SMART RECYCLE REWARD BIN – WASTE RECOGNITION AND SORTING FOR REVERSE VENDING MACHINE

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

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DECLARATION

I declare that this report entitled "Smart Recycle Reward Bin - Waste Recognition and Sorting for Reverse Vending Machine" is the result of my 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.

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Date : 27 January 2023

DEDICATION

I would like dedicate this thesis to my parents, who gave the little they had to ensure I would have the opportunity of an education.

ABSTRACT

A Smart Recycle Reward Bin serves as the prototype for a Reverse Vending Machine (RVM) is a cutting-edge idea introduced to western nations to assist in collecting recyclable materials as a result of promoting recycling activities. A reverse vending machine provides an effective, convenient and incentive option to recycle beverage containers. With the help of the RVM prototype, users may earn rewards while recycling aluminium, plastic and paper containers. The container material is identified by the sensor system and it is subsequently deposited into the appropriate bins through the hole. The type of material of the beverage container determines the amount of points awarded for recycling. The total point is added up before being stored in their mobile application. In order to update the latest point, a database will be used. The program includes a user-friendly Graphical User Interface (GUI). Authorized personal and user also will be notified every time the waste reach the maximum level through the mobile apps. The proposed project will provide practical insight into better managing waste disposal to reduce pollution and landfills saturation.

ABSTRAK

Tong Ganjaran Kitar Semula Pintar berfungsi sebagai prototaip untuk Mesin Layan Diri Balikan (RVM). RVM ialah idea termaju yang telah diperkenalkan kepada negara barat untuk membantu dalam pengumpulan bahan kitar semula sebagai hasil untuk menggalakkan aktiviti kitar semula. Mesin layan diri balikan menyediakan pilihan yang berkesan, mudah dan insentif untuk mengitar semula bekas minuman. Dengan bantuan prototaip RVM, pengguna boleh memperoleh ganjaran semasa mengitar semula bekas aluminium dan plastik. Bahan bekas dikenal pasti oleh sistem penderia dan ia kemudiannya didepositkan ke dalam tong yang sesuai melalui lubang. Jumlah mata yang diberikan untuk kitar semula ditentukan oleh jenis bahan bekas minuman. Jumlah mata ditambah sebelum disimpan dalam aplikasi mudah alih mereka. Untuk mengemas kini mata terkini dan menebus mata, pangkalan data akan digunakan. Program ini termasuk Antara Muka Grafik Pengguna (GUI) yang mesra pengguna. Peribadi dan pengguna yang diberi kuasa juga akan dimaklumkan setiap kali sisa mencapai tahap maksimum melalui aplikasi mudah alih. Projek yang dicadangkan akan memberikan gambaran praktikal tentang pengurusan pelupusan sisa yang lebih baik untuk mengurangkan pencemaran dan ketepuan tapak pelupusan sampah.

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LIST OF SYMBOLS AND ABBREVIATIONS

CSS	:	Cascading Style Sheets
HTML	:	Hyper Text Markup Language
IR	:	Infrared
IT	:	Information Technology
LCD	:	Liquid Crystal Display
LDR	:	Light Dependent Resistor
LED	:	Light Emitting Diode
PDA	:	Personal Digital Assistant
RVM	:	Reverse Vending Machine
UI	:	User Interface
UPC	:	Universal Product Code

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Solid waste management is one of the most important services given by municipal governments in the country to maintain cities clean. However, because the mechanisms used are unscientific, antiquated, and inefficient, population coverage is low, and the poor are marginalized, it is one of the worst-performing services in the basket. The situation is worse due to increased urbanization. According to the 2001 Census, the urban population has increased fivefold in the last six decades, with 285.35 million people living in urban areas [1].

The Reverse Vending Machine (RVM) is a novel concept that has been introduced by Western countries to aid in the collection of recyclable materials and, as a result, to increase recycling activity. Wicanders, a Swedish startup, invented this technology in the late 1950s. It was functional, but quite basic and one-dimensional, accepting only one plastic bottle at a time. The machine did not accept other recycled materials, such as aluminum or glass, as well as vast amounts of bottles. An engineer, Aage Tveitan designed and upgraded the reverse vending machine in 1962 to improve this technology. The device could thus accept bottles made of various recyclable materials as well as several bottles at the same time. It is a creative way to collect unwanted beverage containers at the site and use a reward system to boost recycling rates. By dumping recyclable materials such as plastic, glass bottles or aluminum beverage can into the smart machine, user can conserve and collect garbage individually and cleanly at the site where waste happens. Users can choose from a variety of awarding methods to receive the payments. Users are more encouraged to recycle as a result of these incentives since it benefits both the environment and themselves.

The global market for reverse vending machine production is highly concentrated. Tomra Ltd of Norway, Diebold Nixdorf of Germany, and Envipco of the United States compete for the majority of the market. With a market share of 65 percent, Tomra Ltd is the market leader [2]. Table 1.1 shows the analysis of the Reverse Vending Machine for collecting PET bottles.

Table 1.1: RVM and The Characteristic [2]

Company	Producer	Max productivity[a], units/min	Capacity[a]	Price in thou rubles[b]	Rewards
Tomra Ltd	Norway	30/40	200/450 units	no data	no data
Diebold Nixdorf	Germany	40/60	н/д	no data	no data
Envipco Holding N.V.	USA	40/42	300/2333 units	388 – 905	no data
Loetec Elektronische Fertigungssysteme GmbH	Germany	н/д	0,43 m^3	н/д	Cash, coupons, mobile phone account
"RICH", Ltd.	Russia	15	Up to 1 m^3 (20–40 kg of PET bottles)	350	Coupons, utility bills, mobile phone account
PANDA-MAT	Ukraine	12	300 units	125	Cash
Zhengzhou Honest Machinery CO., Ltd	China	30/50	400 units	388 – 646	Coupons, mobile phone account
INCOM TOMRA Recycling Technology (Beijiing) co., Ltd	China	15	335 units	518 – 972	Coupons

1.2 Problem Statement

An automatic self-service machine for recycling is one of the ideas for establishing a smart city. The implementation of the Reverse Vending Machine (RVM) concept as a recycle station can change the city into a better solid management waste. Several problems triggered the idea of developing this project. Users do not receive any returns for the long term every time they recycle their waste is one of the reasons Malaysian people lack a recycling spirit. They prefer to throw away their waste everywhere without considering its effect on nature. On the other hand, there is always dumping of waste at recycle station. Usually, the waste collection will be done once or twice a week according to the schedule. Within that time frame, there is already a lot of waste at recycle station. Customers also need to bring back the recycle waste when the machine is already full of waste and cannot accept even a single waste anymore. Malaysia already has a recycling system with three different coloured containers for different types of waste. Evidently, people must consider and choose which container the rubbish should be placed in. People who do not recycle their waste may dump it in the trash without considering the colour of the bin. This circumstance has a lot to do with how was is sorted. Furthermore, proper waste management plays a main role in a global environment. Therefore, Smart Recycle Reward Bin for Reverse Vending Machine is needed and used in communities, offices and industries as it is part of smart waste management.

1.3 Objectives

This project aims to develop Reverse Vending Machine (Smart Recycle Reward Bin). The objectives of this project are:

1. To develop a mobile app to offer personal rewards for the end-user.
2. To track the waste level inside the beverage container.
3. To analyze the effectiveness of sensors to differentiate the different types of material.

1.4 Scope of Work

The scope of this project is divided into two parts; hardware and software. Several sensors will be used in Smart Recycle Reward Bin for the hardware part. A sensor circuit will be developed to recognize the type of waste material, identify the container waste and detect the maximum level of the container. The mechanism design on the prototype will also be designed to accommodate the sensors placement. For the software part, a mobile app will be developed and placed on the prototype of the Reverse Vending Machine. A mobile app sends a notification to the user and be authorized every time the container reaches the maximum level and update the user's recent reward point.

1.5 Importance/ Significant

It is the responsibility of all citizens to recycle their waste. This act is considered as responsible 'green' citizenship. The majority of European consumers have made recycling part of their everyday routine. Today, most people associate contemporary recycling with the 1970s, when grass-roots campaigns and environmental policies resulted in new consumer practices [3]. For several years, the recycling of solid wastes such as plastic bottles, glass bottles and aluminum can have been concern. State and local governments have gotten more interested in recycling as environmental concerns have become more significant to individuals. Many cities now provide convenient recycling options for residents, such as drop-off locations or curbside pickup. Unfortunately, despite the fact that many communities have made recycling process easier, compliance still remains low. Given the high reliance on individual cooperation for successful recycling, it is clear that a better knowledge of the antecedents of recycling behaviors would be tremendously beneficial [4].

Hence, Reverse Vending Machine (RVM) is designed to encourage recycling by rewarding recyclers with reward point for each item recycled. Many big countries have already implemented RVM machines after realizing the benefits. Despite Malaysia's efforts to reduce waste, RVM machine is not widely employed yet due to its expensive installation and high maintenance costs. The main goal of this project is to help Malaysia implement the RVM machine by creating a prototype of the machine that focuses on reducing installation and maintenance cost simultaneously.

CHAPTER 2

LITERATURE REVIEW

This chapter presents the finding of the previous study that are relevant to this project. These studies also serve as the key source of information for the project with the theoretical, methodological and interpretation of the studies assisting in the material support.

2.1 Reverse Vending Machine

The first RVM, dubbed the 'Bottle Return and Handling Machine' was invented in the United States in 1920. There are currently over 100,000 RVMs deployed all over the world. An example of a Reverse Vending Machine is shown in Figure 2.1. [5]

Figure 2-1: A simple Reverse Vending Machine [5]

The RVM is the type that accepts empty recycle waste and rewards the user in cash or a deposit receipt and is seen at supermarkets and other locations. The principle work of the reverse vending machine is a quick simple idea. The user will place the waste in the machine and automatically rotate it for bar-code scanning. Next, the waste will have transported to a container when the bar-code is identified and matched with a universal product code (UPC) in a database. Instead of scanning, some RVM uses a material identification system that weighs the item [5]. The end user is usually given a deposit or return amount by machine. This distinguishes it as a 'reverse' vending machine instead of inserting money and receiving a commodity like a candy vending machine. The concept is that users insert a product and will receive a monetary value as a return.

