ISSN 2278-3091
Volume 12, No.6, November - December 2023
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse011262023.pdf
https://doi.org/10.30534/ijatcse/2023/011262023

# A Prototype of Smart Plastic Bottle Recycle Machine Using IoT

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Received Date : October 18, 2023 Accepted Date: November 23, 2023 Published Date: December 06, 2023

**ABSTRACT**

The growing concern over plastic pollution and its adverse impact on the environment has prompted the development of innovative solutions to address the issue effectively. Improper disposal of plastic bottles leads to environmental pollution. This paper presents the design and implementation of a prototype of smart plastic bottle recycle machine, integrating the Internet of Things (IoT). The Arduino board is used to control the machine. The smart plastic bottle recycling machine incorporates the ESP8266 and a Wi-Fi enabled system-on-chip (SoC) module used to develop IoT embedded applications. The utilization of IoT technology enables seamless real-time data transmission, allowing for efficient communication with the central system and simpliying remote monitoring and management processes. The IoT-enabled sensors and cameras capture information about the plastic bottles, such as their material, size, and condition. Thus, it makes recycling easy and satisfying, which motivates people to get involved in recycling activities. Moreover, implementing a point system that rewards individuals for their recycling efforts not only serves as an extra motivation for users, but also encourages them to actively participate in the preservation of the environment. Therefore, this prototype demonstrates the potential to foster sustainable recycling practices, which is a promising first step towards a future that prioritizes environmental consciousness.

**Key words :** Internet of Thing (IoT), Plastic bottle, Prototype, Recycling

## 1. INTRODUCTION

Plastic waste has become a global environmental challenge, contributing to pollution and harming ecosystems. A serious and complicated issue for the environment is plastic bottle waste. Despite their convenience and widespread use, these bottles have far-reaching and long-lasting negative impacts on ecosystems and human health. High demand for the manufacture of plastic bottles results in the loss of priceless natural resources and a continued reliance on unsustainable energy sources. The main issue is that ingredients from drinks as well as potentially dangerous compounds from containers used improperly to store domestic cleaners or gardening chemicals could be absorbed into the polymer. Thus, plastic pollution is becoming a major problem that contaminates land, rivers, lakes, and the oceans. Animals may consume or become entangled in plastic trash, endangering their health as well as the health of marine and terrestrial ecosystems. Moreover, the improper disposal of plastic bottles, in particular, poses a significant threat to our planet. Meanwhile, the waste management systems are overburdened and landfills are overflowing as a result of the low recycling rates for plastic bottles. Nevertheless, recycling is the only way to make a sustainable environment [1]. In addition, reusing and recycling materials has long-term advantages by extending their useful lives.

Recycling plastic bottle is essential for several reasons, including the fact that it combats the environmental problems caused by plastic waste and helps to create a more sustainable future. However, existing waste plastic bottle recycling equipment has shortcomings such as low utilization rate, poor user experience, and unavoidable fraud behavior [2]. In Malaysia, even after launching a new waste management programme since 1993, the recycling rate in households is still low as 15.4% [3]. According to [4] although 100,000 free dustbins were given to each household in several cities in Malaysia, the public still disposed of their waste irresponsibly. Thus, an automatic smart recycle bin can encourage people to recycle in the right recycle bin and developing the culture of recycling in our society [5]. Therefore, by incorporating recycling into our daily routines and supporting recycling initiatives, we can reduce the damage that plastic waste does to the ecosystem. In order to address the growing environmental issues caused by plastic bottle waste, an effective bottle recycling system is needed. A study by [6] stated that recycle plastic can be used as raw material in different industries, such as automotive, concrete, textiles, and others. Nevertheless, the process of recycling of plastics is quite complex when compared to recycling of other materials like paper, glass and metals [7]. Thus, it is necessary to build an effective recycling mechanism as plastic bottle consumption rises. In response to this growing concern, innovative technologies have emerged to combat plastic pollution and promote sustainable practices.

