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Eco-Friendly Bottle Reverse Vending Machine

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Abstract*: The Bottle Dispenser is an automated recycling system designed to promote waste management and environmental sustainability. It efficiently detects, weighs, classifies, and rewards users based on the type and weight of the bottle they deposit. The system is powered by an ESP32 microcontroller, which processes data from multiple sensors and controls motorized operations. An IR sensor detects the presence of a bottle, while a load cell measures its weight. A metal sensor determines whether the bottle is metal or non-metal, and two servo motors direct the bottles into their respective collection bins. To encourage recycling, the system rewards users based on the weight of the deposited bottle. A third servo motor activates a coin dispenser to provide a corresponding reward. Additionally, an LCD display presents real-time system updates, including bottle type, weight, and reward details, ensuring a transparent and interactive user experience. The system can be deployed in public spaces such as malls, parks, offices, and recycling stations to promote responsible waste disposal and incentivized recycling.*

I.INTRODUCTION

With the rapid increase in plastic and metal waste, effective recycling methods have become essential for environmental sustainability. Traditional recycling methods often require manual sorting, which is inefficient and labor-intensive. The Bottle Dispenser is an automated system designed to address these challenges by promoting recycling through an interactive and rewarding process. By integrating smart technology, the system efficiently detects, classifies, and sorts bottles while providing users with incentives for responsible disposal. This not only helps reduce environmental pollution but also encourages the adoption of recycling habits among the general public.

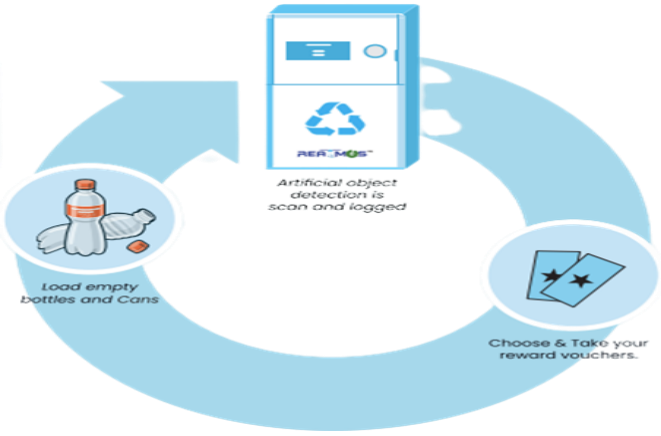


Fig1. Reverse bottle vending machine process

The Bottle Dispenser operates using an ESP32 microcontroller, which serves as the core processing unit, managing sensor inputs and motorized actions. The system is equipped with an IR sensor to detect the presence of a bottle, a load cell to measure its weight, and a metal sensor to differentiate between metal and plastic bottles. Based on the collected data, servo motors guide the bottles into separate collection bins to ensure effective sorting. This automated mechanism significantly enhances the recycling process by minimizing human intervention and errors. To make recycling more engaging, the Bottle Dispenser incorporates a reward system where users receive a coin reward based on the weight of their deposited bottle. A servo motor controls the coin dispenser, which releases a reward once the bottle has been classified and disposed of. The entire process is displayed on an LCD screen, providing real-time feedback on bottle type, weight, and the reward earned. This interactive approach encourages individuals to participate actively in recycling, making it an efficient and user-friendly solution.

Our key objectives are to:

- The Bottle Dispenser has the potential for future enhancements that could further improve its efficiency and scalability.
- For instance, integrating a mobile application would allow users to track their recycling history and receive digital rewards instead of physical coins.
- Solar-powered operation could make the system more energy-efficient, contributing to overall sustainability.
- With continued advancements and modifications, the Bottle Dispenser can serve as a model for smart recycling initiatives worldwide.

II.LITERATURE SURVEY

A review of the existing literature on Bottle Reverse Vending Machines (RVMs) indicates their growing importance in managing plastic waste and promoting sustainable recycling practices. RVMs are automated systems that accept used beverage containers, identify and sort them using technologies such as barcode scanners, weight sensors, and image recognition, and provide monetary or reward-based incentives. Research highlights their effectiveness in encouraging public participation in recycling, especially when integrated with user-friendly interfaces and mobile apps. Studies also emphasize the incorporation of IoT for real-time monitoring and data collection, which helps in optimizing maintenance and collection logistics. Recent advancements explore solar-powered and AI-enabled RVMs for enhanced environmental performance and automation, aligning with smart city and circular economy goals.

