Waste Classification CNN and AlexNet

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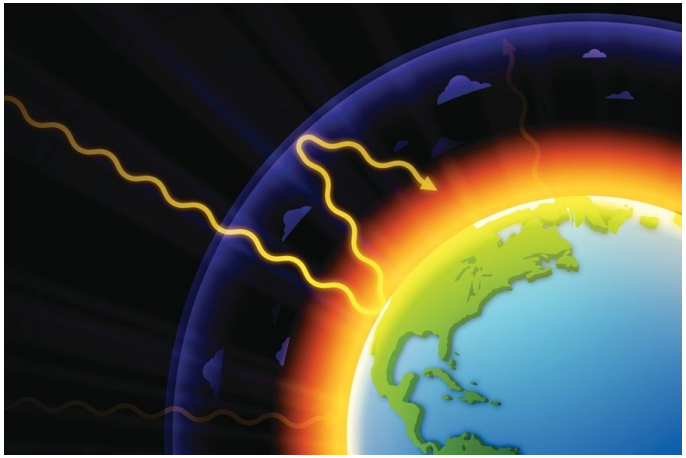
Problem

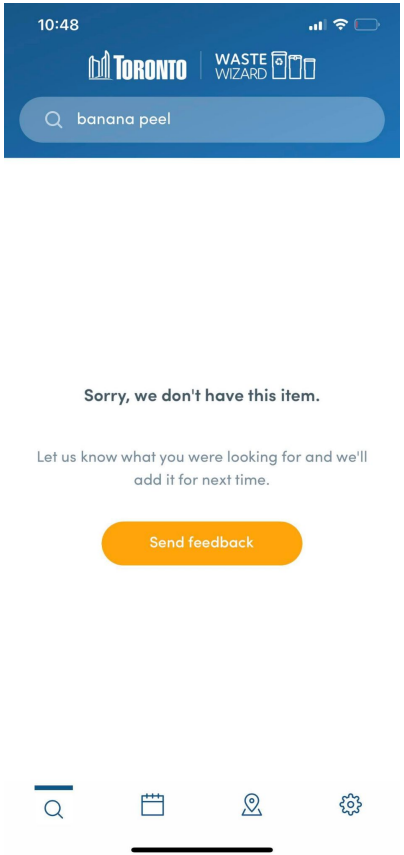
- Global Temperature has increased in the past century at a drastic rate
- Landfills produce greenhouse gases such as Carbon Dioxide and Methane
- Proper waste disposal would help in reducing the size of landfills



Gap

- Many people often dispose their waste incorrectly and applications exist to help them classify their waste
- Countless products with varying material composition make it hard for applications such as TOwaste to accurately classify all waste users can have