There are two key reasons deposit return schemes succeed in raising recycling rates and, at the same time can reduce pollution. First, the public has a financial incentive to recycle. Users are rewarded financially for returning beverage containers under deposit return systems. Instead of being perceived as trash, this shows that containers have value. The second key is self-sorting leads to high quality recycling. The beverage containers are collected without contamination from other types of garbage in a residential recycling bin when the bottles and cans are separated for recycling through a deposit scheme. This means containers can be recycled into new bottles rather than disposed of in landfills. It will reduce the amount of raw resources needed to make a new beverage container.

The most basic reverse vending machine model can only accept one type of containers such as glass bottles or cans. More sophisticated machines may accept a variety of containers and crates. Furthermore, certain machines can be linked to backroom equipment, located in a room separate from the shop, allowing empty containers to be mechanically sorted and stored. A machine's storage capacity is greatly increased when it is connected to backroom equipment. This type of machine is commonly referred as a 'high-end' RVM. A single standing RVM is known as a 'low-end' RVM [6].

2.2 Mobile Application

For a long time, mobile computing has attracted the attentions of researchers, and it has now reached the commercial industry and general consumers via smartphones and PDAs. Such devices may now execute powerful stand-alone apps as well as distributed client-server applications that access data over a web gateway more than ever before. This opens up new possibilities for future mobile app and service development [7]. The use and development of mobile applications is a new and fast growing industry. Mobile applications have a positive global influence. People and societies in developing countries are upgrading themselves and creating a new information technology infrastructure (IT) through a mobile application. Mobile applications run on a small hand-held mobile device that can be moved, used easily, and accessed from any location. Many people nowadays use mobile applications to communicate with friends, access the internet, manage files, create and manage documents and enjoy themselves. Users can get mobile application services from anywhere. People can accomplish a variety of tasks in their daily and professional lives. [8]

A mobile phone was recently closed environments with software developed and maintained by mobile terminal manufacturers. However, open platform technologies such as the Symbian operating system and Java-technology have fundamentally transformed the scenario. Anyone with the necessary knowledge can create an application for mobile terminals. However, it necessitates a thorough understanding of the unique characteristics and constraints of designing software for devices [9]. According to MobiLens, the number of mobile app users in the United States increased by 28% between April 2009 and April 2010 [9]. Several platform tool make it possible to create an app and its user interface (UI) using web standards such as HTML and CSS. The software can then be developed for various mobile platforms, including iOS, Android, Windows Phone 7 and Blackberry. This technique is beneficial only when a compromise user experience in order to launch the app on several platforms and reach the largest number of users. This method allows for the simultaneous development of the application for many mobile platforms. As a result, the application development costs and time to market are reduced [10].

2.2.1 MIT App Inventor

The online platform MIT App Inventor aims to introduce computational thinking ideas through the creation of mobile applications. Users build apps by dragging and dropping elements into a design view and programming application behavior in a visual block language [11]. Working with MIT App Inventor can allow developers to observe user's project while it is being built. This will encourage users to test as they construct and lets them gradually develop their app. Every time user adds a new component to the designer or builds a new functionality using blocks, the connected device or emulator will instantly and immediately receive those new artefacts. By using 'Do It' command from a contextual menu, the user can choose a specific block and immediately see the outcome of the operation. This has very beneficial repercussion in terms of the advantages of getting feedback quickly as well as a way to test and troubleshoot their ideas as it is being developed. Once the app is ready, it may be uploaded to Google Play or directly downloaded to the connected device in *apk* format [12]. MIT App Inventor currently boasts 6.8 million users from more than 190 countries, with over 1.1 million active users each month. Around 24 million apps have been made using App Inventor by users worldwide to address real-life issues [13].

2.3 Type of Sensor

A sensor is a piece of equipment that receive a signal or stimulus and reacts to it by producing an electrical signal. The output signals represent various types of electrical signals, such as current or voltage. The sensor is an apparatus that receives various signals, such as physical, chemical or biological signals, and transforms them into an electric signal. The sensors are classified into several types based on the uses, input signal, conversion method and material properties of the sensor, such as price, accuracy or range [14]. An approach to thinking of sensors is as additional human senses. Electrical signals produced by sensors are typically simple to process and send by manufactured devices or system of devices. Due to the development of communication technology as well as the availability of processing equipment to control output signal, the use of sensors has experienced an accelerated expansion in recent years [15].

System of classifying sensors might be simpler or complicated. Different classification criteria may be chosen depending on the objective of the categorization. There are two different types of sensor, which is passive and active. A passive sensor responds to an external stimulus by producing an electrical signal without the requirement for an extra energy source. Active sensor requires external power to allow it to function. The sensor modifies the signal to create the output signal. Because their properties change in response to an external action and can be turned into electrical signals, active sensors are frequently referred to as parametric sensors.

2.3.1 Ultrasonic Sensor

Ultrasonic sensor uses a transmitter and receiver, or transceiver, to send and receive ultrasonic sound when measuring the distance without touching the objects as shown in Figure 2-2. The main goal is to determine the time taken for an ultrasonic sound wave to travel from a sensor to an object being detected. An ultrasonic transmitter delivers a sound frequency above 18kHz into the air at a speed of 344 meter per second [16]. The wave that transmits the ultrasonic signal is pointed at a 30˚ angle. Unlike infrared sensors, ultrasonic range finder's measurement are unaffected by sunshine or the color of objects. Although practically every surface, including transparent reflect the ultrasonic sound, it might be challenging to estimate the distance to the fluffy of microscopic objects. The measurements will be most precise if the sensor is pointed perpendicular to the object. Additionally, if the angle of incidence is too great, the wave that is reflected from the object will not reach the receiver and the measurement will be off [17].

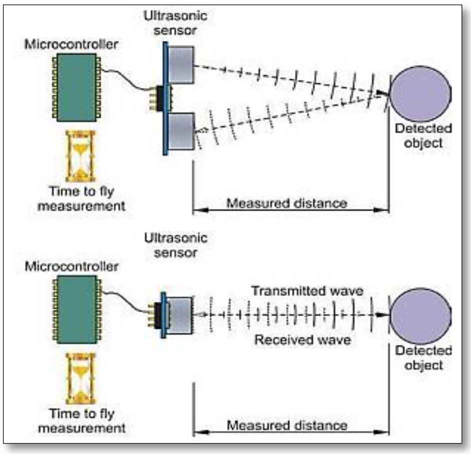

Figure 2-2: Ultrasonic Working Principle [17]

2.3.2 Infrared (IR) Sensor

In robotics, Infrared (IR) sensors are frequently employed as proximity sensors and obstacle avoidance systems. Compared to ultrasonic sensors, it is less expensive and have quicker response times [18]. Thermal and photonic IR detector are the two primary categories. Thermal detector functions based on detecting the thermal effects of the incident IR radiation. Numerous temperature-dependent phenomena are used in the thermal sensing technique. In contrast, incoming IR radiation induces internal or extrinsic electrical excitations in photonic detectors. IR photonic detectors may be photovoltaic or photoconductive. The resistivity of the detector element is seen in photoconductors. In contrast, photovoltaic detectors are essentially p-n diodes that produce a photoelectric current when exposed to IR light. The main characteristics of thermal detectors are their high volume, low performance, and low price. However, the market for photonic detectors is small but highly competitive in terms of performance and price. With high demands on detection effectiveness, operating temperatures, and particularly the capacity for multicolor detection, high-performance IR detector technology is entering its third generation.[19].

2.3.3 Inductive Proximity Sensor

In many technical goods and systems, inductive proximity sensors are frequently employed for the contactless measurement of an object or target displacement and location [20]. As depicted in figure 2-3, the detection coil, which is placed at the front of the sensor generates a high-frequency magnetic field. Induced currents flow in the metal as a metallic item approaches this magnetic field, resulting in heat loss and reducing or stopping oscillations. It detects an object without any mechanical touch, unlike a limit switch. As a result, there is no chance that contact will harm either the sensing object or the sensor. Non-metals whereby current cannot flow cannot be detected by inductive proximity sensors since they rely on heat loss from generated current for detection. Although there are numerous ways to increase the sensing range, including employing non-shielded sensor heads and enlarging the detection coil, the sensing range is still less than that of photoelectric sensors. [21]. There are several application of inductive proximity sensor. It can be uses to counting products during production or transfer in industrial control. It can also be used to detect metal objects, arm and land mines in terms of security.

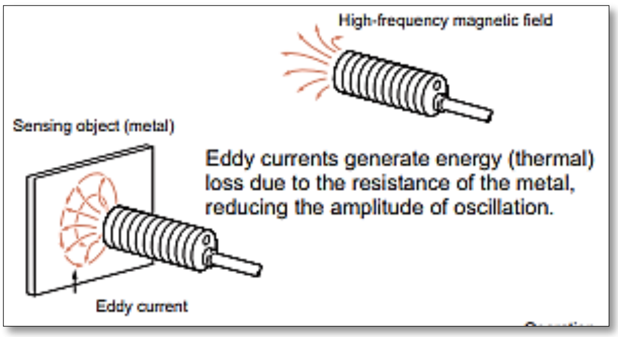

Figure 2-3: Inductive Proximity Sensor Working Principle [21]

2.4 Previous Works

Mariya Deena et al. proposed plastic bottles are accepted as the input in the machine design and the user is rewarded with credit points that may be used for online purchasing. The classification is done through image processing. Image processing, reverse vending machine and application software are the three parts that make up the suggested system. To detect the material of the bottle, image processing is used. If a plastic bottle is detected, the machine will accept it. The users enter their unique password to access the machine. A credit point is calculated and the total point is recorded in the database. If a non-plastic is detected, the machine will be rejected, and an error message will be displayed on the LCD display. The app allows users to monitor the latest credit points and use the available promotion code to purchase. An IR sensor detects when the machine is filled with bottles and sends a notification to authorities through the app, making it easier to find the RVM and retrieve the bottles. A simpler user identification method, solar energy may be used for power supply and can be used by a wide number of people are the remaining problems and scopes of the study [22].

