

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ



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Graduation Project II



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Disclaimer

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Chapter 1

Abstract

The world is currently facing a growing waste management crisis as more rubbish is thrown every day. This not only contributes to environmental contamination but also poses a threat to both human health and the welfare of wildlife. If we want to successfully address this issue, we must develop novel, creative methods for managing rubbish. The necessity to find a solution to the issue of improper and ineffective waste management techniques served as the inspiration for the "Greeny" project.

By sorting waste into classes including plastic, glass and other classes using machine learning, the initiative aims to increase the effectiveness and accuracy of trash management. As well as offering the authenticated users a point system, which basically will add points based on the waste type a user has dropped. User will be authenticated by 2 methods, either by scanning the QR code, or by entering his unique ID. Additionally, Greeny will keep users informed about the status of the bins, including the capacity for each bin, which will be stored into database, Therefore, it will alert authorities to empty it immediately if it fills up. By allowing for the correct recycling of various waste kinds, this not only benefits the environment by lowering the quantity of garbage that ends up in landfills but also encourages sustainability.

In essence, With Greeny, people are encouraged to embrace sustainable behaviors, contribute to a cleaner environment, and adopt good trash disposal habits. In the end, this creative waste management approach may help create a community that is greener and more environmentally conscious.

Chapter 2

Introduction

2.1 Problem

Multiple issues with the way garbage is currently managed have a harmful impact on the environment. Human beings are among those who will be impacted by this. When waste management infrastructure is inadequate, humans and waste may interact in ways that harm and endanger the former's humanity.(6). Traditional manual sorting methods waste time and resources, are labor-intensive, prone to errors, and result in incorrect disposal and inefficient resource use. Because of this, current approaches to global waste management (WM) focus more on alleviating consequences than on preventing them and suggest smart fixes.(8). Progress in trash management is further hampered by the lack of a systematic strategy to reward safe rubbish disposal. There is currently no simple way to reliably detect and classify various sorts of rubbish. Additionally, the physical touch necessary to access trash cans compromises hygiene standards and raises the danger of infection. An automated and intelligent solution is urgently needed in light of these major difficulties.

2.2 Objective

The goal of the "Greeny" project is to create a smart waste management system that can accurately classify trash using machine learning and computer vision. The main objectives are to automate trash classification, encourage responsible behavior, and improve user comfort.

- Enhance user convenience with two entry methods (QR code scanning and keypad input) and improve hygiene standards through an intelligent garbage disposal mechanism.
- Incentivize responsible behavior through a point system that rewards users based on proper garbage disposal.

2.3 Scope Of the Work

The main scope of "Greeny" is categorizing rubbish into categories like glass, metal and plastic to ease the process of recycling. It combines the development and use of a machine learning model and it highlights the inclusion of user-friendly interfaces for simple interaction, a camera-based rubbish recognition system and smart garbage disposal systems depending on user proximity. It also places a strong emphasis on environmental protection and nudges people to start recycling their trash.

2.4 Importance

Pollution of the land, water, and air can result from improper trash management, particularly when it comes to non-biodegradable materials like plastics. For instance, it might take hundreds of years for plastic waste to disintegrate, releasing toxic compounds into the ecosystem and endangering wildlife. Intelligent trash systems employing machine learning algorithms can efficiently classify and sort various sorts of waste. When compared to human sorting, this automated procedure is more efficient and ensures that garbage is accurately categorized for recycling or proper disposal. A quick and user-friendly approach to engage with the smart trash system is added through the use of mobile QR code authentication. Individuals are encouraged to take an active role in waste disposal as a result.

2.5 Report Organization

The first chapter is the abstract. The second one is the introduction. The other chapter is three, it will show the limitations we faced and will include the courses we went through to do the project. Chapter 4 is the literature review, it views some ideas that related to the field we worked on. Chapter 5 is the methodology, it will describe the method required to complete this work and also includes the technologies included to do the system. Chapter 6 is the results and discussion. Finally, chapter 7 will discuss talk about the conclusion and recommendation.

Chapter 3

Constraints and Earlier coursework

3.1 Constraints and limitations

1. **Electronic components:** Electronic components are very sensitive and easy to burn or damage, so we had to deal with them with caution, and also due to our lack of experience in dealing with some of them in terms of electrical connections.
2. **Technical Expertise:** Some challenges faced due to the lack of in expertise in multiple disciplines such as electronics, mechanical engineering, firmware development, and system integration.
3. **Time limit:** This is the first time building that big hardware project and dealing with new electronic components, and programming new software so the learning curve was a bit long the project was done under pressure during the semester course and political strikes.
4. **Data Availability and Quality:** The machine learning model may be constrained by the quantity and caliber of training data available. Careful data collection and preparation are necessary since biased or limited data may impair the model's accuracy and generalization.
5. **Environmental Variability:** The project might run into issues with environmental unpredictability, including shifting clarity, item shadows, or variations in rubbish size and shape. These variables may have an impact on the efficacy of garbage identification and classification algorithms, necessitating the use of robust image processing methods and model adaption.
6. **The Power:** Due to the project's many elements, dealing with the electricity is a significant issue. Each element differs from the others. A 12 Volt battery is needed to operate the motor that rotates the bins. Other modules can be powered by a USB with minimal current requirements and are less difficult to use.
7. **Cost:** We had a limited budget so it influenced the selection of components and materials used in the hardware project and we went through alternative executed ideas. so the work was endangered of overall performance and quality.

