Internet of Things (IoT) in Smart Recycle Bin Application Using AI Technology.

LIONG WOEI CHI

Bachelor of Computer Science (Computer Systems & Networking) with Honors

UNIVERSITI MALAYSIA PAHANG

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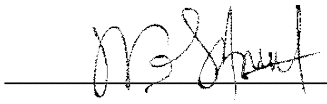

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Internet of Things (IoT) in Smart Recycle Bin Application Using AI Technology.

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Thesis submitted in fulfillment of the requirements
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ABSTRAK

Dengan pertumbuhan ekonomi dan pembangunan perindustrian yang pesat, jumlah sisa pepejal yang dihasilkan telah meningkat dengan ketara. Menurut Lembaga Pembangunan Pelaburan Malaysia (MIDA), walaupun dengan peningkatan kadar kitar semula sebanyak 17.5 peratus pada 2018, kuantiti sisa pepejal yang dijana meningkat kepada 38,000 tan sehari. Di samping itu, seperti merujuk kepada Tabung Hidupan Liar Sedunia (WWF) Malaysia, kuantiti sisa plastik yang dijana memegang bahagian kedua tertinggi di antara semua sisa pepejal yang dihasilkan di Malaysia. Namun begitu, kadar kitar semula plastik di kalangan rakyat Malaysia hanya 20 peratus berdasarkan temu bual yang dibuat oleh WWF Malaysia. Ini telah menyebabkan kesan besar terhadap alam sekitar. Di Malaysia terdapat 20 universiti awam dan 467 universiti swasta. Bukan itu sahaja, di universiti amalan kitar semula adalah sangat rendah kerana niat untuk pelajar universiti untuk mengamalkan kitar semula dalam kehidupan seharian adalah perit bagi mereka. Dalam projek ini, Aplikasi Tong Kitar Semula Pintar Menggunakan Teknologi Kepintaran Buatan (AI) dibangunkan. Aplikasi web juga dibangunkan untuk memantau status tong kitar semula pintar. Dengan menggunakan sistem ini, ia adalah kamera yang dipasang pada peranti dan teknologi AI digunakan untuk mengenal pasti barangan kitar semula seperti kertas, plastik, logam dan lain-lain. Selain itu, sensor ultrasonik digunakan untuk menyemak status tahap pengisian dalam tong kitar semula dan jika tong kitar semula hampir penuh, mesej amaran akan dihantar kepada pengurusan atasan dalam aplikasi web. Dengan menggunakan sistem ini di universiti, pelajar universiti dapat mengamalkan kitar semula setiap hari. Ini akan menambah baik persekitaran universiti dan juga meningkatkan kesedaran alam sekitar hijau di kalangan remaja. Selain itu, ini juga membantu pelajar universiti mengembangkan tanggungjawab mereka terhadap alam sekitar. Pihak pengurusan universiti dapat memperoleh keuntungan daripada sistem ini. Pihak pengurusan universiti boleh menghubungi atau bekerjasama dengan pihak berkuasa untuk mengumpul dan menjual barang kitar semula apabila tong kitar semula penuh. Ini juga akan membantu pihak pengurusan universiti untuk mengurus kebersihan persekitaran dengan mudah. Selain itu, sistem ini juga membantu pengurusan universiti untuk mengurangkan kos buruh manusia dalam mengekalkan persekitaran universiti. Metodologi membangunkan sistem ini melibatkan kedua-dua bahagian perisian dan bahagian perkakasan. Dalam bahagian perkakasan, sistem ini menggunakan raspberry pi model 4B, sensor ultrasonik, motor servo, kamera web dan motor DC. Pembinaan sistem menggunakan tali pinggang penghantar sebagai bahagian utama yang dikawal oleh motor DC. Kamera web, motor servo akan dipasang pada sisi tali pinggang penghantar. Selain itu, sensor ultrasonik dipasang di antara tali pinggang penghantar dan petak tong pintar. Raspberry pi akan mengawal semua gerakan sensor, pemberitahuan amaran tentang tong kitar semula dan pemindahan data ke pangkalan data. Dalam bahagian sensor, Kamera web adalah untuk tujuan pengesanan objek AI yang menggunakan modul Tensorflow Keras. Penderia ultrasonik adalah untuk tujuan mengesan baki kapasiti tong sampah. Motor servo bertindak sebagai penolak pada tali pinggang penghantar untuk membolehkan sisa buangan masuk ke dalam petak yang betul. Sekiranya ketinggian petak kurang daripada 5 cm, mesej amaran akan dihantar kepada pihak pengurusan universiti melalui telegram. Mesej amaran akan memaparkan lokasi tong pintar yang penuh. Pangkalan data yang digunakan dalam sistem ini ialah MySQL. Data yang dikumpul dalam raspberry pi akan diluluskan sebagai tatasusunan dan dihantar ke phpMyAdmin yang telah menjadi hos kepada AWS. Dalam AWS, data akan disegerakkan ke aplikasi web secara automatik. Dalam bahagian perisian, sistem ini

menggunakan aplikasi web dalam rangka kerja Laravel untuk memaparkan output sistem yang telah menjadi hos kepada AWS. Dalam aplikasi web menunjukkan kapasiti semasa setiap petak dalam tong kitar semula pintar. Selain itu, aplikasi web akan mengemas kini dan memuat semula secara automatik dalam masa 10 saat. Selain itu, laporan trend kitar semula juga dipaparkan dalam aplikasi web.

ABSTRACT

With the economic growth and rapid industrial development, the amount of solid waste generated has been increases significantly. According to Malaysian Investment Development Authority (MIDA), even though with the increasing of recycling rate of 17.5 percent in 2018, the quantity of solid waste generated rose to 38,000 tons per day. In addition, as refer to the World Wildlife Fund (WWF) Malaysia the quantity of plastic waste generated hold the second highest share among all solid waste generated in Malaysia. Nevertheless, the plastic recycling rate among Malaysian is only 20 percent based on interview made by WWF Malaysia. This has caused a major impact toward the environment. In Malaysia there are 20 public universities and 467 private universities. Not only that, in universities the practice of recycle are significantly low as the intention for universities students to practice recycling in their daily life is a pain for them. In this project, Smart Recycle Bin Application Using Artificial Intelligence (AI) Technology is developed. The web application is also developed to monitor the smart recycle bin status. By using this system, the is a camera that attached to the devices and the AI technology is used to identify recycle item such as paper, plastic, metal, and others. Other than that, the ultrasonic sensor is used to check the status of filling level in the recycle bin and if the recycle bin is almost full, the alert message will be send to top management in web application. By using this system at university, the university's students able to practice recycling daily. This will improve the university environment and also enhance the awareness of green environment in youngster. Moreover, this also help universities student develop their responsibility towards environment. University's management able to gain profit from this system. University's management able to contact or collaborate with authority to collect and sell recycle item when the recycle bin is full. This also will help university's management to easily manage environment cleanness. Other than that, this system also helps university's management to reduce human labour cost in maintaining university's environment. The methodology of developed this system involved in both software part and hardware part. In hardware part, this system used raspberry pi model 4B, ultrasonic sensor, servo motor, web camera and DC motor. The construction of the system used a conveyer belt as the main part which control by a DC motor. The web camera, servo motor will be attached on the side of the conveyer belt. Moreover, the ultrasonic sensor attached in between the conveyer belt and the compartment of the smart bin. The raspberry pi will control all the sensor motion, alert notification of the recycle bin and data transfer to database. In sensor part, The web camera is for the purpose of AI object detection which used the Tensorflow Keras module. The ultrasonic sensor is for the purpose of detect the remaining bin capacity. The servo motor is act as the pusher on the conveyer belt to allow the waste drop into correct compartment. If the height of the compartment is less than 5 cm, an alert message will be sent to the university's management through telegram. The alert message will display the location of the smart bin which is full. The database used in this system is MySQL. The data collected in the raspberry pi will passed as an array and sent to the phpMyAdmin which has been host to the AWS. In the AWS the data will be sync to the web application automatically. In software part, this system used web application in Laravel framework to display the output of the system which has been host to AWS. In the web application shows the current capacity of each compartment in the smart recycle bin. Moreover, the web application will auto update and refresh within 10 second's time. Other than that, the report of the recycle trend also been displayed in the web application.

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LIST OF SYMBOLS

%	Percentage

LIST OF ABBREVIATIONS

WFF	World Wildlife Fund
F&B	Food & Beverage
MCO	Movement Control Order
AI	Artificial Intelligence
IoT	Internet Of Things
MHLG	Ministry of Housing and Local Government
RAD	Rapid Application Development

CHAPTER 1

INTRODUCTION

1.1 Introduction

Malaysia as a developing country in Southeast Asia. In past decade, the transmission of Malaysia to becoming a developed country was in vision 2020, yet it has brought Malaysia to another level of industrial revolution. Fourth Industrial revolution (4IR) is the transformation of various industries through the implementation of emerging technology which stated in vision 2030[1]. To achieve this vision, Malaysia government has put up a huge effort to ensure sustainable economy during the pandemic convid-19. According to Department of Statistics Malaysia, economic performance in 2021 showed a recovery momentum with the growth of 3.1 percent as compared to economic performance in year 2020 [2].

With the economic growth and rapid industrial development, the amount of solid waste generated has been increases significantly. According to Malaysian Investment Development Authority (MIDA), even though with the increasing of recycling rate of 17.5 percent in 2018, the quantity of solid waste generated rose to 38,000 tons per day [3]. In addition, as refer to the World Wildlife Fund (WWF) Malaysia the quantity of plastic waste generated hold the second highest share among all solid waste generated in Malaysia [4]. Nevertheless, the plastic recycling rate among Malaysian is only 20 percent based on interview made by WWF Malaysia [4]. This has caused a major impact toward the environment.

On the other hand, Malaysia government did lot of effort in introducing 3Rs (reduce, reuse and recycle) program and encourage recycling behaviour in public since the last decade and even with the scheme for household solid waste and solid waste similar to household solid waste regulations 2011 which under solid waste and public cleansing

management has been implemented, yet the awareness toward green environment in Malaysians still low.

In Malaysia there are 20 public universities and 467 private universities [5]. The awareness of youngster in Malaysia towards recycling are quite low. Moreover, a study show that public universities own the greatest electricity users in Malaysia because of lack of awareness and inefficient use of energy [5]. Indirectly, the carbon emissions from a single university are significantly high. This led to unsustainable environment. Not only that, in universities the practice of recycle are significantly low as the intention for universities students to practice recycling in their daily life is a pain for them [6]. This is due to the mindset and behaviour of universities students. As recycling solid waste daily will consume lot of time and energy. Therefore, they prefer throwing solid waste without filtering recyclable item [6]. To change this situation, this study is conduct to increases the practice of recycling in universities. As with the emerging of Internet of Things (IoT) and Artificial Intelligence technology, the intention for universities students to practice recycling will significantly increase.

1.2 Problem Statement

According to World Wildlife Fund (WWF) Malaysia, the plastic usage in Malaysia is significantly high [4]. Most of the plastic waste generated mainly is from packaging especially food packaging. With the food & beverage (F&B) industries growth during the pandemic of covid-19, most of the restaurant and hawker stalls provide take-away services for public. Indirectly, the culture of “Bungkus” or “Ta-Pau” in Malaysia becoming daily basis or even a trend for some restaurant. This has cause lot of plastic waste generated even though most of the food packaging are recyclable or even bio-degradable. However, the awareness and intention of recycling among universities student are still low. Therefore, lot of plastic waste is generated daily [4]. Indirectly, this issue has harmed the eco-system and sustainable environmental health. As the increase of solid waste will affecting human health and diseases. Moreover, this also will affect the environment quality not only for human also for animal.

Furthermore, the paper usage in Malaysia also becoming a huge issue [7]. As movement control order (MCO) implemented during the pandemic of covid-19, in order to maintain the business most of the businessman or seller adopt e-commerce platform and technology such as Shopee and Lazada. Indirectly, this has led the growth in e-commerce and logistic industry. As the industries growth, the parcel packaging used involved many materials such as paper box, tape, bubble wrap and plastic which all can be reuse and recycle. In e-commerce, most of seller is over packaging their product. As they would like to impress their client. This had led to a huge waste in resource and also will led to increase number in solid waste. In consumer perspective, most of the consumer only care about the product quality rather than the packaging. The packaging receive by consumer will be direct throw as a rubbish instead of recycling them [8].

Not only that, the mindset and intention of universities student to practice recycling is quite low. As they busy with their activities, task, assignment and project, most of them rarely have spare time to practice recycling in universities [6]. Other than that, universities students felt practice recycling is a burden for them [5]. This is due to most of the recycle bin station is not convenient in term of distance and availability. Therefore, with the help of Artificial intelligence (AI) and Internet of Things (IoT) technology implement in recycle bin, universities student able to practice recycling which can enhance their awareness toward important in maintaining environment cleanness and through this technology also able to develop universities students' responsibility towards environment. Not only that, universities' management also able to gain profit from this system. As the recycle bin is full, universities' management able to inform authority to collect respective item in recycle bin and gain profit from there.

1.3 Objective

I. To study the existing smart, recycle bin application and respective hardware used.

II. To design and develop Internet of Things (IoT) smart recycle bin application using AI technology.

III. To evaluate the effectiveness and functionality of the propose system by using user acceptance testing.

1.4 Scope

I. User Scope

- Committee in University Malaysia Pahang (UMP).
- University Malaysia Pahang (UMP) Management.

II. System Scope

- Monitoring availability of smart recycle bin for students and management in University Malaysia Pahang (UMP).

III. Development Scope

- Using artificial intelligence (AI) to identify recycle item.
- Using ultrasonic sensor to check the status of filling level in the recycle bin
- Using web application as a monitoring system.

1.5 Significance of the Project

I. Students in University Malaysia Pahang (UMP).

University's students able to practice recycling daily. This will improve the university environment and also enhance the awareness of green environment in youngster. Moreover, this also help universities student develop their responsibility towards environment.

II. University Malaysia Pahang (UMP) Management.

University's management able to gain profit from this system. University's management able to contact or collaborate with authority to collect and sell recycle item when the recycle bin is full. This also will help university's management to easily manage environment cleanness. Other than that, this system also helps university's management to reduce human labor cost in maintaining university's environment.

1.6 Thesis Organization

This thesis consists of five chapters. Chapter 1 explained about the introduction to the smart recycle bin project, problem statements, objectives, scope and significance of the project as well as the thesis organization.

In chapter 2, literature review on three current existing systems of IoT in smart recycle bin is explained.

In chapter 3, the methodology of creating IoT in smart recycle bin used is explained. There are five stages involved in this project which are analysis, design, develop, implementation and evaluation.

In chapter 4, the development of IoT in smart recycle bin of hardware system and software system is explained. At this stage the implementation and testing also explained in this chapter.

In chapter 5, the future prospects of this project are discuses and explained.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In Malaysia, the first official recycling program was launched back in 1993 which was initiated by Ministry of Housing and Local Government (MHLG)[9]. However, the program was unsuccessful due to lack of public participants involved. The recycling program was re-lunched back in December 2000. This time the recycling program was successful. As Ministry of Housing and Local Government (MHLG) had planned and advertised a series of activities and campaigns with terms and conditions to encourage public participants to be involved. Although the recycling program was successful back then using manual recycling system. However, without continuous planning and advertising, the initiative and awareness of public towards the recycling has declining in recent year due to lack of innovation.

Recently, many industries have embedded technology to innovate in their products. To maintain sustainable environment, smart recycle bin has been invented and introduced back in 2013 in France. The innovation of smart recycle bin has been continuous improved till now. Therefore, many studies of smart recycle bin has been carried out. As result, in this section will be mainly introduce the related work of smart recycle bin.

2.2 Previous Research Work

2.2.1 IOT Based Smart Waste Management System Using Lora and TensorFlow Deep Learning Model - University Kebangsaan Malaysia (UKM)

According to studies of smart recycle bin by Teoh Ji Sheng and Mohammad Shahidul Islam from University Kebangsaan Malaysia (UKM) [10], the smart recycle bin used LoRa protocol with mobilenetv2 machine learning architecture. The smart recycle bin come with five compartment which are metal, plastic, paper and general as shown in figure 2.2.1.1.

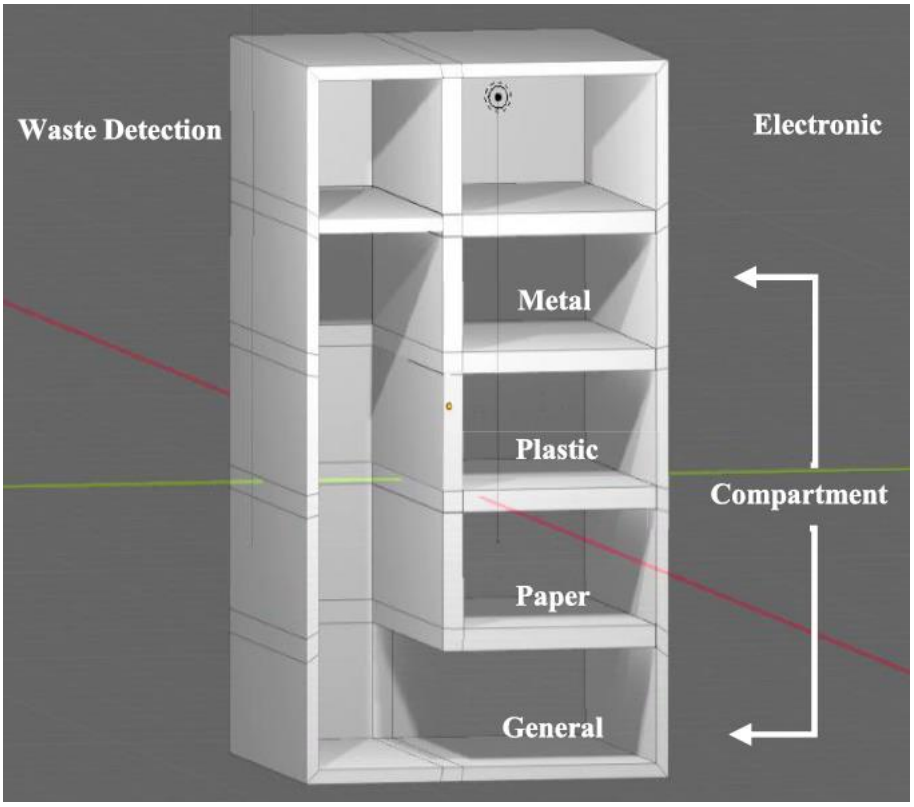

Figure 2.2.1.1 The 3D Physical Design for Hardware System.
Source: Teoh Ji Sheng and Mohammad Shahidul Islam (2020)

On the other hand, the LoRa module is connected to Arduino through a multiprotocol radio shield which enable both of them to communicate simultaneously as shown in figure 2.2.1.2.

