DEVELOPMENT OF USER-CENTERED SMART BIN FOR A SMART CITY VIA IOT PLATFORM

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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DECLARATION

I declare that this report entitled "Development Of User-Centered Smart Bin For A Smart City Via Iot Platform" is the result of my own work except for quotes as cited in the references.

Signature :

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

Signature :

Supervisor Name : DR NUR FATIHAH BINTI AZMI

Date : 25/6/ 2021

DEDICATION

I dedicate this to my beloved mother, Nafisah Binti Md Salim, my family and my housemate's friends.

ABSTRACT

In today's society, the performance of a neighbourhood’s garbage management system has become a crucial part in accomplishing the Smart Residence Vision. Garbage bins in residential public parks and gardens are frequently overflowing, ruining the city's environment, residential neighbourhood, and affecting the lives of those who live nearby. Hence, this project aims to provide an alternative solution to the above-mentioned issue by developing a User-Centered Smart Bin which is able to monitor trash by using an IoT system to analyse the performance and helps to separate the waste material from metal and non-metal and eased the recycling process. The system’s requirement is designed based on the market survey to provide direction for the optimized Smart Bin system. The developed IoT system is envisioned to be implemented to monitor the whole waste trash management system.

ABSTRAK

Pada era globalisasi ini, prestasi sistem pengurusan sampah telah menjadi bahagian penting dalam mencapai Visi Kediaman Pintar. Tong sampah di taman awam dan taman perumahan sering melimpah, menjejaskan persekitaran bandar, kawasan perumahan, dan mempengaruhi kehidupan mereka yang tinggal berdekatan. Oleh itu, projek ini bertujuan untuk memberikan penyelesaian alternatif kepada masalah yang disebutkan di atas dengan membangunkan Tong Sampah Berpusatkan Pengguna yang dapat memantau sampah dengan menggunakan sistem IoT untuk menganalisis prestasi serta membantu memisahkan bahan buangan dari logam dan bukan-logam sekaligus memudahkan proses kitar semula. Pembinaan sistem ini dirancang berdasarkan tinjauan pasaran pengguna untuk membantu sistem Tong Sampah Pintar ke tahap optimum. Sistem IoT yang diintegrasikan diharap dapat dilaksanakan untuk memantau keseluruhan sistem pengurusan sampah.

ACKNOWLEDGEMENTS

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LIST OF SYMBOLS AND ABBREVIATIONS

UCSB	:	User-Centered Smart Bin
MSW	:	Municipal Solid Waste
SMM	:	Sustainable Materials Management
IoT	:	Internet of Things
GPS	:	Global Positioning System
GPRS	:	General Packet Radio Service
HTML	:	Hypertext Markup Language
A.I	:	Artificial Intelligence
Wi-Fi	:	Wireless Fidelity
IR	:	Infrared
IDE	:	Integrated Development Environment

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CHAPTER 1

INTRODUCTION

1.1 Background of Project

There are some terms or keywords that first, need to be introduced as a background of a waste management. First, it is municipal solid waste (MSW), more commonly known as trash or garbage—consists of daily things that we use and then throw away [1], such as product packaging, grass clippings, furniture, clothes, bottles, food waste, newspapers, appliances, paint, and batteries. All these types of waste, normally comes from our residential area, schools, clinics, and corporations. The other important keyword in waste management is the sustainable materials management (SMM), which refers to the use and reuse of resources over their entire life cycle in the most efficient and sustainable ways [2]. Throughout the decade, the local waste management or government had promoted activities such as waste reduction, recycling, and composting that reduce the amount of waste that needs to be disposed of. Many inventions were designed to decrease the amount of waste that will need to be thrown away later, and thus, make the resulting waste less toxic. The term for this method is known as waste reduction or waste prevention. Next, is the composting, which requires gathering and preserving agricultural waste, such as food scraps and yard trimmings, in conditions intended to make it break down naturally [3]. The resulting compost will then be used as a natural fertilizer. Lastly, we have a recycling term. This method or term is the recovery of useful materials, such as paper, glass, plastic and plastics, from the trash to be used to produce new items, decreasing the amount of pure raw materials available [4].

The recycling rate is very important for monitoring waste recycling, and usually calculated as the proportional value (in percentage (%)) of waste recycled from the total waste generated [5]. In 2018, the National Recycling rate was reported at only 3.4%. Considering the economic and population growth, Malaysia is expected to generate more waste now compared to any previous point of time in history with at least 18,000 tons of wastes produced per day [6]. And this figure will increase exponentially for the next decades and will affect the country. To curb these issues, the relevant government agencies have been taken various step and campaign to raise awareness among the people such as The Three R's campaign (Reduce, Reuse and Recycle), local program 'Cleanliness Starts at Home' in south Klang, IPC Shopping Center with Recycling and Buy-Back Center and so on [7]. Despite these efforts, only 5% of the total waste generated was recycled while the rest 95% is sent to landfill. The low percentage of the waste recycled clearly shows that the level of awareness among the community is still at an unsatisfactory level. Hence, the aim for this project is to provide an alternative solution of waste management by: Developing a prototype that is able to monitor garbage bin via IoT platform. By collecting the data from the prototype, the garbage monitoring's efficiency can be improved compared with the normal dustbin.

1.2 Problem Statement

The current issues on waste management were proved to be very important for the future of our country. It is clear that the level of awareness of recycling and waste management is low among the community from the statistic discussed in the previous sections. In addition, the overflow of the dustbins is causing concern to the local authorities. Usually, they do not get information about the situation within a stipulated time. There are several special days, such as weekends, public holidays, and major events, on which many garbage bins soon fill up, forcing quicker collection intervals the schedule for current waste management, especially for trash collection is not efficient enough to solve this problem. The overflown bin will make the environment becomes unhygienic and causes people to suffer from extreme illness due to poor waste management [8].

1.3 Objectives

The main objective of this project is to develop a prototype of the User-Centered Smart Bin for Smart City Via IoT Platform. The system is envisioned to be able to measure the level of the garbage by using ultrasonic sensor, inductive proximity sensor to detect the metal material, infrared sensor to detect non-metal material and DHT-11 temperature sensor to monitor the trash's surrounding in case of fire by using the IoT system. The next objective is to analyze the performance of the Smart Bin using IoT system.

1.4 Scope of Project

There are several related topics which need to address if we want to make some progress in the field of a Smart Dustbin for waste management with IoT implementation. The topics range from user aspects and needs via physics to engineering aspects. Figure 1.1 shows the preliminary overview of the overall topics which seems relevant to the project.

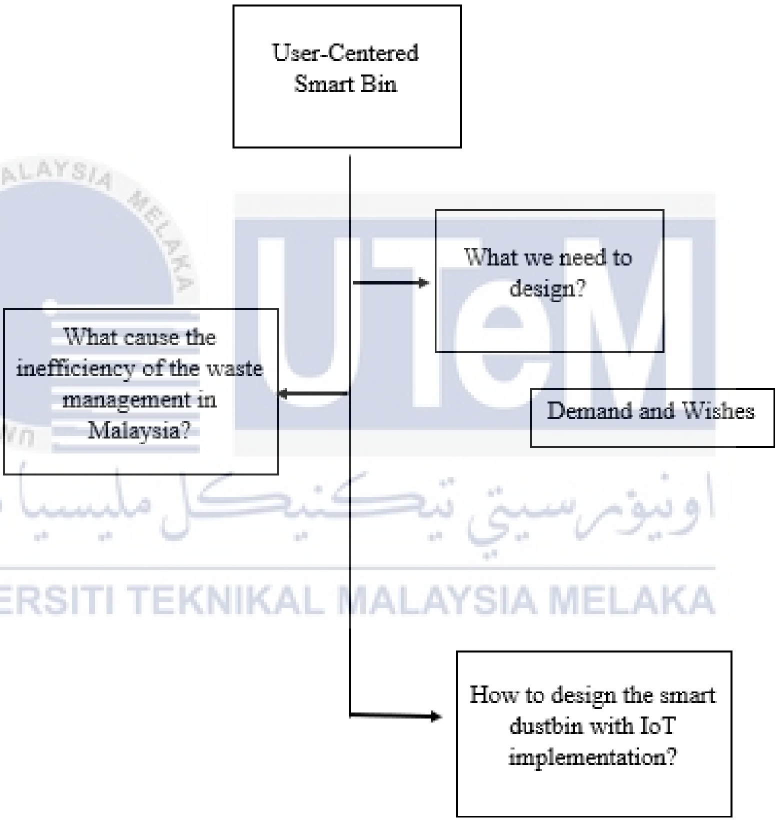

Figure 1.1: Preliminary overview of the overall topics

In the diagram, there are many topics meant to improve the awareness of the waste management which play a role. These are important for making contributions to the third branch, “How to design the prototype?” (The engineering aspects). The thesis’s focus is mostly on technical part, in line with “demands and wishes” from the user.

In order to answer all above questions, there are three stages of the scope of the project:

i. User requirement

Before designing a User-Centered model, a research needs to be conducted before begin to build the prototype. From the research that was conducted, the main component can be chosen such as microcontroller and sensors for the system. The suitable IoT platform can be chosen that is compatible with all the sensors that picked earlier.

ii. Hardware & software

The hardware that will be used in this project is Arduino Uno with ESP8266 Wi-Fi Shield with multiple sensors which are DHT 11 to detect the temperature and humidity, ultrasonic sensor to detect the waste level tank and inductive proximity sensor to detect metal material and IR Line tracking sensor for non-metal material. The interface use is the LCD display. The application that is used to synchronized the data with the smartphone device is the Blynk application. Blynk application able to monitor the sensor output in real-time and capable to display the graph output for data collection.

iii. Prototyping and User testing

After developing the prototype, all of the sensors will be analyzed and test to gauge the performance of the whole system. It is also important to ensure the data or information is successfully transmit to the IoT platform that was selected earlier.

1.5 Thesis Outline

The content of this document is structured as follows. Chapter 2 will provide a deeper insight on the related research or previous project regarding the User Centered Smart Bin technology. The selected papers were thoroughly inspected by understanding the major component of the system including hardware and software of the proposed project. Their functionality varied slightly from each other but almost similar to the User Centered Smart Bin. The third chapter starts by reviewing a classification scheme for the methods used in this project. It then introduces the background of the technology used in this project by listing all of the hardware and software used for the proposed system. The detail explanation of the experimental setup and studies are provided in chapter 4. All of the results produce from the User Centered Smart Bin was thoroughly presented and analyze based on the parameter that was set in order to gain the desired outcome. The conclusion for this project will be shown in chapter 5. It also gives some suggestions on how it could be continued and improved in the future.

CHAPTER 2

BACKGROUND STUDY

2.1 Introduction

The activities and actions required to manage trash from its source to its final disposal are referred to as waste management. It also involves garbage collection, transportation, treatment, and disposal, as well as waste control and monitoring. The waste management system with the legal procedure will lead the direction towards recycling material as a whole. Municipal Solid Waste or MSW was a part of the waste management system along with the agricultural and social waste [9]. It is intended to minimize the unfavorable effect of garbage towards the environment and the community especially among the developed countries and developing nations residential and industrial area. It is proved that the number of MSW were rapidly increased as the population of a city increase [10]. This situation leads to an urgent solution to the current waste management which is incompetent to solve waste pollution. As a result, many researchers from various fields, are combining their efforts and sharing knowledge in creating a solution for a smarter waste management system. The concept of smart cities in developed countries with smart waste management system always assisted with an electronic component and network as the ecosystem resources suit the smart city as a whole. The IoT platform proved to be very useful in providing the alternative solution to this issue along with the used available technology, such as the PIC microcontroller and various modern tools and sensors.