3.2 Earlier coursework

The expertise of the participants in Hardware was acquired in the Computer Engineering

Department from all the courses we have done, including: Microprocessor, Micro-controller, Electrical Circuits, Digital Design, and Critical Thinking Research. Other knowledge was gained by participating in some courses and sessions online, such as:

- ESP8266 ESP32 course.
- Raspberry Pi 4 courses and articles.
- Firebase Documentation.
- Flutter Flow Documentation.

Chapter 4

Literature Review

Any solid waste management system in developing country is heavily faces challenging factors, such as the increasing generation of waste, the availability of funding big systems(4), and the support of the community in putting waste minimization principles into practice(1). Regarding Palestine, no law nor actual application of the 3R waste management approach (reduce, reuse, and recycle) has been made yet(1).

It is difficult to say with certainty how much awareness there is among people, especially youth about how important is applying the 3Rs approach in developing country (3).

We had a look at some other works that helped to influenced to build our idea .

- There are many studies and applications available now that use to classify trash by using different models like an Efficient Net-b0 CNN.(2) When a waste item is placed in the bin, the top compartment scans it to identify the sort of waste it is, and when that prediction is correct, the corresponding bottom compartment's lid opens, forcing the waste down.
- many problems appeared due to the dumped waste, some of the solutions this paper (7) classifies and separates waste materials in a dump area using the Internet of Things (IoT), deep learning (DL), and cutting-edge methods. Additionally, it suggests a technique for segmenting waste that maps the pile at the waste yard into grid-like sections. To establish a trash grid, a camera records the waste yard image and delivers it to an edge node. The grid cell picture segments serve as a test image for deep learning that has been taught to anticipate a specific waste item. The 16-layer Visual Geometry Group (VGG16) deep learning technique was employed for this particular project. To reduce overall latency, a cloud server is deployed at the edge node where the model is trained.
- This paper proposed (5) that our society must be inspired to participate in recycling activities if we want to increase the amount of waste that is recycled. Because of this, a system that promotes citizen involvement by securing decreases in the trash rate applied by their local government, so that the amount of waste collected to be recycled is increased. Regardless of the urban environment in which it is implemented, this system uses a virtual organization of agents that gathers and manages the knowledge of each city and that, through gamification techniques, produces a change in citizens' habits, motivating and increasing citizen participation in recycling.

Chapter 5

Methodology

5.1 Methods and techniques

5.1.1 Project design

- Waste Management device: The device is kinda heavy to move it from one place to another. It has been designed to be placed in one place in public such as parks, universities, and others. When designing it, the following was taken into account:
 - The outer body consists of a different type of wood, the base which holds the bins is a lightweight wood, so the motor can handle it and rotate it without any friction. Moreover, it was designed to hold the bins and the rubbish inside of them. The upper bin, was installed on a heavy wooden pole (See Figure 5.11.a).
 - The weight of the upper bin is neither light nor heavy, in between, and the reason for that is so the wooden pole can handle its weight and the thrown rubbish. On the other hand, to let the motor be able to open the bin from both sides (See Figure 5.11.b).
- Signing Up device: The device has been made to fit in a fixed location above the waste management device. Making it as user-friendly as possible was one of the aspects we took into account when creating it. Additionally, the device offered three ways for users to sign in Greeny. The first two were created for people who already have accounts in our system, while the final one was created for a non-user.

5.1.2 Implementation Process

The essential components of Greeny are 2 devices, the first is the signing-up device, which is in charge of authenticating the user's identity in our system. The second component, a waste management device, which is in charge of classifying the waste using a machine learning model.

- Signing Up Device: This part of the project will be controlled by ESP32 - Wroom controller. Mainly will contains Keypad, 16*2 LCD, and motion sensor besides the ESP32 micro-controllers. This part will handle 2 types of users, the first one is a user who already have account in our system and want to receive points from the recycling process, while the Second type will be users who don't have account in our database and their main concern is to throw rubbish and keep the environment safe.