As a result, this paper proposes a prototype of smart plastic bottle recycle machine to protect and preserve the environment. This approach can be seen as a prototype that have a great potential to contribute to the environment's long-term improvement and pave the way for a brighter and eco-friendly future. There are seven sections in this paper. Section 2 introduces the literature review. Section 3 describes the prototype design; Section 4 shows the implementation of the smart recycle plastic bottle machine; and Section 5 shows the prototype's testing. The discussion of the system is presented in Section 6. The paper is finally concluded in Section 7.

## 2. LITERATURE REVIEW

With a growing awareness of the pressing need for sustainable practices, the focus on recycling bottles emerges as a crucial avenue to reduce resource depletion, curb plastic litter, and contribute to a cleaner and healthier environment. Numerous studies have undertaken comparisons of the environmental and economic impacts of various recycling technologies, as well as evaluations of different methods for reprocessing reclaimed polyethylene terephthalate (PET) resins [8]. For instance, [9] devised a system of returnable bottles and cans where users deposit their bottles into a machine, receiving the corresponding value for the returnable container. The system is equipped with an IoT control device, a Raspberry PI, to enable connectivity. A study by [10] presented CleverTrash, a recycle bin integrated with material recognition algorithms for PET, cardboard, plastic packaging, and various waste materials, aiming to promote proper recycling practices.

According to a study by [11] proposed the smart recycle bin to give a reward to public user who thrown the recyclable waste into the innovated smart recycle bin by giving points. By integrating a point-based reward system, the project aimed to encourage widespread participation in recycling initiatives. The implementation of this system in a web-based environment provided accessibility for both the public users and waste authorities, fostering a collaborative approach to waste management. Expanding on this concept, a study by [12] introduced the Smart Bottle Recycle Machine (SBRM), a sophisticated innovation engineered on a Field Programmable Gate Array (FPGA). This machine was designed to efficiently process and segregate different types of bottles, leveraging advanced technology such as essential sensors, infrared object detection, and rain sensors. The SBRM represented a significant leap forward in the accurate identification and classification of recyclables, streamlining the recycling process and minimizing contamination.

Another study by [13] contributed a comprehensive smart system that integrated a diverse array of sensors to precisely assess and differentiate various types of bottles. By combining infrared object detection with rain sensor integration, the system demonstrated enhanced accuracy in the identification of recyclables, thus optimizing the sorting process and contributing to increased efficiency in waste management. In a more recent development, a study by [14] introduced a paradigm-shifting approach to the recycling industry with their blockchain-based framework. By leveraging smart contracts, their system automated the intricate flow of recovery, transportation, recycling, and distribution of recyclables in the market. Users were incentivized through the allocation of rewards in their digital wallets, effectively fostering active participation in recycling practices. This innovative model aimed to transform the perception of waste from mere disposables to valuable resources, promoting sustainability and reinforcing the integration of recycling in the global industrial ecosystem. A study by [15] proposed design of machine accepts plastic bottles as input and reward the user with credit points that can be useful for online shopping. The user and authority can keep track of their details by maintaining an account in the application software developed. Once the machine at a specified location is filled, this could be notified to the authority via messaging through the application.Through these significant milestones in the evolution of smart recycling, the intersection of technological advancements, incentivized participation, and automated management has paved the way for a more sustainable and environmentally conscious future. Based on the previous studies, the study emphasizes the significance of reward-based recycling systems as essential tools in raising environmental awareness among individuals. Therefore, the goal of this study is to design a prototype of smart recycling system based on IoT. It will reward people for recycling in order to encourage them to safeguard the environment.

## 3. PROTOTYPE DESIGN

This section describes the design of smart plastic bottle recycle machine. Figure 1 shows the basic framework or structure of the proposed prototype. The smart recycle machine, designed using the IoT, comprises a series of interconnected components and processes working cohesively to efficiently manage and recycle plastic bottles.

