AIML Capstone Project: CV - Car Detection

*Final Project Report*

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Summary and Problem Statement

Computer vision can be used to automate supervision and generate action appropriate action trigger if the event is predicted from the image of interest. For example a car moving on the road can be easily identified by a camera as make of the car, type, colour, number plates etc.

**DATA DESCRIPTION*:***

The dataset contains 16,185 images of 196 classes of cars. The data is split into 8,144 training images and 8,041 testing images, where each class has been split roughly in a 50-50 split.

Classes are typically at the level of Make, Model, Year, e.g. 2012 Tesla Model S or 2012 BMW M3 coupe.

* Train Images: Consists of real images of cars as per the make and year of the car
* Test Images: Consists of real images of cars as per the make and year of the car.
* Train Annotation: Consists of bounding box region for training images.
* Test Annotation: Consists of bounding box region for testing images.

**Dataset**: https://drive.google.com/drive/folders/1y6JWx2CpsOuka00uePe72jNgr7F9sK45?usp=sharing,

**PROJECT OBJECTIVE*:*** Design a DL based car identification model

EDA and Pre-processing

Step #1: **Importing the dataset in dataframes**

#Different car labels

car\_names = pd.read\_csv( 'Car names and make.csv', header=None, names = ['CarLabel'] )

#Train data

train\_data = pd.read\_csv( 'Annotations/Train Annotations.csv', skiprows=1, names = ['ImageName', 'X1', 'Y1', 'X2' , 'Y2', 'Class'] )

#Test data

test\_data = pd.read\_csv( 'Annotations/Test Annotation.csv' , skiprows=1, names = ['ImageName', 'X1', 'Y1', 'X2' , 'Y2', 'Class'])

**Display few records**

CarLabel

0 AM General Hummer SUV 2000

1 Acura RL Sedan 2012

2 Acura TL Sedan 2012

3 Acura TL Type-S 2008

4 Acura TSX Sedan 2012

ImageName X1 Y1 X2 Y2 Class

0 00001.jpg 39 116 569 375 14

1 00002.jpg 36 116 868 587 3

2 00003.jpg 85 109 601 381 91

3 00004.jpg 621 393 1484 1096 134

4 00005.jpg 14 36 133 99 106

ImageName X1 Y1 X2 Y2 Class

0 00001.jpg 30 52 246 147 181

1 00002.jpg 100 19 576 203 103

2 00003.jpg 51 105 968 659 145

3 00004.jpg 67 84 581 407 187

4 00005.jpg 140 151 593 339 185

**Problem faced**: While trying to read few images using cv2, we were getting return type as None. After troubleshooting, we found that this is due to folder name of images. Some of folder names have a '/' in it. Therefore, we decided to update such names as part of pre-processing step.

Step #2: **Find class name with '/' and update**

for i in range(len(car\_names)) :

  if '/' in car\_names.loc[i,"CarLabel"]:

    print(car\_names.loc[i,"CarLabel"])

    print(i)

Ram C/V Cargo Van Minivan 2012

173

**Thus, there was only 1 class with '/' in it's name.**

#Replace '/' with '-' in the name

car\_names.loc[173,'CarLabel'] = 'Ram C-V Cargo Van Minivan 2012'

### Step #3: Map training and test images to corresponding classes and annotations.

car\_names['Class'] = car\_names.index + 1

car\_train\_df = pd.merge(train\_data, car\_names, how = 'left', left\_on='Class', right\_on='Class' )

car\_train\_df.head()

car\_test\_df = pd.merge(test\_data, car\_names, how = 'left', left\_on='Class', right\_on='Class' )

car\_test\_df.head()

Display few records

| **ImageName** | **X1** | **Y1** | **X2** | **Y2** | **Class** | **CarLabel** |
| --- | --- | --- | --- | --- | --- | --- |
| **0** | 00001.jpg | 30 | 52 | 246 | 147 | 181 | Suzuki Aerio Sedan 2007 |
| **1** | 00002.jpg | 100 | 19 | 576 | 203 | 103 | Ferrari 458 Italia Convertible 2012 |
| **2** | 00003.jpg | 51 | 105 | 968 | 659 | 145 | Jeep Patriot SUV 2012 |
| **3** | 00004.jpg | 67 | 84 | 581 | 407 | 187 | Toyota Camry Sedan 2012 |
| **4** | 00005.jpg | 140 | 151 | 593 | 339 | 185 | Tesla Model S Sedan 2012 |

Step #4: **Exploratory Data Analysis**

* **For each car image label, separate year, make, model and body**

import nltk

nltk.download('punkt')

#Different body types

car\_body\_type = ["suv","sedan","type-s","type-r","convertible","coupe","wagon","hatchback","cab","supercab","van","minivan"]

car\_body\_type = [item.lower() for item in car\_body\_type]

#Different car make

car\_make = ['am', 'general', 'acura', 'aston', 'martin', 'audi', 'bmw', 'bentley', 'bugatti', 'buick', 'cadillac', 'chevrolet', 'chrysler', 'daewoo',

            'dodge', 'eagle', 'fiat', 'ferrari', 'fisker', 'ford', 'gmc', 'geo', 'honda', 'hyundai', 'infiniti', 'isuzu',

            'jaguar', 'jeep', 'lamborghini', 'land', 'rover', 'lincoln', 'mini', 'cooper', 'maybach', 'mazda', 'mclaren', 'mercedes-benz',

            'mitsubishi', 'nissan', 'plymouth', 'porsche', 'ram', 'rolls-royce', 'scion', 'spyker', 'suzuki', 'tesla', 'toyota', 'volkswagen', 'volvo', 'smart']

car\_make = [item.lower() for item in car\_make]

#Define dataframe to store results

eda\_df = car\_test\_df.copy()

eda\_df["year"] = None

eda\_df["make"] = None

eda\_df["model"] = None

eda\_df["body"] = None

pattern="[0-9][0-9][0-9][0-9]"

for col in eda\_df.columns:

    if col == 'CarLabel':

        for index, row in eda\_df.iterrows():

            wordsl = word\_tokenize(row[col].lower())

            print(index, wordsl)

            if len(wordsl)>1:

                year = re.findall(pattern,wordsl[len(wordsl)-1])#row[0])

                if year:

                    eda\_df.loc[index, 'year'] = year[0]

                body = list(set(wordsl).intersection(car\_body\_type))

                if body:

                    eda\_df.loc[index, 'body'] = body[0]

                make = list(set(wordsl).intersection(car\_make))

                if make:

                    eda\_df.loc[index, 'make'] = ' '.join(make)

                iden=year + body + make

                print(iden)

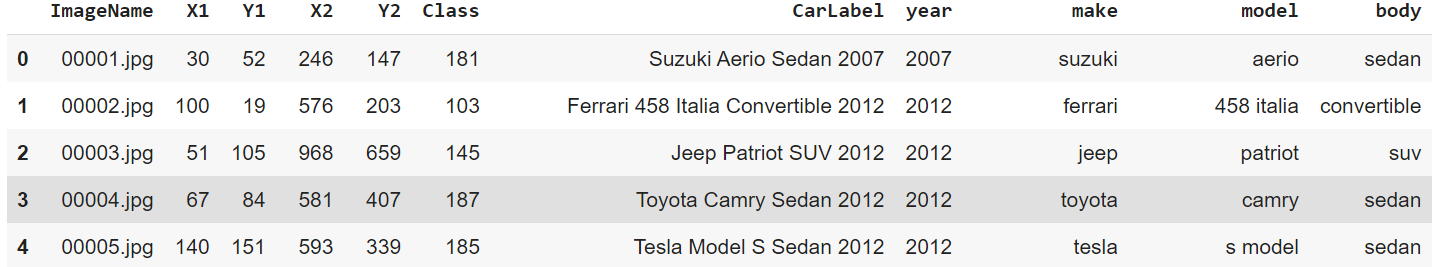
                model = list(set(wordsl).difference(iden))

                print(model)

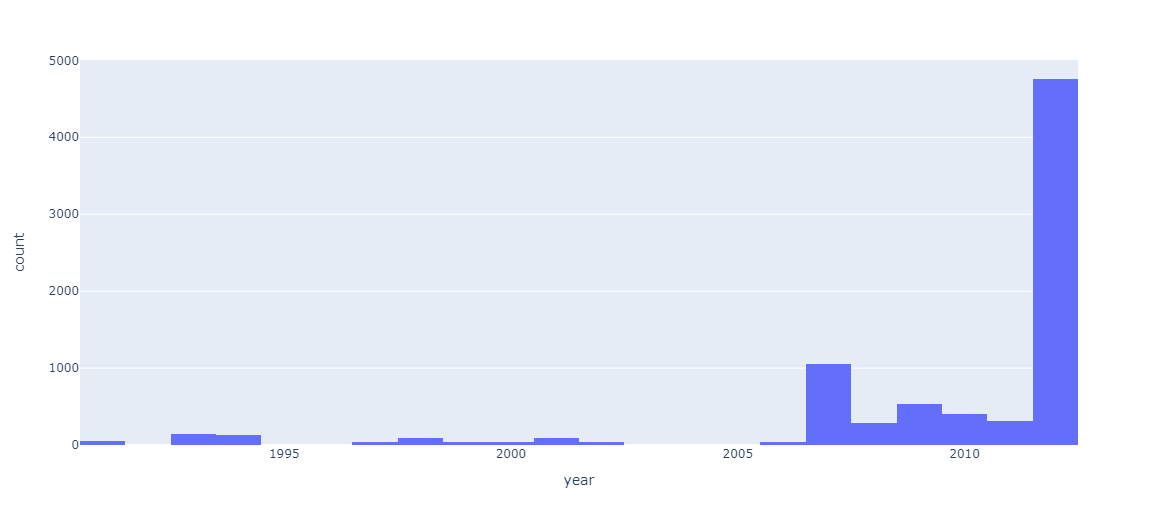
                if model:

                    eda\_df.loc[index, 'model'] = ' '.join(model)

Display Few records:

