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MOVICES ARCHITECTURE FOR MELIPONICULTURE DIAGNOSTIC APPLICATION SYSTEM DEVELOPMENT

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MOVICES ARCHITECTURE FOR MELIPONICULTURE DIAGNOSTIC APPLICATION SYSTEM DEVELOPMENT

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

MOVICES ARCHITECTURE FOR MELIPONICULTURE DIAGNOSTIC APPLICATION SYSTEM DEVELOPMENT

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April 2021

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Stingless beekeeping or meliponiculture is a growing phenomenon in Malaysia. It has a bright prospect in the agriculture sector where farmers can generate high income from it. Stingless beekeepers currently face problems in rehabilitating weakened stingless bee colonies, which they failed to rehabilitate most of these colonies. It is vital to have effective aids to help them to rehabilitate the weakened colonies. Hence, this study aimed to determine an appropriate borescope-based diagnostic application system, Dr. Kelulut, to rehabilitate domesticated stingless bee colonies in Malaysia. Due to this, an investigation on the effectiveness of weakened colonies rehabilitation in Malaysia was conducted. Interviews, nest inspection experiments and the development of Dr. Kelulut were carried out to achieve the study objectives.

The Model-View-Controller (MVC) framework for expert system (MoViCES) architecture had been developed and used for Dr. Kelulut. This expert system verified the usability of MoViCES architecture. The system's structure can be illustrated in one diagram instead of two different diagrams from this architecture. The study finds that the effective technique for stingless bee hive inspection using a borescope is minimal surgery. Any symptoms found from the inspection can be diagnosed through Dr. Kelulut. Based on correctness evaluation, the diagnosis function of Dr. Kelulut is 81.7%. It shows that this system is most of the time identifying the colony problem correctly.

The study concludes that the MoViCES architecture is useful in expert system development. The borescope inspection technique and Dr. Kelulut are effective combination diagnostic tools for rehabilitating domesticated stingless bee colonies in Malaysia. By using the combination tool, stingless beekeepers can prevent the stingless bee colonies from collapsing. Further, the weakened

stingless bee colonies can be effectively rehabilitated. Therefore, it is highly suggested that the combination of the inspection technique and Dr. Kelulut should be introduced to the stingless beekeepers in Malaysia.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

SENIBINA MOVICES UNTUK PEMBANGUNAN SISTEM APLIKASI DIAGNOSTIK MELIPONILUTUR

Oleh

IZATUL LAIL BIN MOHD YASAR

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Pengerusi : Rozi Nor Haizan Binti Nor, PhD
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Penternakan lebah kelulut atau umumnya dikenali sebagai meliponikultur adalah fenomena baru yang semakin meningkat di Malaysia. Meliponikultur mempunyai prospek cerah di sektor pertanian di mana petani dapat menjana pendapatan lumayan daripadanya. Pada masa ini, penternak lebah kelulut menghadapi masalah dalam pemulihan koloni lebah kelulut, yang mereka gagal pulihkan sebahagian besar koloni yang lemah. Oleh itu, kajian ini bertujuan untuk menentukan sistem diagnostik berasaskan borescope, Dr. Kelulut yang sesuai untuk pemulihan koloni lebah kelulut ternak di Malaysia. Selain itu, penyelidikan mengenai keberkesanan pemulihan koloni yang lemah di Malaysia telah dijalankan. Untuk mencapai objektif ini, temuramah, eksperimen pemeriksaan sarang dan pembangunan Dr. Kelulut telah dilaksanakan.

Dalam pembangunan Dr. Kelulut, seni bina *Model-View-Controller (MVC) for expert system* (MoViCES) telah dibangunkan dan digunakan. Dr. Kelulut telah mengesahkan kebolehgunaan seni bina MoViCES. Struktur sistem pakar dapat digambarkan dalam satu rajah sahaja berbanding dua rajah yang berbeza seperti sebelum ini. Kajian mendapati bahawa teknik yang berkesan untuk pemeriksaan sarang lebah kelulut menggunakan borescope ialah teknik yang dinamakan pembedahan surgeri minimum. Segala gejala yang didapati dari pemeriksaan dapat didiagnosis melalui sistem diagnostik yang dibangunkan dan disahkan dalam kajian ini. Dari penilaian kebenaran, purata hasil penggunaan fungsi diagnosis dalam sistem diagnostik adalah 81.7% benar. Ini menunjukkan, sistem diagnostik selalunya mengenal pasti masalah koloni dengan betul.