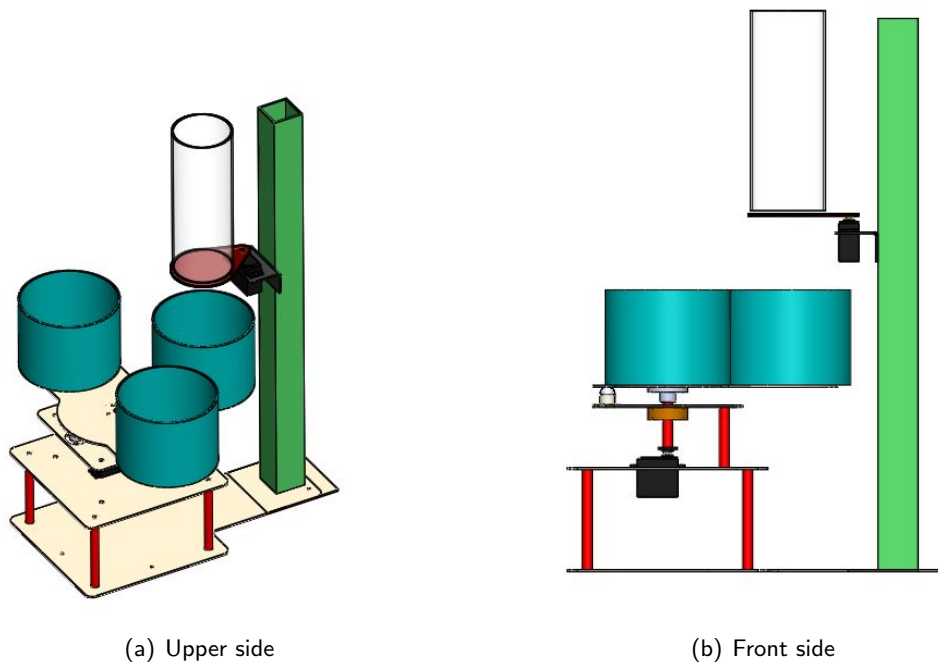


Figure 5.1: Waste Management device

Basically, the system will keep waiting till the motion sensor senses any movement (the user wave his hands above the sensor). If any motion detected, then Signing method will be triggered. To make system more convenient for the users, ESP32 micro-controller will provide 2 ways to sign in the system:

- QR code scanning: in this method the user will use mobile application to sign in the system. This will be done after scanning QR code belongs to the systems database, then he will appears online and authenticated.
- Keypad: in this method both keypad and the 16*2 LCD will be used to let the user enters his account ID - using this method requires having an account in the system -, user will appears online in the system right after entering his ID. In case the user enters ID doesn't match one of the requirements, which is:
 1. ID should consists only of 4 digits.
 2. ID shouldn't contains any special characters.
 3. All digits should be integers.

ESP will print message on LCD warns him, and ask again for the ID. In the other hand, if the ID meets the requirements, the ESP will connects to the database to check if the user is authenticated or no.

After the user has been online in the system, then ESP will be responsible to fetch the online user from the database, and send it to the Raspberry pi micro-controller serially. Notice that in case user use keypad as a sign in method, the ESP won't fetch the online user from the database, since it will fetch user id from keypad directly.

- Waste Management device: For this part of the project, 2 micro-controller be responsible to handle all the process, Raspberry pi4 and Arduino. raspberry pi will be responsible

on classifying waste thrown by the user. Moreover it will receive the online user in the system, so it can add the points to the user after the classification process is over.

Following is the process description for both Raspberry pi and arduino micro-controllers:

- Arduino: this micro-controller will be responsible on the mechanic movements in the system, such as opening the main bin from both sides and triggering the motor after classification is done.

First of all, opening the main bin from above, this movement will be done after ESP check that user is already authenticated and online. The servo motor will be triggered by arduino to open a light weight bin cover. In the other hand, the other side of the bin will be triggered to open after raspberry pi finishes classification process, and the motor centers the appropriate bin underneath the main bin.

An infrared sensor Tx and Rx was placed face to face inside the main bin. This will put sensor under 2 possibilities:

1. Sensor detecting an object: in such a situation the connection between IR Tx, IR Rx will be cut off by the object. So the arduino will tells the raspberry pi to start the classification process.
2. Sensor detecting no object: the connection between IR Tx, IR Rx will be stable, and nothing will interrupt them. Here the system will give the user a time limit of 15 seconds, in case nothing cut off the connection, the user session will be closed and the whole system will go to the initial state.

In essence, after the rubbish has been classified and dropped in the appropriate bin, an ultrasonic sensor will be used to detect the level of the appropriate bin. Moreover, this level will be send to the raspberry pi to update the level in the database, also will be updated on the 16*2 LCD screen (See Figure 5.3).

- Raspberry pi 4: Two tasks will be carried out using this micro-controller, Waste classification, and updating the points for the user based on the thrown rubbish. Raspberry pi will keep waiting ESP to receive the online user in the system. Moreover it will receive a start command by the arduino indicating that there is rubbish in the main bin needs to be classified. After that camera will be triggered to start capturing frames for the rubbish and then apply the model on it.