Gap



TOwaste Application - Unable to classify waste disposal method for a Banana Peel

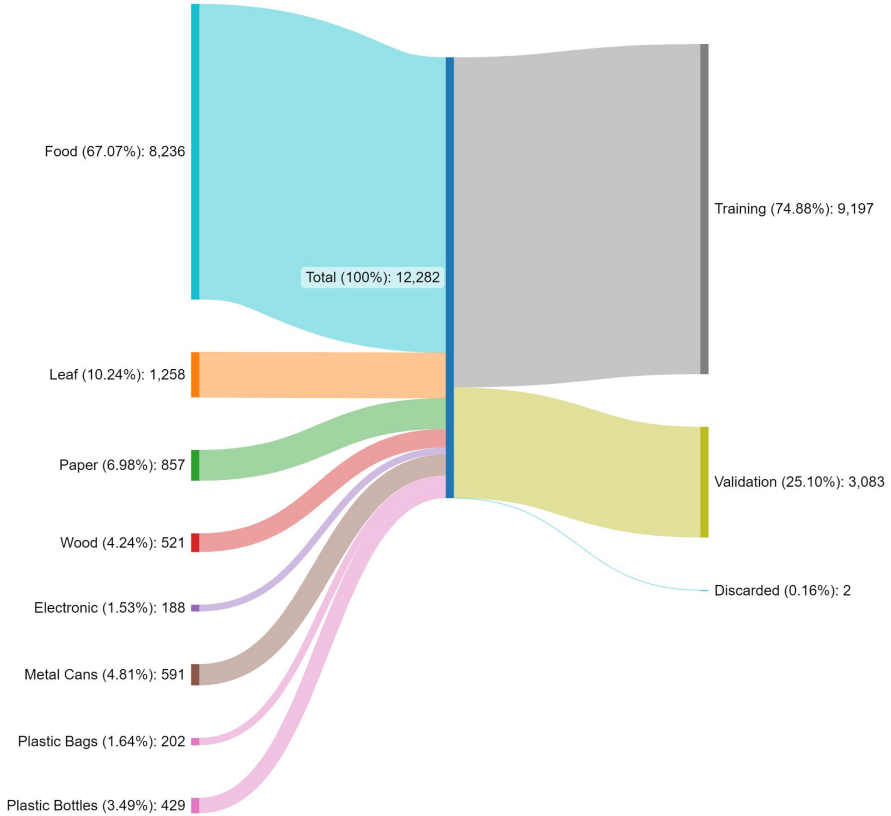
Goal

Use Machine Learning to classify waste with its proper method of disposal for any given picture of waste

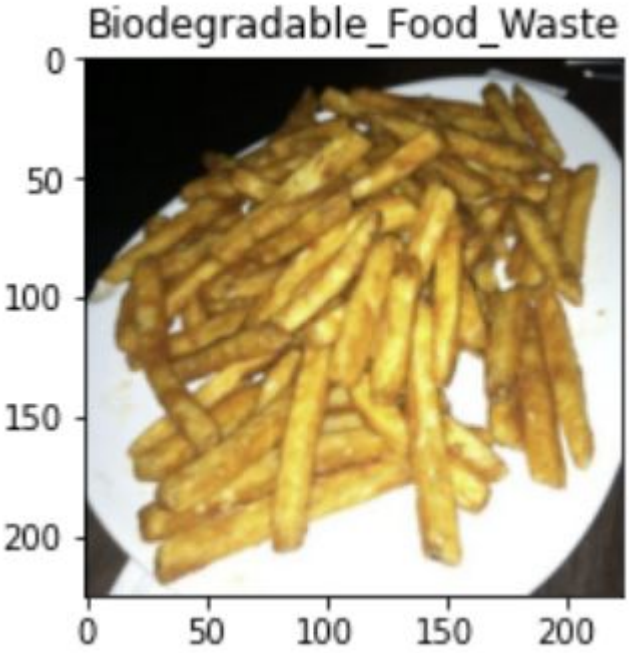
Data

- Waste Segregation Image Dataset (Kaggle)
  - Biodegradable: Food, Leaf, Paper, Wood
  - Non-Biodegradable: Electronic, Metal Cans, Plastic Bags, Plastic Bottles
- Two images caused failure in processing and required removal
- Food classification is densely populated compared to other classifications
- GPU Limitation on Google Colab
- Other Datasets (such as Trashnet) are primarily used for Testing

Data


Food (67.07%): 8,236
Leaf (10.24%): 1,258
Paper (6.98%): 857
Wood (4.24%): 521
Electronic (1.53%): 188
Metal Cans (4.81%): 591
Plastic Bags (1.64%): 202
Plastic Bottles (3.49%): 429
Total (100%): 12,282
Training (74.88%): 9,197
Validation (25.10%): 3,083
Discarded (0.16%): 2
Made with SankeyMATIC

Data Processing



Preprocessed input image in training set

224 x 224 x 3 (height x width x colour channels)

- Datasets contained images of various resolutions
- Preprocessed all images to be 224x224x3 to ensure an adequate amount of details present while preventing time inefficient processing

Additional Data Processing

- Removed images that were in compatible with the model
- Limited the number of cartoon images as we wanted to have more realistic representations of waste items
- Had a secondary dataset with duplicated images to deal with class imbalance

