José Rizal University

E-COLLECT: DESIGN AND DEVELOPMENT OF ELECTRONIC WASTE REVERSE VENDING MACHINE

A Thesis Submitted to the Faculty of the College of Computer Studies and Engineering

In Partial Fulfilment of the Requirements for the Degree

Bachelor of Science in Computer Engineering

By

Alleckzer A. Querido

Ameenah F. Guro

Elizher P. Ursabia

Michael Dennis D. Paragas

S.Y 2023 - 2024

Chapter 1

Introduction

1.1. Background of the Study

The increasing volume of electronic waste produces a significant environmental challenge worldwide. Here in the Philippines, the improper disposal of electronic waste is very common, and there is an urgent need to address this issue effectively.

The improper disposal of electronic waste in the Philippines is an all-around issue. Firstly, the lack of awareness among the people regarding the impact of improper disposal of electronic waste worsens the problem. Second, many people do not know about the harmful effects of throwing away e-waste the wrong way. The people do not realize that electronic devices have dangerous substances in them. Second, it is hard for people to find recycling centers nearby. This makes it inconvenient for them to properly dispose of their e-waste. As a result, people end up throwing it in regular trash bins or burning it, which makes the environment even more polluted. These things contribute to the main issue of improper e-waste disposal in the Philippines. The people need new solutions and motivation to manage e-waste responsibly. Technology is growing fast, and more people are using electronic devices. Some measures have been implemented but the enforcement and execution remain inconsistent.

Based on a report by One Network (2019), engineers from the University of Philippines conducted a study revealing the alarming disposal rate of mobile phones among Filipinos. The study highlighted the necessity for a nationwide ewaste management policy. In 2016, the Philippines accumulated a staggering 22 million units of discard mobile phones. Furthermore, the study found that approximately 95% of respondents had no awareness regarding the appropriate disposal methods for e-waste.

Additionally, the report indicated that the country generated 290 million kilograms of e-waste in 2016, equivalent to an estimated 280 kilograms per person. As per the Environmental Management Bureau's report (2020), the Philippines produced a significant amount of electrical and electronic waste in 2019, amounting to 32,664.41 metric tons. The report emphasized the importance of proper disposal for electronic waste, as failure to do so could result in environmental and health concerns. Within the e-waste management market, several products exist, but there are gaps in their functionality.

Within the e-waste management market, several products exist in other countries, but there are gaps in their functionality. For example, Eco ATM in United States, it is a machine that specifically targets mobile phones. On the other hand, RecycleBank that is based on New York City, offers rewards based on the collection of recyclables, but it primarily focuses on general waste like plastics, paper, and glass, neglecting electronic waste.

Similarly, GreenBean Recycle that is based on Boston, USA, is a recycling kiosk system that incentivizes the recycling of beverage containers, but fails to address the problem of e-waste. With these gaps on existing products, the researchers aim to provide incentives for the proper disposal of e-waste, encouraging participation. To address the challenge of e-waste management, the researchers' proposed solution is to design and develop an electronic waste reverse vending machine. The machine will have image processing technology to quickly and accurately detect and classify types of e- waste items based on their visual features. By implementing a reward system within our machine, this will encourage individuals to deposit their e-waste in the machine in exchange for reward points. The study belongs to Panatag section of the AmbisyonNatin2040 because E-waste can be harmful to our health resulting in various disease or worst it can even lead to death. It also falls under the Goal 12 Responsible Consumption and Production of the SDG Goals, based on the Goal 12 "The efficient management of our shared natural resources, and the way we dispose of toxic waste and pollutants, are important targets to achieve this goal."

1.2. Objectives of the Study

1.2.1 General Objective

The main objective of this study is to design and develop an innovative machine for the collection of electronic waste, utilizing Image Processing Algorithm and incorporating a reward system.

1.2.2 Specific Objectives

Specifically, this study aims the following specific objectives:

1. To design and develop an electronic waste reverse vending machine that is capable of receiving electronic devices.
2. To use image processing algorithms to accurately recognize and classify different types of electronic waste based on their visual features.
3. To implement and develop a reward system within the electronic waste machine that can be redeemable using the web application for user and a feature for admins to handle the reward system.
4. To implement an IoT technology for monitoring the capacity level inside the machine, specifically for tracking the bin's status.

1.2. Significance of the Study

Students

Students will benefit from this study because this will provide a chance for the students to learn and engage to waste management practices. They can gain knowledge about the bad effects of wrong disposal of e-waste.

Government

The results of this study can be important to the government agencies for e-waste management. This study can give solutions and strategies to resolve the challenges of e-waste. The government can help make the e-waste management practices better and for a more sustainable environment.

General Public

The general public will make the most out of this study because they can access to a more suitable method of throwing or disposing their e- waste. With the help of monetary rewards, it motivates the public dispose their e-waste properly.

Future Researchers

The future researchers will benefit from this study because they can expand this study about e-waste management. The findings from this study can be beneficial for the future researchers. It can also inspire future researchers to explore more things about e-waste management.

1.4. Scope and Limitations

The study will include the following features:

- Integration of image processing algorithm to accurately classify e- waste items. List of items allowed: Mouse, Phone, Remote, Tablet, Watch
- Touchscreen display is used for the visual presentation of end user input and machine output.
- A servo motor will be used for the function of the opening lid of the machine.
- The machine overall size is 30 inches' length, 60 inches' height and 18 inches' width.

- The trash bin lid will have a height of 20 cm and a length of 40 cm.
- The machine will be deployed at Jose Rizal University.
- Each time the user finishes the act of disposing to the machine, there is a total accumulated reward points that will automatically transfer to their account in the web application. Each type of electronic waste has corresponding points that can be exchanged for cash rewards.

Table 1. Reward Pricelist of E-waste

E-Waste	Reward Price	Valuable Parts
Watch	30 PhP	Clockarm, Transmission
Mouse	50 PhP	Sensor, Laser
Phone	20 PhP	MOBO, Power Button, Battery
Remote	30 PhP	Buttons
Tablet	10 PhP	MOBO, Power Button, Battery

The table presented above provides a comprehensive list of various type of e-waste that our machine is capable of identifying. It illustrates different reward prices based on the valuable parts of each e-waste. The researchers decided to give it at least a low-price reward. In this way, the machine could still provide rewards to common e-waste items and it will still encourage users to recycle their waste. The reference of the prices came from Emedtrix, a buy and sell electronics shop in Mandaluyong City.

- The user of web application has two main parts. First, is for users to monitor and redeem their reward points. Second, it also be used by admins for granting reward requests and bin monitoring.
- With IoT technology implementation, real-time data of the machine will be sent to the database. In the web application, there will be a dashboard where admins can view the bin capacity with the use of monitoring device inside the machine. After monitoring, admins can view notification reports of sensor data through the notification tab for the admins to take action if there is a problem with the machine.

However, the project is limited to the following:

- The machine is not capable of testing for functionality of the e- waste items.
- The image processing algorithm have limitations in identifying certain types of e-waste items. It only relies on the dataset that the researchers will provide.
- The minimum amount of reward points that can be redeemable is 50 points that is equivalent to 50 pesos. G-cash will be the e-wallet platform where admins will transfer the points withdraw by the users.

1.5. Conceptual Framework

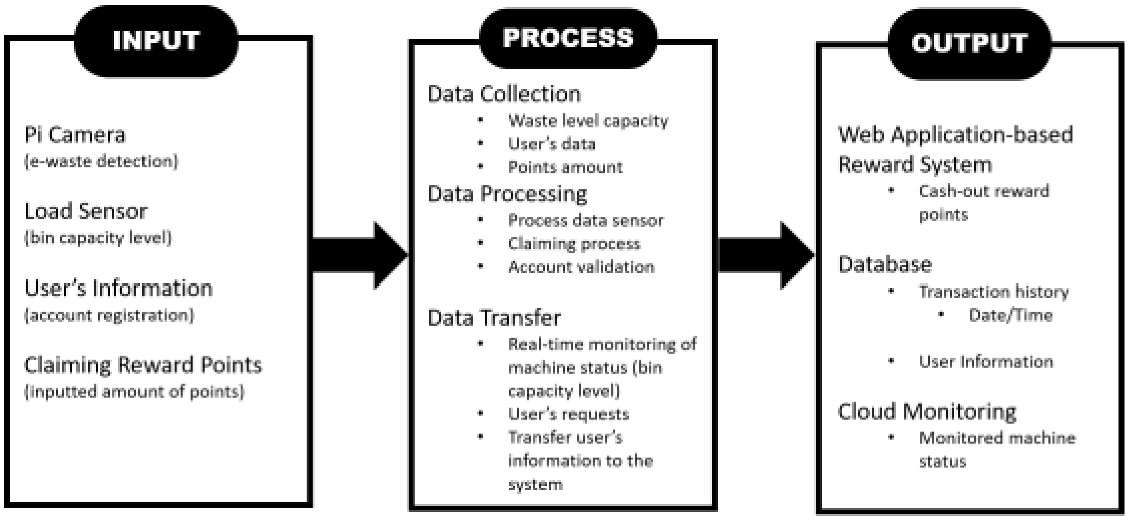


Figure 1. Presents an Input-Process-Output chart to determine the input, the process needed to be done and the output acquired.

The figure 1 above, illustrates and defines the three stages of the process of a system which are input, process, and output. In the input section it includes Pi Camera for e-waste detection. Load Sensor to monitor the weight of the total collected e-waste inside the machine's bin. User's information for account registration on the web-application. And the accumulating reward points. The operational process includes involve continuous data collection, ensuring updates on waste levels, user data, and reward points. The data processing phase manage user accounts, reward points, and authorize reward claims. The data transfer aspect facilitates communication between the waste management system and users, providing notifications on bin capacity and enabling users to cash-out requests. The output of the system includes a user-friendly web application for claiming rewards, cash-out system and database for storing transaction and user information. The cloud based monitoring component ensures accessibility for real-time insights into machine status.

1.6. Operational Definition of Terms

In this study, the Operational Definition of Terms are the variables and data that we need to gather in order to manipulate or measure the actual process used by the researchers. It is the data that needs to be gathered in order to see the result of the study.

- **E-waste type** – refers to what type of E-waste the users donated.
- **User's Information** – refers to the information of the user that will use the machine to donate E-waste.
  a. Name
  b. Contact
  c. Email Address
- **Number of E-waste** – refers to the number of E-waste that the user will put in the machine.
- **Weight** – refers to the total weight of the collected E-waste that the machine can handle.
- **Equivalent points** – refers to the equivalent point that the user will get on every E-waste that he/she will donate in the machine.
- **Size** – refers to the size of the E-waste that will put to the machine

Chapter 2

Review of Related Literature and Studies

This chapter cited different relevant studies and literature, including previous articles that are significant to the goals, methods, and outcomes of the current study. Each literature and studies are carefully analyzed and sorted by the researchers. It also discusses the perspectives and ideas put forth by another electronic waste system and an alternative automated system, made possible through a different image processing method. These studies helped the researches to come up with the development of electronic waste machine with reward system. Additionally, it highlights the significant elements of these systems and their relevance to the area of interest.

2.1. Foreign & Local Literatures

2.1.1. E-Waste Management Policies and Programs

(L.T.T. Doan, et al., 2019) tackles various strategies that can be used to manage electronic waste. Based on the study, electronic waste is a rapid growing waste problem. In 2021, it produced an estimated 50 million tons of waste. It is also alarming because it threats the human health and the environment. Electronic waste has a variety of harmful substances such as metals, plastics, and substances that causes fire.

In currently growing countries especially in Asia, electronic waste is disposed in an informal manner. People just burn or dump it anywhere which could cause pollution in the environment and in air. The researchers provided a number of strategies for e-waste management. Based on them, to manage e-waste effectively is to prevent it being generated. Extending the lifespan of an electronic device, repairing, donating and recycling it would lessen the electronic waste in different places. Disposing e-waste in landfills could prevent by properly recycling the items. E-waste can also be recycled to recover materials that is still essential and valuable. Another thing is that e-waste should be collected in a safe environment. Having infrastructures for e-waste collection would help in resolving this problem. Electronic waste is a global problem so it requires an international cooperation. Countries should work together to implement policies for e-waste management.

In the study of (C. Baoas, et al., 2016) they assessed the e-waste management implementation practices in Metro Manila. They aim to assess the current status of electronic waste management in the Philippines. Based on the study, the Philippines gathered an estimated 4,700 tons of waste and few of this is recycled or properly disposed. The researchers identified the challenges of e-waste management in the Philippines including lack of awareness among people, lacks of infrastructures, and lack of enforcement of laws. But challenges also require improvement. The people should be aware about electronic waste, the local government should build more e-waste collection facilities, and strengthen the enforcement of laws in managing the wastes. It is good that the government has passed the Ecological Solid Waste Management Act of 2000 or Republic Act 9003 however, a lot of efforts should be done to ensure the proper management of e-waste.