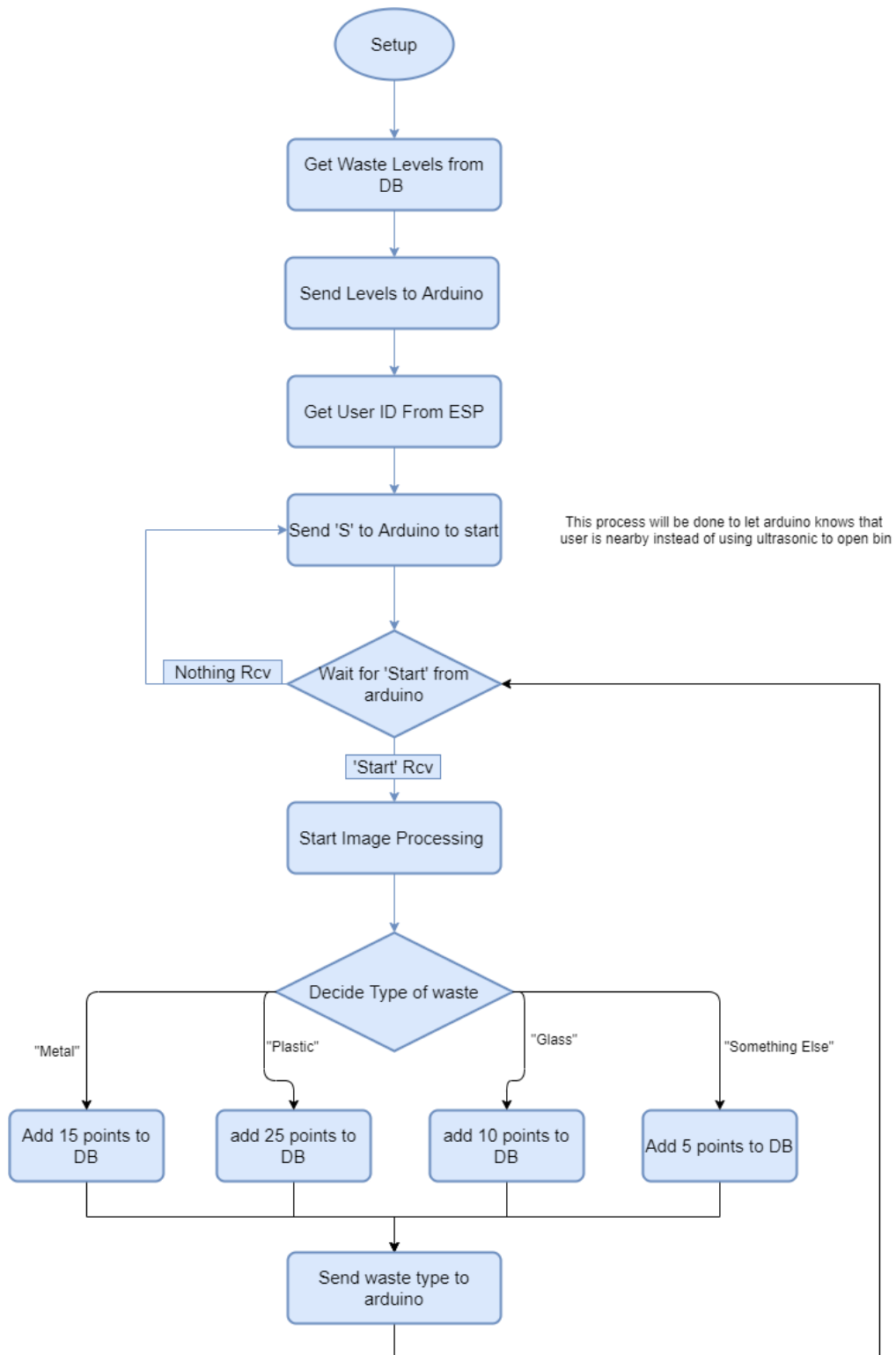
Increased confidentiality for the system will result from applying the model to various frames of the same object. Each frame's output will provide the category of trash that the model estimates this object falls under. The confidence percentage will then be averaged out, and if it was greater than 75%, the raspberry pi will transmit this category to the Arduino so that it can move the motor. Additionally, dependent on the trash tossed, this micro-controller will add particular points to the user account (See Figure 5.2).

5.2 Technical and Components choices

- **Arduino Mega**

The Arduino Mega is based on the ATmega2560 microcontroller and features 54 digital input/output pins, 16 analog inputs, and 4 hardware serial ports. This extensive set of pins allows for the connection of a wide range of sensors, actuators, and other electronic components, making it suitable for more advanced projects with larger requirements.

Figure 5.2: Raspberry Pi 4 Logic Flow



With its increased memory capacity, the Arduino Mega can handle more complex programs. It has 256 KB of Flash memory for storing code, 8 KB of SRAM for variables and data, and 4 KB of EEPROM for non-volatile storage. (See Figure 5.4).

