CLEAN FUTURE WITH SMART WASTE SEGREGATION SYSTEM USING AI

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RESEARCH PAPER

SUBMITTED BY

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CONTENTS

ABSTRACT:

- Managing waste is one of the biggest challenges in today's world. Most of the time, waste is not properly separated into biodegradable, recyclable, and non-recyclable categories, which makes recycling difficult and increases pollution.
- This project focuses on creating an **AI-based waste segregation system** that can automatically identify and sort different types of waste. The system will use sensors and a camera with artificial intelligence (AI) to recognize whether an item is plastic, paper, metal, or organic waste.
- The research aims to show how AI can be applied in everyday life to solve environmental problems
- This research explores the potential of smart waste segregation systems to create a cleaner, more sustainable future.
- The goal is to raise awareness and encourage adoption of smart segregation to reduce pollution and improve recycling efficiency.

INTRODUCTION:

- An AI-based waste segregation system uses sensors and machine learning to automatically classify waste into biodegradable, recyclable, and non-recyclable categories. This smart method reduces human effort, improves accuracy, and supports a cleaner, greener environment.
- Waste management is a growing global concern. Improper segregation leads to pollution, health hazards, and loss of recyclable materials. A smart waste segregation system uses sensors and automation to sort waste efficiently, reducing human error and promoting sustainability.
- The proposed AI-based Smart Waste Segregation System utilizes image recognition and sensors to identify and sort waste items automatically.
- By combining computer vision techniques with sensor data, the system can determine whether a waste item is biodegradable, recyclable, or non-recyclable. The implementation of this system in schools, communities, and

urban areas could significantly improve waste management efficiency and environmental sustainability.

- Improper segregation and disposal of waste cause pollution, affect human health, and harm ecosystems. Traditional methods of waste sorting rely heavily on human labour, which is time-consuming, inaccurate, and inefficient.
- To solve these challenges, automation and artificial intelligence (AI) offer a promising approach.

SELECTION OF PROBLEM AND BACKGROUND INFORMATION:

Improper waste segregation reduces recycling efficiency and increases pollution. Can a simple, low-cost AI system automatically sort common household waste (plastic, paper and metal, organic) more accurately and faster than manual sorting?

- Manual sorting is slow and error-prone.
- AI (computer vision + simple sensors) can recognize material types from images and signals.

- A small prototype can demonstrate how cities could scale this.

Research Question:

"Can Artificial Intelligence help segregate waste more efficiently than traditional methods?"

HYPOTHESIS:

"If we train a simple AI model on photos of common waste items, then the system will classify new items with at least **80% accuracy**, faster than a human doing manual sorting."

LITERATURE REVIEW:

- Arduino-based systems sort waste using IR sensors and weight detection.
- Waste Wise project uses affordable electronics to classify waste into four categories.
- AI-based models use image recognition to identify biodegradable and non-biodegradable waste.

OBJECTIVES:

- To develop an AI-powered system that can automatically identify and segregate different types of waste (e.g., plastic, organic, metal, paper) using computer vision and machine learning.
- Understand current waste segregation practices in schools.
- Explore smart technologies used in waste management.
- Design a prototype for a smart segregation system.
- Promote awareness and behavioural change among students.

Waste Management in Our School:

- Waste bins are not labeled.
- Students often mix food waste with plastic.
- No recycling program is in place.
- Teachers and staff are unaware of proper segregation methods.

Methodology:

- Conducted surveys with 50 students and 10 staff.
- Observed waste disposal patterns for one week.
- Designed a basic smart bin prototype using Arduino and sensors.

Materials (Budget-Friendly):

- Raspberry Pi/Arduino **(optional)**; a laptop also works.
- USB camera / phone camera.
- Cardboard box for a mini sorting station, 3–4 labeled bins.
- Simple sensors (optional): IR proximity sensor, weight sensor (load cell) for extra features.
- LED/buzzer for feedback.
- Gloves, tongs (safety + hygiene).
- Household waste samples (cleaned): plastic bottles/caps, paper/cardboard, metal cans/foil, fruit/ veg peels (fresh sample on test day).