This study evaluates the e-waste management implementation of Higher Education Institutions (HEI) in South Central Mindanao, Philippines. There are certain policies and provisions to educate and promote the proper disposal of e-waste but unfortunately, these practices are not well understood. The study found that 39% of HEIs have an annual budget of less than 1,950 USD. ICT equipment are purchased by 23% of HEIs. Also, 53.8% of these devices ends up in landfills and 23.1% of these devices are in junk shops. One of the challenges of e-waste management in HEIs is the lack of priority, procedure, and there is no definite legislation of laws. The study found out that the Higher Education Institution in the South-Central Mindanao are not well equipped to manage electronic waste. There is a need of proper information to the staff and students about e-waste management, there is also a need to invest in facilities, and they need to work with the local government to develop plans essential for e- waste management. (M. Dayaday & F. Galeto Jr., 2022)

In another article (R. Celestial, et al., 2018), there is no comprehensive e-waste management in place. The DENR has not yet issued any regulations about the management of e-waste. There are still two pending bills in the congress that aims to help in resolving the problem of e-waste. Senate Bill No. 568 that will create an e- waste management program authored by Senator Antonio Trillanes and House Bill No. 5901 that will establish a recycling program for e-waste authored by Emmi de Jesus. Based on the study mathematical models can be used to gather data about the amount of e-waste generated. This could be used to design and plan an effective e-waste management system. The Philippines is one of the manufacturers of e-waste, producing 3.9 kilograms of e-waste per capita in 2019. Based on this study, the Philippines e- waste system is informal and there is no centralized collection.

This study recommends that the Philippines should adopt comprehensive measure such as, providing incentives to businesses and individuals and regulating the import and export of e-waste. The researchers also noted that the Philippines signed to the Basel Convention, an international treaty that bans the export of hazardous waste to countries. However, this study shows that the Philippines is not entirely enforcing the Basel Convention proving that it needs more to stop the illegal importation of e-waste into the country. (N. Campit, 2020).

2.1.2. Electronic Waste System

(Han et al., 2022) developed an innovative solution called smart e-waste collection, aiming to tackle the difficulties related to gathering and dismantling electronic waste.

The advancement of Internet connectivity, along with other emerging technologies like cloud computing, big data analysis, and artificial intelligence has created fresh prospects for China's e-waste recovery and treatment approaches. Notably in China, online recycling platforms have become highly favored by individuals seeking responsible disposal options for their electronic devices.

The widespread acceptance of IoT-enabled smart recycling bins in communities and public areas has considerable potential. This advanced technology facilitates immediate monitoring, optimized processing methods, and complete traceability throughout the recycling journey. These innovative systems come equipped with numerous functions such as data statistics, managing collection orders efficiently, warehouse storage, and ensuring quality control during dismantling processes. These inclusive solutions can encourage residents to engage more actively in recycling initiatives by highlighting the economic rewards resulting from smarter practices.

Another example of an electronic waste system was done by (Kang, et al., 2020). The authors proposed a system where it uses IoT sensors to track volumes of e-waste in household boxes. The sensors will send data to a central server and the server would alert the e-waste collectors when the boxes in household reach a certain level. The researchers still believe that with the help of IoT, it will revolutionize the e-waste management in Malaysia.

2.1.3. Image Processing

Image processing is the process of enhancing and extracting useful information from images. A photograph or video section are the inputs to this technique, which analyzes images as two-dimensional signals. An image is the input, and the output could be either an improved version or characteristics or features related to the original image.

In the recent study by (Mitra, 2021), it highlights that image processing plays an important role within the broader framework of signal processing. With the use of an image processing algorithm, it recognizes wastes based on their shape, color, dimension, and size and the notion of a convolutional neural network. Using this method will enable the algorithm to recognize the relevant features in new images by automatically learning them from sample images of waste. Convolutional neural networks will be used to classify waste into different classes.

The study of (Nawokowski et al., 2020) also emphasize the significance of image processing and recognition techniques in waste management and processing applications. Particularly, the sorting of items based on specific shapes and transparencies heavily relies on image processing methodologies. These techniques enable efficient and accurate identification of waste materials, enhancing the overall waste management process.

Convolutional Neural Networks (CNNs) have become effective image processing algorithms in the field of artificial intelligence (Madhav et al., 2020). CNNs have become useful because of their ability to successfully address a variety of computer vision issues. This success can be attributed to improvements in architecture and processing capability, which have allowed CNNs to utilize the power of artificial intelligence.

2.1.4. Waste Sensor

A sensor is a device that, in response to an input, generates an output signal that contains data on a certain phenomenon. The application of sensor across different industries is extensive and it also imbedded into people's daily lives and has broad applicability across numerous industries. (Shreya et al., 2022)

Researchers have investigated the feasibility of equipping trash cans with sensors to enable automatic image-based waste segregation, and their endeavors have effectively automated the separation of common waste. Microcontroller-based smart bins based on convolutional neural networks (CNN) have been developed with the aim of improving the trash segregation process in both commercial and residential environments. High-resolution cameras and sensors are employed in hybrid deep learning approaches to differentiate recycling waste from other types of waste during the collection of garbage from public facilities. (Chu et al., 2018). Furthermore, transfer learning has been employed to automate the trash segregation process using various pre-trained networks.

(Vishnu, et al., 2022) There are several challenges of solid waste management. Increasing waste, not enough landfill space, and impact of improper waste disposal. There are different types of sensors such as, RFID, ultrasonic, and image sensors. Sensor-based waste can apply to waste collection and waste sorting. Based on the paper, using sensor-based systems can help in reducing the environmental impact of waste disposal. More intelligent sensors and use of data analytics can be a potential trend in the future of sensor-based waste systems.

2.1.5. Microcontrollers

A microcontroller is a device that will automatically execute a specified program or instruction to control a system. Microcontrollers are used as controlling components in a wide variety of devices and pieces of equipment.

The microcontroller components are primarily responsible for the functionality of the complete instrument. If the instrument malfunctions, this indicates that this is the most likely cause. Understanding the major block inside the microcontroller is crucial for maintenance and repairs of such a device.

During this pandemic, a researcher made an automated product dispenser based on a microcontroller. According to (K.R. Sarath, et al., 2022), the objective of their paper is to design and develop a product dispenser that can help to reduce unnecessary product waste and avoid physical contact during the pandemic. In the researchers proposed system, they have chosen Arduino UNO as the microcontroller because it is open source, supports a wide range of microcontroller chips, and has serial communication ports. Arduino uses Embedded C, which is a subset of C and based on the researchers it is easy to learn and use. This makes it also ideal for automation tasks. The machine has an additional section for checking the user's body temperature before they can use the dispensing section. The user is required to show their hands to the temperature sensor, which will automatically sense their body temperature and determine whether they can proceed to further processing. The temperature sensor measures the user's body temperature, and the ultrasonic sensor measures the distance to the product and sends the information to the Arduino.

The Arduino then powers the DC motor circuit, which rotates the spiral ring counterclockwise. The limit switch engages when the product is dispensed, stopping the motor's rotation. Arduino boards are employed in a variety of applications and studies. (J. Dioses JR., 2020) stated that for conducting various segregation methods, the Arduino kits are among the most popular on the market today because of how simple and easy are they to use and how well they work with the microcontrollers. In determining if the materials are metal or plastic, it uses two sensors with the use of ultrasonic proximity sensor, it sends out ultrasonic waves to detect the presence or absence of a target. An inductive proximity sensor connected to an ultrasonic proximity sensor is used to distinguish between metals and polymers. To differentiate between metals and polymers, an inductive proximity sensor that is coupled to an ultrasonic proximity sensor is employed. In detecting the induction current flow, inductive proximity sensor is used, which increases as the object gets closer to the sensor. Metals have higher frequencies than plastic, so the induction current flow increases more for metals than for plastic. The data from both sensors is sent to a microcontroller, which processes the data and determines the type of material that was dropped. A system was developed using Arduino Uno and an inductive proximity sensor to automatically segregate plastic bottles and tin cans. The sensor detects the presence of metal and plastic, and the system separates the two materials accordingly. The study showed that the system achieved a testing accuracy of 90% for plastic bottles and 98% for tin cans. The overall accuracy of the system was 94%. The aims of this project were to develop a system that could automatically segregate plastic bottles and tin cans with high accuracy.

Another article that discusses microcontrollers is an article made by (AlKofahi, et al., 2019). The goal of the researchers in making this article is to discuss the energy consumption of microcontrollers and IoT systems. According to the researchers, energy efficiency is critical in microcontrollers and IoT systems as these devices are battery powered. The factors that can affect the energy consumption is the clock speed and the operating voltage. The researchers concluded that using low-power peripherals, optimizing the codes and using sleep modes will lessen the energy consumption of microcontrollers and IoT systems.

2.1.6. Reward System

The study of (Rao, et al., 2020) presents a solution that utilizes IoT and introduces a concept of rewards to encourage proper plastic garbage disposal. The goal of incentives is to encourage individuals to use sustainable waste disposal practices. When the garbage is disposed of before the session expires, the weight of the plastic disposed of is updated in real-time to the user, and the user is awarded depending on the amount of plastic weight dumped.

An Android application is developed allowing the user to interact with the reward points and, in particular, to scan the QR code on the trash can. The proposed incentive model encourages people to be mindful of ethical plastic consumption and disposal. As a result, municipalities can handle discarded garbage more efficiently. The awards might be tailored to the deployment circumstances.

QR code is widely used nowadays, and it is evident in various application in different industries. With QR code, it can store information and it is popular because it is integrated in smartphones wherein most people do have. QR codes allow consumers to scan a code with their smartphones. In this way, they can scan information about certain product or services. A group of researchers conducted a survey in Malaysia to gather their insights about QR codes and mobile payment. The researchers found that consumers are positive about this technology although there are some concerns about privacy. In addition, QR code is more popular in younger consumers, it is likely because they are more familiar with technology. (Yan, et al., 2021)

2.1.7. Touchscreen Display

According to (M. Krithikaa, 2016), a touch screen is an electronic visual display that can detect the presence and location of a touch within the display area. A basic touch screen has three main components, a touch sensor, a controller, and a software driver. Four main technologies are used to make touch screen, it consists of resistive, capacitive, surface acoustic wave, and infrared LED or optical. Touch screens provides a natural and intuitive way to interact with electronic devices. Users can just simply touch or swipe the screen to perform actions, making it easy to use.

This study is supported by (H. Nam, et al., 2021), based on their own study paper, an analog resistive scheme is the oldest touchscreen technology. The most popular resistive touchscreen panels are fabricated by 4-wire and 5-wire architectures. Capacitive touch screen can sense changes in capacitance with just a light touch on the screen. This allows for smooth and fast scrolling, durability, and good display quality. The acoustic wave scheme is composed of a wave guide, receivers and sources of sound wave. The most used technology is a surface acoustic wave (SAW) touch screen. It holds two pairs of ultrasonic transmitters and receivers. Optical touch screens were created based on infrared that is invisible to the human eye. Without any additional layers, the conventional

IR-based touchscreen places the transmitter at two sides and the receivers at their opposing sides.

According to (E. Jokisuu, et al., 2016), the growing popularity of self-service technology (SST) is due in part to its convenience and accessibility. The only method of interacting with self-service technology is via a touch screen. They present a research study on how to make touchscreen interaction on SSTs accessible to people with visual impairment, especially when entering private information such as a PIN. The researchers had four concepts for PIN entry. Concept A is visual tallies, to enter a number, swipe up or down on the screen the number of times corresponding to the number you want. Concept B is multi-finger multi-tap, you can enter a number by touching and holding the screen for the number of fingers you want entered, or by tapping repeatedly with one or multiple fingers the number of times you want entered. For example, you would tap twice with two fingers to enter the number 4. Concept C is tactile markers, a plastic strip with raised bumps is attached to the bottom of the screen to help guide a user's finger to the correct target area. Concept D is multi-finger tap & hold, to enter a number, touch and hold the screen for the number of fingers you want entered.

A test was conducted with 49 participants, 27 of them are women and 22 are men who had varying levels of visual impairment. Of these participants, 9 were partially sighted, 22 were blind with some useful residual vision, and 18 were blind without any useful residual vision. Based on the results, Concept B which is Multi-finger multi-tap and Concept C which is Tactile markers were rated the easiest to use and the most confidence-inspiring by participants among the four concepts tested. Self-service terminals have unique accessibility requirements due to their public nature and large screens. Users must be able to interact with them without training or assistive technologies, and touchscreen gestures from personal mobile devices may not be transferable.

