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Smart Recyclable/Non- Recyclable Product Sorting Garbage Bin

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Abstract

As the global population continues to grow, efficient waste management and sustainable practices have become paramount for environmental preservation. This paper introduces an Intelligent Waste Segregation and Management System that capitalizes on artificial intelligence and image processing. This model offers a holistic approach to discerning recyclable and non-recyclable waste items. Key components of the proposed system encompass a smart garbage bin fitted with integrated cameras and an image processing unit, complemented by a machine learning model trained on a diverse array of waste item images. When a waste item is placed into the smart bin, the integrated camera captures an image, subsequently processed by the image processing unit. The machine learning model classifies the item as recyclable or nonrecyclable, directing it accordingly. This model offers numerous advantages: heightened waste segregation precision, augmented recycling rates, and curbed landfill waste. Moreover, it simplifies waste disposal for users, requiring minimal effort. The system's potential to bolster environmental sustainability is substantial, aligning with global waste mitigation endeavors. In summary, the Intelligent Waste Segregation and Management System showcased in this paper promises an effective, scalable solution for surmounting waste management challenges, embodying a significant stride toward eco-conscious waste disposal.

Keywords: Camera, Sensor, Sorting, Garbage Bin, Smart.

1. Introduction

The need for efficient waste management is growing in importance in urban areas that are expanding quickly. The need for creative solutions is highlighted by overflowing trash cans, litter-strewn streets, and environmental effects. This paper, which draws conclusions from global research and waste management context in Bangladesh, introduces a novel approach that has the potential to transform waste management practices. Visualize a waste management system that defies convention. We put forth a cutting-edge plan that incorporates automated segregation into waste collection techniques, which is motivated by ideas presented by Valera et al. [1]. This method makes use of technology, as opposed to traditional practices, which rely heavily on manual intervention. Here's how it works: Garbage cans with cutting-edge sensors which classify different types of waste. This breakthrough is based on work by Reva University [2], which used real-time data to streamline waste collection routes and lessen their negative environmental effects. The need for effective waste disposal is made even more clear when taking into account Bangladesh's unique waste management situation. The country's expanding urban environment necessitates innovative solutions, as do its particular waste management issues. The suggested system provides a structured and environmentally friendly approach that fits this need. The innovation, however, goes beyond collection and includes intelligent sorting as well. The importance of appropriate segregation is frequently overlooked in traditional waste management. By automating the sorting procedure, in line with the strategies clarified by researchers [3], [4], and [5], our approach fills this gap. This paper acknowledges the gravity of the problem, especially in the context of Bangladesh's unique waste management challenges. With urbanization accelerating and waste generation soaring, there is an urgent requirement for a transformative approach that aligns with the evolving urban landscape. The proposed waste management system, introduced in this paper, breaks away from traditional norms by integrating cutting-edge technology, specifically automated segregation.

As we examine the nuances of waste management in Bangladesh, it becomes clear that the suggested strategy fits with the changing dynamics of the urban environment. We envision cleaner, healthier, and more sustainable cities by implementing a system that automates waste management.

2. Literature Review

A significant amount of research has been done on waste management all over the world. The majority of them concentrated on the manual collection of waste, its distribution, and its recycling. Recently, technology has become more widely used by individuals to efficiently monitor and classify the waste to collect it efficiently. The monitoring system for trash cans based on Zig-Bee has been proposed by Mahajan and Chitode. The sensors in the trash cans detect the amount of trash inside the cans [6]. But before monitoring, it is necessary to classify it. Viral et al. are bringing in a dynamic scheduling and routing of the garbage collector and a smart dustbin moisture detection system that is based on the Internet of Things. They have proposed a way to automatically segregate wet and dry waste using moisture detection [1]. Another paper suggests an Internet of Things (IoT)-based smart trashcan for garbage segregation that uses sensor devices to detect wastes in the dustbin and promptly separates them into different chambers. The IoT module and the sensors are connected through the microcontroller. Many sensors, including ultrasonic sensors, moisture sensors, and metal sensors, are used to determine how close waste is, evaluate the moisture level of the waste, and separate metal objects from other items. Using an image processing method, the plastic and biodegradable objects are separated into different pieces [7]. A suggested smart garbage bin design separates waste into dry and moist waste. The suggested system has a common tray that is coupled to a servo motor, two sub bins for wet and dry materials, and two sub bins in total. The system works by activating a humidity sensor, which separates the trash into wet and dry waste when garbage is thrown into the waste tray. An IR sensor attached to the plate detects the presence of the waste [2]. An automated waste segregation model that separates garbage into dry, moist, and metallic waste was proposed in a different study. This device uses a capacitive sensor to distinguish between dry and wet trash and a parallel resonance technology to identify metals. The appropriate sub canisters for the segregated wastes were placed using the PIC16F877A microprocessor and servo motor [3]. M. Sejera et al. [4]created a method that uses the average frequency response of the item when it strikes a galvanized iron platform to differentiate plastic bottles from tin cans. The system employed a comparator to reduce noise and a piezoelectric microphone to acquire input signals. This platform was created to tilt either side of the garbage can using a servo motor, depending on the choice the Arduino made [4]. W. Pereira et al. [5] developed a system that separates garbage into three categories: plastics, moist waste, and dry waste using an embedded microcontroller system. The system distinguished between wet and dry garbage using a capacitive copper-clad plate.

