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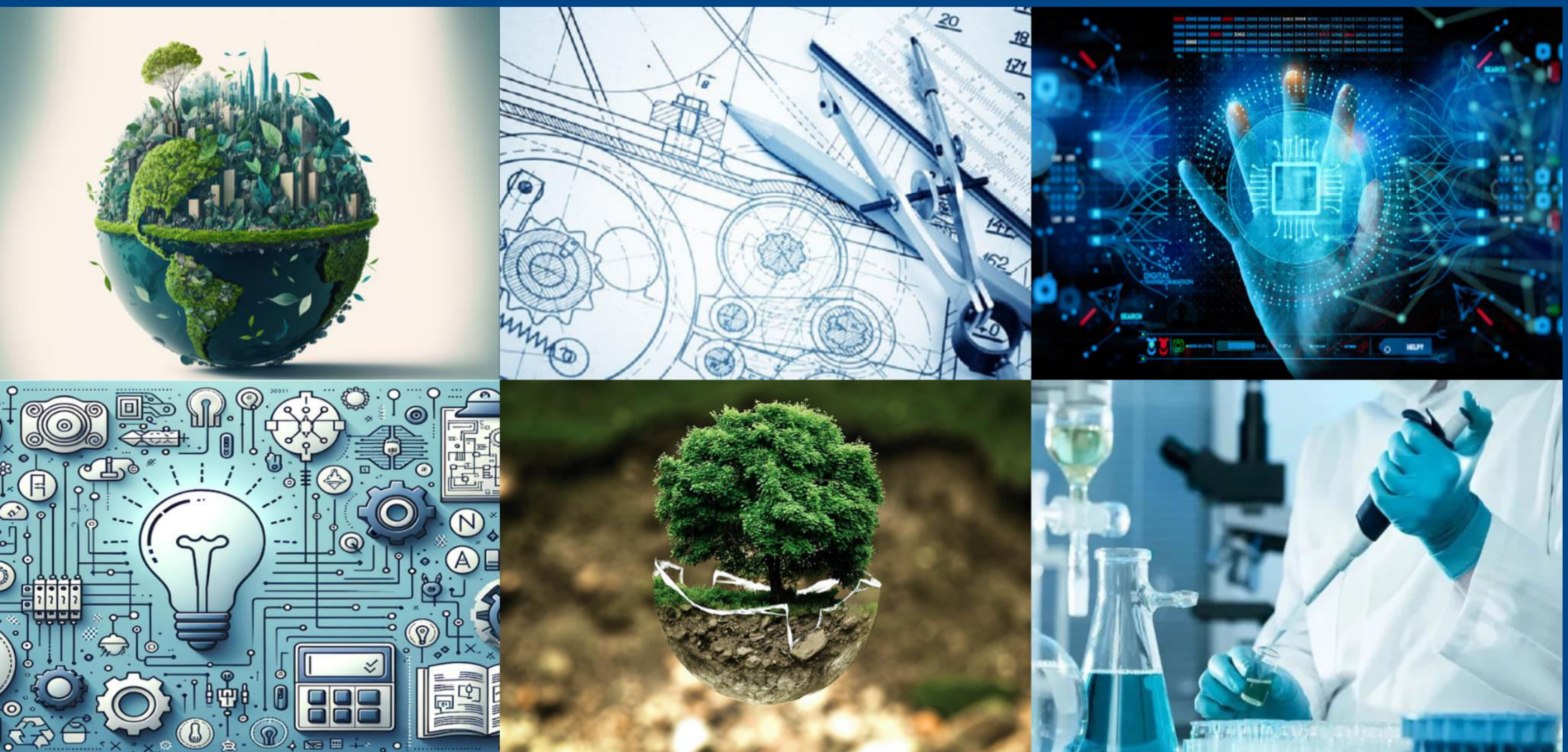

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AquaSweep: Intelligent Automatic Robot for Waterway Cleanliness & Waste Management

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ABSTRACT: This project presents an IoT-based Smart Garbage Segregation System designed to automatically separate waste materials such as plastic, aluminum, and other types of garbage. The system uses an ESP32 microcontroller as the main control unit, integrated with sensors and actuators for efficient operation. An IR sensor detects the presence of objects, an ultrasonic sensor measures the waste level in bins, and an aluminum sensor identifies metallic items, while an ESP32 camera assists in object detection and classification. A servo motor is used to direct the garbage into the appropriate bin, and gear motors control the movement of a conveyor belt for transporting waste. The system is connected to a mobile application via Wi-Fi, allowing users to monitor the waste levels and system status in real time. This automated segregation system minimizes human effort, improves sorting accuracy, and promotes efficient waste management for a cleaner and more sustainable environment.

