Image Classification for Environmental Conservation:

Organic vs. Recyclable

Group 3:

- Brody Sherwood
- Woojong Choi

From Waste to Wisdom: Classifying Organic vs. Recyclable waste

Problem statement & Objectives

Background

- The U.S. produces 268 million tons of waste — 140 million going into landfills — each year, with the average American tossing 4.5 pounds of trash per day.
- The US recycling rate has increased steadily: from less than 7% in 1960 to the 32% as of 2022

Problem:

- Lack of recycling infrastructure in the US
- Manual waste classification process is time-consuming, labor-intensive, and prone to human error
- Mostly going to landfills and incinerators

Solution:

- Design a model to accurately classify items in images as either organic or recyclable and integrate the model into EcoSolutions' facilities for streamlined waste sorting process

Success Criteria:

- Create a model that scores higher than **90%** accuracy when classifying ‘organic’ vs ‘recyclable’ images

Steps

1. **Obtain image data**
2. **Load, process and analyze images**
3. **Train and validate binary classification models to predict whether an image corresponds to 'organic' or 'recyclable' waste**
4. **Evaluate model performance on unseen images**

Image Data & Preprocessing

Images

Source: Kaggle

Data:

- 22,564 images for training
- 2,513 images for testing

Preprocessing

1) Convert to RBG
2) Image size 128 x 128 (multiple iterations)
3) Binarize class labels

Sample Images

organic

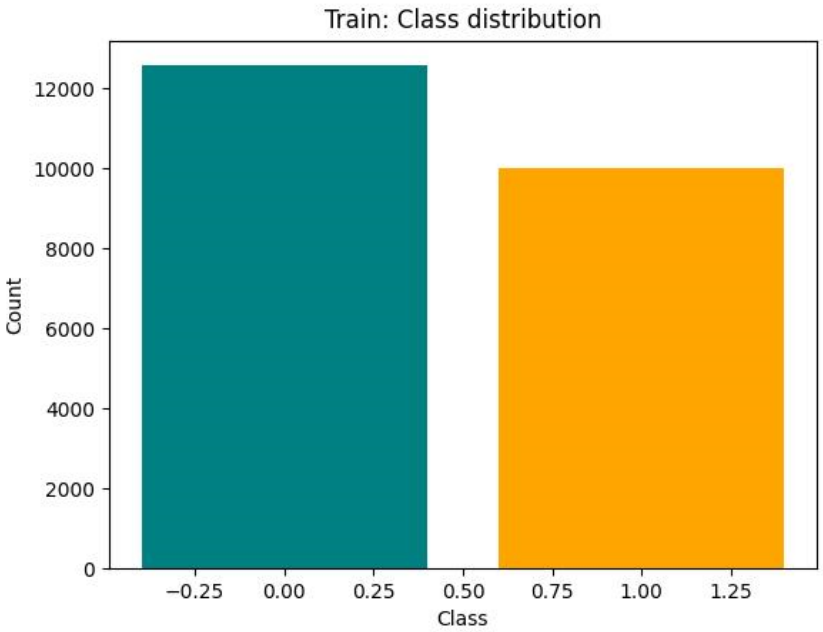
organic

recyclable

recyclable

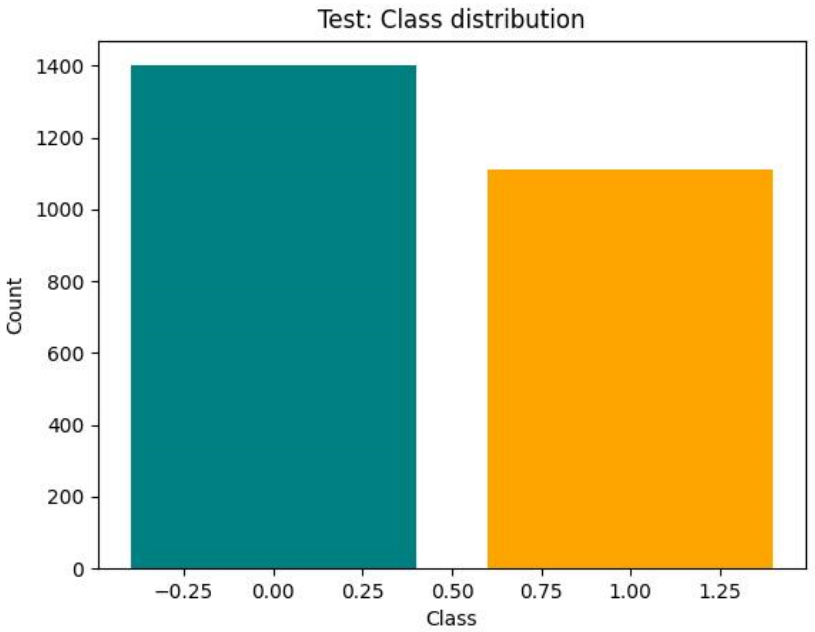
Organic vs Recyclable: Class Distribution

