazquez, V. M., Lormendez, C. C., Toribio-Jimenez, J., Romero-Ramirez, Y., & Leon-Rodriguez, R. (2022). The stingless bees (Hymenoptera: Apidae: Meliponini): A review of the current threats to their survival. *Apidologie, 53*(1), Article 8. https://doi.org/10.1007/s13592-022-00913-w

Zaman, A., & Dorin, A. (2023). A framework for better sensor-based beehive health monitoring. *Computers and Electronics in Agriculture, 210*, Article 107906. https://doi.org/10.1016/j.compag.2023.107906