Interim Report Capstone Group 3

BOUNDING BOX REGRESSION AND MULTICLASS CLASSIFICATION OF STANFORD CAR IMAGES

Submitted by - AIML Batch-B Jun, 23

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SECTION 1: INTRODUCTION

Summary of problem statement

Abstract

The project is situated within the field of Automotive Surveillance. The primary objective is to develop a deep learning model capable of identifying various attributes of a car from an image. The attributes include the make, model, type, color, and number plates of the car.

The dataset used for this project, known as the Cars dataset, contains 16,185 images of 196 classes of cars. The data is split into 8,144 training images and 8,041 testing images, with each class split approximately evenly. This ensures a balanced representation of all car classes in both the training and testing sets.

The images are real-world images of cars, providing a diverse and representative sample for the model to learn from. This diversity is crucial for the model to generalize well to new, unseen images.

The initial findings suggest that the data is well-distributed across different classes, providing a solid foundation for model training. This well-distributed data is expected to aid in the effective training of the model, enabling it to learn distinguishing features across all classes.

The project aims to leverage the power of deep learning to tackle this challenge. Deep learning, with its ability to learn complex patterns and representations, is well-suited for tasks such as this that involve understanding visual data.

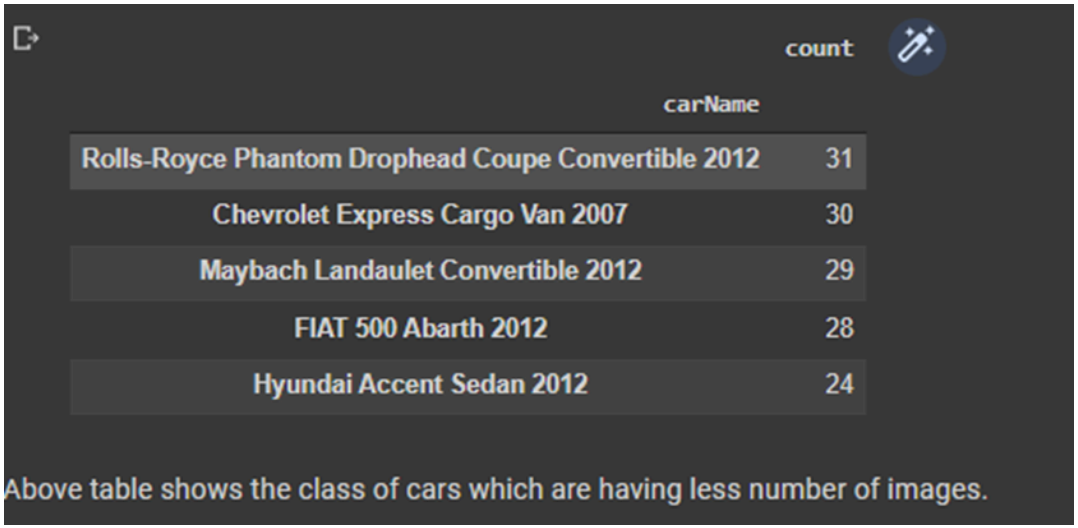
The ultimate goal is to develop a robust and reliable model that can be used in real-world automotive surveillance applications. Such a model could have numerous applications, from automated traffic monitoring to advanced driver-assistance systems.

In conclusion, this project represents an exciting opportunity to push the boundaries of what's possible with deep learning in the field of Automotive Surveillance. The journey so far has been promising, and there is much potential for further exploration and discovery.

SECTION 2: DATA ANALYSIS AND PRE-PROCESSING Approach to EDA

The dataset is a set of images segregated as train and test samples. Train Images have 8144 images which are related to cars of different models. Test Images have 8041 images which are related to cars of different models. There are 196 classes of cars. Given the number of images, the dataset is almost equally divided as train and test set. Both sets have 196 classes of cars.

Class having minimum number of images in train dataset

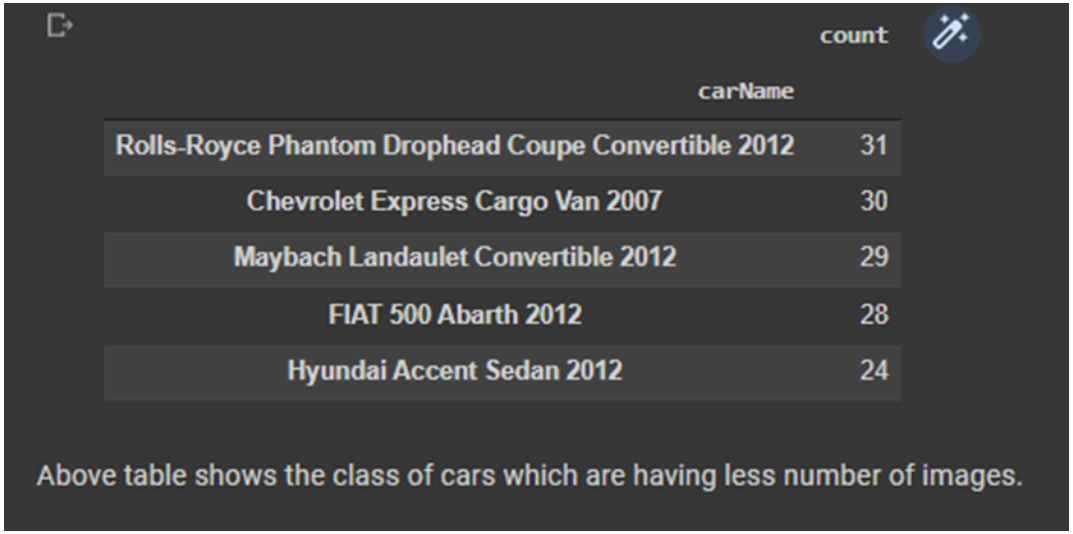


carName	count
Rolls-Royce Phantom Drophead Coupe Convertible 2012	31
Chevrolet Express Cargo Van 2007	30
Maybach Landaulet Convertible 2012	29
FIAT 500 Abarth 2012	28
Hyundai Accent Sedan 2012	24

Above table shows the class of cars which are having less number of images.

Below mentioned picture shows 5 classes which are having less number of images in the Train dataset.

Class having maximum number of images in train dataset



carName	count
Rolls-Royce Phantom Drophead Coupe Convertible 2012	31
Chevrolet Express Cargo Van 2007	30
Maybach Landaulet Convertible 2012	29
FIAT 500 Abarth 2012	28
Hyundai Accent Sedan 2012	24

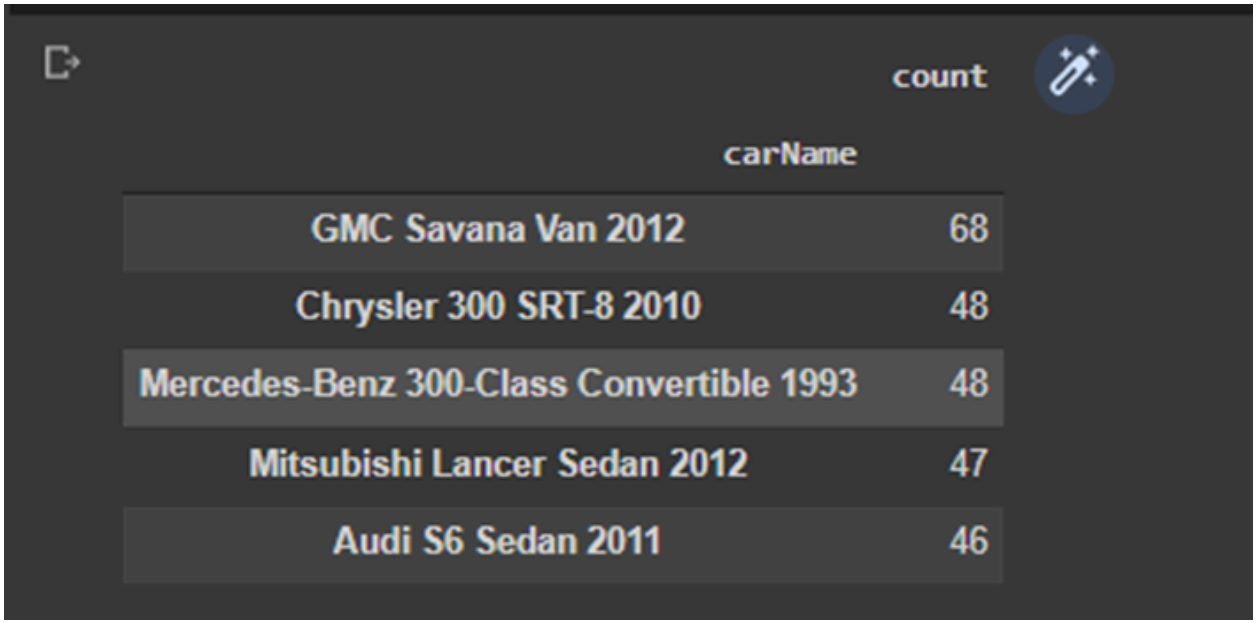
Above table shows the class of cars which are having less number of images.

Below mentioned picture shows 5 classes which are having less number of images in the Train dataset.

Class having minimum number of images in test dataset

carName	count
Rolls-Royce Phantom Drophead Coupe Convertible 2012	30
Chevrolet Express Cargo Van 2007	29
Maybach Landaulet Convertible 2012	29
FIAT 500 Abarth 2012	27
Hyundai Accent Sedan 2012	24

Below mentioned picture shows 5 classes which are having less number of images in the Test dataset.

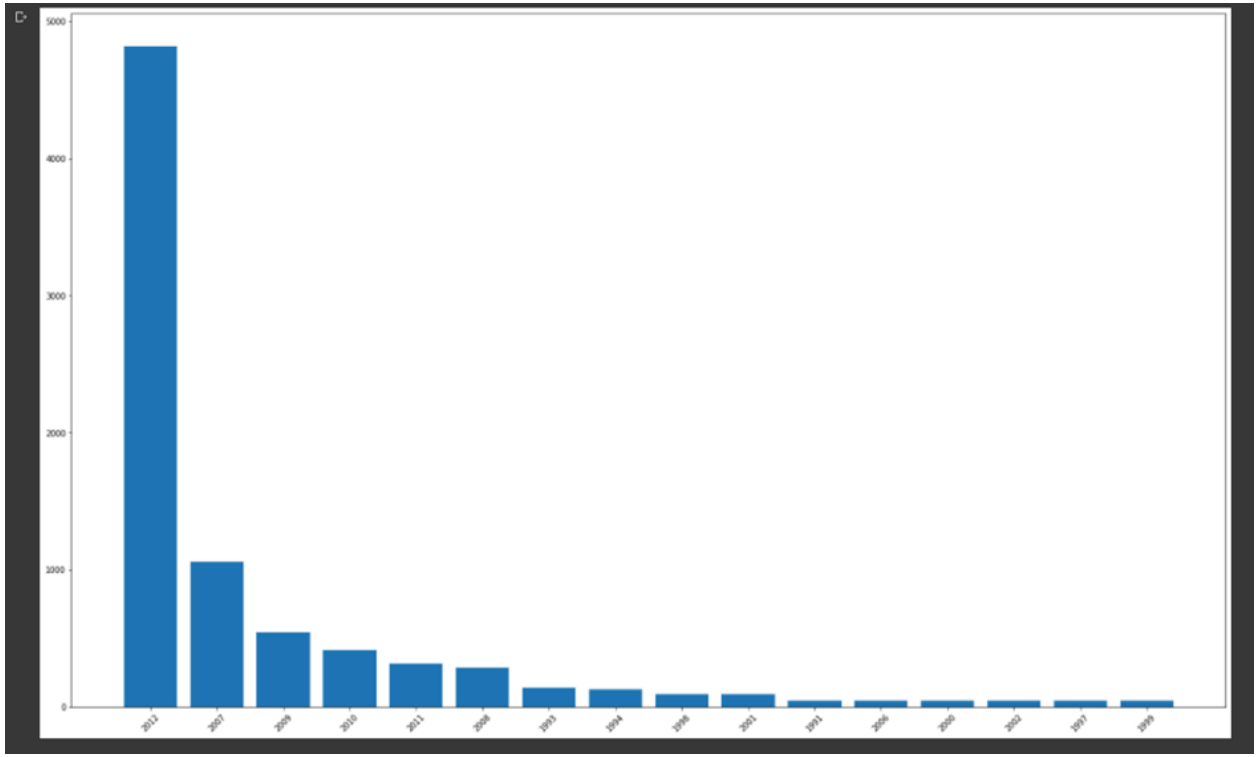


carName	count
GMC Savana Van 2012	68
Chrysler 300 SRT-8 2010	48
Mercedes-Benz 300-Class Convertible 1993	48
Mitsubishi Lancer Sedan 2012	47
Audi S6 Sedan 2011	46

Class having maximum number of images in test dataset

Below mentioned picture shows 5 classes which are having more number of images in the Test dataset.