Train



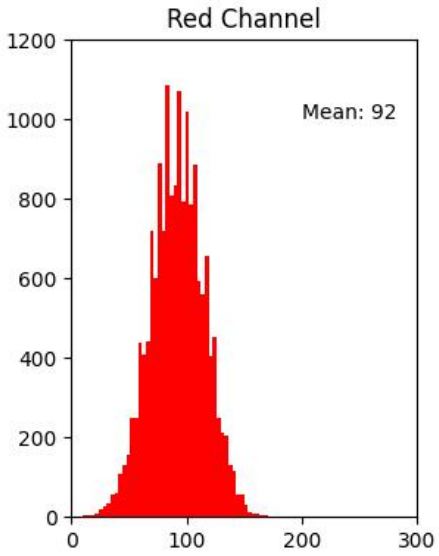
- Organic: 12,565 (55.7%)
- Recyclable: 9,999 (44.3%)

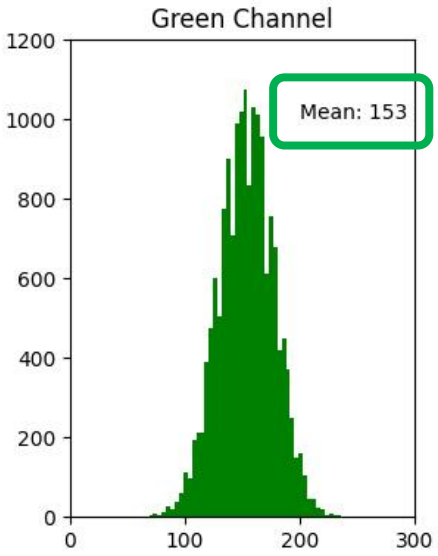
Test

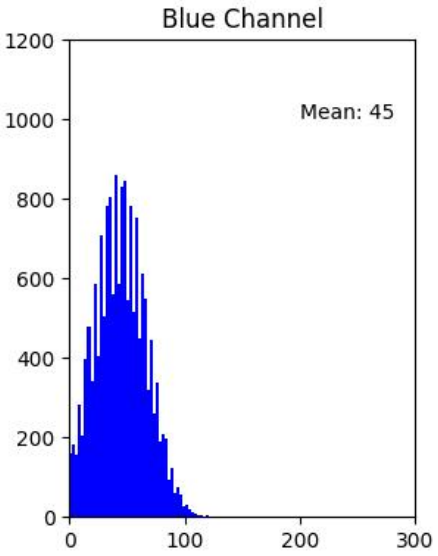


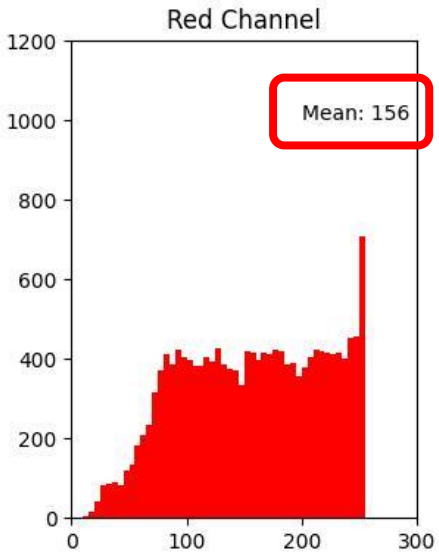
- Organic: 1,401 (55.7%)
- Recyclable: 1,112 (44.3%)