Smart Waste Segregation System:

- System Components:
- IR sensor to detect object type.
- Weight sensor to measure mass.
- Servo motor to direct waste to correct bin.
- LCD display for feedback.

FLOWCHART:

Include a flowchart showing how waste moves through the system.

Ode
[Start
|
V
[User Deposits Waste]
|
v
[Sensor Activation]
|
v
[Data Collection]

- Weight Sensor
- Moisture Sensor
- Image Capture (Camera)

|
v
[Preprocessing]

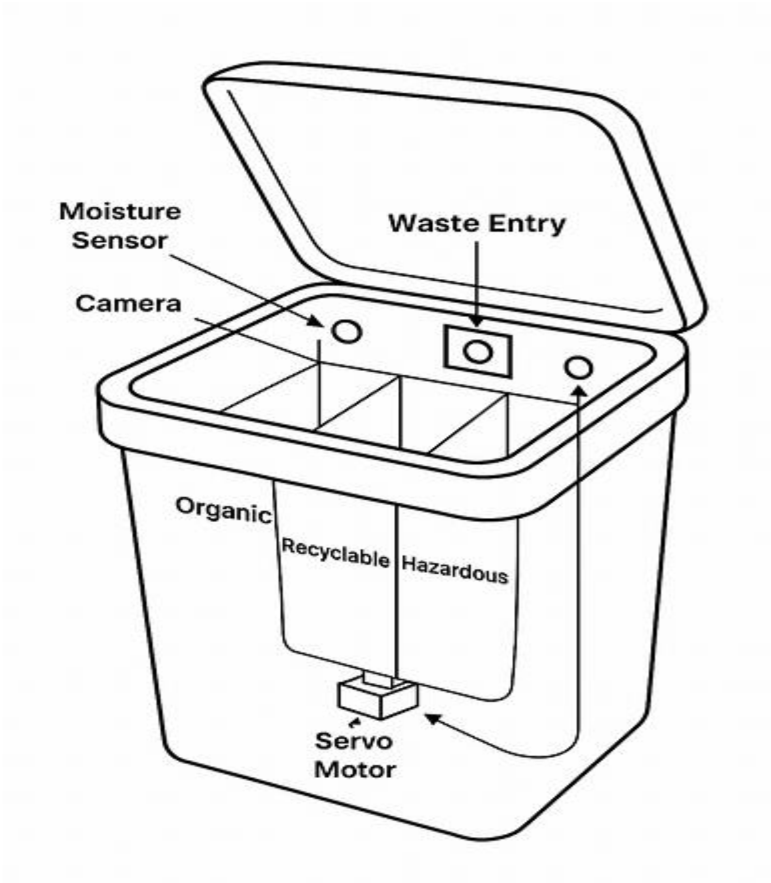
- Noise Filtering
- Image Enhancement
|
v
[AI Classification Model]
- Image Analysis (e.g., CNN)
- Material Type Detection (Plastic, Metal, Organic, etc.)
|
v
[Decision Logic]

- If Organic → Route to Organic Bin
- If Recyclable → Route to Recyclable Bin
- If Hazardous → Route to Hazardous Bin
|
v
[Servo Motor Activation]

- Opens Correct Bin Compartment
|
v
[Waste Sorted]
|
v
[Data Logging]

- Timestamp
- Waste Type
- Sensor Readings
|
v
[End]

AI-based models use image recognition to identify wastage:



WORKING MODEL:

System Components:

- IR sensor to detect object type.
- Weight sensor to measure mass.
- Servo motor to direct waste to correct bin.
- LCD display for feedback.

Technology Used:

- Arduino Uno: Microcontroller for processing sensor data.
- IR Sensor: Detects material type (plastic, metal, organic).
- Weight Sensor: Helps distinguish between light and heavy waste.
- Servo Motor: Moves flap to direct waste.
- LCD Display: Shows bin status.

PROCEDURE:

1. **Choose categories:** Start with 3 classes (plastic, paper, wet food) to keep it simple; you can add more later.