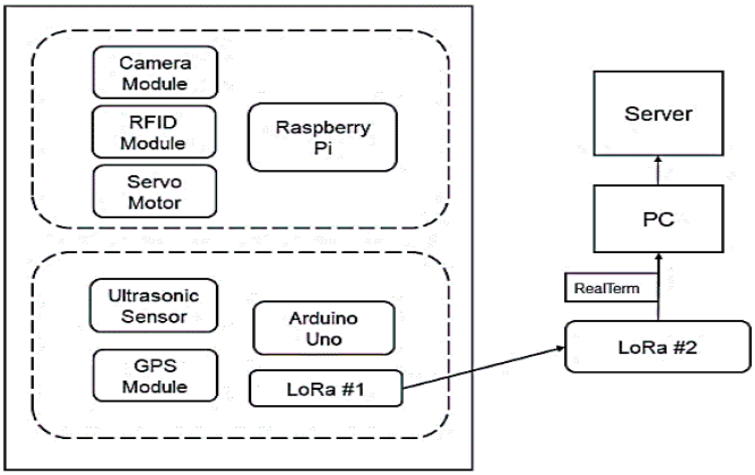

Figure 2.2.1.2 Overall System of Smart Bin
Source: Teoh Ji Sheng and Mohammad Shahidul Islam (2020)

In top compartment which for waste detection has embedded with ultrasonic sensor to detect the present of the waste as shown in figure 2.2.1.3.

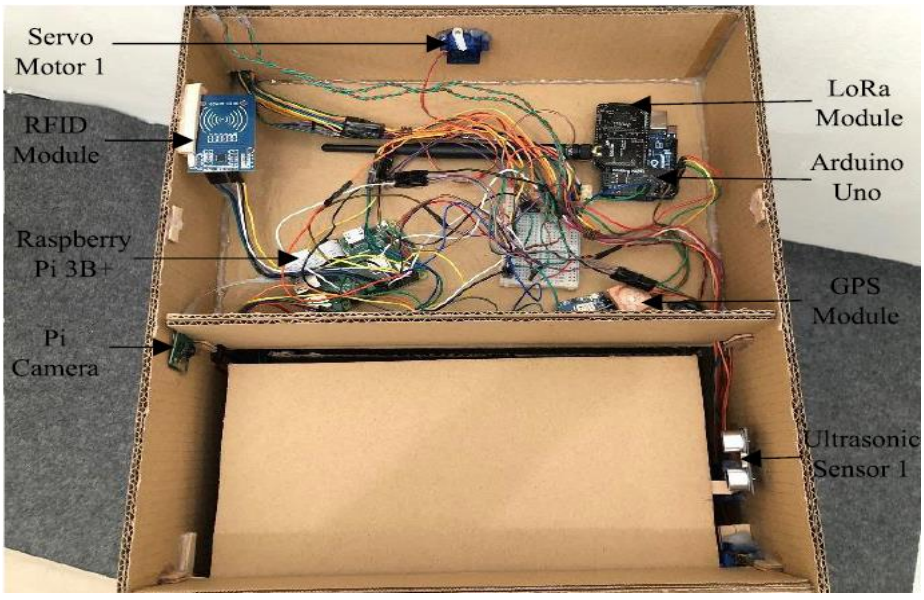

Figure 2.2.1.3 Position of Sensors Top View.
Source: Teoh Ji Sheng and Mohammad Shahidul Islam (2020)

Once the waste has been detected, a camera will capture the image and send to raspberry pi to perform image classification. The detection of waste through raspberry pi used cloud analysis where the image capture will be uploaded to the database through Wi-Fi connectivity by using LoRa gateway as shown in figure 2.2.1.4.

Figure 2.2.1.4 LoRa Gateway Equipment.
Source: Teoh Ji Sheng and Mohammad Shahidul Islam (2020)

A mobile CPU with mobilenetv2 was implemented in this stage for waste detection. After raspberry pi has perform the waste detection, the waste will be drop to respective compartment with servo motor is implemented to open and close the compartments and ultrasonic sensor to detect the compartment capacity as shown in figure 2.2.1.5 and 2.2.1.6.

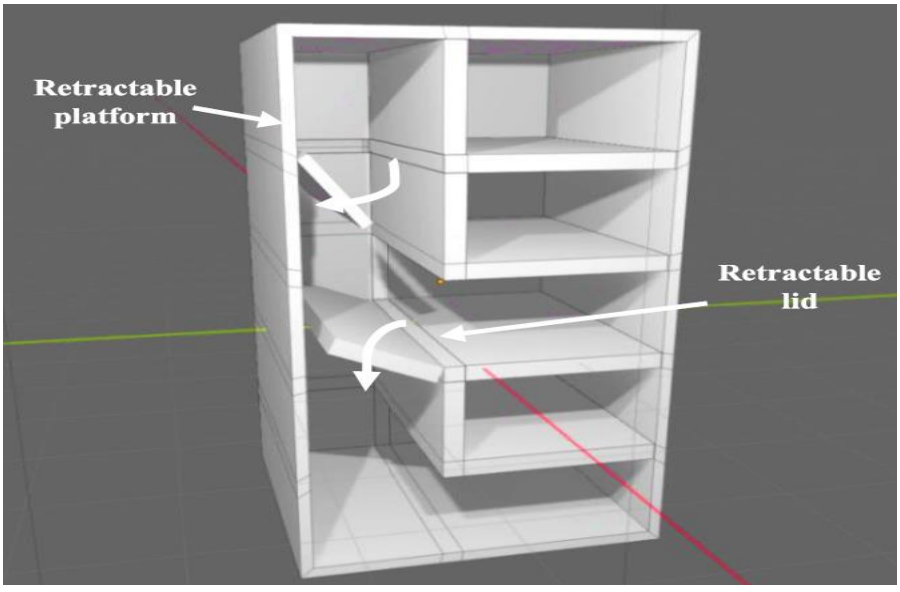

Figure 2.2.1.5 Movement of Servo Motor.
Source: Teoh Ji Sheng and Mohammad Shahidul Islam (2020)

Figure 2.2.1.6 Position of Sensors Side View for Each Compartment.
Source: Teoh Ji Sheng and Mohammad Shahidul Islam (2020)

For monitoring, RFID operation is implemented, which allow the capacity, real time geometry of the smart bin collected from ultrasonic and GPS module. LoRa module will acts as a mode to receive data from Real Term Hyper Terminal. Based on that, the data of the smart recycle bin will be displayed in Real Time Serial Capture Program software as shown in figure 2.2.1.7.

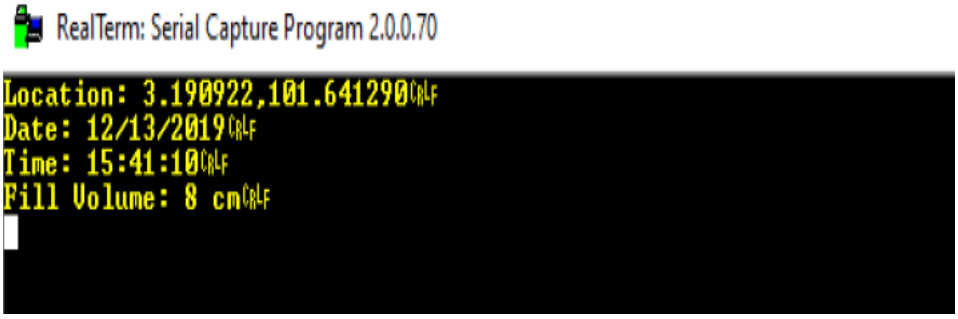

Figure 2.2.1.7 Monitoring System of Smart Recycle Bin
Source: Teoh Ji Sheng and Mohammad Shahidul Islam (2020)

2.2.2 Holistic Solution Design and Implementation for Smart City Recycle Waste Management in Saensuk City - Burapha University

According to studies of smart recycle bin by K. Thibuy, S. Thokrarairak and P. Jitngernmadan from Burapha University, Thailand [11], the smart recycle bin used MQTT protocol. In this study, raspberry pi also acts as the main processor controlling the operation of sensor and electronic devices, where all the data of the recycle bin will be transmitted via NETPIE services using MQTT protocol as shown in figure 2.2.2.1.

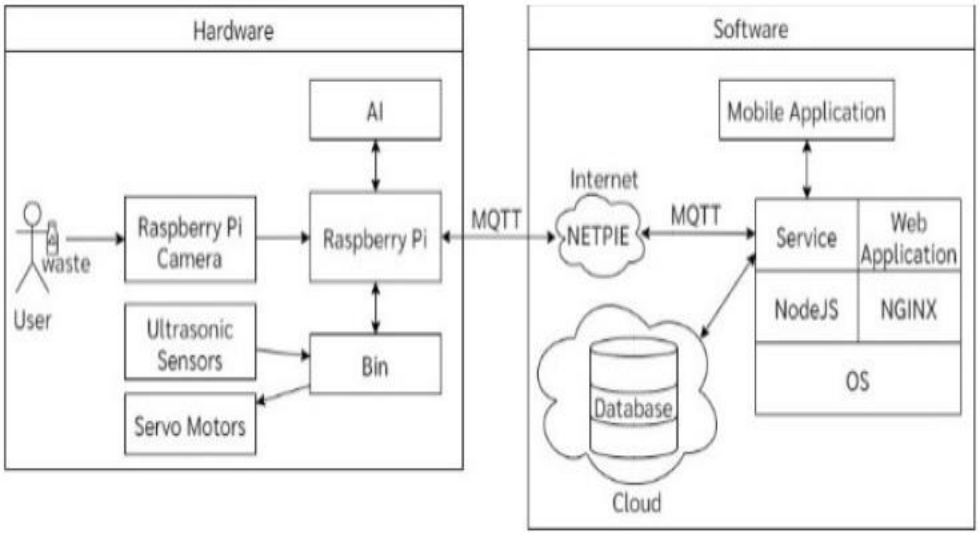

Figure 2.2.2.1 Overall System of Smart Bin
Source: K. Thibuy, S. Thokrarairak and P. Jitngernmadan (2020)

In hardware design used raspberry pi and MobileNet for artificial intelligence (AI) model. At the top opening of the smart bin, raspberry pi camera was implemented and connected to control box. The mechanism of the control box is shown in figure 2.2.2.2.

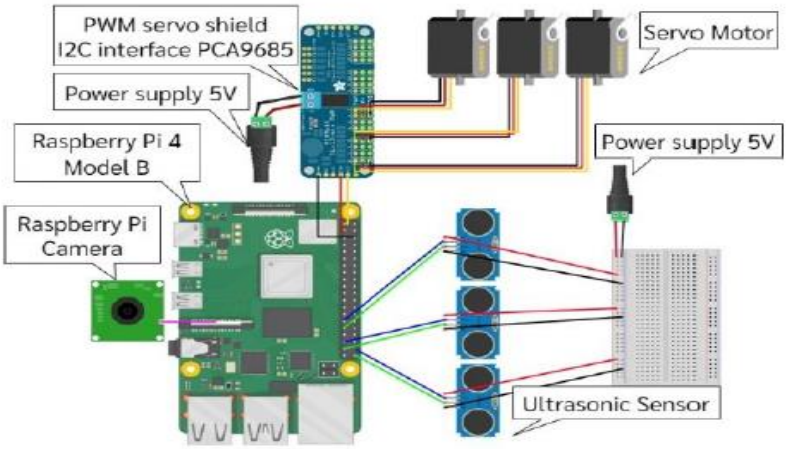

Figure 2.2.2.2 Mechanism of The Control Box
Source: K. Thibuy, S. Thokrarairak and P. Jitngernmadan (2020)

For waste collection, this system has three compartments which involved metal, plastic and glass. 60 litre standard bin is used for each compartment. The sensors that involved in each compartment is ultrasonic sensor for the purpose of capacity detection. Servo motor is used to control the motion of lid for each compartment. Therefore, when a waste is detected the respective compartment lid will be opened. Then, the waste will drop on a slop surface to roll into the respective compartment. The hardware system design in shown in figure 2.2.2.3.

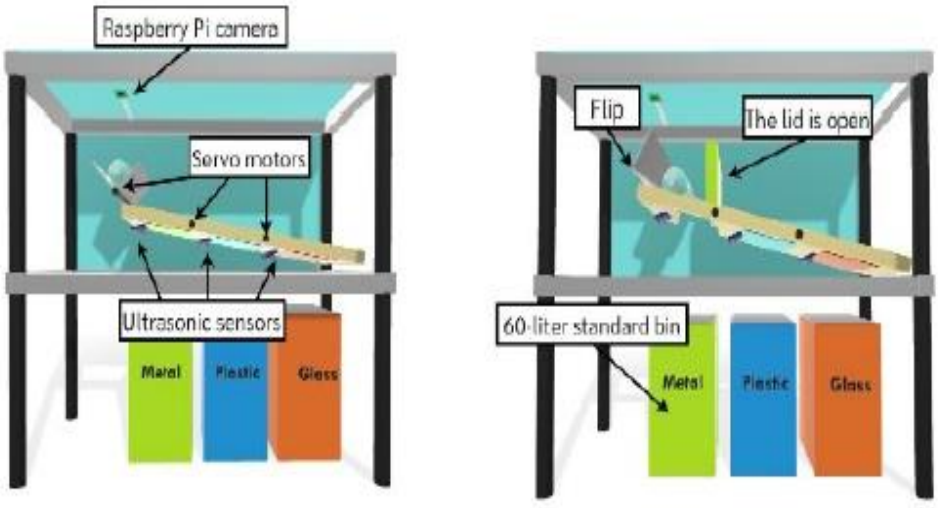

Figure 2.2.2.3 Hardware System Design of Smart Recycle Bin
Source: K. Thibuy, S. Thokrarairak and P. Jitngernmadan (2020)

In software design mobile application and web application is used for monitoring purposes. Both applications shared the same database. In mobile application, this study used android application which mainly concentrate at end user. As this mobile application is a reward-based application which allow their end user to scan QR code which located in front of the smart recycle bin for identification and collecting point by recycling waste one by one. Figure 2.2.2.4 show the mobile application of smart recycle bin.

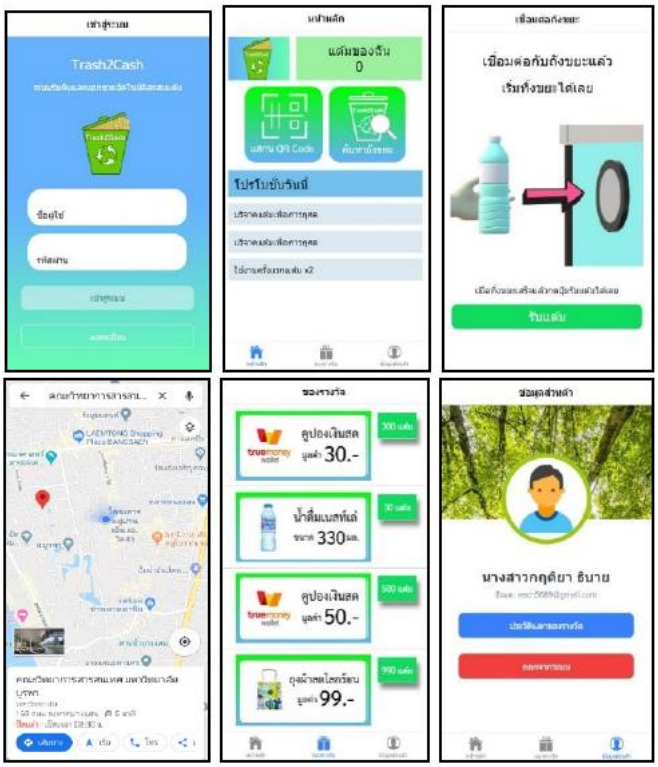

Figure 2.2.2.4 Mobile Application of Smart Recycle Bin
Source: K. Thibuy, S. Thokrarairak and P. Jitngernmadan (2020)

In web application, this study mainly focuses about monitoring the capacity left in the smart recycle bin through data visualisation. The real time location data also will be collected and displayed through the web application. Figure 2.2.2.5 show the web monitoring application of smart recycle bin.

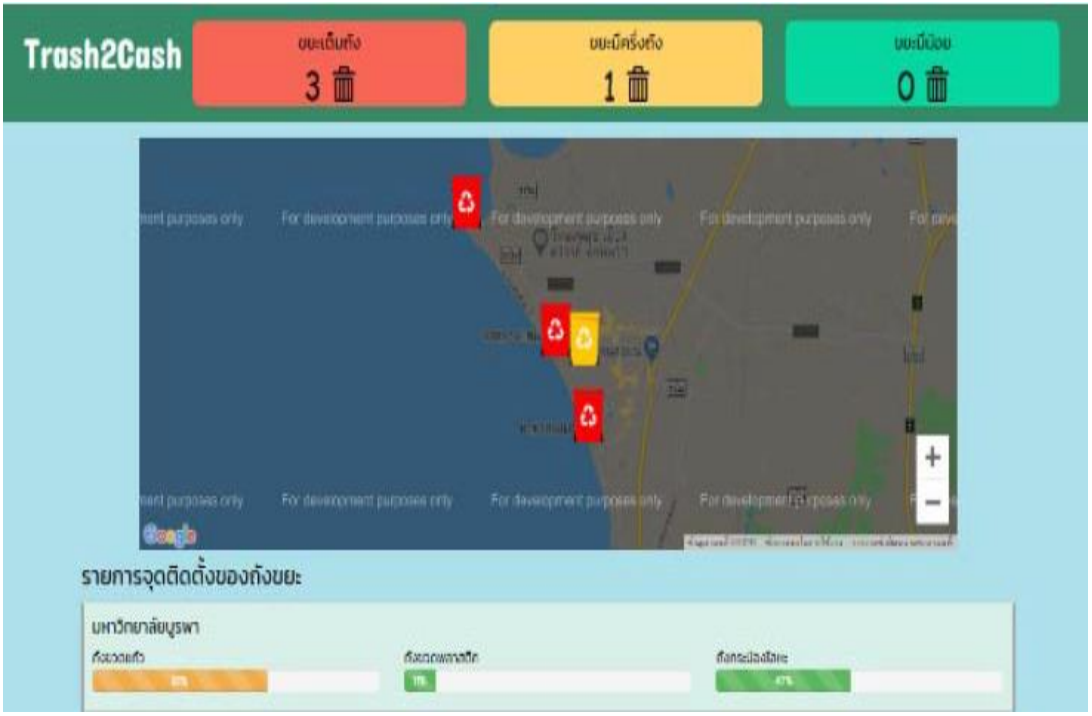

Figure 2.2.2.5 Web Application of Smart Recycle Bin

Source: K. Thibuy, S. Thokrarairak and P. Jitngernmadan (2020)

2.2.3 Design Of IOT-Based Smart Waste Sorting System, With Image-Based Deep Learning Application - Kesetsart University

According to studies of smart recycle bin by C. Sirawattananon, N. Muangnak and W. Pukdee from Kesetsart University, Thailand [12], the smart recycle bin used ResNet-50 for machine learning with TensorFlow framework and hardware module for recycle bin.

In hardware system, this study used raspberry pi as the core module for controlling and image processing. In this system contain five compartment which are bottle cap bin, general plastic bottle bin, metal can bin, PET plastic bin and non-recycled bin. Ultrasonic sensor is used to monitor the level of capacity occupied in the recycle bin which implemented in each compartment. While servo motor is used to control the movement of the path which is a tube to allow waste drop to correct compartment.