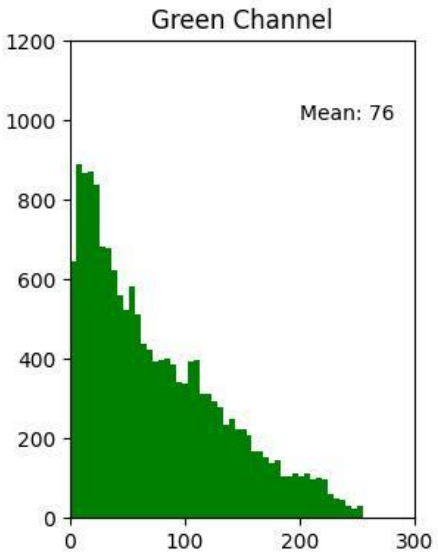
RGB Color Channels

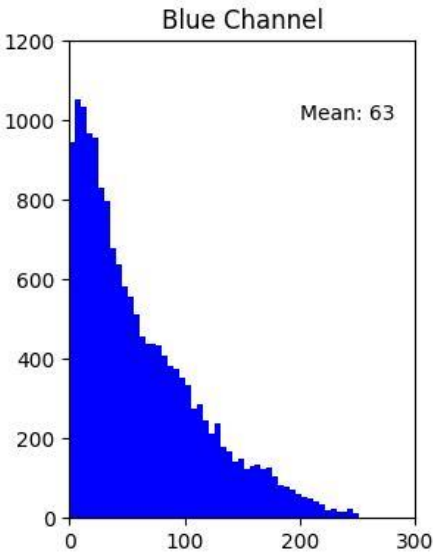








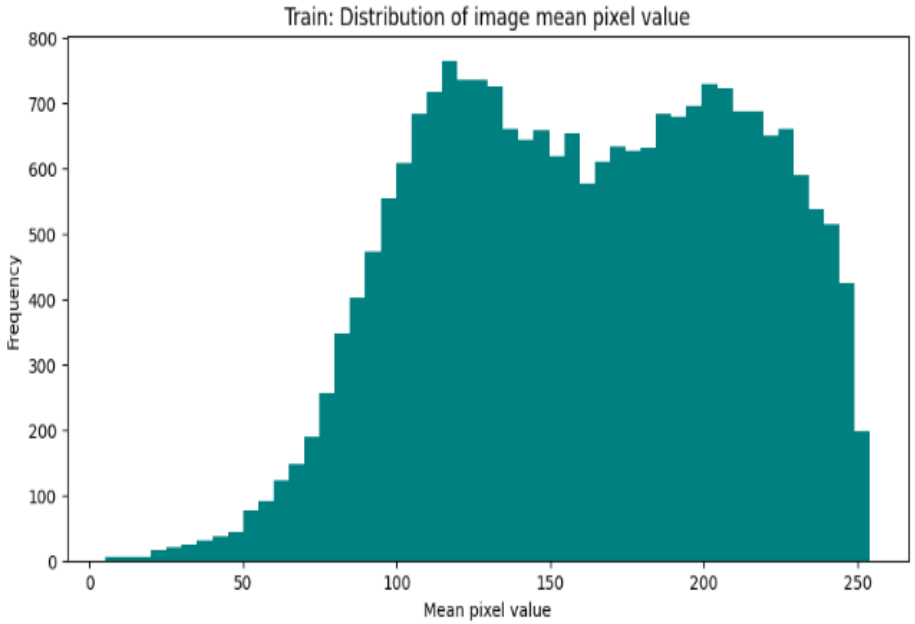




Distribution of mean pixel RGB value for images

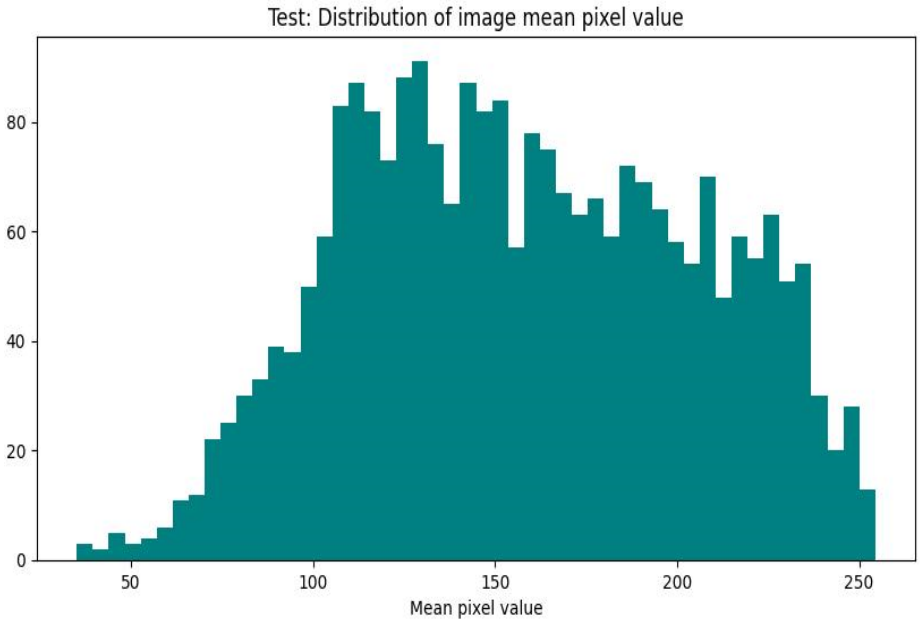
Color intensity / brightness of pixels

Train



Mean: 161.20

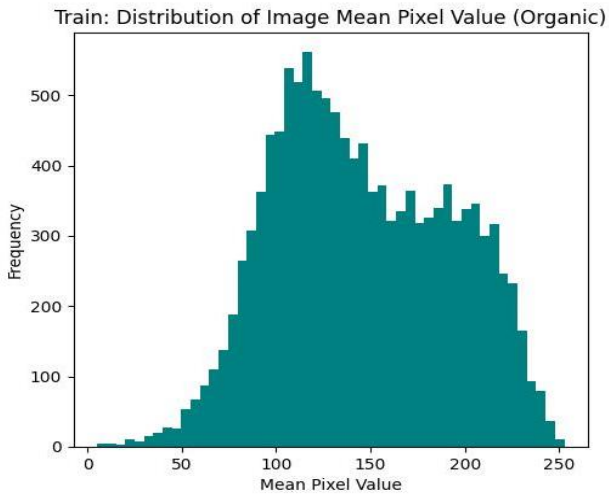
Test

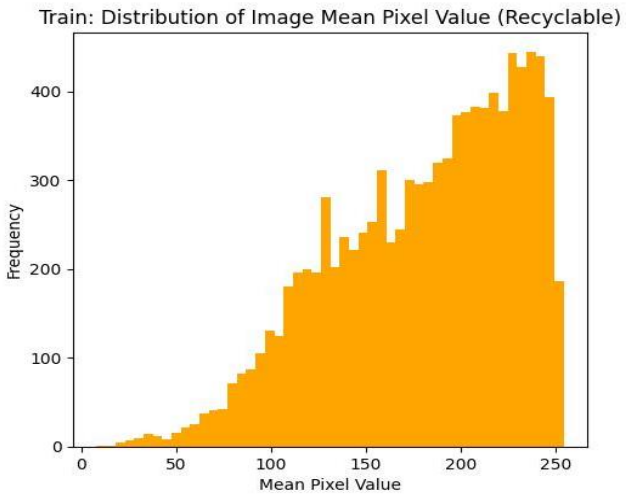


Mean: 157.73

