

BLOCK DIAGRAM

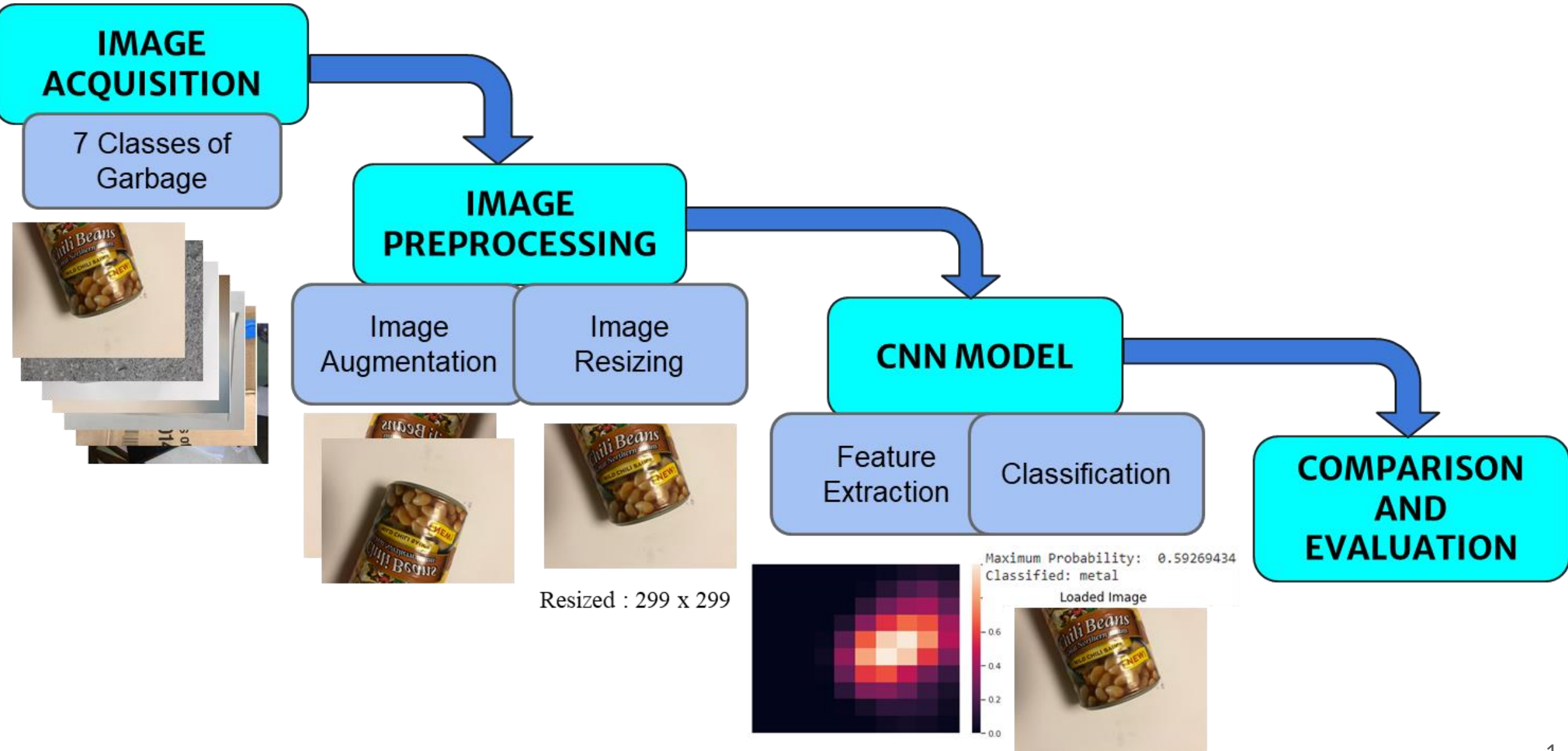


IMAGE ACQUISITION



- Images collected from online sources.
- Live Images have been obtained.
- Classification into 7 Different classes of Garbage - Cardboard, Metal, Paper, Plastic, Glass, Trash, Ewaste.
- Image Format: jpg
- Image sizes: 4032x3024, 3024x4032, 3264x2448, 2448x3264

Sources:

1. <https://github.com/garythung/trashnet>
2. <https://www.kaggle.com/kaustubh2402/ewaste-dataset>

IMAGE DATA AUGMENTATION



- Image Flip
- Image Shear
- Image Zoom
- Image Height Shift
- Image Width Shift
- Image Rotation