Using the techniques mentioned above might have a lot of limitations. In several of the studies mentioned above, waste items were separated using sensors. Since sensors may be damaged by dust, heat, and noise, and since they are unreliable and prone to delays, sensors might not be the best choice for waste segregation. Many of the research don't focus on segregation of recyclable and non-recyclable waste. They also don't concentrate on image processing techniques which are more reliable than sensors. To overcome all these gaps, we aim to create a smart recyclable/non-recyclable product sorting garbage bin which segregates the recyclable and non-recyclable waste with image processing techniques which will create a more reliable and efficient for classifying the waste with the aim of proper waste management.

3. Proposed Architecture

This proposed model introduces an advanced waste segregation and management system designed to evaluate waste items prior to disposal. Utilizing artificial intelligence and image processing technologies, the primary objective is to distinguish between recyclable and non-recyclable waste. When a waste item is identified as recyclable, it is directed to the appropriate recycling bin; otherwise, it is directed to the non-recyclable waste bin. This model relies on image processing techniques and a machine learning model trained on images of recyclable and non-recyclable products for waste segregation.

3.1 Methodology

The working principle of the smart bin is described in brief.

- ON the Device: By pressing the push button, the smart bin is started and is prepared to sort the recyclable/non-recyclable product with initial rotating of the servo motor in both clockwise and anticlockwise.
- Object Detection: When any waste comes in front of the camera sensor, the camera detects it. The ESP-32 cam captures real-time images of the waste placed in front of it.
- Image Processing: The captured images are processed using computer vision techniques to identify the waste object.

- Classification: The processed image is then sent to a pre-trained machine learning model that classifies the object as recyclable or non-recyclable based on its features. The machine learning model is pretrained using the picture of the waste before the classification.
- Decision-making: The system decides which bin to use based on the classification result. The processed image is used to make the decision whether the waste would be recyclable or non-recyclable.
- Servo Control: When the waste is recognized as recyclable or non-recyclable, the servomotor is activated to dump the waste or trash in a suitable bin. If the waste is recyclable, the servo motor will rotate anticlockwise otherwise in case of nonrecyclable, the servo motor will rotate clockwise to keep the waste to the bin.
- Trash Disposal: The waste is automatically dumped into the respective bin, based on its classification.