Distribution of mean pixel RGB value for images – by class

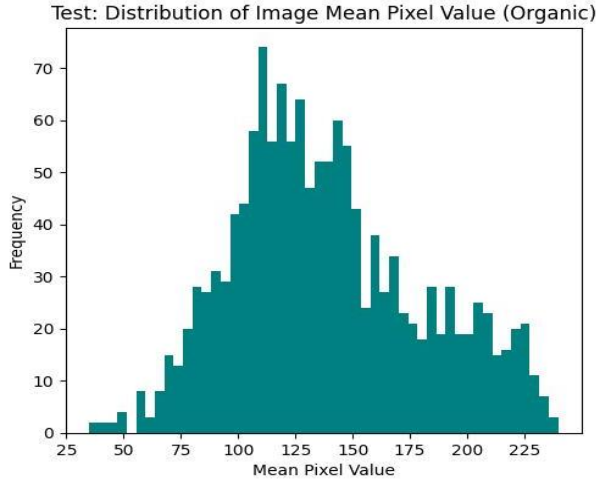
Train

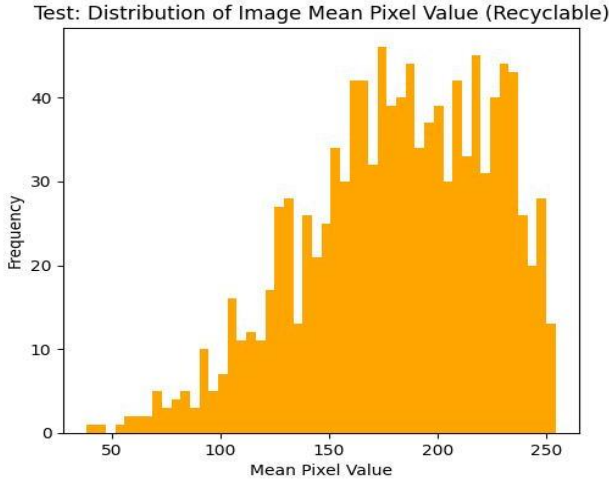




- **Organic: 145.65**
- **Recyclable: 180.75**

Test

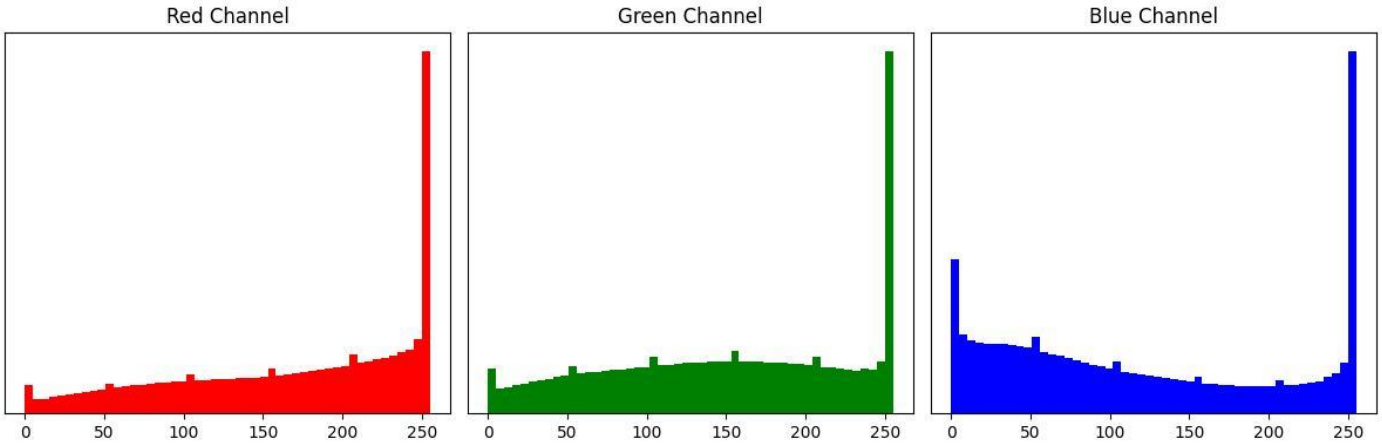




- **Organic: 138.93**
- **Recyclable: 181.42**

Distribution of color channels – by class

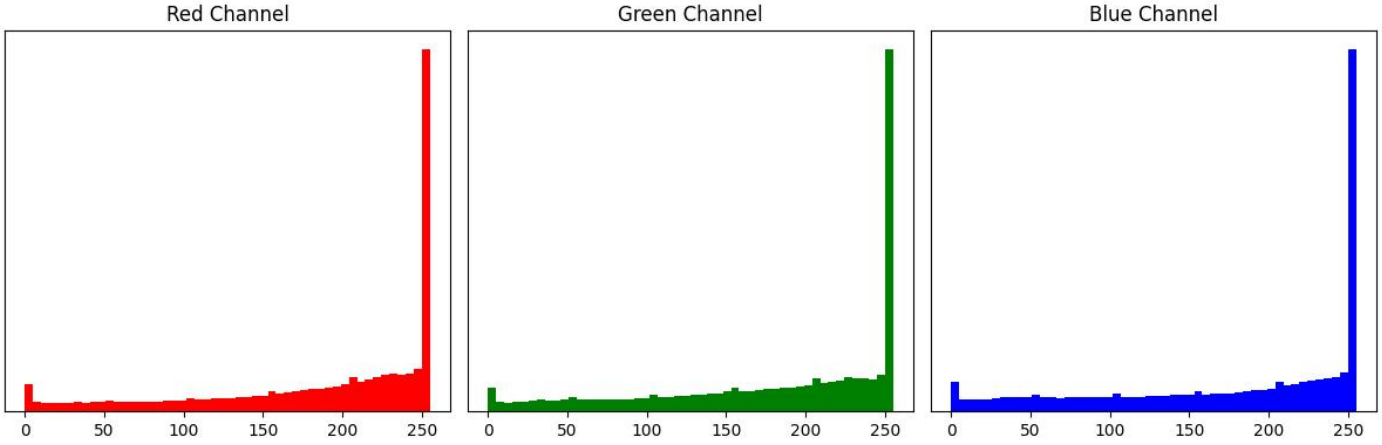
Organic



Color Channel Mean

- **Red: 167**