When a waste is detected, if it is non-recyclable waste will direct slide into non-recycled bin though the conveyer belt. If the waste is recyclable, the waste will drop into tube and servo motor will control the movement of the tube to allow wate drop into correct compartment. Figure 2.2.3.1 shows the mechanism of the smart recycle bin. Once the waste has been dropped to correct compartment, the LCD display acts as the I/O module to allow end user to view their earn point and also to allow management to monitor fullness of the smart recycle bin.

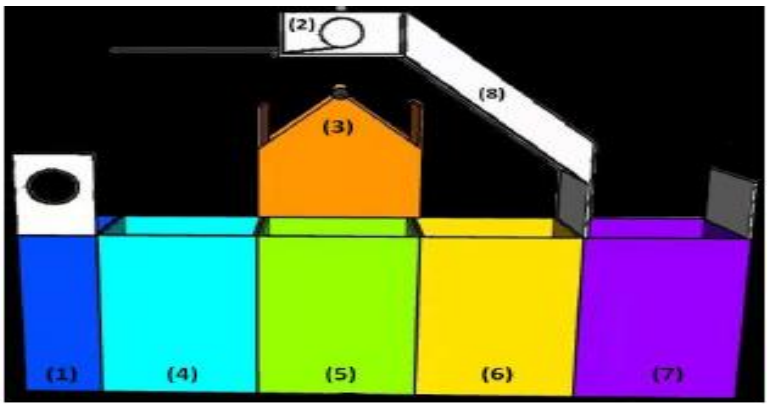

Figure 2.2.3.1 The Hardware Design of The Smart Recycle Bin
Source: C. Sirawattananon, N. Muangnak and W. Pukdee (2021)

In machine learning, ResNet-50 is implemented to allow object detection and classification perform in the cloud. Figure 2.2.3.2 shows the overall implementation of machine learning link to smart recycle bin. In this system, the waste sorting algorithm process start will webcam capture the wate image. Then the image will be sent to cloud server to perform classification through TensorFlow framework which contained pre-trained classification model.

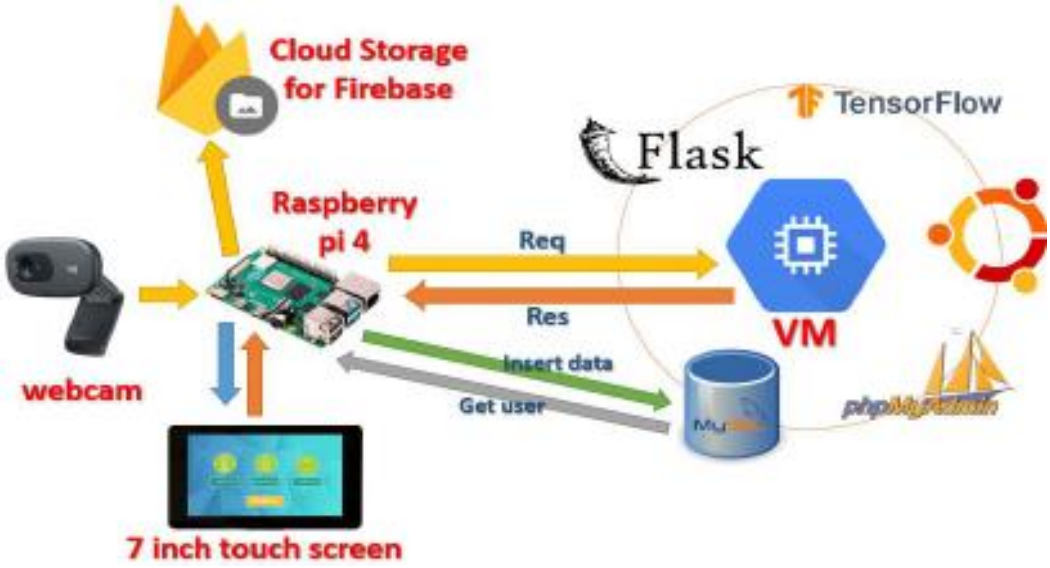

Figure 2.2.3.2 Implementation of Machine Learning to the Smart Recycle Bin
Source: C. Sirawattananon, N. Muangnak and W. Pukdee (2021)

In software system, web application mainly is for maintenance team where displayed statistical report, system configuration and also waste disposal transection. In other word, the web application is for monitoring the fullness of the smart recycle bin. While mobile application mainly is for end user or public for checking the reward and point earned. Both of the application implemented in the built-in touch screen monitor devices which located at the smart recycle bin.

2.3 Comparison Of Previous Research Work

Based on the studies, the type of waste collected in each study is different. In studies by Teoh Ji Sheng and Mohammad Shahidul Islam [10], the smart recycle bin only collect paper, plastic, metal and general waste. While in studies by K. Thibuy, S. Thokrarairak and P. Jitngernmadan [11] the smart recycle bin only collect plastic, metal and general waste. In studies by C. Sirawattananon, N. Muangnak and W. Pukdee [12] smart recycle bin only collect bottle cap, PET plastic, plastic, metal, and general waste.

In term of sensors, studies by Teoh Ji Sheng and Mohammad Shahidul Islam [10] uses three sensors which are camera, ultrasonic sensor and GPS sensor. While in studies by K. Thibuy, S. Thokrarairak and P. Jitngernmadan [11] uses also three sensors in their smart recycle bin which are camera, ultrasonic sensor, PWM and servo. In studies by C. Sirawattananon, N. Muangnak and W. Pukdee [12], only two sensor is used which are ultrasonic sensor and camera. In common, ultrasonic sensor is used in these three studies. In term of communication protocol, only two studies involved communication protocol in their smart recycle bin. Where studies by Teoh Ji Sheng and Mohammad Shahidul Islam [10] used LoRa protocol, while studies by K. Thibuy, S. Thokrarairak and P. Jitngernmadan [11] used MQTT protocol. In term of micro-controller, studies by Teoh Ji Sheng and Mohammad Shahidul Islam [10] used Arduino Uno and Raspberry Pi. While studies by K. Thibuy, S. Thokrarairak and P. Jitngernmadan [11] uses Raspberry Pi. In studies by C. Sirawattananon, N. Muangnak and W. Pukdee [12] uses Raspberry Pi micro-controller. In common, these three studies used raspberry pi micro-controller. In term of machine learning architecture, studies by Teoh Ji Sheng and Mohammad Shahidul Islam [10] used MobileNetV2 architecture. While studies by K. Thibuy, S. Thokrarairak and P. Jitngernmadan [11] used MobileNetV1. In studies by C. Sirawattananon, N. Muangnak and W. Pukdee [12] uses ResNet-50.

In term of mobile application only studies by K. Thibuy, S. Thokrarairak and P. Jitngernmadan [11] and by C. Sirawattananon, N. Muangnak and W. Pukdee [11]uses android based mobile application. However, studies by Teoh Ji Sheng and Mohammad Shahidul Islam [11] does not support mobile application. While for web application all of this study implemented monitoring the capacity of the smart recycle bin through web application. Based on the studies that has been carried out, a comparison table between studies is shown in table 2.3.1.

Table 2.2.3.1 Comparison Table of Related Work

Reference	IOT BASED SMART WASTE MANAGEMENT SYSTEM USING LORA AND TENSERFLOW DEEP LEARNIN MODEL - UNIVERSITY KEBANGSAAN MALAYSIA (UKM) [10]	HOLISTIC SOLUTION DESIGN AND IMPLEMENTATION FOR SMART CITY RECYCLE WASTE MANAGEMENT IN SAENSUK CITY - BURAPHA UNIVERSITY [11]	DESIGN OF IOT-BASED SMART WASTE SORTING SYSTE, WITH IMAGE-BASED DEEP LEARNING APPLICATION - KESETSART UNIVERSITY [12]	Internet of Things (IoT) in Smart Recycle Bin Application Using AI Technology.
Type of Waste	• Paper • Plastic • Metal • General	• Plastic • Metal • General	• Bottle Cap • PET Plastic • Plastic • Metal • General	• Paper • Plastic • Metal • Others
Sensors	• Camera • Ultrasonic sensor • GPS module	• Camera • Ultrasonic sensor • PWM • Servo	• Camera • Ultrasonic sensor	• Camera • Ultrasonic sensor
Communication Protocol	LoRa	MQTT	N/A	MQTT
Micro-controller	• Arduino Uno	Raspberry Pi	Raspberry Pi	Raspberry Pi 4 model B

	• Raspberry Pi			
Machine Learning Architecture	MobileNetV2	MobileNetV1	ResNet-50	MobileNetV2
Mobile Application	No	Yes	Yes	No
Web Application	No	Yes	Yes	Yes

2.4 Advantage, Disadvantage and Limitation of Previous Research Work

Based on studies of smart recycle bin by Teoh Ji Sheng and Mohammad Shahidul Islam from University Kebangsaan Malaysia (UKM) [10], the advantage of this studies is LoRa communication protocol that implemented allow long range data transmission with minimum power consumption. Moreover, with solar panel implemented in the smart recycle bin, the power supply for a smart recycle bin is optimal to be operate at anywhere. Other than that, the implementation of MobileNetV2 in machine learning also bring the accuracy of 86.7% for metal, 96.3% for plastic and 82.3% for 86.2%. The overall accuracy of the machine learning is 80% in term of waste detection performance. The disadvantage of this studies is the cost of implementation is significantly high where the overall system cost required is $380 per bin with gateway. The limitation of this studies training dataset for waste classification. This is due to training dataset required long period of training and huge databases to ensure each waste to be thrown able to be classified. In these studies, the author classified general waste as waste that unbale to be identify or covered with foreign item which blocking the raspberry pi to classified. The second limitation is the capacity of the recycles bin. This is due to as refer to the studies, the capacity for each compartment is limited as the dimension of each compartment only 0.2m* 0.45m*0.1m only.

Based on studies of smart recycle bin by K. Thibuy, S. Thokrarairak and P. Jitngernmadan from Burapha University, Thailand [11], the advantage of this studies is the accuracy of machine learning where plastic own 95% of accuracy, glass own 82% of accuracy and metal own 86% of accuracy. The disadvantage of this smart recycle bin is the time taken for waste detection and classification. This is due to for plastic waste required 6.65 seconds, while for glass waste required 5.33 seconds and metal waste required 6.85 seconds. The main reason of high time consuming due to the dataset for training and machine learning. Indirectly, this has become the limitation of the smart recycle bin. Not only that, the smart recycle bin only accepted cylinder-shaped waste to recycle. This also become a disadvantage of this system as it is not convenience for user if the waste is in other shape.

Based on studies of smart recycle bin by C. Sirawattananon, N. Muangnak and W. Pukdee from Kesetsart University, Thailand [12], the advantage of this studies is the accuracy of the smart recycle bin where 98.81% accurate with training loss of 0.0346 only. High performance of RESNet-50 allows the availability and capacity of the network. The disadvantage of this smart recycle bin is the plastic waste only can be fit from range 100 ml to 1500 ml only without twisted. The limitation of this smart recycle bin is the opening space to allow end user to put in their recycle waste. Based on the studies that has been carried out, an advantage, disadvantage and limitation table of these studies is shown in table 2.3.2.

Table 2.2.3.1 An Advantage, Disadvantage and Limitation Table of These Studies

Reference	IOT Based Smart Waste Management System Using Lora and TensorFlow Deep Learning Model - University Kebangsaan Malaysia (UKM) [10]	Holistic Solution Design and Implementation for Smart City Recycle Waste Management In Saensuk City - Burapha University [11]	Design Of IOT-Based Smart Waste Sorting System, With Image-Based Deep Learning Application - Kesetsart University [12]
Advantage	• Long range data transmission. • Minimum power consumption required. • High performance.	• High accuracy of waste classification.	• High accuracy of waste classification. • Short time consumption for waste detection and classification. • High network performance.
Disadvantage	• High cost required to implement.	• Long-time consumption for waste detection and classification. • Only cylinder-shaped waste is accepted.	• All waste must be in good condition • Only 100 ml to 1500 ml plastic bottle able to be fit in smart recycle bin.
Limitation	• Small capacity in each compartment. • Lack of dataset training.	• Lack of dataset training.	• Small opening space for placing or inserting waste.

2.5 Conclusion

In this chapter 2, the analysis of the related work of IoT in smart recycle bin is done. Which involved comparison of all related work. Through this process, the most suitable method to be used are using MQTT protocol with Raspberry Pi microprocessor and MobileNetV2 machine learning. This is due to the MQTT protocol required lightweight device resources requirement. At the same time the MQTT protocol is reliable due to MQTT protocol able to ensure the data security during data transmission. The cost to implement by using MQTT protocol is low as compare to LoRa and Lora Wan protocol. For microprocessor, Raspberry Pi is suitable to be implement in smart recycle bin. This is due to Raspberry Pi uses its operating system called Raspbian OS. In the Raspbian OS support coding and configuring. Basically, Raspberry Pi will become a small version of motherboard with computer feature. This is due to the microprocessor that built in the Raspberry Pi motherboard. With the features, camera and can be implement through Raspberry Pi. Compare with Arduino microprocessor, Arduino work well in controlling sensors only. This is due to Arduino is acts as a distributer to distribute task for each sensor to execute with minimum power consumption. However, Arduino required connected to other computer to support general purpose input output configuration. While using Raspberry Pi support general purpose input output pin which allow direct configuration from itself. Therefore, Raspberry Pi is more suitable. MobileNetV2 is suitable to be implement in smart recycle bin due to its speed of processing image and training compare with Mobile Net.

Other than that, the compartment for my proposed work contains paper, plastic, metal and others. Based on previous research, waste that in cylinder-shaped with specific size only able to be recycle for the purpose of letting the waste roll or slide to correct compartment. Therefore, in my propose work the recycle waste does not constrained with the shape of the waste as a conveyer belt with pusher will push the waste to the right compartment. Not only that the sensor that involved is ultrasonic sensor. Ultrasonic sensor will be controlling the detect for the remaining capacity of each compartment.

In term of software development, web application is used for University Malaysia Pahang student to check the availability of the recycle bin near them. Through the web application University Malaysia Pahang’s management able to monitoring the status of the smart recycle bin.

2.6 Summary

In summary, smart recycle bin is suitable to be implement in University Malaysia Pahang or department of environment Malaysia. This is due to this system will reduce the amount of waste produce each day. Moreover, with this system the waste that have been collected can be reprocess to become a new material for industrial use.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter will discuss on the methodology used to implement the smart recycle bin which involved the workflow of developing this system. The system development methodology is act as a guideline for developer to plan, structure and method to develop the whole smart recycle bin system according to phases.

3.2 Methodology

The methodology used to plan and structure the guideline for development this smart recycle bin system is important. In this methodology will discuss on different type of software development life cycle (SDLC). There are few software process models which are agile model, waterfall model, joint application development (JAD) model and rapid application development (RAD) model. Each of this software process model containing five fundamental phases were including planning phase, crating phase, development phase, testing phase and deploy phase.

3.2.1 Agile Model

In agile model, agile allow developer to frequently changing the system requirement according to stakeholder feedback. The agile model containing six phases which are planning phase, designing phase, development phase, testing phase, deployment phase and review phase. The agile model phases are in a looping form to allow developer to collect feedback from stakeholder and change the system requirement[13]. The advantage of this model is the system developed met the stakeholder's requirement and the modification or changing the system requirement during development of the system will not be an impact towards the progression as testing and development phases can be

overlap. The disadvantage of this model is it required high cooperation between stakeholder and development team. Not only that, the demand of stakeholder towards the system itself also become a serious impact. As stakeholder expectation might not able to be implement in the system due to the constraint or restriction[13].

3.2.2 Waterfall Model

Waterfall model is the traditional model of the software development life cycle (SDLC). In waterfall model the developer required to follow and complete each phase before moving to next phase[14]. The planning of the system can be done beforehand. However, this model required high man power as all phases need to be completed. If there is any modification or changes of the system itself, development team required to plan and structure all the phases again after completing all the phases. In simple word, the developer only can modify or changing the system requirement after developed the system. This model contained five phases which are requirement definition phase, system and software design phase, implementation and unit testing phase, integration and system testing phase and operation and maintenance phase[15].

3.2.3 Joint Application Development (JAD) Model

Joint application development (JAD) model containing four phases which are define specific objective phase, session preparation phase, session conduct phase and documentation phase[16]. The benefit of JAD model is it able to fasten the delivery time of the system. As the developer have most high understanding about stakeholder's requirement. Therefore, time required to developed the system will be reduced. Indirectly, this also will improve the quality of the system as the system fulfilled stakeholder's requirement.

3.2.4 Rapid Application Development (RAD) Model

Rapid application development (RAD) model is the low-risk model for software development where it is a formation of agile methodology that focus on rapid prototype and iterations [17]. RAD model provide high flexibility for developer as developer can make changes and modification during the development process in order to meet stakeholder requirement. This will allow high quality and accuracy systems is developed. This is due to developer able to modified directly system requirement after getting

feedback from stakeholder. From here, the efficiency of developing will be increase. There are five phases include in RAD model which are analysis and quick design phase, in development phase brake into three part which are built phase, demonstrate phase and refine phase. Then after the system is developed will go into testing phase and implementation phase.

3.3 Project Management Framework

Rapid application development (RAD) model is the most suitable methodology to plan, structure and develop this system compare to other software development models. This is due to RAD model can reduce the time required to develop the smart recycle bin system [17]. As in developing phase of RAD model, modification and improvement of the smart recycle bin can be done. This will improve the quality of the smart recycle bin as the system developed met the requirement by adopting feedback and testing.

In RAD model containing five phases which are analysis and quick design phase, development phase, testing phase and implementation phase [18]. In development phase brake into three part which are built phase, demonstrate phase and refine phase. These three phases will act as a looping to allow developer to do modification or improvement of smart recycle bin by collecting feedback. Therefore, in this development phase, developer able to notify the structure, physical design, software design and connection between software and hardware. This will increase the understanding of current status for developer towards smart recycle bin. Figure 3.2.4.1 shows the Rapid application development (RAD) model.

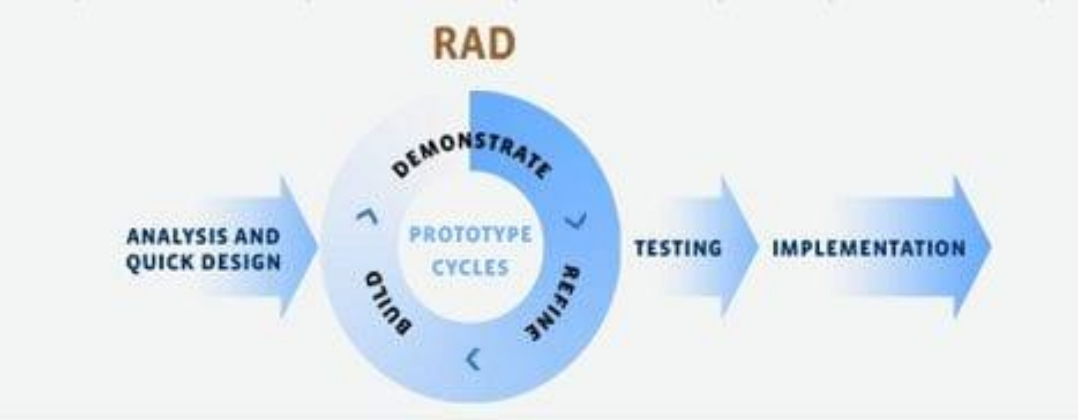

Figure 3.2.4.1 Application Development (RAD) Model

3.3.1 Analysis And Quick Design Phase

In this analysis and quick design phase will focus on the objective and user scope, where the system requirement of smart recycle bin is collected. Therefore, by determine the scope of user and objective. The visualisation of the overall system can be notice by developer. As objective collected for this system will become the system requirement for hardware part and software part. Through the objective also able to identify and understand current technology and its constraint. From user scope, developer able to understand their domain and by observing the behaviour and awareness of the student of the University Malaysia Pahang towards environment. From there developer also can observe the surrounding environment and infrastructure of the area to understand the cause of environmental issue in University Malaysia Pahang.