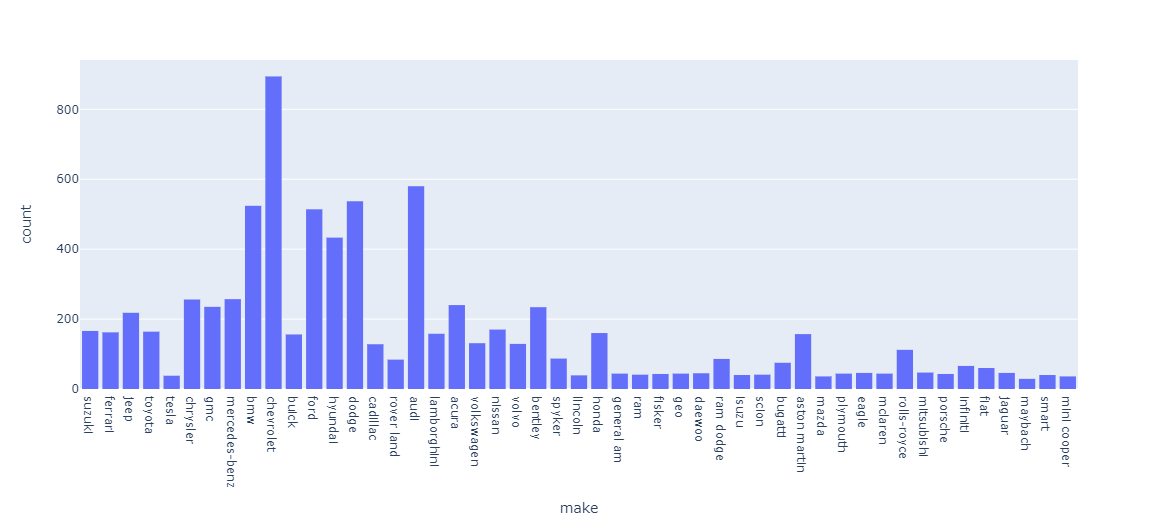


* **Display bar charts for different columns**
* Count of different cars by year



**As seen, most of cars are of make year between 2007 – 2012**

* Count of different cars by make

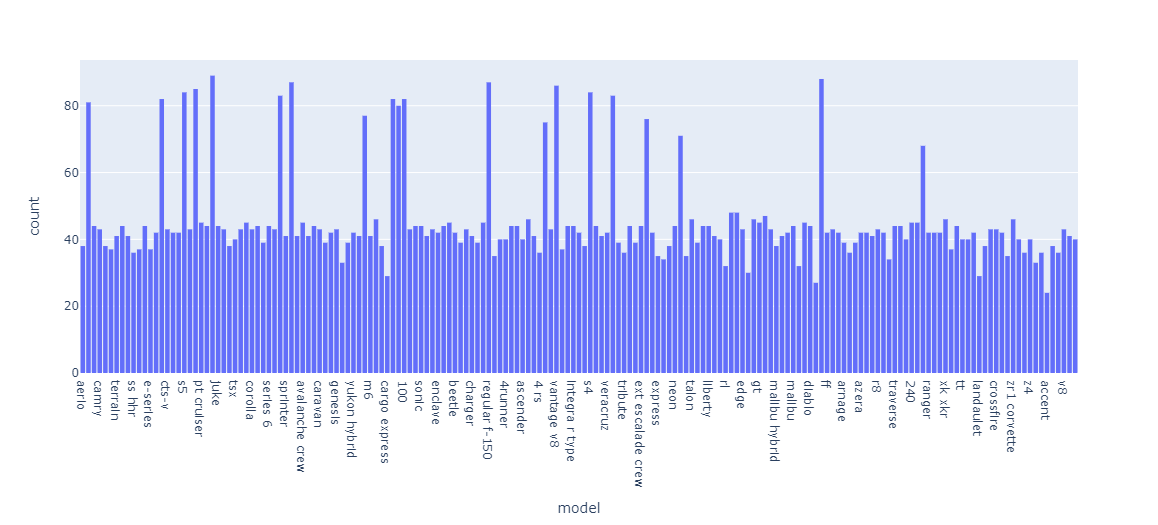


**As seen, most of cars are of make Chevrolet, audi, bmw and dodge. ‘Mini Cooper’, ‘Smart’**

**and ‘Jaguar’ are less represented. Therefore, an effective model would be the one which can**

**identify cars belonging to these classes.**

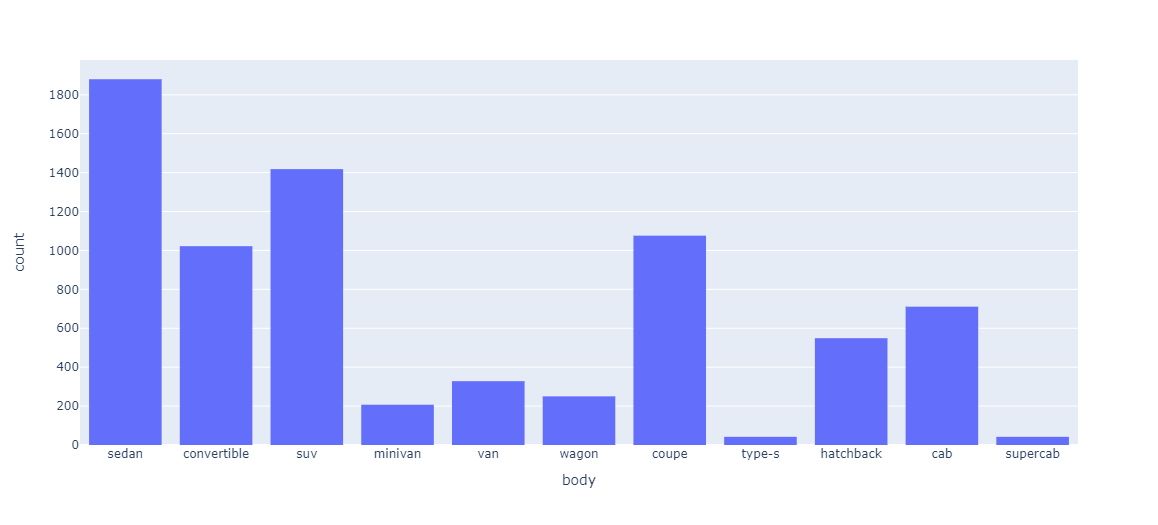
* Count of different cars by model



**As seen, cars evenly belong to different models, with some models having more number of**

**cars.**

* Count of cars by different body types



**As seen, most of cars are of type Sedan**

### ****Display images with bounding box.****

IMAGE\_SIZE = 224

IMAGE\_HEIGHT = IMAGE\_SIZE

IMAGE\_WIDTH = IMAGE\_SIZE

HEIGHT\_CELLS = 28

WIDTH\_CELLS = 28

print ( 'Generating bounding boxes images for Eg Train Data')

i = 1

plt.figure(figsize=(20,20))

for no in [0 , 6, 67, 89 , 99, 340 ]:

    eg\_car  = car\_train\_df.iloc[ no ]

    path = 'Car Images/Train Images/{0}/{1}'.format( eg\_car['CarLabel'], eg\_car['ImageName'] )

    img = cv2.imread( path )

    img\_shape = img.shape

    img = cv2.resize(img, dsize = (IMAGE\_SIZE, IMAGE\_SIZE), interpolation=cv2.INTER\_AREA)

    x1 = int(eg\_car['X1']   \* IMAGE\_SIZE  / img\_shape[1] -3 )           # Normalize bounding box by image size

    y1 = int(eg\_car['Y1']   \* IMAGE\_SIZE / img\_shape[0] - 3 )        # Normalize bounding box by image size

    x2 = int(eg\_car['X2']   \* IMAGE\_SIZE / img\_shape[1] + 3)           # Normalize bounding box by image size

    y2 = int(eg\_car['Y2']   \* IMAGE\_SIZE / img\_shape[0] + 3 )          # Normalize bounding box by image size

    cv2.rectangle(img, (x1, y1), (x2, y2), (255,255,255) )

    i +=1

    plt.subplot(4,2,i+1)

    plt.grid(False)

    plt.imshow(img);

### 

### ****Save training images with bounding box.****

### We will extract bounding boxes and then save those as images

for i in range(len(car\_train\_df)):

  eg\_car  = car\_train\_df.iloc[i]

  source\_path = 'Car Images/Train Images/{0}/{1}'.format( eg\_car['CarLabel'], eg\_car['ImageName'] )

  dest\_path = 'Car Images/Train Images Annoted/{0}/{1}'.format( eg\_car['CarLabel'], eg\_car['ImageName'] )

  image = cv2.imread(source\_path)

  if image is None:

    print(source\_path)

  x1 = int(eg\_car['X1'])

  y1 = int(eg\_car['Y1'])

  x2 = int(eg\_car['X2'])

  y2 = int(eg\_car['Y2'])

  im2 = image[y1:y2,x1:x2]

  im2 = cv2.resize(im2, (IMAGE\_SIZE, IMAGE\_SIZE))

  destdirname = 'Car Images/Train Images Annoted/{0}'.format( eg\_car['CarLabel'])

  destfilename= eg\_car['ImageName']

  if not os.path.exists(destdirname):

    os.mkdir(destdirname)

  cv2.imwrite(os.path.join(destdirname, destfilename), im2)

### Display few cropped training images

eg\_car  = car\_train\_df.iloc[8]

path = 'Car Images/Train Images Annoted/{0}/{1}'.format( eg\_car['CarLabel'], eg\_car['ImageName'] )

img = cv2.imread( path )

plt.grid(False)

plt.imshow(img)

### 

eg\_car  = car\_train\_df.iloc[16]

path = 'Car Images/Train Images Annoted/{0}/{1}'.format( eg\_car['CarLabel'], eg\_car['ImageName'] )

img = cv2.imread( path )

plt.grid(False)

plt.imshow(img)

### 

### Do the same for test images.

### ****Load the cropped train & test images using ImageDataGenerator****

train\_path = 'Car Images/Train Images Annoted'

test\_path = 'Car Images/Test Images Annoted'

BATCH\_SIZE = 32

IMG\_SIZE = (224, 224)

train\_datagen = ImageDataGenerator(

    rescale=1./255,

    shear\_range=0.2,

    zoom\_range=0.2,

    horizontal\_flip=True)

test\_datagen = ImageDataGenerator(rescale=1./255)

train\_generator = train\_datagen.flow\_from\_directory(

    train\_path,

    target\_size=IMG\_SIZE,

    batch\_size=BATCH\_SIZE,

    class\_mode='categorical')

validation\_generator = test\_datagen.flow\_from\_directory(

    test\_path,

    target\_size=IMG\_SIZE,

    batch\_size=BATCH\_SIZE,

    class\_mode='categorical')

**Found 8144 images belonging to 197 classes.**

### Found 8041 images belonging to 197 classes.

### Train Different Models

### For this problem, we tried following models:

### Custom CNN Classifier

### ResNet50 (with multiple layers)

### VGG16

### ResNet50 (without multiple layers)

### InceptionResNetV2

### Custom CNN Classifier

### Create the model

# Initialising the CNN classifier

classifier = Sequential()

INPUT\_SIZE = (224, 224, 3)

# Add a Convolution layer with 32 kernels of 3X3 shape with activation function ReLU

classifier.add(Conv2D(32, (3, 3), input\_shape = INPUT\_SIZE, activation = 'relu', padding = 'same'))

# Add a Max Pooling layer of size 2X2

classifier.add(MaxPooling2D(pool\_size = (2, 2)))

# Add another Convolution layer with 32 kernels of 3X3 shape with activation function ReLU

classifier.add(Conv2D(32, (3, 3), activation = 'relu', padding = 'same'))

# Adding another pooling layer

classifier.add(MaxPooling2D(pool\_size = (2, 2)))

# Add another Convolution layer with 32 kernels of 3X3 shape with activation function ReLU

classifier.add(Conv2D(32, (3, 3), activation = 'relu', padding = 'same'))

# Adding another pooling layer

classifier.add(MaxPooling2D(pool\_size = (2, 2)))

# Flattening the layer before fully connected layers

classifier.add(Flatten())

# Adding a fully connected layer with 512 neurons

classifier.add(Dense(units = 512, activation = 'relu'))

# Adding dropout with probability 0.5

classifier.add(Dropout(0.5))

# Adding a fully connected layer with 128 neurons

classifier.add(Dense(units = 128, activation = 'relu'))

# The final output layer with output size 197 classes for  the categorical classifcation

classifier.add(Dense(units = 197, activation = 'softmax'))

### Summary

Model: "sequential\_1"

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Layer (type) Output Shape Param #

=================================================================

conv2d\_3 (Conv2D) (None, 224, 224, 32) 896

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

max\_pooling2d\_3 (MaxPooling2 (None, 112, 112, 32) 0

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

conv2d\_4 (Conv2D) (None, 112, 112, 32) 9248

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

max\_pooling2d\_4 (MaxPooling2 (None, 56, 56, 32) 0

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

conv2d\_5 (Conv2D) (None, 56, 56, 32) 9248

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

max\_pooling2d\_5 (MaxPooling2 (None, 28, 28, 32) 0

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

flatten\_1 (Flatten) (None, 25088) 0

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

dense\_3 (Dense) (None, 512) 12845568

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

dropout\_1 (Dropout) (None, 512) 0

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

dense\_4 (Dense) (None, 128) 65664

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

dense\_5 (Dense) (None, 197) 25413

=================================================================

Total params: 12,956,037

Trainable params: 12,956,037

Non-trainable params: 0

### \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

### Define Optimizer

opt = Adam(learning\_rate=0.001, beta\_1=0.9, beta\_2=0.999, epsilon=None, decay=0.001, amsgrad=False)

classifier.compile(optimizer = opt, loss = 'categorical\_crossentropy', metrics = ['accuracy'])

### Training [Forward pass and Backpropagation]

#Early stopping

early = EarlyStopping(monitor='val\_accuracy',min\_delta=0,patience=40,verbose=1,mode='auto')

# There are 3823 training images and 500 test images in total

hist\_CNNClassifier = classifier.fit\_generator(train\_generator,

                         steps\_per\_epoch = int(train\_generator.samples/BATCH\_SIZE),

                         epochs = 20,

                         validation\_data = validation\_generator,

             validation\_steps = int(validation\_generator.samples/BATCH\_SIZE

),

                         callbacks = [early])