Sample Cartoon Image found in Dataset

High Level Overview of Our Model

Input: A Waste Image

CNN Deep Learning Model

Compost

Output: Waste Disposal Category

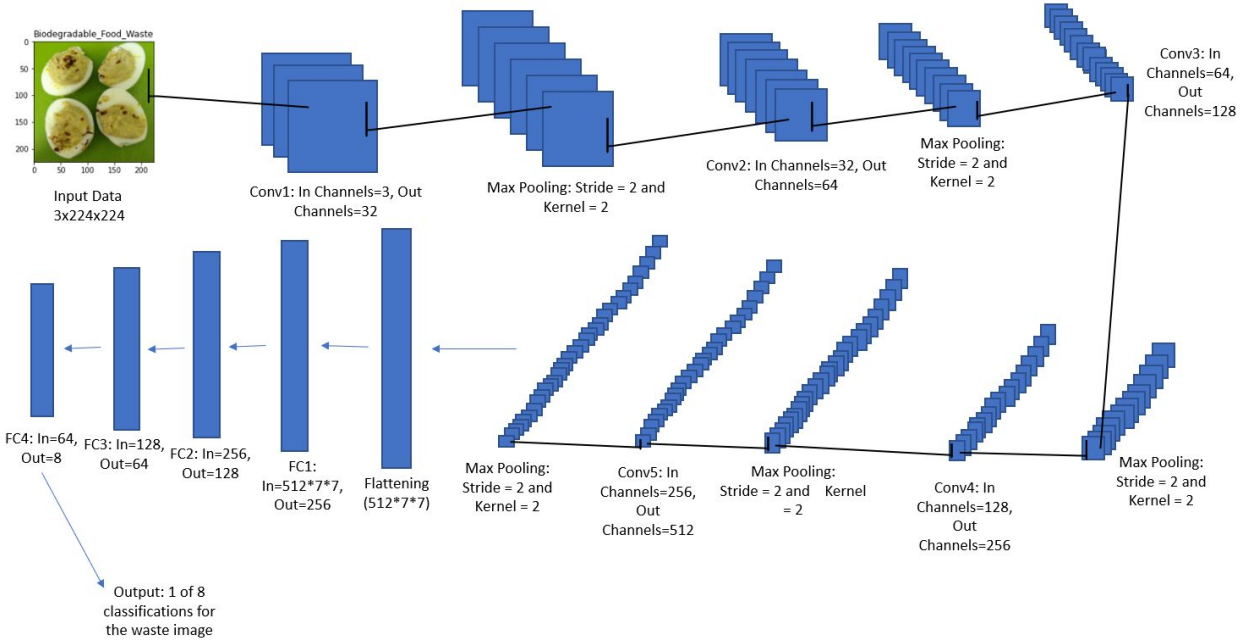
Output Classification Categories:
Compost, Containers, Fibres, Garbage, Yard, Unknown

Models we Explored in this Project

During the duration of the project, we looked into 2 models.

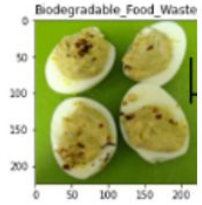
- Our own implementation of a Convolutional Neural Network model where we got decent performance, but thought that we could do better.
- A standard AlexNet Architecture

Model - A Diagram of our CNN



- 5 convolution layers
- 5 max pooling layers (stride = 2 and padding = 2)
- 4 Fully Connected Layers with ReLu activation
- Kernel Size of 3 (stride = 1 and padding = 1)