- **Green: 150**
- **Blue: 120**

Recyclable



Color Channel Mean

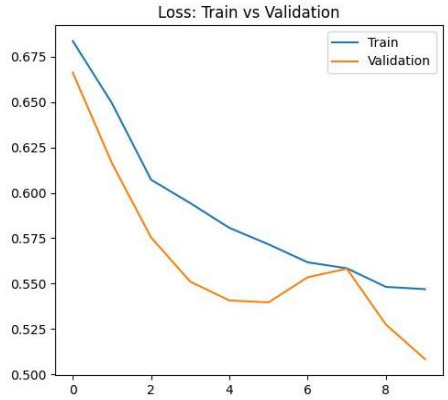
- **Red: 186**
- **Green: 181**
- **Blue: 175**

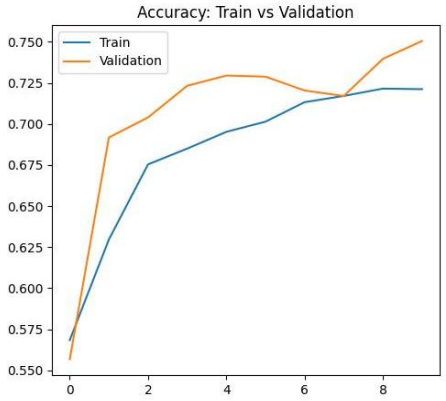
Modeling – Exploratory Modeling

Baseline:
Organic: 55.69%
Recyclable: 44.31%

Model 1

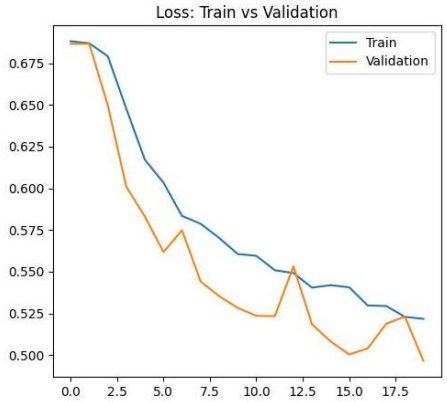
- 2 Convolutional layers
- 1 Dense layer
- Accuracy:
  - Train: 0.721
  - Validation: 0.750

