# WISE: Waste Identification, Segmentation, and Evaluation
## Convolutional Neural Networks for Garbage Classification

**Brett Castro, Tyler Gorecki, Vishwanath Guruvayur, Akaash Kamdar, Isaac Levy**

### Motivation

Proper waste management is a crucial aspect of sustainability, yet many people struggle to correctly sort their trash into garbage, recycling, and compost. Misclassification of waste contributes to environmental pollution and inefficient recycling processes. Our project aims to address this issue by developing a deep learning model capable of classifying waste into the appropriate category. We are also motivated by the tangibility of our project to hopefully make an immediate positive impact in our community.

Initially, we explored datasets related to garbage classification and image detection for recycling, as well as a dataset for distinguishing fresh versus rotten fruit. This sparked the idea of combining these concepts into a comprehensive classification model that not only identifies waste types but also assesses food spoilage. By leveraging computer vision and classification techniques, our model could help optimize waste disposal systems, potentially benefiting schools, businesses, and urban environments.

This project is an application-driven approach to sustainability, harnessing deep learning to improve waste sorting efficiency and promote responsible disposal practices. We aim to contribute to ongoing sustainability efforts within the UVA School of Data Science, demonstrating the potential of AI to drive meaningful environmental impact.

### Dataset

One dataset we will be using is a Garbage Dataset from Kaggle. This dataset contains 10 classes of garbage, ranging from metals to plastic to battery to clothes. The full dataset holds just under 20,000 images with a balanced distribution, meaning each of the ten categories is sufficiently populated with high quality images. The second dataset that we will also be using is a Fruit and Vegetable Dataset (Healthy vs Rotten) from Kaggle. This dataset contains 28 different classes, including healthy and rotten images for 14 different fruits and vegetables with 200 or more images per class. We plan to incorporate this dataset with the garbage dataset to train a garbage classifier to understand when a product may be trash or not.

### Related Work

There is a litany of previous work exploring the application of deep learning models to recycling and waste identification. Aral et al. (2018, p. 1) determined that using a tuned version of DenseNet121 with Adam optimizer could achieve an accuracy of 95% in classifying the Trashnet dataset. Chen et al. (2023, p. 1) proposed combining "ShuffleNet v2 and the depth-separable convolution method to create lightweight YOLOv5s for classifying and positioning recyclable waste," which requires only 62% of the parameters of the original model and still manages to achieve an accuracy of 94%, while also being 11.5% faster. Finally, there is a need for more efficiently and accurately identifying not just waste vs recycling, but also different types of recyclable materials. "[C]onventional techniques like near-infrared spectroscopy (NIRS)...face difficulties in accurately classifying chemically similar samples, such as polyethylene terephthalate (PET) and PET-glycol (PET-G), which have similar chemical compositions but distinct physical characteristics" (Choi et al., 2023, p. 1). Their work uses a

YOLO model to identify different plastic types that need to be separated for recycling to increase efficiency and recycling purity that surpasses conventional techniques. Overall, there is a substantial history and continued development aimed at improving the image segmentation and classification and subsequent processing of waste materials.

**Technical Plan**

Firstly, we would preprocess and standardize all the images from the various valuable datasets we have by resizing and normalizing them using data augmentation. This should help the model to be trained on a generalized dataset and avoid any biased predictions. Our project consists of 2 primary deep learning tasks - an Object Segmentation Task – to identify multiple objects in an image and a Classification Task – to classify the identified objects into one of the 3 garbage labels/classes.

For the Object Segmentation Task, we will explore segmentation models like YOLOv8-seg or Mask R-CNN to identify and outline distinct objects in an image. For the Classification Task we will mainly explore fine-tuning pretrained architectures like ResNet or MobileNet for improved accuracy on the cropped images from the Object Segmentation Task. We will train the model using cross-entropy loss, comparative selection within optimizers and an adaptive learning rate schedule.

The final product is a trained model that takes in any image as input and it will first detect and outline distinct objects in the image, then classify each object by labelling them as one of the categories – plastic, metal, or compost.

**Evaluation Plan**

To evaluate the model we create in this project, the first thing we will do is test the classifications on unseen pictures into one of the three categories: garbage, recycling, and compost. This set of pictures will be curated for deep learning image classification applications and we will expect high performance. However, something that we would like to implement further into the project is being able to classify pictures instantly from our phones. This would provide a more realistic use case if this was to be implemented either on an app or as a trash sorting model from a corporate perspective. Being able to classify pictures in unique lighting, parts of the whole, or just different angles in general would take our image classification project to the next level. By exploring these various classification scenarios, we aim to develop a versatile model that can adapt to real-world waste sorting challenges, ultimately contributing to more effective and efficient waste management practices.

**References**


Garbage Dataset, Fruit and Vegetable Dataset

Aral, R. A., Keskin, S. R., Kaya, M., & Haciomeroglu, M. (2018). Classification of trashnet dataset based on deep learning models. *2018 IEEE International Conference on Big Data (Big Data)*, 2058–2062. https://doi.org/10.1109/BigData.2018.8622212

Chen, Y., Luo, A., Cheng, M., Wu, Y., Zhu, J., Meng, Y., & Tan, W. (2023). Classification and recycling of recyclable garbage based on deep learning. *Journal of Cleaner Production*, *414*, 137558. https://doi.org/10.1016/j.jclepro.2023.137558

Choi, J., Lim, B., & Yoo, Y. (2023). Advancing plastic waste classification and recycling efficiency: Integrating image sensors and deep learning algorithms. *Applied Sciences*, *13*(18), 10224. https://doi.org/10.3390/app131810224