2.2 Introduction to the Internet of Things (IoT)

With the development of the internet in the past decade, various technology has been introduced to us revolving around the internet infrastructure. This global network of computer largely based on wireless platform or wireless communication that allows us to exchange information transcending space and time. Apart from this ecosystem is the Internet of Things (IoT) that is the main element for this project. So what is IoT? An IoT is an ecosystem consist of smart devices that able to communicate or exchange information by using the internet [11]. These devices such as smartphone can gather data from their environment and send it to other smartphone that allow us to control and analyze the collected data. The best thing about IoT is they can operate without human involvement as long as it was already pre-program to do the instruction given. It make use of artificial intelligence (A.I) and machine learning to assist in collecting and analyze the data making the process so much easier and efficient[12]. Apart from collecting the data, it also able to take action based on the data received. By synchronizing with the other devices such as sensor and component, IoT provides us with a real-time monitoring system as the information exchange is very fast, thus, delivering insight in all operation.

The ability to monitor operation surrounding would help us increase the performance of the current system. IoT brings so much benefit such as efficient workflow, cost-saving and saves time. The capability to receive information from anywhere and anytime allow us to make better decision and judgement. To sum it up, any device or physical object that can be connected to the internet to be controlled or communicate with each other to relay information can become an IoT device. The term IoT mainly defines the object or devices that are usually have an internet connection and able to operate without human intervention.. The Internet of Things is changing the course of the human civilization making the world smarter and responsive, bymerging the digital and physical universes.

2.3 Literature Review

One of the most prominent related work to smart bin device is the garbage monitoring system using IoT platform ThingSpeak [13]. The suggested system includes an ultrasonic sensor for measuring garbage level, an ARM microprocessor for controlling system operation, and everything will be connected to the IoT platform via a ThingSpeak. Four ultrasonic sensors are used in the system, which are coupled to an ARM microprocessor and an ESP8266 wifi module through a logic level converter. With LCD as the interface, it also includes a rechargeable battery as the main power source. The four ultrasonic sensors allow the smart bin to be divided into several categories such as plastic, paper, glass and domestic waste. The data collected from the sensors will be collected and send to the ThingSpeak for monitoring purposes. This method would therefore assist waste management in dispatching a garbage collector to collect the trash when the trashcan is full.

Similarly in [14], the author (Pardini et al., 2020) proposed a solution to solve the same issues by approaching the IoT based system. It aims to improve the present waste management system and involving a citizen in the decision-making process. Sensors continuously monitor the thrown garbage from the smart bin, informing the filling level of each compartment in real-time. The data then can be calculated to offer data for waste collection with optimum routes and to generate crucial statistical data for reliable waste collection monitoring in terms of resource management and community services. The system includes weight, temperature and humidity sensor. Is also able to detect the object based on the physical characteristic parameter based on the sensors installed. The sensors used are HC-SR04 module ultrasonic sensor, load sensor HX711, DHT11 temperature and humidity sensor and GPS module (model Neo-6M) to enable smart bin tracking location of each bin.

For this proposed system (Ashok Kumar Yadav, 2019) use microcontroller-based system with IR wireless systems and a central system that displays garbage status on a mobile web browser with HTML page over Wi-Fi [15]. Instead of smartphone devices monitoring, he uses the web browser as the interface to monitor the data gathered. With GPRS modem and Node MCU/ESP8266, the system enables the real-time monitoring of the bin surrounding and also waste level by using the ultrasonic sensor. The results are shown in a virtual form. The municipality office receives information on the dustbin's level and the area in which it is located, as well as the dustbin's unique ID. This feature will allow users to access their data wherever they are and without having to install anything else.

The system concept of referee (Hajar Yusoff et al., 2018) [16] proposed an alternative solution by using Arduino Uno as the microcontroller with ESP8266 Wi-Fi module that will give the project access to the internet. The Wi-Fi module then is connected with Blynk application with project authentication ID that can be installed on a smartphone. This approach will allow the user to monitor the garbage level by using a smartphone as long as the Blynk app is running in the background of the smartphone to get the real-time notification. However, this project does not specify the main power source for the system and can be considered as a working prototype.

The project in [17] focuses on a study of planned and computer-controlled vehicle routes for municipal solid garbage collection in Pakistan's various regions. The system is separated into three stages: the collection of our waste, loading it onto a truck, and recycling it in a recycling unit. The sensors interact with the respective centers as they detect the volume of the rubbish, signaling the volume of the garbage. The garbage collection truck will be dispatched to the garbage centers to collect rubbish from the garbage bins and recycle it in the recycle bins. By developing their own algorithm, the optimized route for the garbage collector can be calculated. The algorithm called as Efficient Route Election procedure (EREP). The aim is to minimize the end-to-end delay is smart waste management.

The IoT Based System proposed by [18] consist of Arduino Uno board, Ultrasonic sensor with GSM modem as the interface. A weight sensor is also installed, which is used to calculate the dustbin's weight. The ultrasonic sensor is added at the top of the trashcan to measure the garbage level, while the weight sensor is placed at the bottom to measure the dustbin's weight. By pre-setting the threshold for the sensor, it will later trigger the GSM modem that gives notification to the waste management authority. Depending on the position, the garbage van will collect the garbage after the device sends a notice to the authorized worker.

The IoT innovation project [19] Solar systems, sensor, and wireless networking technologies are all used in the design of a smart garbage bin with a real-time control system. Its aims are to deliver a dependable and cost-effective trash disposal management system via a Wi-Fi connection, assuring a safe, balanced, and regenerative environment. The project can be divided into three sections which are renewable energy source, WSN and control station. The main highlight for this paper is the renewable energy source used which is solar power. Three components make up a solar power system: a solar panel, a solar charger controller, and a rechargeable battery. Solar panel is used for converting solar energy into electrical energy. The SR-HM solar charger with rechargeable battery is the main power source for the project. With Liquid Crystal Display (LCD) display and the real time clock (RTC) as the indicator, the system able to send data via Wi-Fi connection by using ESP8266 module. The combination of the sensor and SMS notification allows the system to monitor the garbage waste in the waste bin.

The project proposed by [20] have the system to detect garbage thrown around the bin. This is accomplished with the help of a buzzer that sounds to deter people from throwing trash outside. At the same time, it also warns the authorities about the storage of dustbin in the event of an overflow of more than 75%. A water sensor is also installed, which detects water and, as a result, closes the entrance in the event of a rainfall. Through a transmitter and receiver, the ultrasonic sensor detects the distance between the waste level of the bin and the lid of the bin. The main microcontroller is the Arduino Uno with ESP8266(Wi-Fi module) that will allow the system to connect with the internet. An infrared sensor is essentially used for two tasks: first, it is used to detect any waste that is disposed of around the dustbin and, second, to detect the presence of the user around the bin. Next, is the Capacitive Proximity Sensor that will help in recognition of metals as well as nonmetallic materials such as paper, glass and wood. And lastly, servo motor with the help of servomechanism allow the dustbin if a user approaches the trashcan and the lid is triggered by an IR sensor, the lid will open.

2.4 Literature Review matrix.

Table 2.1: Literature Review matrix.

No	Author/Year	Project Title	Type of Application/ Objectives	Sensor used	IoT Platform
1.	Mustafa M.R1, and Ku Azir K.N.F1 (2017)	Smart Bin: Internet-of-Things Garbage Monitoring System	Store the data for future use and analysis, such as prediction of peak level of garbage bin fullness	Ultrasonic sensor	ThingSpeak
2.	Kellow Pardini 1 , Joel J.P.C. Rodrigues 2,3,4,* , Ousmane Diallo 5 , Ashok Kumar Das 6 , Victor Hugo C. de Albuquerque 7 and Sergei	A Smart Waste Management Solution Geared towards Citizens	The proposed system can efficiently change the way people deal with their garbage and optimize economic and material resources.	Weight, Temperature, humidity, and RFID	Zigbee

	A. Kozlov 4 (2020)				
3.	Ashok Kumar Yadav (2019)	Waste Management and Monitoring System using IOT	Minimize the amount of edible food that is wasted, foster efficient use of energy and water in the food production process, and simultaneously reduce pollution externalities and create opportunities from recycled energy and nutrients.	Ultrasonic Sensor	GSM
4.	Siti Hajar Yusoff, Ummi Nur Kamilah Abdullah Din, Hasmah Mansor, Nur Shahida Midi, Syasya Azra Zaini (2018)	Design of Smart Waste Bin and Prediction Algorithm for Waste Management in Household Area	Very useful to provide optimized route for the waste collector	Ultrasonic Sensor	GSM
5.	Asim Zeb ,1 Qurban Ali,2 Muhammad Qaiser Saleem,3	A Proposed IoT-Enabled Smart Waste Bin Management System and	Preventing the waste from spilling from the waste bins during transportation to the recycling units	RFID reader, Ultrasonic sensors, weight sensor	ZigBee

	Khalid Mahmood Awan ,4 Ali Saeed Alowayr,3 Jamal Uddin,2 Saleem Iqbal ,5 and Faisal Bashir6 (2019)	Efficient Route Selection			
6.	Prof. Rajshri Nikam (2019)	IoT Based Smart Garbage System		Ultrasonic sensors, weight sensor	GSM module
7.	Norfadzlia Mohd Yusof, Mohd Faizal Zulkifli, Nor Yusma Amira Mohd Yusof, Azziana Afififie Azman (2018)	Smart Waste Bin with Real-Time Monitoring System		Ultrasonic sensors	GSM module, Zigbee
8.	Shubham Rai (2020)	Waste Management Through Smart Bin	Have the potential of detecting overflow and wastes thrown around the bin	Ultrasonic sensors, IR sensor, Capacitive Proximity Sensor	ZigBee

2.5 Comparison between previous work and the proposed work.

Table xx show the comparison of related previous project with sensor and major element implemented in the system.

Table 2.2: Comparison between previous work and the proposed work.

Project	Year	Sensor and major element used			
		Waste segregation	Monitoring system	User detection	IoT
Smart Bin: Internet-of-Things Garbage Monitoring System	2017	X	✓	X	✓
A Smart Waste Management Solution Geared towards Citizens	2020	X	✓	X	✓
Waste Management and Monitoring System using IOT	2019	X	✓	X	✓
Design of Smart Waste Bin and Prediction Algorithm for Waste Management in Household Area	2018	X	✓	X	✓
A Proposed IoT Enabled Smart Waste Bin	2019	X	X	X	X

Management System and Efficient Route Selection					
IoT Based Smart Garbage System	2019	***X***	✓	***X***	***X***
Smart Waste Bin with Real-Time Monitoring System.	2018	***X***	✓	***X***	✓
Waste Management Through Smart Bin.	2020	***X***	✓	✓	✓

2.6 Research gap

Most of the project focuses on the route optimization for garbage truck in order to improve the waste management efficiency. However, the research does not help the society to improve awareness on recycling. In order to do that, it is important to understand the recycling process from beginning to the end and understand the user perspective. The most troublesome process when recycling is the waste segregation (Desa et al., 2012). It is important to develop the habit and behavior of recycling among the society in order to increase the number of waste recycling in this country. If a system could help or assist people in such way, surely it would also help to increase the awareness of recycling among the people [21].