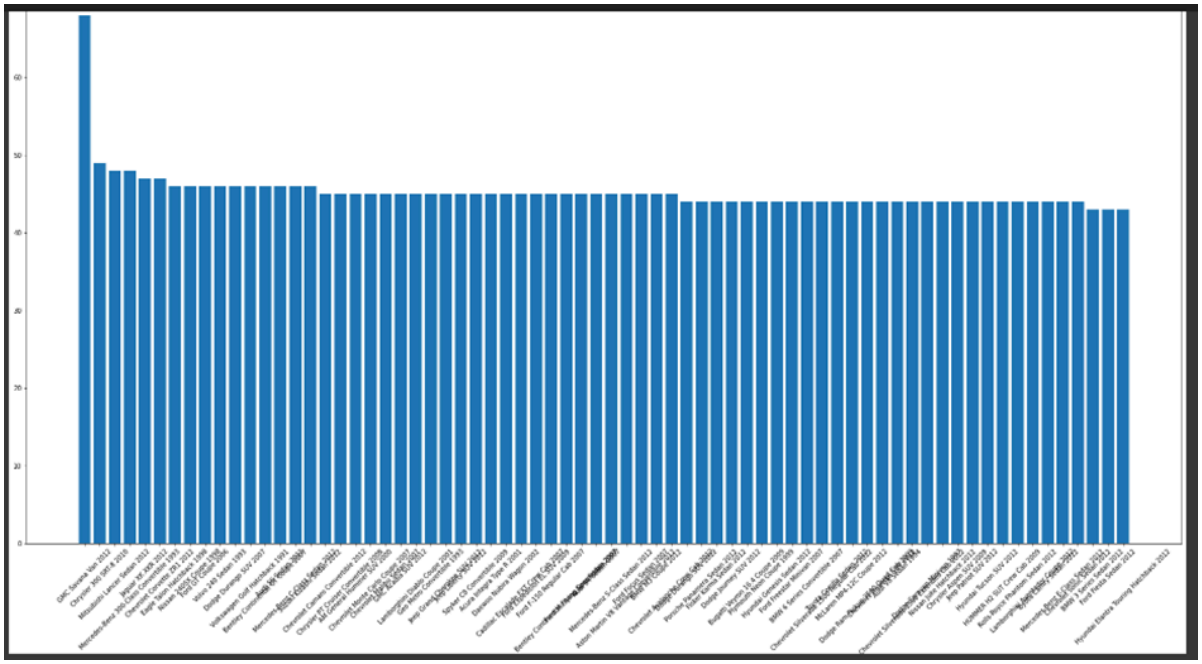
Number of car images based on Year

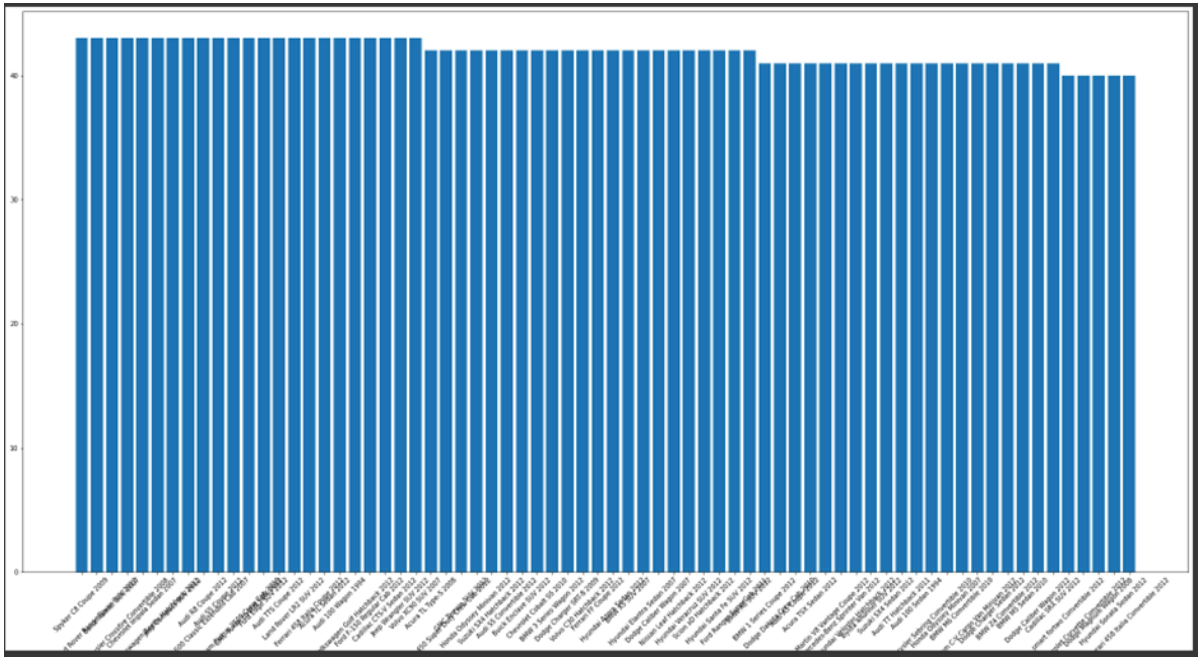


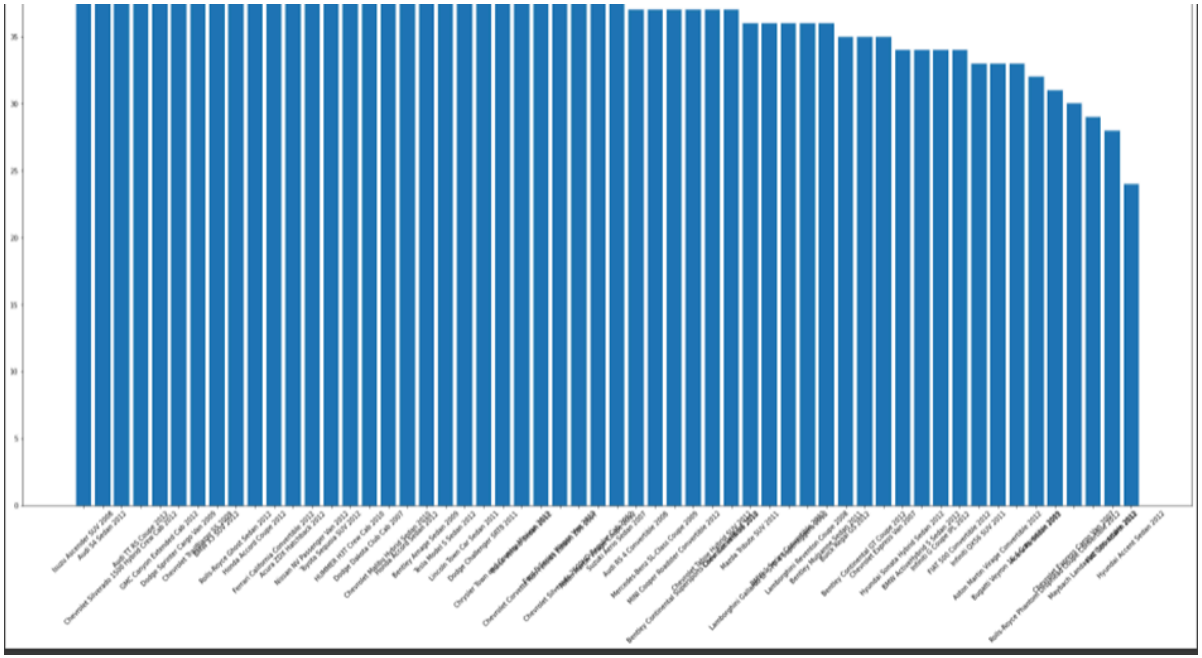
Below mentioned picture depicts the number of car images based on car model year. There are more images of cars which are of model 2012 and very less images belonging to model 1996.

Class distribution

Almost all classes of cars images have an equal number of images which is of count around 40. There is a class named “GMC savana van 2012” which has 60 images and “Hyundai Accent sedan 2012” which has around 25 images. In below mentioned pictures we can view the class distribution.



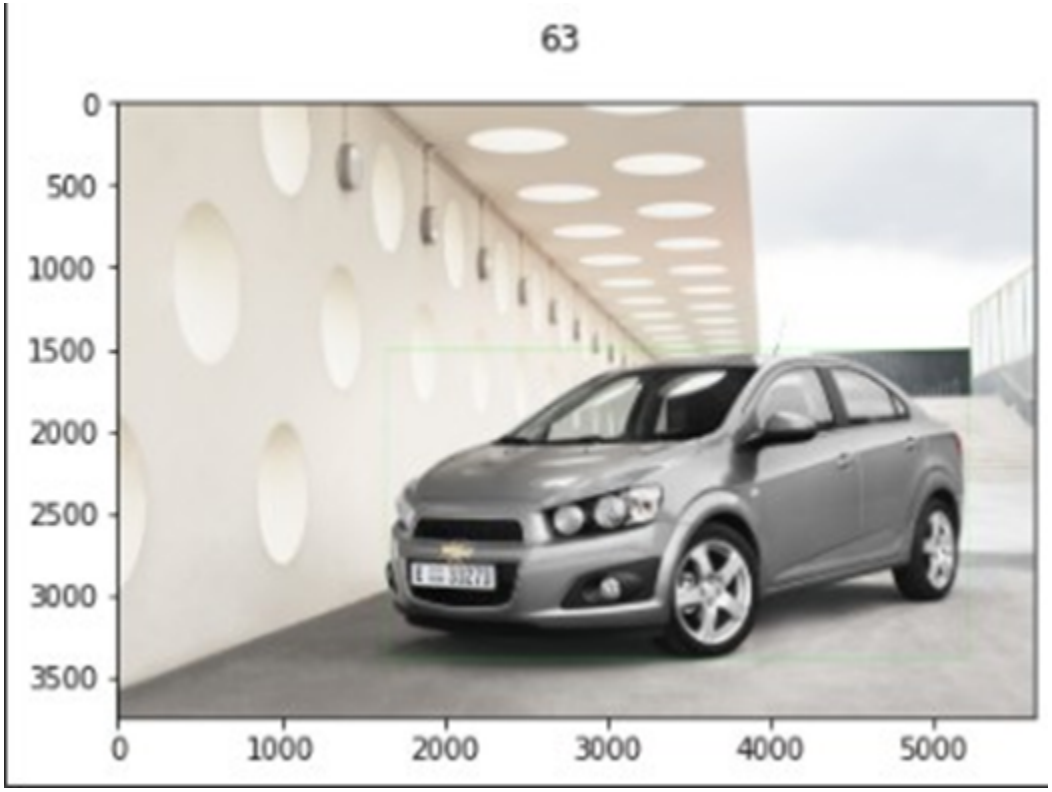

40
30
20
10
0



Maximum Size of the image available in dataset

	carName	imageName	Height	Width
2779	Chevrolet Sonic Sedan 2012	05945.jpg	3744	5616

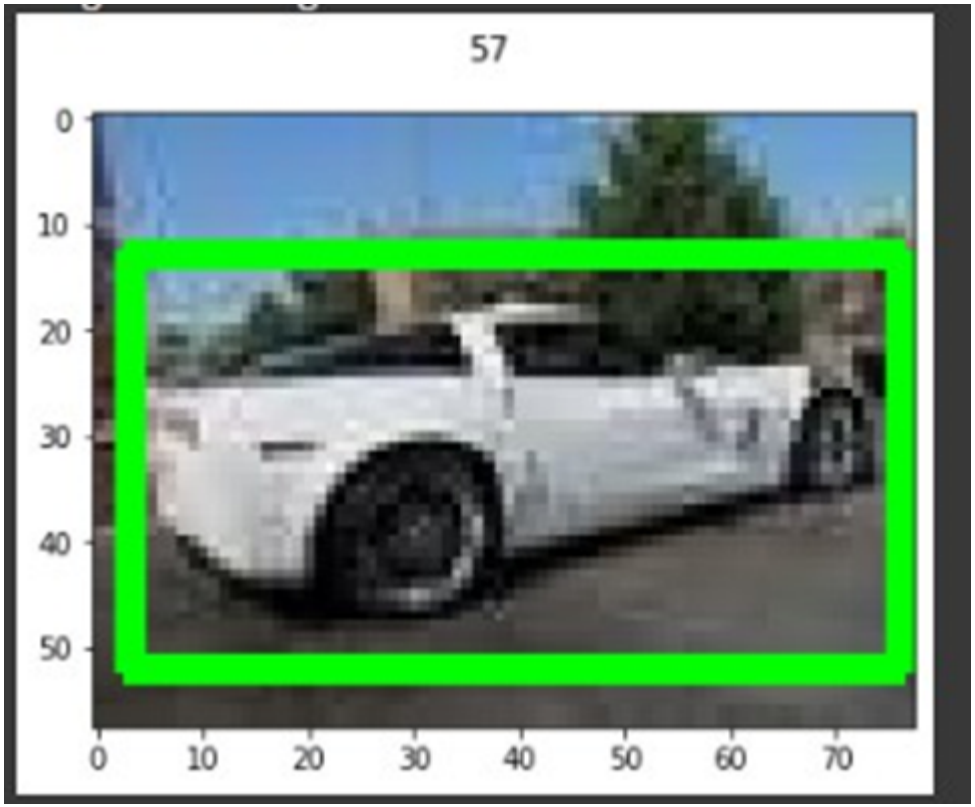
Image with name 05945.jpg which belongs to class "Chevrolet Sonic Sedan 2012" is having maximum height and width. The dataset has uneven distribution of the image size and hence preprocessing is required before running the model on data. While preprocessing we have to define a fixed image size and the tensorflow preprocessing function should be applied on each images before training the model.

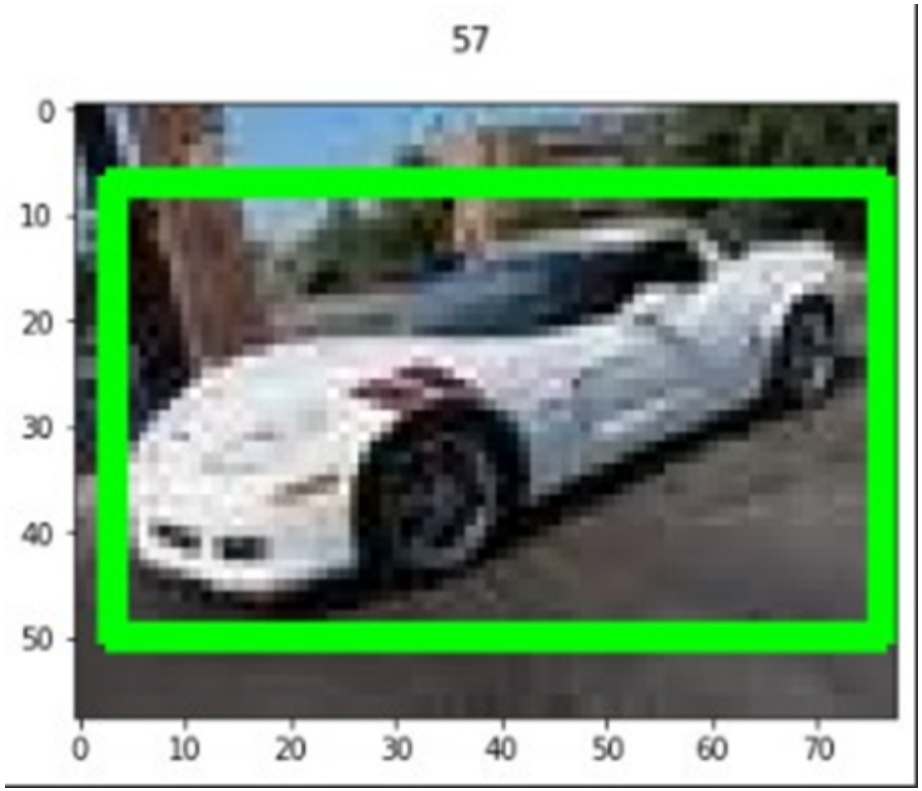


Minimum Size of the image available in dataset

	carName	imageName	Height	Width
2543	Chevrolet Corvette Ron Fellows Edition Z06 2007	07469.jpg	58	78
2558	Chevrolet Corvette Ron Fellows Edition Z06 2007	00097.jpg	58	78

Below mentioned pictures show the details which are images which are having very less size.


57
0
10
20
30
40
50
0
10
20
30
40
50
60
70


57
0
10
20
30
40
50
0
10
20
30
40
50
60
70

Checking bounding boxes on the image

Applying bounding boxes on random images to check if the annotations provided are matching with that of images. The images are decided to be resized to 224x224 and corresponding bounding boxes are modified based on ratio of height and width.

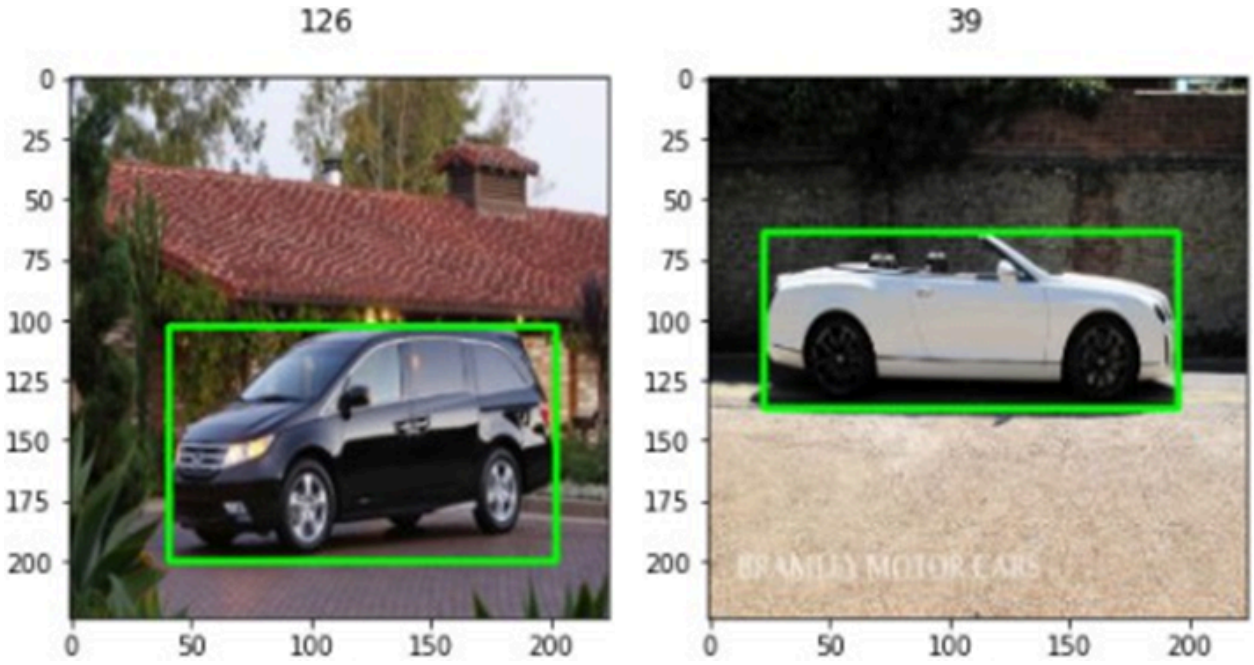

126
39
0
25
50
75
100
125
150
175
200
0
50
100
150
200

Image Pre-processing

For Preprocessing images, below mentioned simple 3 steps are followed.

1. **Reading images from images folder**
2. **Reading annotation file**
3. **Extracting image height and width**
4. **Merging image annotation dataset with data produced in above 2 steps.**

Creating dataset from images folder

The images subdirectory contains all images in our dataset, with a corresponding subdirectory for the name of the label. We start with loading the Car Name and Class Name into a pandas dictionary object.

Loading Annotations file in a pandas Dataframe object. Each row in Annotations file consists of consists of six elements:

1. **Image Filename**
2. **Starting x-coordinate**
3. **Starting y-coordinate**
4. **Ending x-coordinate**
5. **Ending y-coordinate**
6. **Class label number**

Looping over our CSV annotation files, we grab all rows in the file and proceed to loop over each of them.

Inside our loop, we unpack the comma-delimited row giving us our filename, (x, y)- coordinates, and class label for the particular line in the CSV. We again loop through the annotations dataframe and update

new columns for Class Name and build Image path name. Using the imagePath derived from our config, class label, and filename,we load the image and extract its spatial dimensions. We then scale the bounding box coordinates relative to the original image‘s dimensions to the range [0, 1] — this scaling serves as our preprocessing for the bounding box data.

Finally we load the image from disk in Keras/TensorFlow format and preprocess it with a resizing step which forces the image to 224×224 pixels for input for the model. Next step is to One-hot encode our labels using LabelBinarizer.

SECTION 3: MODEL DETAILS

Model Building and Training

The CNN architecture consists of the following layers:

1. **Convolutional Layers:**
    - **First Convolutional Layer:**
        - **Details: This layer uses 16 filters of size 3x3 to scan the image. It’s like applying a small window that moves across the image to detect basic features like edges.**
        - **Normalization & Activation: After filtering, batch normalization helps standardize the data, and ReLU activation introduces non-linearity to allow the network to learn more complex patterns.**
        - **Pooling: Max pooling (2x2) is applied to reduce the size of the feature maps, keeping only the most important information.**
    - **Second Convolutional Layer:**

        - **Details: This layer has 32 filters of the same 3x3 size, further extracting features from the output of the first layer.**
        - **Normalization & Activation: Again, batch normalization and ReLU activation are used.**
        - **Pooling: Another round of max pooling (2x2) is performed to further reduce the feature map size.**
2. **Fully Connected Layers:**
    - **First Fully Connected Layer:**
        - **Details: This layer takes the output from the convolutional layers (which is flattened into a long vector) and processes it into 512 nodes. It acts like a traditional neural network layer.**
        - **Activation: Uses ReLU to allow the model to learn complex relationships.**
    - **Dropout:**
        - **Details: A dropout rate of 25% is applied, meaning one in four neurons is randomly "turned off" during each training step to prevent the model from overfitting to the training data.**
    - **Second Fully Connected Layer:**
        - **Details: This layer outputs the final classification scores for each of the 196 car categories.**

MobileNet

MobileNets are built on a simplified design that builds light weight deep neural networks using depth-wise separable convolutions. Two simple global hyper-parameters are introduced that efficiently trade off latency and accuracy. These hyper-parameters help the model builder to select the appropriate model size for their application based on the problem constraints. We are using a specific version of mobile net model MobileNetV2. MobileNetV2 is very similar to the original MobileNet, except that it uses inverted residual blocks with bottlenecking features. It has a drastically lower parameter count than the original MobileNet. MobileNets support any input size greater than 32 x 32, with larger image sizes offering better performance.

