1. Introduction

Improper waste disposal contributes to pollution, health hazards, and unsustainable environmental practices. Traditional waste sorting is slow and depends heavily on manual labor. With advancements in computer vision, automatic waste classification has become a realistic solution for improving recycling processes.

This project develops a real-time waste detection and classification system using YOLO for object detection and a Streamlit interface for user-friendly interaction. The system captures live images through a camera, analyzes the waste type, and displays predictions instantly.

2. Problem Statement

Waste segregation is often inaccurate and inconsistent due to human error. Most smart waste systems require heavy hardware or pre-sorted waste.
There is a need for a **lightweight, real-time AI model** that can:

- Detect waste objects accurately
- Classify them into categories (plastic, paper, metal, etc.)
- Run efficiently on a laptop or low-power device

3. Project Objectives

Primary Objectives

- Develop an AI-powered waste classification model using YOLO.
- Run real-time detection from a webcam or uploaded image.
- Provide an interactive user interface using Streamlit.

Secondary Objectives

- Improve waste sorting efficiency.
- Support environmental sustainability initiatives.
- Create a portable system that can be deployed anywhere.

4. System Architecture

The project is structured in the following pipeline:

```
Camera Input → YOLO Model → Waste Detection + Classification
→ Streamlit UI → Output to User
```

5. Dataset

The dataset contains labeled images of waste such as:

- Concrete

- Brick

- Tile

- Gypsum board

- Wood

- Foam

- Stone

- General w

- Pipes

- Plastic

The dataset was annotated with **bounding boxes** following YOLO format:

```
class_id  x_center  y_center  width  height
```

Split:

- **Train:** 80%
- **Validation:** 10%
- **Test:** 10%

6. Model Development

6.1 Model Choice

We used **YOLOv8** because of:

- High accuracy
- Real-time speed
- Strong multi-class performance
- Easy export to ONNX/PB formats

6.2 Training

We trained the model for 50 epochs using:

- `imgsz = 640`
- `batch = 16`
- Adam optimizer
- Augmentations (flipping, scaling, brightness adjustments)

10. Results

- The system detects and classifies multiple waste objects in real time.
- The Streamlit app performs smoothly and is easy to use.
- The model can detect small, overlapping, and multiple objects accurately.
- Overall performance is suitable for real-world deployment.

11. Limitations

- May misclassify objects in very low light.
- Performance depends on camera quality.
- Some waste types look visually similar (e.g., cardboard vs paper).

12. Future Work

To enhance the system, future improvements may include:

- Adding more waste classes
- Building a mobile version
- Integrating with IoT bins
- Using a lightweight model for edge devices (e.g., YOLO-NAS, YOLO-N)
- Enhancing dataset diversity

13. Conclusion

This project successfully demonstrates how computer vision can automate waste classification in real time. By integrating YOLO with a Streamlit interface, we created a powerful yet accessible system that promotes environmental sustainability. The solution is scalable, user-friendly, and suitable for educational, industrial, and environmental applications.