1. Project Overview

This project explores an **Edge AI prototype** that classifies waste into six categories (plastic, paper, glass, metal, organic, and battery) using a lightweight CNN model. The trained model is converted to **TensorFlow Lite** for real-time, on-device deployment — showcasing the potential of AI in environmental sustainability and smart city solutions.

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2. Tools & Frameworks

- **Framework:** TensorFlow, TensorFlow Lite
- **Platform:** Google Colab
- **Dataset:** Garbage Classification (Kaggle – 775 images per class)
- **Model Architecture:** Lightweight CNN with 3 convolutional blocks, dropout
- **Deployment:** TensorFlow Lite Model

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3. Dataset Description

- Total Images: ~4,650
- Categories:
  - plastic
  - paper
  - metal
  - glass
  - battery
  - organic
- Format: Folder-based, one subfolder per class
- Train/Validation Split: 80/20 (via ImageDataGenerator)

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4. Model Architecture

plaintext

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Input: (150, 150, 3)

- Conv2D(16) + MaxPooling2D
- Conv2D(32) + MaxPooling2D
- Conv2D(64) + MaxPooling2D
- Flatten
- Dense(128) + Dropout(0.3)
- Dense(6, Softmax Output)
  - Activation: ReLU for hidden layers, Softmax for output
  - Loss: Categorical Crossentropy
  - Optimizer: Adam
  - Regularization: Dropout (0.3) to reduce overfitting

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5. Training Results

Metric	Value
Final Training Accuracy	~96%
Final Validation Accuracy	~62% (before overfitting prevention)
Epochs	6–10 (EarlyStopping used)

- **Training Time:** ~10 minutes on Google Colab
- **EarlyStopping:** Activated on plateau in validation loss
- **Augmentation:** Flip, rotate, zoom, shift

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6. Evaluation Metrics

Classification Report:

Precision, Recall, F1-Score: Evaluated per class

Confusion Matrix: Validated true vs predicted labels

```
30/30 ━━━━━━━━━━━━━━━━━━━━ 19s 594ms/step
Classification Report:
              precision    recall  f1-score   support

     battery       0.21      0.14      0.16       155
       glass       0.12      0.07      0.09       155
       metal       0.20      0.21      0.21       155
     organic       0.12      0.15      0.13       155
       paper       0.15      0.23      0.19       155
     plastic       0.21      0.19      0.20       155

    accuracy                           0.17       930
   macro avg       0.17      0.17      0.16       930
weighted avg       0.17      0.17      0.16       930

Confusion Matrix:
[[21 14 24 31 44 21]
 [ 8 11 26 41 45 24]
 [18 15 33 39 32 18]
 [24 11 29 23 40 28]
 [18 25 21 30 36 25]
 [12 18 30 29 36 30]]
```

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7. Deployment Steps

✅ **Model Conversion to TFLite:**

python

```
converter = tf.lite.TFLiteConverter.from_keras_model(model)

tflite_model = converter.convert()

with open("garbage_classifier_6classes.tflite", "wb") as f:

    f.write(tflite_model)
```

✅ **On-Device Inference Code:**

python

```
interpreter = tf.lite.Interpreter(model_path="model.tflite")

interpreter.allocate_tensors()

...
```

✅ **Real-Time Prediction Sample:**

python

Prediction: Plastic (Confidence: 0.87)

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8. Edge AI Benefits in Real-Time Applications

Edge AI Advantage	Explanation
🧠 Local Inference	No internet needed — classification runs directly on-device
⚡ Low Latency	Fast response for real-time classification
🔋 Power Efficient	Lightweight model = lower energy consumption
🔒 Privacy & Security	No data is sent to the cloud
🌍 Scalable Impact	Can be deployed on phones, Raspberry Pi, or smart bins

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9. Challenges & Future Work

Challenge	Solution
Overfitting due to small dataset	Solved with augmentation + dropout
Limited validation accuracy	Explore deeper architectures or pre-trained MobileNetV2
Binary class imbalance	Dataset was balanced; future: real-world imbalance mitigation

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10. Ethical Considerations

- ✅ Waste classification promotes environmental responsibility
- ⚠️ Models must be tested on diverse image conditions (lighting, backgrounds)
- ⚠️ Avoid overreliance — edge AI should assist, not replace, human oversight

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📢 Closing Statement

This project demonstrates how **Edge AI and sustainability** can work together — creating smarter, cleaner, and more responsive cities. With future integration into **IoT trash bins** or **smart recycling centers**, this prototype could serve as a base for impactful green technology.