The network is a fairly simple network with less number of weights to be trained. We are retraining the model right from input layer and we have added dense layer and dropout layer along with batch normalization as final layer for classification and regression (calculation of bounding box).

We are using categorical_crossentropy for classification and mse for regression. We calculate the overall loss of the model by adding regression loss and classification loss. For calculating accuracy of the bounding box on the images, we have defined a function to

calculate IOU. This Intersection over Union is an evaluation metric used to measure the accuracy of an object detector on a particular dataset.

Below mentioned are the weight which are to be learnt for mobile net model Total params:

4,988,104

Trainable params: 4,953,352

Non-trainable params: 34,752

Resnet50

ResNet50 is a ResNet variation of 48 Convolution layers, 1 MaxPool layer, and 1 Average Pool layer. There are 3.8 x 109 floating point operations in it. It's a popular ResNet model. ResNet is a technique for dealing with the vanishing gradient problem in deep CNNs. They work by bypassing some layers, believing that very deep networks should not have a higher training error than shallower networks.

Here we have retrained the entire model, this model has 28 Million trainable parameters. The Last layer of the model has GlobalAveragePooling2D, 2 Dense layer, 1 dropout layer and a Batch normalization layer. For classification we have used softmax activation function with 196 classes and for regression we have used sigmoid activation function for 4 coordinates of the bounding box.

We are using categorical_crossentropy for classification and mse for regression. We calculate the overall loss of the model by adding regression loss and classification loss. For calculating accuracy of the bounding box on the images, we have defined a function to calculate IOU. This Intersection over Union is an evaluation metric used to measure the accuracy of an object detector on a particular dataset.

Below mentioned are the weight which are to be learnt for mobile net model Total params: 28,937,800

Trainable params: 28,883,656

Non-trainable params: 54,144

Efficientnet-b5

Efficientnet-b5 model with ImageNet weights is used for developing network for classification and regression tasks for the given problem statement. The efficientnet-b5 model is one of the EfficientNet models designed to perform image classification. All the EfficientNet models have been pre trained on the ImageNet image database.

Efficientnet-b5 has 576 total layers, from layer number 257 we have made it trainable. This model has 28 Million trainable parameters. The Last layer of the model has GlobalAveragePooling2D, 1 Dense layer and a Batch normalization layer. For classification

we have used softmax activation function with 196 classes and for regression we have used sigmoid activation function for 4 coordinates of the bounding box.

We are using categorical_crossentropy for classification and mse for regression. We calculate the overall loss of the model by adding regression loss and classification loss. For calculating accuracy of the bounding box on the images, we have defined a function to calculate IOU. This Intersection over Union is an evaluation metric used to measure the accuracy of an object detector on a particular dataset.

Number of weights after final model building is as mentioned below.

Total params: 33,127,871
Trainable params: 31,496,968
Non-trainable params: 1,630,903

Efficientnet-b7

Efficientnet-b7 model with ImageNet weights is used for developing network for classification and regression tasks for the given problem statement. The efficientnet-b7 model is one of the EfficientNet models designed to perform image classification. All the EfficientNet models have been pre trained on the ImageNet image database.

Efficientnet-b7 has 813 total layers, from layer number 351 we have made it trainable. This model has 64 Million trainable parameters. The Last layer of the model has GlobalAveragePooling2D, 1 Dense layer and a Batch normalization layer. For classification we have used softmax activation function with 196 classes and for regression we have used sigmoid activation function for 4 coordinates of the bounding box.

We are using categorical_crossentropy for classification and mse for regression. We calculate the overall loss of the model by adding regression loss and classification loss. For calculating accuracy of the bounding box on the images, we have defined a function to calculate IOU. This Intersection over Union is an evaluation metric used to measure the accuracy of an object detector on a particular dataset.

Number of weights after final model building is as mentioned below.

Total params: 71,176,287

Trainable params: 67,594,112
Non-trainable params: 3,582,175

Conclusion

Here we have chosen EfficientNet-B7 and since this is an interim submission, we are planning to continue our experiment with other networks and methodologies. We are trying to build YOLO and we are also using the TFOD framework to check which would give the best result. We also started with efficientDet. For final submission we will compare all the models and get the best model deployed and produce a result in a nice user interface.

Training Details

- **Loss Function: Cross-entropy loss is used to measure how well the model's predictions match the actual car categories.**
- **Optimizer: The Adam optimizer adjusts the model's learning rate throughout training, speeding up convergence and improving the model's performance.**
- **Regularization: Dropout helps prevent the model from memorizing the training data, which enhances its ability to generalize to new images.**
- **Custom Model was trained for 10 epochs**

SECTION 4: RESULTS AND DISCUSSION

Model performance

For this object localization problem we have tried MobileNet, Resnet50, EfficientNet-B5 and EfficientNet-B7. Among these three models we have found the best performing model is EfficientNet-B5. In this section we have mentioned the observed test accuracy and few test samples.

MobileNet being a streamlined architecture, has shown good accuracy for train and validation set of data but performs poorly on unseen test dataset. Test results are mentioned in the table with the title "Test Result for different model". Classification report is available in Tables and figure section in table with title "Classification report for MobileNet"

ResNet50 but performs poorly on unseen test dataset. Test results are mentioned in the table with the title "Test Result for different model". Classification report is available in Tables and figure section in table with title "Classification report for ResNet"

EfficientNet-B5 performs well on unseen test dataset. Test results are mentioned in the table with the title "Test Result for different model". Classification report is available in Tables and figure section in table with title "Classification report for EfficientNet-B5"

EfficientNet-B7 performs well on unseen test dataset. Test results are mentioned in the table with the title "Test Result for different model". Classification report is available in Tables and figure section in table with title "Classification report for EfficientNet-B7"

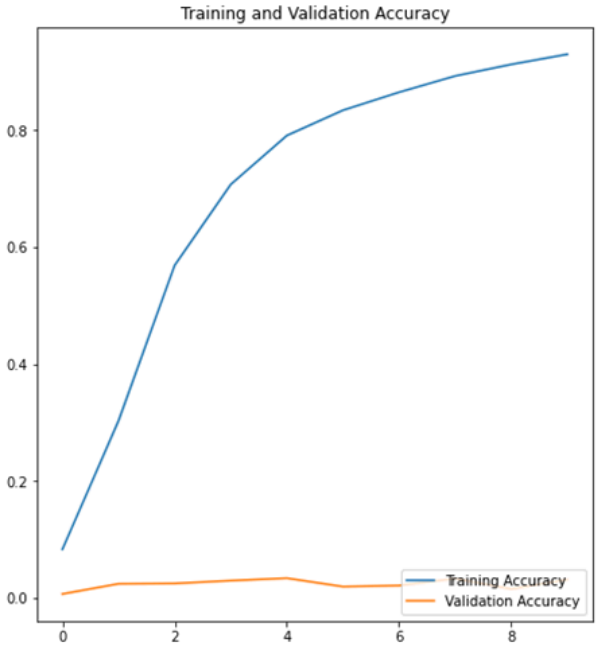
Model	loss	Class_op_loss	reg_op_loss	class_op_accuracy	reg_op_IoU

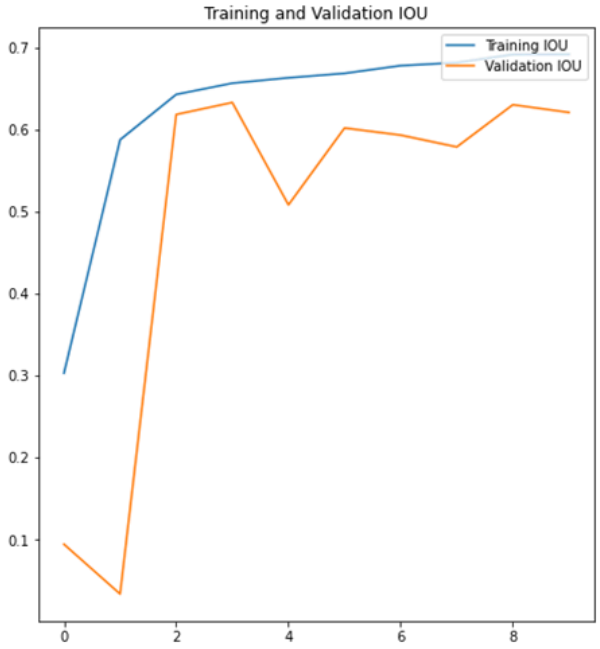
MobileNet	**1.143170595**	**1.140172958**	**0.002998107346**	**0.7411249876**	**0.8120642304**
ResNet50	**4.882508278**	**4.872550488**	**0.009955173358**	**0.0672499845**	**0.7253609896**
EfficientNet-B5	**1.271269798**	**1.268125296**	**0.003145831171**	**0.7512500286**	**0.8126088381**
EfficientNet-B7	**1.153328776**	**1.150439143**	**0.002889547963**	**0.7966250181**	**0.8201269507**

Table 1.1 : Test Result for different model

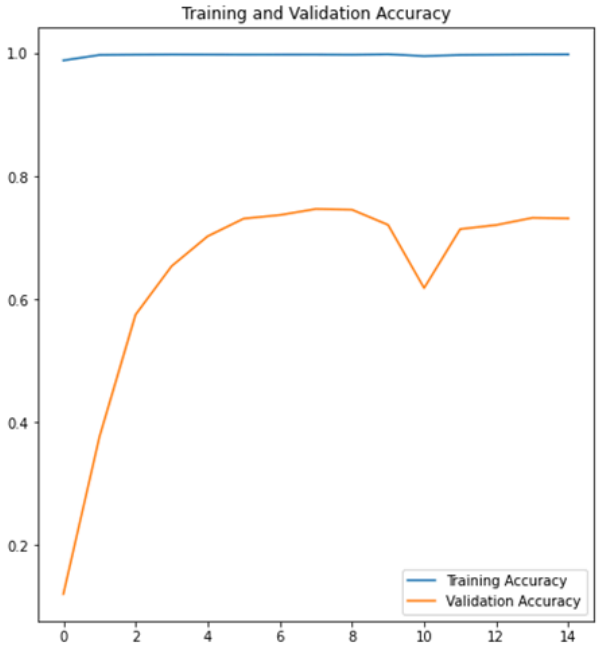
Mobile Net Classification accuracy and IOU

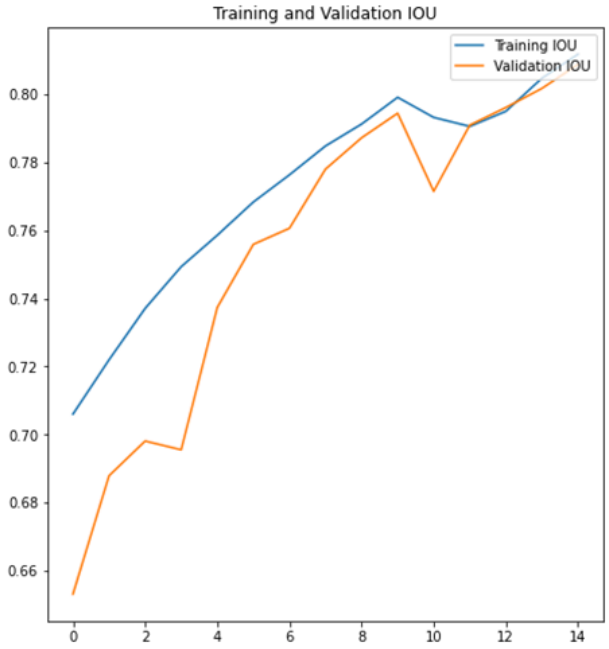
The mobile net is trained in 2 phases, 1st phase with 10 epochs and batch size as 64 and in 2nd phase 15 more epochs with batch size as 16.


Training and Validation Accuracy
Training Accuracy
Validation Accuracy
0.0
0.2
0.4
0.6
0.8
0
2
4
6
8


Training and Validation IOU
Training IOU
Validation IOU
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
2
4
6
8

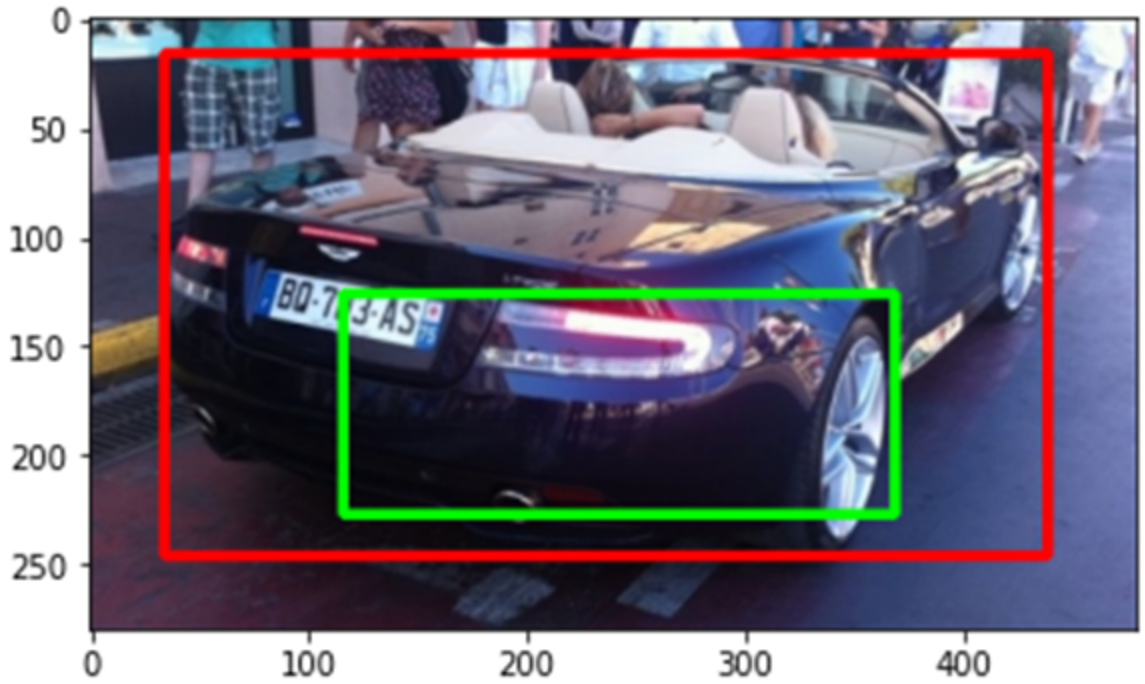
Above figure shows the training vs validation accuracy and Training vs validation IOU in first phase.


Training and Validation Accuracy
1.0
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12
14
Training Accuracy
Validation Accuracy


Training and Validation IOU
0.80
0.78
0.76
0.74
0.72
0.70
0.68
0.66
0
2
4
6
8
10
12
14
Training IOU
Validation IOU

Above figure shows the training vs validation accuracy and Training vs validation IOU in the second phase.

As we can observe the accuracy for classification is very low in validation and the model is an overfitting model with a large gap between training vs validation accuracy. Although the model IOU is fine as per graph, the final output on the data is not acceptable. Few samples of the output of the MobileNet model are mentioned below.