**Epoch 1/20**

**254/254 [==============================] - 2523s 10s/step - loss: 5.2871 - accuracy: 0.0048 - val\_loss: 5.2809 - val\_accuracy: 0.0085**

**Epoch 2/20**

**254/254 [==============================] - 188s 739ms/step - loss: 5.2378 - accuracy: 0.0094 - val\_loss: 5.1779 - val\_accuracy: 0.0108**

**Epoch 3/20**

**254/254 [==============================] - 187s 736ms/step - loss: 5.1521 - accuracy: 0.0126 - val\_loss: 5.1202 - val\_accuracy: 0.0149**

**Epoch 4/20**

**254/254 [==============================] - 185s 728ms/step - loss: 5.1024 - accuracy: 0.0164 - val\_loss: 5.1068 - val\_accuracy: 0.0144**

**Epoch 5/20**

**254/254 [==============================] - 184s 724ms/step - loss: 5.0617 - accuracy: 0.0180 - val\_loss: 5.0464 - val\_accuracy: 0.0223**

**Epoch 6/20**

**254/254 [==============================] - 182s 719ms/step - loss: 5.0102 - accuracy: 0.0221 - val\_loss: 4.9850 - val\_accuracy: 0.0253**

**Epoch 7/20**

**254/254 [==============================] - 184s 726ms/step - loss: 4.9130 - accuracy: 0.0303 - val\_loss: 4.8883 - val\_accuracy: 0.0408**

**Epoch 8/20**

**254/254 [==============================] - 184s 724ms/step - loss: 4.7473 - accuracy: 0.0477 - val\_loss: 4.6899 - val\_accuracy: 0.0603**

**Epoch 9/20**

**254/254 [==============================] - 184s 725ms/step - loss: 4.5756 - accuracy: 0.0664 - val\_loss: 4.5243 - val\_accuracy: 0.0706**

**Epoch 10/20**

**254/254 [==============================] - 184s 725ms/step - loss: 4.3834 - accuracy: 0.0867 - val\_loss: 4.3964 - val\_accuracy: 0.0820**

**Epoch 11/20**

**254/254 [==============================] - 184s 725ms/step - loss: 4.2401 - accuracy: 0.0987 - val\_loss: 4.2711 - val\_accuracy: 0.0999**

**Epoch 12/20**

**254/254 [==============================] - 183s 723ms/step - loss: 4.0806 - accuracy: 0.1187 - val\_loss: 4.2011 - val\_accuracy: 0.1048**

**Epoch 13/20**

**254/254 [==============================] - 183s 722ms/step - loss: 3.9654 - accuracy: 0.1387 - val\_loss: 4.2050 - val\_accuracy: 0.1112**

**Epoch 14/20**

**254/254 [==============================] - 184s 727ms/step - loss: 3.8438 - accuracy: 0.1456 - val\_loss: 4.0591 - val\_accuracy: 0.1213**

**Epoch 15/20**

**254/254 [==============================] - 185s 728ms/step - loss: 3.7540 - accuracy: 0.1610 - val\_loss: 4.0304 - val\_accuracy: 0.1300**

**Epoch 16/20**

**254/254 [==============================] - 184s 726ms/step - loss: 3.6654 - accuracy: 0.1700 - val\_loss: 3.9678 - val\_accuracy: 0.1376**

**Epoch 17/20**

**254/254 [==============================] - 183s 722ms/step - loss: 3.5846 - accuracy: 0.1811 - val\_loss: 3.9020 - val\_accuracy: 0.1416**

**Epoch 18/20**

**254/254 [==============================] - 183s 723ms/step - loss: 3.5153 - accuracy: 0.2046 - val\_loss: 3.8804 - val\_accuracy: 0.1493**

**Epoch 19/20**

**254/254 [==============================] - 184s 725ms/step - loss: 3.4546 - accuracy: 0.2061 - val\_loss: 3.8908 - val\_accuracy: 0.1504**

**Epoch 20/20**

**254/254 [==============================] - 184s 725ms/step - loss: 3.3658 - accuracy: 0.2226 - val\_loss: 3.8429 - val\_accuracy: 0.1584**

### Accuracy and Loss for Training and Validation

train\_loss = hist\_CNNClassifier.history['loss']

val\_loss   = hist\_CNNClassifier.history['val\_loss']

xc = hist\_CNNClassifier.epoch

plt.title("Accuracy ValAccuracy Vs NumEpochs CNN")

plt.plot(xc,hist\_CNNClassifier.history['accuracy'], label='train')

plt.plot(xc,hist\_CNNClassifier.history['val\_accuracy'], label='test')

plt.legend()

plt.show()

plt.figure()

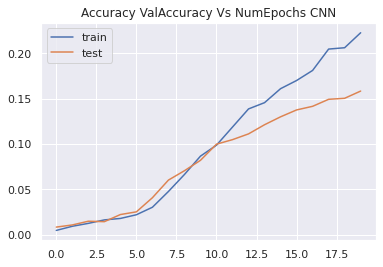
plt.title("Loss ValLoss Vs NumEpochs CNN")

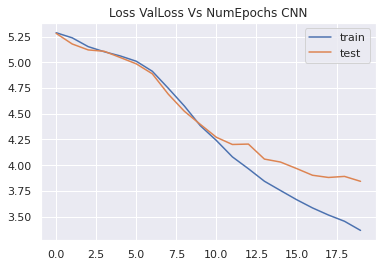
plt.plot(xc, train\_loss,label='train')

plt.plot(xc, val\_loss,label='test')

plt.legend()

plt.show





**Graph shows that model tends to increase both training and validation accuracy, and decrease training and validation loss with each epoch.**

1. **Evaluation**

train\_acc = classifier.evaluate\_generator(train\_generator,steps = int(train\_generator.samples/BATCH\_SIZE))

val\_acc = classifier.evaluate\_generator(validation\_generator, steps = int(validation\_generator.samples/BATCH\_SIZE))

print(train\_acc[1])

print(val\_acc[1])

**0.3591289222240448**

**0.15861554443836212**

**Final evaluation shows that overall training accuracy is only around 36% and validation accuracy is around 16%. Therefore, this reveals both high bias and high variance issues.**

1. **Store result in a dataframe for final comparison of different models**

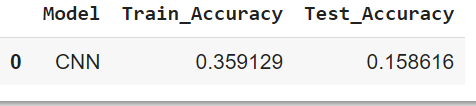
#Store the Performance Matrix for each model in a dataframe for final comparison

resultsDf = pd.DataFrame({'Model':['CNN'], 'Train\_Accuracy': train\_acc[1],'Test\_Accuracy': val\_acc[1],

                          })

resultsDf = resultsDf[['Model', 'Train\_Accuracy','Test\_Accuracy']]

resultsDf



### Pickle the model for future use

classifier.save('./classifier.h5')

classifier.save\_weights('./classifier\_weights.h5')

### ResNet50 (with multiple layers)

### Creating the model

resnet50 = resnet50

conv\_model = resnet50.ResNet50(weights='imagenet', include\_top=False, input\_shape=(224,224,3))

x = Flatten()(conv\_model.layers[-1].output)

x = Dense(512, activation='relu')(x)

x = Dense(224, activation='relu')(x)

x = Dense(224, activation='relu')(x)

x = Dense(224, activation='relu')(x)

x = Dense(224, activation='relu')(x)

x = Dense(224, activation='sigmoid')(x)

x = Dense(224, activation='sigmoid')(x)

predictions = Dense(197, activation='softmax')(x)

full\_model = Model(inputs=conv\_model.input, outputs=predictions)

### Summary of model

full\_model.summary()

Model: "model\_1"

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Layer (type) Output Shape Param # Connected to

==================================================================================================

input\_3 (InputLayer) [(None, 224, 224, 3) 0

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conv1\_pad (ZeroPadding2D) (None, 230, 230, 3) 0 input\_3[0][0]

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conv1\_conv (Conv2D) (None, 112, 112, 64) 9472 conv1\_pad[0][0]

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conv1\_bn (BatchNormalization) (None, 112, 112, 64) 256 conv1\_conv[0][0]

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conv1\_relu (Activation) (None, 112, 112, 64) 0 conv1\_bn[0][0]

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pool1\_pad (ZeroPadding2D) (None, 114, 114, 64) 0 conv1\_relu[0][0]

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pool1\_pool (MaxPooling2D) (None, 56, 56, 64) 0 pool1\_pad[0][0]

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conv2\_block1\_1\_conv (Conv2D) (None, 56, 56, 64) 4160 pool1\_pool[0][0]

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conv2\_block1\_1\_bn (BatchNormali (None, 56, 56, 64) 256 conv2\_block1\_1\_conv[0][0]

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conv2\_block1\_1\_relu (Activation (None, 56, 56, 64) 0 conv2\_block1\_1\_bn[0][0]

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conv2\_block1\_2\_conv (Conv2D) (None, 56, 56, 64) 36928 conv2\_block1\_1\_relu[0][0]

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conv2\_block1\_2\_bn (BatchNormali (None, 56, 56, 64) 256 conv2\_block1\_2\_conv[0][0]

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conv2\_block1\_2\_relu (Activation (None, 56, 56, 64) 0 conv2\_block1\_2\_bn[0][0]

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conv2\_block1\_0\_conv (Conv2D) (None, 56, 56, 256) 16640 pool1\_pool[0][0]

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conv2\_block1\_3\_conv (Conv2D) (None, 56, 56, 256) 16640 conv2\_block1\_2\_relu[0][0]

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conv2\_block1\_0\_bn (BatchNormali (None, 56, 56, 256) 1024 conv2\_block1\_0\_conv[0][0]

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conv2\_block1\_3\_bn (BatchNormali (None, 56, 56, 256) 1024 conv2\_block1\_3\_conv[0][0]

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conv2\_block1\_add (Add) (None, 56, 56, 256) 0 conv2\_block1\_0\_bn[0][0]

conv2\_block1\_3\_bn[0][0]

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conv2\_block1\_out (Activation) (None, 56, 56, 256) 0 conv2\_block1\_add[0][0]

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conv2\_block2\_1\_conv (Conv2D) (None, 56, 56, 64) 16448 conv2\_block1\_out[0][0]

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conv2\_block2\_1\_bn (BatchNormali (None, 56, 56, 64) 256 conv2\_block2\_1\_conv[0][0]

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conv2\_block2\_1\_relu (Activation (None, 56, 56, 64) 0 conv2\_block2\_1\_bn[0][0]

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conv2\_block2\_2\_conv (Conv2D) (None, 56, 56, 64) 36928 conv2\_block2\_1\_relu[0][0]

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conv2\_block2\_2\_bn (BatchNormali (None, 56, 56, 64) 256 conv2\_block2\_2\_conv[0][0]

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conv2\_block2\_2\_relu (Activation (None, 56, 56, 64) 0 conv2\_block2\_2\_bn[0][0]

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conv2\_block2\_3\_conv (Conv2D) (None, 56, 56, 256) 16640 conv2\_block2\_2\_relu[0][0]

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conv2\_block2\_3\_bn (BatchNormali (None, 56, 56, 256) 1024 conv2\_block2\_3\_conv[0][0]

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conv2\_block2\_add (Add) (None, 56, 56, 256) 0 conv2\_block1\_out[0][0]

conv2\_block2\_3\_bn[0][0]

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conv2\_block2\_out (Activation) (None, 56, 56, 256) 0 conv2\_block2\_add[0][0]

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conv2\_block3\_1\_conv (Conv2D) (None, 56, 56, 64) 16448 conv2\_block2\_out[0][0]

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conv2\_block3\_1\_bn (BatchNormali (None, 56, 56, 64) 256 conv2\_block3\_1\_conv[0][0]

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conv2\_block3\_1\_relu (Activation (None, 56, 56, 64) 0 conv2\_block3\_1\_bn[0][0]

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conv2\_block3\_2\_conv (Conv2D) (None, 56, 56, 64) 36928 conv2\_block3\_1\_relu[0][0]