CHAPTER 3

METHODOLOGY

3.1 Introduction

In recent years, there has been several interests in smart bin technology for smart city purposes. The main purpose for this interest is because the lack of reliable solution in waste management efficiency. Most project focuses on the current waste management system problem such as garbage spilling from the waste bin, no optimized route for the waste collector and also waste pollution in certain area. In order to answer the research question stated above, there is a need to choose an appropriate research methodology.

This chapter will provide a detailed explanation of the process that was used to complete and successfully complete this project. It will cover the methodological approach and methods used to gather data for this project.

3.2 Methodology

To design this system, a previous research of similar project has been conducted to gather data before designing the project. The type of sensors and component should be carefully picked in order to ensure the compatibility between each other. The general idea for the whole system can be visualized after the major component was chosen. For this project, a prototyping methodology is the most suitable to apply for the model design. The prototyping model is a process used for the development of systems or products [22]. This procedure involves the building of a prototype, which is then tested and reworked as necessary to reach an acceptable outcome. It starts with developing a simple design that include all of the main component characteristic to achieve the outcome of the project. After that, the first prototype will be evaluated by recognizing its weaknesses and strength. The product or the system can be reworked as many times as needed until the final prototype was created.

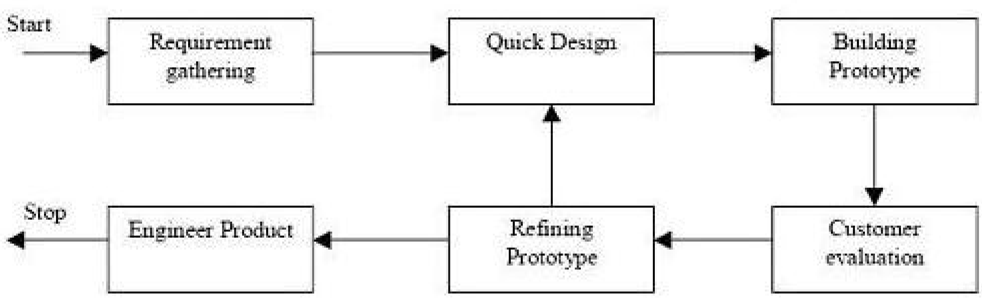

Figure 3.1: Prototyping methodology block diagram

This type of model design is suitable to be implemented when the desired system has a lot of interaction with the users. Prototyping helps in creating a system that has a longevity characteristic to its advantage. It also can be reused in the future for further improvements and additional features in case the product seems to be outdated. However, the main disadvantage of this type of this methodology is that it requires more time and cost when compared to other methods. As such, this model design is a suitable approach when designing the User Centered Smart Bin (UCSB) with the time and cost factor to keep in mind.

3.3 Project Planning

To ensure the workflow for this project run smoothly, the planning preparation was crucial. It is important to identify all of the hardware and software requirement before starting the project. All of the component needs to be compatible with each other. Then, begin to create flow chart of the proposed system by including all of the chosen component.

Data collection is an important aspect of any type of research study. Unreliable data collection would affect the outcome for this project and produce undesired results. At the start of this project, various materials regarding the proposed project such as journal, books, research paper were collected to enhance a deeper understanding on this project. Finding out about research that already exist will help form new research. A previous study and data collected from other paper certainly helps to develop a better solution in waste management issues. It also includes the electronic component and various IoT platform that was used in the previous project. This will allow the proposed project to improve thus, producing greater results.

A market survey was carried out at the beginning of the study to collect feedback from the users and gather their expectations and requirement together with the analysis of their needs and preferences perceived of the system. For this purpose, Google forms was used as the platform to gather the required data. It is because of the restricted movement due to the Covid-19 pandemic that an online survey was chosen. The survey consists of several types of question such as demographic, Likert scale and comment or suggestion from the participant.


PSM 2 RESEARCH SURVEY

I. Purpose of the User Study

This survey will be used for academic purposes only. Its main objective is to collect the user requirements to create Analysis table for User-Centered Smart bin Via IoT Platform in Malaysia. Kindly provide your honest answers to the following questions. Please note that your answers will be treated as private and confidential and will be used for this study only.

II. Benefits

Your participation in the study can provide the information that could help us for the future design for this User-Centered Smart bin project.

III. Extent of Anonymity and Confidentiality

As a participant in this study, you will be ensured confidentiality. This study is being conducted solely for research and development purposes, and the resulting data and interpretations will also be a part of the researchers' academic work and use for scientific publications only. Your answers will be anonymous.

IV. Freedom to Withdraw

Participation in this study is entirely voluntary, and you have the right to withdraw from the study at any time you wish.

Should I have any pertinent questions about this research or its conduct, I may contact:

Researcher's contact e-mail: zaimhilmi91@gmail.com

Supervisors' contact e-mail: fatihah@utem.edu.my

Figure 3.2 Google forms survey front page description.

Google forms are very popular to create surveys. They allow us to collect valuable information in a simple and effective way. The features also allow us to include several types of question in the survey which makes it so much easier in terms of creating the survey and collecting the data. The interface is user-friendly and free online platform with minimum requirement such as Gmail. As long as the participant have internet connection, anyone that receives the link would be able to answer the questionnaire regardless of their location. This platform is very useful especially for preliminary data collection before determining the main design of User Centered Smart Bin (UCSB).

3.4 Block Diagram

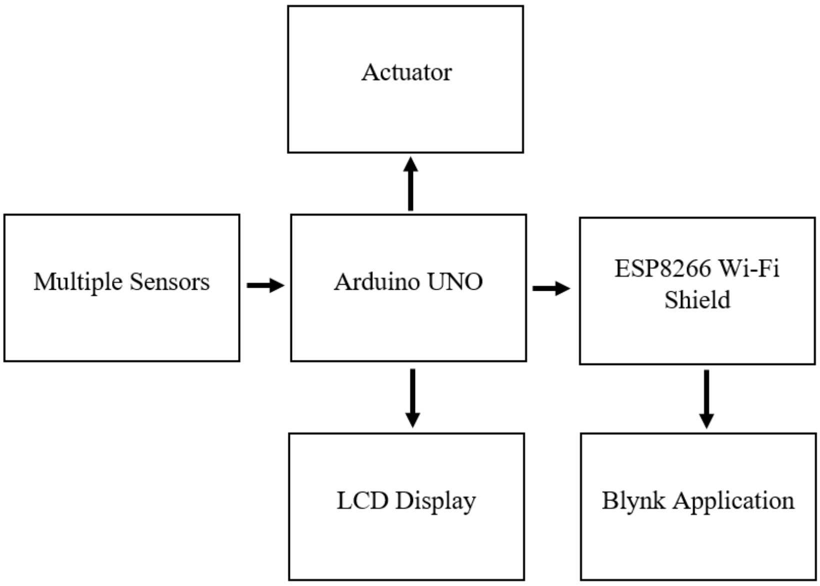

Figure 3.3: Block diagram of the User Centered Smart Bin.

This project offers a way to track the amount of garbage in real time by delivering data to a mobile device application. When the device is turned ‘ON’, all of the sensors will detect the level of garbage waste and also the temperature/humidity sensor. There will be two dustbins that will separate the metal and non-metal material. The metal-only dustbin will open only when an inductive proximity sensor detects any metallic object in its vicinity. The non-metal dustbin will open if the infrared sensor detects any object in front of the sensor. The information will be displayed on the LCD installed on the bin lid to let the people know the garbage level. If the garbage is full, the user will know and not throw any trash into it. This will prevent the bin from overflow and polluted the surrounding. At the same time, the municipal authority would be able to know and monitor the garbage level and surrounding as the sensor output also sending the information via the IoT platform.

3.5 System Requirement

3.5.1 Hardware requirement

For this section, the connection was set up first before writing the programming in Arduino IDE. The UCSB system was divided into two circuit which are Arduino 1 and Arduino 2. Therefore, below are the list of components for both Arduino 1 and Arduino 2:

Arduino 1 Component (Monitoring):

- Arduino
- DHT11 (temperature sensor)
- 2 Ultrasonic sensor
- ESP8266 Wi-Fi Shield
- I2C LCD display
- Power Bank (power supply)

Arduino 2 Component (Actuator):

- Arduino
- Inductive Proximity Sensor
- Line Tracking Sensor TCRT5000.
- 2 servo motor.
- DC Auto Buck Boost Converter.
- Lithium-ion battery.

Arduino 1 operate as the real time monitoring system that was transmitted through the Wi-Fi Shield. This means, only sensors from the Arduino 1 will display information in Blynk application and also I2C LCD. On the other hand, Arduino 2 is the actuator component that does not need to transmit data through the Wi-Fi. It operates only to open the UCSB lid according to the material detected which are metal and non-metal. Arduino 2 also requires a DC Buck Boost converter to step up the voltage required in order for inductive proximity sensor to operate with minimum 6V. The Lithium-ion battery will be connected to the Buck Boost converter as the input voltage to step up the voltage around 6V-12V.

3.5.2 Arduino Uno

Figure 3.4: Arduino Uno. Retrieve from https://en.wikipedia.org/wiki/Arduino_Uno

Arduino Uno is a microcontroller board based on the ATmega328P (datasheet). It is one of the famous inexpensive microcontrollers with relatively easy programming language making it very useful for student’s project. The IDE software are also open platform and able to operate on any operating system such as Windows and Linux. A USB was provided that allow voltage of 7 to 20 volts as the supply.

3.5.3 ESP8266 Wi-Fi Shield

Figure 3.5: ESP8266 Wi-Fi Shield. https://my.cytron.io/p-cytron-esp8266-wifi-shield

Arduino Uno by itself cannot connect to the internet thus, making it hard to transmit data especially if the project is IoT based. Therefore, ESP8266 Wi-Fi Shield is used as an external component for Internet of Things application or project. The module will allow the microcontroller to connect and transmit the information to the internet. The Wi-Fi Shield has ESP8266 embedded in the circuit. By simply put on top of the Arduino Uno will allow Arduino to connect to the internet. The Arduino Wi-Fi shield stack on an Arduino will allow the board to connect to the internet.

3.5.4 Servo motor

Figure 3.6: SG90 mini–Servo motor. Retrieve from https://components101.com/motors/servo-motor-basics-pinout-datasheet

SG90 mini servo motor is a small and pocket-sized motor with high torque power at 2.5Kg/cm. it able to rotate at about 180 degrees due to the gear layout. This type of servo motor is usually used for variable speed motors. It can operate from 4.8V to 6.5V. The SG90 servo motor have 3 wire configuration which are Brown for ground, Red as the power connection and Orange as the PWM signal that is received from the microcontroller. With the exceptional lightweight size and high-power torque, it is suitable for the User-Centered Smart Bin prototype as a mechanical device to open the lid of the bin. The servo motor will be connected to the Arduino board that receive signal from IR sensor then convert the signal into PWM signal and send it to the SG90 mini servo motor.

3.5.5 Lithium-ion Battery

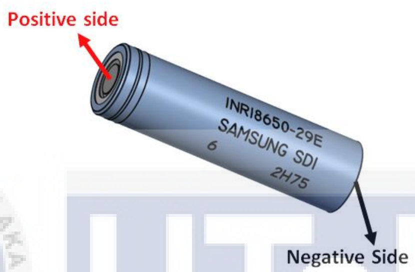

Figure 3.7: Lithium-ion Battery. Retrieve from https://components101.com/batteries/18650-lithium-cell

Lithium-ion batteries are rechargeable batteries that can be used again and over again. They're applied in a wide variety of electronic and electrical devices. Lithium ions pass through an electrolyte to reach a positive electrode in Li-ion batteries. When charging, they return to the negative electrode. Lithium batteries have a higher capacity than lithium-ion batteries, despite the fact that they are not rechargeable. Due to their higher energy density, they can go for longer periods of time on a single charge—even if they only have one charge in their lifetime. One battery would provide 3.5V supply to the circuit. Therefore, two battery was needed with total voltage supply at around 7V to power up the Arduino 2.