3.3.2 Development Phase

In development phase, developer will develop hardware system and software system for smart recycle bin in University Malaysia Pahang. In this phase, the analysis and comparison of related work is carried out. This will help the developer to understand current implementation and technology involved in different domain. Through this analysis and comparison of related work, developer able to choose the most suitable methods to be implement based on different aspects. In smart recycle bin, the overall design of the system will be carried out from hardware system to software system. The flowchart and the use case diagram of the smart recycle bin will be illustrate to gain better understanding of development. Then the UI design of the interfaces in web application will be proposed. The programming language that will be used in this smart recycle bin is Python for hardware system. While for software system, the programming language used are PHP in Laravel framework.

In hardware system, the compartment for smart recycles bin contains paper, plastic, metal and others. MQTT protocol with Raspberry Pi microprocessor and MobileNetV2 machine learning will be implemented in the hardware system. The training of the machine learning will be implemented for waste detection through TensorFlow. Not only that, sensor that involved is ultrasonic sensor will be implemented in respective compartment. To allow waste drop into correct compartment after waste detection, a conveyer belt and servo motor need to be implemented.

In software system, after the design of the UI interface, the database of the smart recycle system need to be implement. The database must connect with internet to collected real time data of the smart recycle bin and web application. The web application of this smart recycle bin allow University Malaysia Pahang's student and management to view current status of the smart recycle bin. The PHP programming language will be used to develop web application in Laravel framework.

3.3.3 Testing Phase

In this phase, the development of hardware system and software system is finished. The testing of the smart recycle bin will be implemented. The machine learning through MoblieNetV2 will be tested in term of image detection, accuracy and faulty. Then the accuracy of Raspberry Pi microprocessor controlled the movement of the conveyer belt to allow waste to drop to correct compartment will also be tested. The function and response of the monitoring dashboard will be tested. Moreover, the accuracy of location displayed on the web application also will be tested. This testing phase is to ensure the system that had developed met the objective and domain of the system.

3.3.4 Implementation Phase

In this phase, the smart recycle system is completed and ready to be use. The hardware system and the software system of the smart recycle bin can be used. The guideline of web monitoring application will be implemented before launched.

3.4 Project Requirement

In this project requirement will be discussed on functional requirement, non-functional requirement, constrained and limitation of smart recycle bin.

3.4.1 Functional Requirement

The functional requirement in hardware system is the detection function in smart recycle bin. In the smart recycle bin, the waste will be detect using raspberry pi for image processing to identify the type of waste. Next is motion function in smart recycle bin. Once finish the conveyer belt will be move to corresponding compartment and a pusher will push the waste to the compartment. Next is sensor function. Each compartment will contain one ultrasonic sensor to detect the capacity of the bin and response back to

raspberry pi microprocessor. If the bin is full the alert notification will be sent from bin to monitoring system.

The functional requirement in software system in term of web monitoring application is monitoring function. The dashboard of status of each smart bin will be displayed in term of the remaining capacity. Next is location function. In the dashboard the location of the smart recycle bin will be displayed. Moreover, a report of displaying the insight of recycle bin data will be displayed. Other than that, notification will be sent to admin of University Malaysia Pahang through telegram message.

3.4.2 Non-Functional Requirement

The non-functional requirement of smart recycle bin is the reduce processing time of waste detection. This is due to reduce the processing time of waste detection will improve the efficiency of collecting waste. As processing image uses large resources to filter and classification. Therefore, lower the processing time of waste detection higher the efficiency.

Not only that, the non-functional requirement of smart recycle bin is the ease of use in term of software application and hardware system. Provide user friendly system. In monitoring web application dashboard is used for ease of viewing data and status of smart recycle bin. In term of hardware system, user only need to put the waste to be recycle only.

Next, he non-functional requirement of smart recycle bin is reliable of the system. With high performance and high accuracy will make the smart recycle bin reliable in term of software and hardware. This will increase the confidence of user towards the system.

3.4.3 Constrained

The constrained of the smart recycle bin is this system only can be applied in small area. This is due to the as the range of area become wider the bandwidth and the connection between recycle bin and the monitoring system will become not accurate as the data transmission might be lost.

Other than that, the constrained of smart recycle bin is the training of the machine learning required more resources space to classified and identified images. The dataset

of image is huge. Therefore indirectly, will require higher space to storing and running the program.

Not only that, the constrained of smart recycle bin is the power consumption of the smart recycle bin. This is due to Raspberry Pi microprocessor and all sensor required high power supply to allow high performance. If low power supply, the smart recycle bin unable to be function.

3.4.4 Limitation

The limitation of the smart recycle bin is this only can be applied in small area. This is due to the as the range of area become wider the bandwidth and the connection between recycle bin and the monitoring system will become not accurate as the data transmission might be lost.

Other than that, the constrained of smart recycle bin is the training of the machine learning required more resources space to classified and identified images. The dataset of image is huge. Therefore indirectly, will require higher space to storing and running the program.

3.5 Proposed Design

3.5.1 Architecture Design

In the architecture design of smart recycle bin raspberry Pi microprocessor is used as the controller for all sensor and data transfer to database. In hardware consist of camera and sensors. Image will be capture by camera module when University Malaysia Pahang's student wanted to recycle item. The image taken will be send to raspberry pi 4 and the image will go through AI for object detection which used MobileNetV2. Once finished, the raspberry pi 4 will send command to respective servo motor to set the angle. Once finish ultrasonic sensor module will send the real time signal to the raspberry pi micro-processor. Microprocessor will receive all data and signal. Then the hardware will connect to internet in order to send data to database. From database, website will retrieve all data and display at the website. Figure 3.5.1.1, 3.5.1.2 and 3.5.1.3 shows the architecture design of this system.

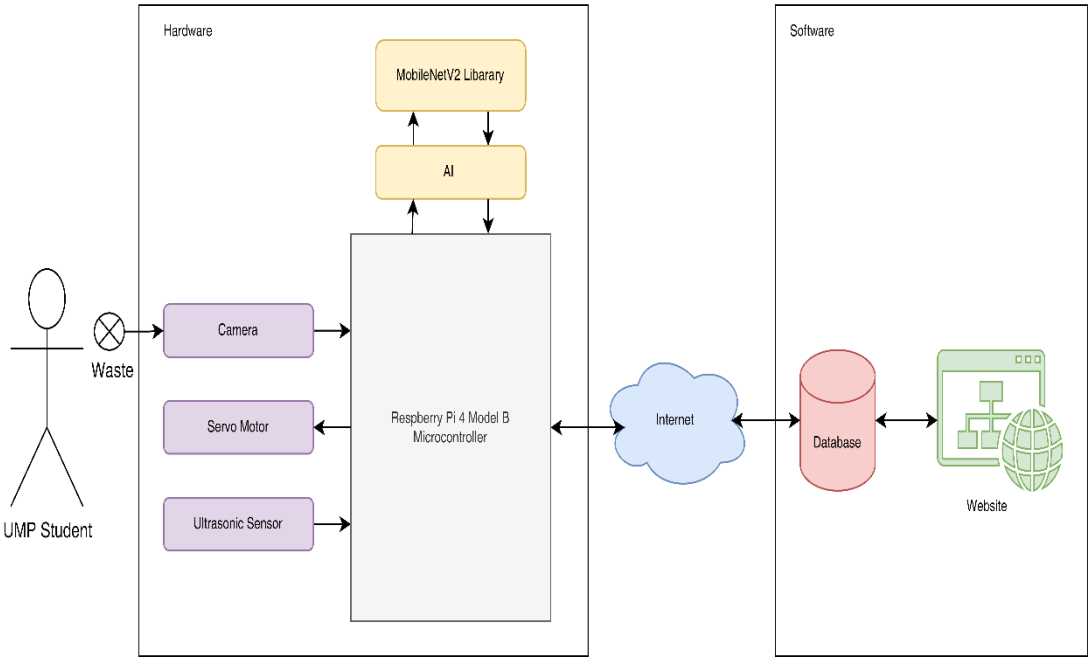

Figure 3.5.1.1 Architecture Design of Smart Recycle Bin System

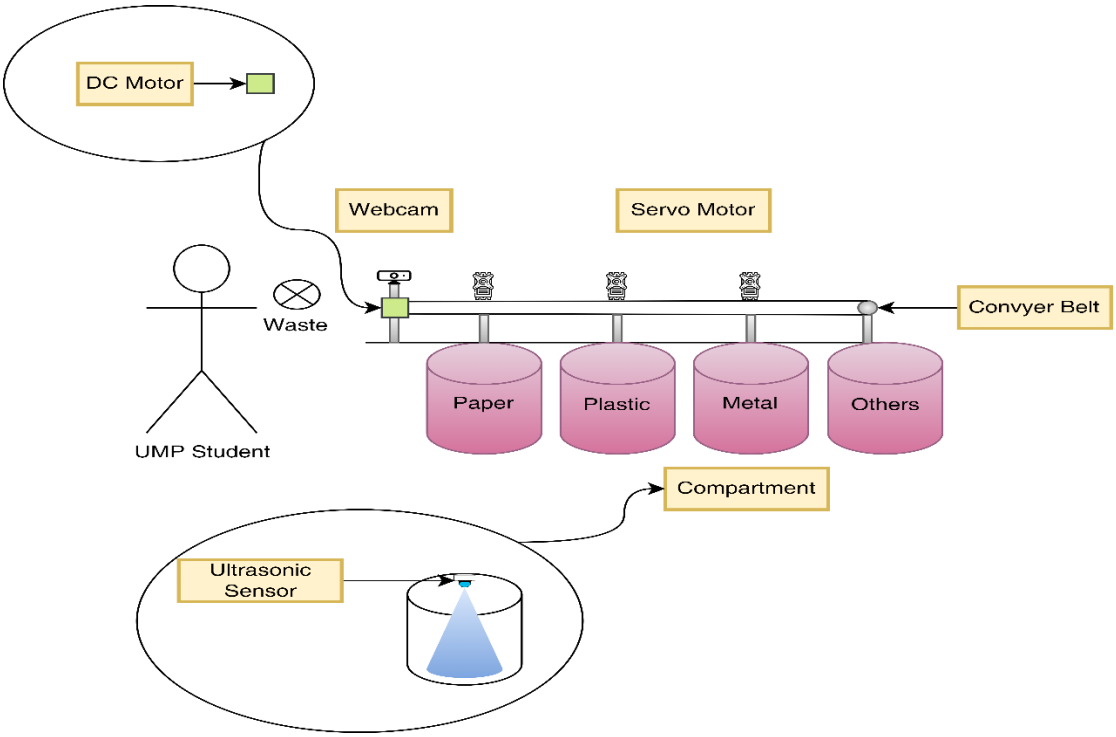

Figure 3.5.1.2 Overall Smart Recycle Bin System Side View

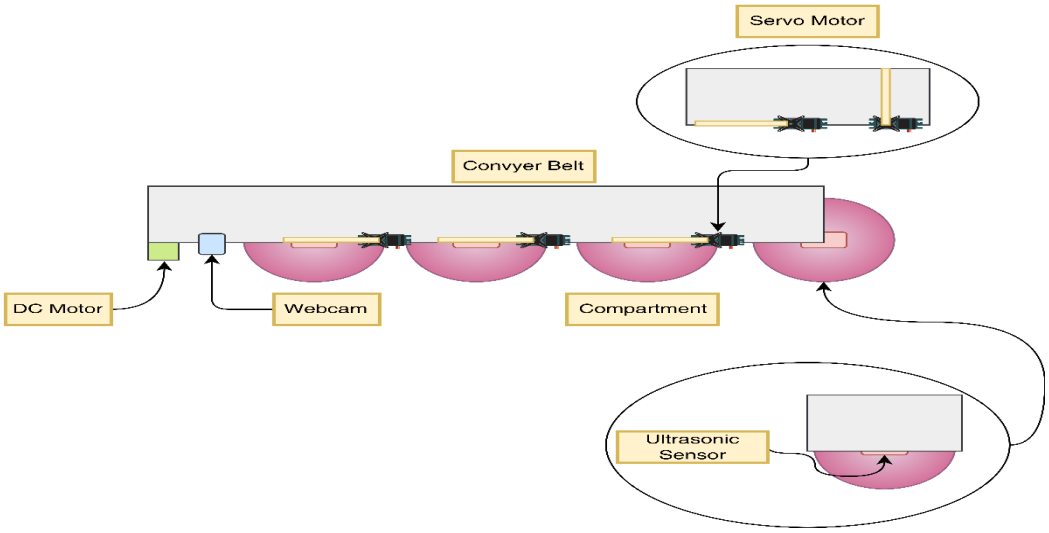

Figure 3.5.1.3 Overall Smart Recycle Bin System Top View

3.5.2 Overall Flowchart

The proposed system is Internet of Things (IoT) in Smart Recycle Bin Application Using AI Technology, where in this smart recycle bin system will monitor the recycle bin condition based on the remaining capacity of the recycle bin in figure 3.5.2.1. First, the power supply for smart recycle bin must be on to ensure connection between internet to the smart recycle bin and also the connection between microprocessor to all sensor implemented. Once all the connection is established, the smart recycle bin system will be fully function. When the power is on, the object placed will be capture by a camera to do image processing at through TensorFlow keras module. After the object is classified, the sensor process module will be taken placed. Once is done the data of the smart recycle bin will be collected and send to database through internet. After the database have receive the data from the hardware system. Then the database will be update and display the data to web application of the smart recycle bin. In software part, user required to open the web application through website link. When user open the website will display two navigation tab which are home page and report page. In home page, user able to view all the smart recycle bin information including the capacity left in each compartment and recycle bin location. In report tab, user able to view the insight of recycle bin through data visualisation.

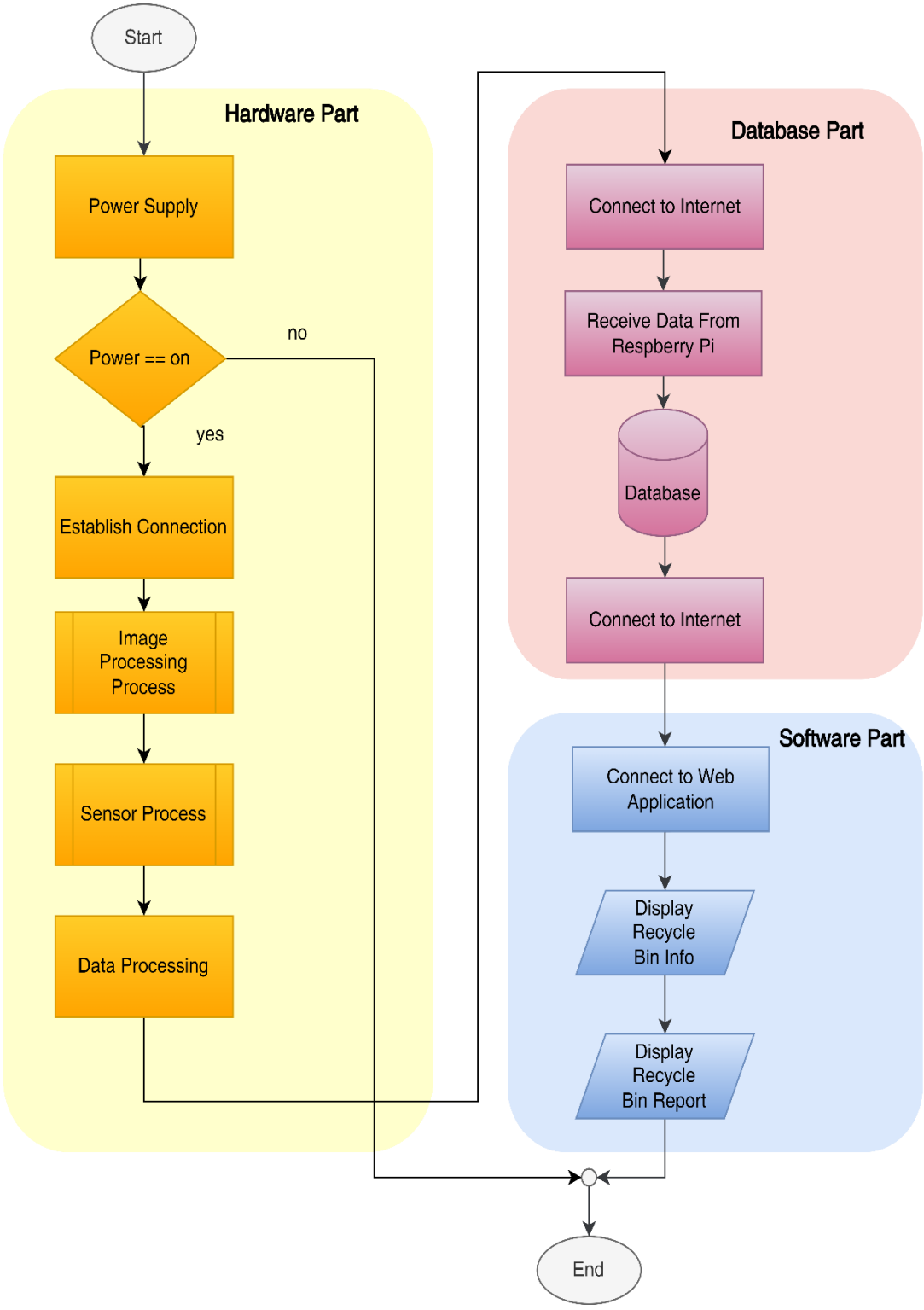

Figure 3.5.2.1 Overall Flowchart

3.5.3 Hardware Flowchart

Based on the overall hardware flowchart in figure 3.5.3.1, in the hardware part the power supply must be on. Once the power is on, the connection will be established between sensors. Once all the connection is established, the smart recycle bin system will be fully function. The object placed will be capture by a camera to do image processing at mobileNetV2 through TensorFlow keras module. After the object is classified, the sensor process module will be taken placed. Once is done, the data of the smart recycle bin will be collected and send to database through internet.