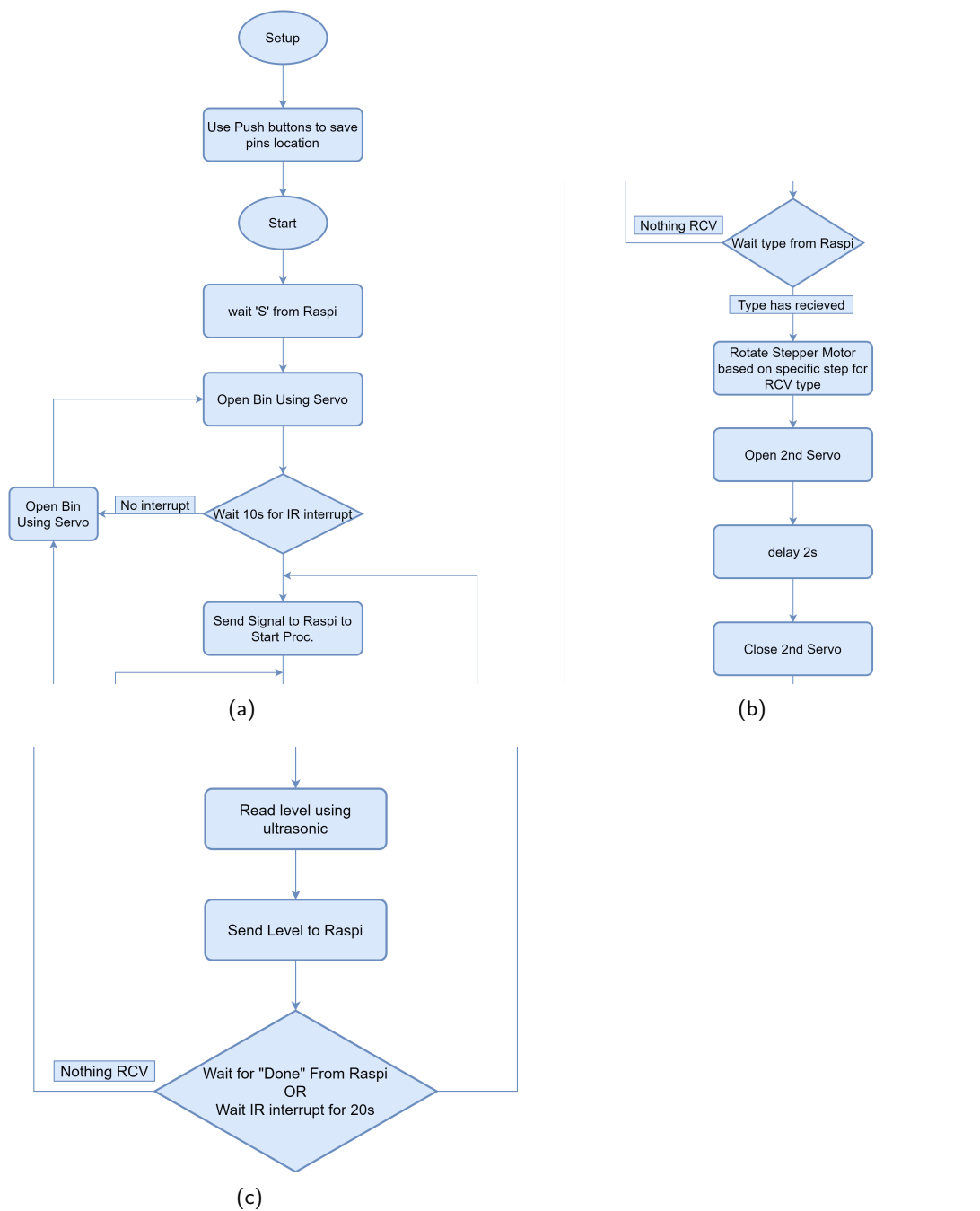
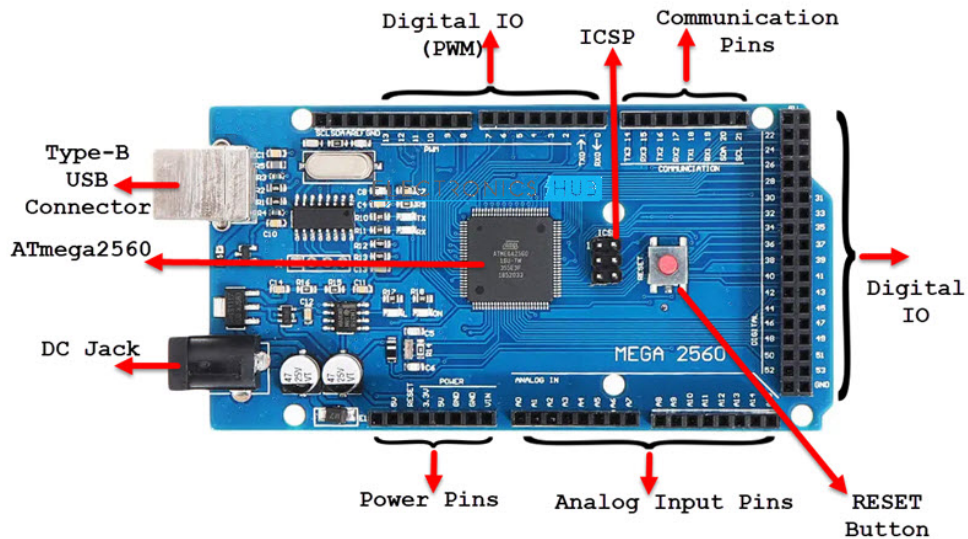


Figure 5.3: Arduino Logic Flow

Libraries used with arduino:

1. Wire: used for communicating with I2C devices.
2. LiquidCrystal_I2C: used to interface with I2C-based LCD displays in Arduino projects.
3. Servo: used to control servo motors and precisely position them at specific angles.
4. Stepper: used to control stepper motors by specifying the number of steps, speed, and direction of the stepper motor.

