AI-Powered Plastic Type Classification System

PROBLEM STATEMENT:

Plastic pollution is one of the most pressing environmental challenges of our time, affecting ecosystems, wildlife, and human health globally. A critical step in addressing this crisis is effective recycling, which requires accurate identification and sorting of different plastic types. However, traditional methods of plastic sorting rely heavily on manual inspection or basic mechanical separation, which is often time-consuming, labor-intensive, and prone to errors.

With the advancement of Artificial Intelligence (AI) and Deep Learning, it is now possible to create intelligent systems capable of identifying plastic types automatically from images. Using Convolutional Neural Networks (CNNs), these systems can analyze plastic item images, detect visual patterns, and predict the type of plastic material accurately.

To address this problem, there is a need for an intelligent, automated system that can classify plastic images into different categories such as HDPE, LDPA, PET, PP, PS, PVC, and Others. Such a system will support recycling facilities in efficient sorting, reduce contamination in recycling streams, and promote sustainable waste management by improving recycling accuracy and reducing plastic pollution.

PROJECT OBJECTIVES:

1. Develop an automated plastic classification system using Convolutional Neural

Networks (CNN) for accurate identification of plastic types from images.

2. Train a deep learning model capable of distinguishing between 7 different plastic categories with high accuracy.
3. Create a robust and scalable solution that can be integrated into recycling facilities to improve sorting efficiency.
4. Reduce human error and labor costs associated with manual plastic sorting.
5. Contribute to environmental sustainability by enabling better recycling practices and reducing plastic waste contamination.

DATASET INFORMATION:

Dataset Name:

Plastic Classification Dataset - Comprehensive Image Dataset for Plastic Material Recognition

About Dataset:

This dataset contains high-quality images of plastic items collected under various conditions. The images represent different plastic types, making it ideal for building machine learning and deep learning models focused on plastic material identification.

Key Details:

- Number of Classes: 7 classes (covering different plastic types)
- Image Type: RGB plastic item images
- Image Format: JFIF/JPEG
- Total Images: 2,100 images
- Dataset Split:
  - Training Set: 1,470 images (70%)
  - Validation Set: 420 images (20%)

- Test Set: 210 images (10%)

- Plastic Types Included:

  1. HDPE (High-Density Polyethylene) - Used in milk jugs, detergent bottles
  2. LDPA (Low-Density Polyethylene) - Used in plastic bags, squeeze bottles
  3. PET (Polyethylene Terephthalate) - Used in beverage bottles, food containers
  4. PP (Polypropylene) - Used in food containers, bottle caps
  5. PS (Polystyrene) - Used in disposable cups, packaging materials
  6. PVC (Polyvinyl Chloride) - Used in pipes, credit cards
  7. Other - Mixed or unidentified plastic materials

Dataset Source:

[Plastic Classification Dataset]

SOLUTION APPROACH:

The proposed solution involves developing an AI-powered classification system using Convolutional Neural Networks (CNN) with the following approach:

1. Data Preprocessing:
   - Image resizing to uniform dimensions (224x224 or 150x150 pixels)
   - Normalization of pixel values (0-1 range)
   - Data augmentation (rotation, flip, zoom) to improve model generalization
2. CNN Model Architecture:
   - Multiple convolutional layers for feature extraction
   - MaxPooling layers for dimensionality reduction
   - Flatten layer to convert 2D features to 1D
   - Dense (Fully Connected) layers for classification

- Dropout layers to prevent overfitting
- SoftMax activation for multi-class classification

3. Model Training:
   - Framework: TensorFlow/Keras
   - Optimizer: Adam
   - Loss Function: Categorical Cross-Entropy
   - Metrics: Accuracy, Precision, Recall
   - Training Environment: Python with GPU acceleration (if available)
4. Model Evaluation:
   - Accuracy and loss analysis on validation set
   - Confusion matrix to identify misclassifications
   - Precision, Recall, F1-Score for each class
   - Testing with unseen images from test set

EXPECTED OUTCOMES:

1. A trained CNN model with minimum 75-80% accuracy on validation data
2. Saved model file (.keras format) for deployment
3. Comprehensive analysis reports with accuracy/loss graphs
4. Sample prediction visualizations
5. Documentation of implementation process
6. Reusable Python scripts and Jupyter notebooks

IMPLEMENTATION PLAN:

Week 1: Dataset Collection Phase

✓ Problem identification and research

✓ Dataset collection from Kaggle

✓ Dataset organization (train/validation/test split)

✓ Initial exploration and understanding of plastic types

✓ Technology stack selection

Week 2: Implementation Phase

✓ Environment setup (Python virtual environment)

✓ Data analysis and visualization

✓ CNN model architecture design

✓ Initial model implementation

✓ Data preprocessing and augmentation setup

✓ Training pipeline development

Week 3: Final Implementation and Results

✓ Model training and hyperparameter tuning

✓ Model evaluation and testing

✓ Achieved 48.13% test accuracy

✓ Confusion matrix and classification reports generated

✓ Sample predictions visualization

✓ Complete documentation with results

✓ Final working model saved and ready for deployment

Conclusion:

Successfully developed a CNN-based plastic classification system achieving 48.13% test accuracy. The model performs best on PP (97% recall), LDPA (83% recall), and PET (67% recall) classes. While challenges remain with PS, Other, and PVC classes due to visual similarities and class imbalance, the system demonstrates the feasibility of AI-powered plastic classification for recycling applications.

Future Enhancements:

- Web application development (Streamlit/Flask)
- Model optimization for better accuracy
- Real-time classification system
- Integration with recycling facility systems

TECHNOLOGIES USED:

- Programming Language: Python 3.x
- Deep Learning Framework: TensorFlow / Keras
- Data Processing: NumPy, Pandas
- Visualization: Matplotlib, Seaborn
- Image Processing: PIL/Pillow, OpenCV
- Development Environment: Jupyter Notebook, VS Code
- Version Control: Git/GitHub

REAL-WORLD APPLICATIONS:

1. Recycling Facilities: Automated sorting of plastic waste for efficient recycling
2. Waste Management Companies: Reducing contamination in recycling streams
3. Environmental Monitoring: Tracking plastic waste types in different regions
4. Educational Tools: Teaching AI applications in environmental sustainability
5. Smart Bins: Integration with IoT-enabled waste bins for automatic classification

CHALLENGES AND CONSIDERATIONS:

1. Class Imbalance: Some plastic types may have fewer samples
2. Image Quality: Variations in lighting, angle, and background
3. Similar Appearance: Some plastic types look visually similar
4. Real-world Conditions: Model must work with diverse image conditions

5. Computational Resources: Training CNNs requires adequate hardware

PROJECT SIGNIFICANCE:

This project demonstrates the application of AI and Deep Learning in solving real-world environmental problems. By automating plastic classification, we can:

- Improve recycling efficiency and reduce manual labor
- Decrease contamination in recycling processes
- Support the circular economy by enabling better material recovery
- Contribute to reducing plastic pollution and environmental impact
- Showcase the potential of AI in sustainability initiatives