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conv2\_block3\_2\_bn (BatchNormali (None, 56, 56, 64) 256 conv2\_block3\_2\_conv[0][0]

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conv2\_block3\_2\_relu (Activation (None, 56, 56, 64) 0 conv2\_block3\_2\_bn[0][0]

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conv2\_block3\_3\_conv (Conv2D) (None, 56, 56, 256) 16640 conv2\_block3\_2\_relu[0][0]

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conv2\_block3\_3\_bn (BatchNormali (None, 56, 56, 256) 1024 conv2\_block3\_3\_conv[0][0]

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conv2\_block3\_add (Add) (None, 56, 56, 256) 0 conv2\_block2\_out[0][0]

conv2\_block3\_3\_bn[0][0]

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conv2\_block3\_out (Activation) (None, 56, 56, 256) 0 conv2\_block3\_add[0][0]

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conv3\_block1\_1\_conv (Conv2D) (None, 28, 28, 128) 32896 conv2\_block3\_out[0][0]

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conv3\_block1\_1\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block1\_1\_conv[0][0]

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conv3\_block1\_1\_relu (Activation (None, 28, 28, 128) 0 conv3\_block1\_1\_bn[0][0]

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conv3\_block1\_2\_conv (Conv2D) (None, 28, 28, 128) 147584 conv3\_block1\_1\_relu[0][0]

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conv3\_block1\_2\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block1\_2\_conv[0][0]

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conv3\_block1\_2\_relu (Activation (None, 28, 28, 128) 0 conv3\_block1\_2\_bn[0][0]

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conv3\_block1\_0\_conv (Conv2D) (None, 28, 28, 512) 131584 conv2\_block3\_out[0][0]

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conv3\_block1\_3\_conv (Conv2D) (None, 28, 28, 512) 66048 conv3\_block1\_2\_relu[0][0]

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conv3\_block1\_0\_bn (BatchNormali (None, 28, 28, 512) 2048 conv3\_block1\_0\_conv[0][0]

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conv3\_block1\_3\_bn (BatchNormali (None, 28, 28, 512) 2048 conv3\_block1\_3\_conv[0][0]

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conv3\_block1\_add (Add) (None, 28, 28, 512) 0 conv3\_block1\_0\_bn[0][0]

conv3\_block1\_3\_bn[0][0]

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conv3\_block1\_out (Activation) (None, 28, 28, 512) 0 conv3\_block1\_add[0][0]

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conv3\_block2\_1\_conv (Conv2D) (None, 28, 28, 128) 65664 conv3\_block1\_out[0][0]

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conv3\_block2\_1\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block2\_1\_conv[0][0]

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conv3\_block2\_1\_relu (Activation (None, 28, 28, 128) 0 conv3\_block2\_1\_bn[0][0]

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conv3\_block2\_2\_conv (Conv2D) (None, 28, 28, 128) 147584 conv3\_block2\_1\_relu[0][0]

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conv3\_block2\_2\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block2\_2\_conv[0][0]

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conv3\_block2\_2\_relu (Activation (None, 28, 28, 128) 0 conv3\_block2\_2\_bn[0][0]

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conv3\_block2\_3\_conv (Conv2D) (None, 28, 28, 512) 66048 conv3\_block2\_2\_relu[0][0]

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conv3\_block2\_3\_bn (BatchNormali (None, 28, 28, 512) 2048 conv3\_block2\_3\_conv[0][0]

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conv3\_block2\_add (Add) (None, 28, 28, 512) 0 conv3\_block1\_out[0][0]

conv3\_block2\_3\_bn[0][0]

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conv3\_block2\_out (Activation) (None, 28, 28, 512) 0 conv3\_block2\_add[0][0]

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conv3\_block3\_1\_conv (Conv2D) (None, 28, 28, 128) 65664 conv3\_block2\_out[0][0]

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conv3\_block3\_1\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block3\_1\_conv[0][0]

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conv3\_block3\_1\_relu (Activation (None, 28, 28, 128) 0 conv3\_block3\_1\_bn[0][0]

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conv3\_block3\_2\_conv (Conv2D) (None, 28, 28, 128) 147584 conv3\_block3\_1\_relu[0][0]

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conv3\_block3\_2\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block3\_2\_conv[0][0]

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conv3\_block3\_2\_relu (Activation (None, 28, 28, 128) 0 conv3\_block3\_2\_bn[0][0]

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conv3\_block3\_3\_conv (Conv2D) (None, 28, 28, 512) 66048 conv3\_block3\_2\_relu[0][0]

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conv3\_block3\_3\_bn (BatchNormali (None, 28, 28, 512) 2048 conv3\_block3\_3\_conv[0][0]

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conv3\_block3\_add (Add) (None, 28, 28, 512) 0 conv3\_block2\_out[0][0]

conv3\_block3\_3\_bn[0][0]

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conv3\_block3\_out (Activation) (None, 28, 28, 512) 0 conv3\_block3\_add[0][0]

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conv3\_block4\_1\_conv (Conv2D) (None, 28, 28, 128) 65664 conv3\_block3\_out[0][0]

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conv3\_block4\_1\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block4\_1\_conv[0][0]

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conv3\_block4\_1\_relu (Activation (None, 28, 28, 128) 0 conv3\_block4\_1\_bn[0][0]

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conv3\_block4\_2\_conv (Conv2D) (None, 28, 28, 128) 147584 conv3\_block4\_1\_relu[0][0]

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conv3\_block4\_2\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block4\_2\_conv[0][0]

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conv3\_block4\_2\_relu (Activation (None, 28, 28, 128) 0 conv3\_block4\_2\_bn[0][0]

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conv3\_block4\_3\_conv (Conv2D) (None, 28, 28, 512) 66048 conv3\_block4\_2\_relu[0][0]

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conv3\_block4\_3\_bn (BatchNormali (None, 28, 28, 512) 2048 conv3\_block4\_3\_conv[0][0]

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conv3\_block4\_add (Add) (None, 28, 28, 512) 0 conv3\_block3\_out[0][0]

conv3\_block4\_3\_bn[0][0]

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conv3\_block4\_out (Activation) (None, 28, 28, 512) 0 conv3\_block4\_add[0][0]

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conv4\_block1\_1\_conv (Conv2D) (None, 14, 14, 256) 131328 conv3\_block4\_out[0][0]

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conv4\_block1\_1\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block1\_1\_conv[0][0]

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conv4\_block1\_1\_relu (Activation (None, 14, 14, 256) 0 conv4\_block1\_1\_bn[0][0]

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conv4\_block1\_2\_conv (Conv2D) (None, 14, 14, 256) 590080 conv4\_block1\_1\_relu[0][0]

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conv4\_block1\_2\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block1\_2\_conv[0][0]

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conv4\_block1\_2\_relu (Activation (None, 14, 14, 256) 0 conv4\_block1\_2\_bn[0][0]

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conv4\_block1\_0\_conv (Conv2D) (None, 14, 14, 1024) 525312 conv3\_block4\_out[0][0]

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conv4\_block1\_3\_conv (Conv2D) (None, 14, 14, 1024) 263168 conv4\_block1\_2\_relu[0][0]

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conv4\_block1\_0\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block1\_0\_conv[0][0]

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conv4\_block1\_3\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block1\_3\_conv[0][0]

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conv4\_block1\_add (Add) (None, 14, 14, 1024) 0 conv4\_block1\_0\_bn[0][0]

conv4\_block1\_3\_bn[0][0]

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conv4\_block1\_out (Activation) (None, 14, 14, 1024) 0 conv4\_block1\_add[0][0]

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conv4\_block2\_1\_conv (Conv2D) (None, 14, 14, 256) 262400 conv4\_block1\_out[0][0]

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conv4\_block2\_1\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block2\_1\_conv[0][0]

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conv4\_block2\_1\_relu (Activation (None, 14, 14, 256) 0 conv4\_block2\_1\_bn[0][0]

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conv4\_block2\_2\_conv (Conv2D) (None, 14, 14, 256) 590080 conv4\_block2\_1\_relu[0][0]

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conv4\_block2\_2\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block2\_2\_conv[0][0]

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conv4\_block2\_2\_relu (Activation (None, 14, 14, 256) 0 conv4\_block2\_2\_bn[0][0]

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conv4\_block2\_3\_conv (Conv2D) (None, 14, 14, 1024) 263168 conv4\_block2\_2\_relu[0][0]

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conv4\_block2\_3\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block2\_3\_conv[0][0]

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conv4\_block2\_add (Add) (None, 14, 14, 1024) 0 conv4\_block1\_out[0][0]

conv4\_block2\_3\_bn[0][0]

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conv4\_block2\_out (Activation) (None, 14, 14, 1024) 0 conv4\_block2\_add[0][0]

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conv4\_block3\_1\_conv (Conv2D) (None, 14, 14, 256) 262400 conv4\_block2\_out[0][0]

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conv4\_block3\_1\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block3\_1\_conv[0][0]

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conv4\_block3\_1\_relu (Activation (None, 14, 14, 256) 0 conv4\_block3\_1\_bn[0][0]

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conv4\_block3\_2\_conv (Conv2D) (None, 14, 14, 256) 590080 conv4\_block3\_1\_relu[0][0]

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conv4\_block3\_2\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block3\_2\_conv[0][0]

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conv4\_block3\_2\_relu (Activation (None, 14, 14, 256) 0 conv4\_block3\_2\_bn[0][0]

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conv4\_block3\_3\_conv (Conv2D) (None, 14, 14, 1024) 263168 conv4\_block3\_2\_relu[0][0]

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conv4\_block3\_3\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block3\_3\_conv[0][0]

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conv4\_block3\_add (Add) (None, 14, 14, 1024) 0 conv4\_block2\_out[0][0]

conv4\_block3\_3\_bn[0][0]

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conv4\_block3\_out (Activation) (None, 14, 14, 1024) 0 conv4\_block3\_add[0][0]

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conv4\_block4\_1\_conv (Conv2D) (None, 14, 14, 256) 262400 conv4\_block3\_out[0][0]

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conv4\_block4\_1\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block4\_1\_conv[0][0]

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conv4\_block4\_1\_relu (Activation (None, 14, 14, 256) 0 conv4\_block4\_1\_bn[0][0]

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conv4\_block4\_2\_conv (Conv2D) (None, 14, 14, 256) 590080 conv4\_block4\_1\_relu[0][0]

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conv4\_block4\_2\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block4\_2\_conv[0][0]

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conv4\_block4\_2\_relu (Activation (None, 14, 14, 256) 0 conv4\_block4\_2\_bn[0][0]

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conv4\_block4\_3\_conv (Conv2D) (None, 14, 14, 1024) 263168 conv4\_block4\_2\_relu[0][0]

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conv4\_block4\_3\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block4\_3\_conv[0][0]

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conv4\_block4\_add (Add) (None, 14, 14, 1024) 0 conv4\_block3\_out[0][0]

conv4\_block4\_3\_bn[0][0]

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conv4\_block4\_out (Activation) (None, 14, 14, 1024) 0 conv4\_block4\_add[0][0]

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conv4\_block5\_1\_conv (Conv2D) (None, 14, 14, 256) 262400 conv4\_block4\_out[0][0]

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conv4\_block5\_1\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block5\_1\_conv[0][0]

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conv4\_block5\_1\_relu (Activation (None, 14, 14, 256) 0 conv4\_block5\_1\_bn[0][0]

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conv4\_block5\_2\_conv (Conv2D) (None, 14, 14, 256) 590080 conv4\_block5\_1\_relu[0][0]

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conv4\_block5\_2\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block5\_2\_conv[0][0]

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conv4\_block5\_2\_relu (Activation (None, 14, 14, 256) 0 conv4\_block5\_2\_bn[0][0]

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conv4\_block5\_3\_conv (Conv2D) (None, 14, 14, 1024) 263168 conv4\_block5\_2\_relu[0][0]

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conv4\_block5\_3\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block5\_3\_conv[0][0]

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conv4\_block5\_add (Add) (None, 14, 14, 1024) 0 conv4\_block4\_out[0][0]

conv4\_block5\_3\_bn[0][0]