Model - A diagram of the AlexNet Architecture



Input Data
3x224x224

11x11 Convolution *Stride = 4*

3x3 Max Pooling *Stride = 2*

5x5 Convolution *Padding = 2*

3x3 Max Pooling *Stride = 2*

3x3 Convolution *Padding = 1*

3x3 Convolution *Padding = 1*

3x3 Convolution *Padding = 1*

3x3 Max Pooling *Stride = 2*

FCC *4096 neurons*

FCC *4096 neurons*

FCC *8 neurons*

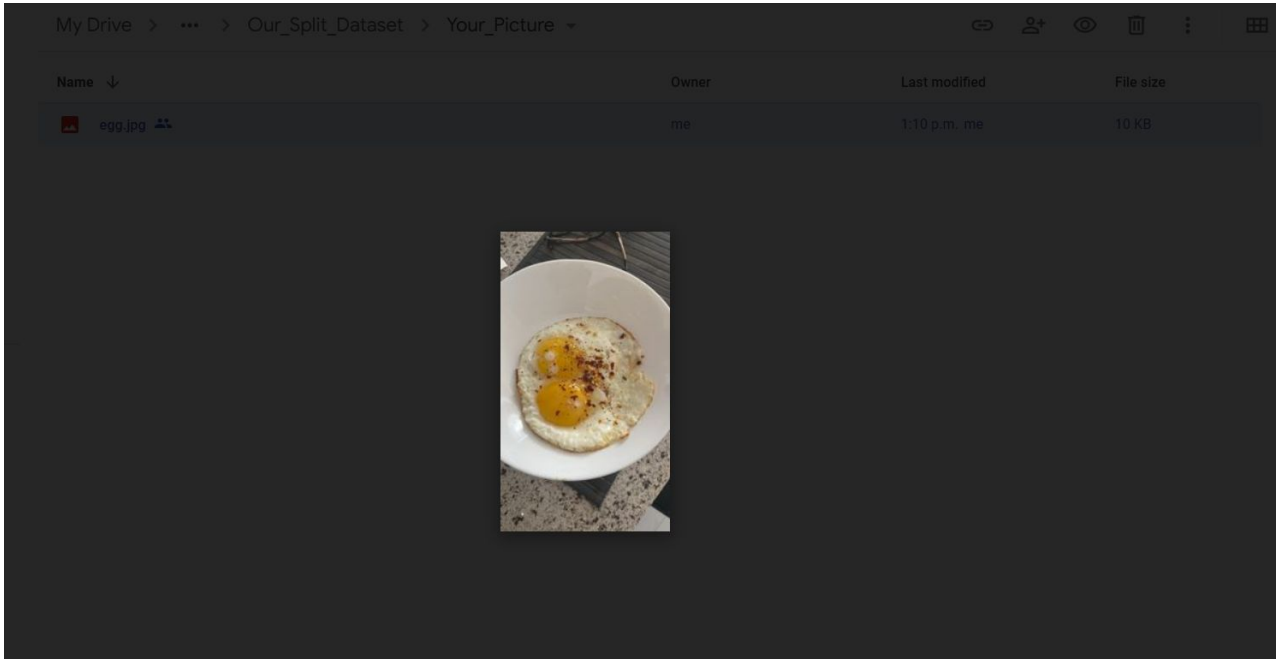
Hidden Layers

Output Layer

Output: 1 of 8 classifications for the waste image

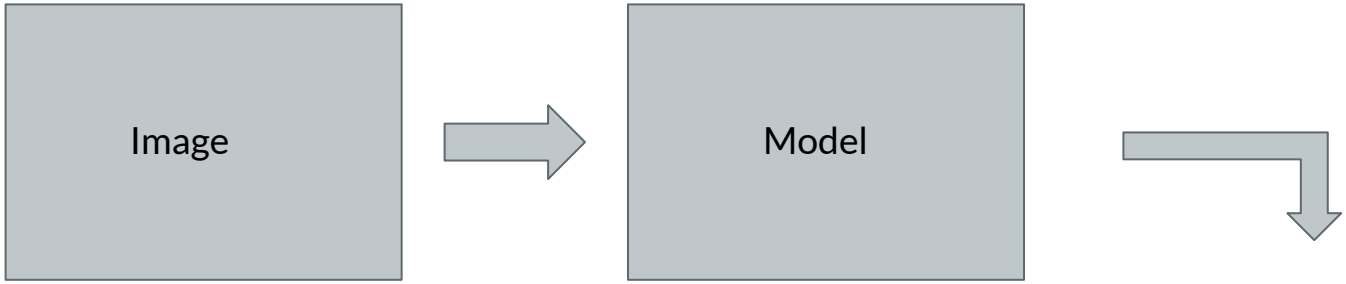
Demonstration: The Dilemma

Dilemma: Which bin does my waste belong to?