Aditya Gaur suggested the Xilinx 14.5 ISE Simulator simulate a Reverse Vending Machine. The user will insert their plastic material waste into the RVM. The system will automatically sum the point throughout the recycling process. The total reward coins are based on the total weight of the recycled plastic that enter the system. If users insert non-plastic material into the RVM, the system will reject it and automatically reset. The system will be a cost effective and efficient project in implementing the design of the recycle machines programmable hardware based detection system, which will be made up of a capacitive proximity sensor, an infrared photoelectric sensor and a strain gauge weight sensor. All needed components are cheap and readily available in the market. However, it has low detection accuracy of the sensor system, only accepts plastic material recycle waste and give a simple reward to the users [23].

In the project by Muhammad Sallehuddin Mohd Adzahare, plastic, glass bottles and aluminum cans will be detected by an inductive proximity sensor, and the data will be conveyed to the processor. The data will then transfer to the Blynk application where the user can view the notification on a liquid crystal display (LCD). The operator will be triggered with the status of the RVM at the same time. Two analogue input of sensor (inductive proximity sensor and capacitance proximity sensor) are configured using the Arduino Mega microcontroller and NodeMCU using the Arduino IDE software. The RVM data indicates the incentives earned based on the overall weight of the recycled item. The reward computation is based on the regular price of recyclable commodities [24].

The optical subsystem for empty container recognition and sorting in a reverse vending machine has been introduced by Andrey N.Kokoulin et al. Some strategies for effective image processing and Reverse Vending Machine structure upgrades were provided in the study to attain competitive advantages. Binocular optical identification module, two layers of data processing (distributed functionality), delegating high-level functionality to the user's smartphone and using optical recognition with a weight sensor instead of pricey equipment. The research of DNN implementations in IoT devices was not the only target of image recognition research. This research also discovered that a C++ programming is superior for image processing in small microcontrollers than Python programming since it is faster and uses less memory [25].

Wisdom Gen P. Dumpayan suggested the vending machine, the control center and the bottle acceptor unit will all be part of the ‘Drop and Tap’ Reverse Vending Machine. A display area will be included in the vending machine as well as storage for the container to be sold. The vending machine will be used to obtain the recycle container. The control center will be supervised and manage all procedures and will housing the microcontroller units and input/output peripherals such as LCD screens and keypads. The RFID reader will also connect to it too. The bottle acceptor unit accepts plastic containers through a bottle inlet. The bottle acceptor dispensing area will refund rejected plastic containers. The machine will be supplied by a solar panel with a rechargeable battery. The photoelectric sensor and capacitive sensor will place at the inlet of the bottle acceptor machine. The conveyor belt goes up and dumps the bottles into the storage if the bottle is approved. The conveyor belt moves down and deposits the bottles on the bottle acceptor dispenser if the bottle is declined. If the storage bin is already full, an ultrasonic proximity sensor will be applied to detect it [26].

A picture of the bottle is taken and send to the bottle recognition algorithm when the barrier detector recognizes a bottle has been proposed by Pravin Dhulekar. If the inductive proximity sensor output is high, the bottle is categorized as an aluminum can and will be automatically placed in the can compartment. If the bottle recognition algorithm produced a high result, the material was identified as a plastic bottle and moved to the plastic bottle division. The bottle count is incremented by one when the loaded material is a bottle or can. Features of an object must be acknowledged and compared with known features in order to identify an object from its image. A classifier is a specialized method that uses convolution neural networks to accomplish this goal. To generate a result, a classifier calculated the features of an input image based on pixel value and compared with known features. One method of training a classifier for an object classifier is supervised learning. A preset library called Tensor flow can be used to quickly train a classifier. Tensor flow is an open source machine learning library that was created with deep learning. Though machine learning produces good outcome for bottle identification, the image of the bottle used to train the algorithm is extremely important [27].

An intelligent automatic recycling garbage container has been designed by Suwon Shin et. al. It offers an intriguing remedy for a problem that arises when recycling paper and metal. This project's main objective is to design a recycling bin specifically for office employees and students who typically work or study while seated at a tiny desk and don't want to take the time to recycle metal or plastic cans every day. The following features are used to achieve automatic movement, which is essential for the garbage can's sensitive sensor. An internal infrared sensor will detect when either bin is getting full, while a lid-mounted LED display lets users know when one or both baskets are full. A motor-operated lid will open when it senses a nearby object and motor-operated tilting plate that closes off one bin to guarantee correct disposal [28]

A Low-Cost Automated Sorting Recycle Bin Powered by Arduino Microcontroller has been developed by Harnani Hassan et. al. This project describes the creation of a low-cost recycle bin that uses an Arduino microcontroller to autonomously sort several types of recyclable material. The objective of this research is to build a prototype recycling bin with a sensing system that can classify recyclable waste (such as metal, paper, and plastic) and automatically assign the garbage to different bin partitions based on types. The prototype recycles bin's sensitivity analysis for accurately sorting waste is also presented in this project. The prototype recycle bin's architecture is divided into two sections, mechanical and sensor. Metal, paper, and plastic waste are all types of waste that the sensing component can identify. An inductive proximity sensor is used to detect waste made of metal, while light-emitting diodes (LEDs) and light-dependent resistors (LDRs) are used to detect waste made of paper and plastic. In order to properly separate the different types of garbage, the mechanical component put a servo motor together with a microcontroller [29].

Table 2.1: Comparison Between Proposed Work and Previous Work

Proposed Work	Features and Characteristic					
	Material Detection	Real Time	Warning Alarm	Reward	Mobile Apps	Actuator
	3	√	√	√	√	X
Previous Work	Features and Characteristic					
	Material Detection	Real Time	Warning Alarm	Reward	Mobile Apps	Actuator
[22]	1	√	√	√	√	X
[23]	1	√	X	√	X	X
[24]	3	√	√	√	√	√
[25]	2	√	X	X	X	√
[26]	1	√	√	√	X	X
[27]	2	√	X	X	X	√
[28]	2	√	√	X	X	X
[29]	3	√	√	X	X	√

Table 2.2: Comparison on Previous Work

Author	Methodology	Result	Limitation/ Recommendation
Deena Mariya, Jaseela Usman, Elsha Nimmy Mathew, Hasna PH, Arifa Azeez [22]	1. If the machine detects a plastic bottle, machine accept it. 2. The user can login to the machine through their unique password, credit point is calculated correspondingly and the value is stored in the database. 3. User can view the credit point from the app and use the available promo code for purchasing.	1. The inlet of the reverse vending machine accepts the plastic bottles. 2. All other bottles are rejected and an error message is displayed in LCD display. 3. Depositor's name and credit points are displayed in the screen once the bottles are accepted by the machine. Once the depositor complete depositing the bottles, they receive credit points accordingly.	The project is a low cost Reverse Vending Machine. 1. It should improve the material detection accuracy. 2. It also should have simpler user identification method to make it easier for user to use it.
Aditya Gaur, Dilip Mathuria, Dr Rashmi Priyadarshini [23]	1. User will insert their plastic material waste into the Reverse Vending Machine.	1. When user insert waste plastic material of weight in range of 249gm to 331gm, it will move to St6	1. It has low detection accuracy of the sensor system as it only accepts plastic material recycle waste.

	2. The system will automatically sum the point throughout the recycling process. 3. The total reward coins are based on the total weight of the recycled plastic that enter the system.	state from St1 state and give 3 coins as an output. 2. When user insert waste plastic material of weight in range of 661gm to 750gm, it will move to St11 state from St1 state and give 8 coins as an output. 3. The machine will move to cancel state when there are no material is inserted.	2. It give a simple reward to the user.
Muhd Sallehuddin Mohd Adzaharee, Afandi Ahmad, Muhd Muzakkir Mohd Nadzri [24]	1. An inductive proximity sensor will detect the items of plastic, glass bottles or aluminum cans and send the data to the processor. 2. Data will transmit to Blynk application and user will able	1. It capable to detect recycle material (aluminum can, plastic and glass bottle) and can collect recycle waste up to 1 kg for each material. 2. The prototype will notify the workers when the machine is full through Blynk mobile application.	1. If developer send more than 100 value per second in Blynk, it may cause Flood Error and the hardware will automatically disconnected from the server.

	to see the notification through the LCD. 3. The operator can be triggered with the status of the Reverse Vending Machine. 4. Two analogue inputs of sensors are configured with Arduino Mega microcontroller and NodeMCU through the software of Arduino IDE.	3. It calculates and display the reward point to user through the LCD .	
Andrey N. Kokoulin, Dmitriy A. Kiryanov [25]	1. Binocular optical identification module, two layer of data processing (distributed functionality), delegating high-level functionality to the user smartphone and using optical	1. Some methods of efficient image processing and Reverse Vending Machine structure enhancements to achieve competitive advantages were proposed. 2. These enhancements include binocular optical recognition	1. LeNet training could be more efficient if use 56x56 and higher resolution of training images. 2. Uses of double LeNet models each of 2 classes is more efficient than the single model of 2-6 classes.

	recognition with a weight sensor instead of pricey equipment. 2. The research of DNN implementations in IoT device was not only target of the image recognition research.	module, two levels of data processing (distributed functionality), delegating of high-level functionality to user's smartphone, use of optical recognition with weight sensor instead of expensive equipment.	3. The most accurate decision was processed by AlexNet CNN, but it only obtained nearly the same accuracy with LeNet and MobileNet models after several enhancements.
Wisdom Gen P. Dumpayan, Matthew Lawrence M. De Mesa, Nathalie Danielle F. Yucor, Jacqueline D. Reynoso, Gabriel Rodnei M. Geslani [26]	1. If user want to deposit bottles, it will be verified using the photo-electric sensor and capacitive sensor. 2. After the deposition of plastic bottles, the corresponding value of the input plastic bottle will be added to the total value stored in the RFID card and the	1. The RFID card recognition mechanism is accurate and reliable. 2. The input sensing and points adding mechanism is accurate and reliable. 3. The item purchasing and dispensing mechanism is accurate and reliable.	1. Design next prototype that shall make use of solar power as default power source for better marketability to big end users.