A. Hardware based design and implementation of a bottle recycling machine using FPGA

Using an FPGA platform, the study describes the hardware-based design and implementation of a Smart Bottle Recycling Machine (SBRM)**[1].** This device uses a low-cost ultrasonic range sensor to detect and count plastic bottles, in contrast to traditional reverse vending machines that depend on intricate picture processing. The design prioritizes functionality and cost-effectiveness. The system, which uses Verilog HDL to implement on the Altera DE2-115 board, gives users points for recycling. High-speed parallel processing is guaranteed by the usage of FPGA, providing a productive substitute for systems based on microcontrollers. Real-time performance, environmental advantages, and lower production costs are all demonstrated by the suggested SBRM prototype.

B. A Reverse Vending Machine for Sorting Yoghurt Cups and PET Bottles

For the Sri Lankan waste management environment, the study suggests a reverse vending machine (RVM) that can sort PET bottles and yoghurt cups according to the type of plastic **[2].** It overcomes the drawbacks of traditional RVMs, which usually don't distinguish between different types of plastic. For efficient separation, the suggested system combines a gravity-based transfer mechanism with Near-Infrared (NIR) plastic identification technology. In order to promote user engagement, an appropriate reward-based incentive model is also presented. The design seeks to promote Sri Lanka's specialized recycling industry and increase recycling efficiency.

C. Using paper prototyping to assess the perceived acceptance of Med Mate: A home-based pill dispenser

Using early-stage paper prototype and user evaluation, the study investigates how well-liked Med Mate, a pill dispenser that can be used at home, is **[3].** To evaluate its usability and user concerns, a user study was carried out utilizing a questionnaire based on the Technology Acceptance Model (TAM) and follow-up interviews. The results showed favourable opinions on the device's practicality and usability. Although they voiced worries about the device's price, mobility, dependability, security, privacy, and medicine compatibility, more than two-thirds of participants said that they would be willing to adopt it. These findings support earlier research on medical devices that are used at home and guide future design decisions for comparable healthcare.

D. Arduino Based Automatic Hand Sanitizer Dispenser System

The hand sanitizers are playing major role in people’s life when the corona virus had started infecting all around the world. To not infecting the corona virus there are some precautions to be followed among that hand sanitizer is one among them. Hand sanitizers contains liquid in the bottle where the liquid is going to sanitize the hands. Hand sanitizes are normally worked as when we press one pump to get the liquid out of it. This effects people when one comes pressed to bottle and another person may also come contact to the bottle where the people gets infected with the virus. Some sanitizers are automatically pumped. The sanitizer’s containers and pumps are designed with some products which is manufactured. If container completes sanitizer then the consumers may refill it.

III. PROBLEM STATEMENT

Plastic and metal waste pollution has become a significant environmental challenge worldwide. Improper disposal of bottles contributes to land and water pollution, affecting ecosystems and human health. Despite existing recycling programs, a lack of public awareness, inefficient manual sorting methods, and limited incentives for participation hinder effective waste management. Traditional recycling systems require human intervention to separate plastic and metal bottles, leading to errors, increased labour costs, and inefficient resource utilization. To address these issues, an automated Bottle Dispenser system is needed to streamline the recycling process. The system must detect and classify bottles accurately using smart sensors, automate sorting to minimize human involvement, and provide incentives to encourage public participation. By integrating modern technologies such as an ESP32 microcontroller, IR sensors for bottle detection, a load cell for weight measurement, and a metal sensor for material classification, the system ensures precise sorting and proper disposal.