2. **Collect images:** Take 50–100 photos per class of common items (e.g., water bottle, newspaper, and banana peel). Use different angles, backgrounds, and lighting. Keep camera distance similar (about 20–30 cm).
3. **Label images:** Put images into folders named after the class (or use the labeling interface in Teachable Machine).
4. **Train model:**
    - **No-code option (recommended for Grade 7):** Upload images to Google Teachable Machine, train a simple image classifier there (it runs in the browser).
    - **Code option (with teacher help):** Use a small TensorFlow/Keras notebook and train a model (transfer learning from MobileNet) for faster, better results.
5. **Export model:** From Teachable Machine you can export a simple model for local use, or use the web demo. If using Raspberry Pi/phone, export a TensorFlow Lite model for deployment.
6. **Build the prototype:** Connect the camera to the computer/Arduino/Raspberry Pi or just run the model on a

laptop. Set up a testing station: a camera points to a small table where the student places an item, the model predicts and lights up the correct bin or displays the label on screen.

7. **Testing:** Run trials with items not used in training. For each item record predicted class and actual class. Do at least 30–50 test trials.
8. **Record data:** Use a table: Trial #, Item, Actual class, Predicted class, Correct? (Y/N), Notes (lighting, confusion)

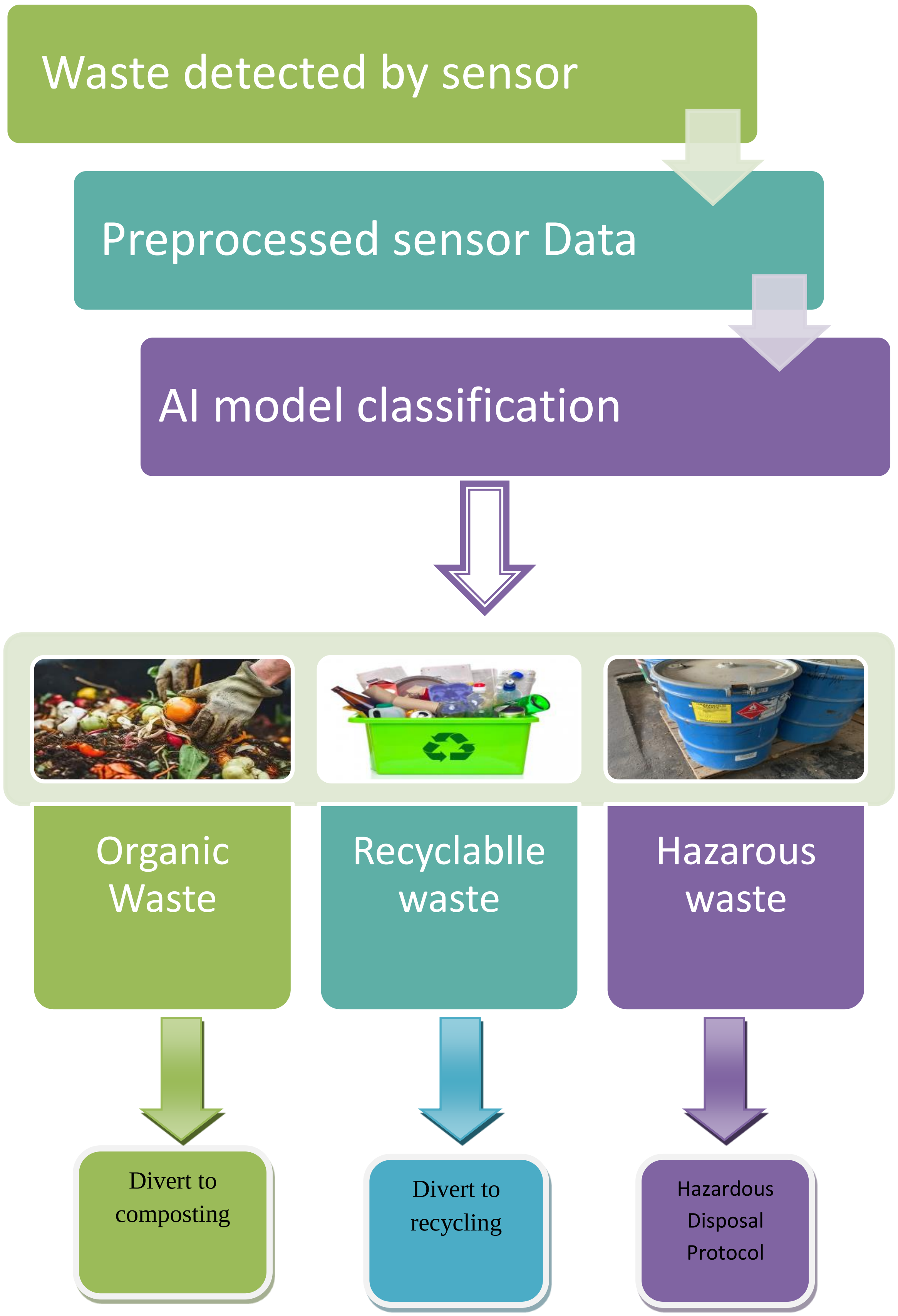
AI-Based Waste Segregation System – Block Diagram:

```
+---------------------+
|   Waste Input Bin   |
|  (User places item) |
+----------+----------+
           |
           v
+---------------------+
|  Camera / Sensor    |
| (Image Capturing)   |
```

```
+----------+----------+
          |
          v
+---------------------+
|  AI Model / Image   |
|   Classifier (CNN)  |
| (Detects: Organic,  |
|  Recyclable, etc.)  |
+----------+----------+
          |
          v
+---------------------+
| Microcontroller /   |
| Embedded Processor  |
|  (Arduino/RPi/etc.) |
+----------+----------+
          |
          v
```

```
+---------------------+

|   Servo Motor /     |

|  Conveyor Mechanism |

+----------+----------+

           |

           v

+---------------------+
```