	sum will be displayed through the LCD screen		
Pravin Dhulekar, S. T. Gandhe, Ulhas P. Mahajan [27]	1. If output of inductive proximity sensor is high, it indicates that bottles is aluminum can and will be moved into compartment of can. 2. If output of bottle identification algorithm is high, object is identified as plastic bottle and it will be move to plastic bottle compartment.	1. Machine takes less than 10 second to identify the bottle in each case. Whereas the accuracy is 80 to 100%. 2. This technology overcome the drawback of conventional image processing technology and accepts almost all types of bottles with highest accuracy over state of art methods.	1. Through use of Machine Learning gives good result for bottle identification, it is heavily depends on the image of the bottles used for training the machine
Suwon Shin, Kaiyuan Fan [28]	1. The project is an intriguing response to a problem that arises from recycling between	1. All of the components, including the automatic main lid, the sorting plate, and the capacity check, operate	1. By adding more types of sensors to detect various types of materials, this idea can be further enhanced to make

	metal and paper and introduces its useful applications. 2. This is one strategy for keeping hands clean by avoiding contact with the garbage can's lid.	successfully, and the system performs exactly as intended. 2. User can avoid opening with their hands, which keeps them clean, and the waste basket can separate aluminum or metal cans for recycling in various bins. 3. The LED notifies users to immediately replace or refresh the bins once the garbage can is full.	recycling for a variety of trash types easier and more user-friendly. 2. The garbage can shouldn't cost a much to purchase, thus employing a more effective sensor rather than a cheap one can achieve this.
Harnani Hassan, Fadzliana Saad, Muhd Suhaimi Mohd Raklan [29]	1. The prototype recycle bin is made up of two separate components, mechanical part and sensor part. 2. The sensor component determines the type of waste,	1. The development of a low-cost automated sorting recycle bin powered by Arduino microcontroller is presented to effectively sort waste according to its base.	1. The effectiveness of garbage collection management will be increased by a more advanced prototype of a recycle bin with IoT characteristics to update and alert end users through mobile application on waste status ('full' or 'not full').

	including metal, paper, and plastic. 3. In order to properly separate the different types of waste, the mechanical component put a servo motor together with a microcontroller.	2. The recycle bin prototype had a high sensitivity to plastic-based waste.	2. Future implementation of a "reward point" system is also possible as it will raise recycling awareness.

CHAPTER 3

METHODOLOGY

This section will go over the design methods that will be used to complete the project. The main tasks, challenges and issues are listed. The functioning concepts will be explaining in detail. Additionally, the milestone that has been set must be achieved through the project.

3.1 Project Overview

The project is divided into three primary areas, which will be completed one at a time. The “Smart” features of the bin are implemented using a solar system. The “Recycle” system is accomplished using a material detection system (inductive proximity sensor and infrared (IR) sensor) as shown by the title “Smart Recycle Reward Bin”. the emphasis is on the “Reward” system, which is implemented through the use of a mobile application.

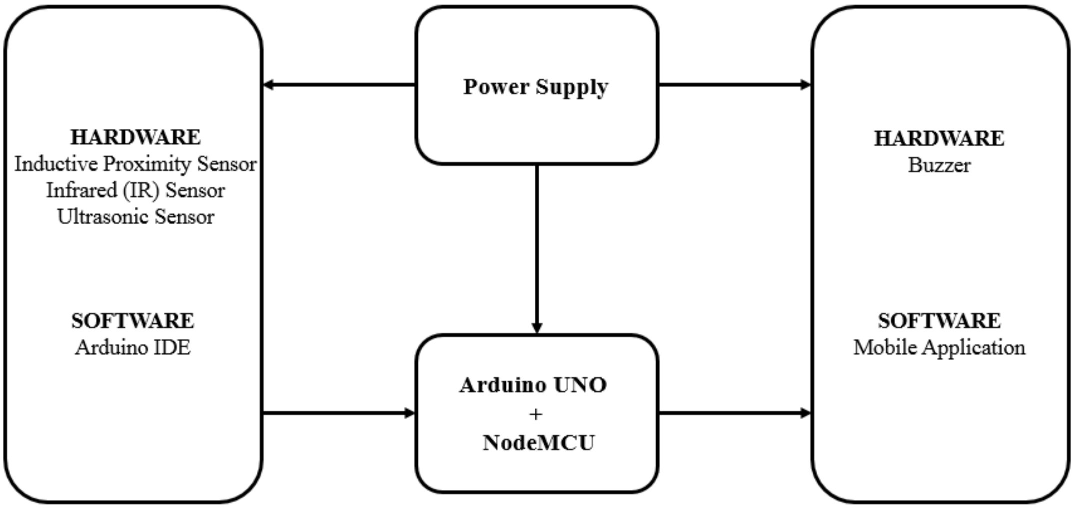

Figure 3-1: Block Diagram

3.2 Project Planning

Solid waste is produced because of human daily life. The amount of waste produced by human increase rapidly day by day and this situation will give a bad impact to future generation. To overcome the issue, the idea of smart recycle reward bin being highlighted. The first thing need to be complete in this project is background study on previous project and thesis, collecting all information related to the component that will be uses in the project and type of mobile application that easy and convenient to access for all users. All component (input, output and microcontroller) that will be use in the project also will be finalize during the background study. The fabrication process and circuit simulation will only start after fully confirming the circuit design to reduce the repetition of the fabrication process. Circuit design must repeat again if an error occurs during the troubleshoot process. Process development of mobile application will start immediately because it is the most complicated process in the project. Next, the input component (ultrasonic sensor, inductive proximity sensor and infrared sensor), microcontroller and Wi-Fi module need to assemble together with the mobile app because the mobile app need to be test before going to the next step, make evaluation on the whole project. Project assemble process need to re-do if there are issue appear during the project testing. Project analysis will only start after the project is fully successful and get the complete result from the project.

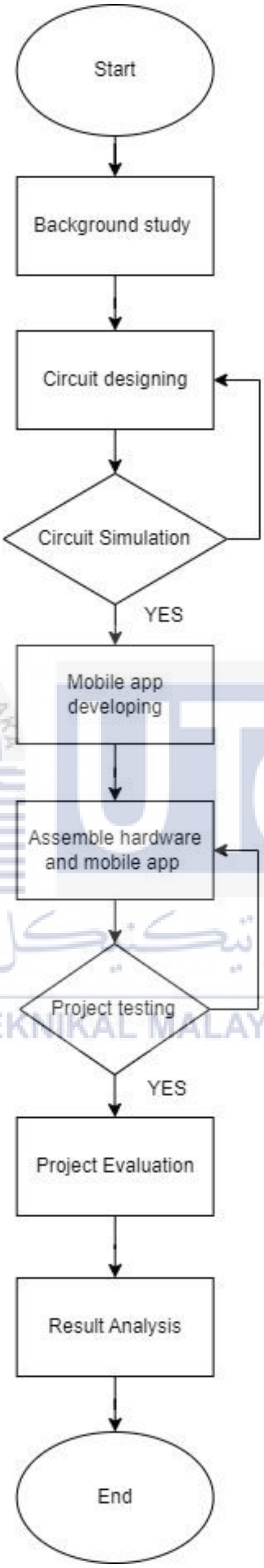

Figure 3-2: Flow Chart Process

3.3 Project Flow Chart

A complete flow chart of Smart Recycle Reward Bin. The flow starts by signing up the mobile apps for the first time user or existing customer can simply logging in the mobile apps through their unique 6-digit password. The working of the machine begins when user insert their recycling material, which either plastic, paper or metal inside the bin. Two type of sensor is used to determine the classification of recycle material. If the sensor does not detect any material, the flow comes to a stop. The reward point is given based on the material of item. The point is calculated correspondingly and the total is stored in the database. User can view their collected credit point from the mobile app. The apps also will display a notification when the machine is full with recycle item. This will notify user to hold them recycle item and also notify authorize person to collect the recycle waste.

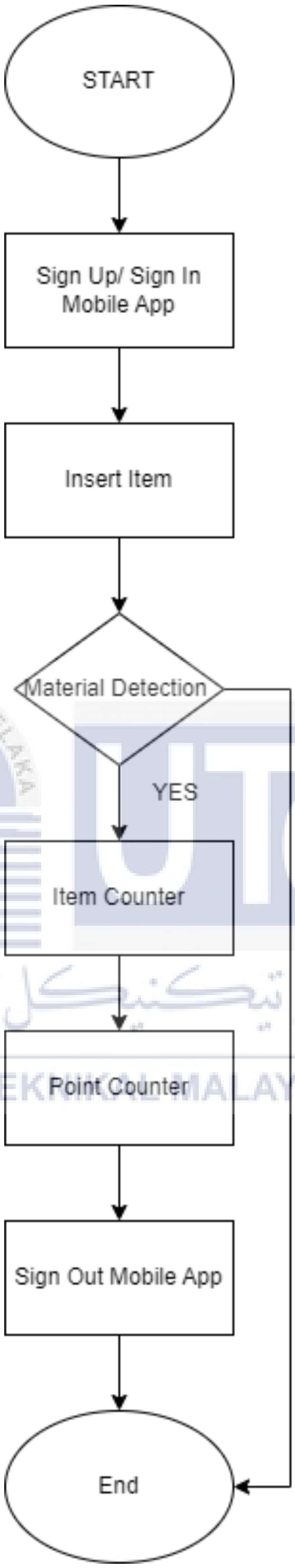

Figure 3-3: Complete Project Flow Chart

3.4 Hardware Prototype Design

3.4.1 Development of Sensing Part

The sensing circuit is built utilizing an ultrasonic sensor, an inductive proximity sensor and Infrared (IR) sensor. Each sensor serves a unique purpose in order to identify the various types of recyclable material. According to Table 3.1, the inductive proximity sensor is used to detect the presence of metal. The infrared (IR) sensor is used to distinguish between paper and plastic bottles. The ultrasonic is for measuring the distance of recycle waste.