3.5.6 LCD Display 16X2

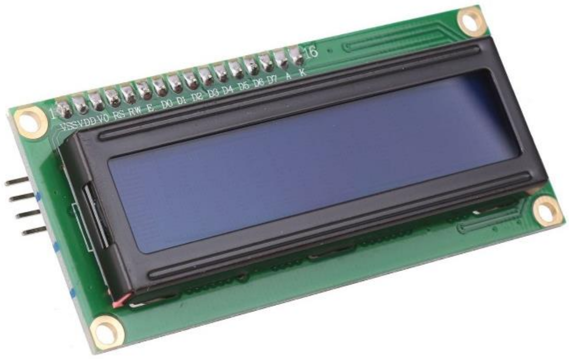

Figure 3.8: LCD Display 16X2 I2C. Retrieve from https://www.diyelectronics.co.za/store/displays/229-lcd-display-16x2-white-on-blue-i2c-backpack-controlled.html

A liquid crystal display (LCD) is an electrical display module that employs liquid crystal to produce a visible image. It consists of 16 pin configuration and operate at around 4.7V to 5.3V power source. The current consumption is also fairly acceptable at 1mA without backlight. The LCD display enable the system to display numeral and alphabets as long as it was pre-programming. It also includes I2C LCD Adapter that convert data from Arduino into 4 pin which are *GND, VCC, SDA* and *SCL*. This way, the I2C LCD able to reduce the pin needed on the Arduino. By putting the instruction in the instruction register, the LCD will be able to display different characters and symbols. There is also a potentiometer across VEE pin that can be used to adjust the contrast of the display of the LCD. The LCD display is easy to program and get the output. The use of a display to warn or notify the user about the current level of rubbish in the Smart Bin would be beneficial. This would prevent the user from throwing the garbage into the Smart Bin thus, prevent it from overspill.

3.5.7 Module for ultrasonic sensor

Figure 3.9: Ultrasonic 5V HC-SR04. Retrieve from https://my.cytron.io/p-5v-hc-sr04-ultrasonic-sensor

The ultrasonic sensor works by detecting the distance of a target object using the reflected sound waves. It basically utilizes two main components: the transmitter (which uses a piezoelectric crystal to emit a signal) and the receiver (which encounters the sound after it has travelled to and from the target). The distance between the object and the sensor is measured using the time it takes for the signal to reach the receiver. The formula used is D = ½ T x C where D is the distance, T is the time and C is the speed of sound (constant value of 343 meters per second). The ultrasonic sensor also known as proximity sensor as it usually used as robotic obstacle detection system. The advantages are the ultrasonic sensors does not affect to interferences such as smoke, gas and other physical variables which makes it very useful for practical application. Besides that, ultrasonic sensors are used for various applications such as level sensors to monitor and detect the position of an object in a container, in this case, dustbin.

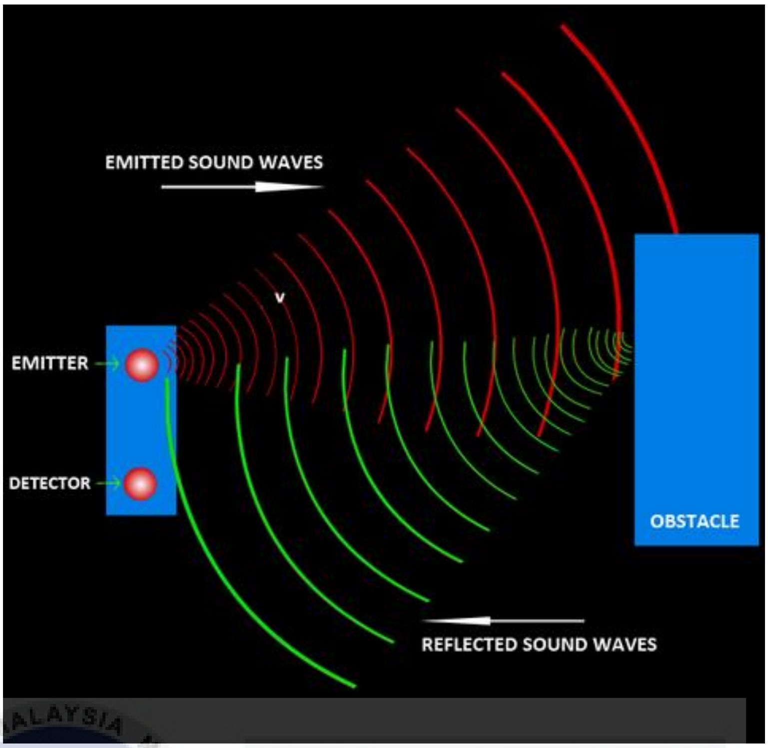

Figure 3.10: Ultrasonic sensor working principle.

The UCSB height was only at around 15 cm thus, the ultrasonic sensor would be able to determine the waste level in the UCSB accurately. Two ultrasonic would be needed to measure the waste level for both metal and non-metal bin and send the information to the Blynk application to notify the municipal authority.

3.5.8 IR Line Tracking sensor.

Figure 3.11: IR line tracking sensor TCRT5000. Retrieve from https://www.makerlab-electronics.com/product/line-tracking-sensor-tcrt5000/

An infrared sensor module is one of the simplest modules capable of detecting any object or obstacle. The IR transmitter and receiver are used to detect obstacles in front of the sensor. The module has a built-in potentiometer that allows the user to set the range of detection. The module can be interfaced with any microcontroller having an IO voltage of 3.3V to 5V. This sensor is very useful for presence detection and used extensively for robot obstacle detection. This infrared sensor is ideal for detecting obstacles through infrared reflection. It uses infrared light to tell the difference between objects and distances. In addition, any infrared source could obstruct detection such as sunlight. It will output logic 'LOW' at output pin based on the threshold that is adjusted, and the green LED will light up to signal the detection. The sensitivity and detection range can be increased by turning the on-board potentiometer clockwise. This sensor was used to open the non-metal dustbin lid if it detects any object in front of it.

3.5.9 Module for Temperature and Humidity sensor DHT11.

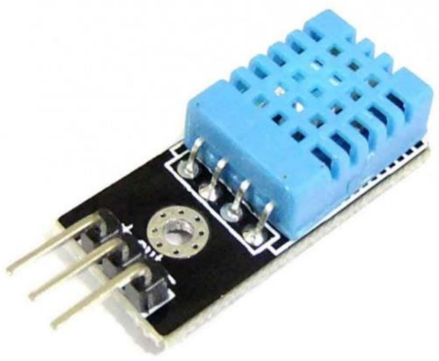

Figure 3.12: Temperature and Humidity sensor DHT11. Retrieve from https://www.electronicscomp.com/dht11-temprature-humidity-sensor-module-india

The DHT11 temperature and humidity sensor is widely used in various industries. It features a dedicated NTC for calculating and displaying temperature and humidity values. This simple humidity sensor works by measuring the ambient air and produce a digital signal on a data pin. The temperature and humidity sensor can measure the temperature and humidity ranges from 0 to 50 degrees Celsius. It can also calculate the humidity ranges from 20% to 90%. The power supply of DHT11 is 3-5.5V DC. The interacting method is around 4ms. The temperature sensor would be installed on Arduino 1 circuit and will transmit the data to the Blynk application. A temperature sensor DHT-11 also was equipped on the Smart Bin because, there are several cases where the cigarette butts were thrown into the dustbin and cause fires to the surrounding [23]. This way, the municipal authority would be able to detect and notice if the UCSB and its surrounding is on fire or not.

3.5.10 Inductive Proximity Sensor

Figure 3.13: NPN inductive proximity sensor with 8mm (contact)

Without making contact with the object, an inductive proximity sensor can easily identify metal targets that are approaching it. An inductive proximity sensor is a type of device that can sense the presence of an object using three different methods: high-frequency oscillation, magnetic type, and capacitance. The high-frequency magnetic field produced by the oscillation circuit can be utilized to generate an induction current. As the target approaches the sensor, the induction current flow increases, putting more strain on the oscillation circuit. The oscillation then attenuates or stops. This sensor will be equipped as the metal sensor for UCSB compartment. The dustbin lid will open only if metal material was detected on the inductive proximity sensor. Thus, it enables the UCSB to assist user when segregating material from metal an non-metal.

3.6 List of Component

Table 3.1: List of Component

No	Component	Quantity
1.	Ultrasonic sensor 5V HC-SR04	2
2.	Infrared module FC-51.	1
3.	Temperature and Humidity sensor DHT11.	1
4.	Arduino Uno.	2
5.	ESP8266 Wi-Fi Shield.	1
6.	SG90 mini–Servo motor.	2
7.	Inductive Proximity Sensor	1
8.	LCD Display 16X2.	1
9.	Lithium-ion Battery	2

3.7 Software Requirement

3.7.1 Arduino IDE Software

For this project, Arduino IDE was used as the foundation for UCSB. It is because the component that was chosen was compatible with Arduino IDE especially the microcontroller Arduino Uno. It is easy to use, as the language is C and C++ programming which is a common programming language for engineering students. The code that is generated by the platform will then be sent to the Arduino board. The library for all of the components were also available on the internet thus, making the compiling coding process so much easier.

To create a new project, select *Save* > rename the project (*Arduino 1*) > click *Save*. The file will be saved as the Arduino file which can opened and compiled in the Arduino IDE software. The coding that was constructed can immediately be uploaded to the Arduino Uno board which allow us to testing the coding in real time thus, saving time. This is practically useful for development of UCSB as it involves mechanical movement when opening the lid of the dustbin and close it afterwards by itself with time-delay. To compile the coding, click *Tools* > *Board:* > *Arduino Uno*. Then, select *Tools* > *Port* > select the available port (*COM3)* > *Upload.*

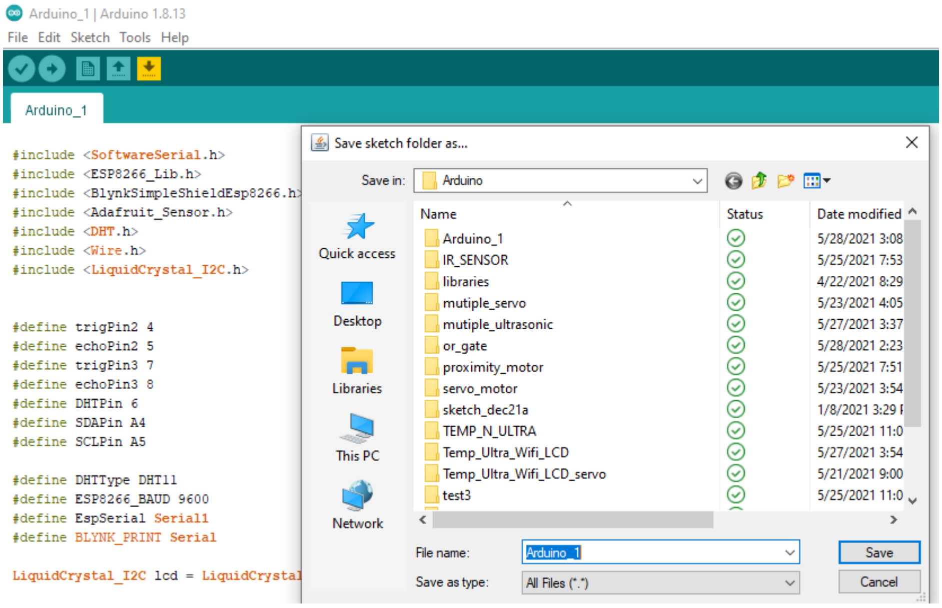

Figure 3.14 sketch Arduino folder file.