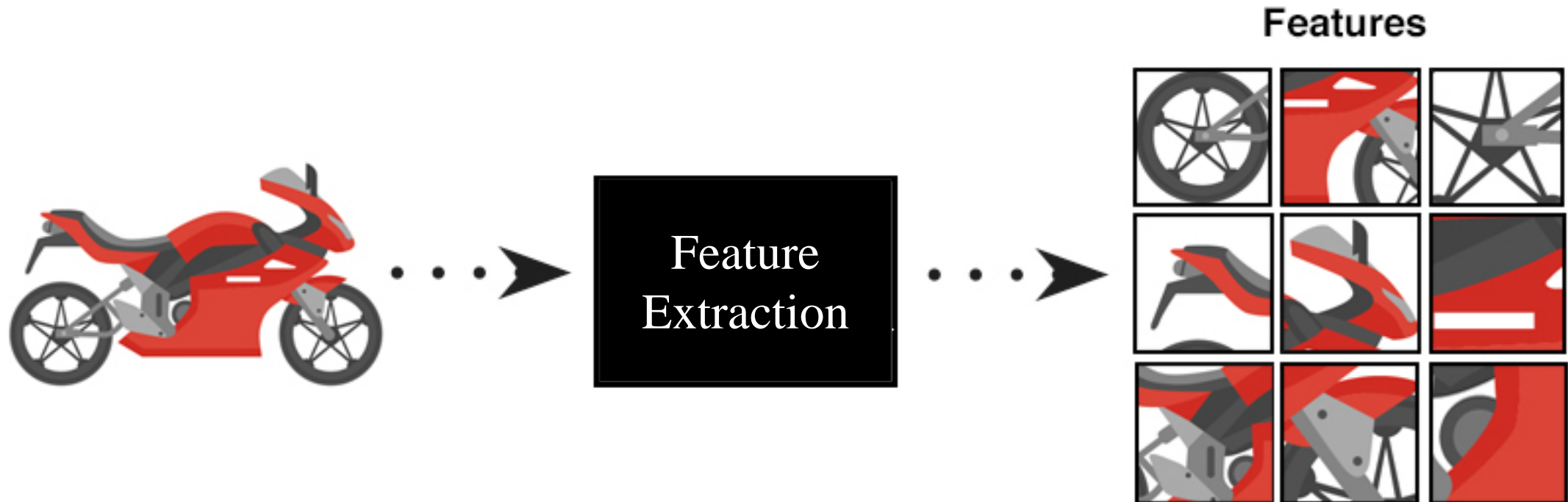
IMAGE RESIZING



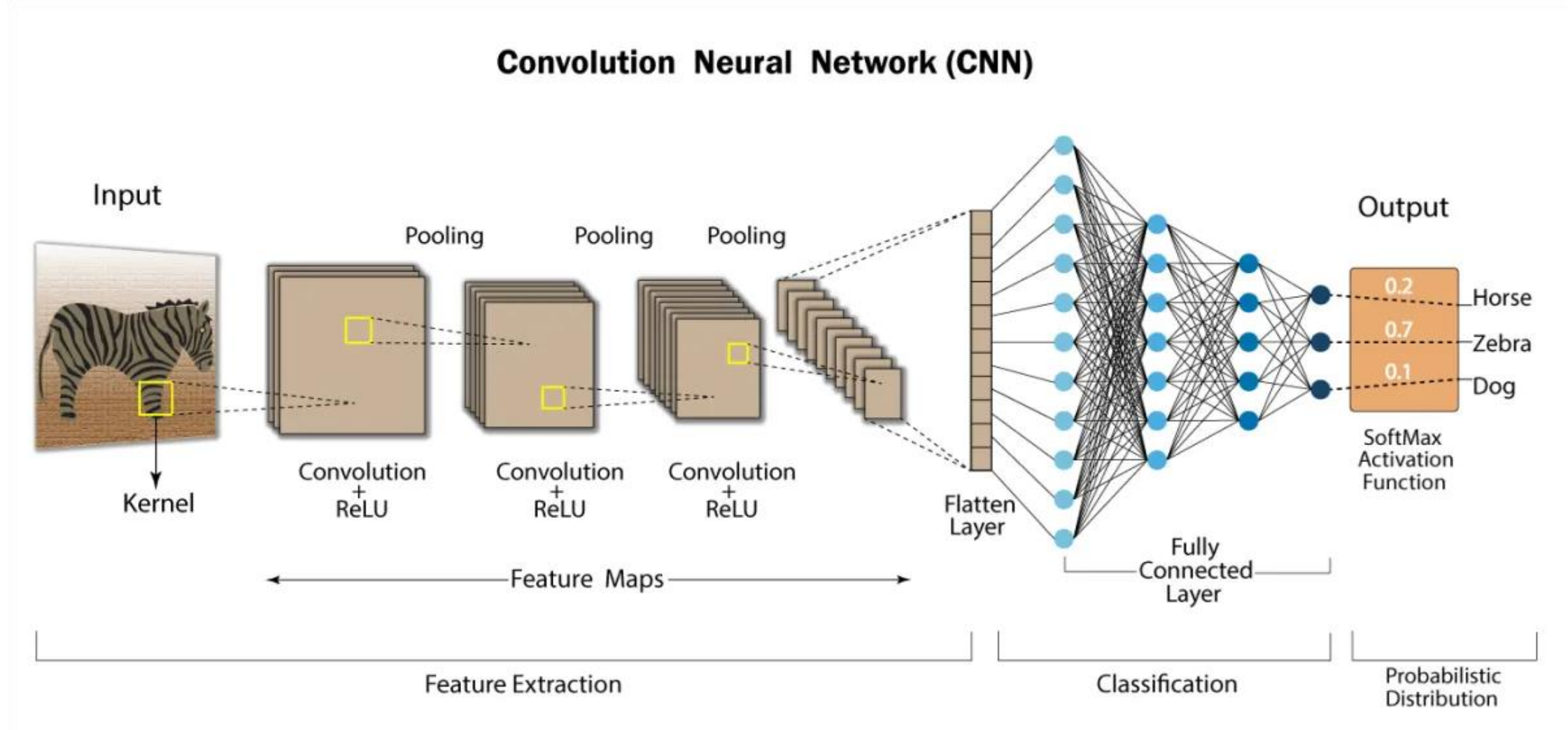
- Resizing an image means changing the dimensions of it, be it width alone, height alone or changing both of them.
- The aspect ratio of the original image is also preserved in the resized image, so that the image does not appear distorted to the naked eye.
- To resize an image, OpenCV in python provides `cv2.resize()` function.
- Python, by default, uses a method called Bilinear Interpolation to resize the image.

FEATURE EXTRACTION

- Feature extraction involves reducing the number of resources required to describe a large set of data.
- Feature extraction refers to the process of transforming raw data into numerical features that can be processed while preserving information in the original dataset.



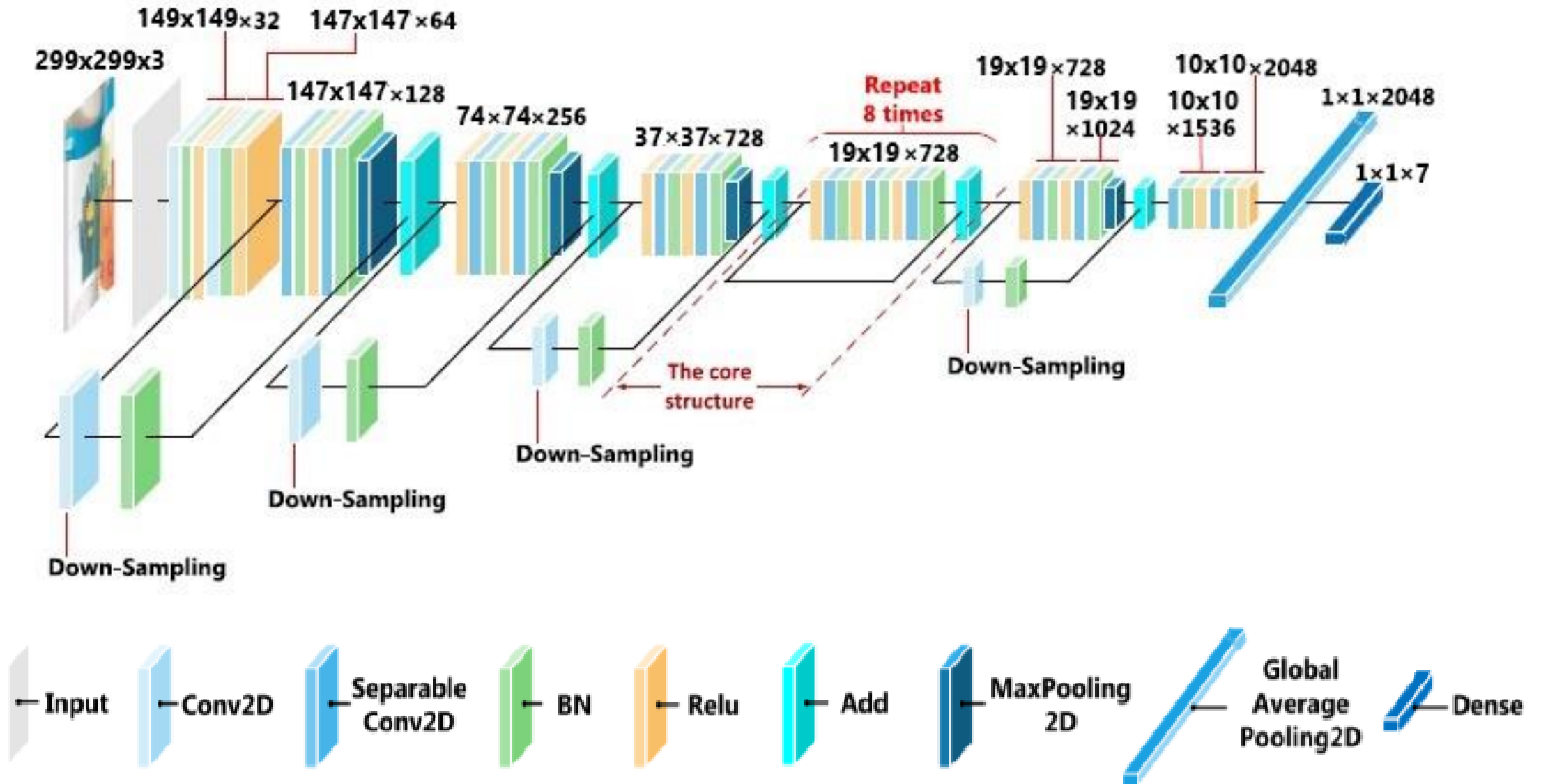
FULLY CONNECTED LAYER



MODEL TRAINING REQUIREMENTS

- Platform used: Google Colab
- Language: Python
- RAM Used: 2.38 GB
- GPU Used: 8.81 GB
- Total No. of Images in Dataset: 3344
- Images Split-up: Cardboard - 403
 - E-waste - 406
 - Plastic - 482
 - Paper - 594
 - Metal - 410
 - Glass - 501
 - Trash - 548
- Training Split – 80% - 2675
- Testing and Validation Split – 20% - 669