Kajian ini menyimpulkan kebolehgunaan seni bina MoViCES oleh pengaturcara dalam pembangunan sistem pakar dalam kerangka MVC. Teknik pemeriksaan borescope dan Dr. Kelulut didapati sebagai kombinasi alat diagnostik yang

berkesan untuk membantu memulihkan koloni lebah kelulut di Malaysia. Penternak lebah kelulut dapat mencegah koloni lebah kelulut daripada runtuh dan memulihkan secara berkesan koloni lebah kelulut yang lemah setelah menggunakan gabungan alat ini. Oleh itu, sangat disarankan agar kombinasi teknik pemeriksaan dan Dr. Kelulut diperkenalkan kepada peternak lebah kelulut di Malaysia.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Declaration by graduate student

I hereby confirm that:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS

AAN	Artificial Neural Network
CBS	Case-Based Reasoning
CCD	Colony Collapsed Disorder
CMOS	Complementary metal-oxide semiconductor
CT Scan	Computerized tomography scan
GA	Genetic Algorithm
ICM	Intelligent Computing Model
ICT	Information and Communication Technology
KBS	Knowledge-Based System
MARDI	Malaysian Agricultural Research and Development Institute
MBR	Model-Based Reasoning
MoViCES	Model-View-Controller for Expert System
MVC	Model-View-Controller
PVC	Polyvinyl chloride
RBS	Rule-Based Reasoning
SDLC	Software Development Life Cycle
WSN	Wireless Sensor Network

CHAPTER 1

INTRODUCTION

1.1 Overview

Stingless beekeeping or known as meliponiculture, is a new phenomenon in Malaysia. Meliponiculture provides high income for stingless beekeepers, same as honey beekeeping or apiculture. Meliponiculture has shown exponential growth in 2010 (Mohd Fahimee et al., 2012). As published in local newspapers (BERNAMA 2018), income generated by meliponiculture was RM300 million a year, involving 6,000 stingless beekeepers and 60,000 stingless bee colonies.

Agriculture-related government agencies actively promote meliponiculture as an alternative to boost high income in the agriculture-based industry. The private sector and non-governmental organizations could work side by side with the government to secure the sustainability of meliponiculture in the country. As reported in the local newspaper, a few stingless beekeepers have successfully generated high income, making more people interested in becoming stingless beekeepers.

Just like other agricultural sectors, meliponiculture has its exceptions. The riskiest obstacle is colony collapse. Predators, parasites and colony infestation are well-known threats for stingless bees, which causes colony disintegration apart from a human error like mishandling by the stingless beekeepers. Without practical diagnostic tools and sufficient studies in meliponiculture, stingless beekeepers could fail to rehabilitate many weakened colonies and be unable to prevent the domesticated colony from becoming weak.

Another big challenge is to add more colonies without cutting down trees in those areas. Meliponiculture should remain eco-friendly. When more colonies collapsed, stingless beekeepers had to cut down more trees, of which some were very precious, to replace the weakened colony. Even, they had already fallen many precious trees before when they started the meliponiculture project. This action will prompt meliponiculture as one major cause of deforestation. Stingless beekeepers should practice proper colony duplication and design natural nest traps to help minimize cutting trees though this approach is unpopular.

All these challenges indicate the importance to train stingless beekeepers and producing an effective diagnostic tool. They shall be enrolled in special designated courses or training to face imminent challenges since meliponiculture studies are still new and continue to develop. The meliponiculture knowledge has been booming since 2012(Mustafa, et al., 2018). Hence, stingless beekeepers have to upgrade their knowledge from time to time regardless of the lack of studies and references in meliponiculture repository constraints.

1.2 Research Motivation

Problems inside stingless bee nests are hidden from sight in the honey box system, the most popular technique among Malaysian stingless beekeepers. Stingless beekeepers and meliponiculture domain experts cannot know the real problem faced by the colonies unless they split the log containing stingless bee nests to see what happened to the colony.