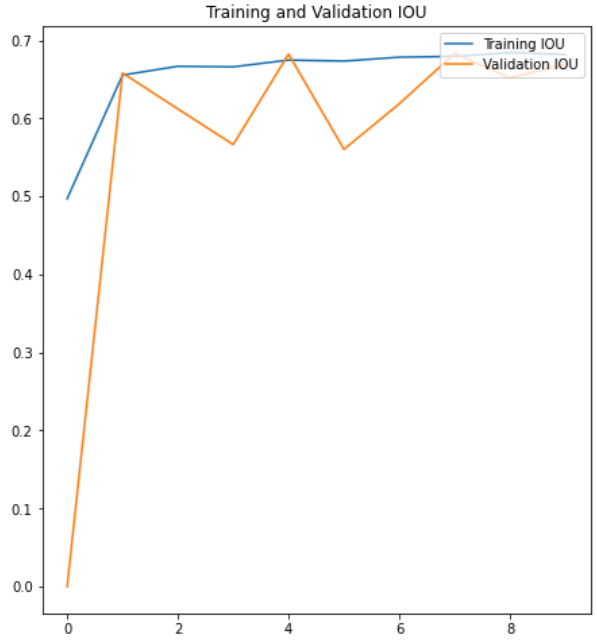
Real Label : Aston Martin Virage Convertible 2012 Predicted Label: Hyundai Veracruz SUV 2012


0
50
100
150
200
250
300
0
50
100
150
200
250
300
350

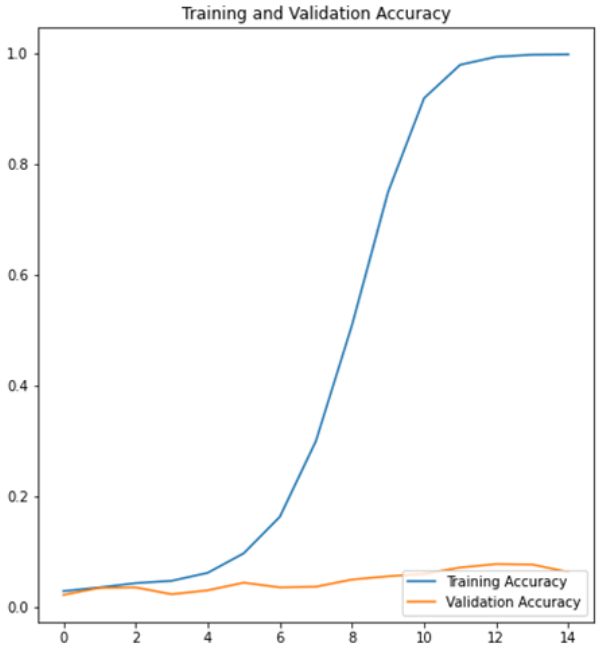
Real Label : Chrysler Sebring Convertible 2010 Predicted Label: Hyundai Veracruz SUV 2012

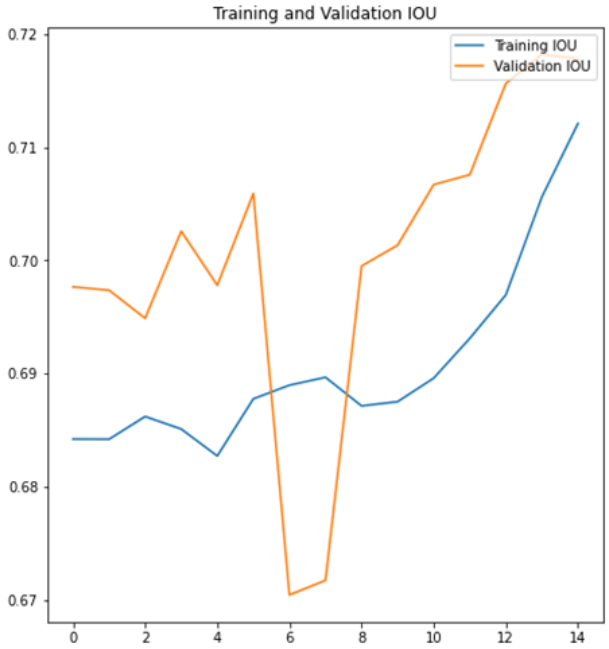
Res Net Classification accuracy and IOU

The Resnet50 is trained in 2 phases, 1st phase with 10 epochs and batch size as 64 and in 2nd phase 10 more epochs with batch size as 16.



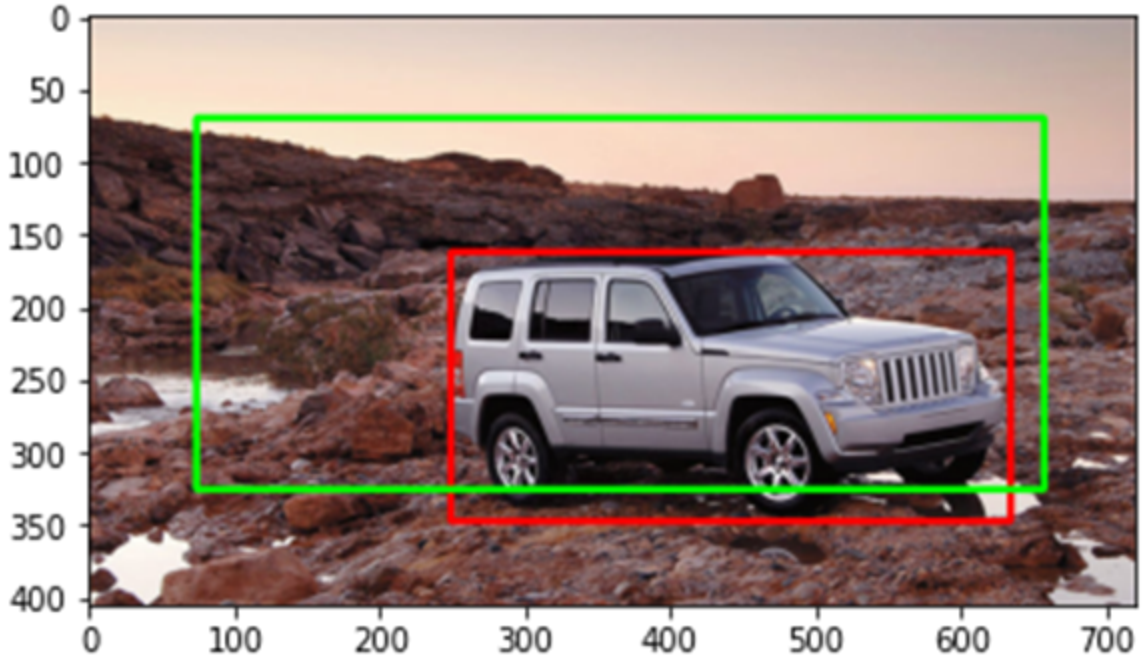
Above figure shows the training vs validation accuracy and Training vs validation IOU in first phase.





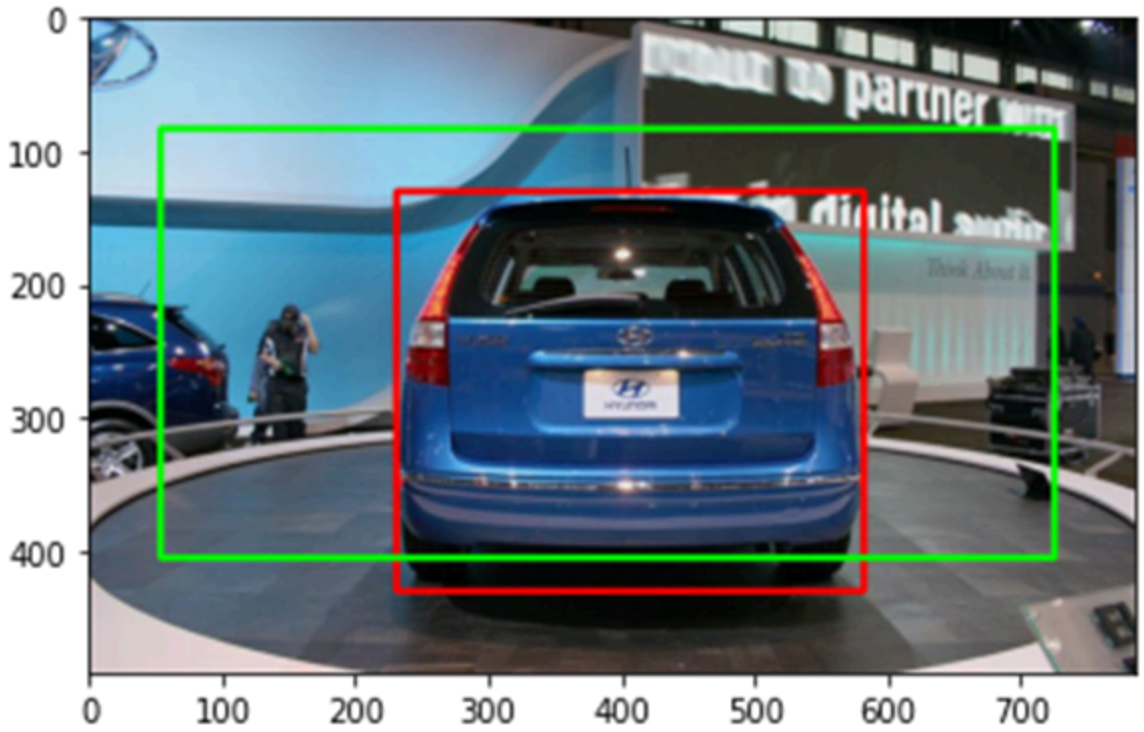
Above figure shows the training vs validation accuracy and Training vs validation IOU in the second phase.

As we can observe the accuracy for classification is very low in validation and the model is an overfitting model with a large gap between training vs validation accuracy. The IOU of the model is also not acceptable. Few samples of the output of the MobileNet model are mentioned below.



Real Label : Jeep Liberty SUV 2012

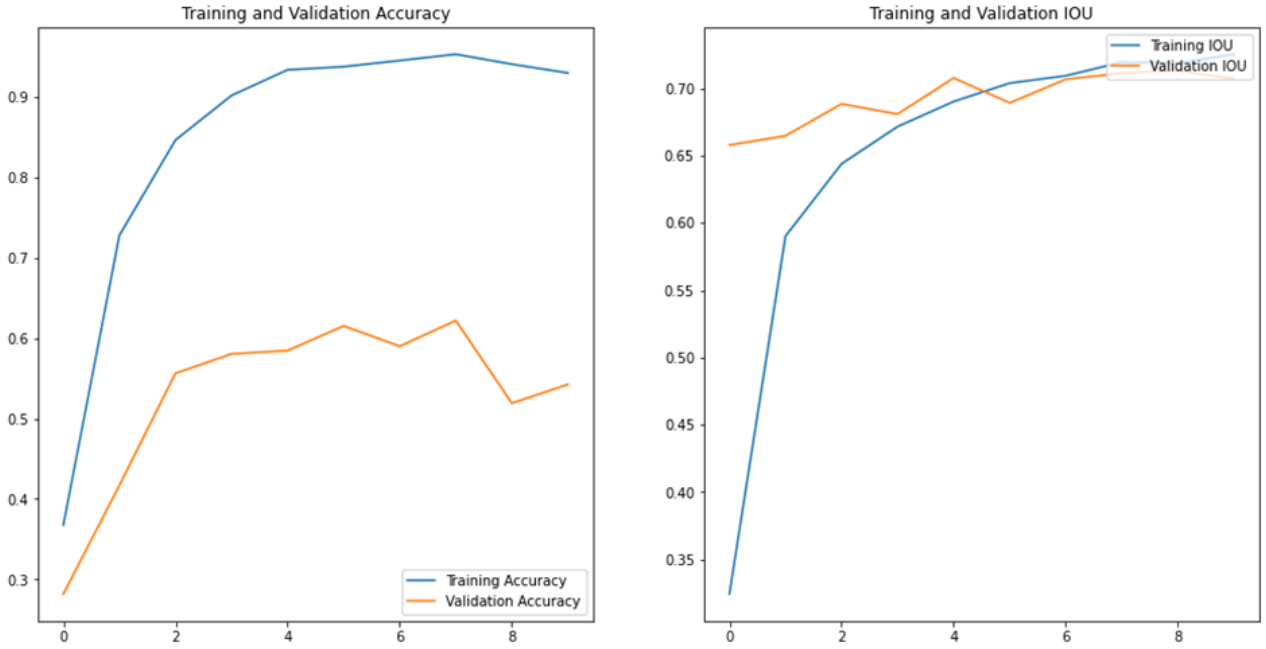
Predicted Label: Dodge Ram Pickup 3500 Crew Cab 2010


0
100
200
300
400
0
100
200
300
400
500
600
700
partner

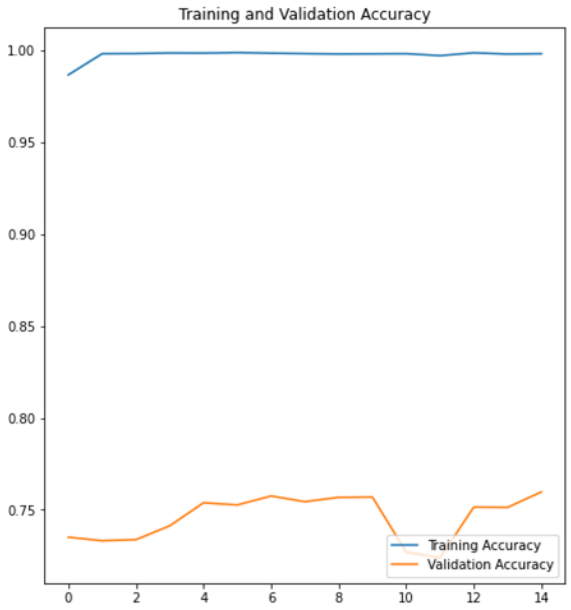
Real Label : Hyundai Elantra Touring Hatchback 2012 Predicted Label: Chevrolet Avalanche Crew Cab 2012

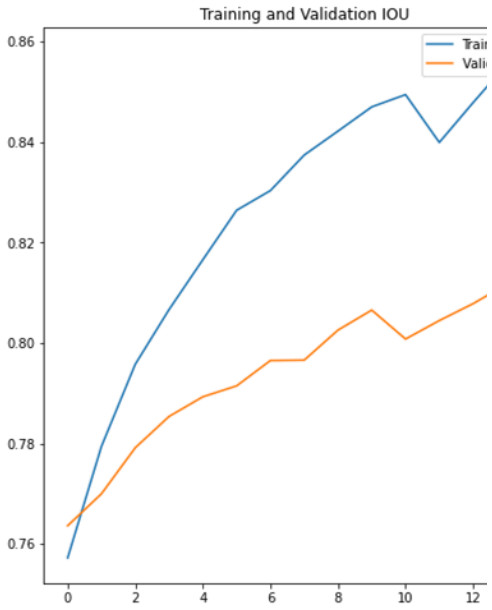
Efficient Net B5 Classification accuracy and IOU

The EfficientNet-B5 is trained in 2 phases, 1st phase with 10 epochs and batch size as 64 and in 2nd phase 10 more epochs with batch size as 16.



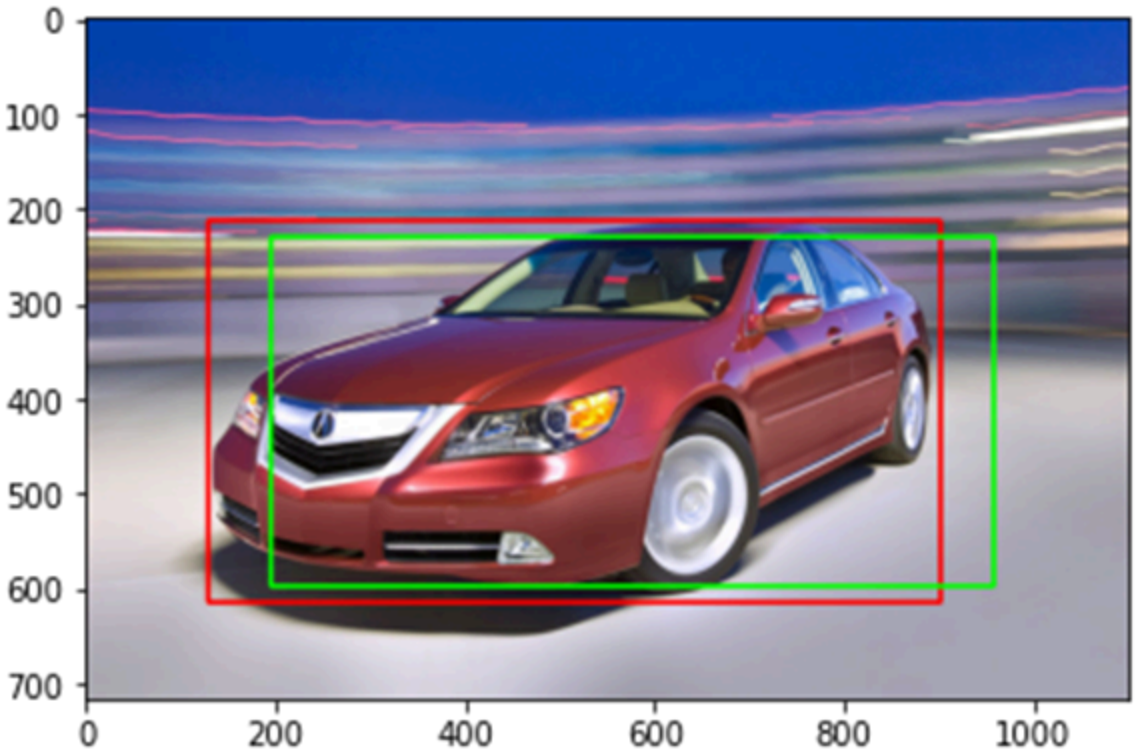
Above figure shows the training vs validation accuracy and Training vs validation IOU in the first phase.


Training and Validation Accuracy
1.00
0.95
0.90
0.85
0.80
0.75
0
2
4
6
8
10
12
14
Training Accuracy
Validation Accuracy

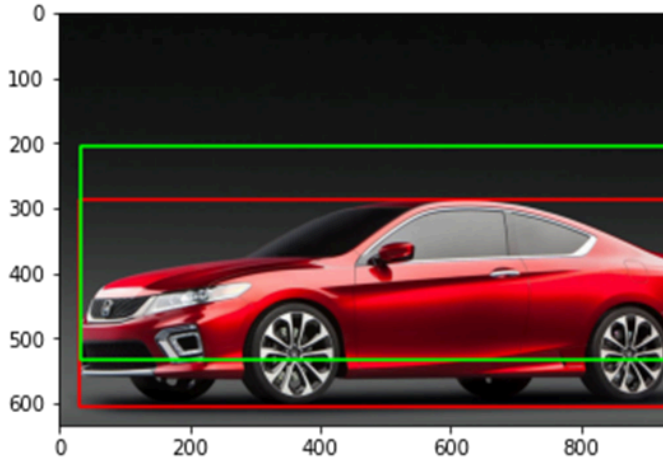

Training and Validation IOU
0.86
0.84
0.82
0.80
0.78
0.76
0
2
4
6
8
10
12

Above figure shows the training vs validation accuracy and Training vs validation IOU in the second phase.

The training vs validation accuracy in the first phase is having a gap between them but with the second phase the validation accuracy has improved. Although the observed gap is more, for a check on a few thousand sample data, the classification seems to be acceptable. The IOU of the model has performed pretty well and compared to resnet50 and MobileNet, the bounding boxes on the sample data has shown improvement. Below mentioned are a few samples of the dataset.