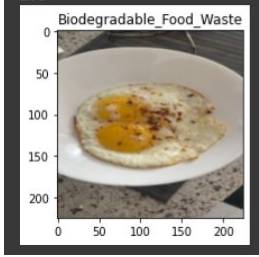


Demonstration: The Model's Prediction

```
model_save_name = 'Waste_Classification_CNN_15epoch_run.pt'
path = F"/content/drive/MyDrive/Colab Notebooks/APS360/Project/{model_save_name}"
first_model.load_state_dict(torch.load(path))
```

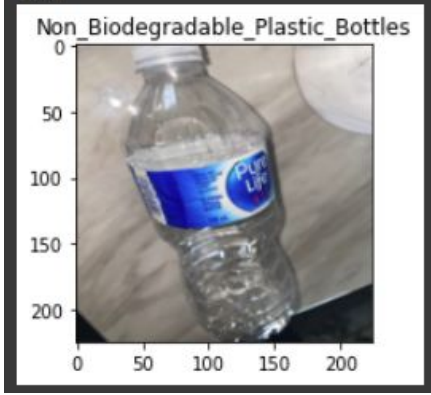



```
This is an example of: Biodegradable Food Waste. It belongs in the Compost, ie. your green bin. Thank you.
1.0
```



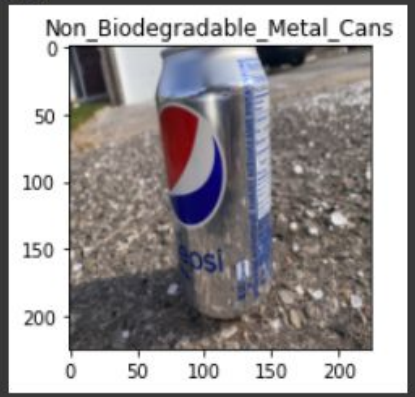
Showcasing Other Unit Tests

```
This is an example of: Non Biodegradable Plastic Bottles. It belongs in the Containers bin. Thank you.
1.0
```



Plastic Bottles -> Containers Bin

```
This is an example of: Non Biodegradable Metal Cans. It belongs in the Containers bin. Thank you.
1.0
```



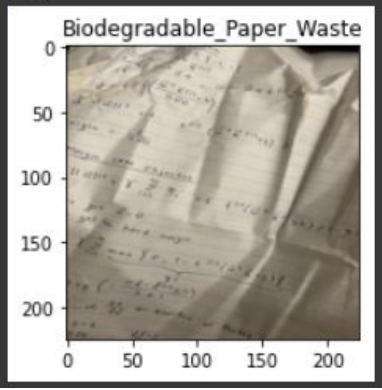
Metal Cans -> Containers Bin

Showcasing Other Unit Tests Continued

```
This is an example of: Biodegradable Wood Waste. It is unknown per our model. Thank you.
1.0
```

Wood Waste -> Unknown per model

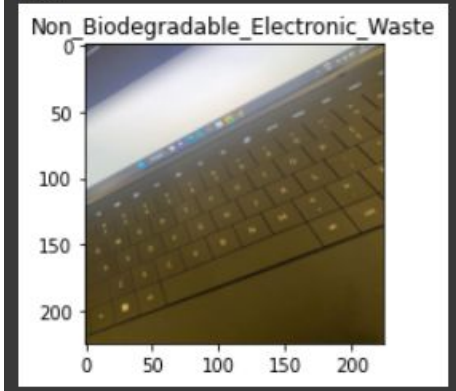
```
This is an example of: Biodegradable Paper Waste. It belongs in the Fibres bin. Thank you.
1.0
```



Paper Waste -> Fibres Bin

Showcasing Other Unit Tests Continued

```
This is an example of: Non Biodegradable Electronic Waste. It is unknown per our model. Thank you.
1.0
```



Electronic Waste -> Unknown per model

```
This is an example of: Biodegradable Leaf Waste. It belongs in Yard Waste. Thank you.
1.0
```