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conv4\_block5\_out (Activation) (None, 14, 14, 1024) 0 conv4\_block5\_add[0][0]

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conv4\_block6\_1\_conv (Conv2D) (None, 14, 14, 256) 262400 conv4\_block5\_out[0][0]

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conv4\_block6\_1\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block6\_1\_conv[0][0]

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conv4\_block6\_1\_relu (Activation (None, 14, 14, 256) 0 conv4\_block6\_1\_bn[0][0]

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conv4\_block6\_2\_conv (Conv2D) (None, 14, 14, 256) 590080 conv4\_block6\_1\_relu[0][0]

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conv4\_block6\_2\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block6\_2\_conv[0][0]

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conv4\_block6\_2\_relu (Activation (None, 14, 14, 256) 0 conv4\_block6\_2\_bn[0][0]

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conv4\_block6\_3\_conv (Conv2D) (None, 14, 14, 1024) 263168 conv4\_block6\_2\_relu[0][0]

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conv4\_block6\_3\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block6\_3\_conv[0][0]

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conv4\_block6\_add (Add) (None, 14, 14, 1024) 0 conv4\_block5\_out[0][0]

conv4\_block6\_3\_bn[0][0]

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conv4\_block6\_out (Activation) (None, 14, 14, 1024) 0 conv4\_block6\_add[0][0]

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conv5\_block1\_1\_conv (Conv2D) (None, 7, 7, 512) 524800 conv4\_block6\_out[0][0]

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conv5\_block1\_1\_bn (BatchNormali (None, 7, 7, 512) 2048 conv5\_block1\_1\_conv[0][0]

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conv5\_block1\_1\_relu (Activation (None, 7, 7, 512) 0 conv5\_block1\_1\_bn[0][0]

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conv5\_block1\_2\_conv (Conv2D) (None, 7, 7, 512) 2359808 conv5\_block1\_1\_relu[0][0]

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conv5\_block1\_2\_bn (BatchNormali (None, 7, 7, 512) 2048 conv5\_block1\_2\_conv[0][0]

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conv5\_block1\_2\_relu (Activation (None, 7, 7, 512) 0 conv5\_block1\_2\_bn[0][0]

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conv5\_block1\_0\_conv (Conv2D) (None, 7, 7, 2048) 2099200 conv4\_block6\_out[0][0]

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conv5\_block1\_3\_conv (Conv2D) (None, 7, 7, 2048) 1050624 conv5\_block1\_2\_relu[0][0]

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conv5\_block1\_0\_bn (BatchNormali (None, 7, 7, 2048) 8192 conv5\_block1\_0\_conv[0][0]

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conv5\_block1\_3\_bn (BatchNormali (None, 7, 7, 2048) 8192 conv5\_block1\_3\_conv[0][0]

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conv5\_block1\_add (Add) (None, 7, 7, 2048) 0 conv5\_block1\_0\_bn[0][0]

conv5\_block1\_3\_bn[0][0]

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conv5\_block1\_out (Activation) (None, 7, 7, 2048) 0 conv5\_block1\_add[0][0]

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conv5\_block2\_1\_conv (Conv2D) (None, 7, 7, 512) 1049088 conv5\_block1\_out[0][0]

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conv5\_block2\_1\_bn (BatchNormali (None, 7, 7, 512) 2048 conv5\_block2\_1\_conv[0][0]

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conv5\_block2\_1\_relu (Activation (None, 7, 7, 512) 0 conv5\_block2\_1\_bn[0][0]

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conv5\_block2\_2\_conv (Conv2D) (None, 7, 7, 512) 2359808 conv5\_block2\_1\_relu[0][0]

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conv5\_block2\_2\_bn (BatchNormali (None, 7, 7, 512) 2048 conv5\_block2\_2\_conv[0][0]

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conv5\_block2\_2\_relu (Activation (None, 7, 7, 512) 0 conv5\_block2\_2\_bn[0][0]

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conv5\_block2\_3\_conv (Conv2D) (None, 7, 7, 2048) 1050624 conv5\_block2\_2\_relu[0][0]

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conv5\_block2\_3\_bn (BatchNormali (None, 7, 7, 2048) 8192 conv5\_block2\_3\_conv[0][0]

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conv5\_block2\_add (Add) (None, 7, 7, 2048) 0 conv5\_block1\_out[0][0]

conv5\_block2\_3\_bn[0][0]

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

conv5\_block2\_out (Activation) (None, 7, 7, 2048) 0 conv5\_block2\_add[0][0]

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conv5\_block3\_1\_conv (Conv2D) (None, 7, 7, 512) 1049088 conv5\_block2\_out[0][0]

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conv5\_block3\_1\_bn (BatchNormali (None, 7, 7, 512) 2048 conv5\_block3\_1\_conv[0][0]

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conv5\_block3\_1\_relu (Activation (None, 7, 7, 512) 0 conv5\_block3\_1\_bn[0][0]

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conv5\_block3\_2\_conv (Conv2D) (None, 7, 7, 512) 2359808 conv5\_block3\_1\_relu[0][0]

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conv5\_block3\_2\_bn (BatchNormali (None, 7, 7, 512) 2048 conv5\_block3\_2\_conv[0][0]

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conv5\_block3\_2\_relu (Activation (None, 7, 7, 512) 0 conv5\_block3\_2\_bn[0][0]

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conv5\_block3\_3\_conv (Conv2D) (None, 7, 7, 2048) 1050624 conv5\_block3\_2\_relu[0][0]

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conv5\_block3\_3\_bn (BatchNormali (None, 7, 7, 2048) 8192 conv5\_block3\_3\_conv[0][0]

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conv5\_block3\_add (Add) (None, 7, 7, 2048) 0 conv5\_block2\_out[0][0]

conv5\_block3\_3\_bn[0][0]

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conv5\_block3\_out (Activation) (None, 7, 7, 2048) 0 conv5\_block3\_add[0][0]

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flatten\_5 (Flatten) (None, 100352) 0 conv5\_block3\_out[0][0]

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dense\_18 (Dense) (None, 512) 51380736 flatten\_5[0][0]

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dense\_19 (Dense) (None, 224) 114912 dense\_18[0][0]

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

dense\_20 (Dense) (None, 224) 50400 dense\_19[0][0]

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dense\_21 (Dense) (None, 224) 50400 dense\_20[0][0]

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dense\_22 (Dense) (None, 224) 50400 dense\_21[0][0]

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

dense\_23 (Dense) (None, 224) 50400 dense\_22[0][0]

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dense\_24 (Dense) (None, 224) 50400 dense\_23[0][0]

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dense\_25 (Dense) (None, 197) 44325 dense\_24[0][0]

==================================================================================================

Total params: 75,379,685

Trainable params: 75,326,565

Non-trainable params: 53,120

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

### Define optimizer

opt= Adam(learning\_rate=0.001)

### Training [Forward pass and Backpropagation]

#Compile

full\_model.compile(optimizer= opt, loss = 'categorical\_crossentropy', metrics = ['accuracy'])

#Early stopping

early = EarlyStopping(monitor='val\_accuracy',min\_delta=0,patience=40,verbose=1,mode='auto')

res\_classifier=full\_model.fit\_generator(train\_generator,steps\_per\_epoch = 2, epochs =30, validation\_data = validation\_generator,

            validation\_steps = 1,callbacks = [early])

**Epoch 1/30**

**2/2 [==============================] - 11s 2s/step - loss: 5.3621 - accuracy: 0.0000e+00 - val\_loss: 5.5525 - val\_accuracy: 0.0000e+00**

**Epoch 2/30**

**2/2 [==============================] - 2s 914ms/step - loss: 5.4601 - accuracy: 0.0000e+00 - val\_loss: 5.7100 - val\_accuracy: 0.0000e+00**

**Epoch 3/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.4117 - accuracy: 0.0000e+00 - val\_loss: 5.5345 - val\_accuracy: 0.0000e+00**

**Epoch 4/30**

**2/2 [==============================] - 2s 993ms/step - loss: 5.3791 - accuracy: 0.0000e+00 - val\_loss: 5.5610 - val\_accuracy: 0.0000e+00**

**Epoch 5/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.5947 - accuracy: 0.0000e+00 - val\_loss: 5.6320 - val\_accuracy: 0.0000e+00**

**Epoch 6/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.3780 - accuracy: 0.0000e+00 - val\_loss: 5.4623 - val\_accuracy: 0.0000e+00**

**Epoch 7/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.4169 - accuracy: 0.0000e+00 - val\_loss: 5.5907 - val\_accuracy: 0.0000e+00**

**Epoch 8/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.4999 - accuracy: 0.0000e+00 - val\_loss: 5.4237 - val\_accuracy: 0.0000e+00**

**Epoch 9/30**

**2/2 [==============================] - 2s 965ms/step - loss: 5.4621 - accuracy: 0.0312 - val\_loss: 5.4819 - val\_accuracy: 0.0000e+00**

**Epoch 10/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.4418 - accuracy: 0.0156 - val\_loss: 5.4853 - val\_accuracy: 0.0000e+00**

**Epoch 11/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.5179 - accuracy: 0.0000e+00 - val\_loss: 5.3407 - val\_accuracy: 0.0312**

**Epoch 12/30**

**2/2 [==============================] - 2s 955ms/step - loss: 5.3203 - accuracy: 0.0000e+00 - val\_loss: 5.5048 - val\_accuracy: 0.0000e+00**

**Epoch 13/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.3476 - accuracy: 0.0000e+00 - val\_loss: 5.3331 - val\_accuracy: 0.0000e+00**

**Epoch 14/30**

**2/2 [==============================] - 2s 954ms/step - loss: 5.2757 - accuracy: 0.0156 - val\_loss: 5.3322 - val\_accuracy: 0.0000e+00**

**Epoch 15/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.3678 - accuracy: 0.0000e+00 - val\_loss: 5.4033 - val\_accuracy: 0.0000e+00**

**Epoch 16/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.4252 - accuracy: 0.0000e+00 - val\_loss: 5.3253 - val\_accuracy: 0.0000e+00**

**Epoch 17/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.4463 - accuracy: 0.0000e+00 - val\_loss: 5.3175 - val\_accuracy: 0.0000e+00**

**Epoch 18/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.4036 - accuracy: 0.0000e+00 - val\_loss: 5.3590 - val\_accuracy: 0.0000e+00**

**Epoch 19/30**

**2/2 [==============================] - 2s 987ms/step - loss: 5.3229 - accuracy: 0.0156 - val\_loss: 5.3885 - val\_accuracy: 0.0312**

**Epoch 20/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.2921 - accuracy: 0.0156 - val\_loss: 5.3115 - val\_accuracy: 0.0000e+00**

**Epoch 21/30**

**2/2 [==============================] - 2s 957ms/step - loss: 5.3349 - accuracy: 0.0000e+00 - val\_loss: 5.2952 - val\_accuracy: 0.0000e+00**

**Epoch 22/30**

**2/2 [==============================] - 2s 993ms/step - loss: 5.3338 - accuracy: 0.0156 - val\_loss: 5.3405 - val\_accuracy: 0.0000e+00**

**Epoch 23/30**

**2/2 [==============================] - 2s 994ms/step - loss: 5.3303 - accuracy: 0.0000e+00 - val\_loss: 5.3367 - val\_accuracy: 0.0312**

**Epoch 24/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.3819 - accuracy: 0.0000e+00 - val\_loss: 5.2927 - val\_accuracy: 0.0000e+00**

**Epoch 25/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.3205 - accuracy: 0.0312 - val\_loss: 5.3621 - val\_accuracy: 0.0000e+00**

**Epoch 26/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.3144 - accuracy: 0.0000e+00 - val\_loss: 5.3109 - val\_accuracy: 0.0000e+00**

**Epoch 27/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.3487 - accuracy: 0.0000e+00 - val\_loss: 5.2597 - val\_accuracy: 0.0000e+00**

**Epoch 28/30**

**2/2 [==============================] - 2s 958ms/step - loss: 5.3365 - accuracy: 0.0000e+00 - val\_loss: 5.3778 - val\_accuracy: 0.0000e+00**

