Convolutional Neural Networks for Sustainable Waste Classification
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Background / Problem Statement

Motivation: Municipal recycling is complicated by inconsistent waste disposal practices—educating consumers on proper disposal methods can significantly enhance the efficiency and safety of recycling processes.

Automated waste classification: Given an input image of some piece of waste, determine the appropriate disposal task as a multi-class classification task.

Mobile use case: Target end use is in a mobile app that should allow consumers to perform real-time waste classification using their phone camera. Therefore, we seek an optimal combination of classification performance and model efficiency (compute- and memory-intensity).

Data Collection and Preprocessing

- We use the TrashNet dataset collected by Yang and Thung as the base of our dataset: 2,027 color images of waste labeled as one of six classes: paper, plastic, metal, card, glass, trash.
- We augment the dataset with an additional 546 images by rotating 588 images across the six TrashNet categories.
- We applied data augmentation techniques (random crops and random flips) to images in the training set.
- Combined dataset size of 3,723 images is split 70/15/15.

Methods

Model Selection: Problem feasibility established with best-in-class performance models: VGG-16, ResNet101, and then optimized for a mobile hardware setting (MobilenetV2). Results compared to RBF SVM baseline.

Transfer Learning: ImageNet pretrained models are used, with output layer swapped to match classification task. Models are fine-tuned (re-trained) on our data using different learning methods:

1. No fine-tuning other than final linear layer
2. Partial fine-tuning of subset of model layers
3. Full fine-tuning of all model layers

Experiments and Results

Confusion Matrices for Test Set Classification
- Convolutional models significantly outperform the SVM baseline, and do so exhaustively across all class categories.
- Summary of Model Performance
  - Convolutional models consistently achieve the best results for all model architectures used.

Conclusions

- High accuracy and performance show that robust waste classification can be achieved by leveraging CNNs and deep learning-based modeling.
- Consistently strong performance for lightweight, compute-optimized models suggests that classification performance can be feasibly adapted to a mobile hardware setting.
- High visual variance in certain waste types (e.g., paper) suggests that augmenting data is an important determinant of robustness.

Future Work

- Expand and enrich dataset, especially for rare or compost classes.
- Measure on-the-fly classification time for model usage on mobile hardware.
- Implement interactive guidance to help users properly dispose of classified waste.