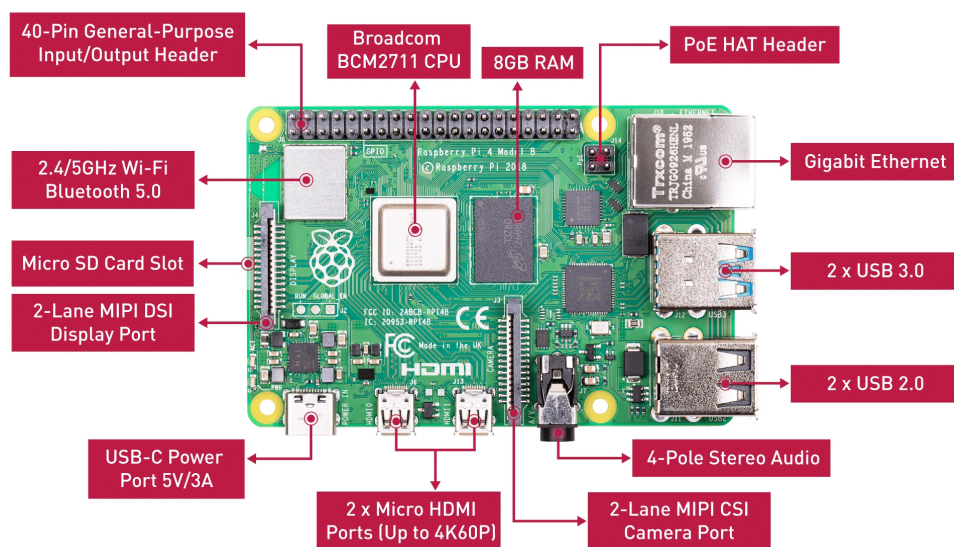
Figure 5.4: Arduino Mega 2560



- **Raspberry pi**

The Raspberry Pi board is roughly the size of a credit card and comes equipped with various hardware components, including a processor, memory, input/output ports, and connectivity options. It runs on a Linux-based operating system, typically the Raspberry Pi OS (formerly known as Raspbian), which is optimized for the device. The Raspberry Pi offers a wide range of applications and can be used for diverse projects. It serves as a platform for learning programming, electronics, and robotics, allowing users to write and execute code in languages such as Python, C/C++, and Java. It can be used as a media center, running media player software to stream and play videos, music, and other multimedia content. Raspberry Pi is also employed in home automation systems, Internet of Things (IoT) projects, retro gaming consoles, and much more. (See Figure 5.5).

Figure 5.5: Raspberry pi 4



- **Esp32**

The ESP32 module is based on the Xtensa LX6 microprocessor, which runs at a clock speed of up to 240 MHz. It is equipped with Wi-Fi and Bluetooth capabilities, making it suitable for wireless communication and connectivity. The module includes integrated 2.4 GHz Wi-Fi 802.11b/g/n and Bluetooth 4.2, with options for Bluetooth Low Energy (BLE) as well. (See Figure 5.6).

Libraries used with arduino:

1. Wire: used for communicating with I2C devices.
2. LiquidCrystal_I2C: used to interface with I2C-based LCD displays in Arduino projects.
3. Keypad: enables seamless integration of keypads with micro-controller boards, simplifying input reading from matrix or single-button
4. WiFi: facilitates seamless integration of WiFi connectivity into Arduino or other micro-controller, enabling communication with wireless networks and the internet.
5. Firebase_ESP_Client: gives ESP8266 or ESP32 micro-controllers a quick and easy way to communicate with Firebase. It streamlines the data transfer process to and from Firebase, facilitating the seamless integration of IoT projects with cloud-based storage and real-time synchronization.
6. HTTPClient: streamlines HTTP requests in Arduino or other micro-controller, enabling seamless communication with web servers and APIs such as CRUD Operation.
7. addons/TokenHelper.h: offers practical utilities and functionalities for using authentication tokens in Arduino or other microcontroller applications. It makes it simpler to build secure authentication procedures in embedded systems by streamlining the generation, management, and validation of tokens. Also increases the security and dependability of Internet of Things (IoT) projects that call for token-based authentication thanks to its extensive capabilities and simple interface.