KEYWORDS: Smart Garbage Segregation, Waste Management, ESP32, IoT, Ultrasonic Sensor, IR Sensor, Aluminum Sensor, Servo Motor, Gear Motor, Conveyor Belt, Object Detection, ESP32 Camera, Automation, Recycling System, Sustainable Environment.

I. INTRODUCTION

Waste management has become one of the most significant challenges in modern society due to the rapid increase in population and industrialization. Improper segregation of waste materials such as plastics, metals, and biodegradable substances leads to environmental pollution and health hazards. To address this issue, an automated garbage segregation system is designed to efficiently separate waste materials into different categories. In this project, an ESP32 microcontroller is used as the main processing unit, which is connected to various sensors and actuators. The system detects and classifies garbage items such as plastic bottles, aluminum cans, and plastic bags using sensors and a camera module. The IR sensor detects the presence of an object, while the ultrasonic sensor measures the level of waste in each bin. An aluminum sensor helps identify metallic items, and the ESP32 camera assists in object recognition. A servo motor is used for directing the garbage into appropriate bins, while gear motors control the movement of a conveyor belt to transport the waste.

The system also features connectivity with a mobile application via Wi-Fi, allowing users to monitor the waste levels in real-time. By automating the segregation process, this project promotes efficient waste management, reduces human effort, and contributes to a cleaner and more sustainable environment.

II. OBJECTIVES

- To design and develop an automated waste segregation system that can efficiently separate garbage into different categories such as plastic, aluminum, and other waste.
- To utilize an ESP32 microcontroller as the main control unit for integrating sensors, motors, and communication modules.
- To implement object detection using an ESP32 camera for identifying different types of waste materials.
- To use IR sensors for detecting the presence of garbage on the conveyor belt.
- To employ ultrasonic sensors for monitoring and measuring the waste levels in each dustbin.

- To integrate an aluminum sensor for accurate detection of metallic waste such as aluminum cans.
- To control the servo motor for directing the waste into the appropriate bin based on material type.
- To operate a gear motor-driven conveyor belt for transporting waste materials efficiently through the segregation process.
- To establish Wi-Fi connectivity between the ESP32 and a mobile application for real-time monitoring and data visualization.
- To promote smart waste management practices by reducing human involvement, improving sorting accuracy, and supporting environmental sustainability.

III. LITERATURE REVIEW

A. IoT-Based Smart Waste Management System

A study by S. Vinoth Kumar et al. (2019) proposed an IoT-based smart waste management system that focuses on monitoring, collecting, and managing municipal waste through the integration of sensors and communication technology. In traditional systems, waste collection is often inefficient due to irregular monitoring of bin levels and delayed response times. To overcome this challenge, the authors utilized ultrasonic sensors to measure the waste level inside garbage bins and interfaced them with a NodeMCU (ESP8266) microcontroller. When the garbage level exceeded a predefined threshold, the system sent an alert message via Wi-Fi to a cloud-based monitoring application, allowing municipal authorities to schedule timely waste collection. The study demonstrated that IoT integration significantly enhances operational efficiency by automating the monitoring process and reducing the need for manual inspection. The use of a mobile application interface allowed real-time data visualization of bin status and location, which optimized waste collection routes and reduced fuel consumption. Additionally, the system was designed to store historical data on waste levels, which could be analyzed for future planning and policy implementation. The authors concluded that incorporating IoT-based systems in urban areas can lead to cleaner environments, lower maintenance costs, and better resource utilization. This study directly supports your project concept, as your system similarly employs ESP32, an advanced IoT-enabled microcontroller, for real-time monitoring and control of waste segregation and bin management.