Xception Model

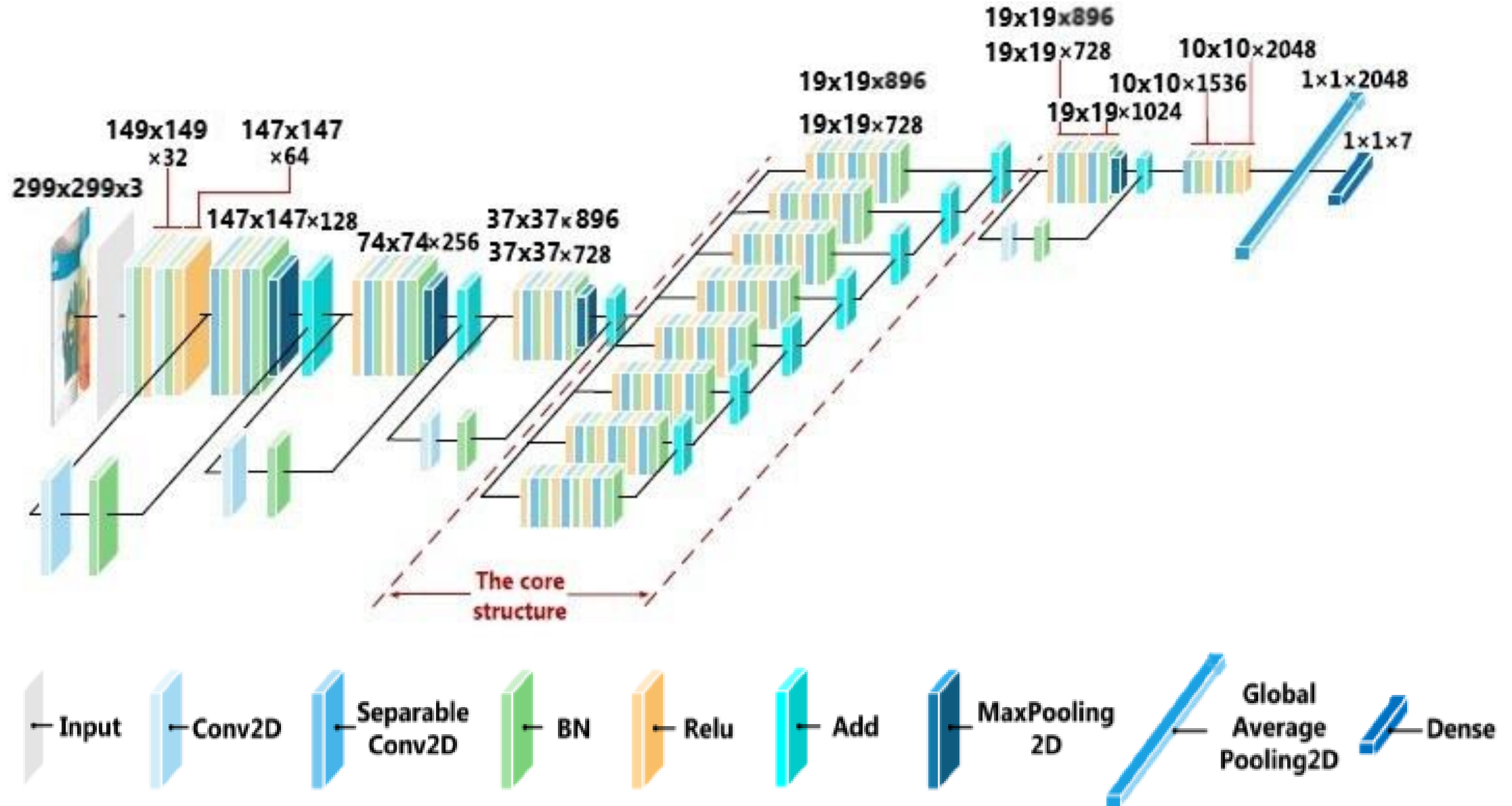


XCEPTION FEATURES

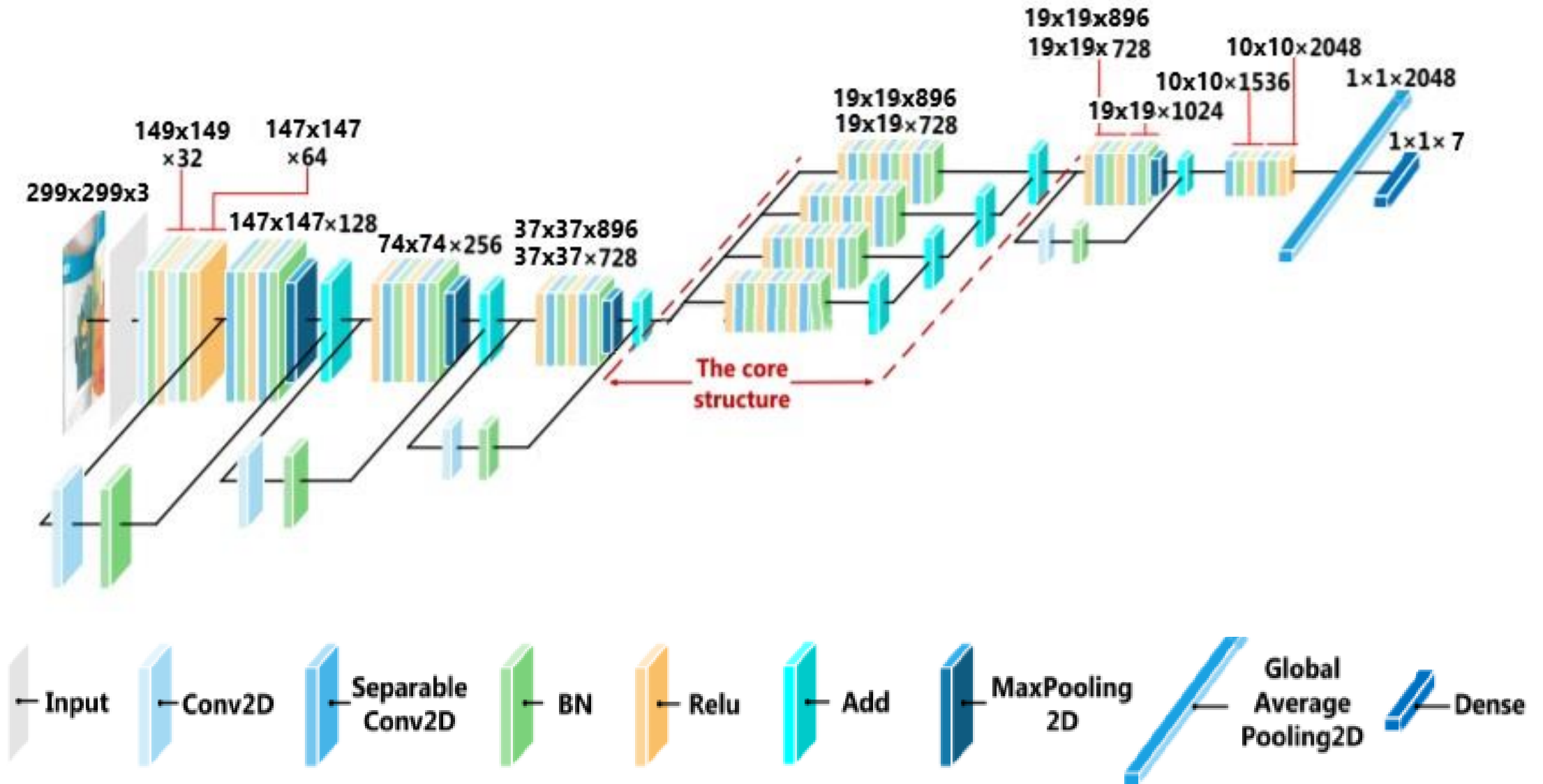


- Total number of Convolutional layers : 36
- Total number of Features extracted : 2048
- Xception uses Modified Depthwise Separable Convolution : Pointwise followed by Depthwise Convolution
- Optimizer Used: SGD (Stochastic Gradient Descent) Optimizer
- Loss function used: Categorical Cross Entropy

Multi Branch Deep Learning Model



Proposed Model



CNN Model Parameters

Models	Features Extracted	Input Size	Model Storage Size	No. of Epochs	Training Time per Epoch	Total Training Time
Xception	2048	299x299	80 MB	250	105 seconds	7.3 hours
Inception V3	2048	299x299	85 MB	500	67 seconds	9.3 hours
Resnet50	2048	229x229	91 MB	500	59 seconds	8.2 hours
VGG16	512	224x224	57 MB	500	50 seconds	6.9 hours
MobileNet	1024	224x224	13 MB	500	45 seconds	6.25 hours


Confusion Matrix

- Confusion Matrix gives us a matrix as output and describes the complete performance of a CNN model.