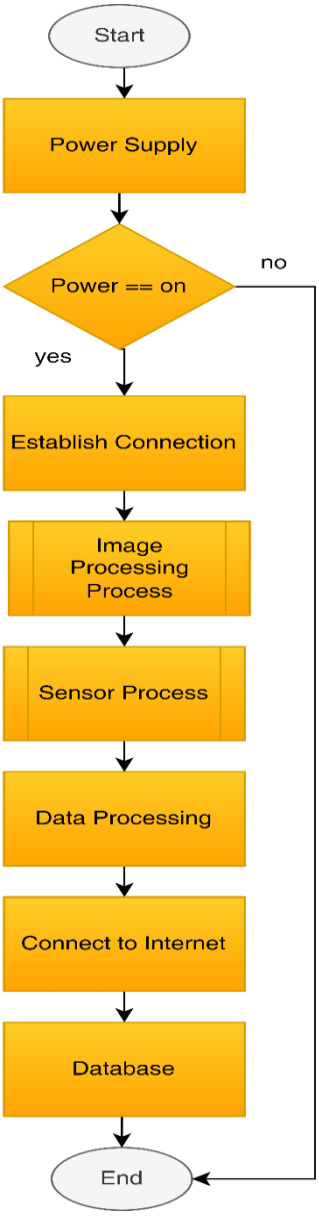

Figure 3.5.3.1 Overall Hardware Flowchart

Based on figure 3.5.3.2, the dataset used in this system is from Kaggle website which contained many datasets. After find the desired dataset the filtration of dataset is implement to filter out blur and unusable dataset. Then, all the dataset will be upload to an AI tool called Teachable Machine. In teachable machine is a premade machine learning application which allow to train model in short period of time. After the dataset has been trained the model will be generated using TensorFlow keras module. Then, by downloading the respective model and implement in the smart bin system.

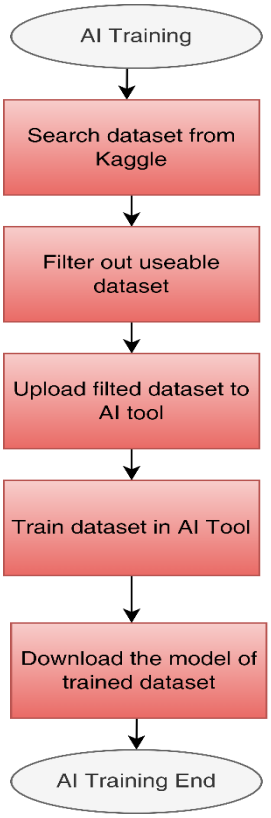

Figure 3.5.3.2 AI Training Module

Based on figure 3.5.3.3 in the image processing module, the camera will capture the image of the object and send it to mobileNetV2. In mobileNetV2, TensorFlow keras module will run object classification and identification based on previous image training sets. Then, once the object is identified. A command will be generated. The TensorFlow will send signal to raspberry pi to push them to correct compartment. If the object is unable to be identify the waste will be set as general waste. Then the image processing module will be end.

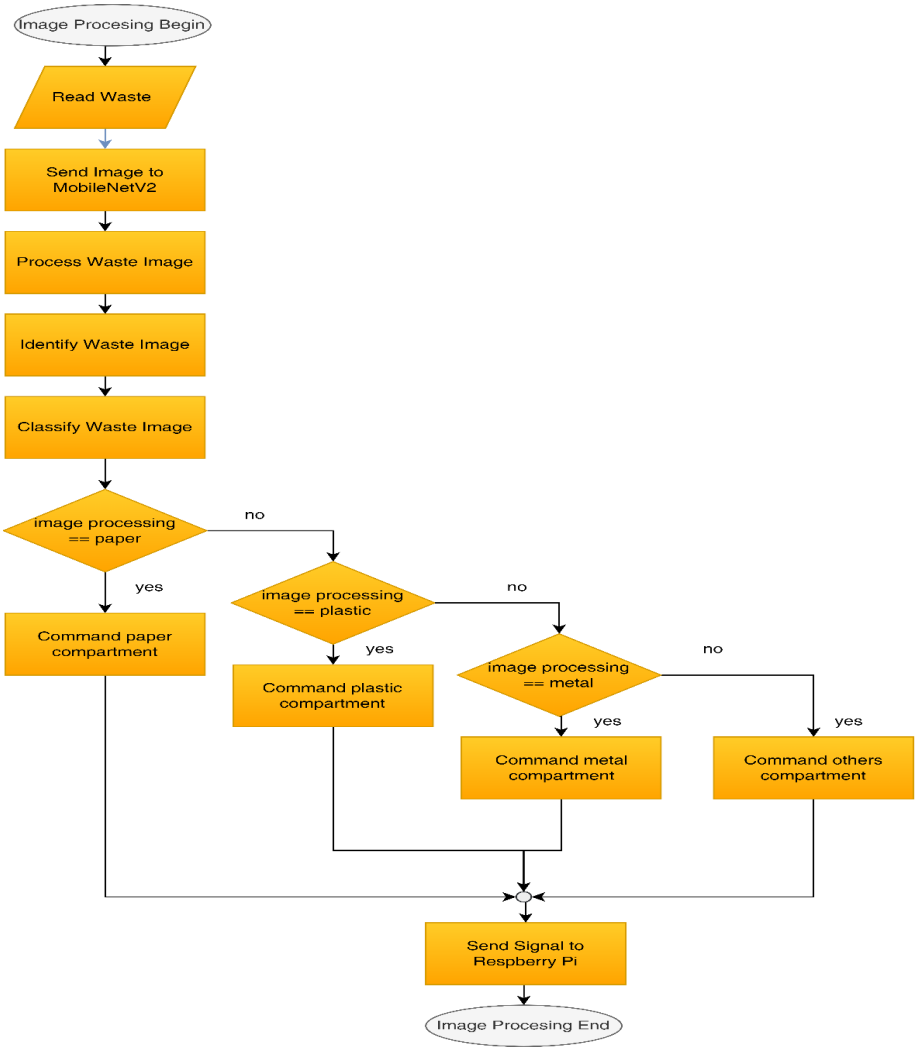

Figure 3.5.3.3 Image Processing Module

Based on figure 3.5.3.4 in sensor process module, starting it will receive the signal from the raspberry pi microprocessor. Then, raspberry pi will control the conveyer belt and the pusher to allow the object is dropped at correct compartment. Once the object is successfully dropped. The ultrasonic sensor will work to detect each compartment remaining capacity level in the compartment. The data of each compartment will be response back to raspberry pi. When raspberry pi received capacity status is full, raspberry pi will send notification message through telegram. Then the sensor processing module will be end.

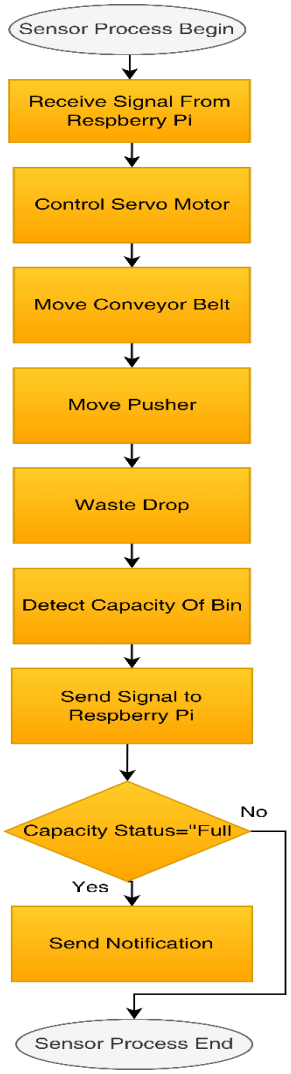

Figure 3.5.3.4 Sensor Process Module

3.5.4 Software Flowchart

Based on figure 3.5.4.1 display software part flowchart. Through this flowchart after the database is connected to internet, database will receive the data from the hardware system from raspberry pi microprocessor. Then the database will be update and display the data to web application of the smart recycle bin. When user open the website will display two navigation tab which are home page and report page. In home page, user able to view all the smart recycle bin information including the capacity percentage in each compartment and recycle bin location. In report tab, user able to view the insight of recycle bin through data visualisation.

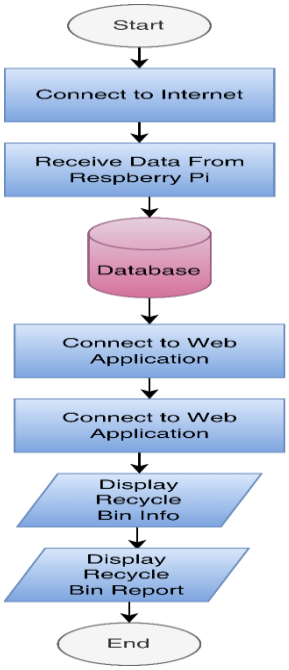

Figure 3.5.4.1 Software Flowchart

3.5.5 Use Case Diagram

Based on figure 3.5.5.1 shows the use case diagram of the smart recycle bin system. In this system, developer of smart recycle bin system and management able to manage recycle bin information and manage report.

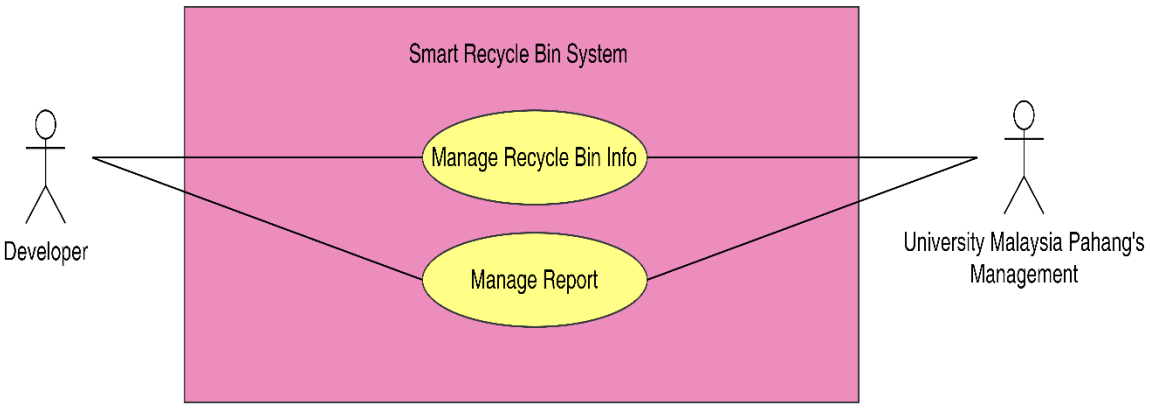

Figure 3.5.5.1 Use Case Diagram of Smart Recycle Bin System

3.5.6 Context Diagram

Based on figure 3.5.6.1 shows the context diagram of the smart recycle bin system. In this figure, Raspberry pi microprocessor will send the smart recycle bin information to the system. Through this, user and management can view smart recycle bin information and report information from the system.

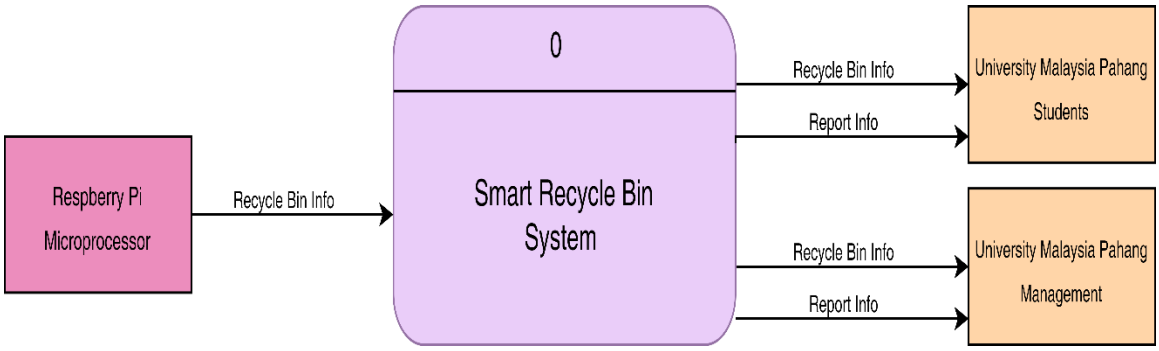

Figure 3.5.6.1 Context Diagram of Smart Recycle Bin System

3.5.7 Activity Diagram

Figure 3.5.7.1 shows the activity diagram of the smart recycle bin system. From the diagram above, the starting point of the activity is at smart recycle bin. In smart recycle bin, the recycle bin information will be collect and send to database based on the remaining capacity and moisture level of each compartment. Once the data reached database, database will save the data. Once the database is updated, the database will connect to web application. When the connection is established, user can access the web application through website link. Then, in the web application there are two navigation option which are home and report. When user choose home option, then database will retrieve recycle bin information and display it on the website. When user choose report option, the database will retrieve report information and display it on the website. User able to end the activity at this phase by closing the web application or after review home page.

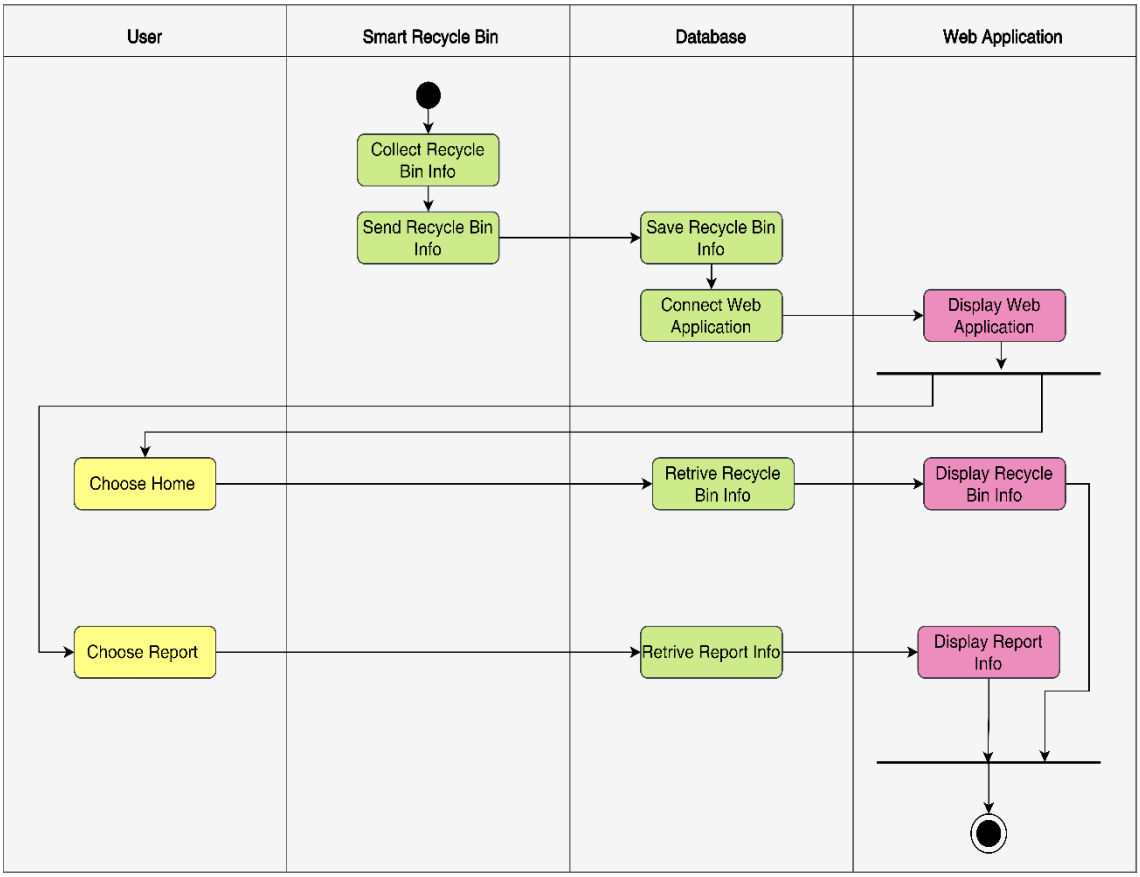

Figure 3.5.7.1 Activity Diagram of Smart Recycle Bin System

3.6 Data Design

3.6.1 Entity Relation Diagram (ERD)

Figure 3.6.1.1 shows the ERD of the smart recycle bin system. There are two table involved which is controller table and bin table. In controller table, there are two attributes where device ID as primary key and bin ID as foreign key. In bin table there are six attributes where bin ID as primary key location, compartment, remaining, status and date. The relationship between these two tables is one to many relationships where one controller can have many bins and vice versa.

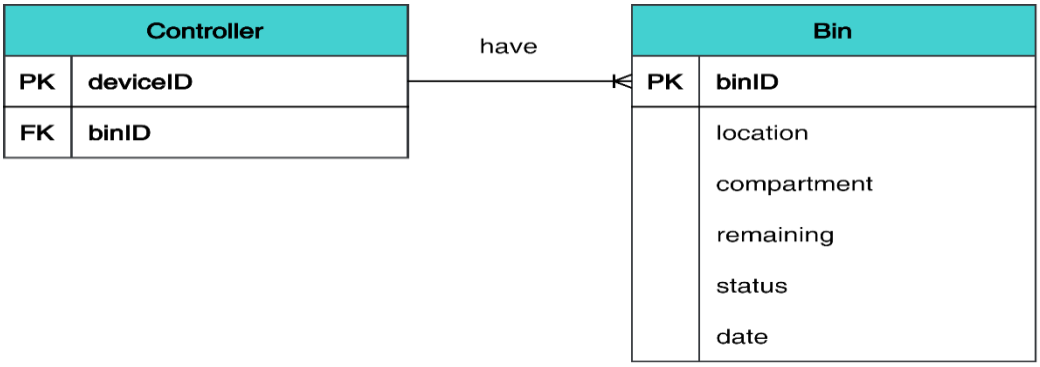

Figure 3.6.1.1 Entity Relation Diagram (ERD) of Smart Recycle Bin System

3.6.2 Data Dictionary

Table 3.6.2.1 Controller Table

Field Name	Description	Data Type	Constraint
deviceID	Micro-controller ID	INT (20)	PK, NOT NULL
binID	Recycle bin ID	INT (20)	FK, NOT NULL

Table 3.6.2.2 Recycle Bin Table

Field Name	Description	Data Type	Constraint
binID	Recycle bin ID	INT (20)	PK, NOT NULL
location	Recycle bin location	VARCHAR (255)	NOT NULL
compartment	Recycle bin compartment	VARCHAR (255)	NOT NULL
remaining	Recycle bin remaining capacity	INT (11)	NOT NULL
status	Recycle bin compartment's status	VARCHAR (255)	NOT NULL
date	Recycle bin detection date and time	DATETIME	NOT NULL

3.7 Hardware & Software

3.7.1 Hardware Support

a. Raspberry Pi Microprocessor

Raspberry Pi 4 model B is a microprocessor is a computer which is in smaller and more compact form. Raspberry Pi 4 model B support gigabit ethernet port, build in wireless networking and Bluetooth. Other than that, this microprocessor also supports 2GB RAM, one USB type C power supply, two micro-HDMI port, two USB 2 port and two USB 3 port. With this device allow controlling all sensor to be done through configuring raspberry pi OS. Not only that, this device also allows data transmission between hardware to database through wireless network connection.

Figure 3.7.1.1 Respberry Pi 4 Model B

b. Webcam

Webcam module is used in this project to detect recycle item and categorise them. The webcam is plug through USB port of the raspberry pi 4. With high definition 1080 pixels, object can be easily detected.