IV. PROPOSED METHODOLOGY

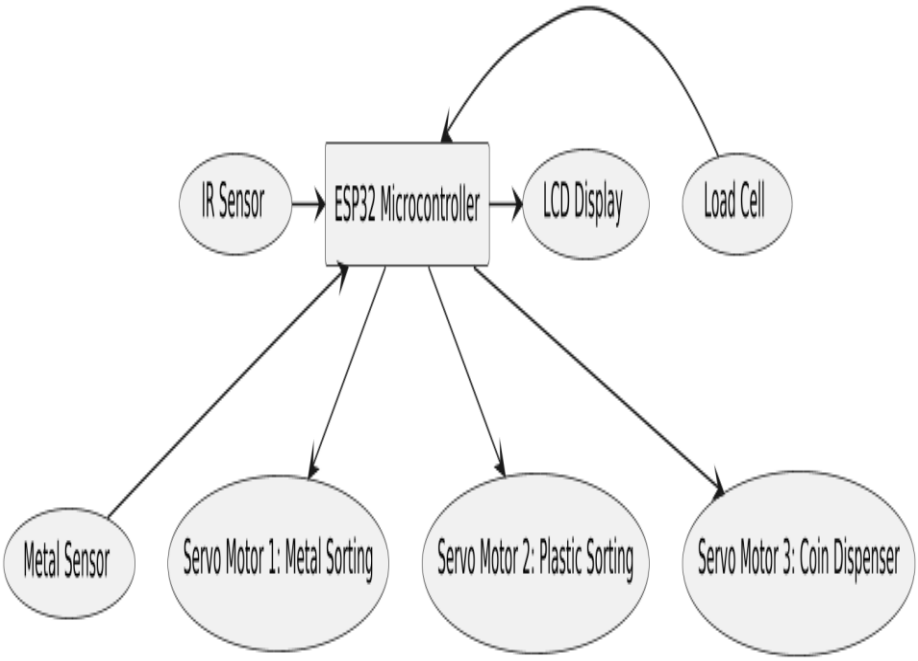


Fig.2: Proposed Block diagram

The Bottle Dispenser system follows a structured approach to automate bottle detection, classification, and reward distribution. The methodology involves multiple stages, including sensing, processing, sorting, and dispensing rewards, all controlled by an ESP32 microcontroller.

A. Bottle Detection and Classification

The system begins with an IR sensor that detects the presence of a bottle when placed in the designated slot.
Once detected, a load cell sensor measures the weight of the bottle to determine its material type and ensure it is within the required limits for processing.
A metal sensor then classifies the bottle as either metal or non-metal (plastic) based on its conductivity.

B. Sorting Mechanism

Based on the classification, two servo motors are used to direct the bottle into the appropriate collection bin:
If the bottle is metal, the first servo motor moves the bottle into the metal collection bin.
If the bottle is plastic, the second servo motor moves it into the plastic collection bin.

C. Reward Dispensing System

After successful classification and disposal, the system calculates the appropriate reward based on the weight of the bottle.
A servo motor controls the coin dispensing mechanism, releasing a coin as an incentive for proper disposal.

D. User Interface and Feedback

An LCD display provides real-time feedback to the user, displaying messages such as:
"Bottle Detected"
"Processing..."
"Metal Bottle Detected" / "Plastic Bottle Detected"
"Coin Dispensed"
This enhances user engagement and ensures transparency in the recycling process.

E. Power Supply and System Integration

The entire system is powered by an appropriate DC power supply to ensure consistent operation.
The ESP32 microcontroller integrates all components, processes sensor data, controls servo motors, and manages the reward mechanism efficiently.

F. Future Enhancements and Scalability

The system can be expanded by integrating a mobile application to track users' recycling history and provide digital rewards.
AI-based object recognition can be introduced to improve the accuracy of material classification.
The system can be made solar-powered to enhance energy efficiency and sustainability.

The Bottle Dispenser methodology ensures an efficient, automated, and user-friendly approach to waste Management. By combining IoT, smart sensors, and reward-based incentives, the system promotes responsible recycling habits while reducing environmental pollution.

Hardware Components:

- **ESP32** – The ESP32 microcontroller acts as the central processing unit, managing inputs from all sensors and controlling the system's operations.
- **Power Supply** – A stable power supply ensures continuous and reliable operation of all electronic components in the reverse vending machine.
- **LCD Display** – The LCD display provides user feedback by showing instructions, status updates, and reward messages.
- **IR Sensor** – The IR sensor detects the presence of a bottle at the insertion point, initiating the processing cycle.
- **Load Cell** – The load cell measures the weight of the bottle to verify its validity and prevent misuse of the system.
- **Metal Sensor** – The metal sensor identifies the material type of the inserted container, helping to distinguish between plastic and metallic bottles.