- There are 4 important terms :
 - **True Positives**
 - **True Negatives**
 - **False Positives**
 - **False Negatives**

n=165	Predicted: NO	Predicted: YES
Actual: NO	50	10
Actual: YES	5	100

Metrics for Model Evaluation



1. *Accuracy* = $\frac{\text{True Positive} + \text{True Negative}}{\text{Total Samples}}$ Range = 0 to 1

2. *Precision* = $\frac{\text{True Positive}}{\text{True Positive} + \text{False Positive}}$ Range = 0 to 1

3. *Recall* = $\frac{\text{True Positive}}{\text{True Positive} + \text{False Negative}}$ Range = 0 to 1

4. *F1 Score* = $\frac{\text{True Positive}}{\text{True Positive} + \frac{1}{2}(\text{False Positive} + \text{False Negative})} = \frac{2}{\frac{1}{\text{Precision}} + \frac{1}{\text{Recall}}}$ Range = 0 to 1

5. *MCC* = $\frac{TP * TN - FP * FN}{\sqrt{(TP + FP)(TP + FN)(TN + FP)(TN + FN)}}$ Range = -1 to 1

6. $\kappa = \frac{po - pe}{1 - pe} = 1 - \frac{1 - po}{1 - pe}$ Range = -1 to 1



Results

IMAGE RESIZING

