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Automatic Metal, Glass and Plastic Sorting Machine

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Abstract: *Rapid urbanization and population growth have significantly increased the generation of solid waste, creating serious environmental and health challenges. Proper waste management begins with effective segregation of waste at the source. This project presents the design and implementation of an automated Waste Segregation System using sensors and a microcontroller. The proposed system automatically identifies and segregates waste into categories such as metal, plastic, glass, and paper using inductive, capacitive, and ultrasonic sensors controlled by an Arduino-based unit. Mechanical components like servo motors and rotating mechanisms are used to direct waste into separate bins. The system reduces human involvement, improves recycling efficiency, and supports sustainable waste management practices. The results demonstrate reliable segregation with minimal error, making the system suitable for smart cities and industrial applications*

Keywords: Waste Segregation, Smart Dustbin, Arduino, Inductive Sensor, Capacitive Sensor, Ultrasonic Sensor, Automation, Recycling, Smart City

I. INTRODUCTION

Solid waste management is one of the most critical challenges faced by modern society. Improper disposal and lack of segregation lead to environmental pollution, health hazards, and loss of recyclable resources. Traditionally, waste segregation is performed manually, which is time-consuming, inefficient, and unsafe for workers.

To overcome these issues, automation and embedded systems can be effectively utilized. An automated waste segregation system helps in separating waste at the initial stage, improving recycling efficiency and reducing landfill load. With advancements in sensors, microcontrollers, and low-cost electronics, smart waste management systems have become feasible and affordable.

This project focuses on developing a sensor-based waste segregation system that detects different types of waste and segregates them automatically. The system aims to minimize human intervention, improve accuracy, and promote eco-friendly waste management.

II. LITERATURE REVIEW

Several researchers have proposed intelligent methods for waste segregation and management:

- Eduardo A. Soares proposed the use of computer vision and AI to classify waste into categories such as plastic, glass, metal, and paper, improving sorting accuracy.
- Anton Satria Prabuwano introduced machine learning models like SqueezeNet and XGBoost for recyclable waste classification, demonstrating high classification performance.
- Mohammed Rafeeq developed an Arduino-based waste segregation system using inductive and capacitive sensors for metal, plastic, and glass detection.

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- Razali Tomari proposed a smart recycle bin integrated with a web-based system to monitor waste levels and encourage recycling behavior.

These studies highlight the importance of automation, sensors, and AI in improving waste management efficiency. However, many systems are complex or costly. The proposed system focuses on a simple, cost-effective, and reliable hardware-based solution.

III. EXISTING SYSTEM

In the existing waste management system:
Waste is collected in a mixed form without segregation.
Manual segregation is carried out at later stages, which is:

- Time-consuming
- Labor-intensive
- Unhygienic

Improper segregation leads to:

- Reduced recycling efficiency
- Environmental pollution
- Health risks to workers

Most traditional systems lack automation and real-time detection. Some advanced systems use AI and image processing but are expensive and complex, making them unsuitable for small-scale or rural deployment.

IV. PROPOSED SYSTEM

The proposed Waste Segregation System is designed to automatically detect and separate different types of waste using sensors and a microcontroller. The system works as follows:

1. The system uses an Arduino-based microcontroller as the main control unit to process sensor data and control mechanical components.
2. Ultrasonic sensors are used to detect the presence of waste when an object is dropped into the system.
3. Inductive proximity sensors are used to identify metal waste such as cans or metallic objects.
4. Capacitive proximity sensors are used to detect non-metallic materials, especially glass and plastic, based on dielectric properties.
5. Based on sensor outputs, the microcontroller determines the type of waste automatically.
6. Servo motors are used to rotate gates or a rotating base to direct the waste to the correct bin.
7. The system segregates waste into separate compartments such as:
   - Metal waste
   - Plastic waste
   - Glass waste
   - Other/dry waste
8. A trapdoor mechanism allows waste to fall into the appropriate partition after classification.
9. The entire system operates on a regulated power supply using an AC-to-DC converter to ensure safe voltage levels.
10. The segregation process occurs without human intervention, improving hygiene and safety.
11. The system reduces manual labor and increases recycling efficiency.
12. The proposed solution is cost-effective, reliable, and suitable for smart city applications.

V. METHODOLOGY

The methodology describes the step-by-step working process of the proposed Waste Segregation System, from waste detection to final segregation.

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System Initialization

- Power is supplied to the system through a regulated AC-to-DC power supply.
- The Arduino microcontroller initializes all sensors and servo motors.

Waste Insertion

- The user places waste into the input section (inlet pipe or opening) of the system.