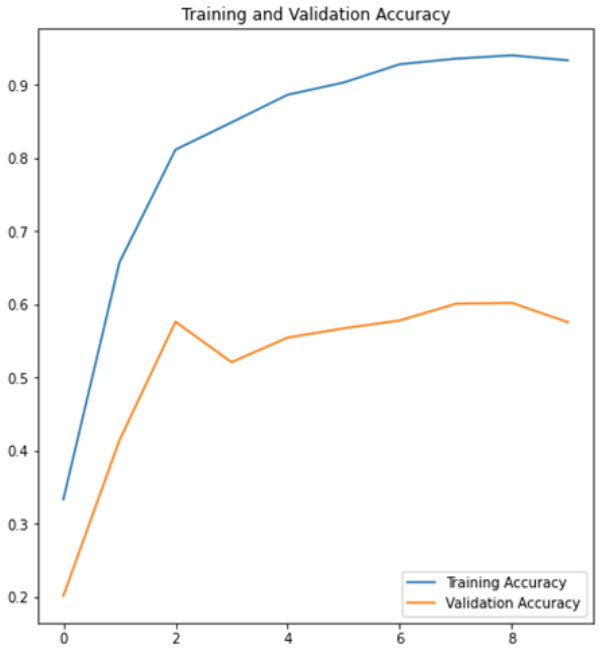
Real Label : Acura RL Sedan 2012 Predicted Label: Acura RL Sedan 2012

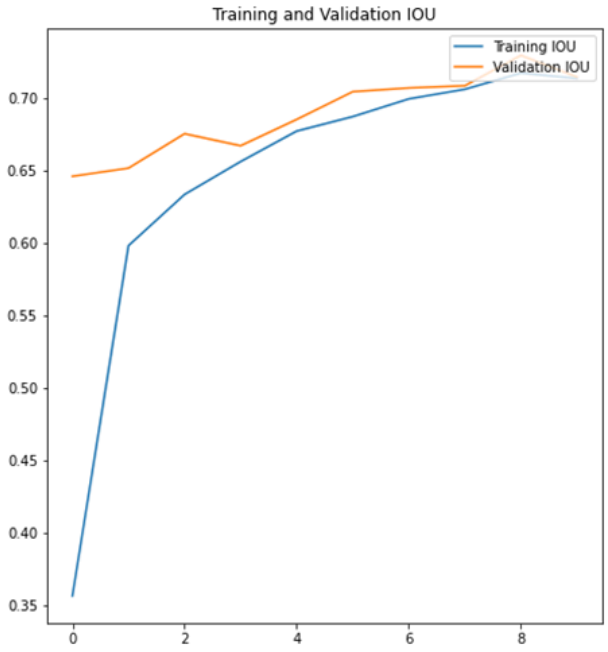

0
100
200
300
400
500
600
0
200
400
600
800

Real Label : Honda Accord Coupe 2012 Predicted Label: Honda Accord Coupe 2012

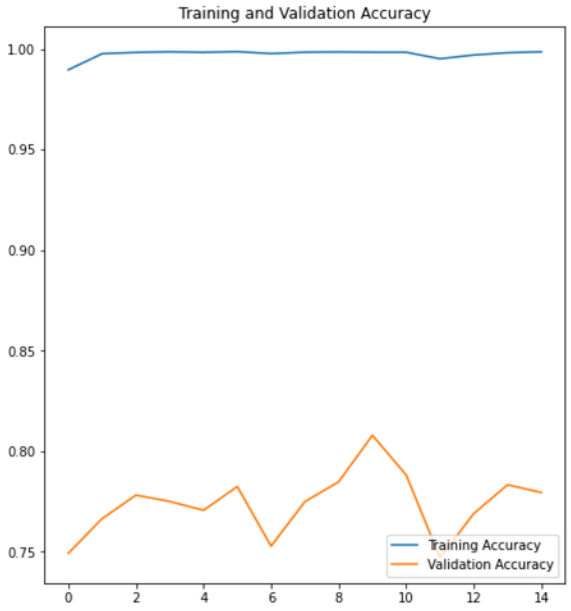
Efficient Net B7 Classification accuracy and IOU

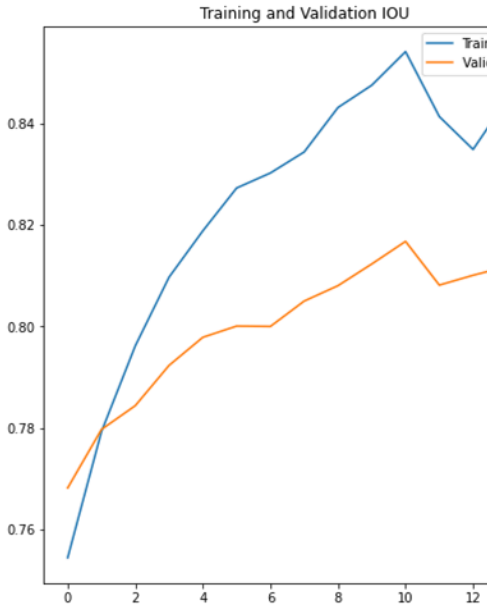
The EfficientNet-B7 is trained in 2 phases, 1st phase with 10 epochs and batch size as 64 and in 2nd phase 15 more epochs with batch size as 16.





Above figure shows the training vs validation accuracy and Training vs validation IOU in the first phase.

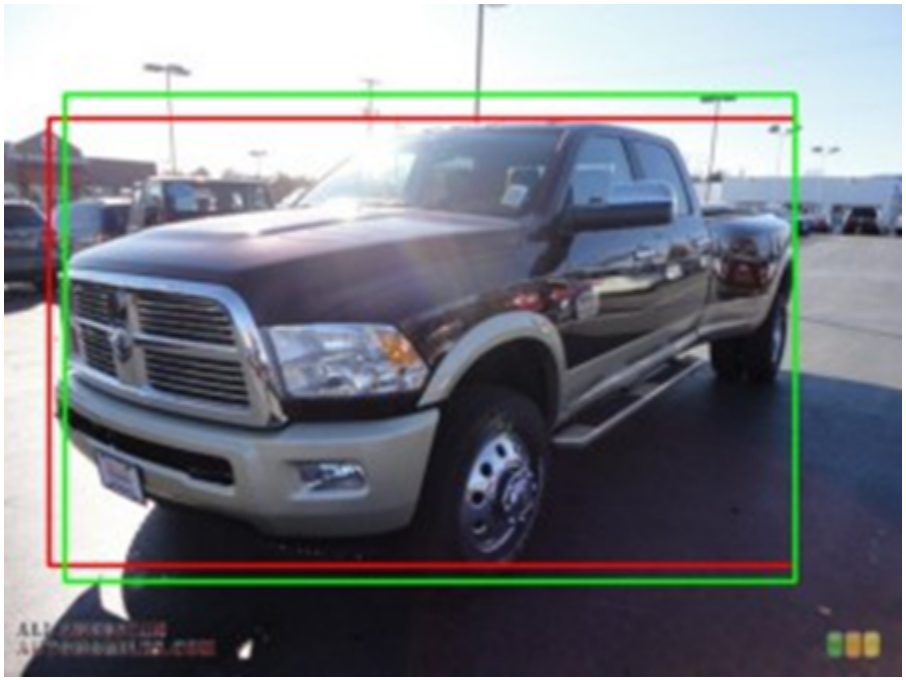




Above figure shows the training vs validation accuracy and Training vs validation IOU in the second phase.

The training vs validation accuracy in the first phase is having a gap between them but with the second phase the validation accuracy has improved. Although the observed gap is more, for a check on a few thousand sample data, the classification seems to be acceptable. The IOU of the model has performed

pretty well and compared to resnet50 and MobileNet, the bounding boxes on the sample data has shown improvement. Below mentioned are a few samples of the dataset.



Real Label : Dodge Ram Pickup 3500 Crew Cab 2010 Predicted Label: Dodge Ram Pickup 3500 Crew Cab 2010


M PE 7202

Real Label : BMW ActiveHybrid 5 Sedan 2012 Predicted Label: BMW ActiveHybrid 5 Sedan 2012

Based on the performance, the EfficientNet-B7 model is finally chosen, which is having the best performance among all the ones we have seen so far.

Approaches for Improve performance of model

Data Augmentation

One of the ways of improving the model performance is to train the model on more images. The training of deep learning models usually necessitates a large amount of data. In general, the more data there is, the better the model will perform. The issue with a paucity of data is that our deep learning model may not be able to learn the pattern from the data, and so may result in poor performance on test data.

Instead of collecting more data, augmentation techniques can be applied to generate as much data as required. Some of the commonly used augmentation techniques are rotation, shear, flip, etc. While applying data augmentation techniques for the given problem statement, we have to modify the bounding box coordinates as well. For this purpose, we can make use of imgaug or chitra libraries which are readily available and apply few inbuilt functions on images for data augmentation.

One of the augmenter which is available in the library is Affine. Affine transformations involve Translation ("move" image on the x-/y-axis),Rotation, Scaling ("zoom" in/out), Shear (move one side of the image, turning a square into a trapezoid). This Augmenter will affect bounding boxes and hence we need to use BoundingBoxesOnImage function on the bounding box coordinates.

Horizontal flips, Resize and change brightness can also be applied on the images and these function can be wrapped in function which can then be applied which using batch generator for the images.

Transfer learning

Unfreezing a portion of a model and retraining it with a very low learning rate on the new data would give significant improvement in model accuracy. Since the dataset which is provided to us has 8144 images and data similarity is quite low, freezing initial layers of the pretrained model and re-train just the remaining layers will help in accuracy improvement.

Here it is recommended to keep the learning rate very low since the layers are unfreezed and model weights are trainable. Because the training will be done on a larger model it's also crucial to utilise a very modest learning rate at this stage. There are substantial weight changes happening here and there is always a danger of overfitting. So incremental readjustment of the pre-trained weights are crucial.

Last layer Classification and regression

If the model is overfitting for given data, dropout layer can be introduced between last dense layers which will help in reduction of overfitting. Dropout is a training strategy in which randomly selected neurons are rejected.They are “dropped-out” randomly. This means that on the forward pass, their contribution to the activation of downstream neurons is removed temporally, and on the backward pass, any weight updates are not applied to the neuron.

Using Batch normalization helps in reduction of general errors. Batch normalisation is a technique for standardising network inputs that can be applied to either the activations of a previous layer or the inputs themselves. Batch normalisation reduces generalisation error by speeding up training (in some situations by halving or bettering the epochs) and providing some regularization.

CLASSIFICATION REPORTS

MobileNet

Classification report

Below mentioned table classification report for MobileNet model. Overall Accuracy is low for this model. The problem observed for MobileNet is that the network is a small network and not suitable for this use case, the number of weights which are to be learnt is very less leading to misclassification and bounding boxes which are overlaid by model on the image are misaligned. The number of samples used for producing reports is 8041

Model	precision	recall	f1-score	support
Acura Integra Type R 2001	0.19	0.09	0.12	44
Acura RL Sedan 2012	0	0	0	44
Acura TL Sedan 2012	0	0	0	32
Acura TL Type-S 2008	0	0	0	43

Acura TSX Sedan 2012	0	0	0	42
Acura ZDX Hatchback 2012	0	0	0	40
AM General Hummer SUV 2000	0	0	0	39
Aston Martin V8 Vantage Convertible 2012	0	0	0	45
Aston Martin V8 Vantage Coupe 2012	0	0	0	41
Aston Martin Virage Convertible 2012	0	0	0	33
Audi 100 Sedan 1994	0	0	0	38
Audi 100 Wagon 1994	0	0	0	40
Aston Martin Virage Coupe 2012	0	0	0	42
Audi A5 Coupe 2012	0	0	0	41
Audi S4 Sedan 2007	0.09	0.02	0.04	43
Audi RS 4 Convertible 2008	0	0	0	36
Audi R8 Coupe 2012	0	0	0	45
Audi S5 Convertible 2012	0	0	0	39
Audi S4 Sedan 2012	0	0	0	42
Audi S5 Coupe 2012	0	0	0	42
Audi TT Hatchback 2011	0	0	0	46
Audi TT RS Coupe 2012	0	0	0	40
Audi TTS Coupe 2012	0	0	0	39

Bentley Continental Flying Spur Sedan 2007	0	0	0	42
Audi V8 Sedan 1994	0	0	0	43

Bentley Arnage Sedan 2009	0	0	0	35
Audi S6 Sedan 2011	0	0	0	41
Bentley Continental GT Coupe 2007	0	0	0	42
Bentley Continental Supersports Conv. Convertible 2012	0.02	0.05	0.03	41
Bentley Continental GT Coupe 2012	0	0	0	44
BMW 1 Series Convertible 2012	0	0	0	34
BMW 1 Series Coupe 2012	0	0	0	44
Bentley Mulsanne Sedan 2011	0	0	0	41
BMW 3 Series Sedan 2012	0	0	0	41
BMW 3 Series Wagon 2012	0	0	0	38
BMW 6 Series Convertible 2007	0	0	0	41
BMW M3 Coupe 2012	0	0	0	42
BMW M5 Sedan 2010	0	0	0	40
BMW M6 Convertible 2010	0	0	0	39
BMW ActiveHybrid 5 Sedan 2012	0.02	0.05	0.02	44
BMW X5 SUV 2007	0	0	0	46
BMW X3 SUV 2012	0	0	0	34
BMW X6 SUV 2012	0	0	0	36
Bugatti Veyron 16.4 Coupe 2009	0	0	0	35
Bugatti Veyron 16.4 Convertible 2009	0	0	0	32
BMW Z4 Convertible 2012	0.11	0.02	0.04	43
Buick Enclave SUV 2012	0	0	0	42
Buick Regal GS 2012	0	0	0	42
Buick Rainier SUV 2007	0.5	0.03	0.05	35

Cadillac Escalade EXT Crew Cab 2007	0.04	0.08	0.05	37
Buick Verano Sedan 2012	0	0	0	43
Cadillac CTS-V Sedan 2012	0	0	0	44
Cadillac SRX SUV 2012	0	0	0	41
Chevrolet Camaro Convertible 2012	0	0	0	45
Chevrolet Cobalt SS 2010	0	0	0	44
Chevrolet Avalanche Crew Cab 2012	0	0	0	41
Chevrolet Corvette Ron Fellows Edition Z06 2007	0	0	0	39
Chevrolet Corvette ZR1 2012	0	0	0	37
Chevrolet Corvette Convertible 2012	0	0	0	46

Chevrolet Express Cargo Van 2007	0	0	0	29
Chevrolet HHR SS 2010	0	0	0	35
Chevrolet Express Van 2007	0	0	0	36
Chevrolet Malibu Hybrid Sedan 2010	0.02	0.02	0.02	43
Chevrolet Malibu Sedan 2007	0	0	0	38
Chevrolet Monte Carlo Coupe 2007	0	0	0	44
Chevrolet Impala Sedan 2007	0	0	0	45
Chevrolet Silverado 1500 Classic Extended Cab 2007	0	0	0	42

Chevrolet Silverado 1500 Hybrid Crew Cab 2012	0	0	0	43
Chevrolet Silverado 1500 Extended Cab 2012	0	0	0	40
Chevrolet Silverado 2500HD Regular Cab 2012	0	0	0	44
Chevrolet Silverado 1500 Regular Cab 2012	0	0	0	38
Chevrolet Sonic Sedan 2012	1	0.02	0.04	44
Chevrolet TrailBlazer SS 2009	0	0	0	37
Chevrolet Tahoe Hybrid SUV 2012	0	0	0	40
Chevrolet Traverse SUV 2012	0	0	0	44
Chrysler PT Cruiser Convertible 2008	0.12	0.02	0.04	48
Chrysler Aspen SUV 2009	0	0	0	43
Chrysler Crossfire Convertible 2008	0	0	0	43
Chrysler 300 SRT-8 2010	0	0	0	45
Daewoo Nubira Wagon 2002	0	0	0	40
Chrysler Sebring Convertible 2010	0	0	0	37
Chrysler Town and Country Minivan 2012	0	0	0	45
Dodge Caliber Wagon 2007	0	0	0	42
Dodge Caravan Minivan 1997	0	0	0	40
Dodge Caliber Wagon 2012	0	0	0	43
Dodge Challenger SRT8 2011	0	0	0	39
Dodge Charger SRT-8 2009	0	0	0	42

Dodge Charger Sedan 2012	0	0	0	41
Dodge Durango SUV 2007	0	0	0	38
Dodge Durango SUV 2012	0	0	0	41
Dodge Dakota Crew Cab 2010	0	0	0	45
Dodge Dakota Club Cab 2007	0.2	0.02	0.04	43
Dodge Journey SUV 2012	0	0	0	44
Dodge Ram Pickup 3500 Crew Cab 2010	0	0	0	40

Dodge Magnum Wagon 2008	0	0	0	42
Dodge Sprinter Cargo Van 2009	0	0	0	44
Dodge Ram Pickup 3500 Quad Cab 2009	0	0	0	39
Eagle Talon Hatchback 1998	0	0	0	46
Ferrari 458 Italia Convertible 2012	0	0	0	27
Ford F-150 Regular Cab 2007	0	0	0	33
Ferrari 458 Italia Coupe 2012	0	0	0	39
Ford Edge SUV 2012	0	0	0	42
Ferrari California Convertible 2012	0	0	0	39
FIAT 500 Convertible 2012	0	0	0	42
Ford E-Series Wagon Van 2012	0	0	0	43
FIAT 500 Abarth 2012	0	0	0	37
Ferrari FF Coupe 2012	0	0	0	43
Fisker Karma Sedan 2012	0	0	0	44
Ford Expedition EL SUV 2009	0	0	0	45
Ford Focus Sedan 2007	0	0	0	42