2.2. Foreign & Local Studies

The researches in India proposes an IoT-based collection vendor machine (CVM) for e-waste management. According to (K. Singh, et al., 2021), the CVM used ultrasonic sensors to measure the capacity of the machine and send an alert message to the concerned authority when it reaches a certain collection point. To get a QR code, the user must sign up for the system. The user must also then attach the code to their e-waste item before placing it in the collection vendor machine. The collector would then take the electronic trash out of the CVM and store it in the warehouse for recycling and billing. According to the study, e-waste management using the suggested CVM would be more secure and effective than using conventional techniques. Real-time tracking of e-waste would be possible with the CVM, assisting in ensuring correct recycling. The proposed CVM would be less expensive to build using Arduino than to import e-waste management equipment.

Another research from (M.A. Ramsi & A.A. Helali, 2022) on e-waste collection and the goal of the study is to encourage individuals to recycle their old or outdated electronics. The gadgets would be sorted into the right category after the system used a smart camera to determine the size of the device being disposed of. Individuals who recycle their electronic waste will also receive reward points from the machine, which can be used at other various local stores. The plan would be put into action utilizing a mix of hardware and software. An e-waste collection machine, a smart camera, and ultrasonic sensors would make up the hardware. An Excel spreadsheet plus an Android app would make up the program. Smartphones, tablets, and other electronic gadgets would each have their own section on the e-waste collecting device.

A smart camera is used to determine the size of the electronic waste being disposed inside the machine and then sort it according to its category. The machine's ultrasonic sensors would be used to gauge its level of capacity and alert users when it needs to be emptied. The users would use the Android app to scan a barcode created specifically for each user. Information about the user, including their name, email address, and reward point balance, would be contained in the barcode. The program will also track how much recycled e-waste each user had generated. The information on how much e-waste has been recycled and how many reward points have been earned would be kept in an Excel spreadsheet.

(K. Singh, et al., 2021) proposes a mobile robot that can identify and segregate electronic waste from household waste. The robot would go throughout the city capturing images of waste while attached to the city's current garbage trucks. A convolutional neural network (CNN) would then be used to analyzed the images in order to detect electronic waste. The recognized e-waste would be gathered and put on the storage platform of the robot. The robot would return to the trash truck at the end of the collecting route, and the collected e-waste would be kept in a secluded location.

A recycling center would subsequently receive the electronic waste. According to the study, the proposed robot could identify e-waste with a 96% accuracy rate. The dataset used in this study consists of 8,000 images of electronic waste items, ranging from completely functional to critically damaged. The images were collected from popular image search engines and resized to 224 × 224 pixels to ensure they were compatible with the training and testing of the E-waste identification model. The dataset used in this study consists of 8,000 images of electronic waste items, ranging from completely functional to critically damaged. The images were collected from popular image search engines and resized to 224 × 224 pixels to ensure they were compatible with the training and testing of the E-waste identification model.

The dataset was split into 8 different categories: computer keyboards, motherboards, mobile phones, refrigerators, laptops, mouse, radios, and televisions. Each category contains 1,000 images. The model was trained and tested on two different CNN architectures: ResNet50 and VGG16. The ResNet50 model achieved an accuracy of 96%, while the VGG16 model achieved an accuracy of 94%. The main controller of the rCubeBot robot was written in Python. The robot moves and captures images using the camera, and the controller code is executed using Pycharm. If the images are classified as E-waste with an accuracy of 90% or higher, the secondary controller is initiated. This controller positions the arm for easier lifting, and the arm then lifts the object and places it on the surface for collection. The Webots simulation software was used to control the camera, differential wheels, and robotic arm. The simulation features of Webots allow for multiple concurrent tasks to be performed, which is essential for the operation of the rCubeBot robot.

Electrical and electronic equipment (EEE) consumption has risen quickly in recent years, and this has resulted in a similar rise in the production of e-waste, according to (L. Andeobu, et al., 2021). The number of e-waste is increasing quickly in the Asia Pacific area. This is brought on by a variety of components, including the region's large population, expanding economy, and rising wealth. Asia Pacific is currently one of the biggest producers of e-waste as a result. The study discovered that the Asia Pacific area needs better e-waste management. The quantity of electronic waste produced in the Asia Pacific area exceeds the capacity of the region's recycling facilities, according to an examination of the handling of this waste. Another factor in the issue is the absence of a coordinated framework for handling toxic and hazardous wastes.

Additionally, developing countries have become dumping sites for e-waste from industrialized nations due to the rising demand for used electronic equipment in these nations. Asia Pacific nations must take action to enhance their e-waste management procedures. This includes investing in formal recycling facilities, developing an integrated framework for managing toxic and hazardous wastes, and reducing the demand for second-hand electronic equipment

2.3. Relevance of the Current Study

The stated literature and studies stated above provide an in-depth design to carry out the structure development of the project. Able to develop a new idea it is important to have such information to guide you in building your project.

The establishment of image processing in electronic waste detection could improve the accuracy of electronic waste detection, by incorporating image processing the machine could identify different kind of electronic device in terms of the kind of material used to the specific device since not electronic device is metal other is made out of other industrial materials. Detection of electronic waste is not possible without the integration of ultrasonic sensor attached to the e-waste machine. The sensor will identify whether the thrown waste is an electronic device and reject the waste if it is not an electronic device.

Gathered related literature and studies make the researchers knowledgeable to proceed to the next part of this research paper and make this proposed project possible. The objective of the team is to build an automated electronic waste system that will detect different variety of electronic waste by the implementation of Artificial intelligence. Therefore, the machine components such as Raspberry Pi microcontroller, Pi Camera, and load sensor will also be the part of hardware components of the physical concept design of the machine. Attaining the efficiency of the machine will require a newer version of hardware components.

The use of hardware mechanisms like servo motors is also important in the waste separation of thrown electronic waste to the machine. The Servo motor will physically separate electronic waste devices from non-electronic devices and reject the waste that is not identified as electronic waste. One of the objectives of the team is to incorporate a reward for potential users. Making this idea feasible is implementing a reward system that will generate a stub using a stub dispenser to be able to use accumulated points by the user in exchange for a reward.

Chapter 3

Methodology

This chapter carries out the overview of the methodologies and procedures that were pertinent to the research. This section contains the design methodology, feature specifications, design constraints, system architecture and experimentation procedures that collectively guide the creation of electronic waste machine with reward system.

3.1 Research Design

The study utilizes constructive research design. By using a constructive research design method, the study will first conduct a thorough literature review, studies and technology assessment to identify the state-of-the-art image processing techniques and existing reward systems for recycling initiatives. Next, the research will involve designing and building the e-waste machine prototype, integrating advanced image processing algorithms to efficiently recognize the visual features and sort various types of electronic waste. Additionally, the reward system will be designed to incentivize and give the users or participants a reward to recycle their electronic waste by generating their reward points to an electronic money to their e-wallet account. The constructed machine will be thoroughly tested using real-world e-waste samples, and user feedback will be gathered to assess its usability and effectiveness. The research will collaborate with partner community. The research outcomes will contribute to sustainable waste management efforts and encourage responsible waste disposal practices while also providing insights for further improvements and scalability of the system.

3.2. Design Methodology

3.2.1. Block Diagram

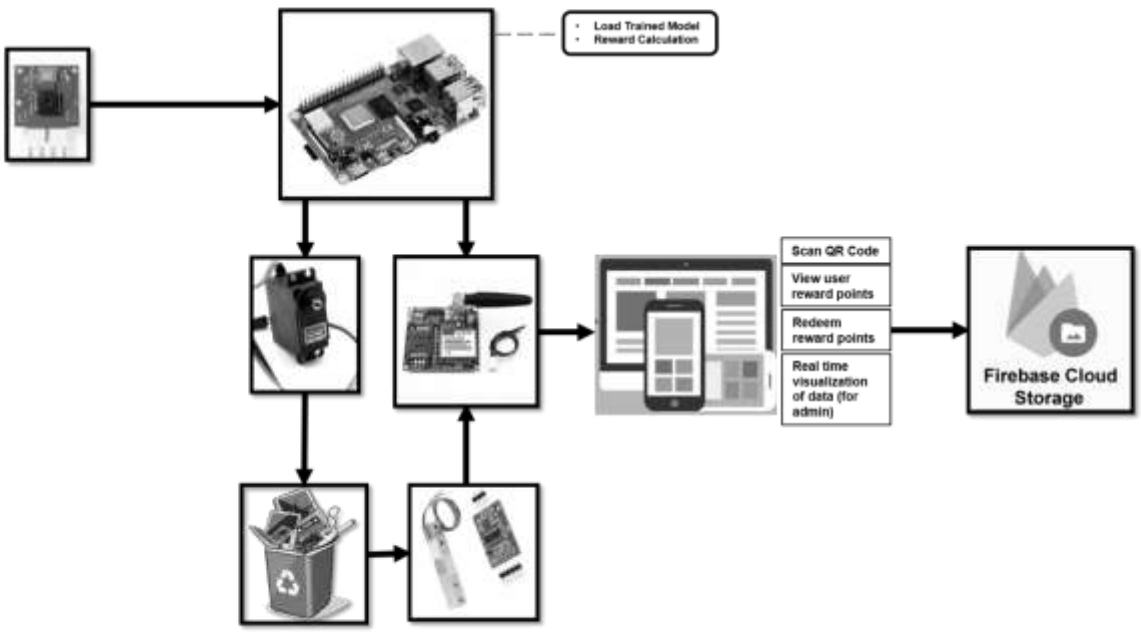


Figure 2. Block Diagram of the Machine

As shown in Figure 2, the block diagram shows the interconnection of the proposed research system. The system process will begin by capturing electronic waste objects placed inside the machine verification platform using Pi Camera, a hardware mechanism that will perform the disposing action supported by a servo motor. The Raspberry Pi 4 will process the captured images to distinguish whether the thrown object is accepted or rejected by the machine. Once it's been processed, the e-waste will be stored in the bin container. Aside from e-waste detection, the Raspberry Pi 4 is also programmed to execute an operation to compute reward points and display them on the touchscreen display attached to the machine. The load sensor will track real-time bin capacity level of the machine. The WIFI Module will transmit sensor data to the cloud storage and can be monitored using the web application. Another use of the web application is to handle the user reward points and the withdrawal requests of the users.

3.2.2. Feature Specifications

3.2.2.1. Marketing Requirements

Marketing Requirements is the overall functionality of the prototype and how the user can use the machine. The prototype is an e-waste reverse vending machine that would help the user properly disposed their e-waste at home to prevent hazardous effects on oneself and to the environment. The users can see how the machine works in every component in the machine more like a user's guide.

Table 2. Marketing Requirements

User Requirement	Specific Function	Design Approach	Standards
User log in and Registration	User needs to create an account to be able to gather points.	A login and registration are developed using Visual studio and firebase to store	ISO/IEC 27701 provides guidance on user registration and deregistration, as well as data

		the information of the users.	privacy by the use of assigned identities.
Touch Screen Display	Claim feature will give you points that corresponds with the E-waste that you disposed in the machine.	Utilize a reachable LCD (Liquid Crystal Display) on the product— established with the program to let users execute the chosen selection.	ISO 7000/EIC 60417 covers both registered ISO and IEC graphical symbols, which can be placed on equipment intended for touch screen displays.
Pi Cam	After the user's selection in the touchscreen display the E-waste will be scanned by the Pi cam that will identify and classify the E-waste.	Sensors will be used for image-processing and integrated with the Pi Cam to establish verification of the E- waste and/or reward points to the user.	SO/IEC 30137-1:2019 provides guidance on selection of camera types, placement of cameras, image specification, and more.

Servo motor	After the E-waste is scanned the servo motor will get the E-waste and will go to bin that collects the E-waste.	A servo motor will be secured near the area where the E- waste is placed, to properly push the E- waste to the bin.	ISO 16484-2:2004 specifies the requirements for the hardware to perform the tasks within a building automation and control system (BACS).
Web Application	The machine has a web application for claiming their reward and points withdrawal. claim the corresponding points of the E-waste donated, the user can view how many points they have in total for donating, and to redeem the corresponding cash rewards on the total of the points they have collected.	Visual Studio and Firebase will be required for the web application integration with the E-waste disposal and reward system.	ISO/IEC/IEEE 23026:2023 - Systems and software engineering — Engineering and management of websites for systems, software and services information.