Object Presence Detection

- An **ultrasonic sensor** detects the presence of waste inside the pipe.
- If an object is detected within a predefined distance, the system proceeds to the next step.

Material Identification

- An inductive proximity sensor checks for metallic content.
- If metal is detected, the waste is classified as metal waste.
- If metal is not detected, a capacitive proximity sensor is used to distinguish between glass and plastic materials.

Decision Making

- Sensor outputs are sent to the Arduino microcontroller.
- The microcontroller processes the sensor data and decides the category of waste.

Mechanical Actuation

- Based on the identified waste type, servo motors rotate the gate or base mechanism to the appropriate position.

Waste Segregation

- A trapdoor mechanism opens to allow the waste to fall into the corresponding partition or bin.

Reset Mechanism

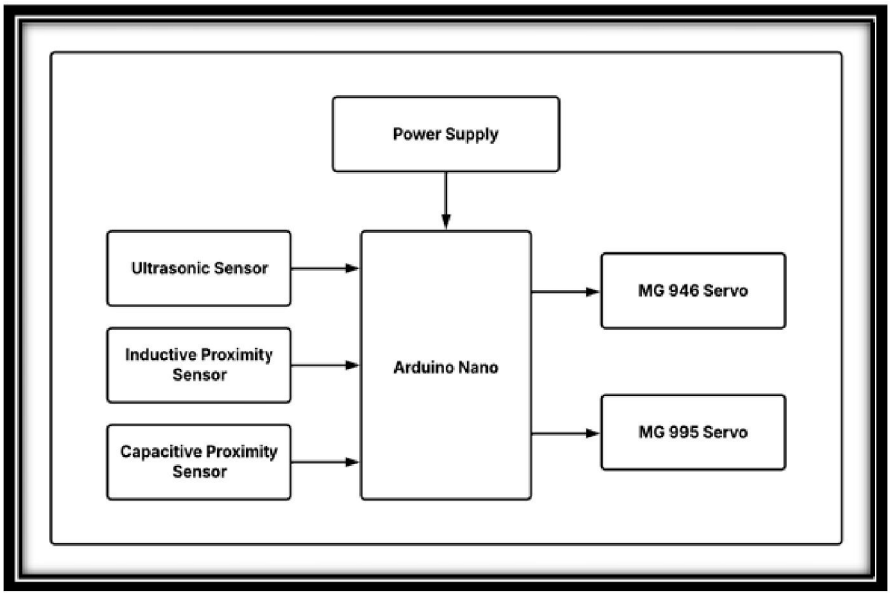
- After segregation, the servo motors return to their default positions.
- The system resets and becomes ready for the next waste item.

Continuous Operation

- The above steps repeat automatically for each new waste item inserted into the system.

Safety and Reliability

- Voltage regulation and controlled motor operation ensure safe and stable performance of the system.



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VI. FUTURE SCOPE

The proposed Waste Segregation System can be further enhanced and expanded in the following ways:

Integration of Artificial Intelligence (AI)

- Image processing and machine learning models can be added to improve accuracy in waste classification.

IoT-Based Monitoring

- Internet of Things (IoT) modules can be used to monitor bin status and send real-time data to authorities.

Mobile Application Support

- A mobile app can be developed to display waste levels, segregation data, and maintenance alerts.

Expansion to More Waste Categories

- The system can be upgraded to segregate additional waste types such as wet waste, e-waste, and hazardous waste.

Smart City Integration

- The system can be integrated with smart city infrastructure for optimized waste collection and management.

Energy-Efficient Operation

- Solar panels or renewable energy sources can be used to make the system energy efficient.

Scalability for Industrial Use

- The design can be modified for large-scale use in industries, railway stations, malls, and public places.

Improved Sensor Accuracy

- Advanced sensors can be used to enhance detection accuracy under varying environmental conditions.

Data Analytics and Reporting

- Collected data can be analyzed to predict waste generation patterns and improve recycling strategies.

User Awareness and Incentive Systems

- Reward-based or gamification systems can be introduced to encourage proper waste disposal by users.

VII. CONCLUSION

The Waste Segregation System developed in this project demonstrates an effective and automated solution to the growing problem of improper waste management. By using a combination of inductive, capacitive, and ultrasonic sensors along with a microcontroller, the system is able to accurately identify and segregate different types of waste such as metal, plastic, and glass. The integration of mechanical components like servo motors and trapdoor mechanisms ensures smooth and reliable segregation with minimal human intervention. This system reduces manual labor, improves hygiene, and increases recycling efficiency while remaining cost-effective and easy to implement. Overall, the proposed system provides a practical approach toward sustainable waste management and can serve as a foundation for future smart city and automation-based waste handling solutions.

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