B. Automated Waste Segregation System Using Sensors

In a research paper by R. S. Dhekale et al. (2020), an automated waste segregation system was developed to address the issue of improper waste management through a combination of sensors and actuators. The system's main goal was to separate waste into categories such as metallic, plastic, and organic waste using infrared (IR) sensors, metal detectors, and servo motors. The IR sensor was responsible for detecting the presence of objects on a conveyor belt, while the metal sensor distinguished metallic items from non-metallic waste. Once the type of waste was identified, a servo motor mechanism rotated and directed the waste to its respective bin.The researchers implemented this system using a microcontroller-based embedded circuit that processed sensor signals and controlled motor operations. Their findings showed that sensor-based segregation systems are highly effective in minimizing manual effort and human error. The automation of waste segregation not only speeds up the process but also ensures higher accuracy and consistency compared to manual sorting. Additionally, the authors emphasized that this approach is cost-effective and can be implemented at both small and large scales, depending on the design complexity. This research aligns closely with your project, where you employ ESP32, IR sensors, ultrasonic sensors, and aluminum sensors to automate the classification and separation of garbage. Furthermore, by integrating IoT connectivity and real-time data visualization, your project enhances the existing system by making it smarter and more efficient.

C. Smart Waste Sorting Using Image Processing

A study conducted by A. Gupta and P. Sharma (2021) explored a machine vision-based waste segregation system that used image processing techniques for object detection and classification. Unlike sensor-based systems that rely on predefined physical properties, this approach employed a Raspberry Pi camera to capture images of waste items on a conveyor belt. The captured images were analyzed using the OpenCV library and machine learning algorithms to identify materials such as plastic, metal, and paper based on their color, shape, and texture features. Once the waste type was identified, the system activated servo motors to direct the waste into appropriate bins. The researchers highlighted that image processing and computer vision technologies improve segregation accuracy by recognizing complex patterns that sensors alone might miss. However, the study also pointed out the challenges of high computational requirements and lighting dependency, which could affect detection accuracy. Despite these limitations, the use of camera-based classification provides a more flexible and scalable approach to waste management. The authors suggested that

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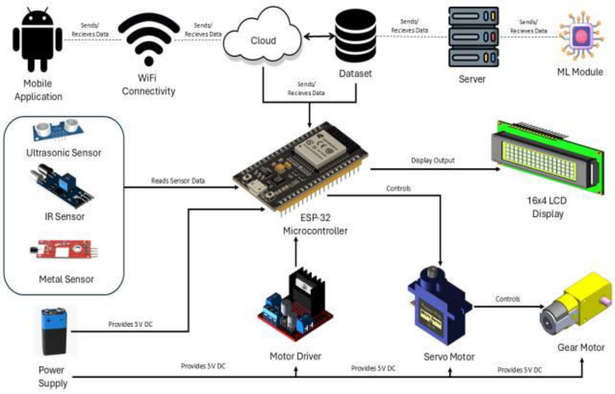
integrating image processing with IoT-enabled microcontrollers could make the system more intelligent and cost-effective. This study is highly relevant to your project, as your system integrates an ESP32 camera with onboard image detection capabilities, eliminating the need for high-end processors like Raspberry Pi. By combining camera-based recognition with sensor-based detection and IoT connectivity, your system achieves both precision and efficiency. The ESP32-based approach offers lower power consumption, cost-effectiveness, and seamless wireless communication, making it an ideal choice for a real-time automated waste segregation system.