3.2.2.2. Engineering Requirements

A thorough list of engineering criteria serves as the cornerstone for designing and creating a cutting-edge electronic waste machine. These requirements have an important role in determining the machine's fundamental design and functionality, ensuring that it runs efficiently and effectively. The structures of the machine are described in detail in the section that follows:

Table 3. Engineering Requirements

Engineering Requirement	Specific Function	Design Approach	Standards
Captured image of different electronic devices	The device must capture images of electronic devices at least 4 angles.	Utilize a Pi Camera mounted on the machine.	ISO/IEC 15948 specifies a data stream and an associated file format compressed individual computer graphics image transmitted across the internet.
Integration of IoT using Blynk software	Storing and receiving sensed data (machine status)	Implement a wireless communication between sensing devices and cloud storage.	ISO/IEC 30163:2021 specifies the system requirements of an Internet of Things (IoT)/Sensor Network (SN) technology-based platform for chattel asset monitoring

			supporting financial services.
Integration of sensors	The machine should have load sensor that monitors the weight of the total collected E-waste.	The sensors will be connected to Raspberry Pi 4.	ISO 23570-1:2005 specifies the interconnection of sensors and actuators with I/O modules that use their input or direct their output, and the diagnostic functions appropriate to those sensors and actuators.
WIFI Module	The WIFI Module is a means of communication for transmitting data to a cloud server.	The WIFI Module will be connected alongside with the microcontroller.	ISO/IEC 5021-1:2023 Telecommunications and information exchange between systems — Wireless LAN access control.

3.2.3. Design Constraints

3.2.3.1. Costs

- The estimated project budget is capped at PHP 40, 000, including all components, materials, and transportation costs.

- The machine must be energy-efficient to minimize electric expenses.
- The maintenance will be conducted every 4 months to ensure proper functioning of the machine and the costs will vary based on the specific issues discovered during the maintenance cycle.

3.2.3.2. Portability

- The machine should weigh approximately 50 kilograms to make it easy for transportation.
- The components should be designed for easy disassembly and reassembly.
- The machine's dimension should be only 75 x 150 centimeters to fit within specific spaces

3.2.3.3. Health & Safety

- The machine should have clear safety instructions for users.
- The machine should implement fire detection system to minimize risk of fires caused by electronic wastes.
- The machine should be made from materials that are non- toxic and safe to use.
- The machine should be designed to be accessible for people with disabilities.

3.2.3.4. Sustainability

- The machine should be made from durable materials.
- The machine should be energy efficient.
- The machine should be easily disassembled and recycled at the end of its life.

3.2.4. System Architecture

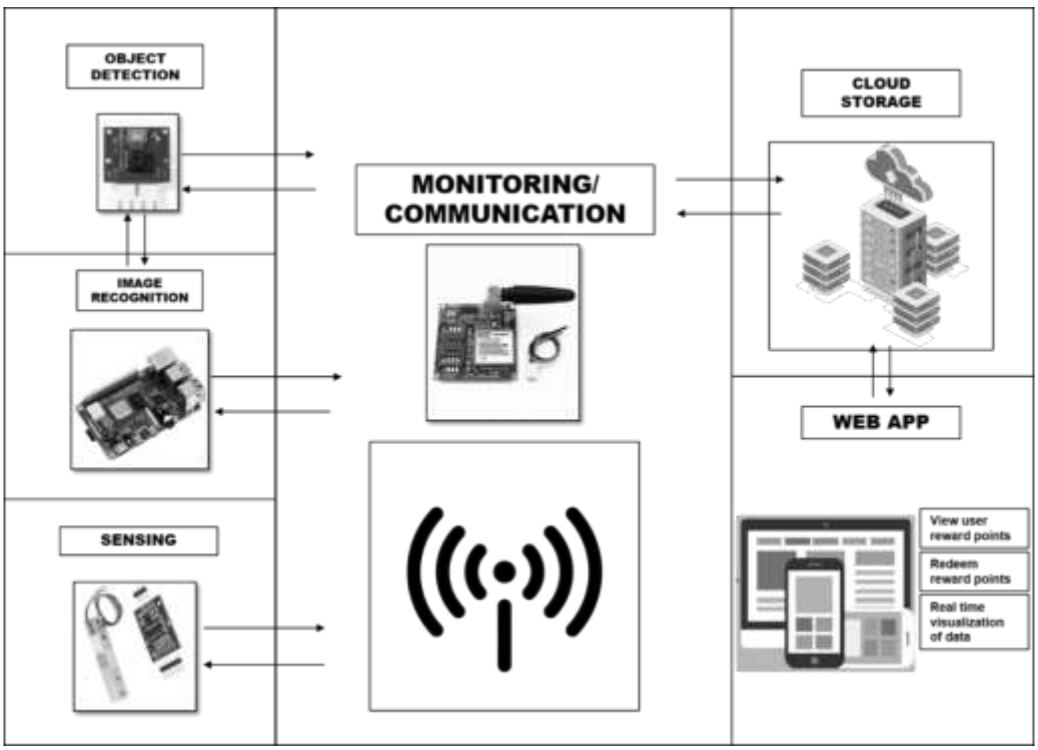


Figure 3. System Architecture of the Machine

As shown in figure 3 above, the proposed system will use an application programming interface (API) to perform the trained model of a dataset on an electronic waste for detection of e-waste object. To have visual representation of sensor data a web application is added for the admins to monitor real time machine status. The transmission of collected data by the microcontroller from the detectors and sensing devices a WIFI module is used to retrieve different data from the machine including temperature, bin capacity status and user transaction. The web application for user is used for rewarding system in terms of collecting, storing and redeeming their points. User will accumulate their points automatically after the disposing act. The equivalent points should reflect on the user account on the web application. Lastly, users can request a withdrawal of their points through the web application as the admins will grant their request of withdrawal with a web application designed for admins.

3.2.4.1. Flowchart

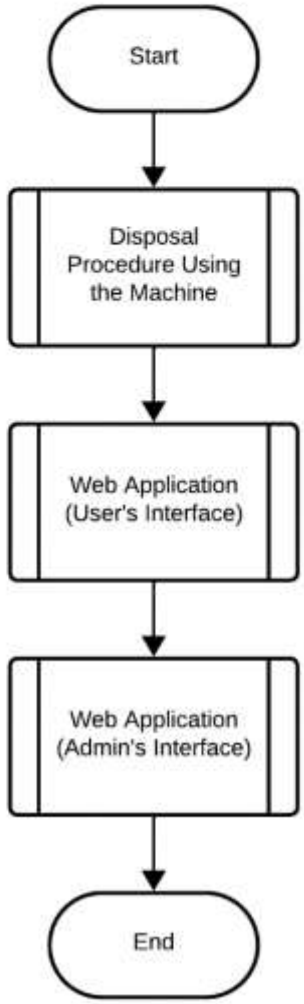


Figure 4. System Flowchart

The figure 4 above illustrates the system flowchart that starts with the disposal procedure using the machine, involving both the act of depositing e-waste and the calculation of rewards, which is handled by the machine. Using the web application, users can redeem reward points upon requesting a cash withdrawal inside the app. While administrators use separate interface for managing user withdrawal requests and monitor machine's status, tracking bin capacity level.

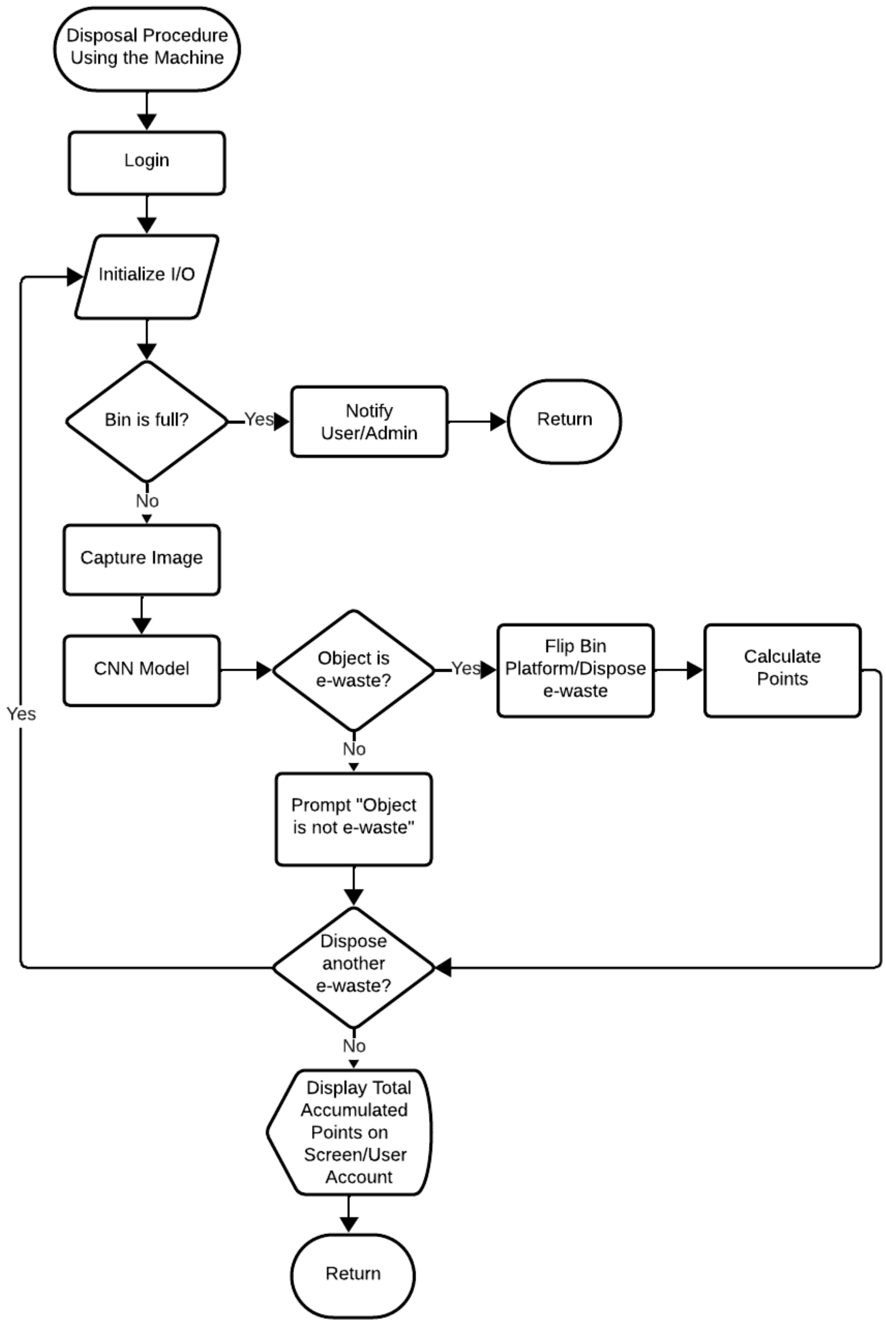


Figure 6. Disposal Procedure Using the Machine

The figure 6 above presents the Machine Flowchart. The process initiates with user login. If the bin is full, the opening lid of the machine will remain closed. The admin will notify in the web application once it is full. However, if the bin is not full, the user can proceed to scan their e-waste using the Pi-Cam. The CNN will then load the pre-trained model for the image recognition. If the scanned image is identified as e-waste, the flip bin platform will open to facilitate e-waste disposal. Subsequently, the system will display the points in each e-waste disposal. If the user disposes additional e-waste items, their points will show on the touchscreen display, reflecting on the total accumulated points in the user's account.