Table 3.1: List of Sensors

Type of Sensor	Type of Detection	Measurement Unit
Inductive Proximity Sensor	Magnetic Field	Tesla (T)
Infrared (IR) Sensor	Light Intensity	Micron (μ)
Ultrasonic Sensor	Distance	Centimeter (cm)

The metal substance begins to be detected by the inductive proximity sensor. If the sensor does not detect metal, it signifies that the inductive proximity detection value is greater than 0. An infrared (IR) sensor will begin to function and gauge the amount of light being recorded to distinguish between paper and plastic. In addition, one LED is mounted directly opposite the stability of the initial light that the infrared captures. The light intensity captured by infrared must be greater than 60 for a plastic bottle and more than 124 for a piece of paper placed into the machine.

When the system detects the existence of any recyclable waste inside the machine, the ultrasonic sensor is the first sensor that function. The process of detecting materials begins once the ultrasonic sensor recognizes the presence of an object by activing on another sensor. An ultrasonic sensor's detecting range is set at zero to 1 meter. Table 3.2 shown the measurement for waste classification.

Table 3.2: Measurement for Waste Classification

Type of Sensor	Type of Material	Detection Range
Inductive Proximity Sensor	Metal	Near to 0
Infrared (IR) Sensor	Plastic	Up to 60
	Paper	Up to 124
Ultrasonic Sensor	All	Below 1m

A message is sent to the microcontroller and mobile app once all the sensors have classified the garbage by kind of material. The control system element, consisting of the Arduino Uno microcontroller and Wi-Fi module, performs all procedures related to verifying the type of material, classifying the type of recycle waste and sending data to mobile apps. The microcontroller serves as the system's brain, which controls and directs the entire setup. All sensors are interfaced with the microcontroller to enable an efficient sensing operation depending on the coding that is uploaded onto the microcontroller.

3.5 Software Design

3.5.1 Development of Programming Part

The microcontroller needs to be programmed in order to command the sensors to perform out a certain task. Only fundamental C++ programming is used for this project. It is employed to specify the pin that will connect the components for the input and output. On the other hand, it is also necessary to include the library of the used components. The C++ standard input and output functions are contained in the library.

In addition, the algorithm used is only ‘if else’ statement. The next block of code will be performed depending on the decision made using this statement.

3.5.2 Development of Mobile App

An android-based application called MIT App Inventor has user login and authority login features. Each user must download the apps and register an account with a six-digit unique password, which will be used to deposit recycle waste in the reverse vending machine. After that, user have to log in to their accounts to view it. If the user's email address or password is incorrect, an error message will be displayed, otherwise, the system will take the user to the application's home page. User need to turn on the machine function on the mobile app to activate the machine. To check the total point obtained from the recycling, user need to turn off the recycle machine first after the recycling process and the system will total up the reward points. Each user will get 3 point for metal waste, 2 point for paper waste and 1 point for plastic waste. Table 3.3 shows the distribution of reward point for each material.

Table 3.3: Reward Point for Waste Classification

Type of Material	Reward Point for Each Item
Metal	3 point
Paper	2 point
Plastic	1 point

CHAPTER 4

RESULTS AND DISCUSSION

This chapter will go over the project's testing and performance. Hardware and software are tested to make sure the expected functionalities are accomplished. Testing is primarily done to make sure that data was sent through programs created to improve communication between the mobile app and microcontroller.

4.1 Prototype of Reverse Vending Machine

To develop the prototype of reverse vending machine (RVM), it has been started with the designing process using software Paint with the detail of the placement of the sensor as depicted in Figure 4-1. The final prototype of reverse vending machine shown in Figure 4-2, Figure 4-3 and Figure 4-4. However, there are several change in the position placement of the hole and wiring box. Circuit implementation of the reverse vending machine is shown in Figure 4-5.

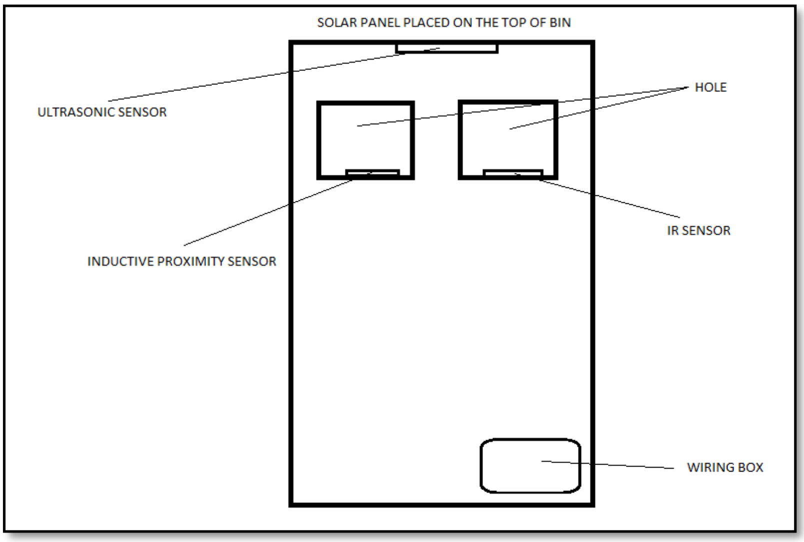

Figure 4-1: Sketch diagram of the RVM

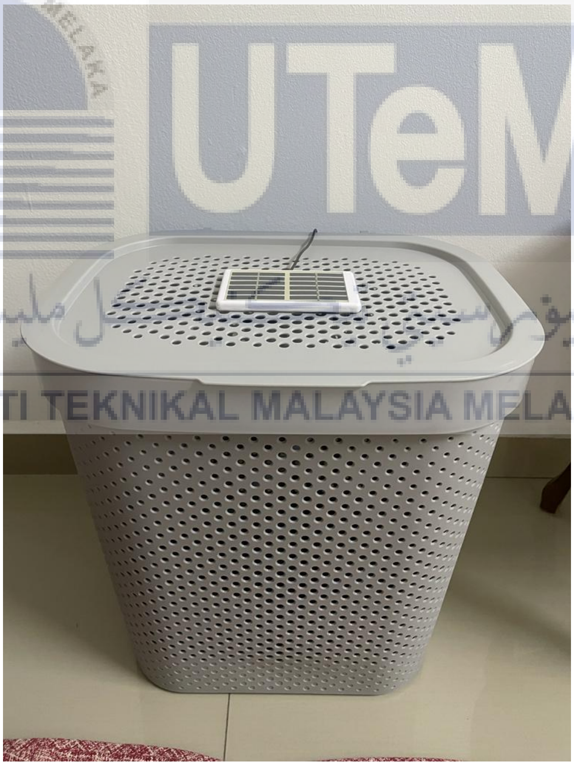

Figure 4-2: Front View of Reverse Vending Machine

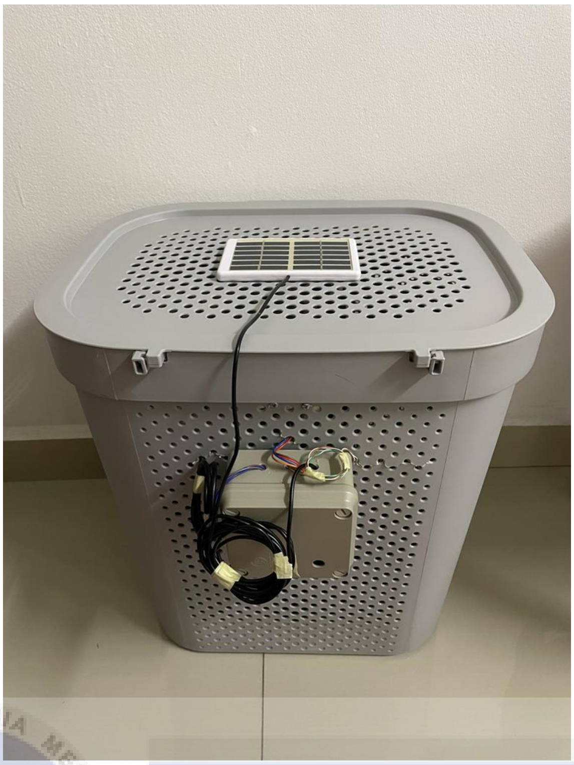

Figure 4-3: Back View of Reverse Vending Machine

Figure 4-4: Inside View of Reverse Vending Machine

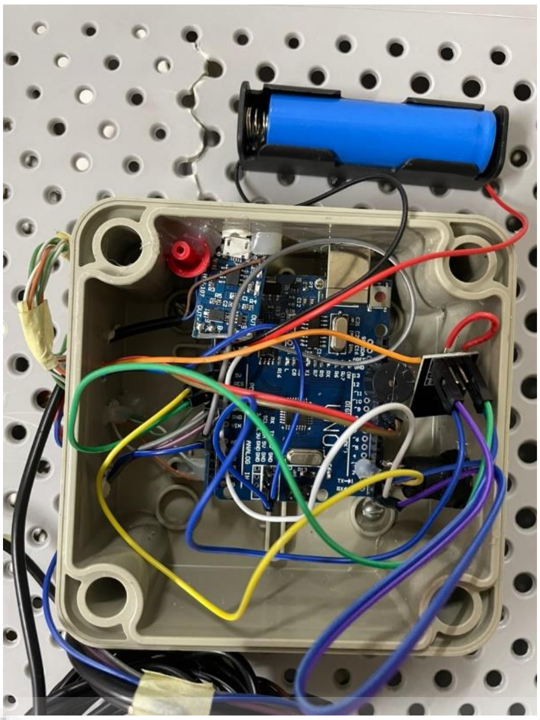

Figure 4-5: Circuit Implementation for Reverse Vending Machine

4.2 Sensing Part

The sensing component uses three types of sensor: ultrasonic sensor, inductive proximity sensor and infrared (IR) sensor. The ultrasonic sensor will first look for any recyclable rubbish. It then transmits the signal to the microcontroller when the item has been found. An ultrasonic sensor can detect an item at a distance of less than 1 meter. The inductive proximity sensor is used to detect the presence of metal objects without actually touching them. The use of an inductive proximity sensor allows for the detection of aluminum cans. The brightness of the light emitted by the LED mounted opposite to it is measured by an IR sensor. As a result, when a piece of paper is tossed, the light that the LED emits is obscured by the paper, reducing the amount of light that the IR sensor can detect. The IR sensor will catch more light intensity from the clear plastic container than it will from a piece of paper. Figure 4-6 shows the sensor placement on the reverse vending machine.