Original Image



Original Size: 4092x3024



Original Size: 3264x2448



Original Size: 3264x2448

Resized Image



Resized: 299x299



Resized: 299x299



Resized: 299x299

IMAGE AUGMENTATION



Original Image



Rotated Image



Sheared Image



Horizontal Flip

IMAGE AUGMENTATION



Original Image



Height Shifted Image

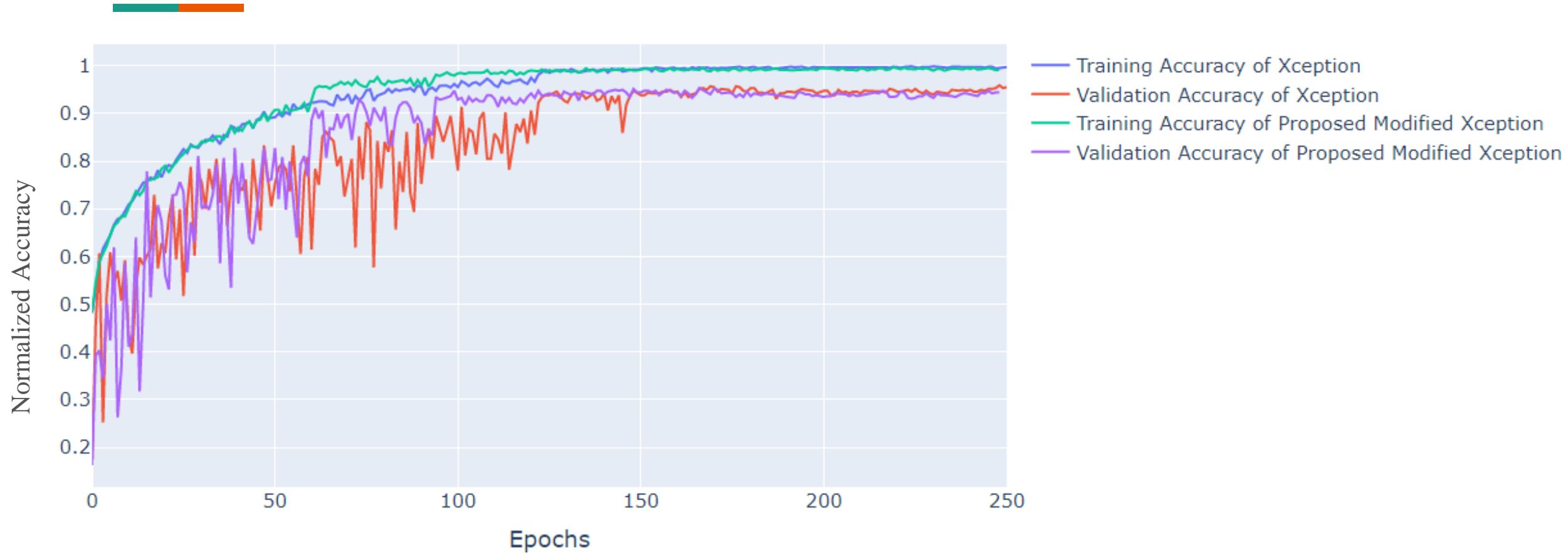


Zoomed Image

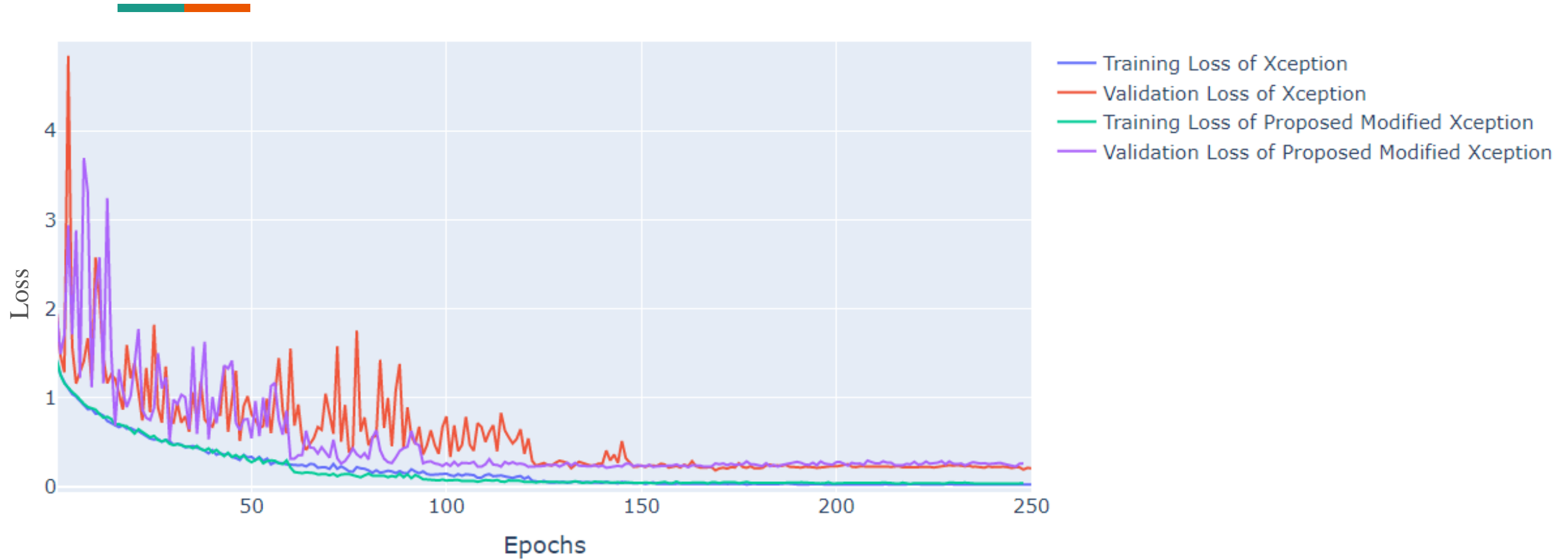


Width Shifted Image

Performance of Xception - Accuracy



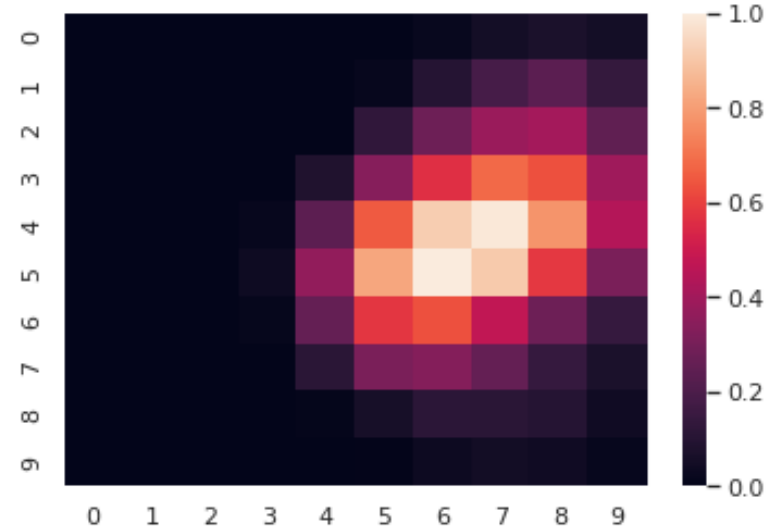
Performance of Xception - Loss



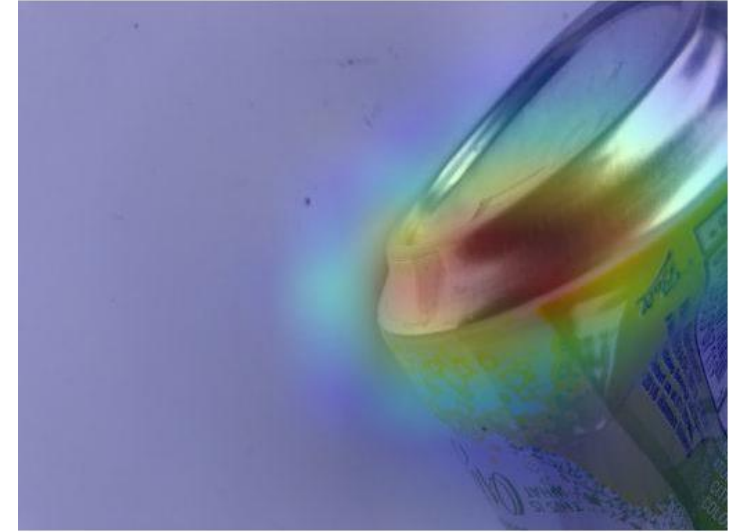
VISUALIZATION OF EXTRACTED FEATURES



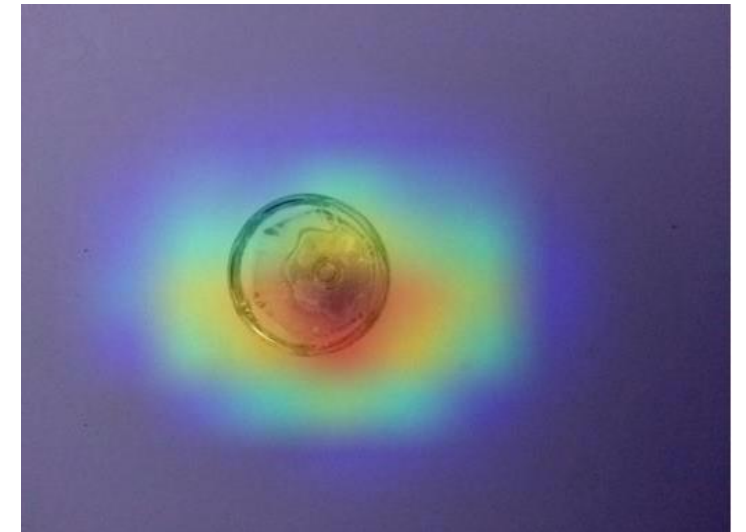
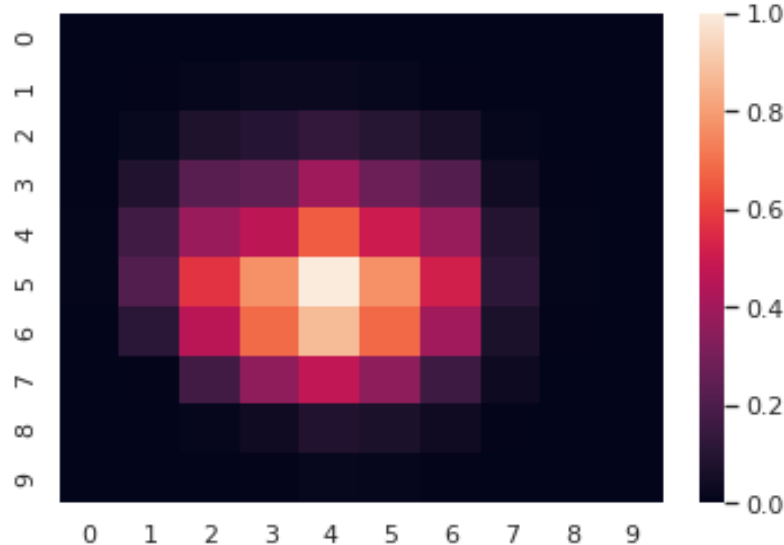
Original Image



Extracted Features

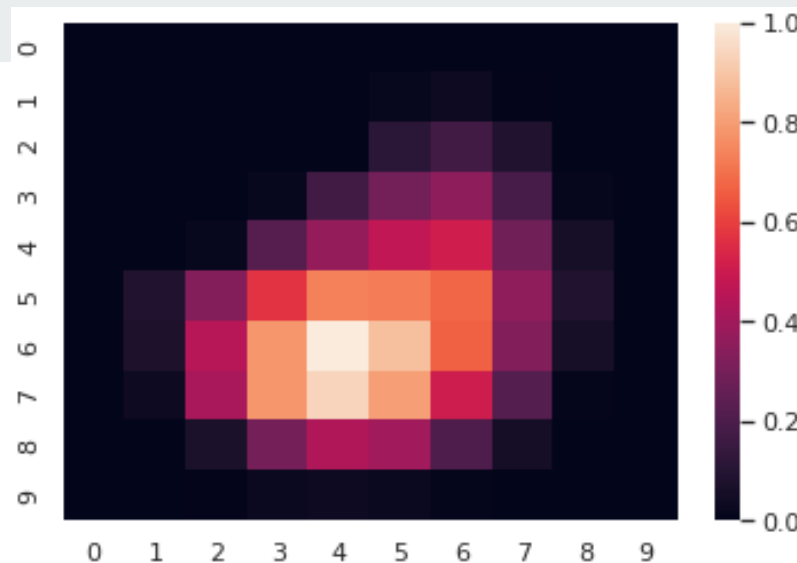


Extracted Features
Visualized over Original Image





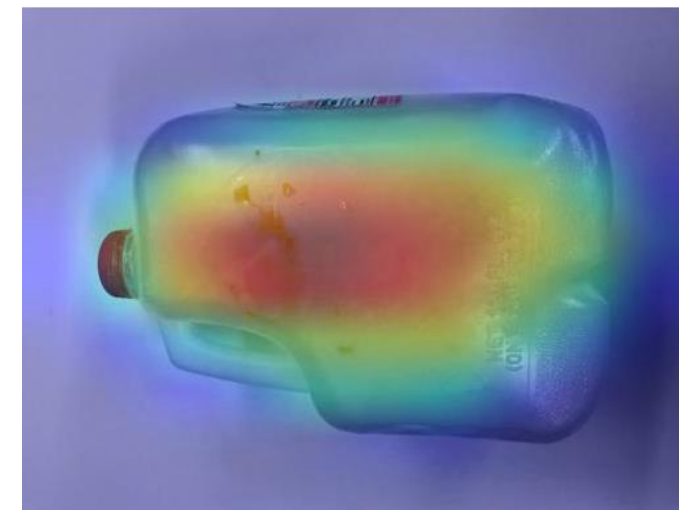
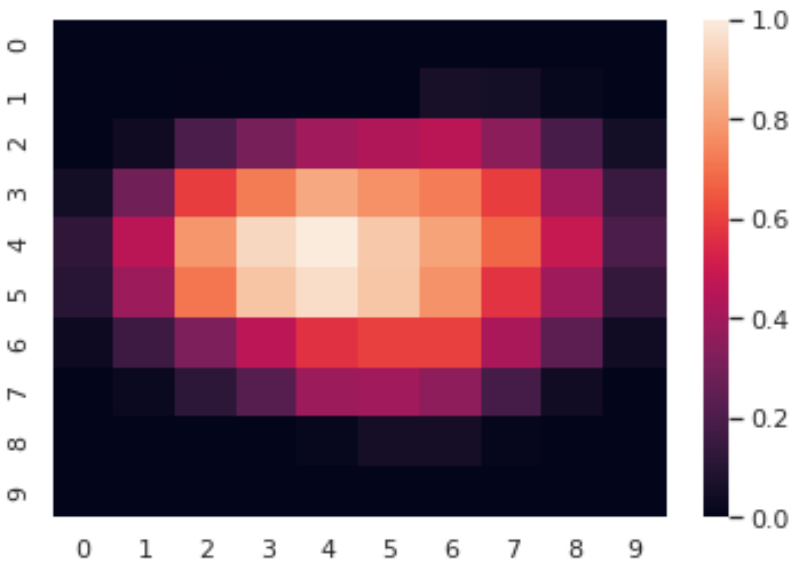
Original Image