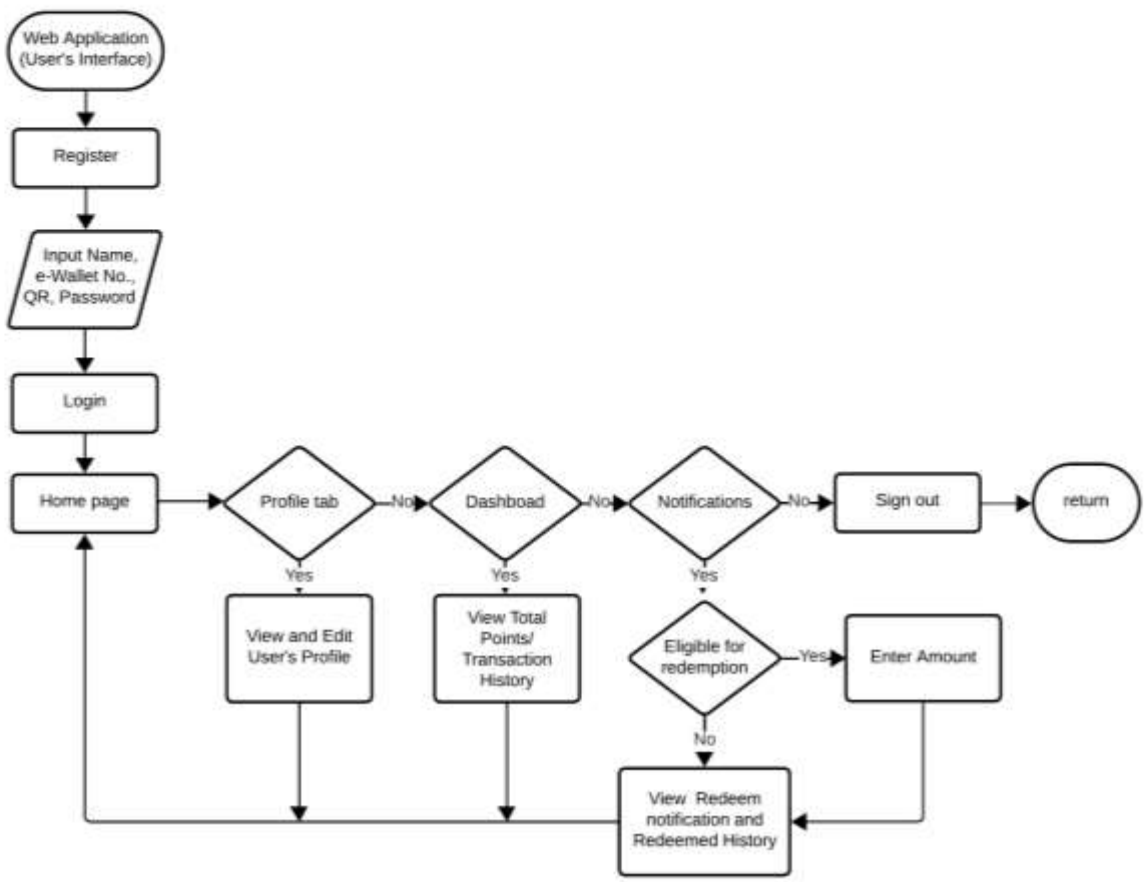


Figure 7. Redeeming Reward Points

As shown in the figure 7above, it outlines a user interaction process. Starting with registration where users provide their personal information including their name, e-wallet no., uploading their GCash QR code and inputting their password. Followed by two alternative paths, one for login leading to the homepage. On the homepage, the user can view and edit their personal information. It also lets the users re-upload or update and change the information associated with their GCash account. Users may view their total points that have been accumulated and view a detailed history on the dashboard page. With the help of this feature, users may keep track of their point balance and record of their previous transactions. Users will be notified via the "Notification" page as to when they are eligible to start a withdrawal. Users will be prompted to choose the desire withdrawal amount after clicking the notice to proceed with the withdrawal. Users may also monitor and manage their redemption requests and transaction history if they are not eligible for withdrawal. The sequential user engagement process including registration, login, reward redemption, and point sufficiency assessments, are presented in this structured flowchart.

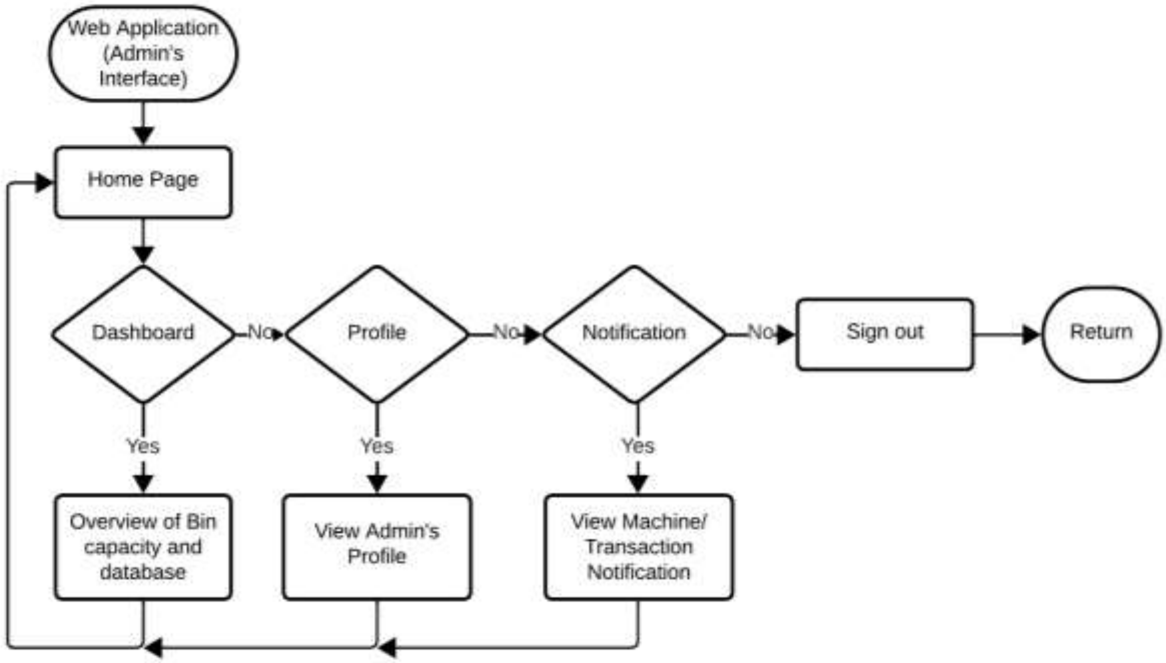


Figure 8. Reward and Machine Status Monitoring

The figure 8 above illustrates the admin section in the web application. The process will start by viewing the homepage, upon selection, the admin has the choice to view the dashboard. If opting for this, the process leads to viewing the machine's status. On the machine status, the admin can monitor the capacity level of the bin inside the machine through the integration of IoT. On the profile tab, the administrator can view and edit their personal information. The administrator can also review and change account settings. If the admin selects to view the notification, the admin can engage in reviewing user requests and also in the machine's status. On this tab, the admin can view access and review all the notifications made by the users. These notification requests primarily pertain to the user's requests for redeeming their accumulated points. In the redeem request tab, the admin will scan the QR code provided by the users upon registering their accounts to redeem their rewards. Point withdrawal occurs in batches every weekend, specifically from 7:00 am to 5:00 pm. This flowchart effectively outlines the administrative tasks within the web application.

3.2.4.2. Convolutional Neural Network (CNN) Algorithm

CNNs are a subset of deep learning methods that are mostly used for object and picture recognition. The proposed E-waste machine system that incorporates CNN can lead to visible improvements. Utilization of resources during recycling is more effective when e-waste items can be precisely identified and categorized. E-waste objects are taken by the machine's camera and identified using deep learning that is loaded to the main unit (microcontroller). The machine's internal bin is now filled with the detected electronic waste.

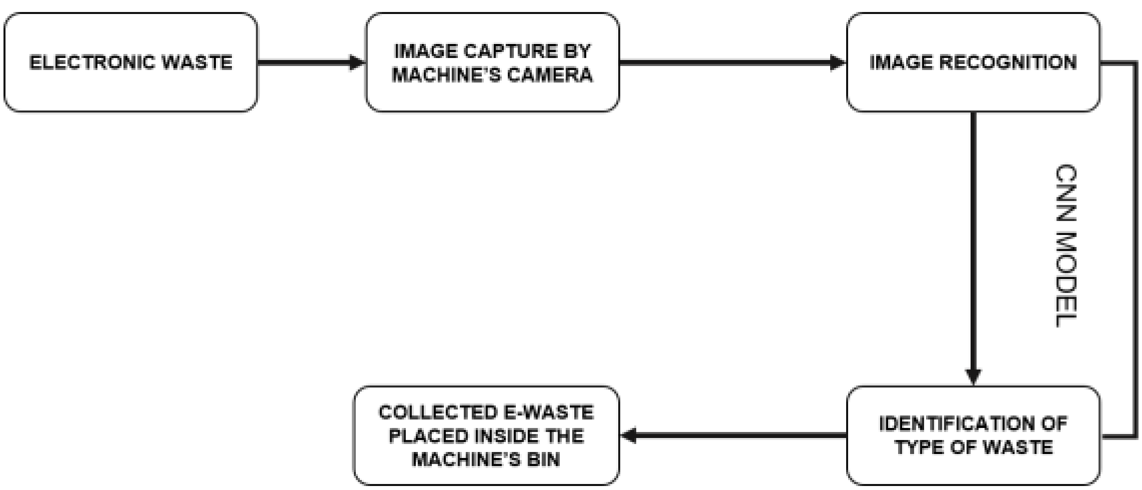
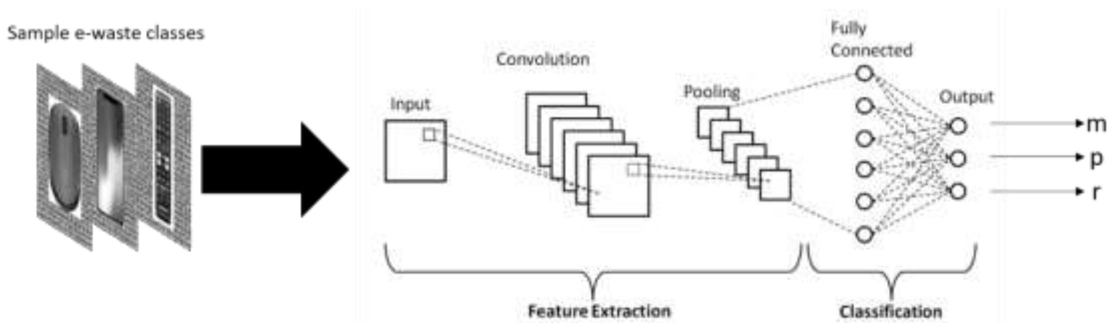


Figure 9. Machine Process Utilizing CNN Model

Sample inputs are e-waste objects that are available categories of e-waste in the dataset. In this example there are three categories of common e-waste you can find inside a household. Including mouse, phone, and battery. Each object has unique qualities that were used in the teaching process.

The output of the model represents the information of the inputted categories. The feature learning module and the classification module are the two primary functional modules of a deep learning CNN. Convolutional layers and pooling layers are used in the feature learning module, and the convolution layer run a 2D convolutional.



Neural Network Classification Model(m = mouse, p = phone, r = remote).

Figure 9. Initial Classification Model Neural Network

The figure shown above is the process of CNN classification model. The inputs for the model are sample classes of selected types of e-waste. As an illustration, the researchers chose three common households e-waste, including mouse, mobile phone, and remote. Each object has unique qualities that are used in the learning process. The model produced data regarding to the three e-waste classes that are represented by the example e-waste classes. The inputs are the different E-waste materials that the machine can accept and identify. After the input, it will pass to the convolutional layer. It will learn to extract the features from the input image. The output of the convolutional layer will be a tensor which represents the features that have been extracted from the image. The next layer will be the pooling, this layer will reduce the size of the tensor. This is done so that image will receive less noise. The fully connected layer will learn to classify the features that have been extracted from the input image. The output of this layer will be letters where each represents that the input image belongs to a specific class. The output of the CNN is a single letter that represents the predicted class of the input image.

3.2.4.2. Initial Prototype Design

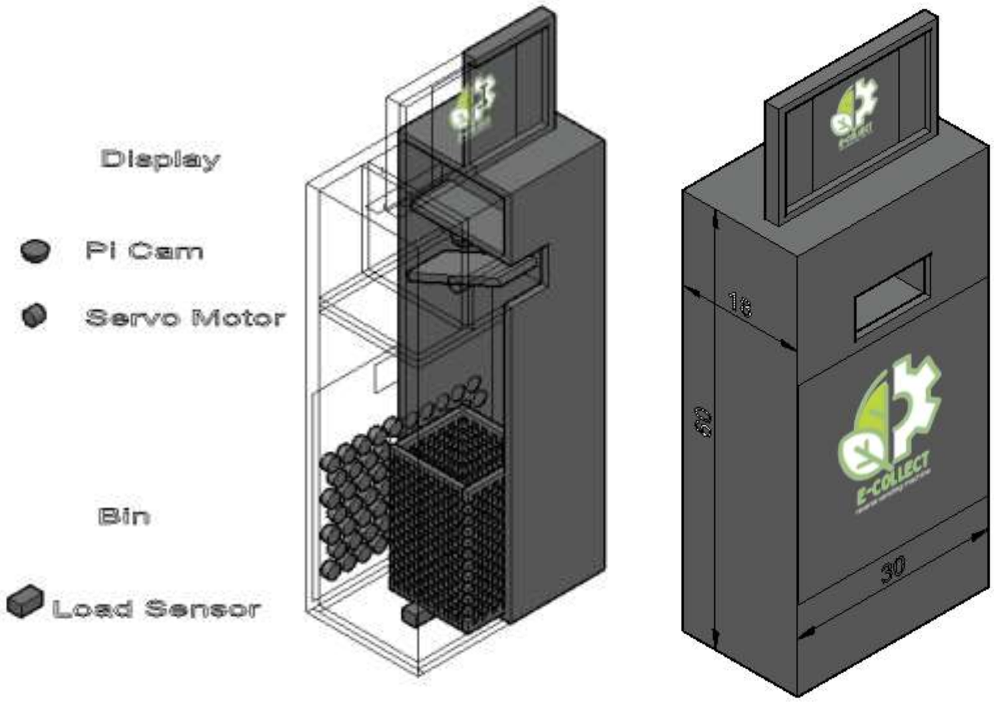


Figure 10. Internal and External View of the Machine

In the figure 10, this is the initial prototype design of the proposed project. The machine has a dimension of 30 inches length by 60 inches height with a width of 18 inches. The touch screen display is placed on top of the body of the machine, the back of the machine has a honeycomb structure that helps prevent the rise of temperature inside of the machine, it helps circulate the airflow inside the machine. The overall components are inside of the machine, the used components are as follows: Pi cam that will classify and identify the object, servo motor that will help flip the platform, bin that will serve as the collector of the e-waste and has a dimension of 20 cm in length and 40 cm in height and Load sensor that will monitor the total weight of the collected e-waste.