Figure 4-6: Sensing Part of Reverse Vending Machine

4.3 Mobile Application

The user must fill out the user registration form to establish an account before using the mobile application for the first time. The user must provide personal data, including their username and password, in order to complete the process. The process shown in Figure 4-7. After the completion of registration, the consumer can sign in the system by inputting their user account and password with the user login interface as shown in Figure 4-8. Through the mobile application, users can easily get details on the amount of garbage inside the container, the overall amount of recyclable items, and the total number of points of collection. The interface shown in Figure 4-9.

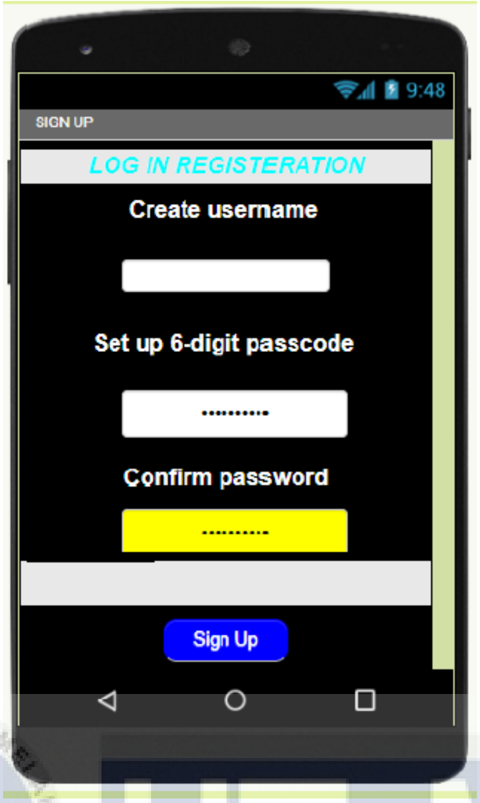

Figure 4-7: Registration Process

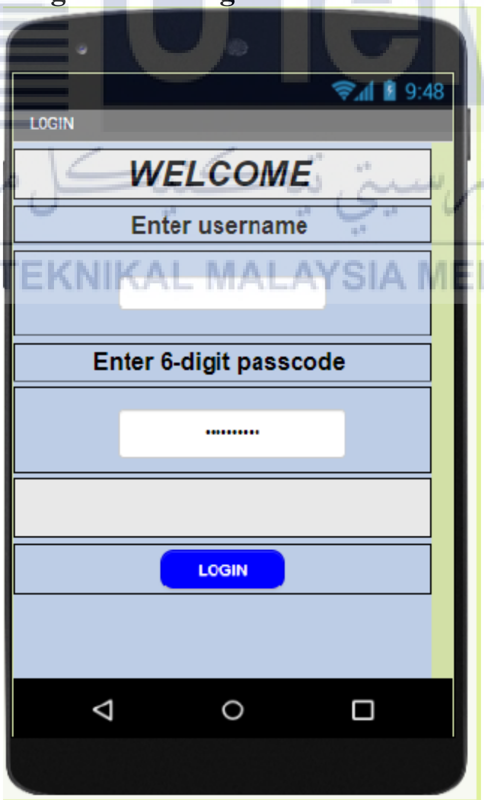

Figure 4-8: Sign In Process

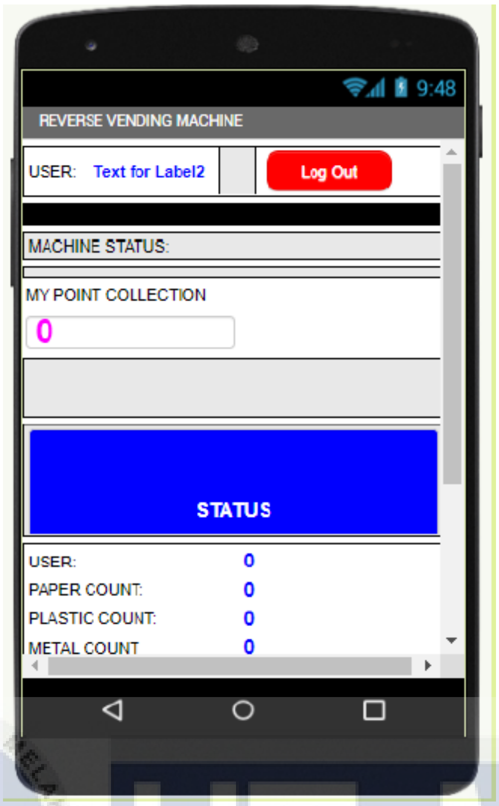

Figure 4-9: Interface of the Mobile Application

4.4 Analysis Result on Sensitivity of Sorting

The results of the tests conducted on the recycling bin prototype are displayed in Table 4.1. Ten attempts at emptying the recycling bin of trash are made for the test, with each attempt being tested three times. All sample for testing are display in Table 4.2.

Table 4.1: Result on Sensitivity of Sorting

Type of Material	1	2	3	4	5	6	7	8	9	10
Metal	√	√	√	√	√	√	√	√	√	√
Paper	√	√	√	√	X	√	√	√	√	√
Plastic	√	√	X	√	√	√	√	√	√	X

Table 4.2: List of Sample for Testing

	Metal	**Paper**	**Plastic**
1	Car Key	Memo Note	Tumbler
2	Keychain	Kitchen Tissue	Mineral Bottle
3	Purse Zip	Bank Note RM10	Wiring Box
4	Spoon	Paper Box	Bottle Cap
5	Fork	Black Mounting Board	Plastic Bag
6	Fingertip	Artificial Flower	Artificial Leaf
7	Metal Watch	Envelope	Mouse
8	Drink Tin	Flyer	Polystyrene
9	Coin	Egg Tray	Medicine Bottle
10	Paper Clip	Paper Plate	Air Pod Case

The proportion of inaccuracy for each material test is determined using Equation 1. The percentage is determined in order to assess the recycling bin's sensitivity and effectiveness. To calculate the percentage error, the unsuccessful attempt will be divided by the total number of attempts and times by 100%. Table 4.4 displays the calculated error percentage based on the findings attained. Formula for percentage of error shows in Equation 4.1

$$Percentage\ of\ error = \left(\frac{Number\ of\ attempt - Successful\ attempt}{Number\ of\ attempt}\right) \times 100\% \qquad (4.1)$$

Table 4.3: Percentage of Error for Different Type of Material

Type of Material	Percentage of Error
Metal	$Percentage\ of\ error = \left(\frac{10-10}{10}\right) \times 100\% = 0\%$
Paper	$Percentage\ of\ error = \left(\frac{10-9}{10}\right) \times 100\% = 10\%$
Plastic	$Percentage\ of\ error = \left(\frac{10-8}{10}\right) \times 100\% = 20\%$

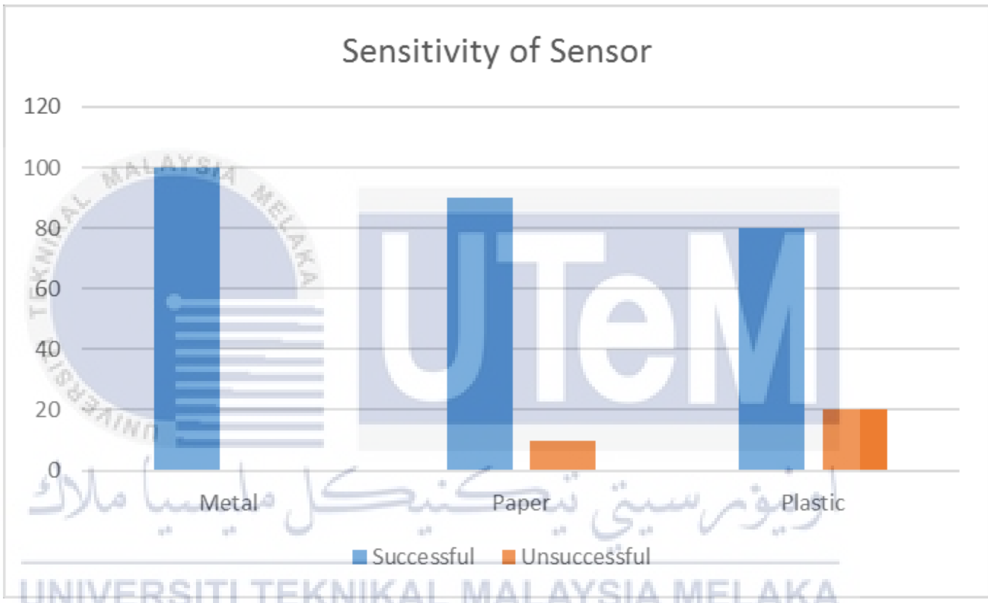

Figure 4-10: Sensitivity of Reverse Vending Machine

The analysis of the sorting system's sensitivity is shown in Figure 4-10. All attempts for metal-based waste are successful, which implies that each of the 10 metal samples is deposited into the appropriate compartment. The size of the metal sample, which is large enough to be detected by the inductive proximity sensor and can be easily categorized as metal-based waste, may have contributed to the success of the endeavor.

Additionally, for waste made of paper, just one out of every ten tries fails. This indicates that there is a 10% error rate for the paper. The colour and surface of the paper might be the cause of this issue. Sometimes, when the colour of the paper is lighter, the infrared sensor cannot detect paper's existence. Referring to the basic concept of an infrared sensor, it captures light intensity from the material. When it captures a light intensity, it will be categorised as paper-based waste.

Lastly, two out of every ten tries fails for waste made of plastic. This indicates that there is a 20% error rate for paper. The colour and surface of the plastic also might be the cause of this issue. Sometimes, when the colour of the plastic is darker, the infrared sensor cannot detect the existence of plastic. Referring to the basic concept of an infrared sensor, it captures light intensity from the material. When it captures small amount of light intensity, it will be categorised as plastic-based waste. In this situation, when the object's surface is darker, the sensor detects as paper-based waste, when the object's surface is lighter, the sensor detects as plastic-based waste. The amount of light intensity captured is not as accurate as the expected measurement.