Ford F-450 Super Duty Crew Cab 2012	0	0	0	41
Ford Ranger SuperCab 2011	0	0	0	42
Ford F-150 Regular Cab 2012	0	0	0	45
Ford Freestar Minivan 2007	0	0	0	44
Geo Metro Convertible 1993	0.07	0.27	0.11	45
GMC Acadia SUV 2012	0	0	0	44
Ford Fiesta Sedan 2012	0	0	0	42
Ford Mustang Convertible 2007	0	0	0	44
Ford GT Coupe 2006	0	0	0	40
GMC Terrain SUV 2012	0	0	0	68
GMC Savana Van 2012	0	0	0	41
GMC Canyon Extended Cab 2012	0	0	0	42
Honda Odyssey Minivan 2007	0	0	0	44
GMC Yukon Hybrid SUV 2012	0	0	0	43
Honda Odyssey Minivan 2012	0	0	0	39
Honda Accord Sedan 2012	0	0	0	39
HUMMER H2 SUT Crew Cab 2009	0	0	0	38
HUMMER H3T Crew Cab 2010	0	0	0	41
Honda Accord Coupe 2012	0	0	0	42
Hyundai Elantra Touring Hatchback 2012	0	0	0	24
Hyundai Santa Fe SUV 2012	0	0	0	42
Hyundai Tucson SUV 2012	0	0	0	42
Hyundai Sonata Hybrid Sedan 2012	0.1	0.02	0.04	42

Hyundai Veloster Hatchback 2012	0	0	0	43
Hyundai Azera Sedan 2012	0	0	0	42
Hyundai Genesis Sedan 2012	0	0	0	33
Hyundai Elantra Sedan 2007	0	0	0	39
Hyundai Sonata Sedan 2012	0	0	0	43
Hyundai Accent Sedan 2012	0.17	0.02	0.04	41
Infiniti QX56 SUV 2011	0.01	0.33	0.01	42
Jeep Wrangler SUV 2012	0	0	0	34
Jeep Patriot SUV 2012	0	0	0	32
Infiniti G Coupe IPL 2012	0	0	0	40
Jeep Compass SUV 2012	0	0	0	46
Jeep Grand Cherokee SUV 2012	0	0	0	42
Jaguar XK XKR 2012	0	0	0	45
Hyundai Veracruz SUV 2012	0	0	0	44
Jeep Liberty SUV 2012	0	0	0	44
Isuzu Ascender SUV 2008	0	0	0	43
Lincoln Town Car Sedan 2011	0.01	0.09	0.02	43
Land Rover Range Rover SUV 2012	0	0	0	44
Lamborghini Reventon Coupe 2008	0.01	0.14	0.01	35
Land Rover LR2 SUV 2012	0	0	0	36
Lamborghini Gallardo LP 570-4 Superleggera 2012	0	0	0	42
Mazda Tribute SUV 2011	0	0	0	42
Lamborghini Diablo Coupe 2001	0	0	0	39
Lamborghini Aventador Coupe 2012	0	0	0	36

Maybach Landaulet Convertible 2012	0.01	0.59	0.01	29
McLaren MP4-12C Coupe 2012	0	0	0	36
Mercedes-Benz E-Class Sedan 2012	0.01	0.02	0.02	44
MINI Cooper Roadster Convertible 2012	0	0	0	48
Nissan Juke Hatchback 2012	0	0	0	45
Mercedes-Benz S-Class Sedan 2012	0	0	0	43
Nissan 240SX Coupe 1998	0	0	0	44
Mitsubishi Lancer Sedan 2012	0	0	0	36
Mercedes-Benz Sprinter Van 2012	0	0	0	41
Mercedes-Benz C-Class Sedan 2012	0	0	0	47
Mercedes-Benz 300-Class Convertible 1993	0	0	0	46

Mercedes-Benz SL-Class Coupe 2009	0	0	0	44
Rolls-Royce Ghost Sedan 2012	0	0	0	42
Nissan Leaf Hatchback 2012	0	0	0	38
Nissan NV Passenger Van 2012	0	0	0	44
Rolls-Royce Phantom Sedan 2012	0	0	0	43
Rolls-Royce Phantom Drophead Coupe Convertible 2012	0	0	0	41
Porsche Panamera Sedan 2012	0.03	0.16	0.06	38
Scion xD Hatchback 2012	0	0	0	30
Ram C-V Cargo Van Minivan 2012	0	0	0	44
Plymouth Neon Coupe 1999	0	0	0	41

smart fortwo Convertible 2012	0	0	0	45
Toyota Camry Sedan 2012	0	0	0	42
Toyota Corolla Sedan 2012	0	0	0	38
Tesla Model S Sedan 2012	0	0	0	46
Spyker C8 Convertible 2009	0.05	0.12	0.07	42
Spyker C8 Coupe 2009	0.01	0.05	0.01	40
Suzuki SX4 Sedan 2012	0	0	0	38
Suzuki Kizashi Sedan 2012	0	0	0	40
Toyota 4Runner SUV 2012	0	0	0	43
Suzuki SX4 Hatchback 2012	0	0	0	43
Suzuki Aerio Sedan 2007	0	0	0	38
Volvo XC90 SUV 2007	0	0	0	42
Volvo C30 Hatchback 2012	0	0	0	46
Volkswagen Beetle Hatchback 2012	0	0	0	43
Volvo 240 Sedan 1993	0	0	0	45
Volkswagen Golf Hatchback 2012	0	0	0	41
Volkswagen Golf Hatchback 1991	0	0	0	43
Toyota Sequoia SUV 2012	0	0	0	40
accuracy			0.01	8041
macro avg	0.01	0.01	0	8041
weighted avg	0.01	0.01	0	8041

Table 5.1: Classification report for MobileNet

Sample outputs of MobileNet are mentioned below, the results are not satisfactory.

ResNet50

Below mentioned table classification report is for Resnet50 model. Overall Accuracy is low for this model. The problem observed for ResNet50 is that the network doesn't learn well. ResNet follows the conventional approach of scaling the dimensions arbitrarily and by adding up more and more layers. As observed, ResNet is not suitable for this use case. There are misclassifications observed and bounding boxes which are overlaid by model on the image are misaligned. The number of samples used for producing reports is 8041

Classification report

	precision	recall	f1-score	support
Acura Integra Type R 2001	0	0	0	44
Acura RL Sedan 2012	0	0	0	44
Acura TL Sedan 2012	0	0	0	32
Acura TL Type-S 2008	0	0	0	43

Acura TSX Sedan 2012	0.03	0.02	0.03	42
Acura ZDX Hatchback 2012	0	0	0	40
AM General Hummer SUV 2000	0	0	0	39
Aston Martin V8 Vantage Convertible 2012	0	0	0	45
Aston Martin V8 Vantage Coupe 2012	0	0	0	41
Aston Martin Virage Convertible 2012	0	0	0	33
Audi 100 Sedan 1994	0	0	0	38
Audi 100 Wagon 1994	0	0	0	40
Aston Martin Virage Coupe 2012	0.01	0.05	0.02	42
Audi A5 Coupe 2012	0	0	0	41
Audi S4 Sedan 2007	0	0	0	43
Audi RS 4 Convertible 2008	0	0	0	36
Audi R8 Coupe 2012	0	0	0	45
Audi S5 Convertible 2012	0	0	0	39
Audi S4 Sedan 2012	0	0	0	42
Audi S5 Coupe 2012	0	0	0	42
Audi TT Hatchback 2011	0	0	0	46
Audi TT RS Coupe 2012	0	0	0	40
Audi TTS Coupe 2012	0	0	0	39
Bentley Continental Flying Spur Sedan 2007	0	0	0	42

Audi V8 Sedan 1994	0.01	0.02	0.01	43
Bentley Arnage Sedan 2009	0	0	0	35
Audi S6 Sedan 2011	0	0	0	41

Bentley Continental GT Coupe 2007	0	0	0	42
Bentley Continental Supersports Conv. Convertible 2012	0	0	0	41
Bentley Continental GT Coupe 2012	0	0	0	44
BMW 1 Series Convertible 2012	0	0	0	34
BMW 1 Series Coupe 2012	0	0	0	44
Bentley Mulsanne Sedan 2011	0	0	0	41
BMW 3 Series Sedan 2012	0	0	0	41
BMW 3 Series Wagon 2012	0	0	0	38
BMW 6 Series Convertible 2007	0	0	0	41
BMW M3 Coupe 2012	0	0	0	42
BMW M5 Sedan 2010	0	0	0	40
BMW M6 Convertible 2010	0	0	0	39
BMW ActiveHybrid 5 Sedan 2012	0	0	0	44
BMW X5 SUV 2007	0	0	0	46
BMW X3 SUV 2012	0	0	0	34
BMW X6 SUV 2012	0	0	0	36

Bugatti Veyron 16.4 Coupe 2009	**0**	**0**	**0**	**35**
Bugatti Veyron 16.4 Convertible 2009	**0**	**0**	**0**	**32**
BMW Z4 Convertible 2012	**0**	**0**	**0**	**43**
Buick Enclave SUV 2012	**0.02**	**0.02**	**0.02**	**42**
Buick Regal GS 2012	**0**	**0**	**0**	**42**
Buick Rainier SUV 2007	**0**	**0**	**0**	**35**
Cadillac Escalade EXT Crew Cab 2007	**0**	**0**	**0**	**37**
Buick Verano Sedan 2012	**0**	**0**	**0**	**43**
Cadillac CTS-V Sedan 2012	**0**	**0**	**0**	**44**
Cadillac SRX SUV 2012	**0**	**0**	**0**	**41**
Chevrolet Camaro Convertible 2012	**0.01**	**0.04**	**0.02**	**45**
Chevrolet Cobalt SS 2010	**0**	**0**	**0**	**44**
Chevrolet Avalanche Crew Cab 2012	**0**	**0**	**0**	**41**
Chevrolet Corvette Ron Fellows Edition Z06 2007	**0**	**0**	**0**	**39**
Chevrolet Corvette ZR1 2012	**0**	**0**	**0**	**37**
Chevrolet Corvette Convertible 2012	**0**	**0**	**0**	**46**
Chevrolet Express Cargo Van 2007	**0**	**0**	**0**	**29**
Chevrolet HHR SS 2010	**0**	**0**	**0**	**35**
Chevrolet Express Van 2007	**0**	**0**	**0**	**36**
Chevrolet Malibu Hybrid Sedan 2010	**0**	**0**	**0**	**43**

Chevrolet Malibu Sedan 2007	**0**	**0**	**0**	**38**
Chevrolet Monte Carlo Coupe 2007	**0.01**	**0.02**	**0.01**	**44**
Chevrolet Impala Sedan 2007	**0**	**0**	**0**	**45**
Chevrolet Silverado 1500 Classic Extended Cab 2007	**0**	**0**	**0**	**42**
Chevrolet Silverado 1500 Hybrid Crew Cab 2012	**0**	**0**	**0**	**43**
Chevrolet Silverado 1500 Extended Cab 2012	**0**	**0**	**0**	**40**
Chevrolet Silverado 2500HD Regular Cab 2012	**0**	**0**	**0**	**44**
Chevrolet Silverado 1500 Regular Cab 2012	**0**	**0**	**0**	**38**
Chevrolet Sonic Sedan 2012	**0**	**0**	**0**	**44**
Chevrolet TrailBlazer SS 2009	**0**	**0**	**0**	**37**
Chevrolet Tahoe Hybrid SUV 2012	**0**	**0**	**0**	**40**
Chevrolet Traverse SUV 2012	**0.01**	**0.05**	**0.02**	**44**
Chrysler PT Cruiser Convertible 2008	**0**	**0**	**0**	**48**
Chrysler Aspen SUV 2009	**0**	**0**	**0**	**43**

Chrysler Crossfire Convertible 2008	0	0	0	43
Chrysler 300 SRT-8 2010	0	0	0	45
Daewoo Nubira Wagon 2002	0	0	0	40
Chrysler Sebring Convertible 2010	0.02	0.03	0.02	37
Chrysler Town and Country Minivan 2012	0.01	0.02	0.01	45
Dodge Caliber Wagon 2007	0	0	0	42
Dodge Caravan Minivan 1997	0	0	0	40
Dodge Caliber Wagon 2012	0.01	0.02	0.02	43
Dodge Challenger SRT8 2011	0	0	0	39
Dodge Charger SRT-8 2009	0	0	0	42
Dodge Charger Sedan 2012	0	0	0	41
Dodge Durango SUV 2007	0	0	0	38
Dodge Durango SUV 2012	0.03	0.02	0.03	41
Dodge Dakota Crew Cab 2010	0	0	0	45
Dodge Dakota Club Cab 2007	0	0	0	43
Dodge Journey SUV 2012	0.02	0.18	0.03	44
Dodge Ram Pickup 3500 Crew Cab 2010	0	0	0	40
Dodge Magnum Wagon 2008	0.05	0.02	0.03	42

Dodge Sprinter Cargo Van 2009	0.04	0.02	0.03	44
Dodge Ram Pickup 3500 Quad Cab 2009	0	0	0	39
Eagle Talon Hatchback 1998	0	0	0	46
Ferrari 458 Italia Convertible 2012	0	0	0	27
Ford F-150 Regular Cab 2007	0	0	0	33
Ferrari 458 Italia Coupe 2012	0	0	0	39
Ford Edge SUV 2012	0	0	0	42
Ferrari California Convertible 2012	0	0	0	39
FIAT 500 Convertible 2012	0	0	0	42
Ford E-Series Wagon Van 2012	0	0	0	43
FIAT 500 Abarth 2012	0	0	0	37
Ferrari FF Coupe 2012	0	0	0	43
Fisker Karma Sedan 2012	0	0	0	44
Ford Expedition EL SUV 2009	0.14	0.07	0.09	45
Ford Focus Sedan 2007	0	0	0	42
Ford F-450 Super Duty Crew Cab 2012	0.02	0.02	0.02	41
Ford Ranger SuperCab 2011	0	0	0	42
Ford F-150 Regular Cab 2012	0	0	0	45
Ford Freestar Minivan 2007	0	0	0	44
Geo Metro Convertible 1993	0	0	0	45
GMC Acadia SUV 2012	0	0	0	44
Ford Fiesta Sedan 2012	0.02	0.1	0.04	42

Ford Mustang Convertible 2007	0.03	0.02	0.03	44
Ford GT Coupe 2006	0	0	0	40
GMC Terrain SUV 2012	0	0	0	68
GMC Savana Van 2012	0.01	0.1	0.02	41
GMC Canyon Extended Cab 2012	0.01	0.02	0.01	42
Honda Odyssey Minivan 2007	0.04	0.3	0.07	44
GMC Yukon Hybrid SUV 2012	0	0	0	43
Honda Odyssey Minivan 2012	0	0	0	39
Honda Accord Sedan 2012	0	0	0	39
HUMMER H2 SUT Crew Cab 2009	0	0	0	38
HUMMER H3T Crew Cab 2010	0	0	0	41
Honda Accord Coupe 2012	0	0	0	42
Hyundai Elantra Touring Hatchback 2012	0	0	0	24
Hyundai Santa Fe SUV 2012	0	0	0	42

Hyundai Tucson SUV 2012	0	0	0	42
Hyundai Sonata Hybrid Sedan 2012	0	0	0	42
Hyundai Veloster Hatchback 2012	0	0	0	43
Hyundai Azera Sedan 2012	0	0	0	42
Hyundai Genesis Sedan 2012	0	0	0	33
Hyundai Elantra Sedan 2007	0.01	0.03	0.02	39
Hyundai Sonata Sedan 2012	0	0	0	43

Hyundai Accent Sedan 2012	0	0	0	41
Infiniti QX56 SUV 2011	0.01	0.14	0.02	42
Jeep Wrangler SUV 2012	0	0	0	34
Jeep Patriot SUV 2012	0	0	0	32
Infiniti G Coupe IPL 2012	0.06	0.03	0.04	40
Jeep Compass SUV 2012	0	0	0	46
Jeep Grand Cherokee SUV 2012	0.01	0.02	0.01	42
Jaguar XK XKR 2012	0	0	0	45
Hyundai Veracruz SUV 2012	0.01	0.09	0.02	44
Jeep Liberty SUV 2012	0.01	0.05	0.02	44
Isuzu Ascender SUV 2008	0	0	0	43
Lincoln Town Car Sedan 2011	0	0	0	43
Land Rover Range Rover SUV 2012	0	0	0	44
Lamborghini Reventon Coupe 2008	0.44	0.11	0.18	35
Land Rover LR2 SUV 2012	0	0	0	36
Lamborghini Gallardo LP 570-4 Superleggera 2012	0	0	0	42
Mazda Tribute SUV 2011	0	0	0	42
Lamborghini Diablo Coupe 2001	0.01	0.03	0.01	39
Lamborghini Aventador Coupe 2012	0	0	0	36
Maybach Landaulet Convertible 2012	0	0	0	29
McLaren MP4-12C Coupe 2012	0	0	0	36
Mercedes-Benz E-Class Sedan 2012	0	0	0	44

MINI Cooper Roadster Convertible 2012	0	0	0	48
Nissan Juke Hatchback 2012	0	0	0	45
Mercedes-Benz S-Class Sedan 2012	0	0	0	43
Nissan 240SX Coupe 1998	0.02	0.02	0.02	44
Mitsubishi Lancer Sedan 2012	0	0	0	36
Mercedes-Benz Sprinter Van 2012	0.1	0.15	0.12	41
Mercedes-Benz C-Class Sedan 2012	0	0	0	47

Mercedes-Benz 300-Class Convertible 1993	0.01	0.02	0.02	46
Mercedes-Benz SL-Class Coupe 2009	0	0	0	44
Rolls-Royce Ghost Sedan 2012	0	0	0	42
Nissan Leaf Hatchback 2012	0	0	0	38
Nissan NV Passenger Van 2012	0	0	0	44
Rolls-Royce Phantom Sedan 2012	0	0	0	43
Rolls-Royce Phantom Drophead Coupe Convertible 2012	0	0	0	41
Porsche Panamera Sedan 2012	0.11	0.05	0.07	38
Scion xD Hatchback 2012	0	0	0	30
Ram C-V Cargo Van Minivan 2012	0.01	0.02	0.02	44

Plymouth Neon Coupe 1999	0	0	0	41
smart fortwo Convertible 2012	0	0	0	45
Toyota Camry Sedan 2012	0	0	0	42
Toyota Corolla Sedan 2012	0	0	0	38
Tesla Model S Sedan 2012	0	0	0	46
Spyker C8 Convertible 2009	0	0	0	42
Spyker C8 Coupe 2009	0	0	0	40
Suzuki SX4 Sedan 2012	0	0	0	38
Suzuki Kizashi Sedan 2012	0	0	0	40
Toyota 4Runner SUV 2012	0	0	0	43
Suzuki SX4 Hatchback 2012	0	0	0	43
Suzuki Aerio Sedan 2007	0.11	0.03	0.04	38
Volvo XC90 SUV 2007	0.04	0.02	0.03	42
Volvo C30 Hatchback 2012	0.01	0.02	0.01	46
Volkswagen Beetle Hatchback 2012	0	0	0	43
Volvo 240 Sedan 1993	0.01	0.22	0.02	45
Volkswagen Golf Hatchback 2012	0	0	0	41
Volkswagen Golf Hatchback 1991	0	0	0	43
Toyota Sequoia SUV 2012	0	0	0	40
accuracy			0.01	8041
macro avg	0.01	0.01	0.01	8041

weighted avg	**0.01**	**0.01**	**0.01**	**8041**

Table 5.2: Classification report for ResNet

EfficientNet-B5

Classification report

Below mentioned table classification report for EfficientNet-B5 model. Overall Accuracy is 74%, Precision is 75%, recall is 74% and f1-Score is 74%. As observed in the classification report, for a few classes the number is low and the same is observed in test samples where the model is showing misclassification. The number of samples used for producing reports is 8041. In

EfficientNet, the authors propose a new Scaling method called Compound Scaling.