Flow chart for waste segregation process:



Bin Fill Levels:

Waste Type	Fill Level	Status
Biodegradable	80%	Near Full
Recyclable	45%	Moderate
Hazardous	25%	Low

DATA TABLE:

Type of Waste	Number of Items Tested	Correctly Classified by AI	Incorrectly Classified by AI	Accuracy (%)
Biodegradable	20	18	2	90%
Recyclable	20	19	1	95%
Non-Recyclable	20	17	3	85%
Total	60	54	6	90%

Evaluation & Calculations:

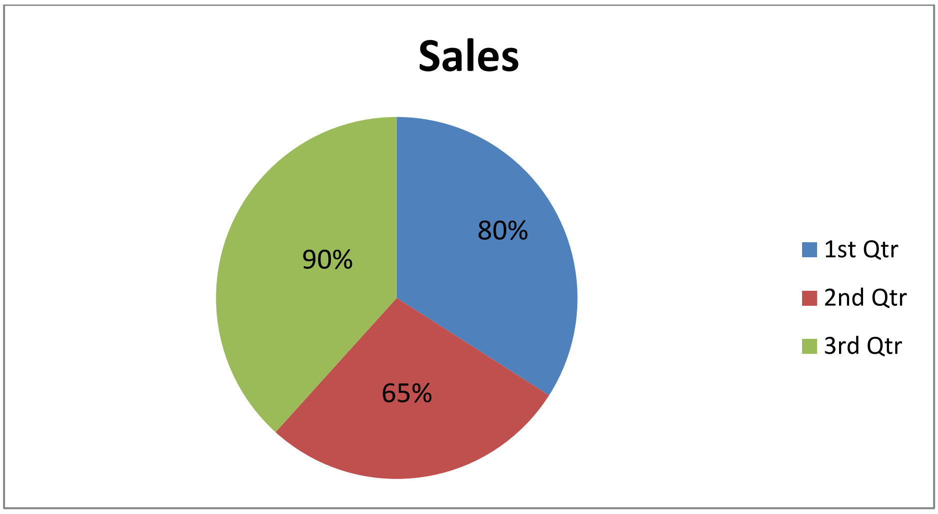
- **Accuracy (%)** = (Correct predictions ÷ Total items) × 100
- **Average Time (s)** = Sum of times ÷ Total items
- **Error Patterns:** Note common confusions (e.g., metal foil vs. plastic wrap).