4.5 Analysis Result on Detection Value

The results of the detection value conducted on the recycling bin prototype are displayed in Table 4.4. Three attempts for each collected sample are made to check each sensor's validity on different types of waste. All samples for testing are displayed in Table 4.2.

Table 4.4: Result of Detection Value for Each Material

Type of Material	1	2	3	4	5	6	7	8	9	10
Metal	0	0	0	0	0	0	0	0	0	0
Paper	213	180	130	102	10	147	163	142	60	150
Plastic	7	10	70	11	38	45	7	4	28	160

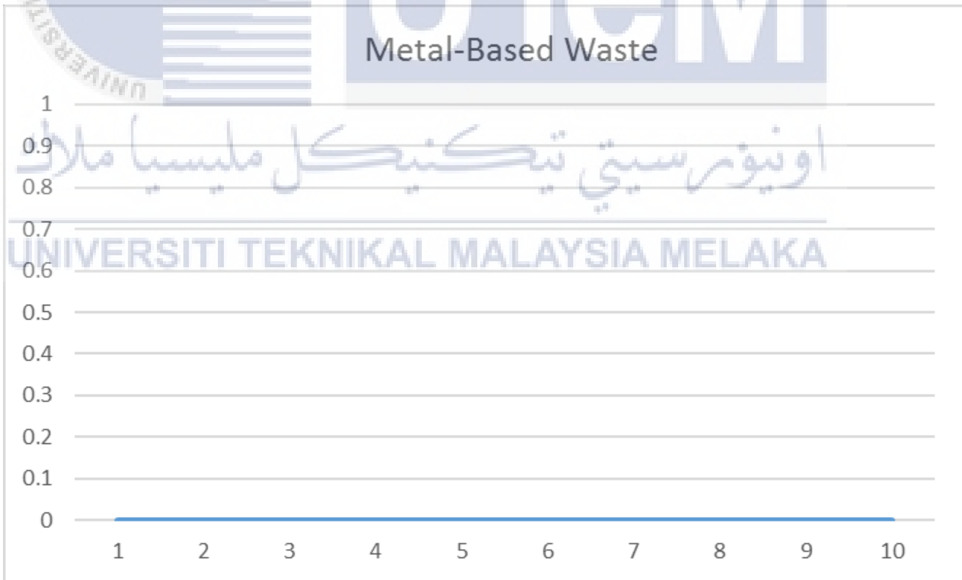

Figure 4-11: Detection Value for Metal-Based Waste

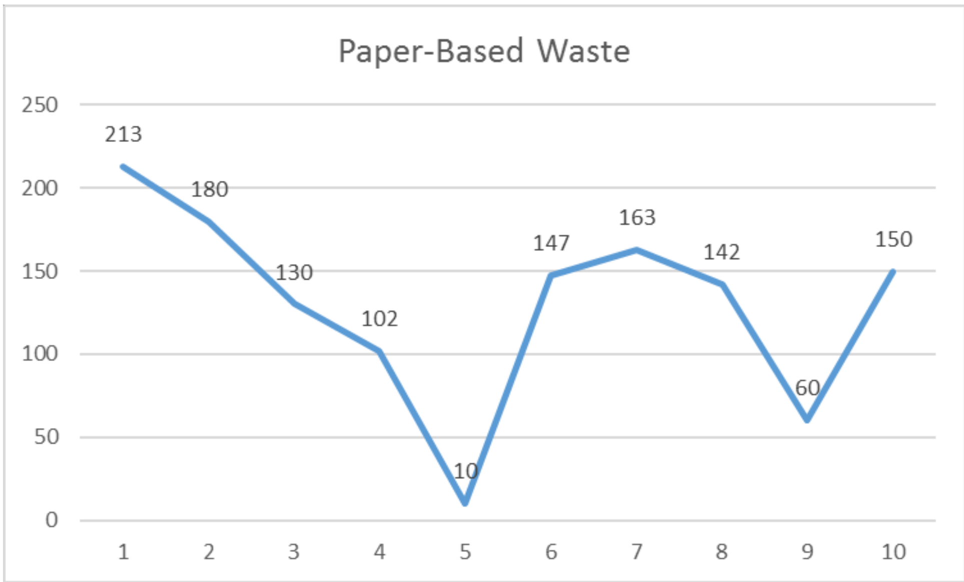

Figure 4-12: Detection Value for Paper-Based Waste

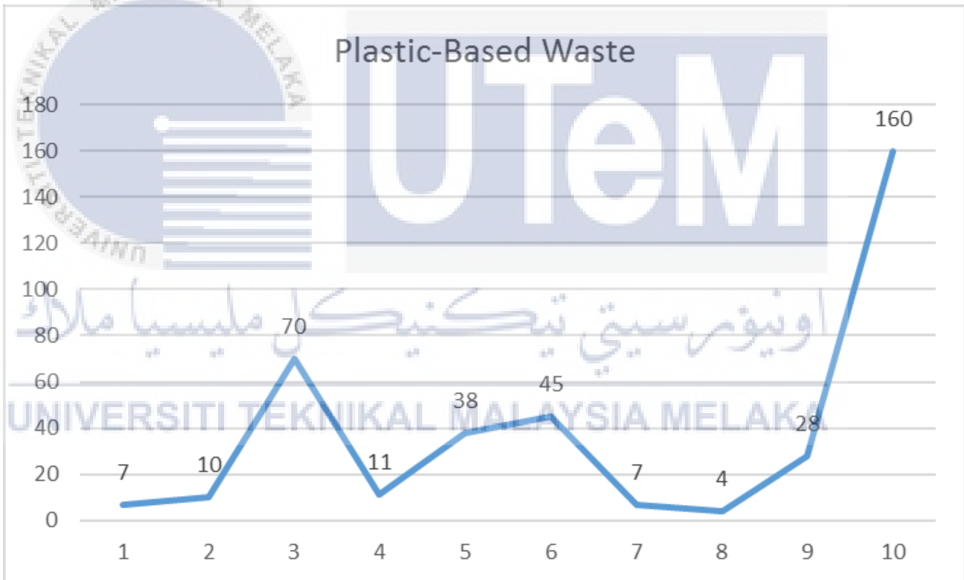

Figure 4-13: Detection Value for Plastic-Based Waste

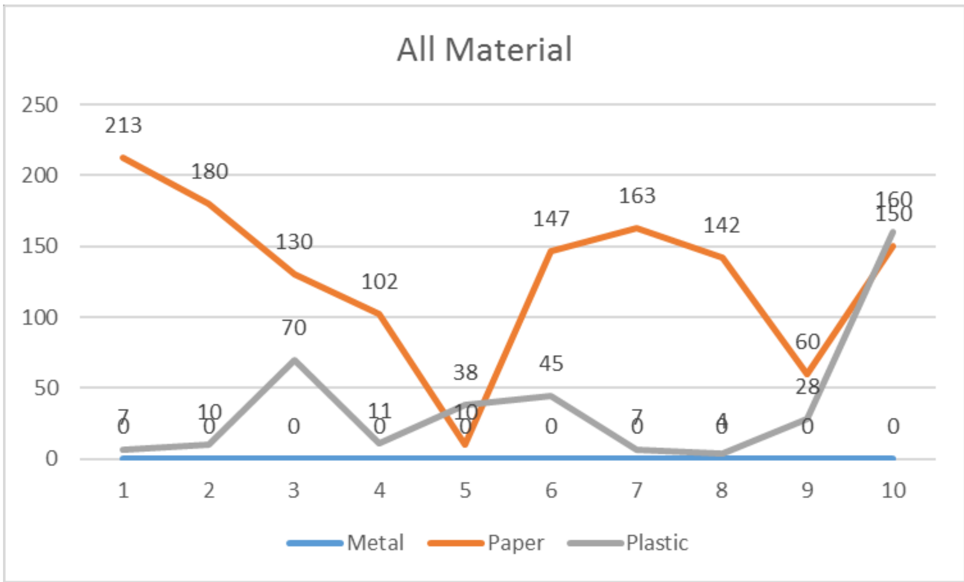

Figure 4-14: Combination Result for All Material

The graph above shows the detection value for metal-based waste, paper-based waste and plastic-based waste. Figure 4.11 show that all detection values for metal-based samples are near 0 and 100% success without any error.

From the paper-based waste graph in Figure 4.12, most of the sample used have detection value between 50 to 220. There is only one sample that gets 10 for detection the value. As a result, paper-based material is 90% successful with one error due to the amount of light intensity captured by the IR sensor.

Finally, the plastic-based waste graph shown in Figure 4-13 shows two inaccurate sample with detection value of 70 and 160. Referring to the basic concept of light intensity capture by the infrared sensor for plastic-based waste, it should be low and be between 1 to 50. As result, plastic-based material only gets 80% accuracy with two errors from 10 samples.

A combination graph for all types of waste is shown in Figure 4.14 to see a clear differentiation of detection value for metal-based waste, paper-based waste and plastic-based waste. From the graph, it can be summarized that there is 0% error rate for metal-based waste due to the sensor efficiency. Inductive proximity sensor is used to detect metal material only while infrared (IR) sensor is used to detect paper-based waste and plastic-based waste.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

The report is concluded with a summary of its contents in the conclusion section. There are also suggestions for future research and potential applications of the findings.

5.1 Summary

The project's goals and objectives have been met. The system as a whole is capable of functioning and the reverse vending machine prototype has been developed successfully.

The microcontroller board was successfully used to implement the display of messages and user prompts for the display system on the Smart Recycle Reward Bin to receive data from the sensor circuit. The microcontroller software was developed using the C++ programming language. The written program contains all message and user prompts that correspond to the circumstances of events. The application also enables the summation of points throughout the recycling process. The mobile apps for managing the reward system serve its function well by displaying details of recycled item, rewarded points, and notification whenever the recycle bin is already full.

However, the prototype does have certain drawbacks. The system itself still has certain flaws and is not fully ideal. Overall, the system can be successfully deployed. The system as a whole offers a straightforward and affordable alternative for the adoption of reverse vending machines in our society.

5.2 Recommendation

As a reverse vending machine prototype, the system is currently in its early stages and need further development to improve its dependability, accuracy and features. From an overview of the project, there are still many obstacles hindering the optimization of the system. The budget allocated in resource limits the purchase of high end components, lack of research regarding reverse vending machine in the country and absence of a standardized database, not to mention its wide database collection if the prototype was to implement digital image processing approach.