Figure 3.7.1.2 5MP Respberry Pi Camera

c. Ultrasonic Sensor

Ultrasonic sensor that implements in this project is HC-SR04. This ultrasonic sensor's main purpose is to detect the capacity of each compartment in recycle bin. This is due to ultrasonic sensor can detect maximum range of 400 cm and minimum range of 2 cm. This is due to ultrasonic sensor emit ultrasound at 40000 Hz. If there are obstacle in front of the sensor the ultrasonic wave will reflect back to the sensor. There is where ultrasonic sensor detects the distance between it and obstacle. In this project the obstacle will be the waste in the bin to detect the remaining capacity of the compartment.

Figure 3.7.1.3 HC-SR04 Ultrasonic Sensor

d. Servo Motor

The servo motor implement in this project is to control the capacity of each compartment. There are 4 servo motor needed in this project. One DC motor will be implemented at the conveyer belt to control the movement of the belt. Three angular servos motor will be implemented as the pusher to push the item to the compartment. The servo motor use in this project will be MG995 180-degree angular servo motor.

Figure 3.7.1.4 MG995 180-Degree Angular Servo Motor

e. Power Supply

The power supply will be use in this project is 5V 3A. In order to power up all raspberry pi 4 model B and four ultrasonic sensors. Other than that, to power up MG995 180-degree angular servo motor uses external power supply which is 5V 2A. Moreover, 12V 2A adapter is used to power up the DC motor.

Figure 3.7.1.5 Power Supply 5V 3A

Figure 3.7.1.6 12V 2A Battery

Figure 3.7.1.7 5V 2A Power Supply

Table 3.7.1.1 Hardware Support Table

Hardware	Specification	Purpose
Laptop	• HP Envy X360 convertible 13-ar0xxx	A mechanism to develop and configure smart recycle bin system.
Micro-processor	• Raspberry Pi 4 Model B	Act as a micro-processor to control all sensors and module involved.
Sensor	• Ultrasonic sensor	Act as a media to send and receive data signal to detect smart recycle bin status.
Breadboard	• Breadboard 400 holes	Act as a circuit base for the smart recycle bin system.
DC Motor	• 12V DC motor	Control the movement of the conveyer belt.
Servo Motor	• MG995 180-degree angular servo motor	Detection of each compartment capacity level.
Power Supply	• 5V/3A charger • 5V/2A power supply • 12V/2A power supply	Act as power source for the whole system.

3.7.2 Software Support

a. Raspberry Pi OS

Raspberry Pi OS also known as Raspbian. It is a operating system for raspberry Pi micro-processor. Raspberry Pi OS provide a computer desktop vison to the developer. This operating software also allow developer to configure sensor and module in it with Python programming language.

Figure 3.7.2.1 Raspberry Pi OS Logo

b. Visual Studio Code

Visual studio code is a streamlined code editor which support most of the programming language. Developer able to plug or add extension of their desire programming language to be program. Other than that, visual studio code also supports Gits Hub. This allows programming become easier. In this project will use Python, PHP programming language.

Figure 3.7.2.2 Visual Studio Code Logo

c. XAMPP

XAMPP is used to deployed database in more convenient ways. XAMPP support Apache Server, MariaDB database, PHP and Perl programming languages. It provides a platform for users to test their website application in localhost before uploading to the remote web server.

Figure 3.7.2.3 XAMPP Logo

d. MobileNetV2

MobileNet-V2 is a convolutional neural network that is 53 layers deep. In this project, ImageNet database is used to extend the dataset to do data training and modelling. The trained network will be used in this project for object detection and classification. As a result, the network has learned rich feature representations for a wide range of images.

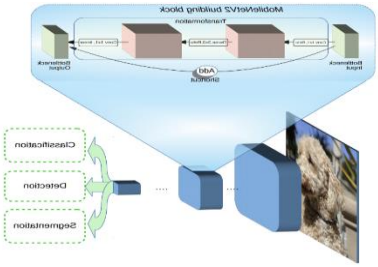

Figure 3.7.2.4 MobileNetV2 Machine Learnning

3.8 Interface Design

3.8.1 Home Interface

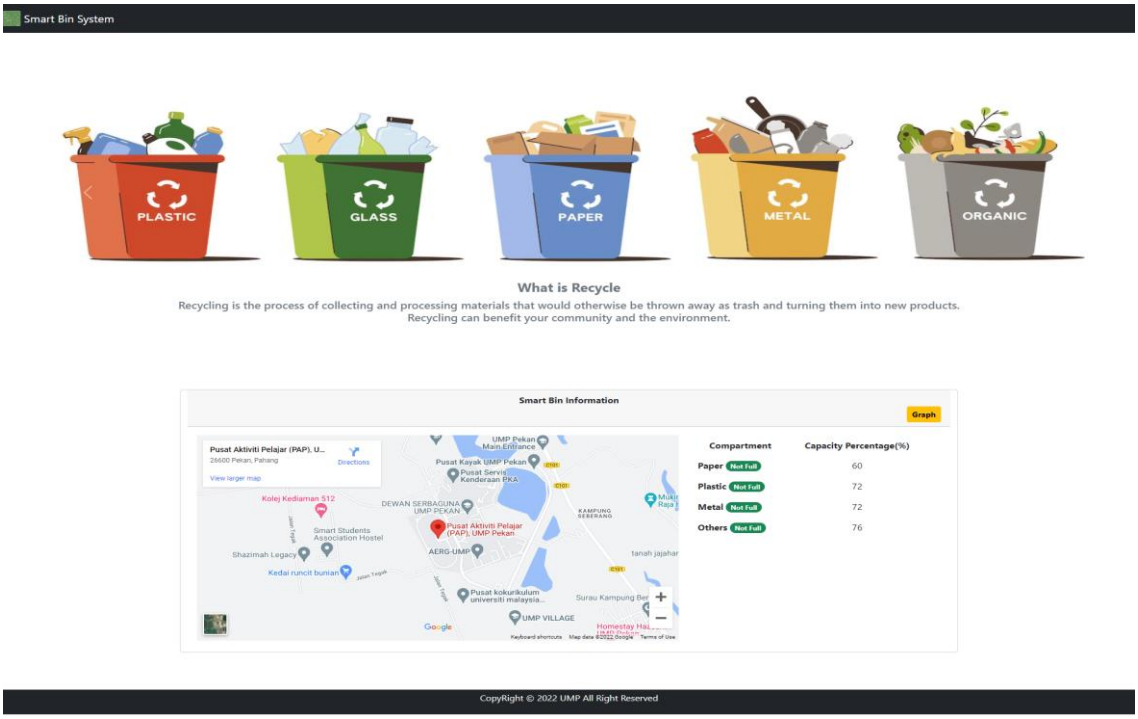

Figure 3.8.1.1 Home Interface of Smart Recycle Bin System

When user open the website of smart recycle bin system, home interface will be displayed as in figure 3.8.1.1. In this home interface include displaying the location of the smart recycle bin through pin the location in the google map. The capacity of each compartment will be displayed in a table form. The status of each compartment will also be displayed.

3.8.2 Report Interface

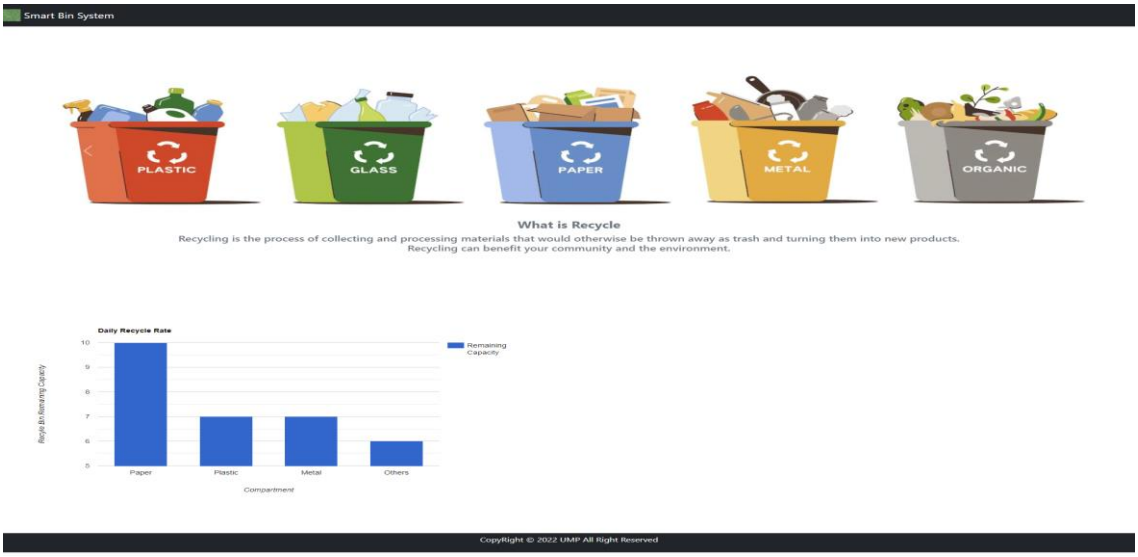

Figure 3.8.2.1 Report Interface of Smart Recycle Bin System

User can select graph button to direct to report interface. In this interface, user able to view the daily recycle percentage of each recycle category. Based on this report can reflect the frequency of user in University Malaysia Pahang implement recycling behaviours.

3.9 Testing Plan

The testing plan parameter of smart recycle bin system will be listed as form below. In the testing phase, the connection between hardware and database must be complete in order to view the outcome of the whole system as web application of smart recycle bin will display all output of the whole system.

Module	Activity	Status		Comments
AI Detection				
Deep learning	Camera	☐ Yes	☐ No	
	Image Processing	☐ Yes	☐ No	
	Image Classification	☐ Yes	☐ No	
	Object Detection	☐ Yes	☐ No	
Sensors				
Sensors	Ultrasonic Sensor	☐ Yes	☐ No	
Motors				
Motors	DC Motor	☐ Yes	☐ No	
	Servo Motor	☐ Yes	☐ No	
Web Application				
Home Interface	Display Recycle Bin Location	☐ Yes	☐ No	
	Display Recycle Category	☐ Yes	☐ No	
	Display Recycle Bin Capacity	☐ Yes	☐ No	

Report Interface	Calculate Daily Capacity of Recycle Bin of each compartment	☐ Yes	☐ No	
	Display Daily Capacity Recycle Percentage	☐ Yes	☐ No	
Notification				
Telegram	Create Alert Notification	☐ Yes	☐ No	
	Successfully Sent Notification	☐ Yes	☐ No	

This test has been performed by:

Name: _____

Signature: _____

Date: _____

3.10 Gantt Chart

The time line of this smart recycle bin system is plan through Gantt Pro application. The purpose of having a Gantt Chart in this project is to ensure the progress of the project met the milestone or the goal of the project from time to time. With this chart, developer involved able to ensure each part of the project met the requirement. The Gantt Chart is shown in Appendix A.

3.11 Conclusion

In Chapter 3, the methodology of this smart recycle bin has been discussed. From here, the smart recycles bin concept, implementation phase, hardware and software requirement has been discussed. Through this developer able to deeply understand toward the concept of implementing this smart recycle system by archiving goal that has been set in each phase. This able to ensure the whole project met the requirement.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter 4, it will focus on the overall deployment of the whole system, testing and result. The process sequence of system implementation and testing was deploy using RAD methodology. This chapter will detailly discuss the system deployment method to ensure this project is closely matching to the objective proposed. Through the implementation, programming language used in this system HTML, PHP and Python language in hardware and software setup. The limitation and constrained will also be discuss in this chapter.

4.1.1 Development Environment

The software that used to build this system include Raspberry OS, Visual Studio Code and XAMPP. The raspberry OS is an environment to setup the GPIO connection from each pin to sensors. The raspberry OS also provide an execution environment for each module as some of the default setting of the sensor has been done. Other than that, Raspbian also used to monitor result and debugging. In visual studio code, web application is developed in PHP language using Laravel framework. Other than that, visual studio code also used to develop machine learning for waste detection. Then, XAMPP is used to setup database for the whole system.

The smart recycles bin of University Malaysia Pahang used Raspbian. Hence, the Raspbian software was utilise to write code and import needed library to the environment. Raspbian OS is the default OS for all raspberry pi. In this Raspbian the default setting and library of the pi will be install directly when installing the OS itself. Once finished

installation of the Raspbian, we can use Python programming language to write respective code for each sensor through terminal or through visual studio code. To compile all the subfile together to be executed, we can use a python file as the execution main file to send command to allow sensor to be executed and the data receive will be at a directory. This directory will have all the data receive.

On the other hand, the web application also is important to smart recycle bin system to display data. The web application able to display the capacity of each tank. The software used to develop are XAMPP and visual studio code. In visual studio code, we can use multiple extension to allow our code more organized and cleaner. In this visual studio code, we can download python, PHP and HTML extension to allow us to write our code.

Next, the XAMPP software is used to setup database server through Apache. The combination of Apache and MySQL database allow us to visualise the web application with data storing at the database. We can observe the data changes from the database through phpMyAdmin.

4.2 Web Application System

The main user who will using this smart recycle bin is University Malaysia Pahang's management. University Malaysia Pahang management can observe each compartment capacity through the web application system and arrange for man power to clearing out the compartment accordingly.

4.2.1 Home Interface

In this home interface include displaying the location of the smart recycle bin through pin the location in the google map in figure 4.2.1.1. The capacity of each compartment will be displayed in a table form. The status of each compartment will also be displayed.

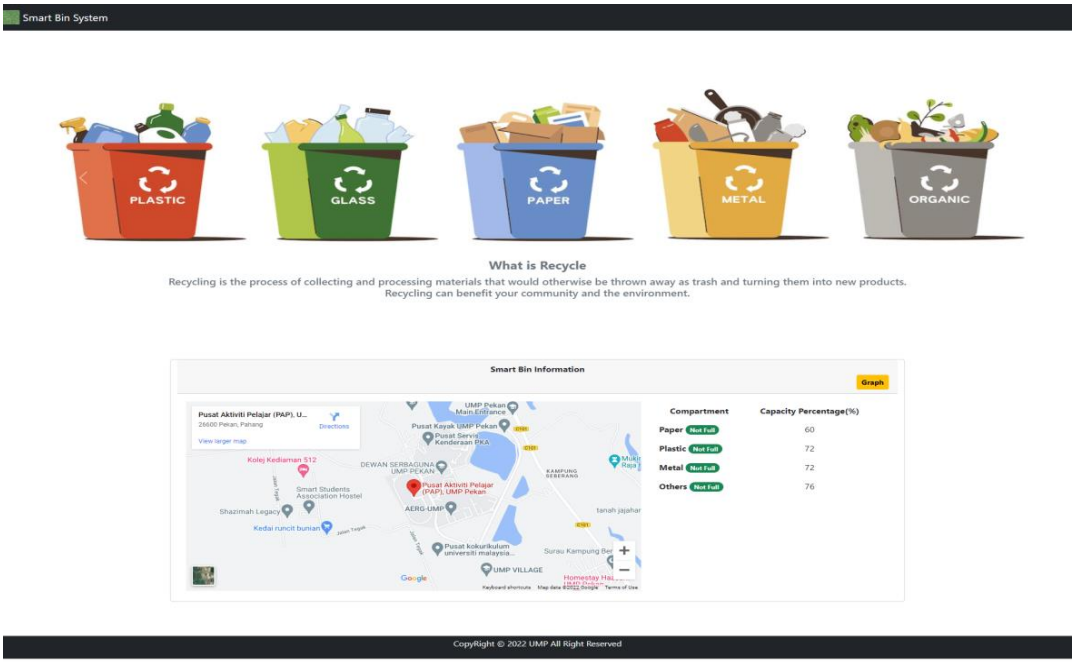

Figure 4.2.1.1 Home Interface of Smart Recycle Bin System

4.2.2 Report Interface

In report interface, University Malaysia Pahang's management can observe the daily capacity rate for each compartment in figure 4.2.2.1. From here, University Malaysia Pahang's management able to know the highest recycle category that practise my University Malaysia Pahang students.

Figure 4.2.2.1 Report Interface of Smart Recycle Bin System

4.3 Hardware System

The hardware connection and the coding implemented is discussed in this subtopic. Other than that, the hardware system also involved the element needed to execute this project.

4.3.1 Hardware Connection

The raspberry pi 4 model B is the core of the whole system. It acts as the commander on the designed circuit to execute each task. The microcontroller board which is raspberry pi 4 model B is used in this system. It had 40 pins in total which divided into eight category which are general purpose IO (GPIO) pin, serial peripheral interface (SPI) pin, inter-integrated circuit (I^2C) pin, universal asynchronous receiver/transmitter (UART) pin, pulse code modulation (PCM) pin, ground pin, 5V pin and 3.3V pin. The pin that used in this smart recycle bin system is GPIO pins, ground pin, 5V pin and 3.3V pin which able to support four ultrasonic sensor and three MG995 angular servo motor.

Figure 4.3.1.1 The Overall Circuit of Smart Recycle Bin

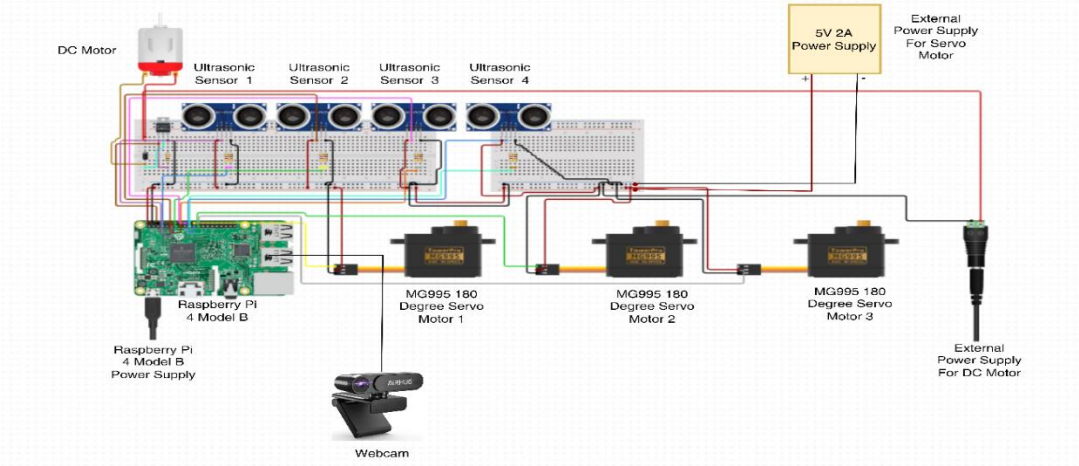

Figure 4.3.1.2 Details Circuit Diagram of Smart Recycle Bin

The camera module used in this smart recycle bin system is USB web camera which it only used the raspberry 3.0 USB port.

The four ultrasonic sensor and three MG995 angular servo motor will connect to the raspberry pi through jumper cable and breadboard. In the circuit, 1k ohm and 2k ohm resister is used to restrict the use of ampere to power up five ultrasonic sensors. This is to reserve more current to power up the microcontroller. Other than that, each ultrasonic sensor uses two GPIO pin to send and receive signal from the raspberry pi 4. Other than that, 5V pin and ground pin is applied to complete the whole circuit. For more details, the ground pin will connect to the negative of the breadboard. While VCC will connect to the positive of the breadboard. The trig pin act as the input pin and echo act as the output pin, both will be connected to the GPIO pin of raspberry to receive and send data.