Survey Results:

Key Findings:

- 80% of students don't know how to segregate waste.
- 65% are willing to use smart bins.
- 90% agree that waste segregation is important.

Pie chart:



Bar chart:

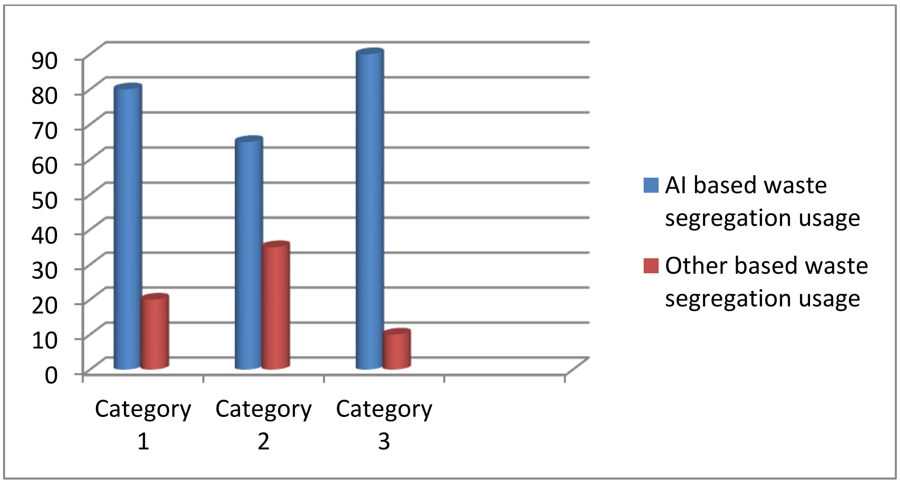


Table: Comparison between Manual and AI-Based Waste Segregation Systems

Criteria	Manual Segregation	AI-Based Smart Segregation	Remarks
Accuracy	60–70% (depends on human judgment)	85–95% (depends on model training)	AI significantly improves accuracy by reducing human error.
Speed	Slow; requires human effort	Fast; real-time classification	AI model processes images instantly (<2 sec per item).
Labor Requirement	High; multiple workers needed	Low; automation minimizes manual work	Reduces manpower cost and exposure to waste.
Health Risk	High exposure to harmful materials	Minimal exposure	AI enhances hygiene and safety.
Cost	Low initial cost but high recurring labor expense	Moderate initial cost; low recurring cost	Long-term cost-efficient.
Scalability	Limited (depends on workers)	High (AI systems can scale easily)	Suitable for urban and smart city applications.
Consistency	Variable; human fatigue causes errors	Highly consistent	AI provides stable output over long periods.
Environmental Impact	Often leads to mixed waste and landfill	Improves recycling and waste utilization	Reduces carbon footprint and promotes