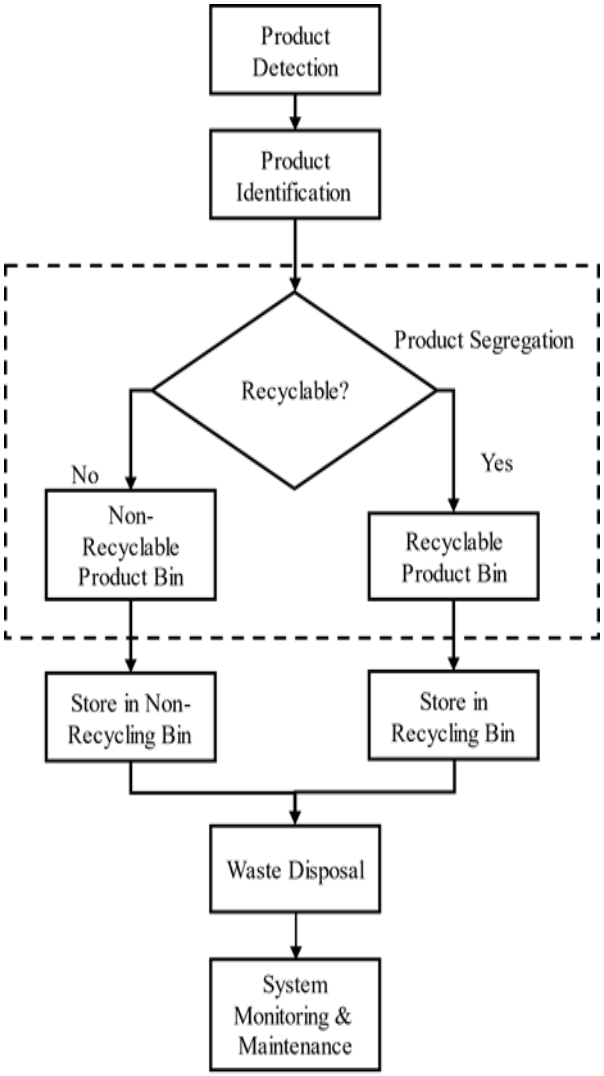


Fig. 1. Proposed Architecture

3.2 IMPLEMENTATION

The automatic recyclable and non-recyclable product sorting garbage bin is deployed at recycling centers and public waste disposal locations. This smart garbage bin can efficiently and accurately classify incoming waste items in real-time. As users deposit waste into the bin, the integrated sensors and machine learning algorithms swiftly identify and separate recyclable materials such as plastic, glass, and paper from non-recyclables like food waste and hazardous materials. The sorted items are then directed to their respective bins for further processing or disposal, promoting recycling rates and reducing landfill waste. The user-friendly interface offers real-time feedback, educating users about responsible waste disposal practices. This innovative solution not only streamlines waste management operations but also contributes significantly to environmental sustainability and a cleaner, greener future. The project will be realized using the following hardware.

1. ESP 32 CAM

The ESP32-CAM is a compact development board centered around the ESP32 system-on-chip. It integrates a camera module (OV2640) and provides dual-core processing, Wi-Fi, and Bluetooth connectivity. Designed by Espressif Systems, the ESP32-CAM is favored for embedded camera applications. It supports various



Fig. 2. ESP 32 CAM.

image formats and resolutions, suitable for diverse projects like home automation, surveillance, and IoT applications. Programming can be done through the Arduino IDE or ESP-IDF, offering flexibility for different user preferences. Its wireless capabilities enable easy network integration and real-time video streaming. The board's GPIO pins further enhance its versatility, permitting the incorporation of additional components. Powered by micro-USB or external sources, the ESP32-CAM's amalgamation of features and convenience has made it a popular choice among makers and developers seeking a robust platform for projects involving image and video functionalities.

2. FTDI Uploader

The FTDI Uploader is a crucial tool for programming and configuring devices using FTDI (Future Technology Devices International) USB-to-UART (Universal Asynchronous Receiver-Transmitter) interface chips. FTDI chips play a pivotal role in bridging the gap between USB and serial communication, enabling microcontrollers and other embedded systems to communicate with computers via USB connections. The FTDI Uploader software, often utilized alongside FTDI USB-to-UART adapter cables or modules, facilitates seamless data transfer and device configuration. It allows developers to program microcontrollers, flash firmware, and even perform hardware testing and debugging. The user-friendly interface of the FTDI Uploader simplifies the process of interfacing with FTDI devices, making it an essential tool for engineers, developers, and hobbyists engaged in creating, debugging, and maintaining a wide range of electronic projects.



Fig. 3. FTDI Uploader.

3. Power Adopter

A power adapter, often referred to as a power supply or AC/DC adapter, is a crucial electronic device used to convert electrical energy from a mains power source (such as a wall outlet) into a format suitable for powering various electronic devices. It typically transforms high-voltage alternating current (AC) from the mains into lower-voltage direct current (DC) that electronic devices require. Power adapters come in various shapes, sizes, and voltage/current ratings, tailored to the specific needs of the device they are intended to power. They usually consist of an input plug, an internal circuitry for voltage conversion, and an output connector that matches the power input requirements of the target device. Power adapters are ubiquitous in modern technology, powering everything from laptops, smartphones, and routers to household appliances and electronic gadgets. Their versatility and importance lie in their ability to provide a safe and standardized power source, ensuring proper functioning and longevity of a wide array of electronic equipment in homes, offices, and industries.



Fig. 4. Power adopter.

4. PVC Board

A PVC (Polyvinyl Chloride) board, commonly known as a PVC foam board or PVC sheet, is a versatile and lightweight material widely used in various applications due to its exceptional properties. Comprising a foamed PVC core encased between smooth or textured PVC surfaces, the PVC board offers durability, weather resistance, and ease of fabrication. It is renowned for being water-resistant, making it a popular choice for outdoor signage, displays, and advertising boards. The material's smooth surface allows for easy printing, painting, or mounting of graphics. PVC boards find utility in construction as well, being used for wall cladding, interior design, and decorative elements. Additionally, the lightweight nature of PVC boards simplifies handling and installation, reducing both labor and transportation costs. Its ability to withstand



Fig. 5. PVC Board.

harsh environmental conditions, coupled with its cost-effectiveness and adaptability, positions the PVC board as a sought-after material across industries, from advertising and architecture to crafts and DIY projects.