Leaf Waste -> Yard Waste

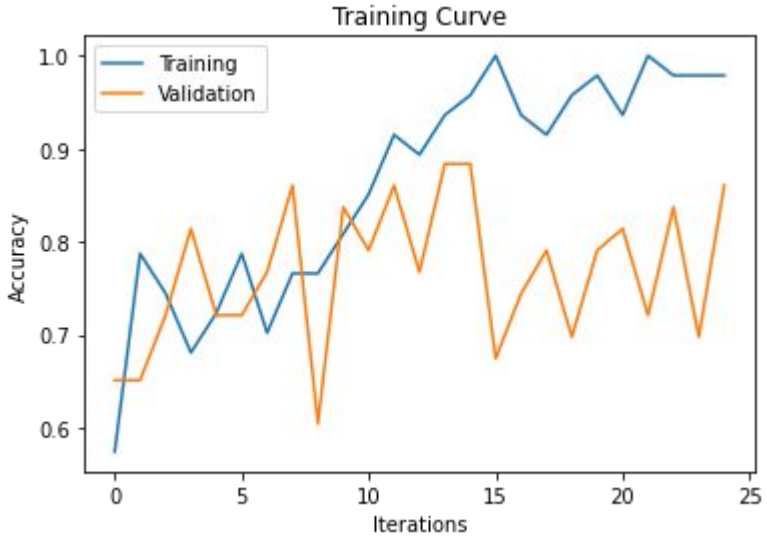
Showcasing Other Unit Tests Continued

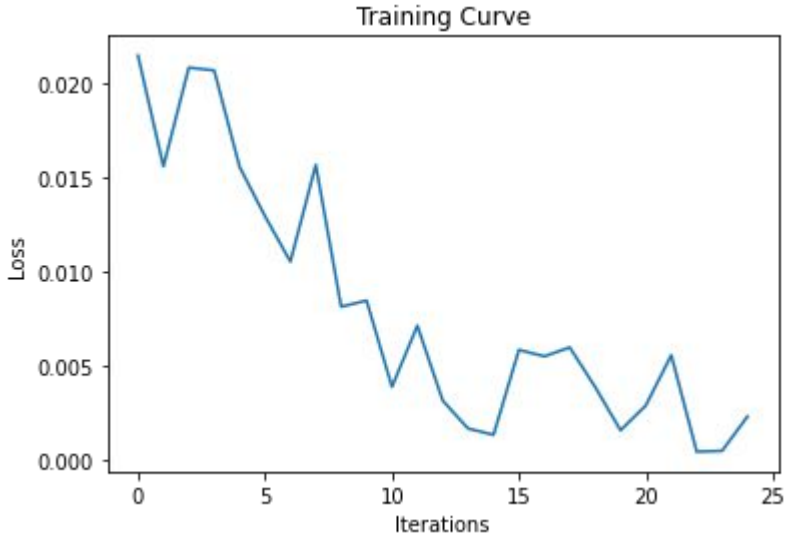
```
This is an example of: Non Biodegradable Plastic Bags. It belongs in the Garbage, ie. your grey bin. Thank you.
1.0
```

Plastic Bags -> Garbage (Grey Bin)

