Final Project Report: Garbage Detection and Classification using Deep Learning

1. Project Summary

This project addresses the need for garbage classification and detection to support smart recycling systems. We developed a deep learning-based computer vision model that classifies and detects garbage into categories such as organic and recyclable. The solution automates the recognition of waste in real-time images, aiding in waste management systems and contributing to environmental sustainability.

2. Problem Statement

# 1. Background & Motivation

# Urbanization and population growth have significantly increased waste production worldwide, placing immense pressure on waste management systems. Manual waste sorting is labor-intensive, inefficient, and often hazardous to health. Automation in waste detection and classification offers a scalable solution to improve recycling efficiency, reduce environmental pollution, and promote sustainable development.

# To address this, we propose a computer vision-based system that integrates object detection and image classification to accurately identify and categorize garbage in real-time from images or video streams.

# 2. Objective

# To develop a robust and efficient Garbage Detection and Classification System that:

# Detects garbage objects in images/videos using YOLOv8, a state-of-the-art object detection algorithm.

# Classifies detected garbage items into predefined categories (e.g., Organic, Recyclable, Hazardous) using a fine-tuned VGG-19 convolutional neural network model.

# 3. Problem Definition

# The core problem is to automatically detect and classify garbage types in real-time to assist in waste segregation and smart waste management systems.

# Given an input image or video frame:

# Step 1: Use YOLOv8 to localize garbage items with bounding boxes.

# Step 2: Extract detected garbage regions and classify each using VGG-19, trained on a labeled dataset of garbage categories.

3. Data Collection & Preprocessing

Dataset Used:  
- Source: [RealWaste Dataset](https://www.kaggle.com/datasets/irkal123narayan456/realwaste-dataset?resource=download)  
- Total Images: ~3,000 images across 9 categories (Plastic, Cardboard , Metal, Glass, Paper, Food Organics, Miscellaneous Trash, Textile Trash, Vegetation)  
  
Preprocessing Steps:  
- Resizing images to 256x256  
- Normalization (Pixel scaling [0,1])  
- Data Augmentation (flip, rotation, zoom, others)  
- Splitting: the data was already split into Test, Train and Val.

4. Model Building

Model Type:

- pre-trained classification model VGG-19  
- pre-trained YOLOv8 object detection  
- Architecture: VGG-19 + unfreeze last 5 layers   
- Framework: TensorFlow/Keras

Evaluation Metrics:  
- Accuracy

5. Training & Validation

Epochs: 100  
Batch size: 64  
Optimizer: Adam  
Loss Function: focal loss  
  
Metric Results:  
- Training Accuracy: 93%  
- Validation Accuracy: 80%

6. Model Deployment

Deployment Stack:  
-Platform: Deployed on Azure Machine Learning Studio within an Azure Workspace.  
-Model Format:

- YOLOv8: Exported as .pt for inference using Python scripts.  
- VGG-19: Saved as a .h5 (Keras format) and registered in Azure ML.

7. Monitoring & Maintenance

- Real-time performance monitoring via logs  
- Alerts for misclassification or dropped accuracy  
- Scheduled model retraining (every 3 months)  
- Continuous integration pipeline for updated models

8. Challenges & Solutions

Challenge: Small dataset size  
Solution: Applied Data Augmentation  
  
Challenge: Model overfitting  
Solution: Used Dropout + EarlyStopping  
  
Challenge: Deployment lag  
Solution: Optimized model using TensorFlow Lite  
  
Challenge: Misclassifying similar items  
Solution: Improved with transfer learning (VGG-19)

Challenge: Unbalanced data  
Solution: Used class weight

Challenge: during train we used categorical loss  
Solution: Used focal loss instead

Challenge: faced crash while fine-tuning YOLOv8

9. Impact on Real-World Application

- Automated waste classification reduces human workload.  
- Supports smart city recycling initiatives.  
- Potential to integrate with robotic arms for waste separation.  
- Contributes to environmental sustainability and smart infrastructure.

10. Conclusion & Future Work

This project demonstrated the feasibility of using VGG-19 for real-time waste classification. The deployed model performs well on test data and is ready for real-world prototyping. Future enhancements will include:  
- Larger and more diverse datasets  
- Multi-class object detection using YOLOv8  
- Integration with IoT sensors for full automation