

RESEARCH PAPER

Project ID:

Project Title: Integrated Solid Waste Management and Separation using Image Processing

Name of the Student: SHAIK ASLAM

Name of School: Safa Matriculation School

Address of School: 1, New Military Road, Masjid-E-Mubarak Campus, Avadi, Tamil Nadu 600054

a. Introduction

Solid waste management is a pressing issue in both urban and rural communities. Im- proper segregation of waste leads to overflowing landfills, soil and water contamination, greenhouse gas emissions, and public health hazards.

This project will aim to design and test an **automated waste segregation system** that integrates computer vision and low-cost embedded hardware. An ESP32-CAM will be used for real-time image capture and classification, while Arduino Uno will control servo motors to divert waste items into separate bins for biodegradable, recyclable, and hazardous materials.

b. Selection of Problem and Background Information

Manual segregation of waste is labor-intensive, inefficient, and unsafe for workers handling hazardous materials.

Traditional waste management systems often fail due to human error, lack of awareness, and poor infrastructure. By introducing a low-cost automation system with AI-based classification, segregation accuracy and efficiency will improve significantly. The system will also contribute to sustainable development by enhancing recycling rates and reducing environmental hazards.

c. Objective

Research Problem / Question: How can low-cost image processing and embedded control systems improve the efficiency and safety of solid waste segregation compared to manual methods?

What will be found out:

- Accuracy of image-based waste classification.
- Effectiveness of servo-controlled sorting.
- Reduction in manual involvement and errors.

Variables:

- Independent Variables: Type of waste item, lighting conditions, model parameters.
- Dependent Variables: Classification accuracy, sorting success rate, throughput of items/min.
- Controlled Variables: Conveyor speed, camera angle, bin positions.

Control in the Study: Manual waste segregation will act as the control to measure improvement in accuracy and efficiency.

d. Hypothesis

If image processing with ESP32-CAM is used to classify waste and Arduino Uno controls the sorting mechanism, then segregation will be faster, more accurate, and safer compared to manual methods.

e. Procedure

Design of Study: The system will consist of an ESP32-CAM for capturing and classifying waste images, an Arduino Uno for servo motor control, and a conveyor belt for moving waste to sorting bins.

Materials Required:

- ESP32-CAM for image capture and classification.
- Arduino Uno for servo and DC motor control.
- Servo motors (3 nos.) for bin flaps.
- Conveyor belt with DC motors.
- Waste bins for biodegradable, recyclable, and hazardous waste.
- 12V power supply and motor driver.

Stepwise Procedure:

1. Place waste items on the conveyor belt.
2. ESP32-CAM captures an image of the item.
3. A lightweight CNN model classifies the item as biodegradable, recyclable, or hazardous.
4. Classification result is sent to Arduino Uno.
5. Arduino activates the corresponding servo motor to open the correct flap.
6. Waste item falls into the correct bin.
7. Accuracy, speed, and consistency of sorting will be recorded.

Proposed Data Tables:

Table A: Classification Results

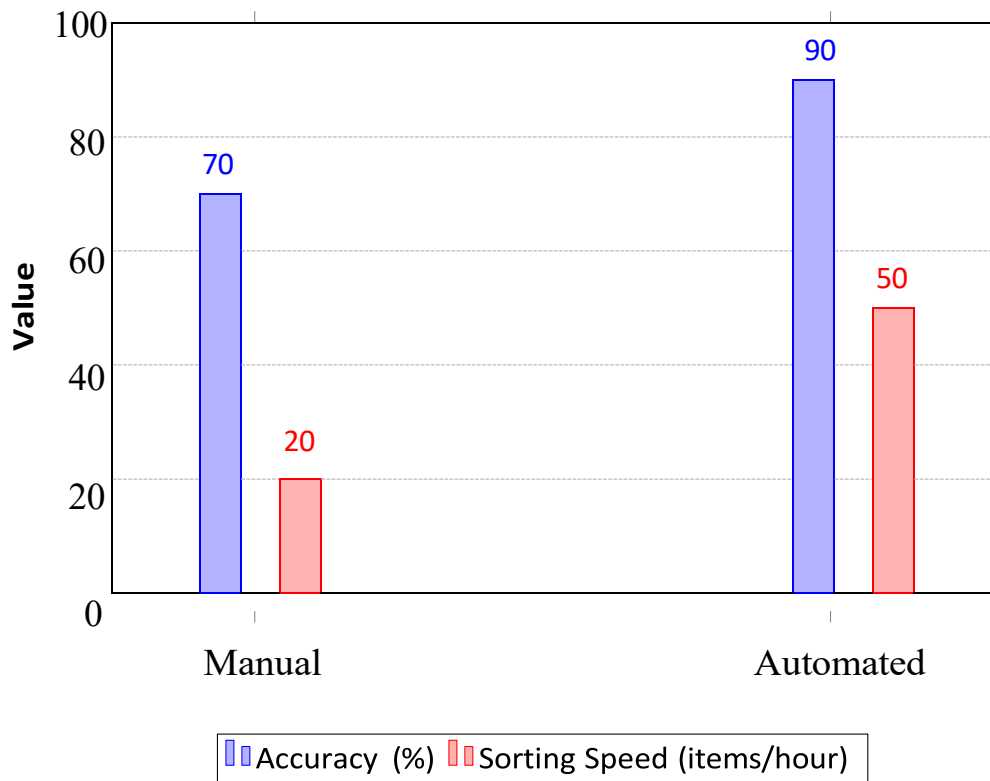
Trial No.	Waste Type (Ground Truth)	Classified Result	Correct / Incorrect
1	Plastic Bottle (Recyclable)	Recyclable	Correct
2	Banana Peel (Biodegradable)	Hazardous	Incorrect
3	Paper (Recyclable)	Recyclable	Correct
4	E-waste Chip (Hazardous)	Hazardous	Correct

Table B: Sorting Accuracy

Method	Avg Accuracy (%)	Sorting Time (s/item)	Safety Rating
Manual	70	5	Medium
Automated	90	2	High

Graphical Representation

Manual vs Automated Waste Segregation – Accuracy and Sorting Time



f. Risk and Safety

- System will be tested using sample dry waste, not medical or hazardous waste.
- Electrical components will be operated at safe low voltages.
- Conveyor and servos enclosed to avoid accidental injuries.

g. Data Analysis

- Classification accuracy will be calculated as percentage of correct results.
- Sorting speed (items/min) will be compared between manual and automated methods.
- Bar graphs will be plotted for accuracy and throughput comparison.
- Error analysis will identify misclassified categories for model improvement.

REFERENCE

1. Al-Khatib, I.A. et al. "Solid waste characterization, quantification and management practices in developing countries." *Waste Management*.
2. Otsu, N. "A threshold selection method from gray-level histograms." *IEEE Transactions on Systems, Man, and Cybernetics*.
3. OpenCV Documentation, *Image Classification with Convolutional Neural Networks*.