Figure 5.6: ESP32-Wroom-32 Module

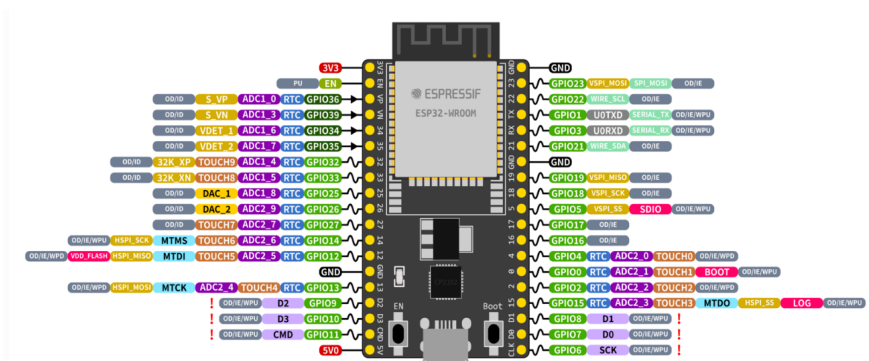
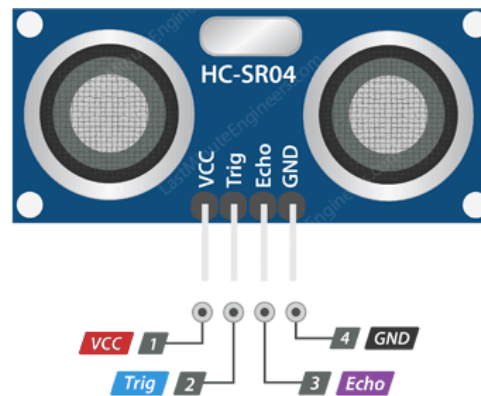


Figure 5.7: Ultrasonic sensor

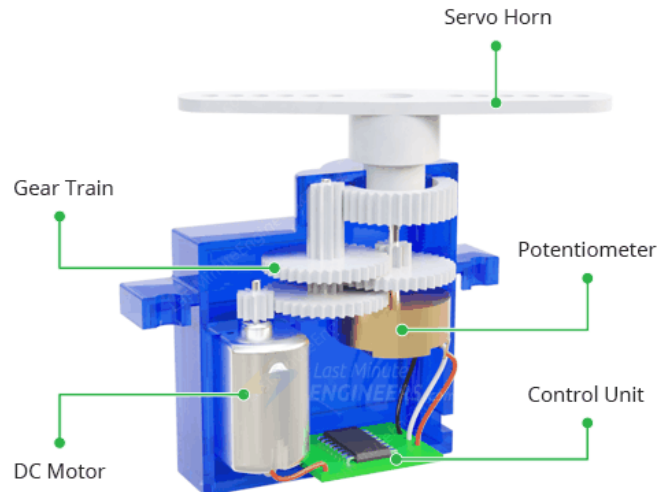


sound waves to return after hitting an object, the sensor can calculate the distance to the object. (See Figure 5.7).

- **Servo Motor**

A servo motor used to implement a door that opens the basic bin from top and down, from top will open after the system is authenticated in the database, also it senses someone in front the bin. From down will open the bin so the rubbish get down it's appropriate bin after the classification process (See Figure 5.8).

Figure 5.8: Servo Motor



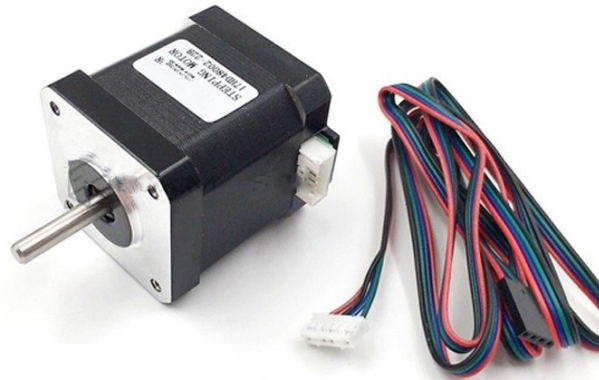
- **Stepper Motor**

A stepper motor used to convert electrical pulses into precise rotational movement. It will receive specific command from the Arduino to rotate in specific range based on the rubbish classification, after finishing it will set an interrupt for the system so it can drop the rubbish in the bin (See Figure 5.9).

- **Keypad**

Keypads are input devices consisting of a grid of buttons or keys, commonly used for entering data or making selections. It has been used to let the user enters his ID in case

Figure 5.9: Stepper Motor



he can't use the QR code sign in method, also to chose the sign in method he wants (See Figure 5.10).

Figure 5.10: Keypad



- **Infrared sensor**

Infrared sensor used to detect infrared radiation emitted by objects, also used to detect the presence or absence of objects without physical contact. In the system it will be used inside the main bin to check whether there is an object dropped in the bin or no. (See Figure 5.11)

- **LCD with I2C module**

2 LCD 16*2 has been used with I2C to indicate the levels for each bin, and also to display some messages and the entered ID for the user. (See Figure 5.12).

- **A4899 Stepper Motor Driver**

A4899 Stepper Motor Driver provides precise control over stepper motors, allowing for step-by-step movement and position control. It supports micro-stepping, and adjustable current limiting (See Figure 5.13).