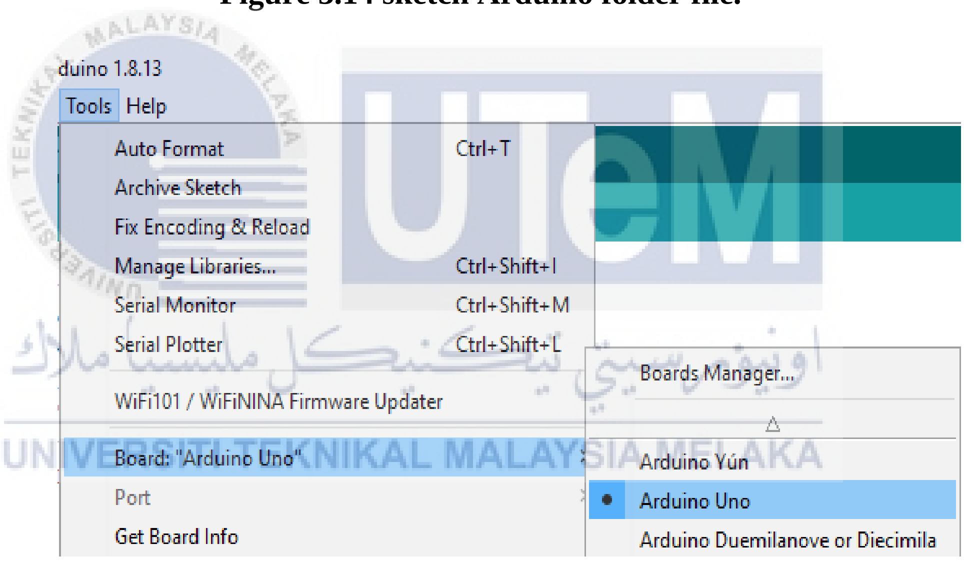

Figure 3.15: select the Arduino board

3.7.1.1 Arduino 1

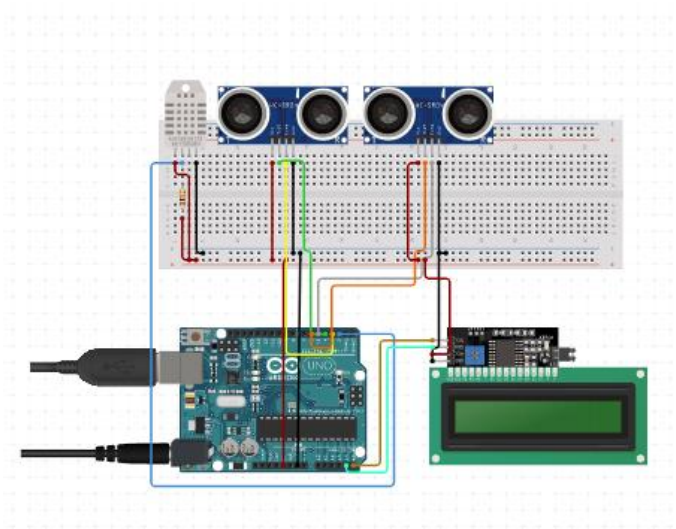

Figure 3.16: circuit design for Arduino 1

UCSB was divided into two circuit which are Arduino 1 and Arduino 2. The circuit design was drawn by using *circuit.io* to get the main idea before writing the coding. Arduino 1 consist of Ultrasonic sensor, DHT11(temperature sensor), I2C LCD display and ESP8266 Wi-Fi shield. These circuit will use power bank as the power supply as it fulfills the minimum power requirement. With this design, the input pin and output pin can be determined before writing the coding.

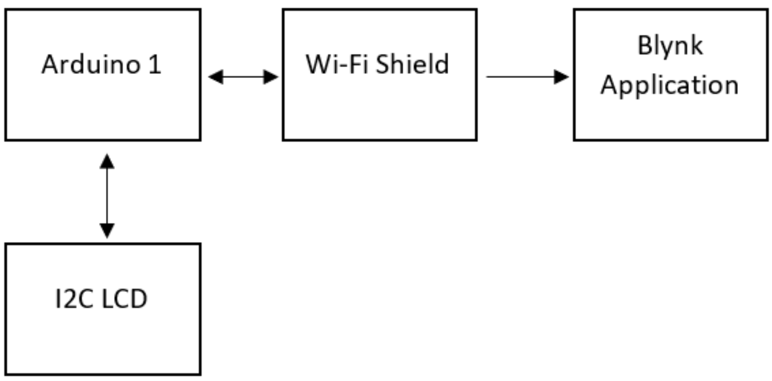

Figure 3.17: Arduino 1 coding interact with each other.

When the sensor in Arduino 1 collects data, it will transmit the data to both Wi-Fi Shield and I2C LCD display. The data that was transmitted will be updated in real-time and can be monitored either by using I2C LCD or Blynk application. This will ensure both user and municipal authority will be able to know the current level of UCSB in real time

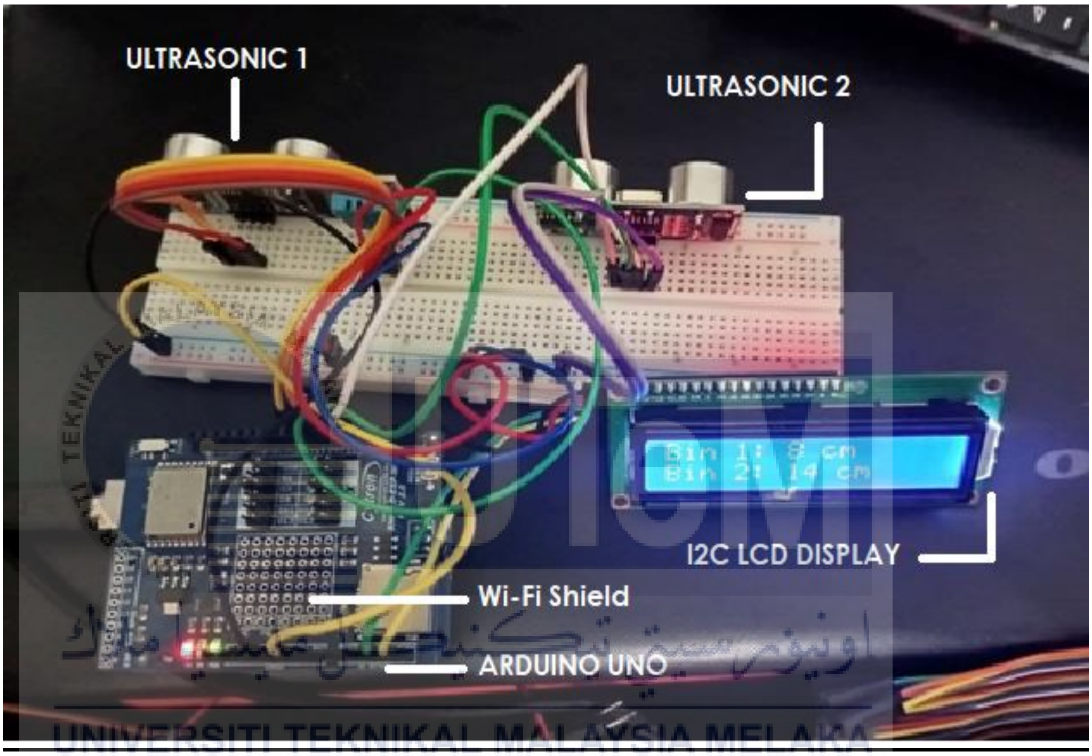

Figure 3.18: Arduino 1 connection to the laptop.

3.7.1.2 Arduino 2

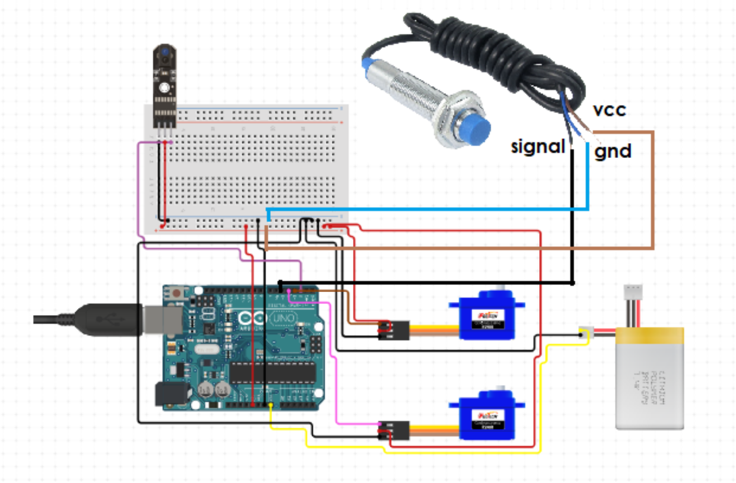

Figure 3.19: circuit design for Arduino 2.

Arduino 2 circuit consist of 2 servo motor, NPN inductive proximity sensor, IR line tracking sensor and Lithium-ion battery as the power supply. The circuit need minimum 6V of voltage input to allow inductive proximity sensor operate at its optimum performance. Therefore, Lithium-ion battery was used instead of power bank as the circuit could not power up 2 servo motor and inductive proximity sensor simultaneously. All of the data gather from the sensor here would not be transmitted to the Blynk application because it only involves in the actuator operation (opening and closing the dustbin lid) and it is not necessary.

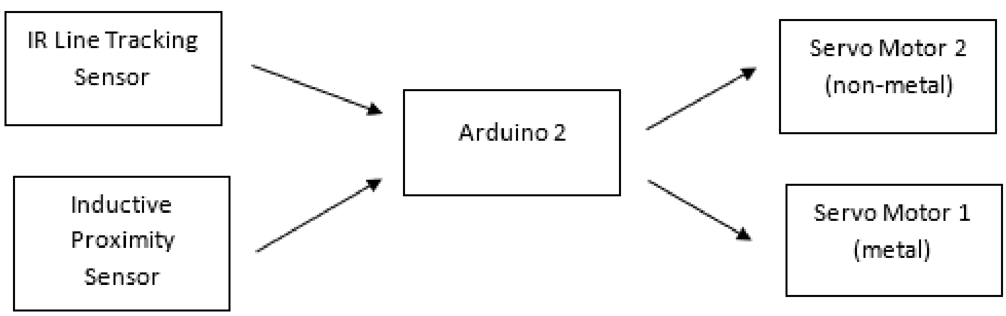

Figure 3.20: Arduino 2 block diagram.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter will discuss about the results gathered from main UCSB component and try to understand how it will affect the whole performance. It also includes the results from Google Forms survey that was conducted before the development of this project. The preliminary question that was asked in Google survey consist of demographic, Likert scale and suggestion question from the participant.