3.2.4.3. Sample Web Application Interface

3.2.4.3.1. UI for Users

Figure 11. Home Page

The home page is the introduction and brief explanation of what the machine is all about and what it can do.

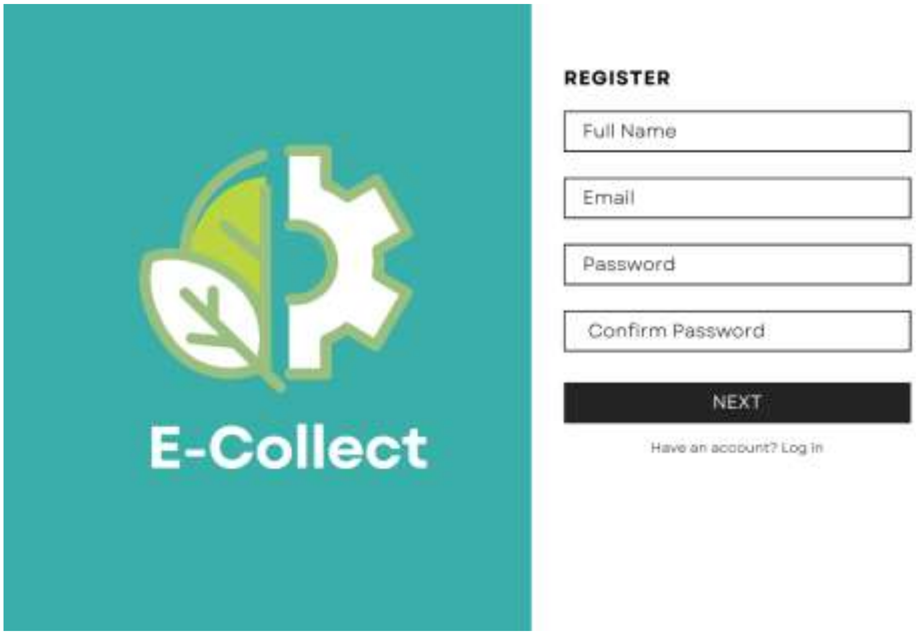


Figure 12. Registration Page

In this page is where the user will register the details their including full name, e-mail, password, and confirmation of password.

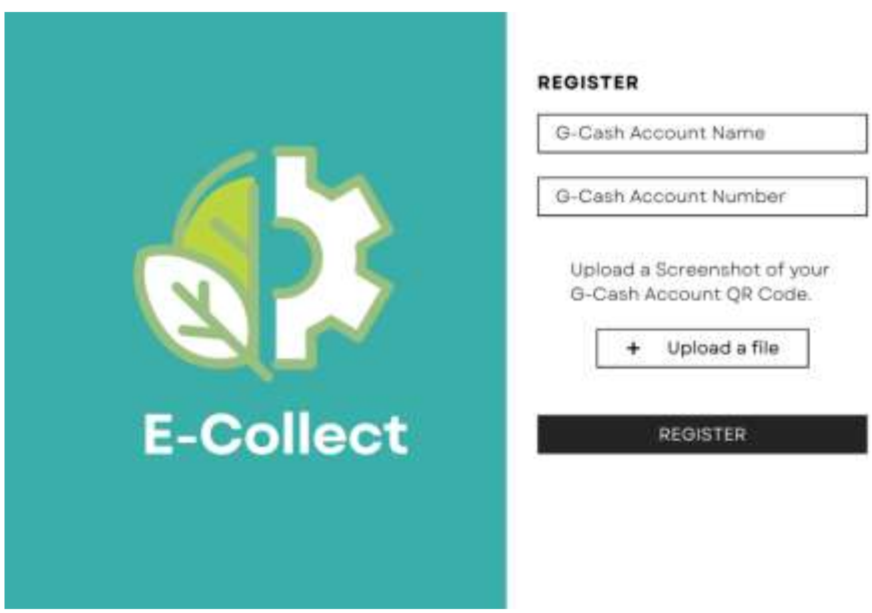


Figure 13. Registration Page (GCash Account)

This page is responsible for registering the GCash account of the user. It will include the details of GCash account name and number together with the screenshot of the generated QR code of the user. This will be use in rewards purposes.

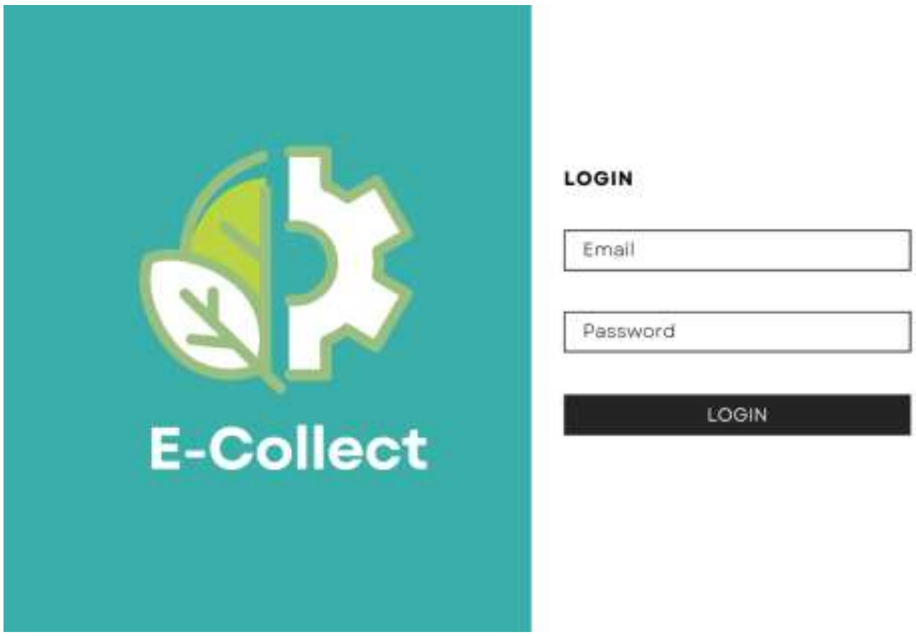


Figure 14. Log In Page for Users

In figure 14, this is where the user will be navigated to login the account.

Figure 15. Profile Tab of Users

As shown in figure 15, this tab is where the user can view the profile picture, together with the details including their full name, e-mail, GCash account name and number. There is also a button included for signing out.

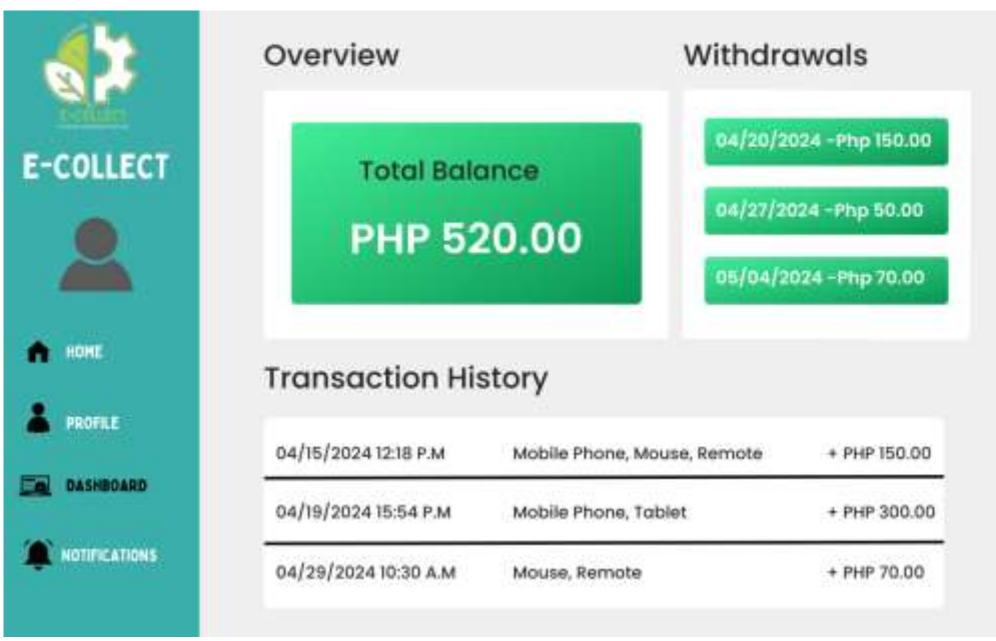


Figure 16. Dashboard for Users

The figure 16 shows where the user can view the total balance or reward points. There is also an information about the transaction history made by the user and the information about the past withdrawals.

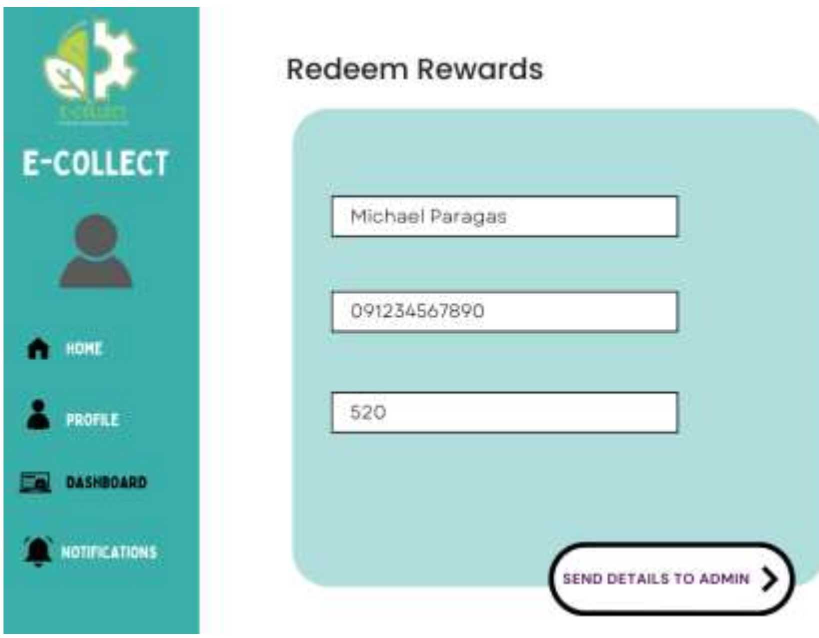


Figure 17. Redeem Reward Page for Users

In figure 17, this is the page for the withdrawal of reward points. The system will ask for the information of the GCash account of the user and the amount to be withdrawn.

Figure 18. Reward Receipt Page for Users

This is the receipt page where it will display the information containing the details of the user and a brief message about the posting of the reward.