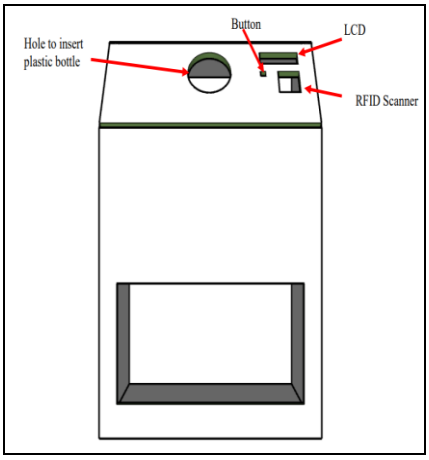


**Figure 1:** Smart Recycle Plastic Bottles Framework

Figure 2 shows the measurements and size of the proposed prototype. The figure outlines the overall dimensions of the proposed prototype, including its height, width, and depth. This information is essential for understanding the space requirements and ensuring that the machine can fit into the intended environment.

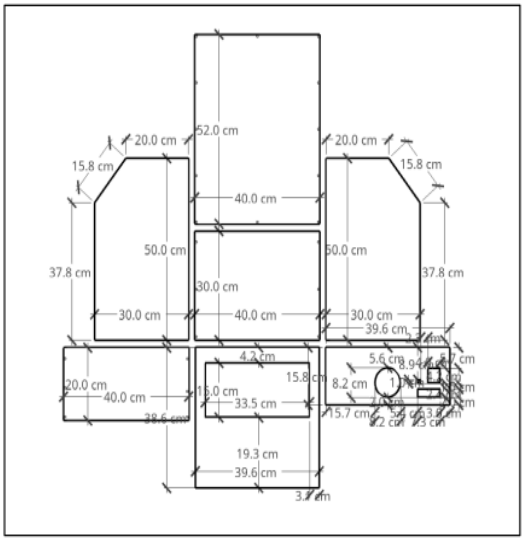


**Figure 2 :** Prototype Sketch Diagram

Based on the framework, Figure 3 depicts the development of smart plastic bottle recycle machine.

**Figure 3:** Smart Recycling Machine Prototype

The machine utilizing IoT technology brings automation, optimization, and connectivity to the recycling process as shown in Figure 4. A microcontroller-based platform called an Arduino board provides an open-source electronics prototyping and development environment. Arduino board is the main component used to control the system. It can receive data from sensors and other devices, process it, and control other components because it has input and output ports.

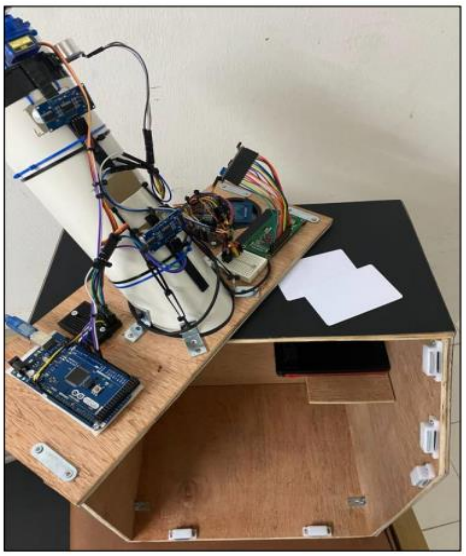

**Figure 4 :** Smart Recycling System Controller and Components

The main functions of an Arduino board as follows:

i) **Input/Output (I/O) Interface:** Arduino boards feature a variety of digital and analog input/output pins that allow them to interact with the physical world. These pins enable the connection of sensors, switches, LEDs, motors, and other electronic components.

ii) **Sensor Interfacing:** Arduino boards can interface with a wide range of sensors, including temperature sensors, light sensors, motion sensors, and many more. This enables the board to collect data from the surrounding environment for various applications.

iii) **Actuator Control:** Arduino boards can control actuators such as motors, lights, and other output devices. This allows them to create physical outputs or trigger actions in response to specific input conditions or commands.