Figure 5.11: Infrared Tx and Rx sensors

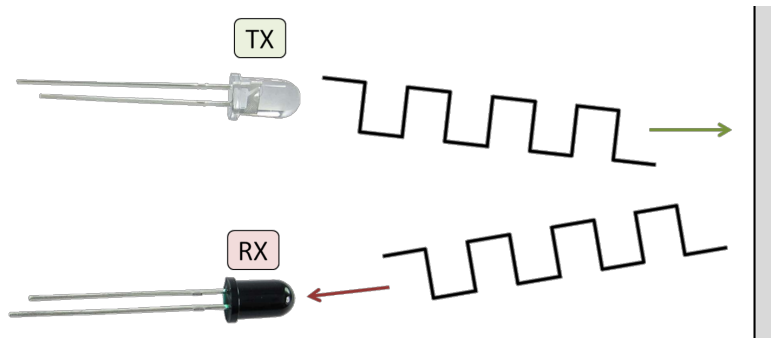


Figure 5.12: 16*2 LCD with I2C

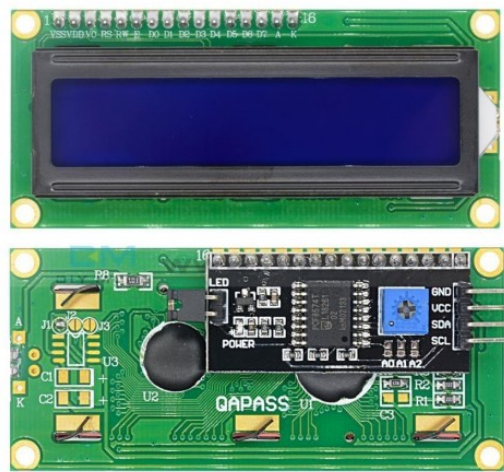
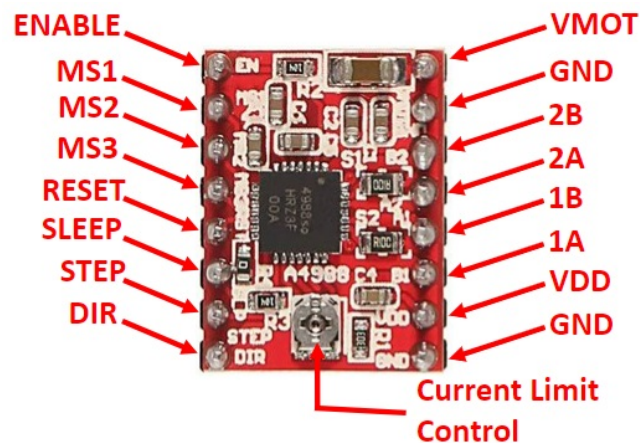


Figure 5.13: A4899 Stepper Motor Driver



- **Power Sources**

Many power sources used in this project including batteries and USB cables that are connected to a computer or a suitable power adapter.

Chapter 6

Results and Discussions

Waste management procedures were enhanced as a result of the introduction of rubbish classification. Users don't need to have a deep understanding of trash segregation when using the automatic sorting option to place their waste in the right compartments. In addition to encouraging recycling, this lightens the load on waste management facilities. The system's gamification feature has shown to be quite successful at encouraging users to adopt sustainable trash management techniques. Users were incentivized to actively participate in garbage classification, appropriate disposal, and recycling programs by adding a component of competition, achievement, or prizes. This had a favorable effect on the environment, raised awareness, and improved trash segregation. Additionally, the incorporation of gamification components and mobile technologies into a smart trash can system that includes waste classification and QR code sign-in has the potential to increase user engagement and foster a favorable environmental impact.

6.1 Learning

When it came to developing the project, we possessed talents that we never anticipated having, from the ability to use and connect electronic components to the precise and diligent search and building that we put in.

6.2 Challenges

- **Garbage Classification Accuracy:** The variety of waste materials, such as similarly-looking products or damaged goods that may be more difficult to classify accurately, makes it difficult to achieve high accuracy in rubbish categorization.
- **User Engagement and Behavior:** It can be difficult to encourage users to dispose of trash properly because doing so calls for the creation of user-friendly interfaces, detailed instructions, and tools that allow for active involvement in waste classification.
- **32-bit based systems:** Some libraries and devices had crash and didn't work appropriately due to the 32-bit based system, so as a solution we change the Raspberry pi OS to 64-bit.

Chapter 7

Conclusion and Recommendations

7.1 Conclusion

As a result of the integration of machine learning, computer vision, and user participation, the "Greeny" project represents a sizable jump in trash management. By tackling the issues of garbage variability, real-time processing, user behavior, and scalability, Greeny encourages environmental awareness among people and gives them the power to actively participate in responsible waste disposal. Greeny turns waste into a useful resource by accurately classifying different sorts of trash, paving the way for a sustainable future. The initiative establishes a precedent for reducing environmental pollution and promoting sustainable practices and shows how effectively sophisticated technologies can be used in trash management.

7.2 Recommendations

Although dealing with electronic components wasn't that hard to configure, things should be focused on the cost, courses, and libraries that need to be provided that help to make things more understandable and low the learning curve and saving time.

7.3 Future work

The project is at the start of development, so we can add more features to make the project more efficient.

- Explore additional waste classification categories beyond glass, metal, and plastic.
- Detecting the current location of the trash, and connect it with web application, that will shows which one needs maintenance, or emptying.
- Sensor Integration: IoT-enabled sensors can be placed in or near trash cans to detect the presence of mobile devices in proximity. These sensors can utilize technologies like Bluetooth Low Energy (BLE) or RFID to establish a connection with nearby mobile devices.

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