25 Epoch CNN Model

- 25 epoch Model
- Overfitting after 15 epochs, so lowered number of epochs

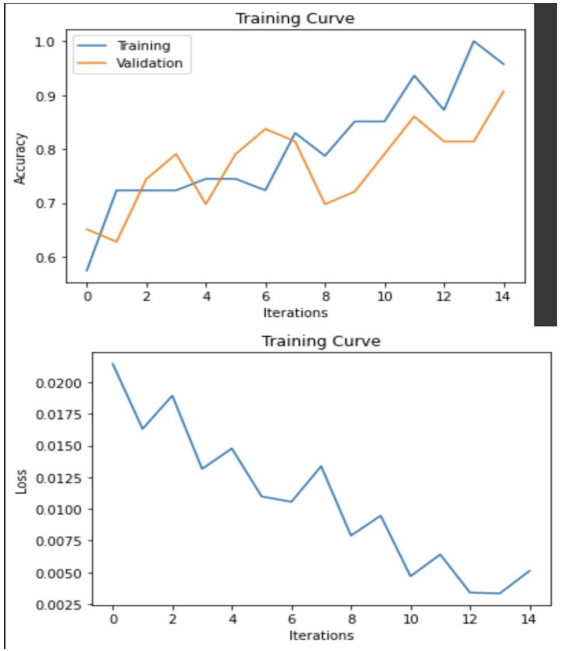




Training Accuracy = 97.8%
Validation Accuracy = 86%

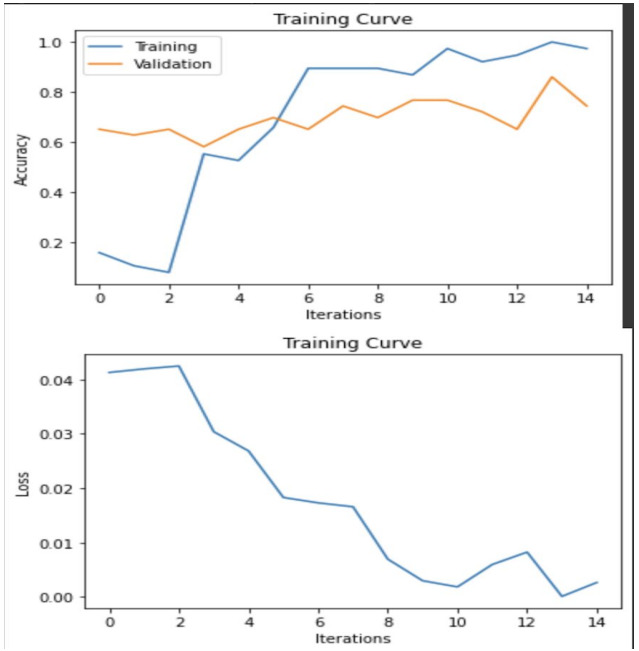
15 Epoch CNN Model

Original Training Dataset



Training Accuracy: 95.7%
Validation Accuracy: 90.7%

Normalized Dataset(Unbiased)



Training Accuracy: 97.4%
Validation Accuracy: 74.4%

Accuracy by Class

Class	Original Dataset Accuracy(%)	Normalized Dataset Accuracy(%)
Food	98.03	89.13
Leaf	86.98	85.71
Paper	51.62	74.88
Wood	98.47	98.47
Electronic	31.91	6.38
Metal Cans	45.27	55.4
Plastic Bags	1.96	23.5
Plastic Bottles	13.56	3.38

Accuracy < 50% and difference between models >10% highlighted in red

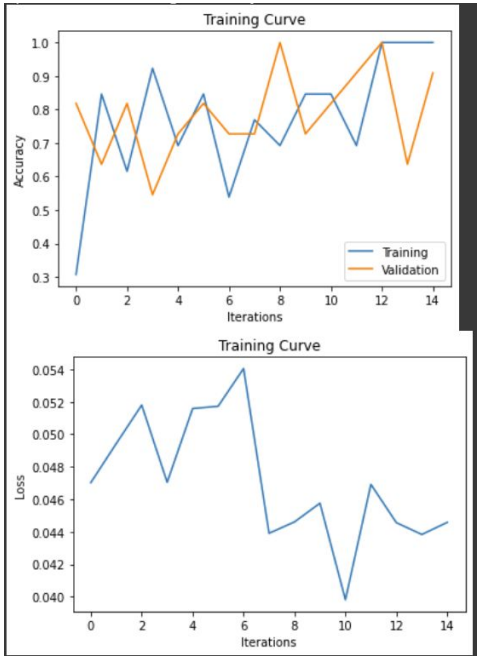
Ratio Between Number of Times Class was Predicted and Number of Times Class is in Dataset

Class	Original Dataset Accuracy	Normalized Dataset Accuracy
Food	1.06	0.93
Leaf	0.98	1.01
Paper	0.97	1.75
Wood	1.28	1.56
Electronic	0.68	0.17
Metal Cans	0.84	1.41
Plastic Bags	0.04	0.37
Plastic Bottles	0.42	0.28