IV. SYSTEM DESIGN AND ARCHITECTURE



The IoT-based Smart Garbage Segregation System is an innovative and automated solution designed to identify, classify, and segregate different types of waste materials such as plastic, aluminum, and organic waste. At the core of the system is the ESP32 microcontroller, which acts as the central processing and control unit responsible for managing data from sensors, making classification decisions, and controlling actuators for sorting operations. The entire setup is powered by a 12V DC battery that passes through a 5V voltage regulator, ensuring a consistent and stable power supply for all electronic components, including the sensors, motors, ESP32, LCD display, and the ESP32-CAM module. This regulated power supply is crucial for maintaining accurate readings and reliable system operation. The architecture is designed to integrate hardware and software components seamlessly to achieve an efficient, fully automated waste segregation process. The waste sorting process begins when a garbage item is placed on the conveyor belt, where the IR sensor detects its presence and signals the ESP32 to begin analysis. As the object moves forward, it encounters several sensors that help determine its type. The metal sensor identifies metallic waste such as aluminum cans, while the ESP32-CAM module captures an image of the item and sends it to a cloud-based machine learning module for classification. The cloud's AI algorithm analyzes the image and categorizes the waste into plastic, aluminum, or organic materials. Simultaneously, the ultrasonic sensor measures the level of garbage in each bin to ensure that items are only directed into bins that have available space. Once the ESP32 receives classification data, it makes a decision about which bin the object should be sorted into, enabling precise and efficient waste management. The sorting mechanism is powered by the L298N H-Bridge motor driver, which acts as an interface between the ESP32 and the actuators. The gear motor operates the conveyor belt, moving the waste to the appropriate position for sorting. At the sorting point, the servo motor controls the movement of the sorting gate, adjusting its angle to direct the waste into the correct bin — plastic, aluminum, or organic. This mechanical process ensures that the segregation is carried out smoothly and accurately without human intervention. The system also includes a 16×4 LCD display, which provides real-time feedback on system operations, including detected waste type, bin fill levels, and system status. This allows users to visually monitor the system's activity and ensure proper functioning at all times. In addition to the local hardware operations, the system incorporates IoT connectivity for smart monitoring and control. Through Wi-Fi communication, the ESP32 sends data such as sensor readings, captured images, and bin statuses to the cloud, where information is stored, analyzed, and shared with a mobile application. The mobile app allows users to monitor the system remotely, view waste levels, receive alerts when bins are full, and access performance analytics. The cloud infrastructure not only enables remote access but also supports continuous learning and improvement of the AI model for more accurate classification. Overall, this system architecture provides an intelligent, efficient, and eco-friendly approach to waste management by combining sensors, microcontrollers, IoT, and AI technologies. It reduces manual effort, enhances accuracy, and contributes to a cleaner and more sustainable environment while laying the groundwork for future smart city waste management systems.

V. IMPLEMENTATION

The implementation of the IoT-based Smart Garbage Segregation System involves integrating hardware components, sensors, and software modules to create a fully automated waste classification and disposal process. The system is powered by a 12V DC battery regulated to 5V for consistent performance, and the ESP32 microcontroller serves as the central processing unit that coordinates data collection and control actions. Sensors such as the IR sensor, metal sensor, ultrasonic sensor, and ESP32-CAM module are connected to the ESP32 to detect waste presence, identify material type, monitor bin levels, and capture images for visual classification. The collected data is processed by the ESP32 and transmitted to a cloud-based machine learning model that determines the waste category. Based on this classification, the ESP32 activates the motor driver (L298N H-Bridge), which controls the gear motor for conveyor belt movement and the servo motor for operating the sorting gate. Waste items are then directed into the appropriate bins for plastic, aluminum, or organic materials. The system also features a 16×4 LCD display for local status updates and uses Wi-Fi connectivity to send data to a mobile application, enabling real-time monitoring, notifications, and performance tracking. This implementation ensures a reliable, intelligent, and sustainable approach to waste segregation through the integration of IoT, automation, and AI technologies.

A. Technologies Used:

The IoT-based Smart Garbage Segregation System uses a combination of embedded systems, IoT, and AI technologies to automate waste classification. The ESP32 microcontroller serves as the main control unit, integrating with sensors such as IR, ultrasonic, and metal detectors to detect and identify waste. The ESP32-CAM module captures images for machine learning–based object detection, while the L298N motor driver controls the gear motor and servo motor for conveyor movement and sorting. A 12V DC power supply regulated to 5V powers the components, and data is sent to a cloud platform for processing and monitoring via a mobile application. These technologies work together to create a smart, automated, and efficient waste segregation system.

Sr. No.	Technology Used	Function
1.	ESP32 Microcontroller	Main controller for sensors, motors, and Wi-Fi communication.
2.	IR Sensor	Detects the presence of waste objects.
3.	Ultrasonic Sensor	Monitors the garbage level in bins.
4.	Metal Sensor	Detects metallic waste like aluminum.
5.	ESP32-CAM Module	Captures images for object identification
6.	L298N Motor Driver	Controls gear and servo motor operations.
7.	Gear Motor	Moves the conveyor belt forward or backward.
8.	Servo Motor	Directs waste into the correct bin.
9.	12V DC Power Supply & 5V Regulator	Provides stable power to all components.
10.	Cloud Platform (IoT & ML)	Classifies waste and stores data online.
11.	Mobile Application	Displays bin levels and system status.
12.	Arduino IDE	Used for coding and programming the ESP32

VI. TESTING AND EVALUATION

The testing and evaluation of the IoT-based Smart Garbage Segregation System were carried out to ensure accurate detection, classification, and segregation of waste materials. Each component, including sensors, motors, and the ESP32 controller, was tested individually and then integrated for full system testing. The system was evaluated for its ability to correctly identify and sort materials such as plastic, aluminum, and organic waste. The ultrasonic sensor was verified for accurate bin level detection, and the mobile app was tested for real-time monitoring and alerts. Overall, the system performed efficiently, demonstrating reliable automation, accurate segregation, and effective IoT communication.