Software Components:

- Arduino IDE – Arduino IDE is used to write, compile, and upload code to the ESP32 for controlling the system functions.
- Embedded C – Embedded C is the programming language used to develop firmware that handles sensor data processing and device control.

V.FLOWCHART

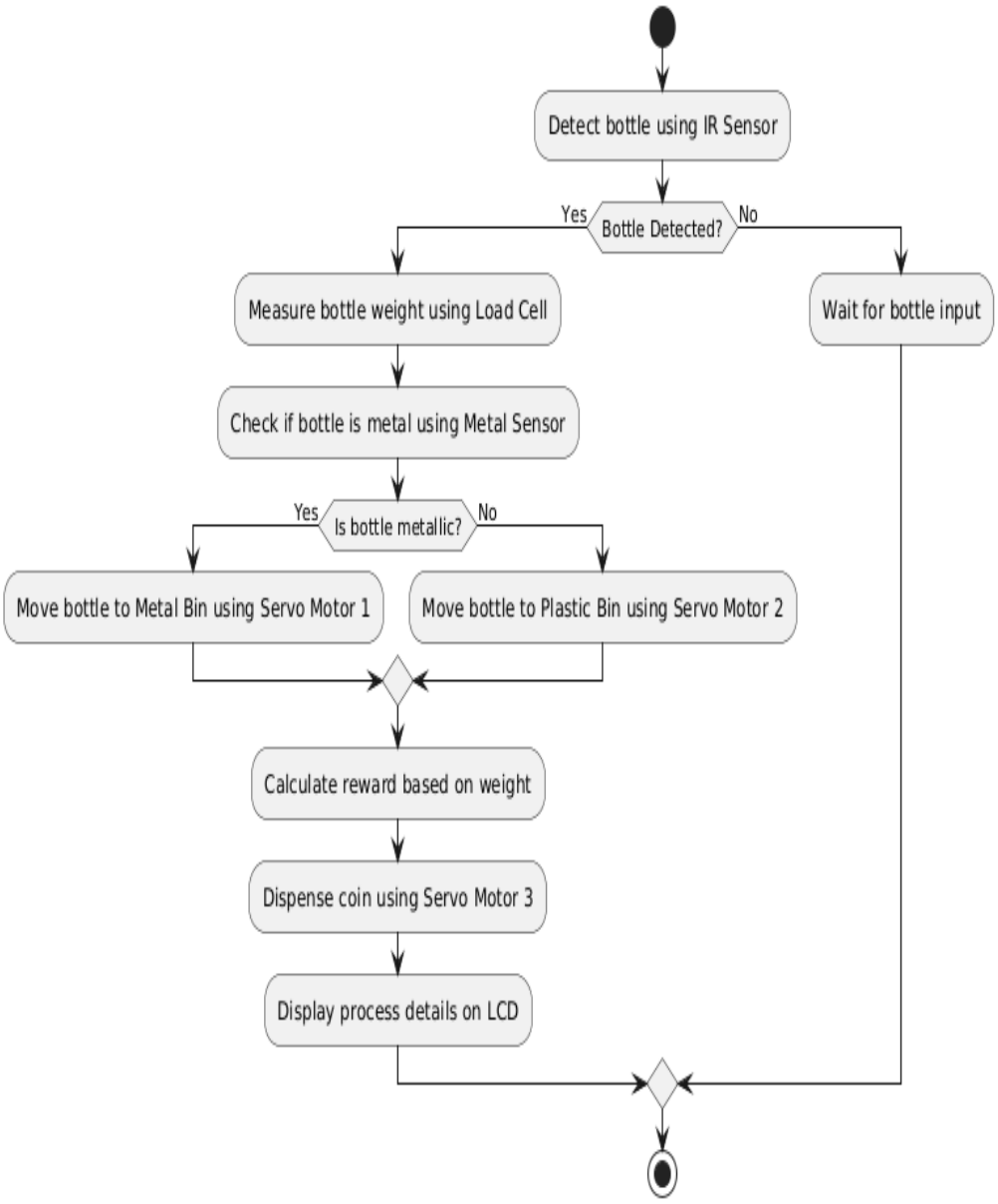
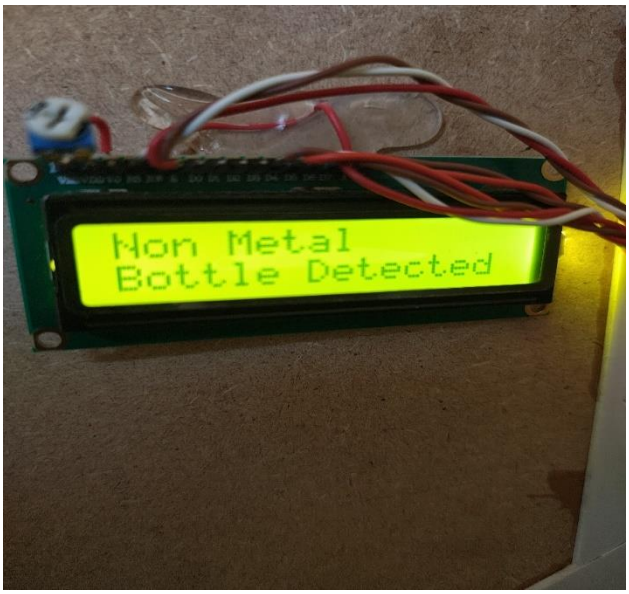