**Epoch 29/30**

**2/2 [==============================] - 2s 1s/step - loss: 5.3138 - accuracy: 0.0000e+00 - val\_loss: 5.3392 - val\_accuracy: 0.0000e+00**

**Epoch 30/30**

### 2/2 [==============================] - 2s 1s/step - loss: 5.3589 - accuracy: 0.0000e+00 - val\_loss: 5.2610 - val\_accuracy: 0.0000e+00

### Plot Accuracy and Loss for Training and Validation

train\_loss = res\_classifier.history['loss']

val\_loss   = res\_classifier.history['val\_loss']

xc = res\_classifier.epoch

plt.title("Accuracy ValAccuracy Vs NumEpochs CNN")

plt.plot(xc,res\_classifier.history['accuracy'], label='train')

plt.plot(xc,res\_classifier.history['val\_accuracy'], label='test')

plt.legend()

plt.show()

plt.figure()

plt.title("Loss ValLoss Vs NumEpochs CNN")

plt.plot(xc, train\_loss,label='train')

plt.plot(xc, val\_loss,label='test')

plt.legend()

plt.show

### 

### Plot shows that model tries to touch peaks and troughs with increasing epochs.

### 

### Plot shows that model tries to reduce loss for both training and validation dataset with each epoch.

### Evaluation

train\_acc = full\_model.evaluate\_generator(train\_generator,steps = int(train\_generator.samples/BATCH\_SIZE))

val\_acc = full\_model.evaluate\_generator(validation\_generator, steps = int(validation\_generator.samples/BATCH\_SIZE))

print(train\_acc[1])

print(val\_acc[1])

**0.005290354136377573**

### 0.005229083821177483

### Thus, this model performs very poorly on both training and validation dataset.

### Adding results to dataframe for final comparison

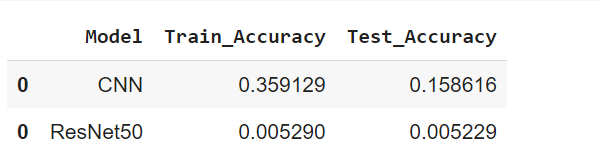
#Adding Performance metrics of ResNet50 to the list

tempResultsDf = pd.DataFrame({'Model':['ResNet50'],  'Train\_Accuracy': train\_acc[1],'Test\_Accuracy': val\_acc[1]})

resultsDf = pd.concat([resultsDf, tempResultsDf])

resultsDf = resultsDf[['Model', 'Train\_Accuracy','Test\_Accuracy']]

resultsDf



### VGG16

### Creating the model

print ( 'VGG with custom FC Layers')

vgg\_conv = VGG16(weights='imagenet', include\_top=False, input\_shape= (224,224,3))

# Freeze all the layers except for the last layer:

for layer in vgg\_conv.layers:

    layer.trainable = False

x = Flatten()(vgg\_conv.output)

x = Dense(197, activation='softmax')(x)

vgg\_model = Model(vgg\_conv.input, x)

**VGG with custom FC Layers**

**Downloading data from** [**https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16\_weights\_tf\_dim\_ordering\_tf\_kernels\_notop.h5**](https://storage.googleapis.com/tensorflow/keras-applications/vgg16/vgg16_weights_tf_dim_ordering_tf_kernels_notop.h5)

**58892288/58889256 [==============================] - 1s 0us/step**

### 58900480/58889256 [==============================] - 1s 0us/step

### Summary of model

vgg\_model.summary()

Model: "model\_3"

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Layer (type) Output Shape Param #

=================================================================

input\_5 (InputLayer) [(None, 224, 224, 3)] 0

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

block1\_conv1 (Conv2D) (None, 224, 224, 64) 1792

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block1\_conv2 (Conv2D) (None, 224, 224, 64) 36928

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block1\_pool (MaxPooling2D) (None, 112, 112, 64) 0

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block2\_conv1 (Conv2D) (None, 112, 112, 128) 73856

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block2\_conv2 (Conv2D) (None, 112, 112, 128) 147584

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block2\_pool (MaxPooling2D) (None, 56, 56, 128) 0

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block3\_conv1 (Conv2D) (None, 56, 56, 256) 295168

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block3\_conv2 (Conv2D) (None, 56, 56, 256) 590080

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block3\_conv3 (Conv2D) (None, 56, 56, 256) 590080

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block3\_pool (MaxPooling2D) (None, 28, 28, 256) 0

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block4\_conv1 (Conv2D) (None, 28, 28, 512) 1180160

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block4\_conv2 (Conv2D) (None, 28, 28, 512) 2359808

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block4\_conv3 (Conv2D) (None, 28, 28, 512) 2359808

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block4\_pool (MaxPooling2D) (None, 14, 14, 512) 0

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block5\_conv1 (Conv2D) (None, 14, 14, 512) 2359808

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block5\_conv2 (Conv2D) (None, 14, 14, 512) 2359808

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block5\_conv3 (Conv2D) (None, 14, 14, 512) 2359808

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block5\_pool (MaxPooling2D) (None, 7, 7, 512) 0

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flatten\_7 (Flatten) (None, 25088) 0

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dense\_27 (Dense) (None, 197) 4942533

=================================================================

Total params: 19,657,221

Trainable params: 4,942,533

Non-trainable params: 14,714,688

### Training [Forward pass and Backpropagation]

#Compile the model with Adam optimizer

vgg\_model.compile(optimizer = Adam(learning\_rate=0.001), loss = 'categorical\_crossentropy', metrics = ['accuracy'])

early = EarlyStopping(monitor='val\_accuracy',min\_delta=0.01,patience=20,verbose=1,mode='auto')

#Training

vgg\_classifier = vgg\_model.fit\_generator(train\_generator, epochs =30, validation\_data = validation\_generator, callbacks = [early]  )

**Epoch 1/30**

**255/255 [==============================] - 187s 731ms/step - loss: 0.3102 - accuracy: 0.9467 - val\_loss: 4.6444 - val\_accuracy: 0.5884**

**Epoch 2/30**

**255/255 [==============================] - 183s 718ms/step - loss: 0.3438 - accuracy: 0.9422 - val\_loss: 4.7269 - val\_accuracy: 0.5948**

**Epoch 3/30**

**255/255 [==============================] - 181s 711ms/step - loss: 0.3808 - accuracy: 0.9408 - val\_loss: 5.6650 - val\_accuracy: 0.5547**

**Epoch 4/30**

**255/255 [==============================] - 180s 708ms/step - loss: 0.3101 - accuracy: 0.9468 - val\_loss: 5.3064 - val\_accuracy: 0.5703**

**Epoch 5/30**

**255/255 [==============================] - 181s 709ms/step - loss: 0.3306 - accuracy: 0.9473 - val\_loss: 5.1069 - val\_accuracy: 0.5900**

**Epoch 6/30**

**255/255 [==============================] - 180s 707ms/step - loss: 0.4257 - accuracy: 0.9353 - val\_loss: 5.2278 - val\_accuracy: 0.5865**

**Epoch 7/30**

**255/255 [==============================] - 180s 708ms/step - loss: 0.2552 - accuracy: 0.9565 - val\_loss: 5.8028 - val\_accuracy: 0.5659**

**Epoch 8/30**

**255/255 [==============================] - 180s 707ms/step - loss: 0.3380 - accuracy: 0.9474 - val\_loss: 5.7594 - val\_accuracy: 0.5743**

**Epoch 9/30**

**255/255 [==============================] - 180s 705ms/step - loss: 0.3781 - accuracy: 0.9398 - val\_loss: 6.2191 - val\_accuracy: 0.5476**

**Epoch 10/30**

**255/255 [==============================] - 180s 706ms/step - loss: 0.3021 - accuracy: 0.9546 - val\_loss: 4.9970 - val\_accuracy: 0.6029**

**Epoch 11/30**

**255/255 [==============================] - 181s 709ms/step - loss: 0.2226 - accuracy: 0.9634 - val\_loss: 5.5075 - val\_accuracy: 0.5799**

**Epoch 12/30**

**255/255 [==============================] - 181s 708ms/step - loss: 0.3211 - accuracy: 0.9540 - val\_loss: 5.6694 - val\_accuracy: 0.5843**

**Epoch 13/30**

**255/255 [==============================] - 182s 715ms/step - loss: 0.2927 - accuracy: 0.9563 - val\_loss: 5.5035 - val\_accuracy: 0.5997**

**Epoch 14/30**

**255/255 [==============================] - 183s 717ms/step - loss: 0.3017 - accuracy: 0.9538 - val\_loss: 6.6898 - val\_accuracy: 0.5348**

**Epoch 15/30**

**255/255 [==============================] - 182s 715ms/step - loss: 0.3076 - accuracy: 0.9554 - val\_loss: 5.8260 - val\_accuracy: 0.5806**

**Epoch 16/30**

**255/255 [==============================] - 183s 717ms/step - loss: 0.2479 - accuracy: 0.9602 - val\_loss: 5.4916 - val\_accuracy: 0.6008**

**Epoch 17/30**

**255/255 [==============================] - 184s 723ms/step - loss: 0.3149 - accuracy: 0.9558 - val\_loss: 6.3606 - val\_accuracy: 0.5646**

**Epoch 18/30**

**255/255 [==============================] - 184s 720ms/step - loss: 0.3615 - accuracy: 0.9506 - val\_loss: 5.5514 - val\_accuracy: 0.6050**

**Epoch 19/30**

**255/255 [==============================] - 181s 711ms/step - loss: 0.2693 - accuracy: 0.9570 - val\_loss: 6.3985 - val\_accuracy: 0.5748**

**Epoch 20/30**

**255/255 [==============================] - 182s 715ms/step - loss: 0.3107 - accuracy: 0.9543 - val\_loss: 5.9179 - val\_accuracy: 0.5907**

**Epoch 21/30**

**255/255 [==============================] - 182s 713ms/step - loss: 0.2523 - accuracy: 0.9629 - val\_loss: 6.2966 - val\_accuracy: 0.5783**

**Epoch 22/30**

**255/255 [==============================] - 182s 713ms/step - loss: 0.2820 - accuracy: 0.9635 - val\_loss: 5.8626 - val\_accuracy: 0.6010**

**Epoch 23/30**

**255/255 [==============================] - 181s 709ms/step - loss: 0.2569 - accuracy: 0.9630 - val\_loss: 6.3886 - val\_accuracy: 0.5886**

**Epoch 24/30**

**255/255 [==============================] - 181s 711ms/step - loss: 0.3322 - accuracy: 0.9564 - val\_loss: 6.0438 - val\_accuracy: 0.5994**

**Epoch 25/30**

**255/255 [==============================] - 182s 714ms/step - loss: 0.2849 - accuracy: 0.9592 - val\_loss: 6.7721 - val\_accuracy: 0.5663**

**Epoch 26/30**

**255/255 [==============================] - 181s 710ms/step - loss: 0.2081 - accuracy: 0.9680 - val\_loss: 5.9842 - val\_accuracy: 0.6064**

**Epoch 27/30**

**255/255 [==============================] - 183s 717ms/step - loss: 0.2362 - accuracy: 0.9662 - val\_loss: 6.4080 - val\_accuracy: 0.5895**

**Epoch 28/30**

**255/255 [==============================] - 182s 713ms/step - loss: 0.2165 - accuracy: 0.9697 - val\_loss: 5.7963 - val\_accuracy: 0.6151**

**Epoch 29/30**

**255/255 [==============================] - 182s 713ms/step - loss: 0.2329 - accuracy: 0.9684 - val\_loss: 6.0159 - val\_accuracy: 0.6081**

**Epoch 30/30**

**255/255 [==============================] - 180s 707ms/step - loss: 0.2903 - accuracy: 0.9608 - val\_loss: 6.4375 - val\_accuracy: 0.5978**

### Plot Accuracy and Loss

train\_loss = vgg\_classifier.history['loss']

val\_loss   = vgg\_classifier.history['val\_loss']

xc = vgg\_classifier.epoch

plt.title("Accuracy ValAccuracy Vs NumEpochs CNN")

plt.plot(xc,vgg\_classifier.history['accuracy'], label='train')

plt.plot(xc,vgg\_classifier.history['val\_accuracy'], label='test')

plt.legend()

plt.show()

plt.figure()

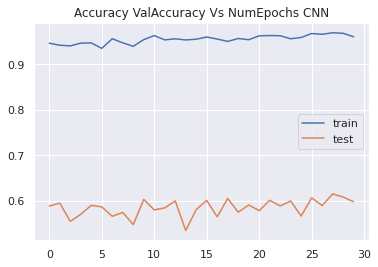
plt.title("Loss ValLoss Vs NumEpochs CNN")

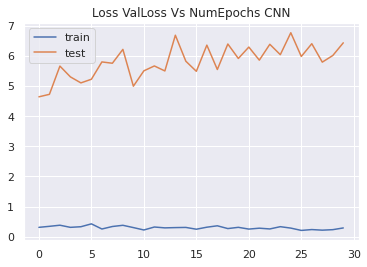
plt.plot(xc, train\_loss,label='train')

plt.plot(xc, val\_loss,label='test')

plt.legend()

plt.show





### Plot shows that both training and validation accuracy, and training and validation loss remains more or less constant over epochs.