iv) **Data Processing:** The microcontroller on the Arduino board processes the data received from sensors and performs computations or logic operations based on programmed instructions.

v) **Communication Protocols:** Arduino boards can communicate with other devices or systems using various communication protocols such as serial communication, I2C (Inter-Integrated Circuit), SPI (Serial Peripheral Interface), and UART (Universal Asynchronous Receiver-Transmitter). This allows them to interact with other devices, including other microcontrollers, computers, or the internet.

vi) **Programming and Customization:** Arduino boards can be programmed using the Arduino Integrated Development Environment (IDE), which is based on a simplified version of C and C++. This allows users to customize the behavior

of the board based on specific project requirements.

vii) **Prototyping and Development:** Arduino boards are widely used for rapid prototyping and the development of interactive electronic projects.

viii) **Compatibility with Various Shields and Modules:** Arduino boards are compatible with a range of expansion modules and shields, which are add-on boards that provide additional functionalities such as wireless communication, motor control, and displays, enabling users to extend the capabilities of the Arduino platform.

Therefore, the design of smart plastic bottle recycle machine based on IoT involves a comprehensive integration of various components and technologies to enhance the efficiency and effectiveness of recycling processes.

## 4. IMPLEMENTATION

After the design is completed, the implementation of the system is carried out. In this project, the Arduino IDE is used to write and upload programs to Arduino compatible boards for smart recycling system controller. Then, the IoT-enabled sensors and cameras capture information about the plastic bottles, such as their material, size, and condition. This data is then transmitted to the central processing unit of the smart recycling system through the internet or a local network. The network gateway serves as the intermediary between the system and the MySQL database, facilitating communication and data exchange between the two components. Its primary function is to enable seamless and secure transmission of information, ensuring that the data collected by the system is appropriately stored, retrieved, and managed within the MySQL database. By integrating real-time monitoring, and user interaction, it enhances the overall efficiency and effectiveness of recycling efforts, contributing to a more sustainable waste management system. Figure 5 shows the architecture of the smart recycling system.

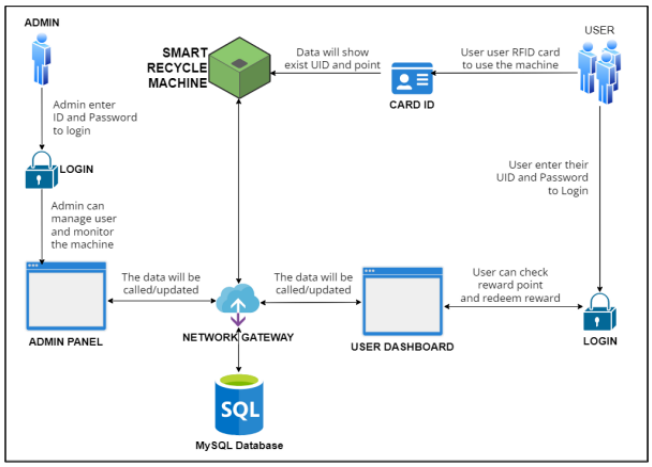


**Figure 5:** Architecture of the Smart Plastic Bottle Recycle Machine

Meanwhile, the central component of this project acts as a connector between the smartphone and the lock, utilizing Wi-Fi connectivity. In addition, an ultrasonic sensor is employed to measure the distance to an object using ultrasonic sound waves. For seamless operation and connectivity, the smart plastic bottle recycle machine incorporates the ESP8266, a Wi-Fi-enabled SoC module developed by Espressif Systems is used for developing IoT embedded applications. The ESP8266 is used because of the low-cost and low-power module gained due to its versatility and ease of use. To enable the entry and usage of the plastic bottle recycling machine, a radio frequency identification (RFID) reader is utilized to scan the user ID. Before using the system, users are required to register, allowing the system to save their data into the user database automatically. Upon registration, users must scan their card ID at the machine to gain access as shown in Figure 6.