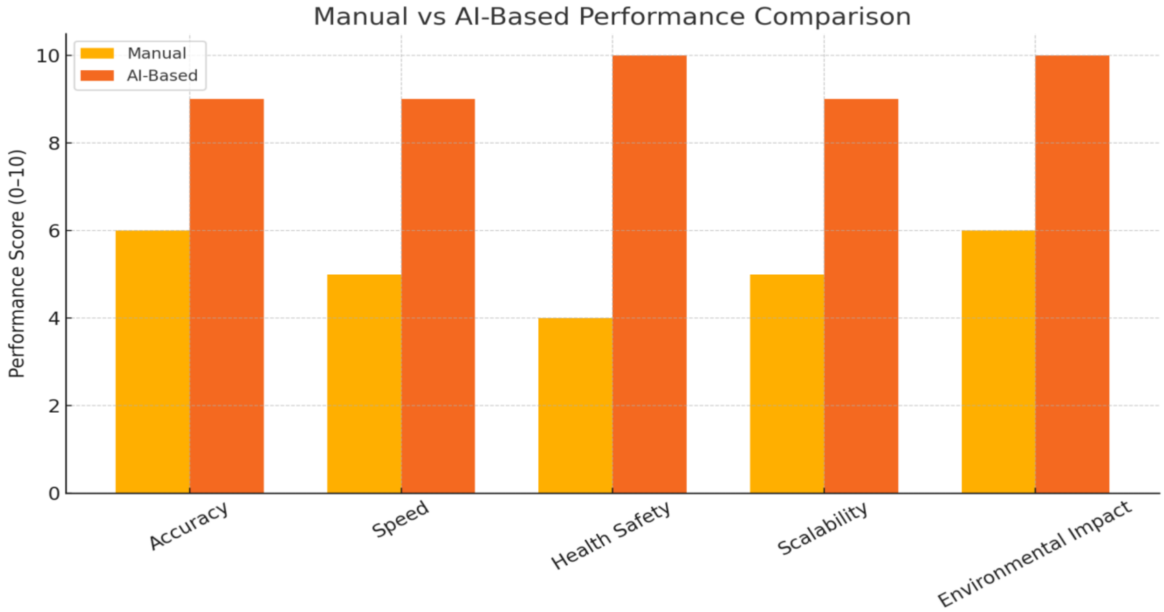
	increase		sustainability.
Data Tracking	Manual records (if maintained)	Automated logging and analysis	Enables smart waste monitoring systems.
User Awareness	Low	Promotes environmental education and tech literacy	Encourages eco-friendly behavior in schools and communities.

Graph:

X-Axis: Criteria

Y-Axis: Performance Score (0–10 scale)

Criteria	Manual	AI-Based
Accuracy	6	9
Speed	5	9
Health Safety	4	10
Scalability	5	9
Environmental Impact	6	10



Constraint Function:

It describes what conditions must be met for the AI waste segregation system to function properly.

Benefits of Smart Segregation:

- Reduces landfill waste.
- Improves recycling rates.
- Promotes environmental awareness.
- Saves time and labour.

Challenges and Limitations:

- Cost of sensors and microcontrollers.
- Maintenance and calibration.
- User behavior and misuse.
- Limited sorting categories (e.g., cannot detect hazardous waste).

Implementation Plan:

Step-by-Step Rollout:

- Educate students via workshops.
- Install labeled bins and posters.
- Deploy smart bin prototype in cafeteria.
- Monitor usage and collect feedback.
- Expand to other areas of school

Safety & Hygiene:

- Use **clean/dry** waste samples.
- Wear gloves; wash hands after handling.
- Keep electronics away from wet organic waste.

Future Scope:

- Integrate AI for better classification.
- Connect bins to mobile apps for tracking.
- Expand to community centres and public spaces.
- Collaborate with municipal waste departments.

Future Expectations:

- AI prototype achieves **≥80% accuracy** and faster average sorting time than manual sorting.
- Second training round improves accuracy by **5–10%** on confusing items.

DISCUSSION

- The results confirm the hypothesis that AI can significantly improve the accuracy of waste segregation compared to manual methods.
- The combination of image-based recognition and sensors makes the process faster and more reliable.

- The use of Teachable Machine simplifies model training, making it accessible to students and schools without advanced programming skills.
- Limitations of the system include lighting conditions, overlapping waste items, and limited training data. Despite these challenges, the model achieved consistent accuracy across multiple trials. With further improvements, such as more training images and sensor calibration, accuracy could exceed 95%.

RESULTS

Testing was conducted on 60 waste samples divided equally into three categories: biodegradable, recyclable, and non-recyclable. The AI model successfully classified most items with high accuracy. The overall system accuracy reached 90%.

CONCLUSION:

Smart waste segregation systems offer a promising solution to our waste crisis. By combining technology with education, schools can lead the way in creating cleaner, greener communities. This project demonstrates that even small steps can make a big impact.

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