### Evaluation

train\_acc = vgg\_model.evaluate\_generator(train\_generator,steps = int(train\_generator.samples/BATCH\_SIZE))

val\_acc = vgg\_model.evaluate\_generator(validation\_generator, steps = int(validation\_generator.samples/BATCH\_SIZE))

print(train\_acc[1])

print(val\_acc[1])

**0.9386072754859924**

**0.5639940500259399**

**Therefore, model shows a high training accuracy of around 94%. But validation accuracy is low at 56%. This shows a high variance problem.**

### Add result to dataframe for final comparison

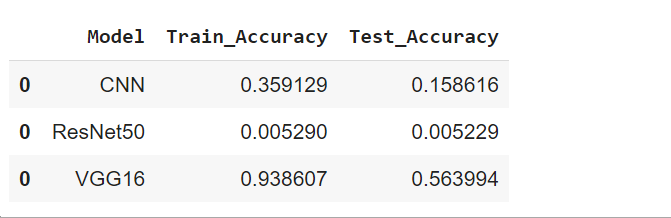
#Adding Performance metrics of ResNet50 to the list

tempResultsDf = pd.DataFrame({'Model':['VGG16'],  'Train\_Accuracy': train\_acc[1],'Test\_Accuracy': val\_acc[1]})

resultsDf = pd.concat([resultsDf, tempResultsDf])

resultsDf = resultsDf[['Model', 'Train\_Accuracy','Test\_Accuracy']]

resultsDf



### Save model for future use

vgg\_model.save('./vgg.h5')

vgg\_model.save\_weights('./vgg\_weights.h5')

### ResNet50 (without multiple layers)

### Creating the model

resnet\_conv = ResNet50(weights='imagenet', include\_top=False, input\_shape=(224,224,3))

# Freeze all the layers except for the last layer:

for layer in resnet\_conv.layers:

    layer.trainable = False

x2 = Flatten()(resnet\_conv.output)

x2 = Dense(197, activation='sigmoid')(x2)

resnet = Model(resnet\_conv.input, x2)

### Summary of model

resnet.summary()

Model: "model\_4"

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Layer (type) Output Shape Param # Connected to

==================================================================================================

input\_5 (InputLayer) [(None, 224, 224, 3) 0

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conv1\_pad (ZeroPadding2D) (None, 230, 230, 3) 0 input\_5[0][0]

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conv1\_conv (Conv2D) (None, 112, 112, 64) 9472 conv1\_pad[0][0]

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conv1\_bn (BatchNormalization) (None, 112, 112, 64) 256 conv1\_conv[0][0]

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conv1\_relu (Activation) (None, 112, 112, 64) 0 conv1\_bn[0][0]

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pool1\_pad (ZeroPadding2D) (None, 114, 114, 64) 0 conv1\_relu[0][0]

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pool1\_pool (MaxPooling2D) (None, 56, 56, 64) 0 pool1\_pad[0][0]

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conv2\_block1\_1\_conv (Conv2D) (None, 56, 56, 64) 4160 pool1\_pool[0][0]

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conv2\_block1\_1\_bn (BatchNormali (None, 56, 56, 64) 256 conv2\_block1\_1\_conv[0][0]

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conv2\_block1\_1\_relu (Activation (None, 56, 56, 64) 0 conv2\_block1\_1\_bn[0][0]

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conv2\_block1\_2\_conv (Conv2D) (None, 56, 56, 64) 36928 conv2\_block1\_1\_relu[0][0]

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conv2\_block1\_2\_bn (BatchNormali (None, 56, 56, 64) 256 conv2\_block1\_2\_conv[0][0]

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conv2\_block1\_2\_relu (Activation (None, 56, 56, 64) 0 conv2\_block1\_2\_bn[0][0]

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conv2\_block1\_0\_conv (Conv2D) (None, 56, 56, 256) 16640 pool1\_pool[0][0]

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conv2\_block1\_3\_conv (Conv2D) (None, 56, 56, 256) 16640 conv2\_block1\_2\_relu[0][0]

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conv2\_block1\_0\_bn (BatchNormali (None, 56, 56, 256) 1024 conv2\_block1\_0\_conv[0][0]

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conv2\_block1\_3\_bn (BatchNormali (None, 56, 56, 256) 1024 conv2\_block1\_3\_conv[0][0]

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conv2\_block1\_add (Add) (None, 56, 56, 256) 0 conv2\_block1\_0\_bn[0][0]

conv2\_block1\_3\_bn[0][0]

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conv2\_block1\_out (Activation) (None, 56, 56, 256) 0 conv2\_block1\_add[0][0]

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conv2\_block2\_1\_conv (Conv2D) (None, 56, 56, 64) 16448 conv2\_block1\_out[0][0]

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conv2\_block2\_1\_bn (BatchNormali (None, 56, 56, 64) 256 conv2\_block2\_1\_conv[0][0]

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conv2\_block2\_1\_relu (Activation (None, 56, 56, 64) 0 conv2\_block2\_1\_bn[0][0]

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conv2\_block2\_2\_conv (Conv2D) (None, 56, 56, 64) 36928 conv2\_block2\_1\_relu[0][0]

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conv2\_block2\_2\_bn (BatchNormali (None, 56, 56, 64) 256 conv2\_block2\_2\_conv[0][0]

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conv2\_block2\_2\_relu (Activation (None, 56, 56, 64) 0 conv2\_block2\_2\_bn[0][0]

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conv2\_block2\_3\_conv (Conv2D) (None, 56, 56, 256) 16640 conv2\_block2\_2\_relu[0][0]

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conv2\_block2\_3\_bn (BatchNormali (None, 56, 56, 256) 1024 conv2\_block2\_3\_conv[0][0]

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conv2\_block2\_add (Add) (None, 56, 56, 256) 0 conv2\_block1\_out[0][0]

conv2\_block2\_3\_bn[0][0]

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conv2\_block2\_out (Activation) (None, 56, 56, 256) 0 conv2\_block2\_add[0][0]

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conv2\_block3\_1\_conv (Conv2D) (None, 56, 56, 64) 16448 conv2\_block2\_out[0][0]

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conv2\_block3\_1\_bn (BatchNormali (None, 56, 56, 64) 256 conv2\_block3\_1\_conv[0][0]

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conv2\_block3\_1\_relu (Activation (None, 56, 56, 64) 0 conv2\_block3\_1\_bn[0][0]

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conv2\_block3\_2\_conv (Conv2D) (None, 56, 56, 64) 36928 conv2\_block3\_1\_relu[0][0]

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conv2\_block3\_2\_bn (BatchNormali (None, 56, 56, 64) 256 conv2\_block3\_2\_conv[0][0]

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conv2\_block3\_2\_relu (Activation (None, 56, 56, 64) 0 conv2\_block3\_2\_bn[0][0]

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conv2\_block3\_3\_conv (Conv2D) (None, 56, 56, 256) 16640 conv2\_block3\_2\_relu[0][0]

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conv2\_block3\_3\_bn (BatchNormali (None, 56, 56, 256) 1024 conv2\_block3\_3\_conv[0][0]

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conv2\_block3\_add (Add) (None, 56, 56, 256) 0 conv2\_block2\_out[0][0]

conv2\_block3\_3\_bn[0][0]

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conv2\_block3\_out (Activation) (None, 56, 56, 256) 0 conv2\_block3\_add[0][0]

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conv3\_block1\_1\_conv (Conv2D) (None, 28, 28, 128) 32896 conv2\_block3\_out[0][0]

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conv3\_block1\_1\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block1\_1\_conv[0][0]

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conv3\_block1\_1\_relu (Activation (None, 28, 28, 128) 0 conv3\_block1\_1\_bn[0][0]

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conv3\_block1\_2\_conv (Conv2D) (None, 28, 28, 128) 147584 conv3\_block1\_1\_relu[0][0]

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conv3\_block1\_2\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block1\_2\_conv[0][0]

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conv3\_block1\_2\_relu (Activation (None, 28, 28, 128) 0 conv3\_block1\_2\_bn[0][0]

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conv3\_block1\_0\_conv (Conv2D) (None, 28, 28, 512) 131584 conv2\_block3\_out[0][0]

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conv3\_block1\_3\_conv (Conv2D) (None, 28, 28, 512) 66048 conv3\_block1\_2\_relu[0][0]

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conv3\_block1\_0\_bn (BatchNormali (None, 28, 28, 512) 2048 conv3\_block1\_0\_conv[0][0]

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conv3\_block1\_3\_bn (BatchNormali (None, 28, 28, 512) 2048 conv3\_block1\_3\_conv[0][0]

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conv3\_block1\_add (Add) (None, 28, 28, 512) 0 conv3\_block1\_0\_bn[0][0]

conv3\_block1\_3\_bn[0][0]

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conv3\_block1\_out (Activation) (None, 28, 28, 512) 0 conv3\_block1\_add[0][0]

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conv3\_block2\_1\_conv (Conv2D) (None, 28, 28, 128) 65664 conv3\_block1\_out[0][0]

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conv3\_block2\_1\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block2\_1\_conv[0][0]

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conv3\_block2\_1\_relu (Activation (None, 28, 28, 128) 0 conv3\_block2\_1\_bn[0][0]

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conv3\_block2\_2\_conv (Conv2D) (None, 28, 28, 128) 147584 conv3\_block2\_1\_relu[0][0]

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conv3\_block2\_2\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block2\_2\_conv[0][0]

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conv3\_block2\_2\_relu (Activation (None, 28, 28, 128) 0 conv3\_block2\_2\_bn[0][0]

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conv3\_block2\_3\_conv (Conv2D) (None, 28, 28, 512) 66048 conv3\_block2\_2\_relu[0][0]

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conv3\_block2\_3\_bn (BatchNormali (None, 28, 28, 512) 2048 conv3\_block2\_3\_conv[0][0]

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conv3\_block2\_add (Add) (None, 28, 28, 512) 0 conv3\_block1\_out[0][0]

conv3\_block2\_3\_bn[0][0]

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conv3\_block2\_out (Activation) (None, 28, 28, 512) 0 conv3\_block2\_add[0][0]

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conv3\_block3\_1\_conv (Conv2D) (None, 28, 28, 128) 65664 conv3\_block2\_out[0][0]

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conv3\_block3\_1\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block3\_1\_conv[0][0]

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conv3\_block3\_1\_relu (Activation (None, 28, 28, 128) 0 conv3\_block3\_1\_bn[0][0]

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conv3\_block3\_2\_conv (Conv2D) (None, 28, 28, 128) 147584 conv3\_block3\_1\_relu[0][0]

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conv3\_block3\_2\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block3\_2\_conv[0][0]

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conv3\_block3\_2\_relu (Activation (None, 28, 28, 128) 0 conv3\_block3\_2\_bn[0][0]

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conv3\_block3\_3\_conv (Conv2D) (None, 28, 28, 512) 66048 conv3\_block3\_2\_relu[0][0]

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conv3\_block3\_3\_bn (BatchNormali (None, 28, 28, 512) 2048 conv3\_block3\_3\_conv[0][0]