4.2 Google Form survey results.

Below here are the result for the preliminary question that was asked to the participant through the Google forms. The data are shown on the figure as follow:

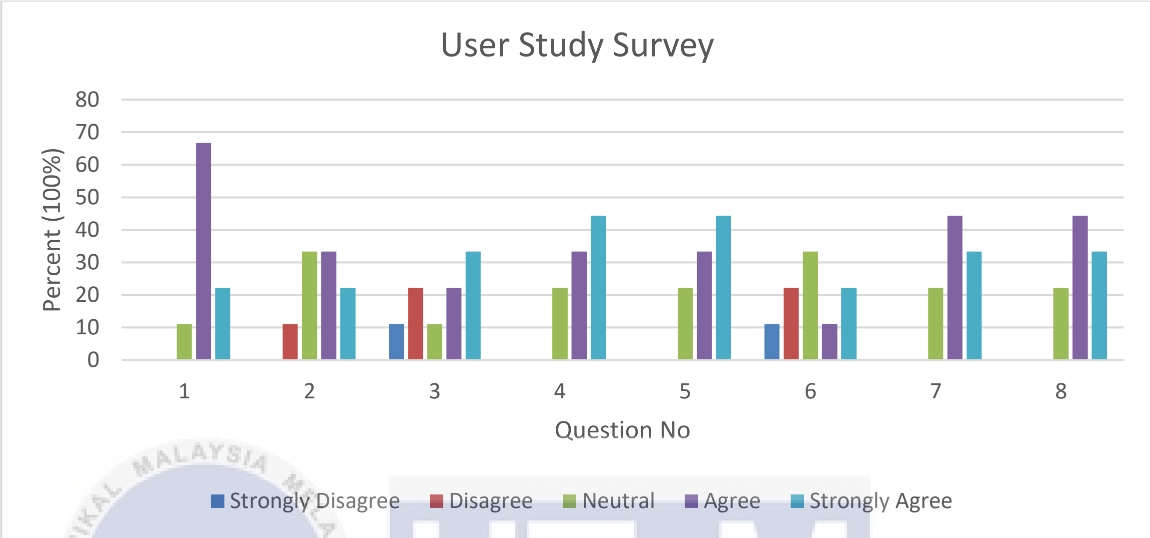

Figure 4.1: Google Forms survey result.

Questionnaire description:

- Q1. Smart bin for household and corporate user are easy to monitor the presence of the trash by using ultrasonic, temperature, and humidity sensors in the system.
- Q2. The current method of waste management monitoring system is efficient?
- Q3. The user or management personnel of the current waste management are promptly alerted when a bin fills up or emits a lot of heat?
- Q4. The waste segregation is useful in recycling process?
- Q5. The smart bin system that can prevent dustbin from overflown and causes environment becomes unhygienic are very useful.
- Q6. The currently domestic bin provides a dashboards and reports for user to monitor bin status?

- Q7. If a proper Internet of Think (IoT) is implemented, I believe that domestic bin monitoring would be made easier?
- Q8. This product is unique and can be commercialized?

From the survey result, most of the respondent agree that waste segregation is an important factor in recycling process (Q4). Also, the respondent agree that a smart bin system can prevent dustbin from overflown (Q5). In addition, the concept of dustbin with monitoring system is relevant with IoT technology implemented in the whole system (Q7).

4.3 Sensor Analysis

4.3.1 Waste level detection sensor

Let's look at the result from the ultrasonic sensor that was integrated in UCSB. For this purpose, serial monitor in Arduino IDE and also I2C LCD display will show the result needed. The distance was measured by using ruler to get the actual distance.

Table 4.1: Actual Ultrasonic Sensor Distance vs. Collected Distance

No	Actual Distance (cm)	Measured Distance (cm)
1.	0	2-3
2.	1	3-3.5
3.	2	3
5.	5	5
6.	7	7
7.	10	10
8.	15	15

The table 4.1 shows the ultrasonic sensor results for UCSB. The UCSB height was only around 17cm, therefore, the maximum measured distance is only 15 cm. It is clear that the ultrasonic sensor accuracy is decreasing as the object is too near and it have been taken into consideration when developing the system. However, the ultrasonic sensor only measures the waste level in the UCSB. And since the indicator was 'FULL' and 'EMPTY' the accuracy can be adjusted in the coding by changing the threshold, (the UCSB threshold is 6cm). Hence, it concludes that the ultrasonic sensor was suitable for the UCSB system.

The algorithm that was used in the coding to measure the distance was 'distance = (travel time/2) / 29.1' where 29.1 is the speed of sound. The *trig* pin sends a high frequency signal and when it detects an object it is reflected back to the *echo* pin. As the signal frequency travel, we can calculate the distance as the value of sound' velocity in the air was constant. In the coding, the library for the ultrasonic sensor needs to be installed first to called certain function. It is necessary to activate the ultrasonic sensor. The general function was shown below.

Table 4.2: the function to execute the Ultrasonic sensor.

No	Function called	Description
1.	`pinMode(trigPin, OUTPUT);` `pinMode(echoPin, INPUT);`	Sets the trigPin as an OUTPUT and echoPin as an INPUT.
2.	`digitalWrite(trigPin, HIGH);`	The *trig* pin was set to HIGH and the sensor will send high frequency soundwave from the sensor.
3.	`delayMicroseconds(2);`	The sensor delay for 2 microseconds after the high frequency signal was send.
4.	`digitalWrite(trigPin, LOW);`	Turn OFF the *trig* pin high high frequency signal.

After the coding was successfully executed, the data collected can be monitored through the Blynk application. This means, the waste level in the UCSB can be viewed in real-time and notify the municipal authority if the UCSB is full or not.

Figure 4.2: user interface for user to monitor the waste level for both compartments.

The Blynk application allows the developer to design their interface easily. This allows the designing process much easier and less complicated especially for students who did not have any experience prior to final year project. One of the useful features is the Super Chart graph that allows the sensors to plot graph according to the coding in Arduino IDE. As long as the pin was written correctly in the coding, it will be able to produce a graph for monitoring purposes. In this case, Super Chart graph use the ultrasonic sensor for both Bin 1 and Bin 2 to measure the waste level of the Smart Bin. The interface also includes a level display for both bins as shown in figure 4.2 in red and green color. Every message or information that the ultrasonic sensors send to server is stored automatically on server. This will allow the user to observe the waste level in better perspective along with the Super Chart graph.

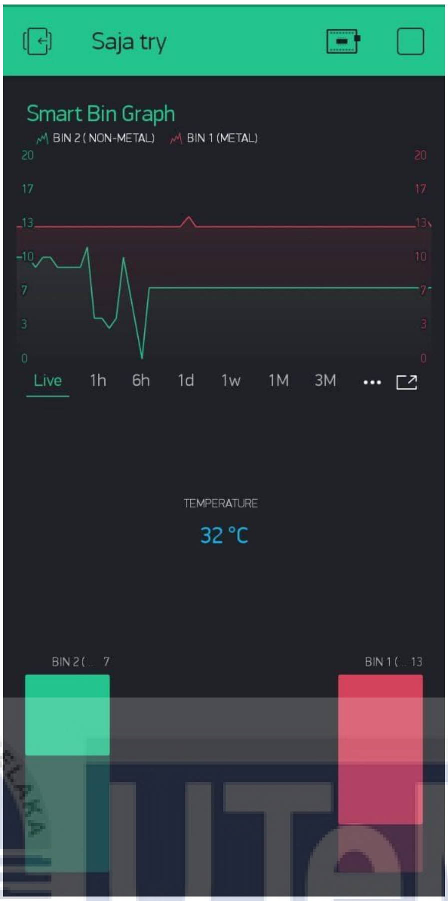

Figure 4.3: Bin 2 (Non-metal) in green color on the left side detect an object inside the dustbin.

In normal circumstances, the normal height for both bins would at around 13cm. When a waste was detected for Bin 2 (Non-metal) by the ultrasonic sensor as shown in figure 4.3, the graph produced in the Blynk application dropped from 13 cm to 7 cm on the Smart Bin Graph. This indicate that the system successfully able to detect and update waste level in real-time situation. The Bin 1 (Metal) level remains the same at 13 cm, means that the bin is still empty at the moment. Whenever the sensor detects waste, there is slight delay before reaching the 7cm level as shown in graph. But this delay is still acceptable as the sensor still able to show the desired results.

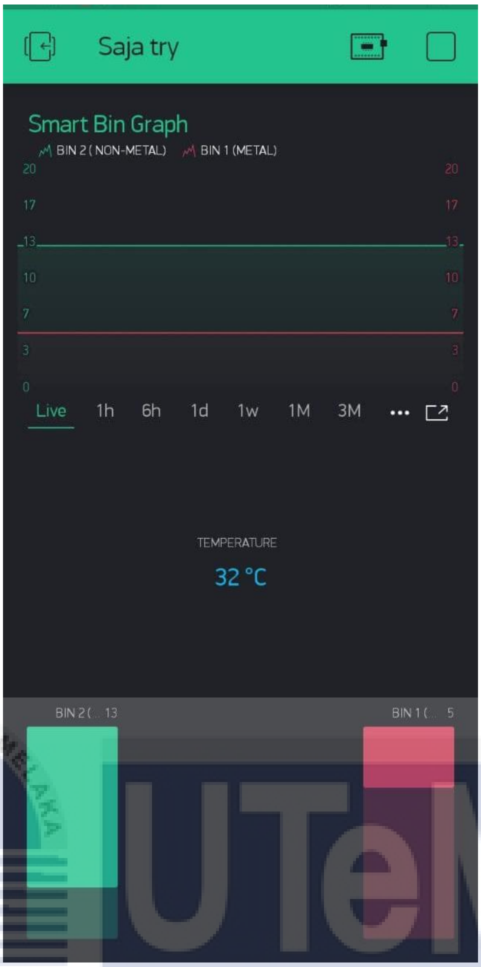

Figure 4.4: Bin 1 (Metal) in red color on the right side detect an object inside the dustbin.

The Smart Bin Graph for Bin 1 (Metal) dropped from 13 cm to 4 cm when the user throws the waste into the dustbin. As mentioned earlier, the accuracy of the ultrasonic sensor is decreasing when the object is near the sensor. If the sensor reading is 4cm, the actual reading is actually 2cm means that the compartment is ‘FULL’ and ready to be collected. In the same time, the LCD display will show the Bin 1 is ‘FULL’ to alert the user and prevent them from throwing the trash into the UCSB.

Figure 4.5: LCD display the current level of waste for both Bin 1 and Bin 2.

The LCD display shows the current level if waste inside both bins. In this case, Bin 1 is ‘FULL’ and Bin 2 is ‘EMPTY’. Instead of showing the waste level in cm, the LCD display was designed to only indicate either it is ‘FULL’ or ‘EMPTY’. The waste level in cm can be observed from the Blynk application. It is designed to simplify the user understanding on current condition of the Smart Bin. The LCD display would help to prevent people from throwing more waste into the Smart Bin, causes it to overflown and pollutes the surrounding. The threshold that was set to change the state from ‘EMPTY’ to ‘FULL’ was 6cm in the coding. This can be changed according to the height of the bin later.