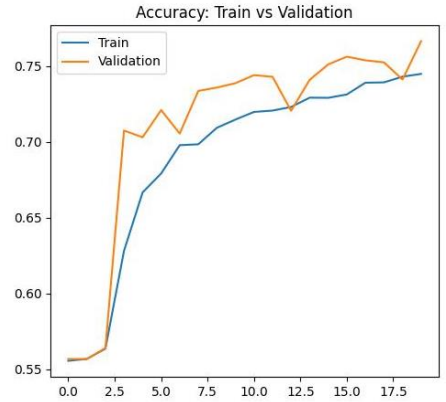




Model 2

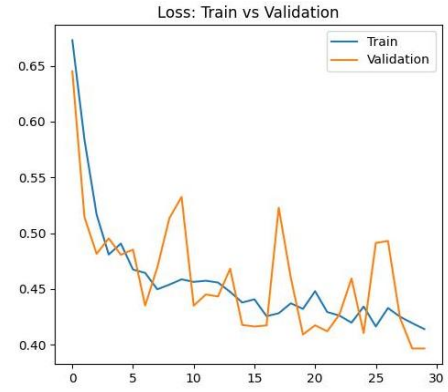
- 3 Convolutional layers
- 1 Dense layer
- Accuracy:
  - Train: 0.745
  - Validation: 0.766

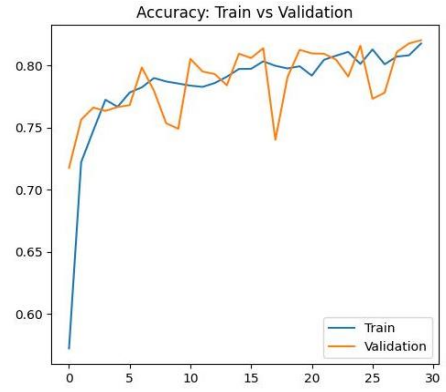




Model 3

- 4 Convolutional layers
- 2 Dense layer
- Accuracy:
  - Train: 0.818
  - Validation: 0.821