Ratios less than 0.5 or greater than 1.5 highlighted in red

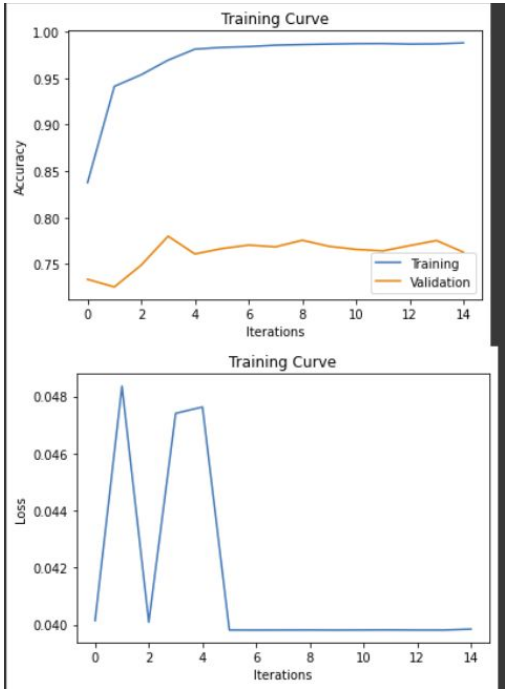
Quantitative Results for AlexNet

Without Data Augmentation:



Training Accuracy = 72.8% as the 0th epoch accuracy is 30.1%
Validation Accuracy = 79.0%

With Data Augmentation:



Training Accuracy = 96.8%
Validation Accuracy = 76.1%

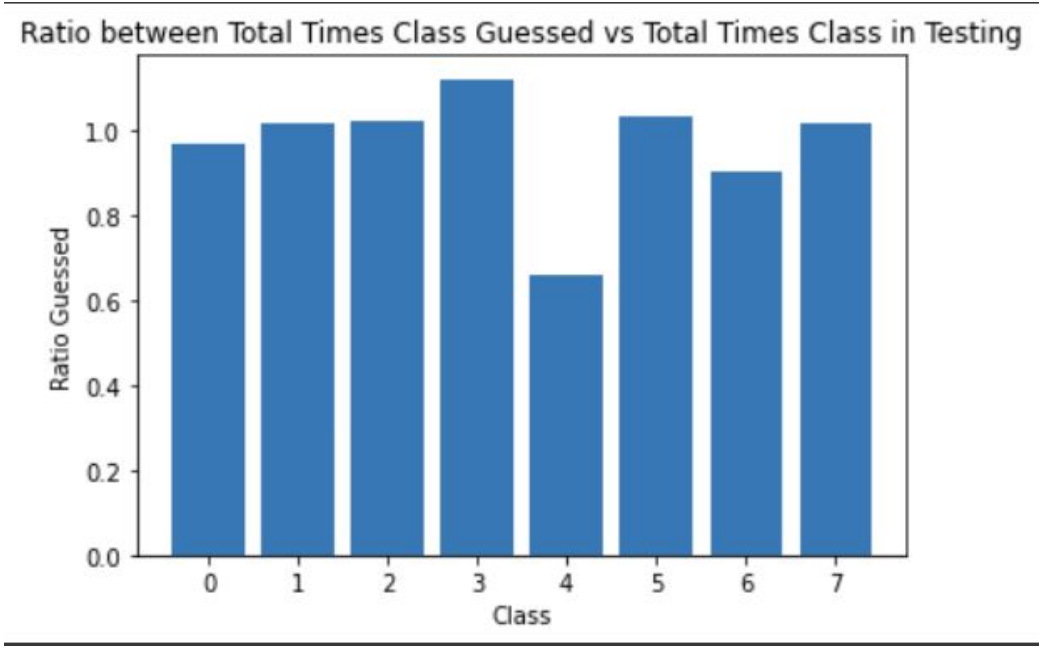
Qualitative Results for AlexNet

- Found how many correct predictions were made for each class

Total Num. of Correct Predictions = 2903

Total Num. of Test Images = 3084

Test Accuracy = 94.1%



Takeaways/Future Steps

AlexNet vs. CNN

- AlexNet performed better than the CNN (94.1% test accuracy vs 85.5% test accuracy)
- Transfer Learning took less time to train (30 min vs. 3 hours)

Data Augmentation

- Normalized dataset by duplicating images from classes with less data
- Created a overfitted model

Future Steps:

- Augment images from classes with less data to reduce overfitting

Use: `transforms.Compose`