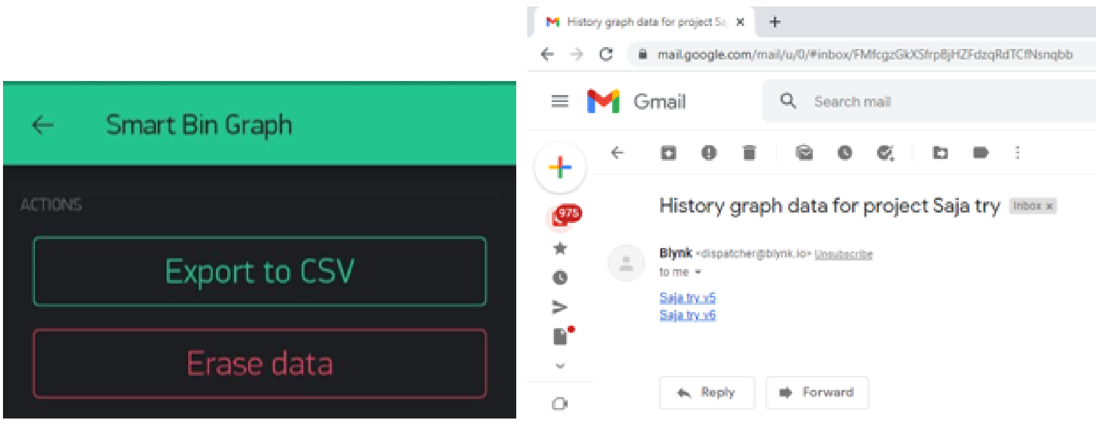

Figure 4.6: Importing data to email from Blynk application.

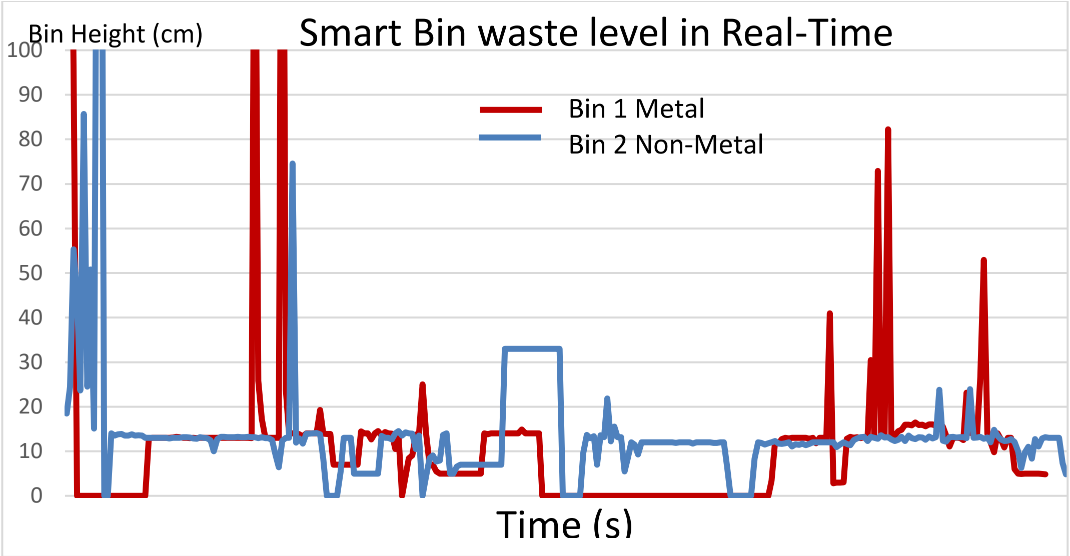

Figure 4.7: Smart Bin waste Level in real-time in Microsoft Excel.

The Super Chart Graph data from Blynk can be imported to the desktop. By using Microsoft Excel, the UCSB waste level in real-time was plotted as shown in figure 4.7. Notice that there were certain spikes from the graph. This is because of the ultrasonic sensor was trying to calibrate the distance as it detects new waste entering the compartment. However, it shows that both ultrasonic sensors were successfully able to measure the waste level in the UCSB and transmit the data to the smartphone.

4.3.2 Waste separation sensor

To help separate the waste from metal and non-metal, two sensors are used which are inductive proximity sensor and IR line tracking sensor. Inductive proximity sensor was able to detect ferrous and non-ferrous metal object for Bin 1 compartment. The UCSB Bin 1 lid only open when Inductive proximity sensor detect a metal object.

Figure 4.8: inductive proximity sensor detects a metal object.

The sensor required at least 6V and maximum 36V to operate. It detects an object without touching it with range 8mm to the sensor. Therefore, the sensor tip was not affected by the object detected or be damaged. Below is the list of materials tested on the inductive proximity sensor.

Table 4.3: Object tested on the inductive proximity sensor.

No	Material/Object	Indication
1.	Plastic	***X***
2.	Wood	***X***
3.	Paper	***X***
4.	Ceramic	***X***
5.	Scissor	✓
6.	Canned food	✓
7.	Copper wire	✓

Various object was tested on the sensor with different composition. It is clear that the sensor was able to detect any ferrous and non-ferrous metal object. However, it appears that the sensing is slightly difference when compared. For example, when copper wire was tested, the sensor was able to detect at the maximum range of 8mm (non-contact). But when, stainless steel (scissor) was tested the sensor need >6mm range to the object. Nevertheless, this variable does not affect the performance or UCSB system as the sensor give a quick response every time a metal object was detected. Below are the results gathered after testing different type of metal on the Inductive proximity sensor.

Table 4.4: Different type of metal testing.

Material	Sensing Range	Type of material
Steel	8mm	Ferrous
Stainless steel	>6mm	Non-Ferrous
Copper-nickel	>7.5mm	Non-Ferrous

For non-metal compartment Bin 2, the IR line tracking sensor was used. The sensor detects any object that is near it thus, the dustbin lid opens every time it detects an object or obstacle. The maximum range was 1.5cm and can be adjusted by twisting the potentiometer embedded in the circuit. The range was adjusted to 1cm for this sensor to prevent any motion that could trigger the dustbin lid to open by mistake. The sensor was fast response and reliable whenever an object was detected.

To analyze whether IR sensor performance were affected by sunlight, a test was done. If there is no object within the Line of Sight (LOS), there is no voltage produce on the sensor. However, if Echo signal was received (an object was detected in LOS) the IR sensor will produce a certain voltage where it is corresponding to the distance. Below are the results.

Table 4.5: Analysis for IR Line tracking sensor

Time	Voltage threshold (V)	Distance (cm)
8.00 am - 9.00 am	>1.3	0.5> x <1.5
11.00 am – 12.00 pm	Cannot be determine	Cannot be determined
4.00 pm – 6.00 pm	>1.3	0.5> x <1.5

The voltage threshold was measured by using the multimeter and the distance was measured by using a ruler. The time taken for one session was exactly 1 hour interval. It is clear that the abundant amount of sunlight affects the performance of this sensor. At 11.00 am – 12.00 pm where it is in the afternoon, when UCSB was brought outside and expose in the open surrounding with no shades, the IR sensor cannot detect any object or receive input. This is because the sunlight emits IR waves and that makes the sensor cannot differentiate the IR waves from sensor or the sunlight. This problem can be solved by putting the UCSB under a tree or a place with shades. The sensor works perfectly indoor even without any amount of light.

4.4 Final Prototype Results

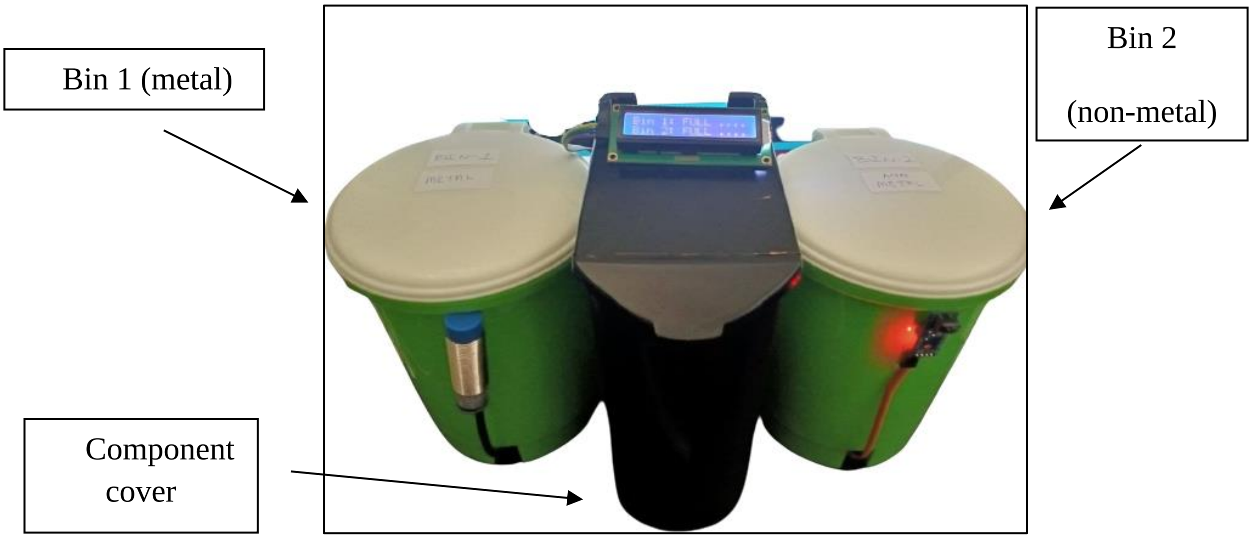

Figure 4.9: Final product design.

The Smart Bin was divided into two compartments. On the left-side is the Bin 1 (metal-only) with inductive proximity sensor installed. The dustbin opens the lid automatically when a metal object was detected. On the right-side is the Bin 2 (non-metal) with infrared as the sensor. When infrared sensor detects any object, the dustbin will open the lid automatically. Inside the Smart Bin, servo motor was used as the actuator to open and close the lid according to the sensor condition. The ultrasonic sensor was also installed at both Smart Bin lid to measure waste level and transmit the data to Blynk application. The user also would be able to determine the waste level inside the Smart Bin by watching the LCD display installed at the middle of both dustbins. This way, if the dustbin is full, it can prevent the overflown garbage issues. The ultrasonic sensor data can be view in desktop or imported into Microsoft Excel for further analysis.

4.4.1 Sensors advantages & disadvantages

Here, all of the sensor's data gathered for UCSB was tabulated to determine if it could affect the system or not.

Table 4.6: Sensors advantages & disadvantages

No	Type of Sensor	Advantages	Disadvantages
1.	Ultrasonic	• Non-contact sensor	• Accuracy decreases when the object is too near the sensor.
2.	Inductive Proximity	• Non-contact sensor	• Lack detection range • Different type of metal could affect the sensing range.
3.	IR Line Tracking	• Lightweight	• Affected by sunlight. • Only works when the object in Line of Sight (LOS)

Overall, the sensors that was used for this project were able to do the task needed. An in-depth analysis was done on the sensors to see if it would affect the performance of the system or not. The only concerns were the IR sensor that is affected by the abundant amount of sunlight. However, as discussed earlier there are solution to this problem by putting the UCSB under a tree or shades.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Conclusion

The ultimate purpose of this project is to develop a User Centered Smart Bin that would surveil waste level in the bin, separate the waste: particularly metal and non-metal and transmit the information to the municipal authority. The system consists of two circuit which are Arduino 1 and Arduino 2 with different sensors and task for each circuit. With multiple tests, the performance for each sensor was analyzed to observe whether it could affect the whole system or not. The information that was gathered the was transmitted to the Blynk application where it could be monitored by the municipal authority. Developing the system required some technical knowledge and implement them into the design. The information that was collected then was recorded and tabulated to the end users.

