Waste Classification Using CNN Feature Extraction with SVM and KNN

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1. Introduction

Waste classification is a critical task in modern waste management systems, enabling efficient recycling and environmental sustainability. Manual waste sorting is time-consuming and error-prone, motivating the use of computer vision and machine learning techniques for automated waste classification.

This project presents a hybrid approach that combines **deep learning–based feature extraction** using a Convolutional Neural Network (CNN) with **classical machine learning classifiers** (Support Vector Machine and K-Nearest Neighbors). The system is designed to classify waste images into predefined categories and includes an **UNKNOWN rejection mechanism** to handle uncertain predictions.

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2. Dataset Description

The dataset used in this project is the **TrashNet dataset**, which consists of labeled images belonging to the following six waste categories:

- Glass
- Paper
- Cardboard
- Plastic
- Metal
- Trash

Each image is resized to **224 × 224 pixels** and normalized to the range **[0, 1]**.
The dataset is split as follows:

- **Training set:** ~70%
- **Validation set:** ~15%
- **Test set:** ~15%

Stratified splitting is applied to preserve class balance across all subsets.

3. Data Preprocessing

3.1 Image Loading and Cleaning

- Images are loaded using OpenCV.
- Corrupted or unreadable images are safely skipped using try/except blocks.
- All images are converted from BGR to RGB format.

3.2 Normalization

- Pixel values are scaled to the range **[0, 1]**.
- During CNN feature extraction, images are additionally processed using MobileNetV2's preprocess_input function.

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4. Data Augmentation

To reduce overfitting and improve generalization, data augmentation is applied to the training set using the following transformations:

- Random rotation (±20°)
- Zooming (up to 15%)
- Width and height shifting (10%)
- Horizontal flipping

Each training image is augmented once, effectively doubling the training data size.

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5. Feature Extraction Methods

5.1 CNN Feature Extraction (MobileNetV2)

A **MobileNetV2** architecture pre-trained on ImageNet is used as a **fixed feature extractor**:

- The classification head is removed (include_top=False)
- Global Average Pooling is applied to produce a **1280-dimensional feature vector**
- All CNN weights are frozen to reduce training time and overfitting

This approach leverages powerful deep visual representations while maintaining computational efficiency.

6. Classifier Models

6.1 Support Vector Machine (SVM)

- Kernel: Radial Basis Function (RBF)
- Parameters:
  - C = 10
  - gamma = scale
- Probability estimation enabled for confidence scoring

SVM performs well in high-dimensional feature spaces and provides robust decision boundaries.

6.2 K-Nearest Neighbors (KNN)

- Number of neighbors: k = 5
- Distance weighting applied

KNN serves as a non-parametric baseline classifier that relies directly on feature similarity.

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7. UNKNOWN Object Rejection

To improve real-world reliability, a confidence-based rejection mechanism is implemented:

- If the maximum predicted probability is below a threshold (0.5), the object is labeled as **UNKNOWN**
- This prevents forced misclassification of unseen or ambiguous objects

This feature is particularly important for deployment in real-world waste sorting systems.

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8. Experimental Results

8.1 Validation Performance

Model	Validation Accuracy
SVM (CNN features)	~0.88
KNN (CNN features)	~0.84

8.2 Test Performance

Model	Test Accuracy
SVM	Comparable to validation
KNN	Slightly lower than SVM

SVM consistently outperformed KNN due to its ability to construct optimal decision boundaries in high-dimensional feature spaces.

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9. Real-Time Classification System

A real-time waste classification application was implemented using a live camera feed:

- Captures frames via OpenCV
- Extracts CNN features in real time
- Performs classification using trained SVM and KNN models
- Displays predicted class and confidence score

This demonstrates the practical applicability of the proposed system.

10. Conclusion

This project successfully demonstrates a hybrid waste classification system that combines deep learning and classical machine learning techniques. By using MobileNetV2 for feature extraction and SVM/KNN for classification, the system achieves high accuracy while remaining computationally efficient.

The inclusion of data augmentation, confidence-based UNKNOWN rejection, and real-time classification makes the solution robust and suitable for real-world deployment.

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11. Future Work

- Fine-tuning the CNN backbone
- Incorporating additional waste categories
- Deploying the system on embedded devices
- Exploring ensemble classification strategies