A. Unit Testing:
Unit testing was conducted to verify the functionality of each module in the smart garbage segregation system.
1. Sensor Module Testing: All sensors (IR, ultrasonic, metal, and camera) were tested and provided accurate and stable readings.
2. Motor Control Testing: The servo and gear motors worked correctly for conveyor movement and waste segregation.
3. Data Acquisition Testing: Sensor data was successfully processed by the ESP32 microcontroller with proper signal conversion and calibration.
4. Cloud Module Testing: Data transmission between ESP32 and the cloud was stable, and real-time data was stored accurately.
5. Mobile App Testing: The app displayed bin levels, waste type, and alerts correctly, ensuring smooth user interaction.

B. Integration Testing:
Integration testing ensured proper communication between all system modules.
1. Sensor–Microcontroller Integration: Sensors interfaced correctly with the ESP32, and real-time detection worked under different conditions.
2. Microcontroller–Motor Driver Integration: ESP32 successfully controlled the servo and gear motors for precise sorting.
3. Microcontroller–Cloud Integration: Sensor and camera data were transmitted to the cloud without data loss.
4. Cloud–Mobile App Integration: The mobile app received real-time updates and notifications accurately.
5. Overall System Testing: The entire system operated smoothly, achieving correct detection, classification, and segregation of waste materials.

VII. RESULT AND DISCUSSION

A. Discussions:
The testing and evaluation of the IoT-based Smart Garbage Segregation System demonstrated that the system effectively achieved its goal of automating waste detection, classification, and segregation. During testing, all sensors—IR, ultrasonic, metal, and ESP32-CAM—performed with high accuracy and stability under different lighting and environmental conditions. The ESP32 microcontroller efficiently processed input signals, controlled motor operations, and ensured proper coordination between hardware modules. The servo motor and gear motor worked smoothly for waste direction and conveyor movement, confirming reliable mechanical performance. Cloud connectivity and the mobile application functioned as expected, allowing real-time monitoring of bin levels, waste types, and system status. The integration between sensors, actuators, and IoT modules proved to be seamless, with minimal data delay or signal interference. The cloud-based machine learning model accurately classified waste images captured by the ESP32-CAM, improving sorting accuracy compared to sensor-only methods. Network testing showed that data transmission remained stable even during brief connectivity losses, as the ESP32 automatically reconnected to the Wi-Fi network. The system's modular design also allows for scalability, making it adaptable for larger-scale waste management applications. Overall, the results indicate that the system is efficient, reliable, and capable of performing autonomous waste segregation with minimal human involvement. The combination of IoT, automation, and AI technologies enhanced system intelligence and operational precision. Although the prototype performed well, future improvements such as enhanced camera resolution, faster image processing, and the addition of more waste categories could further increase accuracy and efficiency. The discussion concludes that this project provides a practical, eco-friendly, and scalable solution for smart waste management in modern cities.