The Smart Recycle Reward Bin aims to motivate people to start recycling by offering them reward points. Therefore, the machine should be placed in public areas such as shopping mall, recreational park, school, university and bus station. Private sector can play a significant role by funding the infrastructure. Consider the fact that the supermarket sponsors the machine and promotes recycling among its patrons. In exchanges, the customers apply for loyalty cards so they can accrue the reward points. Reward points can be redeemed for supermarket goods or gift cards for shopping.

5.3 Future Works

There is a lot of room for the study and development of Reverse Vending Machines (RVM). However, due to their expensive installation and maintenance costs, Reverse Vending Machine are not very widespread in developing nations. It is not adopted in most nations because it is unaffordable. In these situation, this effort ought to provide evidence in support of an affordable Reverse Vending Machine. The remaining issue and this work's scope are:

1) Increase the detecting precision of the sensor system.
2) Can accept glass bottles.
3) Redemption of reward points.
4) Improve the delay in mobile apps.
5) Improve the prototype of recycle bin.

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APPENDICES

Appendix A: Reverse Vending Machine Source Code

```
#include <Wire.h>
#include "MAX30105.h"

#include "heartRate.h"
#include <SoftwareSerial.h>


SoftwareSerial ss(2, 3); // (RX,TX)

MAX30105 particleSensor;




#define trigPin1 8
#define echoPin1 9
#define Buzz 11

int Acount=0;
int Pcount=0;
int Mcount=0;

String inputString = "";
int MODE=0;
float WET=0;
int LCDStat=1;
int MyAlu=0;
```

```
int MyPla=0;
int MyPpr=0;
const byte RATE_SIZE = 4; //Increase this for more averaging. 4 is good.
byte rates[RATE_SIZE]; //Array of heart rates
byte rateSpot = 0;
long lastBeat = 0; //Time at which the last beat occurred
int Tcount=0;
float beatsPerMinute,AvgRead,Glucose;
int beatAvg,i;
float AvgMax,AvgMaxR,AvgMin,AvgMinR,Reading;
int MODEE=0;
int MDD=0;
int ALM1=0;
int ALM2=0;
int Mode=0;
float LDR=0;
int Timerx=0;
int Alm=0;
float Strength=0;
int pos=0;
int pos1=0;
int ALU=0;
int Paper=0;
int Plastic=0;
float LEVEL=0;
int Metal=0;
float Sens1,Metalx;


int TWIFI=0;
//----------------------------------------------
  long UpperThreshold = 518;
    long LowerThreshold = 490;
    long reading = 0;
    float BPM = 0.0;
    bool IgnoreReading = false;
    bool FirstPulseDetected = false;
    unsigned long FirstPulseTime = 0;
    unsigned long SecondPulseTime = 0;
    unsigned long PulseInterval = 0;
    int MyTimer=0;
//--------------------------------------------------

void setup()
{


  pinMode(trigPin1, OUTPUT);
  pinMode(echoPin1, INPUT);

  Serial.begin(9600);
ss.begin(9600);
  Serial.println("Initializing...");
```

```
 Serial.begin(9600);

pos=90;
pos1=90;

pinMode(Buzz,OUTPUT);



  delay(1000);

digitalWrite(Buzz,HIGH);
delay(50);
digitalWrite(Buzz,LOW);
delay(50);
digitalWrite(Buzz,HIGH);
delay(50);
digitalWrite(Buzz,LOW);
delay(50);


  // Initialize sensor
  if (!particleSensor.begin(Wire, I2C_SPEED_FAST)) //Use default I2C port, 400kHz speed
  {
    Serial.println("MAX30105 was not found. Please check wiring/power. ");
    while (1);


  Serial.println("Place your item on the sensor with steady pressure.");

  particleSensor.setup(); //Configure sensor with default settings
  particleSensor.setPulseAmplitudeRed(0x0A); //Turn Red LED to low to indicate sensor is running
  particleSensor.setPulseAmplitudeGreen(0); //Turn off Green LED
}

void loop()
{

   long duration1x, duration2x, distance2, duration3x, distance3, duration4x, distance4, duration5x, distance5;
 float inch,distance1;
  digitalWrite(trigPin1, LOW);  // Added this line
  delayMicroseconds(2); // Added this line
  digitalWrite(trigPin1, HIGH);
  delayMicroseconds(10); // Added this line
  digitalWrite(trigPin1, LOW);
  duration1x = pulseIn(echoPin1, HIGH);
  distance1 = ((duration1x/2) / 29.1); //* 0.26;
  inch=distance1*0.393701;

  if (distance1>=0 && distance1<=100){
    LEVEL=100-distance1;
  }
  if (distance1>100 && distance1<500){
    LEVEL=0;
  }
```

```
  TWIFI++;

  if (TWIFI>1000){
    Serial.println(LEVEL);
    ss.print("*");
    ss.print(LEVEL);
    ss.println("#");
    TWIFI=0;
  }
if (MODEE==1){
    Sens1 = analogRead(A0);          //read the value from the sensor
  Metalx= (5.0 * Sens1)/1024.0;  //convert the analog data to moisture level

if (Metalx<2){
  Metal++;
}

  long irValue = particleSensor.getIR();



  //Serial.print("IR=");
  Reading=irValue/1000;
  long beatIR=map(irValue,60000,80000,0,100);
  if (beatIR<0){
    beatIR=0;
  }

  irValue = particleSensor.getIR();

  Serial.print(Reading);
  Serial.print("\t");
    Serial.print(Metalx);
  Serial.print("\t");
  //Serial.print(", BPM=");
  //Serial.print(beatsPerMinute);
  //Serial.print(", Avg BPM=");
  //Serial.print(beatAvg);
  //Serial.print(" Temperature:");
  //Serial.print(temperature,1);
 Tcount++;



  if (irValue < 50000){
    Serial.print(" No Item?");
    if (LCDStat>0){


    }
  }
```

```
if (Reading>=3){
  LCDStat=1;

}

   //##################################################
   Serial.println();


  if (Reading<3){
    MyTimer++;
    if (MyTimer>=50){
      MyTimer=0;
      MyPla=0;
      MyAlu=0;
      MyPpr=0;
      ALU=0;
      Paper=0;
      Plastic=0;

    }

  }


      if (Reading>=40 && Metalx>3){
    MyPpr++;
    if (MyPpr>=20){
      MyTimer=0;
      MyPla=0;
      MyAlu=0;
      MyTimer=0;
      ALU=0;
      Paper=1;
      Plastic=0;
    }

  }

    if (Reading>=3 && Reading <=40  && Metalx>3){
    MyPla++;
    if (MyPla>=20){
      MyTimer=0;
      MyPpr=0;
      MyAlu=0;
      MyTimer=0;
      ALU=0;
      Paper=0;
      Plastic=1;
    }
```

```
  if (Metalx<2){
    MyAlu++;
     if (MyAlu>=20){
      MyTimer=0;
      MyPpr=0;
      MyAlu=0;
      MyTimer=0;
      ALU=1;
      Paper=0;
      Plastic=0;
    }
  }



//---------------------------------------------------


if (Paper>0){

  Serial.println("PAPER DETECTED!!!");

  digitalWrite(Buzz,HIGH);

delay(20);
//digitalWrite(Buzz,LOW);
delay(20);
//digitalWrite(Buzz,HIGH);
delay(20);
digitalWrite(Buzz,LOW);
delay(20);



ss.println("X");



Reading=0;
irValue=0;
delay(2000);
Paper=0;
MyPpr=0;


}


if (Plastic>0){
```

```
  Serial.println("PLASTIC DETECTED!!!");

  digitalWrite(Buzz,HIGH);
delay(20);
digitalWrite(Buzz,LOW);
delay(20);
digitalWrite(Buzz,HIGH);
delay(20);
digitalWrite(Buzz,LOW);
delay(20);

ss.println("Y");

Reading=0;
irValue=0;
delay(2000);
Plastic=0;
MyPla=0;

}

//***************************************************

if (ALU>0){

 Serial.println("METAL DETECTED!!!");
  digitalWrite(Buzz,HIGH);

delay(20);
digitalWrite(Buzz,LOW);
delay(20);
digitalWrite(Buzz,HIGH);
delay(20);
digitalWrite(Buzz,LOW);
delay(20);
digitalWrite(Buzz,HIGH);
delay(20);
digitalWrite(Buzz,LOW);
delay(20);
ALU=0;

ss.println("Z");
  delay(2000);
  Reading=0;
  MyPla=0;
      MyAlu=0;
      MyPpr=0;
      ALU=0;
      Paper=0;
      Plastic=0;
irValue=0;
delay(2000);
```

```
delay(50);

}

}


void ReadSensor(){

}



void InitSensor(){
  if (!particleSensor.begin(Wire, I2C_SPEED_FAST)) //Use default I2C port, 400kHz speed
  {
    Serial.println("MAX30105 was not found. Please check wiring/power. ");
    while (1);
  }
  Serial.println("Place your index finger on the sensor with steady pressure.");

  particleSensor.setup(); //Configure sensor with default settings
  particleSensor.setPulseAmplitudeRed(0x0A); //Turn Red LED to low to indicate sensor is running
  particleSensor.setPulseAmplitudeGreen(0); //Turn off Green LED


void serialEvent() {
  while (Serial.available()) {
    // get the new byte:
    char inChar = (char)Serial.read();
    // add it to the inputString:
    inputString += inChar;
    // if the incoming character is a newline, set a flag so the main loop can
    // do something about it:
    if (inChar == '!') {
     MODEE=1;
      digitalWrite(Buzz,HIGH);
delay(1000);
digitalWrite(Buzz,LOW);
delay(20);
    }
     if (inChar == '@') {
     MODEE=0;
      digitalWrite(Buzz,HIGH);
delay(1000);
digitalWrite(Buzz,LOW);
delay(20);
digitalWrite(Buzz,HIGH);
delay(1000);
digitalWrite(Buzz,LOW);
delay(20);
digitalWrite(Buzz,HIGH);
```