Extracted Features



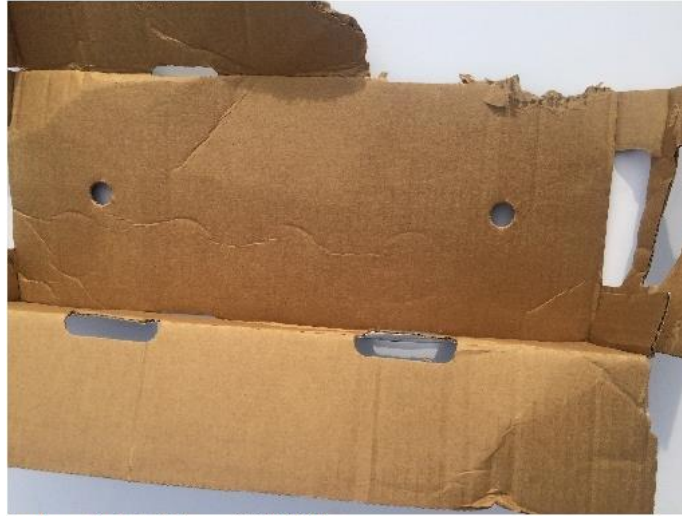
Extracted Features
Visualized over Original Image



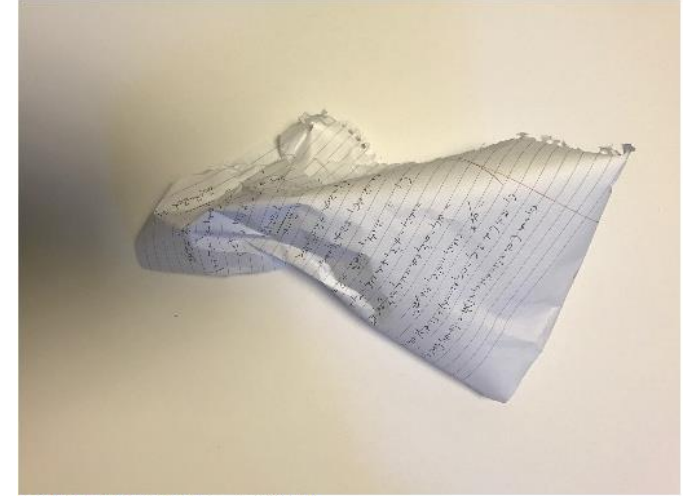
CLASSIFICATION OUTPUT EXAMPLES



Maximum Probability: 0.9979786
Predicted: Ewaste
Truth: Ewaste



Maximum Probability: 0.9999882
Predicted: Cardboard
Truth: Cardboard



Maximum Probability: 0.999979
Predicted: Paper
Truth: Paper



Maximum Probability: 0.9616854
Predicted: Glass
Truth: Glass






Maximum Probability: 0.99974936
Predicted: Metal
Truth: Metal




Maximum Probability: 0.999691
Predicted: Plastic
Truth: Plastic

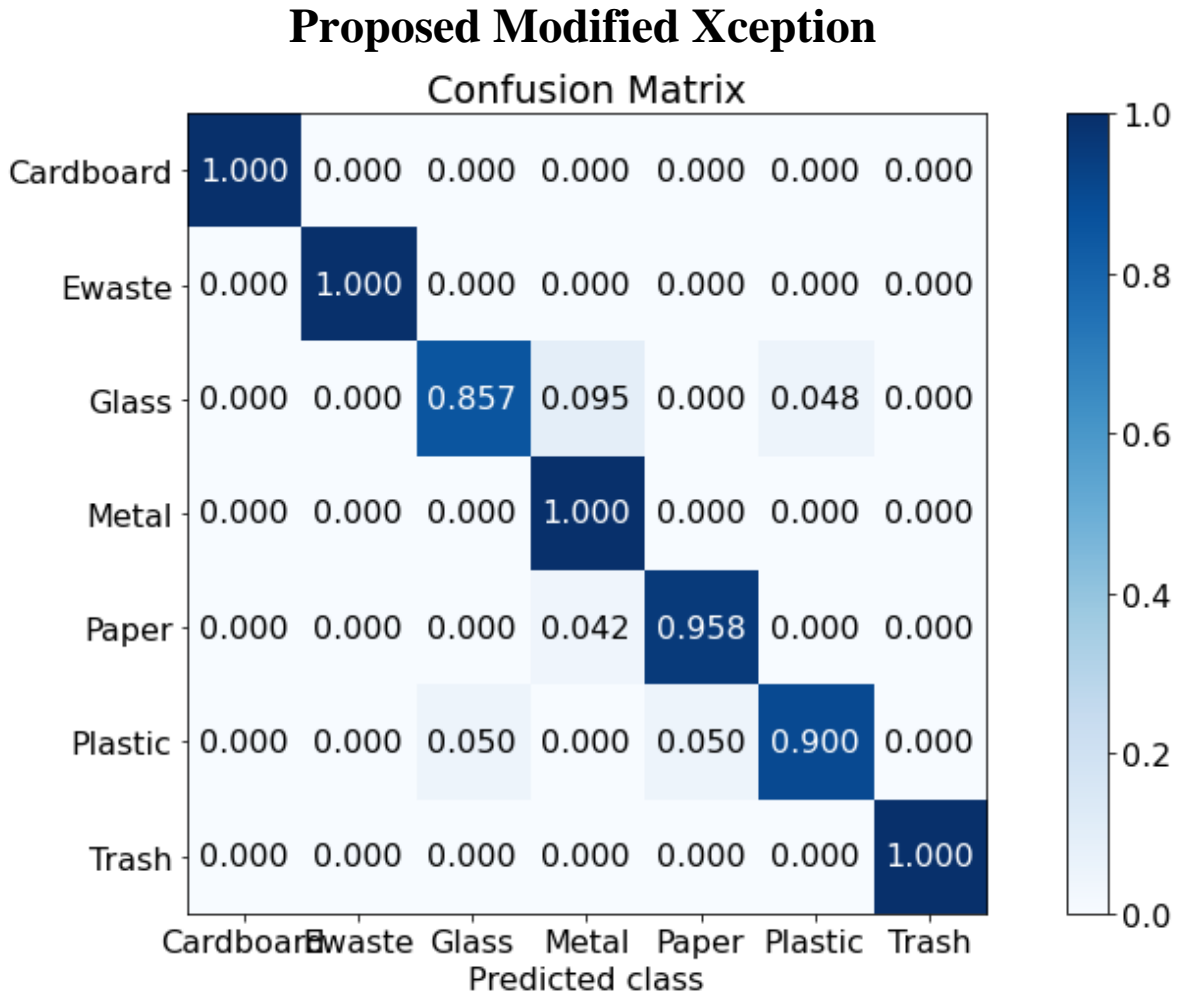
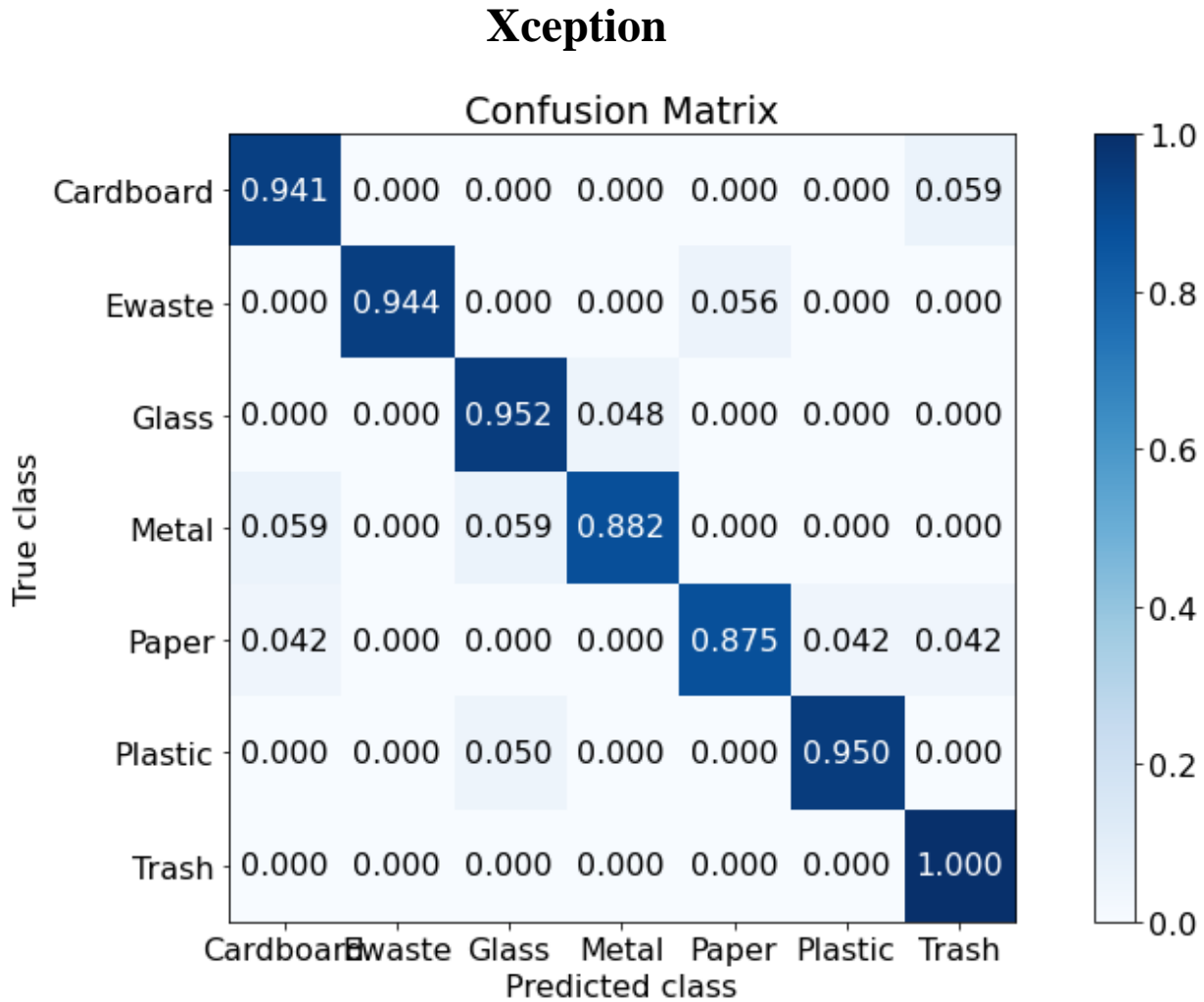
CLASSIFICATION OUTPUT EXAMPLES