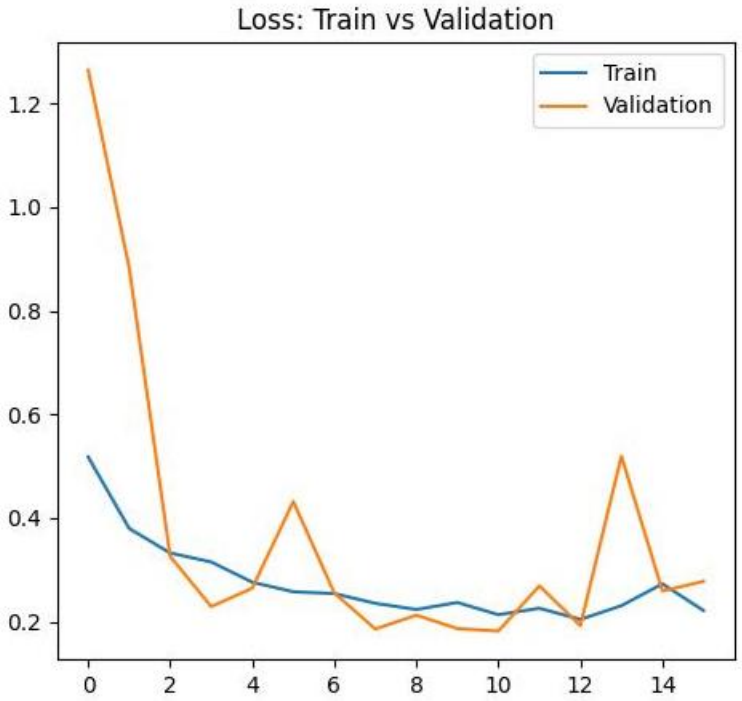


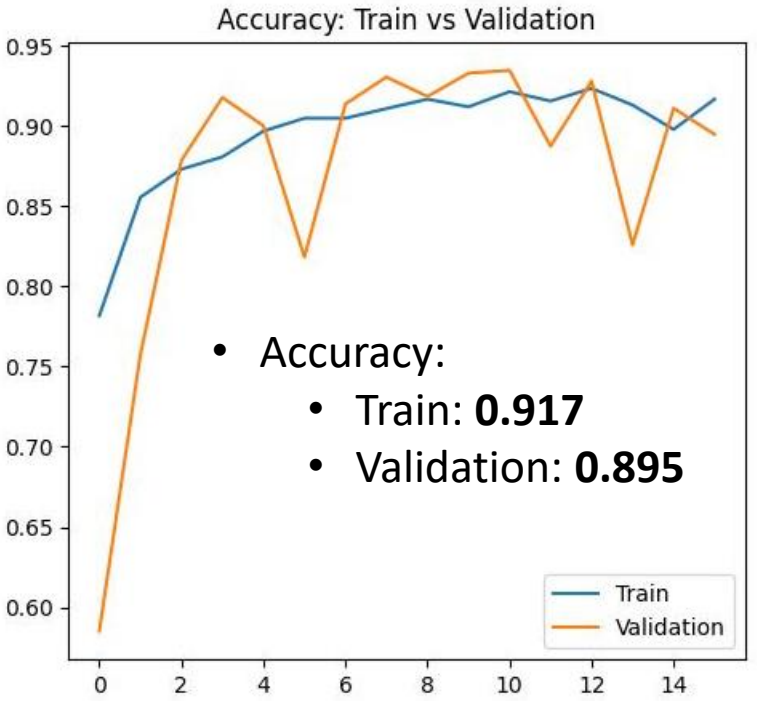
Modeling – Transfer learning – VGG16

Baseline:
Organic: 55.69%
Recyclable: 44.31%

VGG16 + Custom 'top' model

- Base model: VGG16
- Data Augmentation
- 2 Dense layers
- Drop out
- Early stopping





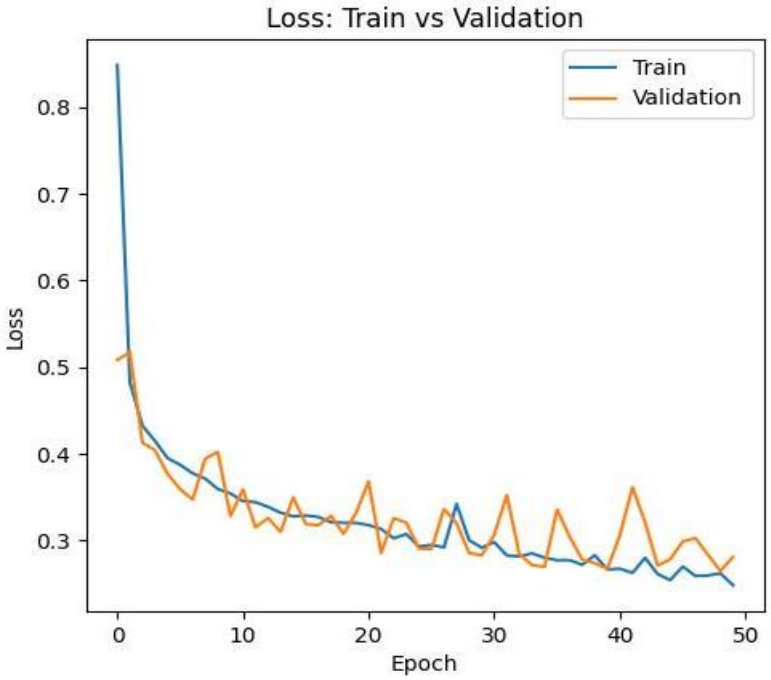
- Accuracy:
  - Train: **0.917**
  - Validation: **0.895**

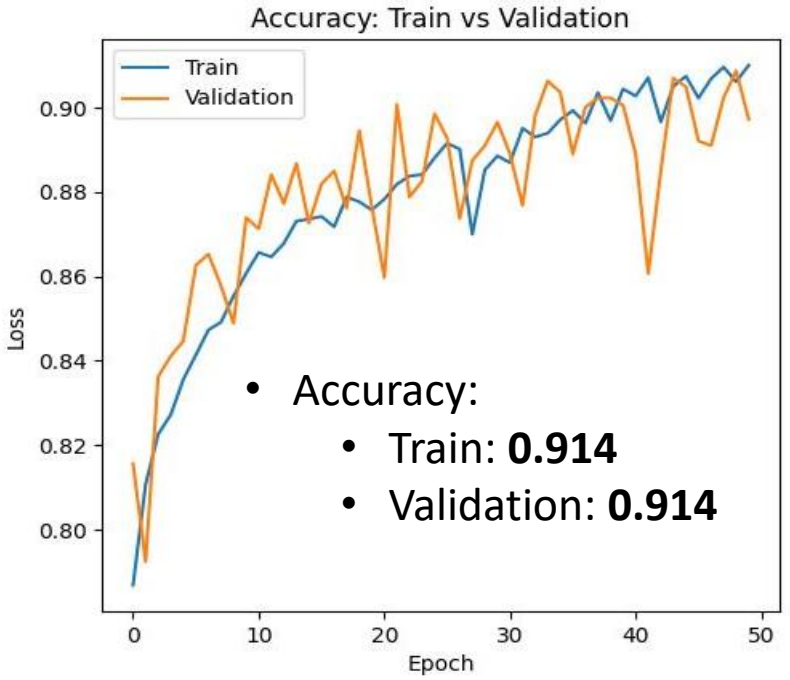
Modeling – Final Model

Baseline:
Organic: 55.69%
Recyclable: 44.31%

Final Model

- Data Augmentation
- 5 Convolutional layers
- 3 Dense layers
- L2 Regularization
- Drop out
- Early stopping