Currently, investigating colony problems is performed through visual or site evaluation on traffic activity at the nest entrance and examining the honey box shape while investing real problems that could occur inside the nest. Most of the time, stingless beekeepers cut the log amid crucial declining movements to determine the problem. When the flyout and fly in traffic at the nest entrance was slowed down dramatically, and the inside honey box condition looked not many workers, the stingless beekeepers split the log to inspect the problem. Then, they will transfer the colony into a hive box (Yaacob 2015b). At this stage, the colony may fail to save if the problems had been reached at the final stage. This method is considered less effective because problems inside the nest have been invisible from sight since early.

Besides, there are limited available knowledge base repositories, expert systems or decision support systems in meliponiculture. These tools are essential to help develop well-trained stingless beekeepers and help them in wise decision-making to rehabilitate the weak colonies, especially in Malaysia. They frequently attend paid courses to stay up-to-date about the latest knowledge in meliponiculture. The meliponiculture domain expert always asked to come to stingless bee farms nationwide to inspect their colonies problems and later recommend how to solve them. They need to come to the farm because phone calls and online discussions cannot accurately picture the problems to help the expert recommend the best solution. However, this small group of field experts were unable to cater nationwide support.

The challenges facing such a sector, stingless beekeepers will have to buy meliponiculture handbooks from experienced stingless beekeepers and experts. Usually, these books did not include the related information on how to rehabilitate the weakened colonies and lacked information about preventing colonies from becoming weak. Malaysian Agricultural Research and Development Institute (MARDI) has introduced a mobile application on the meliponiculture manual at the end of 2014 (MARDI Apps 2014). Still, this application did not include reliable information about rehabilitating the weakened colony and preventing the colony from various problems.

Another knowledge resource for them is an online blog and discussion with other stingless beekeepers through social media, un-supervised by the meliponiculture domain expert (Yaacob, 2015b; Yaacob, 2015a; Jalil, 2015). They often discuss their faced problems in meliponiculture related groups on social media like Facebook and WhatsApp. However, there is a lack of meliponiculture domain experts involved frequently. Amateurs have recommended solving the problem based on their experiences and assumptions without support from scientific research. The effects, indeed they cannot decrypt the issues, or the worse their problems become more complicated such as the weakened colonies were lastly collapsed by mishandled. These situations can have a bad influence on the sustainability of meliponiculture in Malaysia.

In 2016, about 1,200 stingless beekeepers produced 120,000 kg of stingless bee honey annually from 60,000 domesticated colonies (Utusan Malaysia, 2016). In August 2016, a report in the newspaper said about 2,600 domestic stingless bee colonies were collapsed nationwide due to pest infestation make a deficit of RM2.4 million (BERNAMA 2016). Researchers have investigated the cause of the mass infestation of pests in colonies of domesticated stingless bees (Hashim, et al., 2017). They found the primary pest was a black soldier fly (*Hermetia illucens*), which has never become a significant threat to stingless bee colonies worldwide. This situation should not happen if Malaysia aims to make meliponiculture as a sustainable industry.

So, action to help stingless beekeepers maintains the health of the domesticated stingless bee colonies is vital. Before this, a few potential industries in agriculture for high income were collapsed due to various problems. There are catfish farming, worm rearing, Boer goat farming and leech rearing. One of the expert system types, the diagnostic application system, may help stingless beekeepers diagnose the problem faced by the stingless bee colonies.

The expert system architecture, as shown in Figure 1.1 was introduced in the development of the MyCIN System in 1984. Since then, this architecture has been referenced to portray the architecture of the expert system.