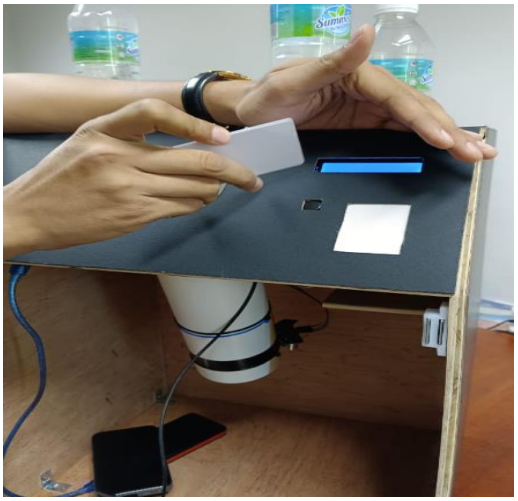

**Figure 6:** Scan the user ID

Afterthat, users will receive a unique user ID, allowing them to access and utilize the recycling service effortlessly as shown in Figure 7.


**Figure 7 :** Registration Page

After verification of their account, users are given the option to insert plastic bottles. When the user inserts an object into the system, the camera inside the machine starts capturing the images. The machine will detect whether the object inserted is a plastic bottle. If it is, points will be added to the user's account.

The machine does not compute the points for non-plastic. Users will be able to request a recycling service via the webpage's request area. This will require them to enter their location, and how many bottles they want to recycle. The recycler will arrange for a pickup of the bottles if a request is made as shown in Figure 8.

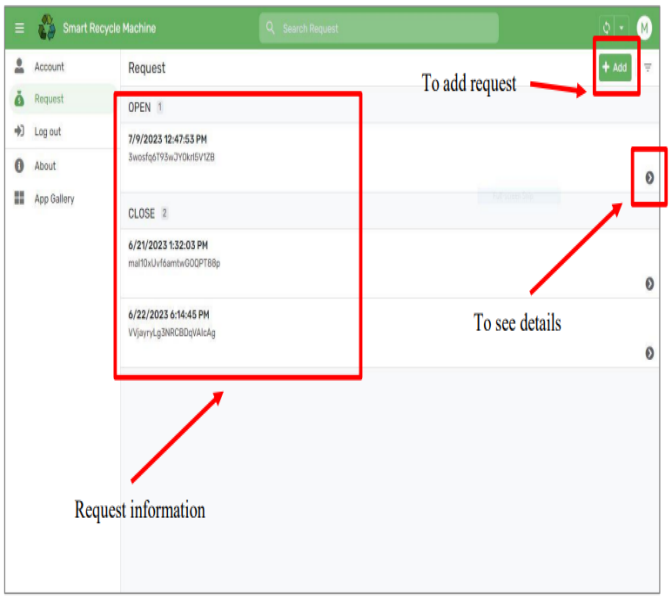


**Figure 8:** Smart Recycle Machine page

Finally, users have the option to redeem rewards through the dedicated webpage, as depicted in Figure 9. The system then calculates the reward points based on the updated contact information and the bottle's measured weight that are stored in the database.

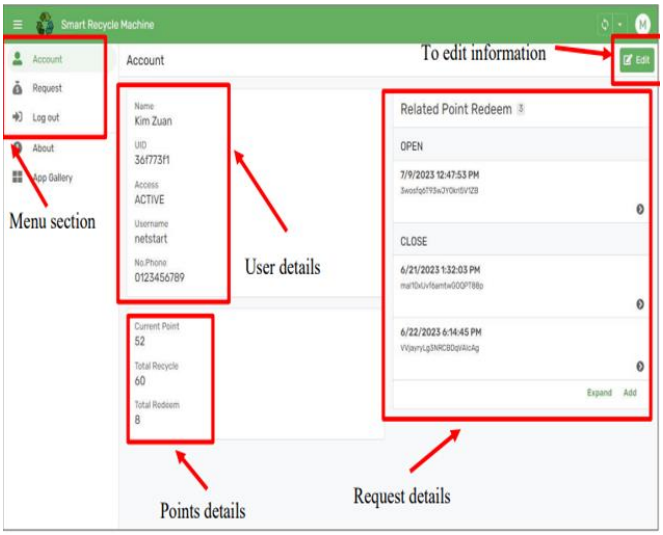


**Figure 9:** Request page

Thus, the smart recycling machine might provide its customers with an interactive interface and rewards for recycling activities. This encourages participation and encourages more people to recycle.