Fig.3: Proposed Flow Chart

VI.RESULTS AND DISCUSSION



Using load cell measurements and infrared sensors, the machine will precisely identify and count plastic bottles.With a metal sensor, the system will differentiate between plastic and non-plastic materials to make sure that only legitimate objects are allowed. Updates like bottle counts, award messages, and item validation will be shown to users in real time on the LCD display. To promote user involvement, the system will award virtual coins for every valid bottle deposited.

VII.APPLICATIONS

1. Public Spaces & Urban Areas – Can be installed in parks, shopping malls, railway stations, airports, and bus stops to encourage recycling in high-footfall areas.
2. Educational Institutions – Schools and universities can use the system to teach students about waste management and promote eco-friendly habits.
3. Corporate Offices & Workplaces – Encourages employees to recycle plastic and metal bottles, contributing to a sustainable work environment.
4. Supermarkets & Retail Stores – Can be placed in retail stores where customers return bottles and receive discounts or loyalty points as incentives.
5. Recycling Centers – Automates the sorting process for plastic and metal bottles, improving efficiency and reducing manual labor.
6. Events & Stadiums – Useful in large gatherings, concerts, and sports stadiums to manage waste effectively and prevent littering.
7. Hospitals & Healthcare Facilities – Helps in the proper disposal of plastic waste generated from packaged drinking water and other medical consumables.
8. Smart Cities & Government Initiatives – Can be integrated into smart waste management systems to promote sustainability and urban cleanliness.

VIII.CONCLUSION AND FUTURE WORK

The Bottle Dispenser project presents an innovative and automated approach to waste management, promoting recycling through a smart and efficient system. By integrating an ESP32 microcontroller, IR sensors, load cells, metal sensors, and servo motors, the system effectively detects, classifies, and sorts plastic and metal bottles. The inclusion of a reward mechanism encourages individuals to participate in recycling, fostering environmentally responsible behavior. Additionally, the LCD display enhances user interaction by providing real-time feedback on the recycling process.This system not only streamlines waste segregation but also reduces human intervention, making the recycling process more efficient and accurate. The implementation of IoT technology ensures scalability and adaptability, enabling integration with future advancements such as AI-based material recognition, digital rewards, and remote monitoring. By deploying the Bottle Dispenser in high-traffic areas, such as malls, schools, and offices, widespread adoption can significantly contribute to reducing plastic and metal waste in the environment.

Future enhancements of bottle reverse vending machines can significantly improve efficiency, user engagement, and environmental impact. One major advancement is the integration with mobile applications, allowing users to track their recycling activity, earn digital rewards, and gain insights into their environmental contributions. Implementing AI-based bottle recognition through advanced machine learning algorithms can improve classification accuracy and reduce sorting errors. To modernize the reward system, digital payment options and wallet integration can replace physical coin dispensing, offering users more convenient and versatile incentives. Solar-powered operation can further enhance sustainability by reducing the machine's reliance on grid electricity. Additionally, the machine can be upgraded to detect and segregate multiple materials, such as aluminum cans, glass bottles, and paper packaging, thereby increasing its utility.

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