5.2 Future works

For this project, there are still room for improvement in order to make this project can be commercialized and be implemented in current waste system. Firstly, the software or the IoT platform use was Blynk application. Although it is sufficient enough to monitor the UCSB system, unfortunately Blynk application does not have a desktop version. This might prove to be difficult for the municipal authority to monitor the UCSB waste by relying only on smartphone.

It is also could be very beneficial if the UCSB was equipped with other sensors that could differentiate more material thus, helping the user to separate waste into more type of material instead of just metal and non-metal. For example, if A.I camera was implemented in the system it could identify all type of waste thus, assist the user segregate their waste and make it more efficient. Next, the graph produce from the Blynk application were affected by the dustbin lid open by itself, producing inaccurate reading. This is because the ultrasonic sensor was mounted on top of the dustbin lid. In the future, the system could be improved further by adjusting the coding to stop the ultrasonic reading whenever the dustbin lid opens by itself thus, producing more accurate data.

In terms of power consumption, the UCSB system can be improved by implementing solar power as the main source. This way, the UCSB can be placed anywhere as long as there is sunlight. As of now, UCSB requires people or personnel to recharge the battery or power bank to keep the system operation running. If a dedicated power bank was designed, where it utilizes solar power to recharge, this problem can be resolved.

If UCSB integrate mechanical principle such as internal waste compression, it could help to maximize the waste collection (Bigbelly, 2016). Currently, the UCSB is only a prototype with about 17cm heights compartment. If the size of dustbin is bigger, it would be able to collect more waste. In addition, with the mechanical compression, the UCSB efficiency would increase exponentially.

In a nutshell, throughout this journey the UCSB system was successfully developed and working as expected. By applying related technical knowledge into this project, it certainly helps me to enhance my understanding on embedded circuit design along with C++ programming language. With some improvements such as better material and accurate sensors, I believe that this project could be commercialized in the future.

REFERENCES

[1] (Home | KDEB Waste Management, 2018)

[2] (Science.gov: USA.gov for Science - Government Science Portal, 2021)

[3] Chapter 6, Composting Questions and Answers - Earth-Kind® Landscaping Earth-Kind® Landscaping. (2021). Tamu.edu.

[4] ("recycling | Definition, Processes, & Facts | Britannica," 2021)

[5] Yasuhiko Hotta, Chettiyappan Visvanathan & Michikazu Kojima, 18 February 2015, 'Recycling rate and target setting: challenges for standardized measurement',

[6] Md. MahmudulAlam, Chamhuri Siwar, Innocent A. Jereme, (2015), 'Waste Recycling In Malaysia: Transition From Developing To Developed Country',

[7] Clean Malaysia, OCTOBER 27, 2015, 'Shopping Center Leads the Way for Recycling in Malaysia',

[8] (*Overflowing garbage bins: 5 impacts on health and environment, and how to prevent | Ecube Labs*, 2016)

[9] Abdel-Shafy, H. I., & Mansour, M. S. M. (2018). Solid waste issue: Sources,

composition, disposal, recycling, and valorization. *Egyptian Journal of Petroleum*, *27*(4), 1275–1290.

[10] Sreenivasan, J., Govindan, M., Chinnasami, M., & Kadiresu, I. (2012). Solid Waste Management in Malaysia – A Move Towards Sustainability. *Waste Management - an Integrated Vision*.

[11] Gillis, A. S. (2017). *internet of things (IoT)*. IoT Agenda; TechTarget.

[12] Tucci, L., Burns, E., & Laskowski, N. (2017). *artificial intelligence*. SearchEnterpriseAI; TechTarget.

[13] M.R Mustafa, & Ku Nurul Fazira Ku Azir. (2017). *Smart Bin: Internet-of-Things Garbage Monitoring System*. ResearchGate; unknown.

[14] Pardini, K., Rodrigues, J. J. P. C., Diallo, O., Das, A. K., de Albuquerque, V. H. C., & Kozlov, S. A. (2020). A Smart Waste Management Solution Geared towards Citizens. *Sensors*, *20*(8), 2380.

[15] Ashok Kumar Yadav. (2019). Waste Management and Monitoring System using IOT. *International Journal of Engineering Research & Technology*, *7*(12).

[16] Hajar Yusoff, S., Abdullah Din, U. N. K., Mansor, H., Shahida Midi, N., & Azra Zaini, S. (2018). Design of Smart Waste Bin and Prediction Algorithm for Waste Management in Household Area. *Indonesian Journal of Electrical Engineering and Computer Science*, *12*(2), 748.

[17] Zeb, A., Ali, Q., Saleem, M. Q., Awan, K. M., Alowayr, A. S., Uddin, J., Iqbal, S., & Bashir, F. (2019). A Proposed IoT-Enabled Smart Waste Bin Management System and Efficient Route Selection. *Journal of Computer Networks and Communications*, *2019*, 1–9.

[18] Prof. Rajshri Nikam, & Prof. Rajshri Nikam. (2014). IOT BASED SMART GARBAGE SYSTEM. *JETIR*, *6*(1), 227–230227–230.

[19] Norfadzlia Mohd Yusof, mohd faizal Zulkifli, Mohd, A., & Nur Azziana Afifie Binti Azman. (2018, May 22). *Smart Waste Bin with Real-Time Monitoring System*. ResearchGate; Science Publishing Corporation.

[20] Shubham Rai, & Nipun Goyal. (2020). Waste Management Through Smart Bin. *International Journal of Engineering Research & Technology*, *9*(9).

[21] Asmawati Desa, Kadir, A., & Yusooff, F. (2012, October). *Waste Education and Awareness Strategy: Towards Solid Waste Management (SWM) Program at UKM*. ResearchGate; Elsevier.

[22] *What is Prototype model- advantages, disadvantages and when to use it?* (2020, August 22). Tryqa.com.

[23] The Daily Star. (2018, October 12). Cigarette butts cause 13.55pc fire incidents. Retrieved May 29, 2021, from The Daily Star website.

[24] Bigbelly. (2016). *JTC Singapore deploys Bigbelly "smart waste bins that alert cleaners via SMS when full."* Bigbelly.com.

APPENDIX

Appendix B: Arduino 1 coding

```
#include <SoftwareSerial.h>
#include <ESP8266_Lib.h>
#include <BlynkSimpleShieldEsp8266.h>
#include <Adafruit_Sensor.h>
#include <DHT.h>
#include <Wire.h>
#include <LiquidCrystal_I2C.h>


#define trigPin2 4
#define echoPin2 5
#define trigPin3 7
#define echoPin3 8
#define DHTPin 6
#define SDAPin A4
#define SCLPin A5

#define DHTType DHT11
#define ESP8266_BAUD 9600
#define EspSerial Serial1
#define BLYNK_PRINT Serial

LiquidCrystal_I2C lcd = LiquidCrystal_I2C(0x27,20,4);

char auth[] = "iTlLNtIMSC7PsjwuQNySKLw94PlWVSYl";
char ssid[] = "madijao";
char pass[] = "lembugoreng012";

long duration, distance1, RightSensor,BackSensor,FrontSensor,LeftSensor, distance, dist;

float speedofsound;


int angle = 0;

SoftwareSerial EspSerial(2, 3);
ESP8266 wifi(&EspSerial);

DHT dht = DHT(DHTPin,DHTType);


void setup() {

pinMode(trigPin2, OUTPUT);
pinMode(echoPin2, INPUT);
pinMode(trigPin3, OUTPUT);
pinMode(echoPin3, INPUT);
  Serial.begin(9600);


  EspSerial.begin(ESP8266_BAUD);
  delay(10);

  Blynk.begin(auth, wifi, ssid, pass);

  dht.begin();
  lcd.init();
  lcd.backlight();
```

```
  Serial.begin(9600);
}


void loop() {

  Blynk.run();

  int temperature = dht.readTemperature();

  Blynk.virtualWrite(V5, LeftSensor);
  Blynk.virtualWrite(V6, FrontSensor);
  Blynk.virtualWrite(V7, temperature);


SonarSensor(trigPin2, echoPin2);
LeftSensor = distance;
SonarSensor(trigPin3, echoPin3);
FrontSensor = distance1;

if(LeftSensor <=6)
{
lcd.setCursor(0,1);
lcd.print("Bin 2: FULL .... ");
lcd.print(LeftSensor);
}
else
{
lcd.setCursor(0,1);
lcd.print("Bin 2: EMPTY ... ");
lcd.print(LeftSensor);

}
```

```
  Serial.begin(9600);
}


void loop() {

  Blynk.run();

  int temperature = dht.readTemperature();

  Blynk.virtualWrite(V5, LeftSensor);
  Blynk.virtualWrite(V6, FrontSensor);
  Blynk.virtualWrite(V7, temperature);


SonarSensor(trigPin2, echoPin2);
LeftSensor = distance;
SonarSensor(trigPin3, echoPin3);
FrontSensor = distance1;

if(LeftSensor <=6)
{
lcd.setCursor(0,1);
lcd.print("Bin 2: FULL .... ");
lcd.print(LeftSensor);
}
else
{
lcd.setCursor(0,1);
lcd.print("Bin 2: EMPTY ... ");
lcd.print(LeftSensor);

}
```

```
Serial.print(LeftSensor);

if(FrontSensor <=6)
{
lcd.setCursor(0,0);
lcd.print("Bin 1: FULL ..... ");
lcd.print(FrontSensor);
}
else
{
lcd.setCursor(0,0);
lcd.print("Bin 1: EMPTY ... ");
lcd.print(FrontSensor);

}


Serial.print(" - ");
Serial.print(FrontSensor);
Serial.print(" - ");
Serial.println(RightSensor);


}
void SonarSensor(int trigPin,int echoPin)
{
digitalWrite(trigPin, LOW);
delayMicroseconds(2);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
duration = pulseIn(echoPin, HIGH);
distance = (duration/2) / 29.1;
distance1 = (duration/2) / 29.1;
}
```

Appendix C: Arduino 2 coding

```
#include <Servo.h>
Servo servo;

int limitswitch=13;
int IR=3;

int servoPin1=11;
int servoPin2=12;
int state= LOW;
int state1= LOW;
int value;
int value1;

void setup()
{
  Serial.begin(9600);
  pinMode(limitswitch,INPUT);
  pinMode(IR,INPUT);
  pinMode(servoPin1,OUTPUT);
  pinMode(servoPin2,OUTPUT);
}
```

```
void loop()
{
value = digitalRead(limitswitch);
value1 = digitalRead(IR);

  if(value1!=state1)
  {
  state1=value1;
  Serial.println("sensor value =");
  }
  if (state1==0)
  {
 Serial.println("target detected");
 servo.attach(servoPin1);
 delay(1);
 servo.write(0);
 delay(3500);
 servo.write(165);
 delay(2000);
 servo.detach();

  }
  if(value!=state)
  {
  state=value;
  Serial.println("sensor value =");
  }
   if (state==0)
  {
 Serial.println("target detected");
 servo.attach(servoPin2);
 delay(1);
 servo.write(0);
 delay(3500);
 servo.write(165);
 delay(2000);
 servo.detach();
```

```
 }
 if(value!=state)
 {
 state=value;
 Serial.println("sensor value =");
 }
  if (state==0)
 {
Serial.println("target detected");
servo.attach(servoPin2);
delay(1);
servo.write(0);
delay(3500);
servo.write(165);
delay(2000);
servo.detach();

 }

  else{
   Serial.println("No target detected");
   servo.write(0);         //close cap on power on
   delay(100);
   servo.detach();

   }
}
```