## 5. TESTING

Testing plays a vital role in refining the user interface and optimizing the user experience of the smart recycling system. Through thorough testing and analysis, the recycling process is designed to be intuitive and user-friendly, ensuring that users can effortlessly navigate the system. Table 1 shows the test cases of the smart plastic bottle recycle machine, with involvement from the stakeholder conducting the tests.

**Table 1:** Smart Plastic Bottle Recycle Machine Testing

| Test ID | Test Approach | Test Scenario | Actual Result | Expected Result | Pass/ Fail |
|---|---|---|---|---|---|
| T1001 | Performance | How long the machine recognise the bottle requirements? | Take less than 15 seconds | Took less than 15 seconds | Pass |
| T1002 | Performance | High traffic | Can handle high traffic | Yes | Pass |
| T1003 | Performance | Time taken to respond during the entire process, from inserting the bottle to getting points. | 5 seconds | 3 seconds | Pass |
| T1004 | Performance | RFIDscanner can scan and identify correctly | RFID scanner well performed | Yes | Pass |
| T1005 | Performance | Test without non-rfid card | Machine needs rfid card to perform | Yes | Pass |

The results indicate an overall successful performance of the smart plastic bottle recycle machine. The machine efficiently recognized bottle requirements within the specified time frame, even under high traffic conditions. In addition, the response time was good within the specified range from bottle insertion to point received. The RFID scanner also demonstrated accurate and reliable scanning capabilities, ensuring proper identification.

The test further confirmed the necessity of an RFID card for the machine's functionality, thereby emphasizing the system's security measures and adherence to its designed protocols. Overall, the machine successfully passed all the defined test scenarios, affirming its robustness and reliability in handling plastic bottle recycling operations.

## 6. DISCUSSION

The prototype has been successfully built, and the entire system functions effectively based on extensive testing. It is designed to provide a comprehensive solution to various aspects of recycling. It consists of IoT-enabled collection bins with fill-level sensors and communication modules installed, enabling effective waste collection and real-time monitoring. The implementation of prototype machine offers numerous advantages. It contributes to a more sustainable and environmentally friendly recycling process by lowering operational costs and energy consumption through the optimisation of garbage collection routes and schedules. In addition, redeem functions in smart plastic bottle recycle machine allow stakeholders to give consumers a more rewarding and engaging recycling experience. This helps to build a sustainable recycling culture and supports worldwide efforts to reduce waste and promote environmental conservation.

## 7. CONCLUSION

In conclusion, the adoption of the smart plastic bottle recycle machine is an important step towards solving the problems associated with contemporary waste management. In addition, the implementation of the smart recycling system has significantly improved the efficacy and precision of trash management. Thus, the machine has completely changed how recycling processes are controlled, tracked, and optimised by utilising IoT technologies. In addition, this prototype machine fosters community involvement and promotes environmental awareness. It achieves this by seamlessly incorporating state-of-the-art technology, user friendly interfaces, and reward driven initiatives, thereby optimizing the recycling process. Furthermore, the emphasis on user engagement through the redeem function encourages individuals to take an active role in recycling efforts by providing tangible incentives and rewards for their contributions. This approach teaches and increases knowledge about the environmental effects of recycling. Therefore, this prototype machine can lead to a future that becomes more resource-efficient and environmentally friendly, helping to protect our environment for future generations.

## ACKNOWLEDGEMENT

The authors gratefully acknowledge the research support provided by the Universiti Selangor (UNISEL).

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