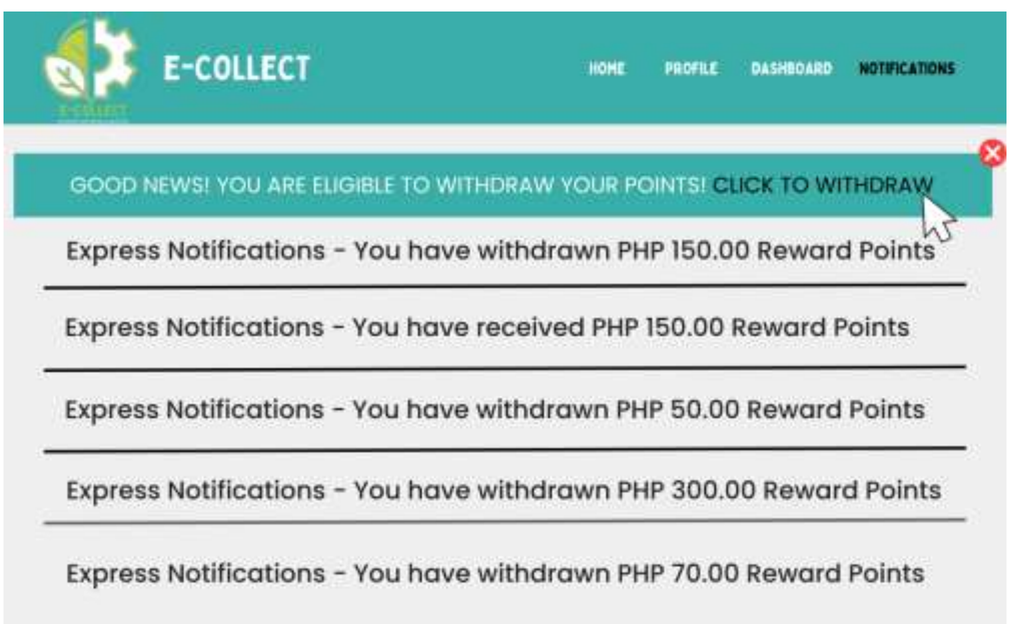


Figure 19. Notification Page for Users

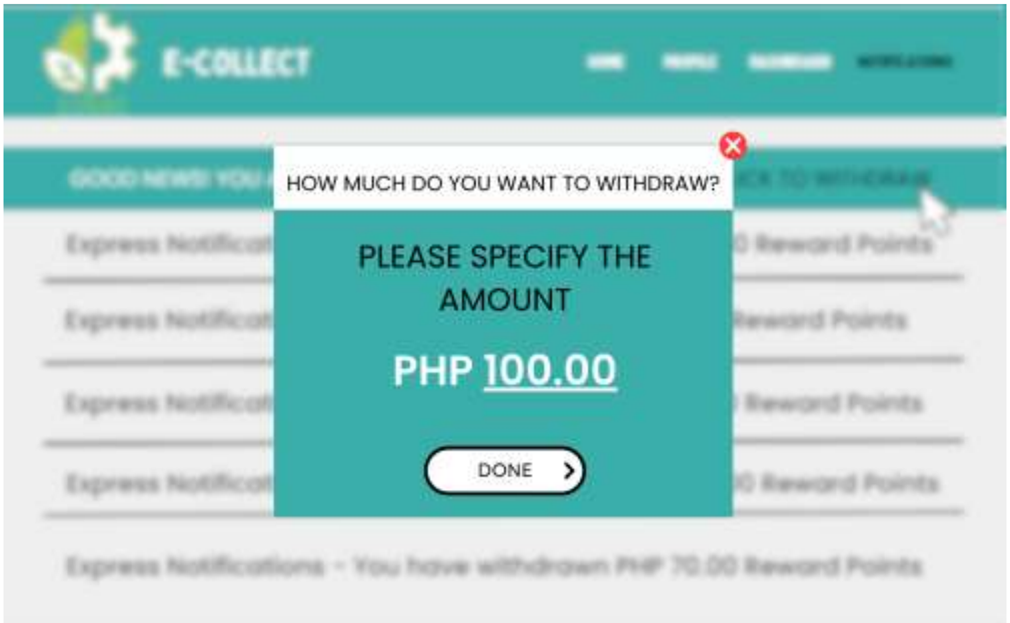


Figure 20. Pop-up Window for Cash-out Amount

In figure 19, the notification tab is where all notifications about withdrawals and receiving reward points will be viewed by the user.

3.2.4.3.1. UI for Admins

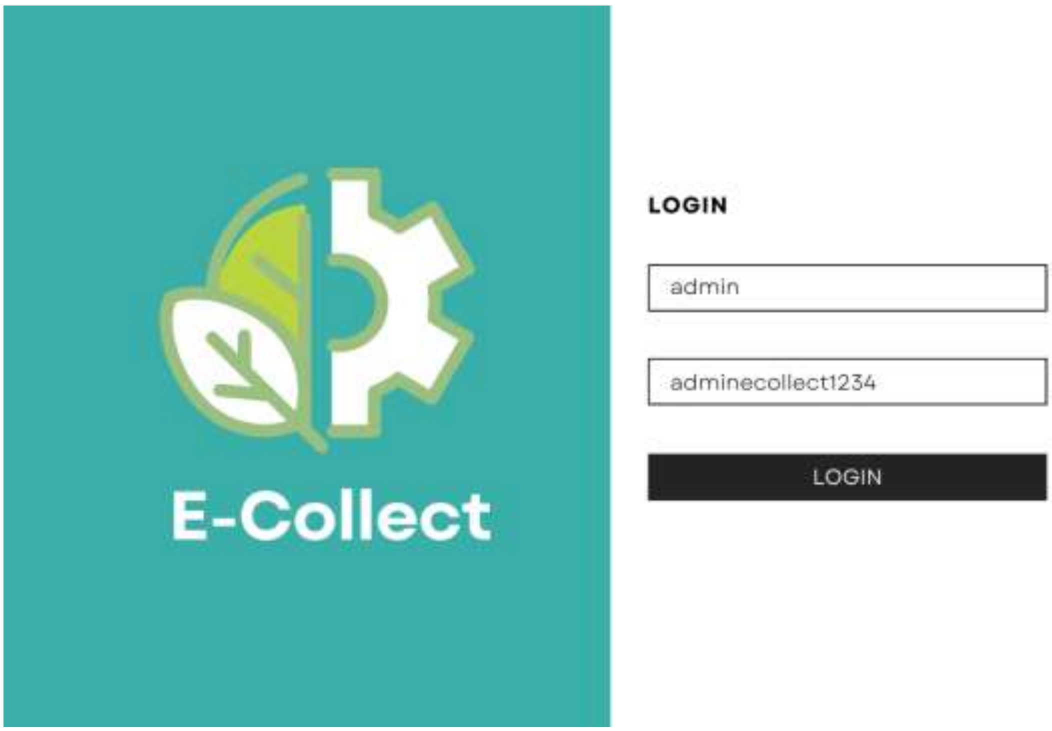


Figure 20. Login Page for Admins

The figure 20 shows the login page for the admins. The account of the admin will be set to default, meaning there is no need for the admin to register.

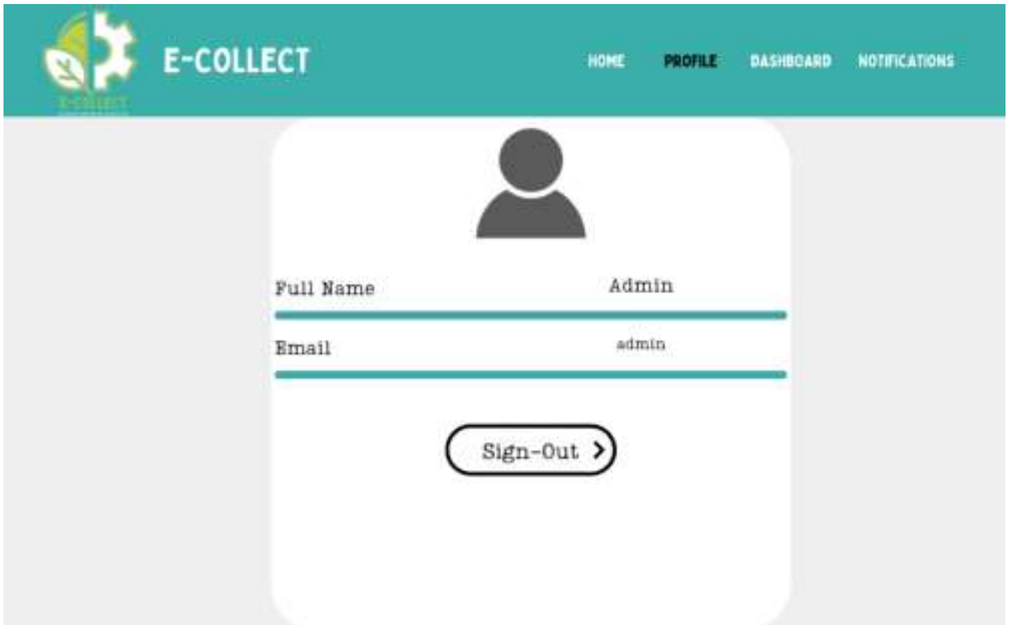


Figure 21. Profile Page for Admins

In figure 21, the profile page of admins contains details of the admin account and a Sign-out button.

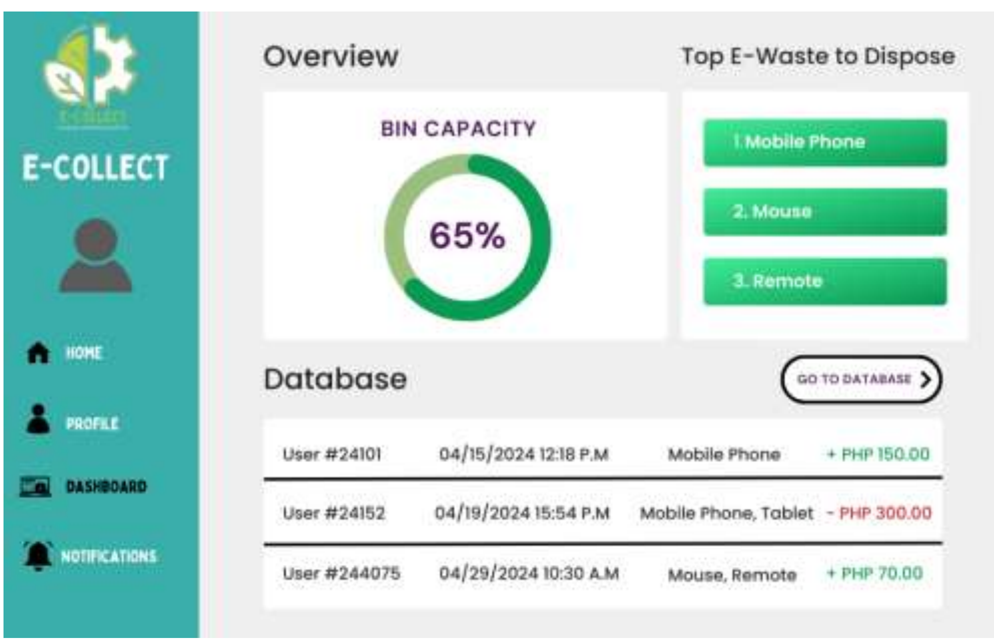


Figure 22. Dashboard Page for Admins

The figure 22 shows the dashboard for admins. In this page, the admin can view the bin capacity of the machine. The admin can also view the most common e-waste disposed by the users. There is also a brief overview of the database here, but the admin can choose to click the button to go to the database and view it live.

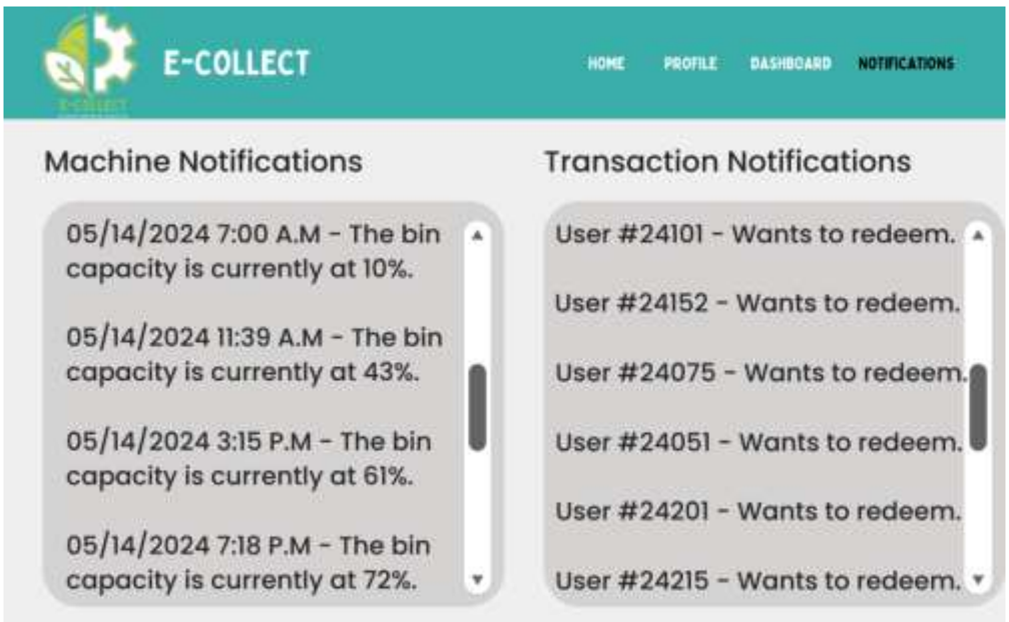


Figure 23. Notification Page for Admins

In figure 23, this is where the notifications about the machine will be viewed. The date and time will be displayed and beside it is the current capacity of the bin. In transaction notifications, this is where the admin will receive a notification that a specific user wants to redeem the points.