Class	precision	recall	f1-score	support
Acura Integra Type R 2001	0.82	0.84	0.83	44
Acura RL Sedan 2012	0.87	0.75	0.8	44
Acura TL Sedan 2012	0.49	0.69	0.57	32
Acura TL Type-S 2008	0.7	0.77	0.73	43
Acura TSX Sedan 2012	0.9	0.67	0.77	42
Acura ZDX Hatchback 2012	0.82	0.57	0.68	40
AM General Hummer SUV 2000				

	0.67	0.72	0.69	39
Aston Martin V8 Vantage Convertible 2012	0.45	0.4	0.42	45
Aston Martin V8 Vantage Coupe 2012	0.54	0.46	0.5	41
Aston Martin Virage Convertible 2012	0.56	0.61	0.58	33
Audi 100 Sedan 1994	0.68	0.66	0.67	38
Audi 100 Wagon 1994	0.53	0.57	0.55	40
Aston Martin Virage Coupe 2012	0.6	0.62	0.61	42
Audi A5 Coupe 2012	0.52	0.8	0.63	41

Audi S4 Sedan 2007	0.72	0.79	0.76	43
Audi RS 4 Convertible 2008	0.81	0.83	0.82	36

Audi R8 Coupe 2012	0.71	0.49	0.58	45
Audi S5 Convertible 2012	0.75	0.54	0.63	39
Audi S4 Sedan 2012	0.74	0.67	0.7	42
Audi S5 Coupe 2012	0.41	0.31	0.35	42
Audi TT Hatchback 2011	0.51	0.72	0.59	46
Audi TT RS Coupe 2012	0.4	0.47	0.44	40
Audi TTS Coupe 2012				

	0.58	0.56	0.57	39
Bentley Continental Flying Spur Sedan 2007	0.51	0.43	0.47	42
Audi V8 Sedan 1994	0.56	0.58	0.57	43
Bentley Arnage Sedan 2009	0.8	0.8	0.8	35
Audi S6 Sedan 2011	0.64	0.88	0.74	41
Bentley Continental GT Coupe 2007	0.54	0.52	0.53	42
Bentley Continental Supersports Conv. Convertible 2012	0.52	0.56	0.54	41
Bentley Continental GT Coupe 2012	0.64	0.66	0.65	44
BMW 1 Series Convertible 2012	0.73	0.56	0.63	34

BMW 1 Series Coupe 2012	0.7	0.7	0.7	44
Bentley Mulsanne Sedan 2011	0.68	0.61	0.64	41
BMW 3 Series Sedan 2012	0.56	0.44	0.49	41
BMW 3 Series Wagon 2012	0.81	0.79	0.8	38
BMW 6 Series Convertible 2007	0.78	0.85	0.81	41
BMW M3 Coupe 2012	0.85	0.69	0.76	42
BMW M5 Sedan 2010	0.61	0.93	0.73	40
BMW M6 Convertible 2010	0.81	0.77	0.79	39
BMW ActiveHybrid 5 Sedan 2012	0.78	0.73	0.75	44

BMW X5 SUV 2007	0.46	0.52	0.49	46

BMW X3 SUV 2012	0.66	0.62	0.64	34
BMW X6 SUV 2012	0.67	0.86	0.76	36
Bugatti Veyron 16.4 Coupe 2009	0.56	0.83	0.67	35
Bugatti Veyron 16.4 Convertible 2009	0.64	0.72	0.68	32
BMW Z4 Convertible 2012	0.52	0.77	0.62	43
Buick Enclave SUV 2012	0.76	0.76	0.76	42
Buick Regal GS 2012	0.86	0.86	0.86	42
Buick Rainier SUV 2007	0.81	0.74	0.78	35

Cadillac Escalade EXT Crew Cab 2007	0.67	0.76	0.71	37
Buick Verano Sedan 2012	0.76	0.81	0.79	43
Cadillac CTS-V Sedan 2012	0.78	0.8	0.79	44
Cadillac SRX SUV 2012	0.89	0.98	0.93	41
Chevrolet Camaro Convertible 2012	0.63	0.69	0.66	45
Chevrolet Cobalt SS 2010	0.76	0.66	0.71	44
Chevrolet Avalanche Crew Cab 2012	0.87	0.66	0.75	41
Chevrolet Corvette Ron Fellows Edition Z06 2007				

	0.6	0.72	0.65	39
Chevrolet Corvette ZR1 2012	0.82	0.84	0.83	37
Chevrolet Corvette Convertible 2012	0.74	0.54	0.62	46
Chevrolet Express Cargo Van 2007	0.41	0.24	0.3	29
Chevrolet HHR SS 2010	0.53	0.6	0.56	35
Chevrolet Express Van 2007	0.82	0.92	0.87	36
Chevrolet Malibu Hybrid Sedan 2010	0.87	0.6	0.71	43
Chevrolet Malibu Sedan 2007	0.75	0.79	0.77	38
Chevrolet Monte Carlo Coupe 2007	0.7	0.68	0.69	44
Chevrolet Impala Sedan 2007	0.67	0.69	0.68	45

Chevrolet Silverado 1500 Classic Extended Cab 2007	**0.82**	**0.86**	**0.84**	**42**
Chevrolet Silverado 1500 Hybrid Crew Cab 2012	**0.37**	**0.79**	**0.5**	**43**
Chevrolet Silverado 1500 Extended Cab 2012	**0.71**	**0.38**	**0.49**	**40**
Chevrolet Silverado 2500HD Regular Cab 2012	**0.69**	**0.41**	**0.51**	**44**
Chevrolet Silverado 1500 Regular Cab 2012	**0.63**	**0.58**	**0.6**	**38**

Chevrolet Sonic Sedan 2012	0.87	0.77	0.82	44
Chevrolet TrailBlazer SS 2009	0.7	0.62	0.66	37
Chevrolet Tahoe Hybrid SUV 2012	0.72	0.85	0.78	40
Chevrolet Traverse SUV 2012	0.93	0.59	0.72	44
Chrysler PT Cruiser Convertible 2008	0.81	0.6	0.69	48
Chrysler Aspen SUV 2009	0.88	0.86	0.87	43
Chrysler Crossfire Convertible 2008	0.8	0.91	0.85	43
Chrysler 300 SRT-8 2010	0.91	0.87	0.89	45

Daewoo Nubira Wagon 2002	0.91	0.75	0.82	40
Chrysler Sebring Convertible 2010	0.8	0.86	0.83	37
Chrysler Town and Country Minivan 2012	0.88	0.82	0.85	45
Dodge Caliber Wagon 2007	0.68	0.64	0.66	42
Dodge Caravan Minivan 1997	0.54	0.7	0.61	40
Dodge Caliber Wagon 2012	0.85	0.91	0.88	43
Dodge Challenger SRT8 2011	0.97	0.82	0.89	39
Dodge Charger SRT-8 2009	0.74	0.62	0.68	42
Dodge Charger Sedan 2012	0.84	0.78	0.81	41

Dodge Durango SUV 2007	**0.58**	**0.79**	**0.67**	**38**
Dodge Durango SUV 2012	**0.76**	**0.76**	**0.76**	**41**
Dodge Dakota Crew Cab 2010	**0.84**	**0.8**	**0.82**	**45**
Dodge Dakota Club Cab 2007	**0.86**	**0.86**	**0.86**	**43**
Dodge Journey SUV 2012	**0.97**	**0.8**	**0.88**	**44**
Dodge Ram Pickup 3500 Crew Cab 2010	**0.79**	**0.65**	**0.71**	**40**
Dodge Magnum Wagon 2008	**0.95**	**0.83**	**0.89**	**42**
Dodge Sprinter Cargo Van 2009	**0.87**	**0.61**	**0.72**	**44**

Dodge Ram Pickup 3500 Quad Cab 2009	0.65	0.82	0.73	39
Eagle Talon Hatchback 1998	0.85	0.74	0.79	46
Ferrari 458 Italia Convertible 2012	0.86	0.93	0.89	27
Ford F-150 Regular Cab 2007	0.79	0.94	0.86	33
Ferrari 458 Italia Coupe 2012	0.66	0.79	0.72	39
Ford Edge SUV 2012	0.71	0.57	0.63	42
Ferrari California Convertible 2012	0.87	0.69	0.77	39
FIAT 500 Convertible 2012	0.69	0.74	0.71	42
Ford E-Series Wagon Van 2012	0.84	0.74	0.79	43

FIAT 500 Abarth 2012	0.97	0.92	0.94	37
Ferrari FF Coupe 2012	0.86	0.84	0.85	43
Fisker Karma Sedan 2012	0.95	0.86	0.9	44
Ford Expedition EL SUV 2009	0.81	0.67	0.73	45
Ford Focus Sedan 2007	0.86	0.9	0.88	42
Ford F-450 Super Duty Crew Cab 2012	0.85	0.95	0.9	41
Ford Ranger SuperCab 2011	0.97	0.86	0.91	42
Ford F-150 Regular Cab 2012	0.73	0.78	0.75	45

Ford Freestar Minivan 2007	0.83	0.91	0.87	44
Geo Metro Convertible 1993	0.78	0.71	0.74	45
GMC Acadia SUV 2012	0.78	0.66	0.72	44
Ford Fiesta Sedan 2012	0.8	0.79	0.8	42
Ford Mustang Convertible 2007	0.93	0.84	0.88	44
Ford GT Coupe 2006	0.64	0.8	0.71	40
GMC Terrain SUV 2012	0.75	0.82	0.78	68
GMC Savana Van 2012	0.77	0.88	0.82	41
GMC Canyon Extended Cab 2012	0.88	0.67	0.76	42

Honda Odyssey Minivan 2007	0.87	0.89	0.88	44
GMC Yukon Hybrid SUV 2012	0.72	0.77	0.74	43
Honda Odyssey Minivan 2012	0.68	0.64	0.66	39
Honda Accord Sedan 2012	0.4	0.69	0.51	39
HUMMER H2 SUT Crew Cab 2009	0.66	0.61	0.63	38
HUMMER H3T Crew Cab 2010	0.9	0.85	0.88	41
Honda Accord Coupe 2012	0.82	0.86	0.84	42
Hyundai Elantra Touring Hatchback 2012	0.81	0.71	0.76	24
Hyundai Santa Fe SUV 2012	0.72	0.67	0.69	42

Hyundai Tucson SUV 2012	0.76	0.74	0.75	42
Hyundai Sonata Hybrid Sedan 2012	0.69	0.79	0.73	42
Hyundai Veloster Hatchback 2012	0.79	0.86	0.82	43
Hyundai Azera Sedan 2012	0.86	0.88	0.87	42
Hyundai Genesis Sedan 2012	0.84	0.82	0.83	33
Hyundai Elantra Sedan 2007	0.58	0.87	0.69	39
Hyundai Sonata Sedan 2012	0.9	0.88	0.89	43

Hyundai Accent Sedan 2012	0.62	0.85	0.72	41

Infiniti QX56 SUV 2011	**0.75**	**0.43**	**0.55**	**42**
Jeep Wrangler SUV 2012	**0.9**	**0.56**	**0.69**	**34**
Jeep Patriot SUV 2012	**1**	**0.88**	**0.93**	**32**
Infiniti G Coupe IPL 2012	**0.82**	**0.93**	**0.87**	**40**
Jeep Compass SUV 2012	**0.76**	**0.7**	**0.73**	**46**
Jeep Grand Cherokee SUV 2012	**0.93**	**0.64**	**0.76**	**42**
Jaguar XK XKR 2012	**0.57**	**0.82**	**0.67**	**45**
Hyundai Veracruz SUV 2012	**0.94**	**0.7**	**0.81**	**44**
Jeep Liberty SUV 2012	**0.8**	**0.82**	**0.81**	**44**

Isuzu Ascender SUV 2008	0.95	0.88	0.92	43
Lincoln Town Car Sedan 2011	0.7	0.7	0.7	43
Land Rover Range Rover SUV 2012	0.79	0.84	0.81	44
Lamborghini Reventon Coupe 2008	0.9	0.74	0.81	35
Land Rover LR2 SUV 2012	0.76	0.81	0.78	36
Lamborghini Gallardo LP 570-4 Superleggera 2012	0.79	0.74	0.77	42
Mazda Tribute SUV 2011	0.84	0.9	0.87	42
Lamborghini Diablo Coupe 2001	0.89	0.85	0.87	39
Lamborghini Aventador Coupe 2012				

	0.94	0.92	0.93	36
Maybach Landaulet Convertible 2012	0.87	0.69	0.77	29
McLaren MP4-12C Coupe 2012	0.83	0.94	0.88	36
Mercedes-Benz E-Class Sedan 2012	0.78	0.91	0.84	44
MINI Cooper Roadster Convertible 2012	0.8	0.85	0.83	48
Nissan Juke Hatchback 2012	0.76	0.87	0.81	45
Mercedes-Benz S-Class Sedan 2012	0.49	0.42	0.45	43

Nissan 240SX Coupe 1998	0.66	0.84	0.74	44
Mitsubishi Lancer Sedan 2012	0.54	0.81	0.64	36
Mercedes-Benz Sprinter Van 2012	0.83	0.73	0.78	41
Mercedes-Benz C-Class Sedan 2012	0.86	0.38	0.53	47
Mercedes-Benz 300-Class Convertible 1993	0.86	0.8	0.83	46
Mercedes-Benz SL-Class Coupe 2009	0.94	0.66	0.77	44
Rolls-Royce Ghost Sedan 2012	0.85	0.95	0.9	42

Nissan Leaf Hatchback 2012	0.91	0.84	0.88	38
Nissan NV Passenger Van 2012	0.93	0.86	0.89	44
Rolls-Royce Phantom Sedan 2012	0.56	0.53	0.55	43
Rolls-Royce Phantom Drophead Coupe Convertible 2012	0.71	0.71	0.71	41
Porsche Panamera Sedan 2012	0.88	0.55	0.68	38
Scion xD Hatchback 2012	0.64	0.7	0.67	30
Ram C-V Cargo Van Minivan 2012	0.77	0.68	0.72	44

Plymouth Neon Coupe 1999	0.7	0.68	0.69	41
smart fortwo Convertible 2012	0.8	0.87	0.83	45
Toyota Camry Sedan 2012	0.8	0.67	0.73	42
Toyota Corolla Sedan 2012	0.68	0.66	0.67	38
Tesla Model S Sedan 2012	0.74	0.67	0.7	46
Spyker C8 Convertible 2009	0.67	0.81	0.73	42
Spyker C8 Coupe 2009	0.55	0.53	0.54	40

Suzuki SX4 Sedan 2012	0.71	0.76	0.73	38
Suzuki Kizashi Sedan 2012				

	0.88	0.9	0.89	40
Toyota 4Runner SUV 2012	0.85	0.81	0.83	43
Suzuki SX4 Hatchback 2012	0.78	0.67	0.72	43
Suzuki Aerio Sedan 2007	0.73	0.84	0.78	38
Volvo XC90 SUV 2007	0.89	0.95	0.92	42
Volvo C30 Hatchback 2012	0.7	0.85	0.76	46
Volkswagen Beetle Hatchback 2012	0.66	0.88	0.75	43
Volvo 240 Sedan 1993	0.88	0.8	0.84	45
Volkswagen Golf Hatchback 2012	0.78	0.85	0.81	41
Volkswagen Golf Hatchback 1991	0.89	0.72	0.79	43

Toyota Sequoia SUV 2012	0.95	0.95	0.95	40

accuracy			0.74	8041
macro avg	0.75	0.74	0.74	8041
weighted avg	0.75	0.74	0.74	8041

Table 5.3: Classification report for EfficientNet-B5

Efficient Net B7

Below mentioned table classification report for EfficientNet-B5 model. Overall Accuracy is 79%, Precision is 78%, recall is 78% and f1-Score is 78%. As observed in the classification report, for a few classes the number is low and the same is observed in test samples where the model is showing misclassification. The number of samples used for producing reports is 8041. In EfficientNet, the authors propose a new Scaling method called Compound Scaling.