Loaded Image			
Predicted Class	Ewaste	Cardboard	Paper
Truth	Ewaste	Cardboard	Paper
Maximum Probability	0.9979786	0.9999882	0.999979

CLASSIFICATION OUTPUT EXAMPLES

Loaded Image			
Predicted Class	Glass	Metal	Plastic
Truth	Glass	Metal	Plastic
Maximum Probability	0.9616854	0.99974936	0.999691

Confusion Matrix

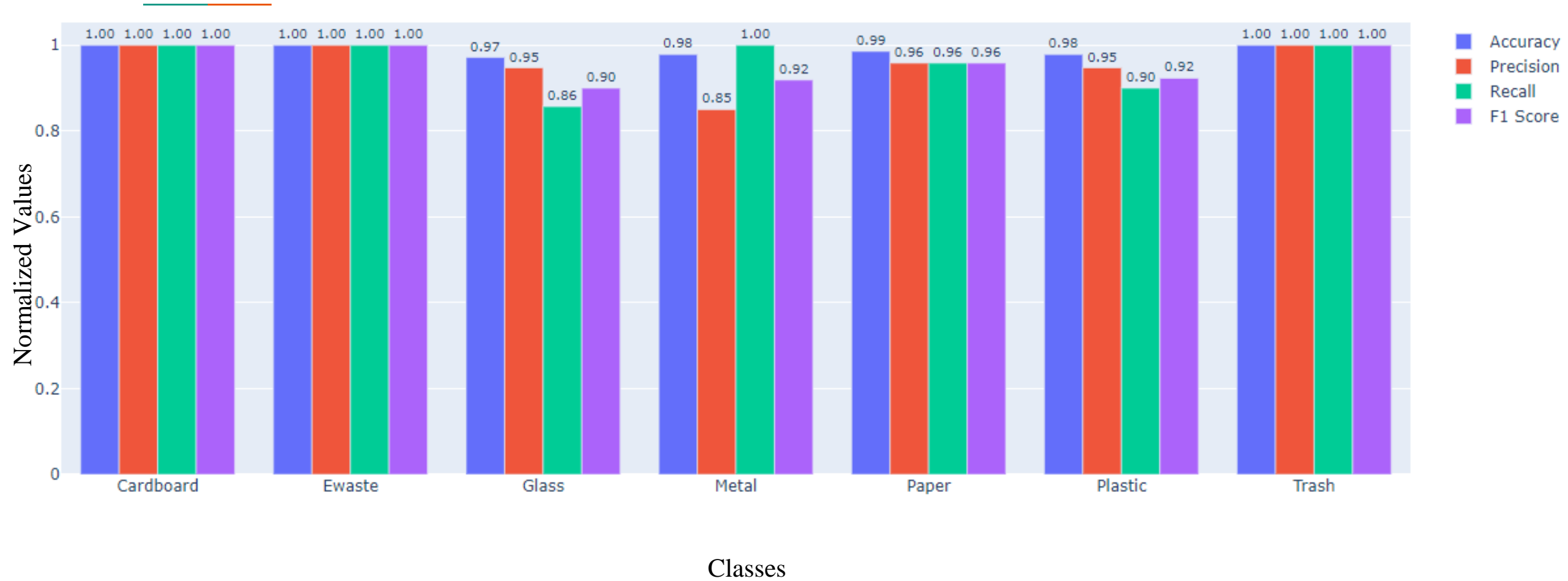


Comparison

Model Metrics	Normalized Values
Accuracy	0.9571
MCC	0.9503
Cohen’s Kappa Coefficient	0.9499

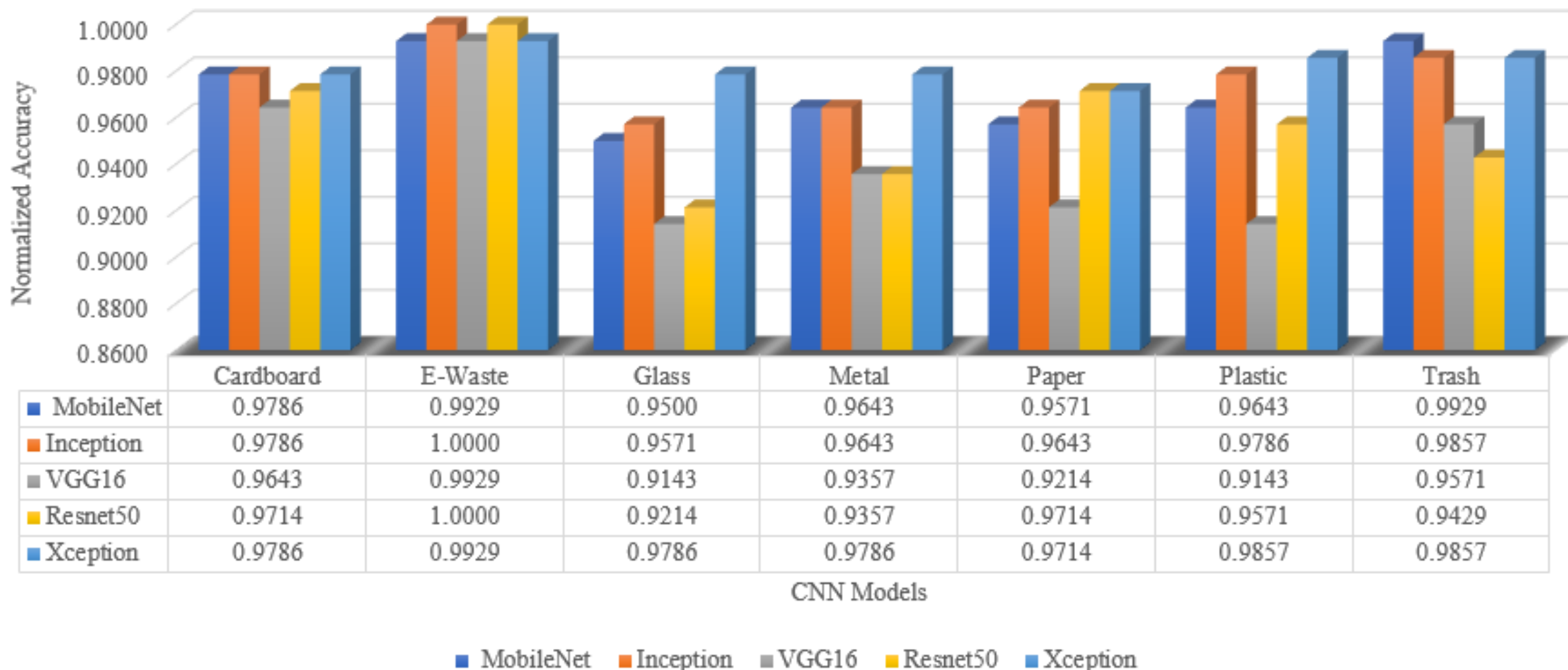
Class	Accuracy	Precision	Recall	F1 Score
Cardboard	1.0000	1.0000	1.0000	1.0000
Ewaste	1.0000	1.0000	1.0000	1.0000
Glass	0.9714	0.9474	0.8571	0.9714
Metal	0.9786	0.8500	1.0000	0.9786
Paper	0.9857	0.9583	0.9583	0.9857
Plastic	0.9786	0.9474	0.9000	0.9786
Trash	1.0000	1.0000	1.0000	1.0000