5. Dustbin

A dustbin, often referred to as a garbage or trash bin, is a container designed for the collection and disposal of waste materials. It serves as a fundamental element of waste management, helping to maintain cleanliness and hygiene in various settings. Dustbins come in various sizes and designs, ranging from small indoor bins to large outdoor receptacles. They are commonly found in homes, offices, public spaces, parks, and urban areas. Dustbins are essential for proper waste segregation, ensuring that different types of waste, such as recyclables, organic matter, and non-recyclables, are disposed of appropriately. Many modern dustbins feature lids to contain odors, prevent pests, and maintain aesthetics. In today's environmentally conscious society, specially marked dustbins encourage responsible waste disposal by separating recyclable materials from non-recyclable ones. The effective use of dustbins contributes to waste reduction, sanitation improvement, and the overall well-being of communities and environments.



Fig. 6. Dustbin

6. Servo Motor

A servo motor is a compact and versatile electromechanical device that converts electrical signals into precise mechanical motion. It consists of a motor, a feedback sensor (usually an encoder), and a controller. The feedback mechanism constantly monitors the motor's position and sends this information to the controller, which adjusts the motor's rotation to achieve the desired position, speed, and torque. Servo motors are known for their accuracy, reliability, and ability to maintain a specific position with minimal error. They are extensively used in robotics, industrial automation, remote-controlled vehicles, and various other applications requiring controlled and precise movement. Servo motors offer different power levels and sizes to accommodate a wide range of tasks, from delicate tasks like camera stabilization to heavy-duty applications in manufacturing. Their widespread use stems from their efficiency in converting electrical energy into mechanical motion, making them an essential component in modern technology and machinery.



Fig. 7. Servo Motor

7. Jumper Wires

A jumper wire is a short piece of electrical wire with connectors on both ends used to connect two points in an electrical or electronic circuit. Jumper wires are commonly used in breadboarding, prototyping, and troubleshooting electronic circuits. Jumper wires come in different lengths, colors, and gauges, and are usually made of stranded copper wire covered with insulation. They can be connected to circuit components using various connectors such as alligator clips, banana plugs, or spade connectors. Jumper wires can be used to bypass a faulty component, make temporary connections, or test circuit functionality. They are an essential tool for electronics hobbyists, engineers, and technicians, as they allow for quick and easy modifications to circuits without having to solder or make permanent changes.



Fig. 8. Jumper wires

8. Vero Board

Vero boards, or stripboards, are essential for electronic prototyping, especially among hobbyists and students. They consist of a board with parallel copper strips in a grid pattern, allowing components to be soldered directly onto tracks to form circuits. Unlike PCBs, Vero boards don’t require complex design processes; components are inserted through holes and soldered, enabling quick assembly and easy modifications. Vero boards are sturdier than breadboards yet more flexible than PCBs, making them ideal for testing and experimentation. This makes them a cost-effective, accessible option for turning electronic ideas into practical, working prototypes before advancing to formal designs.

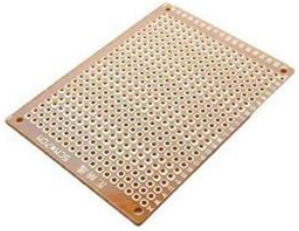


Fig. 9. Vero Board.

10. Final Assembly



Fig.10. Sorting Bin

4. Result & Discussion

The intelligent waste segregation system demonstrated high accuracy, successfully classifying waste items as recyclable or non-recyclable with approximately 90% accuracy. This success is largely due to the ESP-32 CAM module and machine learning model, which processed images of waste in real-time with minimal delays, allowing efficient waste sorting in public settings. The system's servo motor also functioned reliably, ensuring that waste items were directed to appropriate bins without human intervention, which enhances recycling quality by reducing contamination.

Some challenges were noted. The system's performance decreased in low-light conditions, affecting image quality and classification accuracy. Additionally, adapting the system to diverse urban settings may require expanded training data and design refinements to maintain reliability across varied waste profiles. Overall, this model offers a promising, scalable approach to automated waste management, aligning with global sustainability goals by encouraging proper waste disposal and recycling practices.

5. Conclusion

The camera-based smart sorting bin offers a transformative solution in waste management, utilizing computer vision and machine learning to automatically distinguish between recyclable and non-recyclable materials. This technology holds substantial promises for environmental and economic gains; however, notable research gaps remain. Improving object recognition accuracy is critical, especially in diverse conditions like varying lighting and complex waste mixtures, to maximize sorting efficiency. Additionally, studies assessing the scalability and adaptability of smart bins across different urban landscapes and waste profiles are essential to understand their broader applicability. While the system aims to boost public participation in recycling, further research is needed to measure its true impact on user disposal behaviors and environmental awareness. Future enhancements, such as integrating GPS-based collection optimization and multi-compartment bins for specific waste categories, could significantly extend its utility. Addressing these challenges is essential to establish smart sorting bins as a foundational tool in sustainable urban waste management.

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