Classification report

	precision	recall	f1-score	support
Acura Integra Type R 2001	0.89	0.95	0.92	44
Acura RL Sedan 2012	0.92	0.8	0.85	44
Acura TL Sedan 2012	0.59	0.62	0.61	32
Acura TL Type-S 2008	0.81	0.88	0.84	43
Acura TSX Sedan 2012	0.78	0.83	0.8	42
Acura ZDX Hatchback 2012	0.88	0.7	0.78	40
AM General Hummer SUV 2000	0.68	0.72	0.7	39

Aston Martin V8 Vantage Convertible 2012	0.63	0.6	0.61	45
Aston Martin V8 Vantage Coupe 2012	0.63	0.54	0.58	41
Aston Martin Virage Convertible 2012	0.68	0.64	0.66	33
Audi 100 Sedan 1994	0.74	0.82	0.78	38
Audi 100 Wagon 1994	0.68	0.57	0.62	40
Aston Martin Virage Coupe 2012	0.64	0.83	0.72	42
Audi A5 Coupe 2012	0.57	0.88	0.69	41
Audi S4 Sedan 2007	0.68	0.91	0.78	43
Audi RS 4 Convertible 2008	0.79	0.92	0.85	36
Audi R8 Coupe 2012	0.87	0.73	0.8	45
Audi S5 Convertible 2012	0.66	0.59	0.62	39
Audi S4 Sedan 2012	0.77	0.55	0.64	42
Audi S5 Coupe 2012	0.49	0.43	0.46	42
Audi TT Hatchback 2011	0.84	0.8	0.82	46
Audi TT RS Coupe 2012	0.42	0.62	0.51	40
Audi TTS Coupe 2012	0.7	0.59	0.64	39
Bentley Continental Flying Spur Sedan 2007				

	0.53	0.45	0.49	42
Audi V8 Sedan 1994	0.68	0.63	0.65	43
Bentley Arnage Sedan 2009	0.77	0.69	0.73	35
Audi S6 Sedan 2011	0.71	0.83	0.76	41
Bentley Continental GT Coupe 2007	0.69	0.79	0.73	42
Bentley Continental Supersports Conv. Convertible 2012	0.82	0.8	0.81	41
Bentley Continental GT Coupe 2012	0.72	0.64	0.67	44

BMW 1 Series Convertible 2012	0.85	0.68	0.75	34
BMW 1 Series Coupe 2012	0.73	0.82	0.77	44
Bentley Mulsanne Sedan 2011	0.8	0.68	0.74	41
BMW 3 Series Sedan 2012	0.61	0.49	0.54	41
BMW 3 Series Wagon 2012	0.69	0.89	0.78	38
BMW 6 Series Convertible 2007	0.86	0.78	0.82	41
BMW M3 Coupe 2012	0.71	0.76	0.74	42
BMW M5 Sedan 2010	0.74	0.88	0.8	40

BMW M6 Convertible 2010	0.76	0.87	0.81	39
BMW ActiveHybrid 5 Sedan 2012	0.71	0.82	0.76	44
BMW X5 SUV 2007	0.58	0.72	0.64	46
BMW X3 SUV 2012	0.78	0.53	0.63	34
BMW X6 SUV 2012	0.67	0.67	0.67	36
Bugatti Veyron 16.4 Coupe 2009	0.79	0.66	0.72	35
Bugatti Veyron 16.4 Convertible 2009	0.58	0.78	0.67	32
BMW Z4 Convertible 2012	0.8	0.74	0.77	43
Buick Enclave SUV 2012	0.71	0.86	0.77	42
Buick Regal GS 2012	0.9	0.86	0.88	42
Buick Rainier SUV 2007	0.81	0.74	0.78	35
Cadillac Escalade EXT Crew Cab 2007	0.72	0.84	0.77	37
Buick Verano Sedan 2012	0.85	0.93	0.89	43
Cadillac CTS-V Sedan 2012	0.93	0.86	0.89	44
Cadillac SRX SUV 2012	0.93	0.95	0.94	41
Chevrolet Camaro Convertible 2012	0.74	0.78	0.76	45
Chevrolet Cobalt SS 2010	0.74	0.77	0.76	44

Chevrolet Avalanche Crew Cab 2012	0.94	0.76	0.84	41
Chevrolet Corvette Ron Fellows Edition Z06 2007	0.66	0.69	0.68	39
Chevrolet Corvette ZR1 2012	0.8	0.97	0.88	37
Chevrolet Corvette Convertible 2012	0.94	0.74	0.83	46
Chevrolet Express Cargo Van 2007	0.36	0.17	0.23	29
Chevrolet HHR SS 2010	0.4	0.66	0.5	35
Chevrolet Express Van 2007	0.85	0.97	0.91	36

Chevrolet Malibu Hybrid Sedan 2010	0.67	0.74	0.7	43
Chevrolet Malibu Sedan 2007	0.81	0.79	0.8	38
Chevrolet Monte Carlo Coupe 2007	0.78	0.8	0.79	44
Chevrolet Impala Sedan 2007	0.87	0.76	0.81	45

Chevrolet Silverado 1500 Classic Extended Cab 2007	0.79	0.81	0.8	42
Chevrolet Silverado 1500 Hybrid Crew Cab 2012	0.73	0.84	0.78	43
Chevrolet Silverado 1500 Extended Cab 2012	0.71	0.5	0.59	40
Chevrolet Silverado 2500HD Regular Cab 2012	0.66	0.7	0.68	44
Chevrolet Silverado 1500 Regular Cab 2012	0.56	0.66	0.6	38
Chevrolet Sonic Sedan 2012	0.88	0.64	0.74	44
Chevrolet TrailBlazer SS 2009	0.74	0.7	0.72	37
Chevrolet Tahoe Hybrid SUV 2012	0.83	0.85	0.84	40
Chevrolet Traverse SUV 2012	0.88	0.68	0.77	44
Chrysler PT Cruiser Convertible 2008	0.91	0.6	0.72	48
Chrysler Aspen SUV 2009	0.87	0.91	0.89	43

Chrysler Crossfire Convertible 2008	0.88	0.88	0.88	43
Chrysler 300 SRT-8 2010	0.82	0.93	0.87	45
Daewoo Nubira Wagon 2002	0.88	0.88	0.88	40
Chrysler Sebring Convertible 2010	0.86	0.84	0.85	37
Chrysler Town and Country Minivan 2012	1	0.8	0.89	45
Dodge Caliber Wagon 2007	0.67	0.88	0.76	42
Dodge Caravan Minivan 1997	0.76	0.62	0.68	40
Dodge Caliber Wagon 2012	0.76	0.95	0.85	43
Dodge Challenger SRT8 2011	0.94	0.87	0.91	39
Dodge Charger SRT-8 2009	0.74	0.69	0.72	42
Dodge Charger Sedan 2012	0.77	0.9	0.83	41
Dodge Durango SUV 2007	0.71	0.89	0.79	38
Dodge Durango SUV 2012	0.94	0.8	0.87	41
Dodge Dakota Crew Cab 2010	0.81	0.87	0.84	45
Dodge Dakota Club Cab 2007	0.95	0.86	0.9	43

Dodge Journey SUV 2012	0.95	0.89	0.92	44
Dodge Ram Pickup 3500 Crew Cab 2010				

	0.85	0.88	0.86	40
Dodge Magnum Wagon 2008	0.94	0.79	0.86	42
Dodge Sprinter Cargo Van 2009	0.7	0.68	0.69	44
Dodge Ram Pickup 3500 Quad Cab 2009	0.74	0.74	0.74	39
Eagle Talon Hatchback 1998	0.9	0.78	0.84	46
Ferrari 458 Italia Convertible 2012	1	0.96	0.98	27
Ford F-150 Regular Cab 2007	0.91	0.94	0.93	33
Ferrari 458 Italia Coupe 2012	0.71	0.74	0.72	39
Ford Edge SUV 2012	0.75	0.64	0.69	42
Ferrari California Convertible 2012	0.94	0.79	0.86	39
FIAT 500 Convertible 2012	0.87	0.79	0.82	42
Ford E-Series Wagon Van 2012	0.89	0.79	0.84	43
FIAT 500 Abarth 2012	0.94	0.92	0.93	37
Ferrari FF Coupe 2012	0.91	0.93	0.92	43
Fisker Karma Sedan 2012	0.83	0.89	0.86	44
Ford Expedition EL SUV 2009	0.84	0.8	0.82	45
Ford Focus Sedan 2007	0.95	0.93	0.94	42
Ford F-450 Super Duty Crew Cab 2012	0.86	0.9	0.88	41
Ford Ranger SuperCab 2011	0.78	0.83	0.8	42

Ford F-150 Regular Cab 2012	0.84	0.82	0.83	45
Ford Freestar Minivan 2007	0.84	0.98	0.91	44
Geo Metro Convertible 1993	0.86	0.71	0.78	45
GMC Acadia SUV 2012	0.77	0.61	0.68	44
Ford Fiesta Sedan 2012	0.81	0.81	0.81	42
Ford Mustang Convertible 2007	0.88	0.82	0.85	44
Ford GT Coupe 2006	0.76	0.65	0.7	40
GMC Terrain SUV 2012	0.7	0.76	0.73	68
GMC Savana Van 2012	0.88	0.93	0.9	41
GMC Canyon Extended Cab 2012	0.85	0.69	0.76	42
Honda Odyssey Minivan 2007	0.87	0.89	0.88	44
GMC Yukon Hybrid SUV 2012	0.94	0.74	0.83	43
Honda Odyssey Minivan 2012	0.84	0.92	0.88	39
Honda Accord Sedan 2012	0.72	0.74	0.73	39

HUMMER H2 SUT Crew Cab 2009	0.63	0.71	0.67	38
HUMMER H3T Crew Cab 2010	0.92	0.85	0.89	41
Honda Accord Coupe 2012	0.76	0.93	0.84	42
Hyundai Elantra Touring Hatchback 2012				

	0.44	0.83	0.58	24
Hyundai Santa Fe SUV 2012	0.91	0.71	0.8	42
Hyundai Tucson SUV 2012	0.77	0.81	0.79	42
Hyundai Sonata Hybrid Sedan 2012	0.79	0.81	0.8	42
Hyundai Veloster Hatchback 2012	0.74	0.98	0.84	43
Hyundai Azera Sedan 2012	0.97	0.79	0.87	42
Hyundai Genesis Sedan 2012	0.88	0.88	0.88	33
Hyundai Elantra Sedan 2007	0.82	0.95	0.88	39
Hyundai Sonata Sedan 2012	0.72	0.91	0.8	43
Hyundai Accent Sedan 2012	0.77	0.8	0.79	41
Infiniti QX56 SUV 2011	0.9	0.43	0.58	42
Jeep Wrangler SUV 2012	0.85	0.85	0.85	34
Jeep Patriot SUV 2012	0.94	0.91	0.92	32
Infiniti G Coupe IPL 2012	0.58	0.95	0.72	40
Jeep Compass SUV 2012	0.83	0.43	0.57	46
Jeep Grand Cherokee SUV 2012	0.81	0.83	0.82	42
Jaguar XK XKR 2012	0.83	0.87	0.85	45
Hyundai Veracruz SUV 2012	0.88	0.82	0.85	44
Jeep Liberty SUV 2012	0.82	0.82	0.82	44
Isuzu Ascender SUV 2008	1	0.93	0.96	43
Lincoln Town Car Sedan 2011	0.8	0.86	0.83	43

Land Rover Range Rover SUV 2012	0.98	0.91	0.94	44
Lamborghini Reventon Coupe 2008	1	0.8	0.89	35
Land Rover LR2 SUV 2012	0.87	0.94	0.91	36
Lamborghini Gallardo LP 570-4 Superleggera 2012	0.88	0.71	0.79	42
Mazda Tribute SUV 2011	0.85	0.98	0.91	42
Lamborghini Diablo Coupe 2001	0.94	0.87	0.91	39
Lamborghini Aventador Coupe 2012	0.89	0.94	0.92	36
Maybach Landaulet Convertible 2012	0.83	0.86	0.85	29
McLaren MP4-12C Coupe 2012	0.78	0.89	0.83	36
Mercedes-Benz E-Class Sedan 2012	0.77	0.91	0.83	44

MINI Cooper Roadster Convertible 2012	0.94	0.94	0.94	48
Nissan Juke Hatchback 2012	0.79	0.93	0.86	45
Mercedes-Benz S-Class Sedan 2012	0.64	0.37	0.47	43
Nissan 240SX Coupe 1998	0.68	0.91	0.78	44
Mitsubishi Lancer Sedan 2012	0.79	0.72	0.75	36
Mercedes-Benz Sprinter Van 2012	0.75	0.8	0.78	41
Mercedes-Benz C-Class Sedan 2012	0.94	0.64	0.76	47
Mercedes-Benz 300-Class Convertible 1993	0.87	0.89	0.88	46
Mercedes-Benz SL-Class Coupe 2009	0.94	0.66	0.77	44
Rolls-Royce Ghost Sedan 2012	0.95	0.93	0.94	42
Nissan Leaf Hatchback 2012	1	0.82	0.9	38
Nissan NV Passenger Van 2012	0.91	0.89	0.9	44
Rolls-Royce Phantom Sedan 2012	0.69	0.63	0.66	43

Rolls-Royce Phantom Drophead Coupe Convertible 2012	0.78	0.68	0.73	41
Porsche Panamera Sedan 2012	0.76	0.66	0.7	38
Scion xD Hatchback 2012	0.69	0.73	0.71	30
Ram C-V Cargo Van Minivan 2012	0.59	0.66	0.62	44
Plymouth Neon Coupe 1999	0.69	0.8	0.74	41
smart fortwo Convertible 2012	0.75	0.8	0.77	45
Toyota Camry Sedan 2012	0.61	0.64	0.63	42
Toyota Corolla Sedan 2012	0.9	0.68	0.78	38
Tesla Model S Sedan 2012	0.69	0.8	0.74	46
Spyker C8 Convertible 2009	0.78	0.76	0.77	42
Spyker C8 Coupe 2009	0.62	0.57	0.6	40
Suzuki SX4 Sedan 2012	0.69	0.89	0.78	38
Suzuki Kizashi Sedan 2012	0.86	0.93	0.89	40
Toyota 4Runner SUV 2012	0.7	0.88	0.78	43
Suzuki SX4 Hatchback 2012	0.8	0.74	0.77	43
Suzuki Aerio Sedan 2007	0.81	0.79	0.8	38
Volvo XC90 SUV 2007	0.85	0.93	0.89	42

Volvo C30 Hatchback 2012	0.92	0.98	0.95	46

Volkswagen Beetle Hatchback 2012	0.85	0.77	0.8	43
Volvo 240 Sedan 1993	0.91	0.89	0.9	45
Volkswagen Golf Hatchback 2012	1	0.8	0.89	41
Volkswagen Golf Hatchback 1991	0.91	0.74	0.82	43
Toyota Sequoia SUV 2012	0.93	0.97	0.95	40

Table 5.4: Classification report for EfficientNet-B7

Summary

This custom CNN architecture is designed to efficiently recognize and classify car images by extracting relevant features through convolutional layers and using fully connected layers to make the final classification. The use of

normalization, dropout, and adaptive optimization techniques ensures that the model can learn effectively and generalize well to new data.

Model Optimization and Tuning (Future)

In the future, we plan to further optimize and fine-tune our model to improve its performance. This could involve experimenting with different model architectures, adjusting hyperparameters, or using more advanced training techniques. We may also explore the use of additional data or different types of data to further enhance the model's ability to accurately identify car attributes. Ultimately, our goal is to continually refine and improve our model to ensure it remains at the cutting edge of automotive surveillance technology. Potential strategies for optimization and tuning include:

1. Experimenting with different model architectures: There are many different types of deep learning models, each with their own strengths and weaknesses. By experimenting with different architectures, we may be able to find a model that performs better on our specific task.

2. Adjusting hyperparameters: Hyperparameters are the settings of the model that we can adjust before training, such as the learning rate or the number of layers in the model. By fine-tuning these hyperparameters, we can often improve the model's performance.

3. Using more advanced training techniques: There are many techniques for training deep learning models that can help to improve performance, such as batch normalization, dropout, or different types of optimization algorithms. We plan to explore these techniques in the future.

4. Exploring additional data or different types of data: Our model may be able to learn more effectively if we can provide it with more data, or with different types of data. For example, we could consider using additional images, or we could look at other types of data such as the car's specifications or customer reviews.

By pursuing these strategies, we hope to continually improve our model's performance and make it an even more effective tool for automotive surveillance. We look forward to sharing our progress and findings in future reports.

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