Accuracy, Recall, Precision and F1 Score of Proposed Model

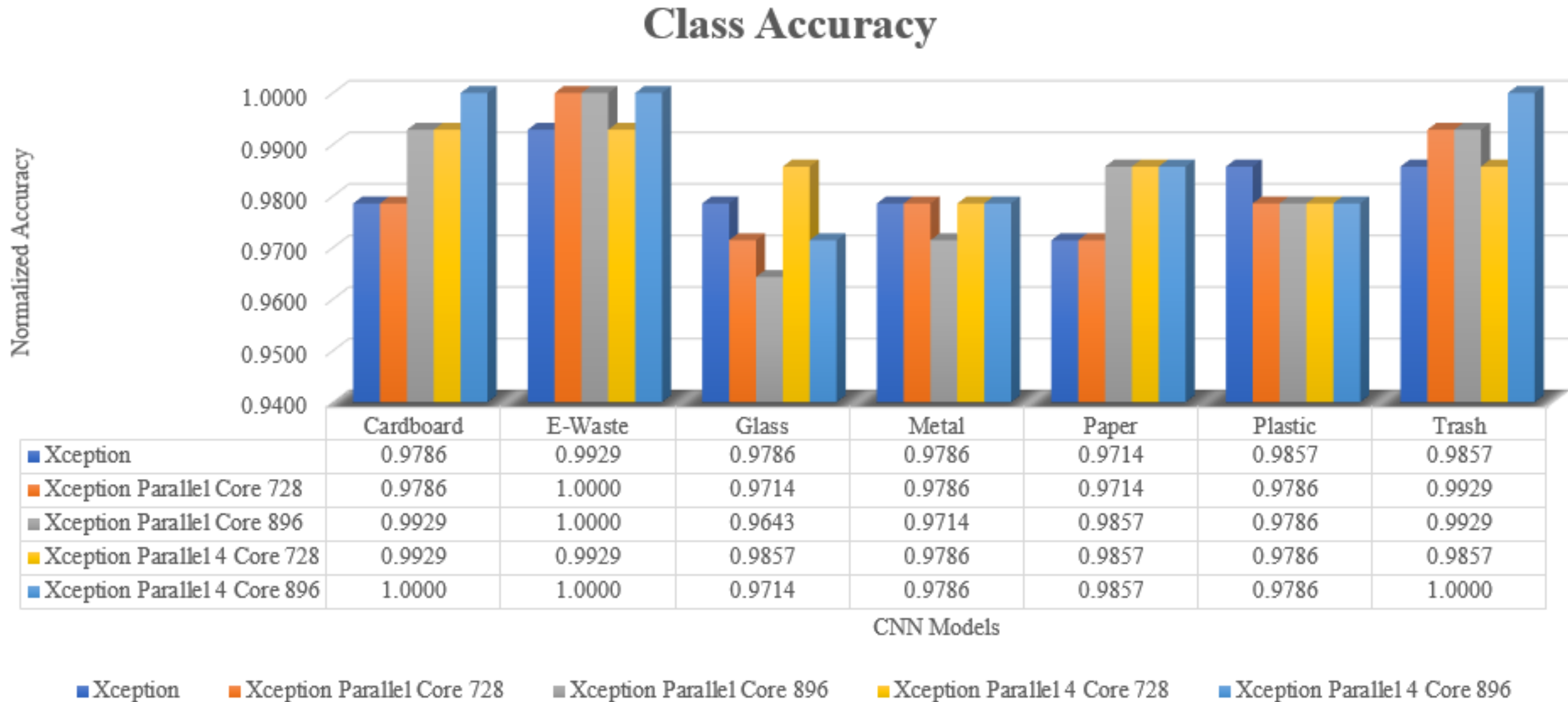


Class Accuracy

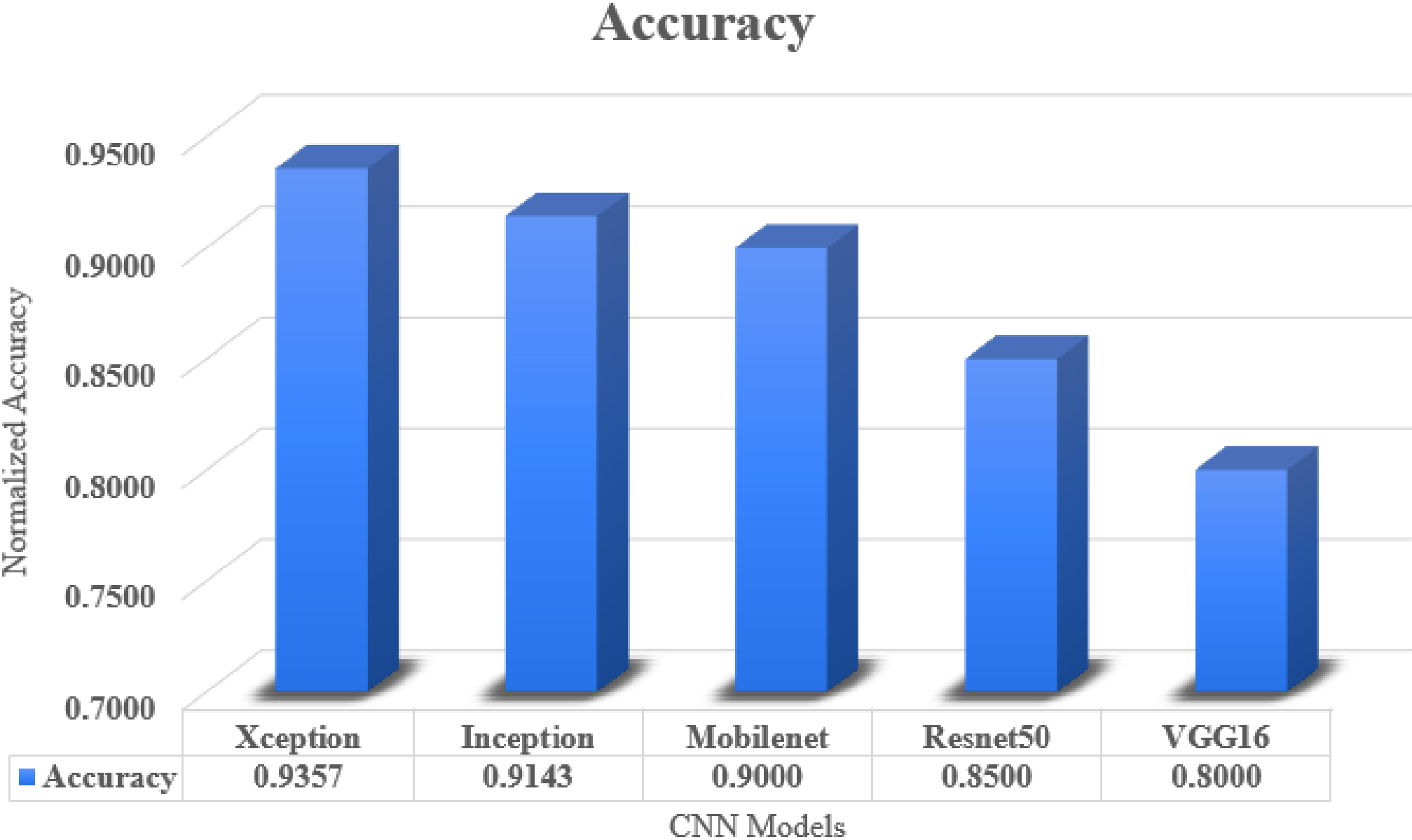
Class Accuracy



Class Accuracy



Model Accuracy Comparison



Proposed Model Accuracy Comparison