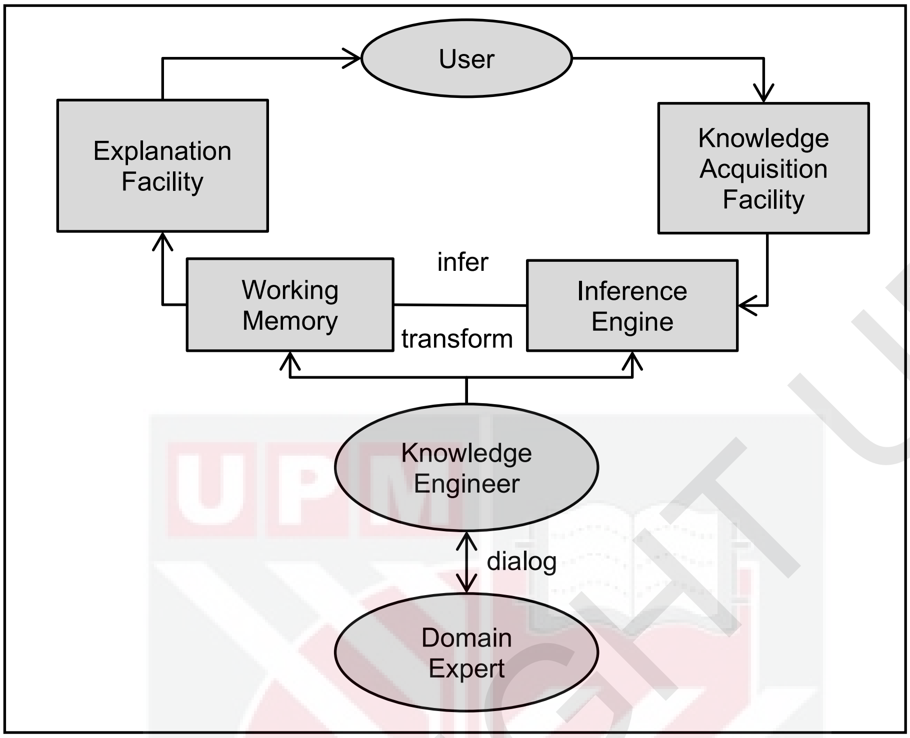

Figure 1.1 : Expert System Architecture

The expert system architecture consists of four interrelated components: the knowledge acquisition facility, inference engine, working memory, and explanation facility. Three actors are involved in the architecture: the user, knowledge engineer and domain expert. The knowledge engineer will discuss with the domain expert to collect the expert knowledge. Then, the knowledge engineer will transform the expert knowledge into the system by using the working memory and the inference engine. The user will use the knowledge acquisition facility to ask a question to the expert system. Then, the inference engine will process the user input based on the rules in the working memory. Finally, the explanation facility will present the answer to the user(Buchanan and Shortliffe 1984).

In 1988, a software design pattern, namely Model-View-Controller or MVC, was introduced. MVC is divided into three interrelated components: the model, controller, and view, as shown in Figure 1.2(Krasner and Pope 1988). The user will use the controller to request something from the system. The controller contains the interface between their associated models, views and input devices such as keyboard and mouse. The controller will manipulate the model, including the complex or straightforward domain-specific simulation or implementation of the application's central structure. The model will then update the view component. The view, which consists of a graphical display of the software, will finally respond to the user request.

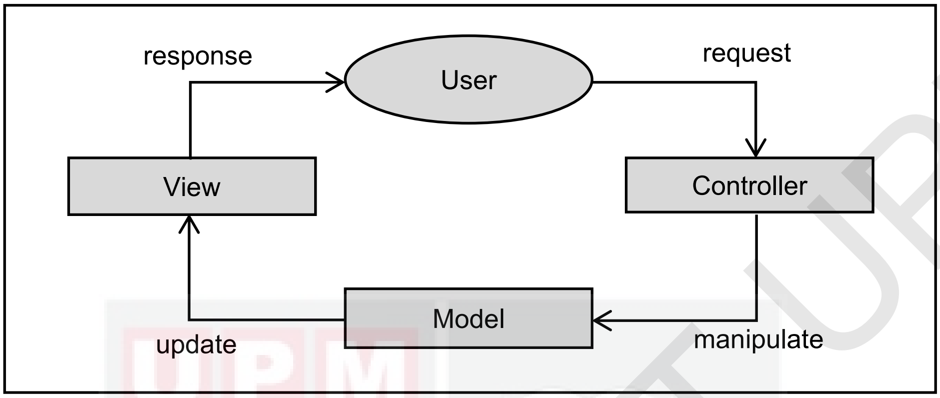

Figure 1.2 : Model-View-Controller framework

In the development of an expert system, the architecture and framework can be used together. But with more than 30 years, there is a question, whether the architecture is still relevant and did not evolve when the expert system was developed by using the MVC framework.