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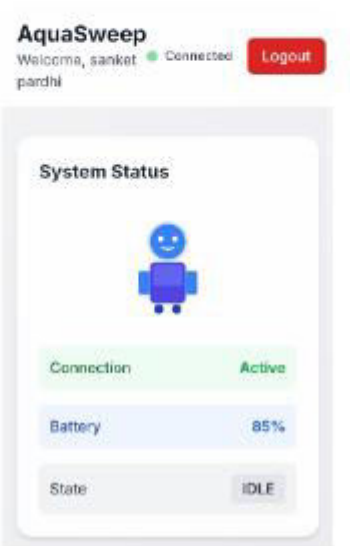
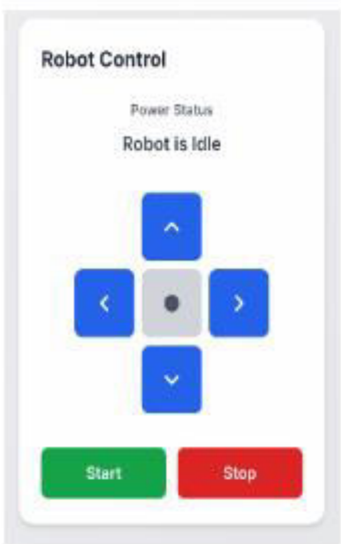
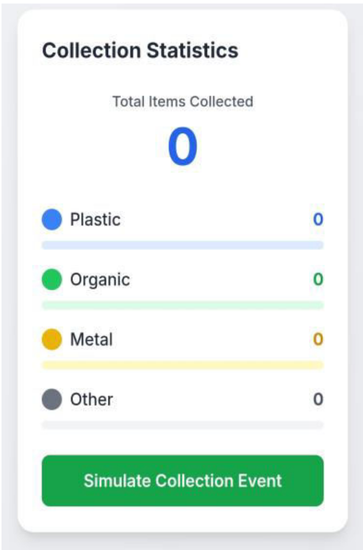
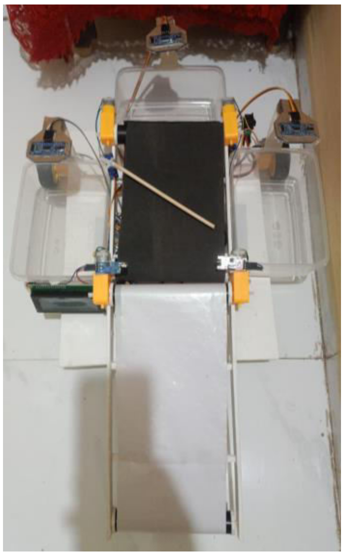
B. Result:









VIII. FUTURE SCOPE

1. Improve machine learning accuracy for better waste classification.
2. Add more waste categories like glass and paper.
3. Implement solar power for energy-efficient operation.
4. Integrate with smart city waste management systems.
5. Enable automatic reporting and data analytics.
6. Upgrade mobile app with remote control and voice features.

IX. CONCLUSION

The IoT-based Smart Garbage Segregation System successfully demonstrates an efficient and automated approach to waste management using modern technologies such as sensors, IoT, and machine learning. The system effectively detects,

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classifies, and segregates different types of waste—such as plastic, aluminum, and organic materials—without human intervention. Through the integration of the ESP32 microcontroller, various sensors, and a cloud-connected mobile application, real-time monitoring and accurate segregation were achieved. Testing results confirmed that all modules worked reliably, and the system performed with high precision and consistency. Overall, this project contributes to sustainable waste management by reducing manual effort, promoting recycling, and supporting cleaner environmental practices. With further enhancements and scalability, the system can be implemented in smart cities to improve waste collection and resource management efficiency.

REFERENCES

1. S. Vinoth Kumar, T. Senthil Kumaran, and R. J. Kumar, "IoT Based Smart Waste Management System," International Journal of Recent Technology and Engineering (IJRTE), vol. 8, no. 2, pp. 330–334, 2019.
2. R. S. Dhekale, P. P. Chavan, and S. R. Kale, "Automated Waste Segregation System Using Sensors," International Journal of Innovative Research in Computer and Communication Engineering, vol. 8, no. 4, pp. 1120–1125, 2020.
3. A. Gupta and P. Sharma, "Smart Waste Sorting Using Image Processing and Machine Learning," International Research Journal of Engineering and Technology (IRJET), vol. 8, no. 7, pp. 1423–1428, 2021.
4. S. B. Patil and N. R. Wagh, "IoT Based Smart Garbage Monitoring System," International Journal of Scientific Development and Research (IJSDR), vol. 4, no. 3, pp. 122–127, 2019.
5. M. K. Singh and R. S. Pandey, "Smart Waste Management Using Internet of Things (IoT)," IEEE International Conference on Computer, Communication and Control (IC4), pp. 1–6, 2018.
6. P. V. Reddy, K. S. Reddy, and V. Kumar, "Waste Segregation and Management Using IoT and Image Processing," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 9, no. 6, pp. 2104–2110, 2020.
7. J. A. Andrews and R. M. George, "IoT Based Waste Collection and Management System for Smart Cities," IEEE Access, vol. 8, pp. 111508–111520, 2020.
8. R. K. Sharma, "Smart Bin Implementation for Smart Cities," International Journal of Engineering Research and Technology (IJERT), vol. 7, no. 5, pp. 312–316, 2019.
9. S. Ahmed and M. Khan, "Automation of Waste Segregation System Using Arduino and Sensors," Journal of Emerging Technologies and Innovative Research (JETIR), vol. 7, no. 9, pp. 290–296, 2020.

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