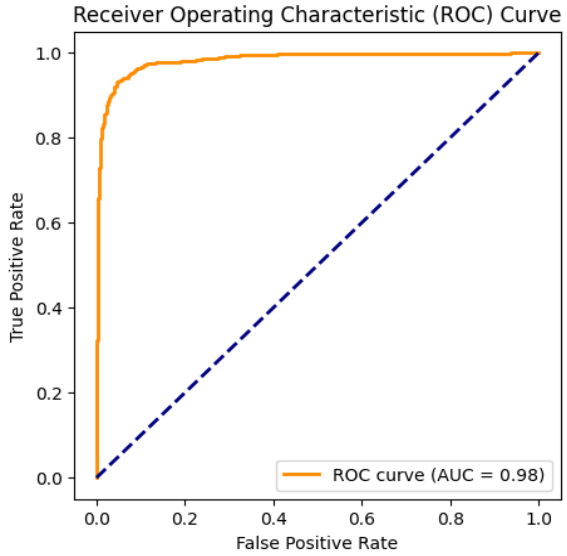
- Accuracy:
  - Train: **0.914**
  - Validation: **0.914**

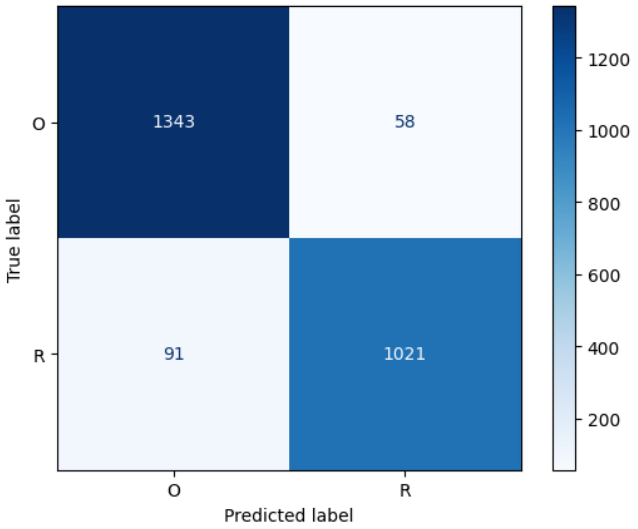
Target Accuracy (VGG16):
- Train: **0.917**
- Validation: **0.895**

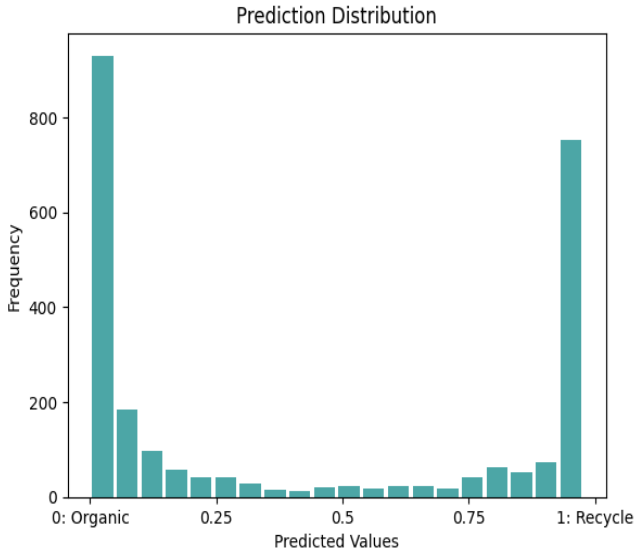
Evaluation - test data

Accuracy: 0.923

	Precision	Recall	F1-Score
Organic	0.94	0.96	0.95
Recyclable	0.95	0.92	0.93







Evaluation - images

Conclusion

- Transfer learning using the pre-trained model VGG16 and customizing the 'top' layers resulted in an accuracy of approximately 90% for both the training and validation datasets.

- By employing data augmentation, various regularization techniques, and adding more Convolutional and Dense layers, we achieved higher training and validation accuracy compared to the model that relies on VGG16.

- Several of the misclassified images are challenging to categorize, even for humans. This suggests that the model is performing at or near an optimal level.

- **Improvement opportunities:**
  - There is potential for improvement if we were not constrained by Colab's limitations, such as limited compute units, memory, and storage.
  - Explore other pre-trained models, such as ResNet50, Inception, EfficientNet, etc.
  - Delve deeper into the misclassified images to discover trends and patterns. For instance, utilize interpretation techniques like LIME (Local Interpretable Model-Agnostic Explanations) to gain a better understanding of model predictions.