Based on the problem background discussed above, these are the research motivations to conduct this research:

1. What is the current status of the weakened stingless bee colony rehabilitation in Malaysia?
2. What is the effective technique to inspect the nest condition of the domesticated stingless bee colony?
3. Is there any diagnostic application system to diagnose stingless bee colony problems based on symptoms found?
4. Are there any changes in expert system architecture when the expert system is developed using the MVC framework?

1.3 Research Objectives

From the research motivations, the research objectives are:

1. To identify the current rehabilitation status of a weakened stingless bee colony domesticated in Malaysia.
2. To determine an effective technique in using a borescope to diagnose the problem inside a domesticated stingless bee nest.
3. To develop new expert system architecture

4. To develop a diagnostic application in meliponiculture as an effective tool to diagnose stingless bee colony problems.

This study aims to prove that stingless beekeepers can successfully diagnose weakened stingless bee colonies when they use the developed diagnostic application and follow the determined inspection technique.

1.4 Research Scope

The scope of the study has been limited to achieving the research objectives. The study of developing new expert system architecture was limited to the expert system which is developed by using the MVC framework only.

The development of the diagnostic system to diagnose the stingless bee colony problems was focused on related modules and functions. It excludes the user registration module and the new symptoms notification module.

The investigation of weakened colony rehabilitation's effectiveness focused on Malaysia only. It includes Sabah and Sarawak states.

The study on determining effective inspection technique using borescope was addressed to *Heterotrigona itama* species in a honey box system and focused on Malaysia situation only. *H. itama* is the recommended species for honey production, the most popular, productive and easy to handle in Malaysia. The domain expert recommended the honey box system and the most popular technique among Malaysian stingless beekeepers.

1.5 Research Outline

This thesis is organized into eight chapters, as shown in Table 1.1. There are inter-related between chapters and sections. It is suggested that the chapters should not be read in isolation to provide a clear understanding of the research flow. Therefore, revisiting the related sections and chapters will assist in understanding the thesis.

Table 1.1 : Organisation of the thesis

Chapter	Description
Chapter 1 – Introduction	Introduces readers to the research focus, scope and motivation.
Chapter 2 – Literature Review	Discusses the literature related to the expert system architecture, MVC framework, diagnostic application for meliponiculture and meliponiculture issues in Malaysia.
Chapter 3 – Research Methodology	Describe the methodology used in the research.
Chapter 4 – The identification of weakened colony rehabilitation status	Discuss the preliminary study to identify the status of weakened stingless bee colony rehabilitation.
Chapter 5 – The determination of effective inspection technique	Describe the experiment to determine an effective stingless bee hive inspection technique using borescope.
Chapter 6 – The development of MoViCES Architecture	Describe the development of new expert system architecture when the expert system is developed using the MVC framework.
Chapter 7 – The development of a diagnostic application for meliponiculture	Describe the development of a simple expert system, a diagnostic application for meliponiculture to verify the usability of MoViCES architecture.
Chapter 8 – Conclusion and future works	Describe the conclusions, contributions and recommendations of the research.

Chapter 1 introduces the background of the study, research motivation, the main objective and supporting objectives, the research scope, and the thesis's outline.

Chapter 2 discussed the literature related to the expert system architecture when the expert system was developed using the MVC framework, searching existing diagnostic applications for meliponiculture and Malaysia's meliponiculture issues.

Chapter 3 described the methodology used in the research. The chapter begins by describing the overview of the methodology. Then, it is followed by the methodology used in the literature review, development of MoViCES architecture, development of a diagnostic application for meliponiculture, identification of the weakened stingless bee colony rehabilitation status and the experiment to determine an effective technique to use a borescope to inspect inside stingless bee hive condition.

Chapter 4 discuss the preliminary study to identify the status of weakened stingless bee colony rehabilitation. It describes the interview and the finding from the interview.

Chapter 5 describe the experiment to determine an effective stingless bee hive inspection technique using a borescope. Before discussing the results, it discusses the statistical analysis of the experiment. The chapter ended with a summary of the chapter.

Chapter 6 describe the development of new expert system architecture when the expert system is developed using the MVC framework.

Chapter 7 describe the development of a simple expert system, a diagnostic application for meliponiculture, to verify the usability of MoViCES architecture. It begins by explaining the development approach, results, and discussion before ending with the chapter's summary.

Chapter 8 is the last, describing the research's conclusion, the contributions from the research, and the recommendation by the research.

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