Next is MG995 angular servo motor, the servo motor is connected in parallel circuit where an external power supply which is 5V 2A is connected to the breadboard through blue white cable from AC adapter. Then in MG995 angular servo motor, the PWM pin will connect directly to the raspberry pi to receive signal. While the VCC pin will connect to the positive of the breadboard and ground pin will connect to the negative of the breadboard.

The conveyer belt is made out of play wood, 12V DC motor, 12V/2A power supply, bolt and nut, cloth tape, PVC pipe and bearing. The 6V 4.5A battery is rechargeable battery which provide power supply to the conveyer belt. Cloth tape is use to act as the

belt. 12V DC motor will move the belt in one direction only. The bearing which located inside the PVC pipe will move simultaneously with the speed of the DC motor.

4.3.2 Object Detection Coding

For waste detection, there are 12 class datasets has been trained and implement in this project in figure 4.3.2.1. Each dataset is an open-source dataset which able to obtained from Kaggle website. Other than that, TensorFlow's mobileNetV2 pretrained data also a good source to expand the training by enlarging the dataset.

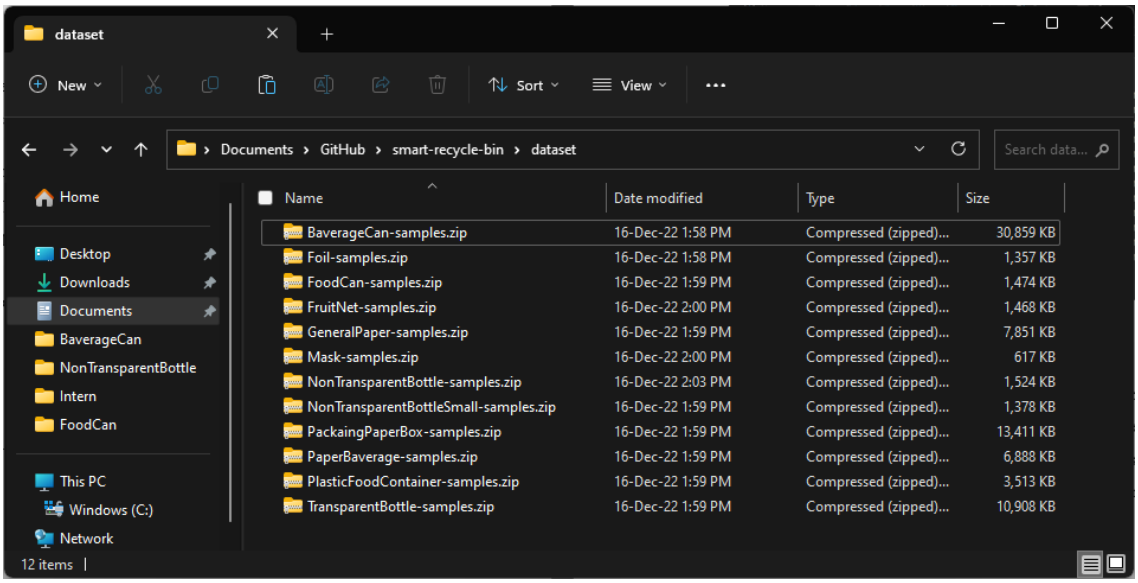

Figure 4.3.2.1 Dataset of Smart Recycle Bin

The tools that use to train the dataset model is Teachable Machine which allow upload multiple class of dataset and train the model in figure 4.3.2.2.

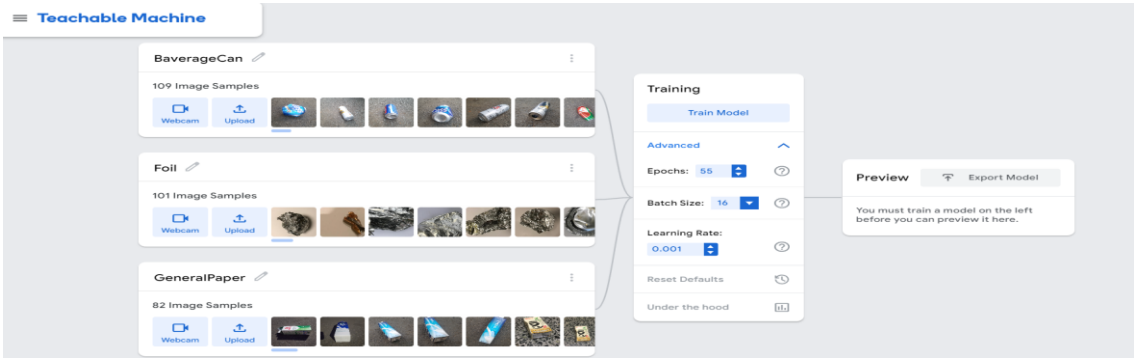

Figure 4.3.2.2 Teachable Machine AI Tool

Once that done, the model.h5 can be exported. The Teachable Machine only support TensorFlow and TensorFlow Lite. The technique that used in this project is implement in TensorFlow keras module with OpenCV in python to detecting the waste. Figure 4.3.2.3, 4.3.2.4 and 4.3.2.5 shows the process of data training.

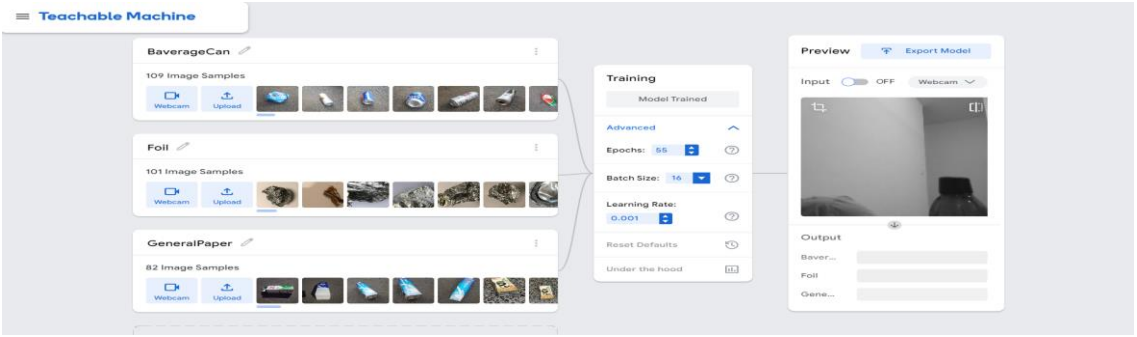

Figure 4.3.2.3 Successful Training AI

Figure 4.3.2.4 Output of Teachable Machine Model

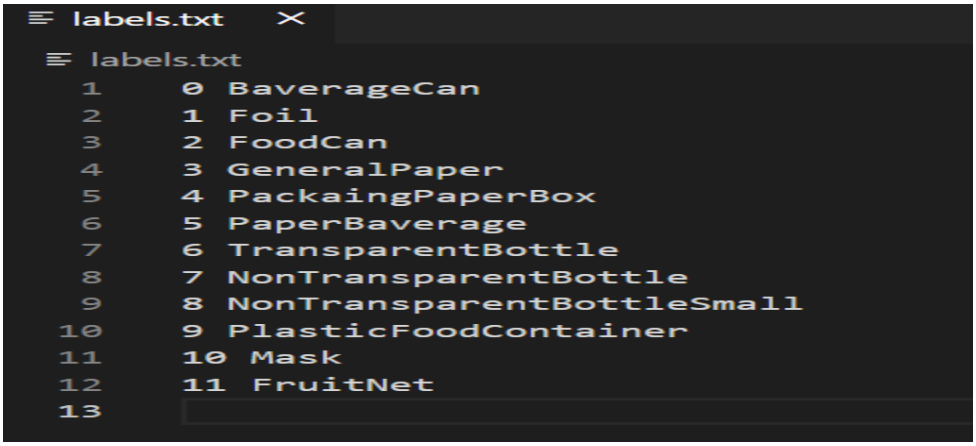

Figure 4.3.2.5 Class Labelling for Dataset

In this code, the model of the dataset has been loaded. Then, the import OpenCV in the python allow the video capturing for object detection. The class labelling is read to allow classification action to be done in figure 4.3.2.6.

```
# Load the model
model = load_model('keras_model.h5')

# CAMERA can be 0 or 1 based on default camera of your computer.
camera = cv2.VideoCapture(0)

# Grab the labels from the labels.txt file. This will be used later.
labels = open('labels.txt', 'r').readlines()
```

Figure 4.3.2.6 Object Detection Code

In this coding is where the detection starts to open the webcam through OpenCV method and start classification of the object in figure 4.3.2.7.

```
        # webcam start
        # Grab the webcameras image.

        ret, image = camera.read()

        # Resize the raw image into (224-height,224-width) pixels.
        image = cv2.resize(image, (224, 224), interpolation=cv2.INTER_AREA)
        # Show the image in a window
        #cv2.imshow('Webcam Image', image)
        # Make the image a numpy array and reshape it to the models input shape.
        image = np.asarray(image, dtype=np.float32).reshape(1, 224, 224, 3)
        # Normalize the image array
        image = (image / 127.5) - 1
        # Have the model predict what the current image is. Model.predict
        # returns an array of percentages. Example:[0.2,0.8] meaning its 20% sure
        # it is the first label and 80% sure its the second label.
        probabilities = model.predict(image)
        # Print what the highest value probabilitie label
        print(labels[np.argmax(probabilities)])
        # 12 class model
        index = np.argmax(probabilities)
```

Figure 4.3.2.7 Object Detection Coding

The output of the waste detection will be according to the class labelling name, to manage the smart bin system the merging of class is implemented according to compartment in figure 4.3.2.8.

```
127         compartment=['Paper','Plastic','Metal','Others']
128
129         #servo start
130         if index >= 3 and index <= 5:
131             motor(0)
132         elif index >= 6 and index <= 9:
133             motor(1)
134         elif index >= 0 and index <= 2:
135             motor(2)
```

Figure 4.3.2.8 Manage Output of Waste Detection

4.3.3 Ultrasonic Sensor Coding

For ultrasonic sensor coding, the declaration of GPIO pin in array format is implemented in figure 4.3.3.1.

```
39  GPIO.setmode(GPIO.BOARD)
40
41  PIN_TRIGGER =[12,15,7,11]
42  PIN_ECHO =[16,18,22,29]
43  distance = [0,0,0,0]
44  pulse_start_time= [0,0,0,0]
45  pulse_end_time= [0,0,0,0]
46  pulse_duration = [0,0,0,0]
```

Figure 4.3.3.1 Ultrasonic Sensors GPIO Pins Declaration

In the coding below is the for loop to read the distance of the remaining space in each compartment through pulse time. After the pulse time is read, the variable ‘i’ will store the time value. By substring the start time and the end time, the pulse duration is calculated. From pulse duration obtained, the distance of the remaining space in each compartment can be calculated in 4.3.3.2.

```
57          # ultrasonic check tank
58          for i in range(len(PIN_ECHO)):
59                  GPIO.setup(PIN_TRIGGER[i],GPIO.OUT)
60                  GPIO.setup(PIN_ECHO[i],GPIO.IN)
61                  GPIO.output(PIN_TRIGGER[i],GPIO.LOW)
62                  time.sleep(1)
63
64                  GPIO.output(PIN_TRIGGER[i],GPIO.HIGH)
65                  time.sleep(0.00001)
66
67                  GPIO.output(PIN_TRIGGER[i],GPIO.LOW)
68                  # print(i)
69
70                  while GPIO.input(PIN_ECHO[i])==0:
71                          pulse_start_time[i]=time.time()
72
73                  while GPIO.input(PIN_ECHO[i])==1:
74                          pulse_end_time[i]=time.time()
75
76                  pulse_duration[i]=pulse_end_time[i]-pulse_start_time[i]
77                  distance[i]=round(pulse_duration[i] * 17150, 2)
78
79                  if distance[i]<=x:
80                      status[i]=False
81                  else:
82                      status[i]=True
```

Figure 4.3.3.2 Ultrasonic Sensor Coding

Once the distance has been calculated, the condition of each compartment can be known by using if else statement. If is the tank is full then the notification message will be sent through telegram bot in figure 4.3.3.3.

```
90          condition=['','','','']
91
92          for i in range(len(status)):
93              if status[i]==False:
94                  condition[i]='Full'
95                  # print("Tank", [i] ,"is full.")
96                  text = "Smart bin is FULL located at PAP!!!"
97                  bot = telegram.Bot(token="5985510909:AAE4YKiMmqk690BL0JR_KOFIeSufeVBy_rQ")
98                  bot.send_message(chat_id=-1001809513671, text=(f'{text}'))
99                  #status[i]=True
100             else:
101                 condition[i]='Not Full'
102                 # print("Tank", [i] ,"is not full.")
```

Figure 4.3.3.3 Compartment Condition

4.3.4 Notification Coding

The notification of smart recycle bin is done using Bot Father in telegram, where generate a custom bot to allow alert notification send to admin of University Malaysia Pahang in figure 4.3.4.1.

Figure 4.3.4.1 Bot Father Interface

After creation of new bot, we named it as smart bin alert bot and obtained the unique token to access HTTP API in figure 4.3.4.2.

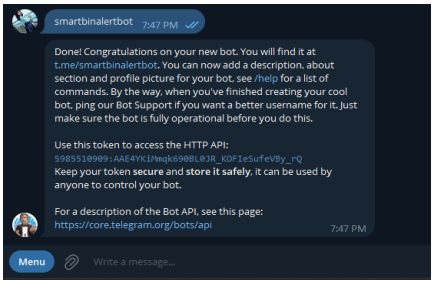

Figure 4.3.4.2 API Token For Smart Bin Alert Bot

Then, create a group with admin and bot to receive alert notification and Raw Data bot is added to obtained unique chat id in figure 4.3.4.3.

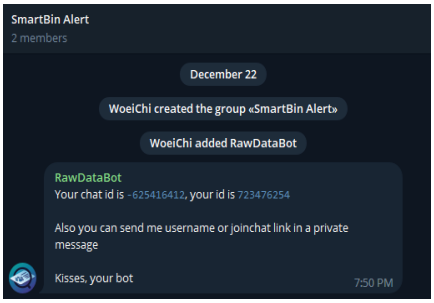

Figure 4.3.4.3 Chat Room For Notification

The notification message will be written as below figure to alert management of University Malaysia Pahang in figure 4.3.4.4.

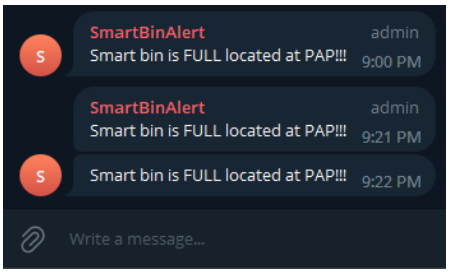

Figure 4.3.4.4 Smart Bin Alert

4.3.5 Servo Coding

In this coding starting with declaration of the servo PWM pin. Then two function is used where set angle function is to set the angle of all servo motor and the motor function is to call each servo motor to execute the specific angle in figure 4.3.5.1.

```
GPIO.setmode(GPIO.BOARD)
GPIO.setup(37,GPIO.OUT)
GPIO.setup(5,GPIO.OUT)
GPIO.setup(35,GPIO.OUT)

pin = [37, 5, 35]
list_servo = [GPIO.PWM(pin[0],50), GPIO.PWM(pin[1],50), GPIO.PWM(pin[2],50)]

for i in range(len(list_servo)):
    list_servo[i].start(0)

def SetAngle(angle, pin, idservo):
    duty = angle / 18 + 2
    GPIO.output(pin, True)
    list_servo[idservo].ChangeDutyCycle(duty)
    time.sleep(1)
    GPIO.output(pin, False)
    list_servo[idservo].ChangeDutyCycle(0)

def motor(index):
    SetAngle(0, pin[index], index)
    SetAngle(45, pin[index],index)
    time.sleep(20)
    SetAngle(0, pin[index],index)
```

Figure 4.3.5.1 MG995 Servo Motor Coding

From the result obtained from the object detection, the motor function is called to move the servo motor stick to a specific angle in figure 4.3.5.2.

```
        compartment=['Paper','Plastic','Metal','Others']

        #servo start
        if index >= 3 and index <= 5:
            motor(0)
        elif index >= 6 and index <= 9:
            motor(1)
        elif index >= 0 and index <= 2:
            motor(2)
```

Figure 4.3.5.2 Motor Function

4.4 Database and PHP

In database and PHP, the database connection from inserting data from raspberry pi to database and retrieve data from database displaying in web application is discussed in this subtopic.

4.4.1 Remote Database Connection Coding

Smart recycle bin web application used PHP programming language in Laravel framework. After create bins table through terminal, up function adding five attributes into the table. Then migrate the whole database together. This will allow the web application connected to database through phpMyAdmin in figure 4.4.1.1.

Figure 4.4.1.1 Migration Table

After successfully migrate, the created database will be appeared in the phpMyAdmin. This shows that the database connection is established in figure 4.4.1.2.

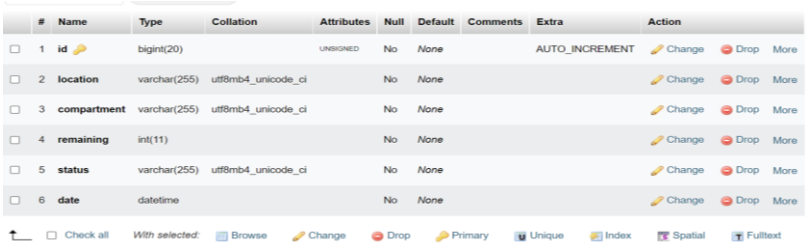

Figure 4.4.1.2 MySQL Table

From raspberry pi, “insertdata.py” file is created to pass the read value to the database. In this python file import MySQL connector to establish the connection to the database. The host is changed due to the MySQL database is implemented outside of the raspberry

pi to ensure raspberry pi have larger resources. The insert query is used to insert data to the database. To ensure database connection is successfully establish, both software and hardware of this project needed to be in the same subnet in figure 4.4.1.3.

```python
import mysql.connector

def insert(value1, value2, value3, value4, value5):
    try:
        #establishing the connection
        mydb = mysql.connector.connect(
        user='root',
        password='',
        host='192.168.27.1',
        database='smartbin')

        #Creating a cursor object using the cursor() method
        mycursor = mydb.cursor()

        # Preparing SQL query to INSERT a record into the database.
        sql = "INSERT INTO bin(location, compartment, remaining, status, date) VALUES (%s, %s, %s, %s, %s)"

        val = (value1, value2, value3, value4, value5)

        # Executing the SQL command
        mycursor.execute(sql, val)

        # Commit your changes in the database
        mydb.commit()

        print(mycursor.rowcount, "record inserted")

    except Exception as e:
        print (e)
```

Figure 4.4.1.3 Insert Database File

Next at the main execution file which is “detect.py”, for loop is used to pass the all the variable to the database and datetime function is used to keep track of the smart recycle bin update timing in figure 4.4.1.4.

```python
        # datetime object containing current date and time
        now = datetime.now()
        dt_string = now.strftime('%Y-%m-%d %H:%M:%S')

        for i in range(4):
            myvalue1='UMP PAP'
            myvalue2= compartment[i]
            myvalue3= distance[i]
            myvalue4= condition[i]
            myvalue5= dt_string

            Insertdata.insert(myvalue1, myvalue2,myvalue3,myvalue4,myvalue5)
```

Figure 4.4.1.4 Pass Variable into Database

4.4.2 Web Application Coding

The “web.py” is the routing of the web application where route is connected to the bin controller in figure 4.4.2.1.