3.2.5. Experimentation Procedures

3.2.5.1. Component Testing

Table 3. Load Sensor

	Sample	Timestamp	Value
Load Sensor	1		
	2		
	3		
	4		
	5		
	6		
	7		
	8		
	9		
	10		

In this table, the sample column refers to a specific instance recorded by the load sensor. The table's rows each correspond to a particular sample or measurement that the sensor received. The time and date that each sample was taken are listed in the timestamp column. Actual load measurements taken by the sensor during each sample are listed in the value column. The magnitude of the load placed on the sensor at a specific time is represented by this numerical value.

3.2.5.2. Functional Testing

Table 4. Confusion Matrix

		Actual Values	
		E-Waste (Positive)	Not E-Waste (Negative)
Predicted Values	E-Waste (Positive)		
	Not E-Waste		

TN: Instances of the CNN correctly identifies non-e-waste objects as non-e-waste.

FN: Instances of the CNN incorrectly identifies e-waste objects as non-e-waste.

FP: Instances of the CNN incorrectly identifies non-e-waste objects as e-waste.

TP: Instances of the CNN correctly identifies e-waste objects as e-waste.

These metrics derived from the confusion matrix enable the team to evaluate the model's performance in a comprehensive way. It can fine-tune the e-waste detection system to ensure this correctly identifies electronic waste and reduces the possibility of false positives and false negatives by assessing accuracy, precision, recall, and F1-score. The team can test the effectiveness of the research and make data-driven decisions to improve the accuracy and dependability of the e-waste detection model.

Table 5. Classification Model

Parameters					
Model	Trials	Accuracy	Precision	Recall	F1-Score
CNN MODEL	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	10				

In Equation (1), the Accuracy metric provides a general measure of our model's correctness. A high accuracy score suggests that the model is overall effective in distinguishing between e-waste and non-e-waste items.

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FN} \quad \textbf{(1)}$$

In Equation (2), the Precision specifically addresses the accuracy of positive predictions made by the model. In the context of e-waste detection, precision measures how well our model identifies actual e-waste items among all the items it predicts as e-waste. A high precision value indicates that when the model predicts an item as e-waste, it is highly likely to be correct. This metric is particularly relevant in scenarios where false positive (misidentifying non-e-waste items as e-waste) could have significant consequences.

$$\text{Precision} = \frac{TP}{TP+FP} \qquad \textbf{(2)}$$

The Recall emphasizes the model's ability to capture all positive instances in the dataset. In the study, recall signifies how well the model detects all actual e-waste items, ensuring that it minimize the chances of missing any electronic waste during the detection process. This metric is critical in applications where false negatives (missed e-waste items) are highly undesirable, such as environmental monitoring and waste management. Equation (3) measures the ratio of correctly predicted positive observations to the all observations in the actual class.

$$\text{Recall} = \frac{TP}{TP+FN} \qquad \textbf{(3)}$$

The F1-score is derived from precision and recall, is calculated as. it considers both false positives and false negatives, giving a fair evaluation of a model's accuracy. An F1-score closer to 1 indicates a well-balances trade-off between precision and recall. In our study, achieving a high F1-score is crucial, as it indicates that the model strikes an optimal balance between minimizing false positives and false negatives. Equation (4) is the weighted average of Precision and Recall.

$$\text{F1 Score} = \frac{2\text{x } Precision \text{ x } TN}{Precision+Recall} \qquad \textbf{(4)}$$

3.2.5.3. Integration Testing

Table 6. – Redeeming Reward Testing Table

Trials	Points generated on Machine	Amount transferred to the users account	%error
1			0%
2			
3			
4			
5			
6			
7			
8			
9			
10			

$$Percentage\ Error = \frac{|\text{Measured Value} - \text{True Value}|}{|True\ Value|} X\ 100 \quad \textbf{(5)}$$

The table 6 above refers to the discussion of the Reward Testing. The first column is Trials, which shows the number of trials that needs to be done to measure the accuracy of the machine. In the 'Points Generated on Machine column, this is the reward points that will be transferred to user account in the web application. In the third column 'Amount Transferred to the Users Account' this is the amount that the user received after using the machine. Equation (5) presents the “%error”, it will state the error percentage of the outcome trials.

Table 7. IoT Bin Monitoring Testing

Sample	Timestamp	Load Sensor	%error
1	00/00/0000/00:00:00		
2	00/00/0000/00:00:00		
3			
4			
5			
6			
7			
8			
9			
10			

In this table, the sample column refers to an instance recorded during the bin monitoring process, a particular sample obtained from the monitoring system in the machine. The time and date that each sample was taken are listed in the timestamp column. The readings of the load sensor's %error contain numerical value in the %error column. This numerical information measures the %error of the load sensor readings and enables a quantitative evaluation of the data collection's reliability. Equation (5) presents the “%error”, it will state the error percentage of the samples.

References

Al-Kofahi, M. M., Al-Shorman, M. Y., & Al-Kofahi, O. M. (2019). Toward energy efficient microcontrollers and Internet-of-Things systems. Computers & Electrical Engineering, 79, 106457.

Al Ramsi, Marwah and Al Helali, Alia, "Towards sustainable cities: E-waste Collecting Machine: A Conceptual Design" (2022). Thesis. Rochester Institute of Technology. Accessed from https://scholarworks.rit.edu/theses/11090

Alam, Z. F. (2016). The assessment of the e-waste management generated from cellular phones, laptops, and personal computers in the Philippines. Manila Journal of Science, 9(2016), 27-42.

Andeobu, L.; Wibowo, S.; Grandhi, S. (2021). A Systematic Review of E-Waste Generation and Environmental Management of Asia Pacific Countries. Int. J. Environ. Res. Public Health, 18, 9051. https://doi.org/10.3390/ijerph18179051

Arghadeep Mitra. (2020). Detection of Waste Materials Using Deep Learning and Image Processing. Retrieved from: https://scholarworks.calstate.edu/downloads/gx41mn74q?fbclid=IwAR38zmk_ChIgu1jTHgcDmVaDi8Q4xYYLPt0tW7SnhnrePoTJT4umvUs1gQ

Arya, S., Kumar, S. (2020) E-waste in India at a glance: Current trends, regulations, challenges and management strategies. Journal of Cleaner Production. vol. 271. https://doi.org/10.1016/j.jclepro.2020.122707

AV Shreyas Madhav, Raghav Rajaraman, S Harini, Cinu C Kiliroor, (2021). Application of artificial intelligence to enhance collection of E-waste: A potential solution for household WEEE collection and segregation in India.

Baoas, C. B. (2016). E-Waste Management: An Assessment of Implementing Practices in Selected Engineering Universities of Metro Manila. Pamantasan ng Lungsod ng Maynila, College of Engineering and Technology, Department of Chemical Engineering, pp. 2-46.

Campit N. (2020). E-Waste Management in the Philippines: An Assessment.Environmental Governance and Citizenship. Monash University, pp. 2-16.

Celestial, R. G., Mauricio, E. D., Tan, L. B., Gumaru, J. C., & Mondragon, R. O. (2018). E-waste management in the Philippines. Agrocultural- Industry. Waste. Management, 5(1), 1-12.

DENR (2020). EMB: National Policy, Regulatory Framework Already in Place for E-Waste MNGT. Retrieved from: https://www.denr.gov.ph/index.php/news-events/press-releases/1918-emb-national-policy-regulatory-framework-already-in-place-for-e-waste-mngt

Doan, L. T. T., Amer, Y., Lee, S. H., & Phuc, P. N. K. (2019). Strategies for E-waste management: a literature review. International Journal of Energy and Environmental Engineering, 13(3), 157-162.

E. Jokisuu, M. McKenna, A. W.D. Smith. (2016). Touchscreen Availability in Self-Service Terminals. Phil Day NCR Corporation. The Journal on Technology and Persons with Disabilities, pp. 114-132. Retrieved from: https://wirelessrerc.gatech.edu/sites/default/files/publications/mitchell_et_al__optimizing _accessibility_of_wireless_emergency_alerts.pdf#page=120

G. Dayaday, M., & A. Galleto, Jr, F. (2022). Electronic Waste (E-Waste) Management of Higher Education Institutions in South Central Mindanao, Philippines: 10.32526/ennrj/20/202200053. Environment and Natural Resources Journal, 20(5), 534–542.

Greenpeace Philippines (2005). Toxic Tech: Looming E-Waste Problems for Thailand and Philippines. Retrieved from: https://www.greenpeace.org/philippines/story/948/toxic-techlooming-e- waste-problems-for-thailand-and-philippines/

Harsha Vardhan M N, & Mallikarjuna Shastry P.M. (2020). Waste Management Using Reward System. Retrieved from: https://www.researchgate.net/profile/MallikarjunaPm/publication/348390926_Waste_Management_Using_Reward_System/links/5ffc670b92851c13fe05b628/Wast e-Management-Using-Reward-System.pdf

J. Mateo, (2019). Phl's E-waste Problem: Over 24M Phones Discarded Yearly by 2021. Retrieved from: https://www.onenews.ph/articles/phl-s-e-waste-problem-over-24-m-phonesdiscarded-yearly-by-2021

Jr, Jesusimo. (2020). Bottle-SegreDuino: An Arduino Frequency-Based Bin for Tin Can and Plastic Bottle Segregation using an Inductive Proximity Effect. International Journal of Advanced Trends in Computer Science and Engineering.https://www.warse.org/IJATCSE/static/pdf/file/ijatcse184942020.pdf

K.R. Sarath, M. Aravind, B. Dayanand, S. Devarajan, S. Aswith, G.L. Cruz (2022). A Micro-Controller Based Automated Product Dispenser. Department of ECE

Sri Krishna College of Engineering and Technology Coimbatore, India. ISSN: 0044-0477

Kahhat, R., Kim, J., Xu, M., Allenby, B., Williams, E., Zhang, P. (2015) Exploring e-waste management systems in the United States. Resources, Conservation and Recycling vol. 52, pp. 955-964. https://doi.org/10.1016/j.resconrec.2008.03.002

M. Krithikaa, (2016). Touch Screen Technology - A Review. International Journal of Trend in Research and Development. Volume 3, ISSN: 23394-9433, Retrieved from: http://www.ijtrd.com/papers/IJTRD1386.pdf

Manish, A., Chakraborty, P. (2019) E-Waste Management in India: Challenges and Opportunities. The Energy and Resources Institute. Retrieved from:https://www.teriin.org/article/e-waste-management-india-challenges-and-opportunities

Nam, H., Seol, K.-H., Lee, J., Cho, H., Jung, S.W (2021). Review of Capacitive Touchscreen Technologies: Overview, Research Trends, and Machine Learning Approaches. Sensors 2021, 21, 4776. https://doi.org/10.3390/s21144776

Pariatamby, A., Victor, D. (2015) Policy trends of e-waste management in Asia. J Mater Cycles Waste Management. 15, 411–419. https://doi.org/10.1007/s10163-013-0136-7

Piotr Nowakowski, Teresa Pamuła, (2020). Application of deep learning object classifier to improve e-waste collection planning. Retrieved from: https://ph02.tci-thaijo.org/index.php/ennrj/article/view/247110

Sari, D. P., Masruroh, N. A., & Asih, A. M. S. (2021). Consumer Intention to Participate in E- Waste Collection Programs: A Study of Smartphone Waste in Indonesia. Sustainability, 13(5), 2759. MDPI AG. Retrieved from: http://dx.doi.org/10.3390/su13052759

Shreyas Madhav A, Rajaraman R, Harini S, Kiliroor CC. Application of artificial intelligence to enhance collection of E-waste: A potential solution for household WEEE collection and segregation in India. Waste Management & Research. 2022;40(7):1047-1053. doi:10.1177/0734242X211052846t

Singh, Kuldeep & Arora, Gayatri & Singh, Pushpa & Gupta, Ankit. (2021). IoT-based collection vendor machine (CVM) for E-waste management. Journal of Reliable Intelligent Environments. 7. 1-13. 10.1007/s40860-020-00124-z.

Vishnu, S., Ramson, S. R. J., Rukmini, M. S. S., & Abu-Mahfouz, A. M. (2022). Sensor- Based Solid Waste Handling Systems: A

Survey. Sensors, 22(6), 2340. MDPI AG. Retrieved from http://dx.doi.org/10.3390/s22062340

Yan, L. Y., Tan, G. W. H., Loh, X. M., Hew, J. J., & Ooi, K. B. (2021). QR code and mobile payment: The disruptive forces in retail. Journal of Retailing and Consumer Services, 58, 102300.

Yafeng Han, & Tetiana Shevchenko. (2022). Exploring incentive mechanism in smart e-waste management system in China. Retrieved July 15, 2023, fromhttps://www.researchgate.net/publication/362945725_Exploring_incentive_mechanism_in_smart_e-waste_management_system_in_China/referenc