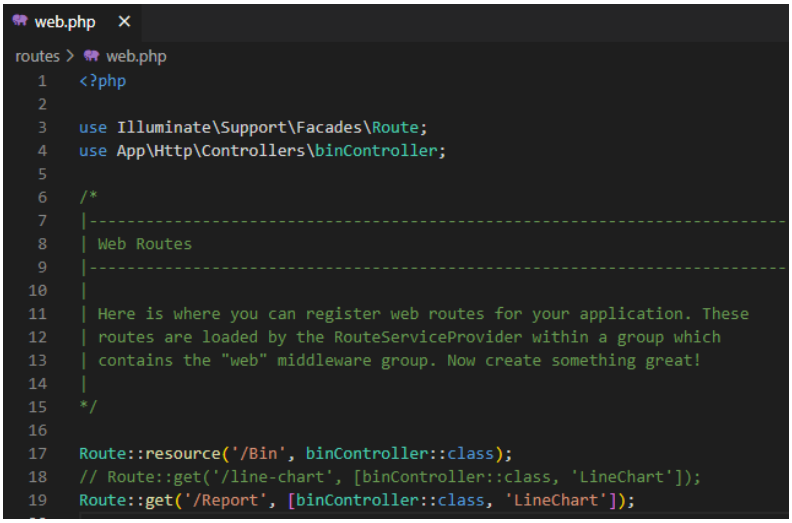

Figure 4.4.2.1 Web Application Route

In bin controller is to call the index function to print all data from bin model. This is due to bin model connected to the database. Other than that, the calculate function is used to calculate the capacity percentage of each compartment in figure 4.4.2.2.

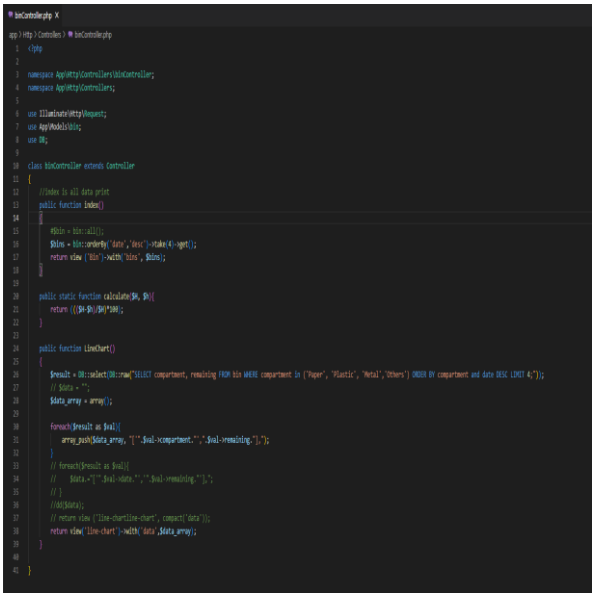

Figure 4.4.2.2 Bin Controller File

In models, the bin table from database is connected at this file where it able to access all bin attribute variable in figure 4.4.2.3.

Figure 4.4.2.3 Bin File

In “bin.blade.php” the interface of smart recycle bin is implemented. In below the looping for retrieve data from database is done and the alert for bin capacity is done in figure 4.4.2.4.

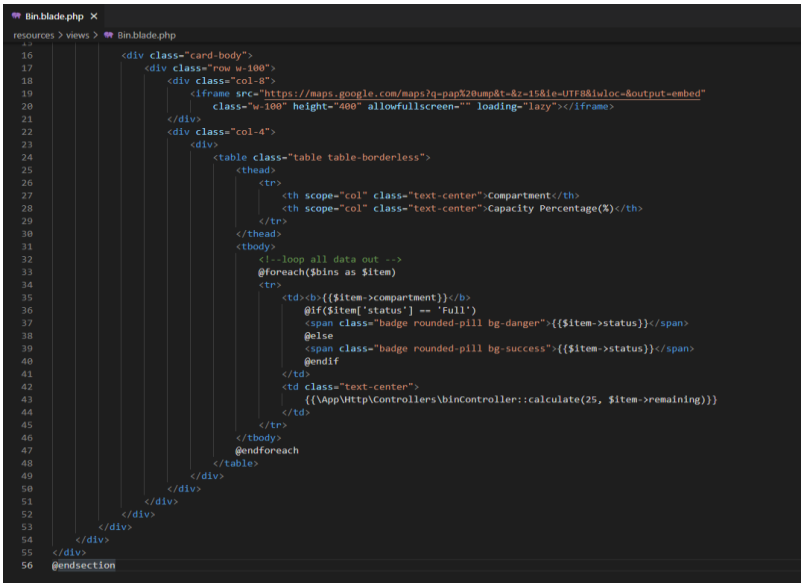

Figure 4.4.2.4 Bin.blade File

In master.blade file, the meta is used to refresh the web application constantly within 10 seconds in figure 4.4.2.5.

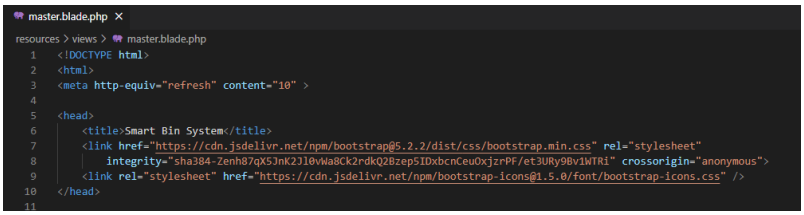

Figure 4.4.2.5 Master.blade File

In report page, the google bar graph is implemented using java script in figure 4.4.2.6.

line-chart.blade.php

resources > views > line-chart.blade.php

```
@extends('master')
@section('content')

<html>
  <head>
    <script type="text/javascript" src="https://www.gstatic.com/charts/loader.js"></script>
    <script type="text/javascript">
      google.charts.load('current', {'packages':['corechart']});
      google.charts.setOnLoadCallback(drawVisualization);

      function drawVisualization() {
        // Some raw data (not necessarily accurate)
        var data = google.visualization.arrayToDataTable([
          //['Date', 'Paper', 'Plastic', 'Metal', 'Others'],
          ['Compartment', 'Remaining Capacity'],
          <?php
          foreach($data as $item){
            echo $item;
          }
          ?>

        ]);

        var options = {
          title : 'Daily Recycle Rate',
          vAxis: {title: 'Recyle Bin Remaining Capacity'},
          hAxis: {title: 'Compartment'},
          seriesType: 'bars',
          series: {5: {type: 'line'}}
        };

        var chart = new google.visualization.ComboChart(document.getElementById('chart_div'));
        chart.draw(data, options);
      }
    </script>
  </head>
  <body>
    <div id="chart_div" style="width: 900px; height: 500px;"></div>
  </body>
</html>

@endsection
```

Figure 4.4.2.6 Bar Chart Code

4.5 Testing and Discussion

In testing phase include hardware and the software testing to ensure the database connection, the sensors and the mobile applications are in track to achieve the objective of this system.

In hardware system, once the sensor successfully detected, the reading ultrasonic sensor will automatically be inserted into the database in figure 4.4.2.1 and 4.4.2.2.

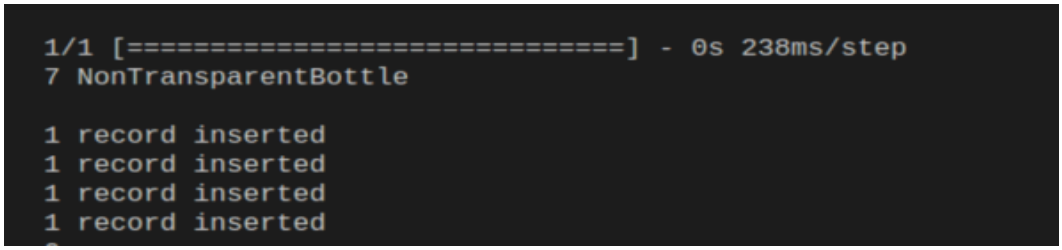

Figure 4.4.2.1 Terminal Interface in Raspberry Pi

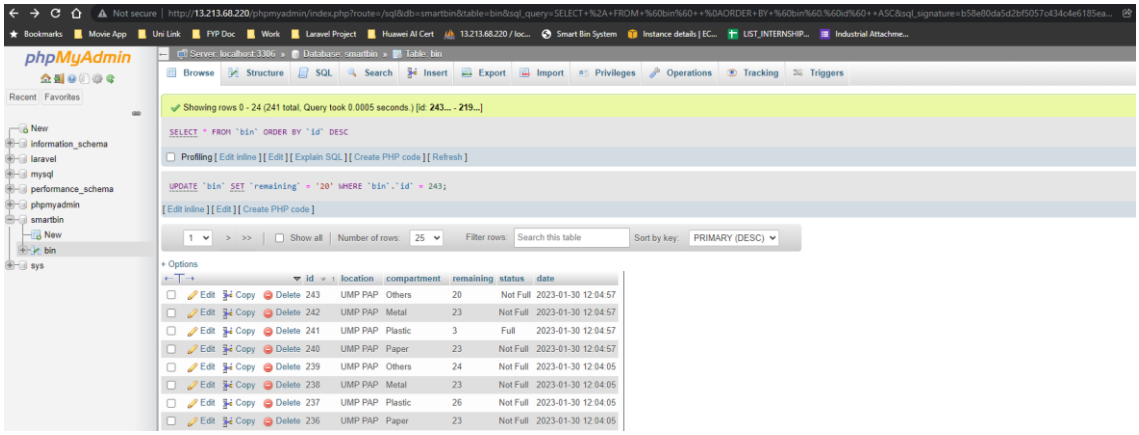

Figure 4.4.2.2 Database Sucessfully Inserted

In software system, once the connection between database and web application establishes the web application will display the latest data through AWS in figure 4.4.2.3 and 4.4.2.4.

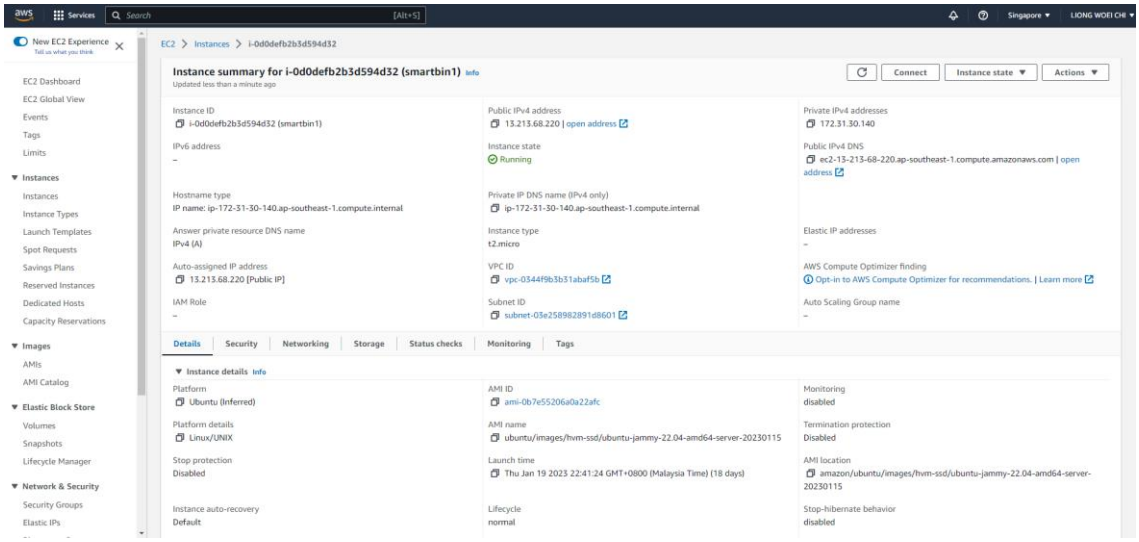

Figure 4.4.2.3 Connection To Web Application Route

Figure 4.4.2.4 Web Application Output

4.6 Conclusion

In conclusion, this project begins with implementation in hardware. Once all hardware component is successfully setup, the configuration of hardware is proceeded. This is to allow hardware system can be fully operate and ensure the reading of sensor is accurate. Then, the configuration of accessing internet is done to ensure hardware system can be connect with database. Next, MySQL database is configured and used to store the sensors reading from the hardware system. Then, software system of this project is designed and implemented to allow displaying smart bin information. Then, the web application must connect to the database to retrieved data. Not only that, the configuration of auto refreshing the web page is done to ensure can display the real time information of smart recycle bin.

CHAPTER 5

CONCLUSION

5.1 Introduction

The smart recycle bin is to implement awareness of public to concern of the environment issue. At the same time able to practices and develop habit to become one of the routine behaviours. This system implements IoT and AI technique to develop hardware system. While in software use PHP programming language in Laravel framework. This chapter will conclude the thesis and explanation on the constraints met in implementation phase of the system and the future work is also discussed in this chapter.

5.2 Constraints

There are several constraints during the system implementation. The constraints include hardware constraint, time constraint, cost constraints and technical constraint.

5.2.1 Hardware Constraints

In hardware constraints of this entire project is the microprocessor which is the Raspberry Pi 4 model B. This is due to AI detection required lager RAM to run the entire process. However, in this project only equip with 2GB RAM. This causes the limitation in speed as a large dataset and data model need to be load. Therefore, the response time for object detection will take a longer time. This also causes the dataset and data model used need to be in the smallest data model to allow the whole system run. Else the system will break down due to insufficient storage space to work on. Therefore, to prevent break down of the system setting for swap file is required as there is no graphic card in raspberry pi yet the speed and accuracy for object detection will decrease.

5.2.2 Time Constraints

Although this system able to implement on time, the improvement in AI part still can be made. This is due to there are AI technique that able to train the dataset in much smaller model which able to improve the accuracy and efficiency when detecting object.

5.2.3 Cost Constraints

The development of this system was high cost for a student. The microprocessor has the major share in costing continue by sensor and motors. Other part from that, is uses recycle item to create it which will have much lesser share compare to above. However, more handling skill and crafting skill is required.

5.2.4 Technical Constraints

The technical constraints that faced in this project is the AI machine learning part where the system will break down when running in raspberry pi. There are many techniques that to develop and train the custom dataset. However due to system environment issue and specs, the most suit technique is used after many failures.

5.3 Future Work

The application of future work in smart recycle bin system is needed to improve the speed and the improve user experience. There are few parts in this system needed to be improve which are the AI machine learning part for detection and the conveyer belt limitation in term handling weight of an object.

In AI machine learning part, the improvement needed is to train the dataset in much smaller model's size. There are many machines learning technique. As future work, you able to compress the model size in large dataset is the best choice in this scenario using different technique. As raspberry pi does not have graphic card which the process of detection in run based on the CPU of the raspberry pi. Therefore, the smaller the model, will lighten up the processing task and increases in speed.

In conveyer belt part, the improvement can be implemented is the weight handle by the belt to move the object. This is due to the DC gear motor use only can handle maximum 1 kg in loaded condition and stall condition only can handle up to 3kg include

weight of the belt itself. Therefore, to improve able to use higher torque and lower RPM DC motor to allow the system able to handle much more type of waste.

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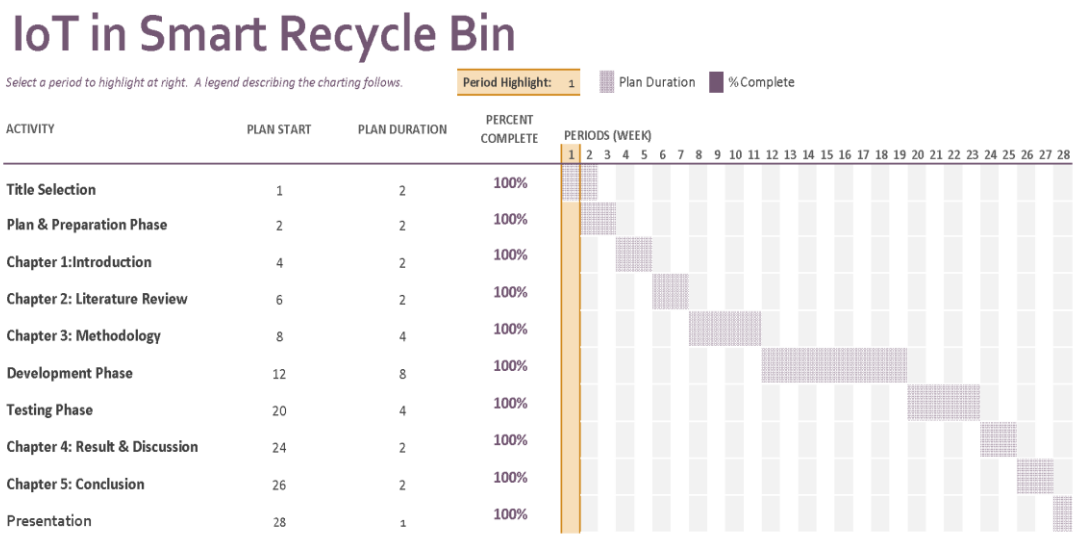
APPENDIX A
GANTT CHART



APPENDIX B
USER ACCEPTANCE TEST (UAT)

Module	Activity	Status		Comments
AI Detection				
Deep learning	Camera	☑ Yes	☐ No	
	Image Processing	☑ Yes	☐ No	
	Image Classification	☑ Yes	☐ No	
	Object Detection	☑ Yes	☐ No	
Sensors				
Sensors	Ultrasonic Sensor	☑ Yes	☐ No	
Motors				
Motors	DC Motor	☑ Yes	☐ No	
	Servo Motor	☑ Yes	☐ No	
Web Application				
Home Interface	Display Recycle Bin Location	☑ Yes	☐ No	
	Display Recycle Category	☑ Yes	☐ No	
	Display Recycle Bin Capacity	☑ Yes	☐ No	
Report Interface	Calculate Daily Capacity of Recycle Bin of each compartment	☑ Yes	☐ No	

	Display Daily Capacity Recycle Percentage	☑ Yes	☐ No	
Notification				
Telegram	Create Alert Notification	☑ Yes	☐ No	
	Successfully Sent Notification	☑ Yes	☐ No	

This test has been prepared by:

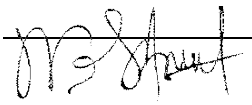
Name: Liong Woei Chi

Signature: 

Date: 08/02/2023

This test has been approved by:

Name: Dr. Nor Syahidatul Nadiah Binti Ismail

Signature: 

Date: 9/2/2023

APPENDIX C
QR CODE FOR WEB APPLICATION