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conv3\_block3\_add (Add) (None, 28, 28, 512) 0 conv3\_block2\_out[0][0]

conv3\_block3\_3\_bn[0][0]

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conv3\_block3\_out (Activation) (None, 28, 28, 512) 0 conv3\_block3\_add[0][0]

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conv3\_block4\_1\_conv (Conv2D) (None, 28, 28, 128) 65664 conv3\_block3\_out[0][0]

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conv3\_block4\_1\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block4\_1\_conv[0][0]

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conv3\_block4\_1\_relu (Activation (None, 28, 28, 128) 0 conv3\_block4\_1\_bn[0][0]

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conv3\_block4\_2\_conv (Conv2D) (None, 28, 28, 128) 147584 conv3\_block4\_1\_relu[0][0]

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conv3\_block4\_2\_bn (BatchNormali (None, 28, 28, 128) 512 conv3\_block4\_2\_conv[0][0]

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conv3\_block4\_2\_relu (Activation (None, 28, 28, 128) 0 conv3\_block4\_2\_bn[0][0]

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conv3\_block4\_3\_conv (Conv2D) (None, 28, 28, 512) 66048 conv3\_block4\_2\_relu[0][0]

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conv3\_block4\_3\_bn (BatchNormali (None, 28, 28, 512) 2048 conv3\_block4\_3\_conv[0][0]

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conv3\_block4\_add (Add) (None, 28, 28, 512) 0 conv3\_block3\_out[0][0]

conv3\_block4\_3\_bn[0][0]

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conv3\_block4\_out (Activation) (None, 28, 28, 512) 0 conv3\_block4\_add[0][0]

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conv4\_block1\_1\_conv (Conv2D) (None, 14, 14, 256) 131328 conv3\_block4\_out[0][0]

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conv4\_block1\_1\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block1\_1\_conv[0][0]

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conv4\_block1\_1\_relu (Activation (None, 14, 14, 256) 0 conv4\_block1\_1\_bn[0][0]

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conv4\_block1\_2\_conv (Conv2D) (None, 14, 14, 256) 590080 conv4\_block1\_1\_relu[0][0]

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conv4\_block1\_2\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block1\_2\_conv[0][0]

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conv4\_block1\_2\_relu (Activation (None, 14, 14, 256) 0 conv4\_block1\_2\_bn[0][0]

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conv4\_block1\_0\_conv (Conv2D) (None, 14, 14, 1024) 525312 conv3\_block4\_out[0][0]

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conv4\_block1\_3\_conv (Conv2D) (None, 14, 14, 1024) 263168 conv4\_block1\_2\_relu[0][0]

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conv4\_block1\_0\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block1\_0\_conv[0][0]

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conv4\_block1\_3\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block1\_3\_conv[0][0]

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conv4\_block1\_add (Add) (None, 14, 14, 1024) 0 conv4\_block1\_0\_bn[0][0]

conv4\_block1\_3\_bn[0][0]

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conv4\_block1\_out (Activation) (None, 14, 14, 1024) 0 conv4\_block1\_add[0][0]

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conv4\_block2\_1\_conv (Conv2D) (None, 14, 14, 256) 262400 conv4\_block1\_out[0][0]

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conv4\_block2\_1\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block2\_1\_conv[0][0]

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conv4\_block2\_1\_relu (Activation (None, 14, 14, 256) 0 conv4\_block2\_1\_bn[0][0]

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conv4\_block2\_2\_conv (Conv2D) (None, 14, 14, 256) 590080 conv4\_block2\_1\_relu[0][0]

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conv4\_block2\_2\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block2\_2\_conv[0][0]

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conv4\_block2\_2\_relu (Activation (None, 14, 14, 256) 0 conv4\_block2\_2\_bn[0][0]

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conv4\_block2\_3\_conv (Conv2D) (None, 14, 14, 1024) 263168 conv4\_block2\_2\_relu[0][0]

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conv4\_block2\_3\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block2\_3\_conv[0][0]

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conv4\_block2\_add (Add) (None, 14, 14, 1024) 0 conv4\_block1\_out[0][0]

conv4\_block2\_3\_bn[0][0]

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conv4\_block2\_out (Activation) (None, 14, 14, 1024) 0 conv4\_block2\_add[0][0]

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conv4\_block3\_1\_conv (Conv2D) (None, 14, 14, 256) 262400 conv4\_block2\_out[0][0]

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conv4\_block3\_1\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block3\_1\_conv[0][0]

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conv4\_block3\_1\_relu (Activation (None, 14, 14, 256) 0 conv4\_block3\_1\_bn[0][0]

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conv4\_block3\_2\_conv (Conv2D) (None, 14, 14, 256) 590080 conv4\_block3\_1\_relu[0][0]

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conv4\_block3\_2\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block3\_2\_conv[0][0]

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conv4\_block3\_2\_relu (Activation (None, 14, 14, 256) 0 conv4\_block3\_2\_bn[0][0]

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conv4\_block3\_3\_conv (Conv2D) (None, 14, 14, 1024) 263168 conv4\_block3\_2\_relu[0][0]

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conv4\_block3\_3\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block3\_3\_conv[0][0]

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conv4\_block3\_add (Add) (None, 14, 14, 1024) 0 conv4\_block2\_out[0][0]

conv4\_block3\_3\_bn[0][0]

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conv4\_block3\_out (Activation) (None, 14, 14, 1024) 0 conv4\_block3\_add[0][0]

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conv4\_block4\_1\_conv (Conv2D) (None, 14, 14, 256) 262400 conv4\_block3\_out[0][0]

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conv4\_block4\_1\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block4\_1\_conv[0][0]

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conv4\_block4\_1\_relu (Activation (None, 14, 14, 256) 0 conv4\_block4\_1\_bn[0][0]

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conv4\_block4\_2\_conv (Conv2D) (None, 14, 14, 256) 590080 conv4\_block4\_1\_relu[0][0]

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conv4\_block4\_2\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block4\_2\_conv[0][0]

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conv4\_block4\_2\_relu (Activation (None, 14, 14, 256) 0 conv4\_block4\_2\_bn[0][0]

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conv4\_block4\_3\_conv (Conv2D) (None, 14, 14, 1024) 263168 conv4\_block4\_2\_relu[0][0]

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conv4\_block4\_3\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block4\_3\_conv[0][0]

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conv4\_block4\_add (Add) (None, 14, 14, 1024) 0 conv4\_block3\_out[0][0]

conv4\_block4\_3\_bn[0][0]

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conv4\_block4\_out (Activation) (None, 14, 14, 1024) 0 conv4\_block4\_add[0][0]

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conv4\_block5\_1\_conv (Conv2D) (None, 14, 14, 256) 262400 conv4\_block4\_out[0][0]

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conv4\_block5\_1\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block5\_1\_conv[0][0]

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conv4\_block5\_1\_relu (Activation (None, 14, 14, 256) 0 conv4\_block5\_1\_bn[0][0]

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conv4\_block5\_2\_conv (Conv2D) (None, 14, 14, 256) 590080 conv4\_block5\_1\_relu[0][0]

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conv4\_block5\_2\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block5\_2\_conv[0][0]

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conv4\_block5\_2\_relu (Activation (None, 14, 14, 256) 0 conv4\_block5\_2\_bn[0][0]

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conv4\_block5\_3\_conv (Conv2D) (None, 14, 14, 1024) 263168 conv4\_block5\_2\_relu[0][0]

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conv4\_block5\_3\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block5\_3\_conv[0][0]

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conv4\_block5\_add (Add) (None, 14, 14, 1024) 0 conv4\_block4\_out[0][0]

conv4\_block5\_3\_bn[0][0]

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conv4\_block5\_out (Activation) (None, 14, 14, 1024) 0 conv4\_block5\_add[0][0]

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conv4\_block6\_1\_conv (Conv2D) (None, 14, 14, 256) 262400 conv4\_block5\_out[0][0]

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conv4\_block6\_1\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block6\_1\_conv[0][0]

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conv4\_block6\_1\_relu (Activation (None, 14, 14, 256) 0 conv4\_block6\_1\_bn[0][0]

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conv4\_block6\_2\_conv (Conv2D) (None, 14, 14, 256) 590080 conv4\_block6\_1\_relu[0][0]

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conv4\_block6\_2\_bn (BatchNormali (None, 14, 14, 256) 1024 conv4\_block6\_2\_conv[0][0]

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conv4\_block6\_2\_relu (Activation (None, 14, 14, 256) 0 conv4\_block6\_2\_bn[0][0]

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conv4\_block6\_3\_conv (Conv2D) (None, 14, 14, 1024) 263168 conv4\_block6\_2\_relu[0][0]

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conv4\_block6\_3\_bn (BatchNormali (None, 14, 14, 1024) 4096 conv4\_block6\_3\_conv[0][0]

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conv4\_block6\_add (Add) (None, 14, 14, 1024) 0 conv4\_block5\_out[0][0]

conv4\_block6\_3\_bn[0][0]

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conv4\_block6\_out (Activation) (None, 14, 14, 1024) 0 conv4\_block6\_add[0][0]

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conv5\_block1\_1\_conv (Conv2D) (None, 7, 7, 512) 524800 conv4\_block6\_out[0][0]

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conv5\_block1\_1\_bn (BatchNormali (None, 7, 7, 512) 2048 conv5\_block1\_1\_conv[0][0]

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conv5\_block1\_1\_relu (Activation (None, 7, 7, 512) 0 conv5\_block1\_1\_bn[0][0]

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conv5\_block1\_2\_conv (Conv2D) (None, 7, 7, 512) 2359808 conv5\_block1\_1\_relu[0][0]

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conv5\_block1\_2\_bn (BatchNormali (None, 7, 7, 512) 2048 conv5\_block1\_2\_conv[0][0]

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conv5\_block1\_2\_relu (Activation (None, 7, 7, 512) 0 conv5\_block1\_2\_bn[0][0]

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conv5\_block1\_0\_conv (Conv2D) (None, 7, 7, 2048) 2099200 conv4\_block6\_out[0][0]

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conv5\_block1\_3\_conv (Conv2D) (None, 7, 7, 2048) 1050624 conv5\_block1\_2\_relu[0][0]

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conv5\_block1\_0\_bn (BatchNormali (None, 7, 7, 2048) 8192 conv5\_block1\_0\_conv[0][0]

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conv5\_block1\_3\_bn (BatchNormali (None, 7, 7, 2048) 8192 conv5\_block1\_3\_conv[0][0]

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conv5\_block1\_add (Add) (None, 7, 7, 2048) 0 conv5\_block1\_0\_bn[0][0]

conv5\_block1\_3\_bn[0][0]

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conv5\_block1\_out (Activation) (None, 7, 7, 2048) 0 conv5\_block1\_add[0][0]

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conv5\_block2\_1\_conv (Conv2D) (None, 7, 7, 512) 1049088 conv5\_block1\_out[0][0]

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conv5\_block2\_1\_bn (BatchNormali (None, 7, 7, 512) 2048 conv5\_block2\_1\_conv[0][0]

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conv5\_block2\_1\_relu (Activation (None, 7, 7, 512) 0 conv5\_block2\_1\_bn[0][0]

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conv5\_block2\_2\_conv (Conv2D) (None, 7, 7, 512) 2359808 conv5\_block2\_1\_relu[0][0]

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conv5\_block2\_2\_bn (BatchNormali (None, 7, 7, 512) 2048 conv5\_block2\_2\_conv[0][0]

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conv5\_block2\_2\_relu (Activation (None, 7, 7, 512) 0 conv5\_block2\_2\_bn[0][0]

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conv5\_block2\_3\_conv (Conv2D) (None, 7, 7, 2048) 1050624 conv5\_block2\_2\_relu[0][0]

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conv5\_block2\_3\_bn (BatchNormali (None, 7, 7, 2048) 8192 conv5\_block2\_3\_conv[0][0]

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conv5\_block2\_add (Add) (None, 7, 7, 2048) 0 conv5\_block1\_out[0][0]

conv5\_block2\_3\_bn[0][0]

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conv5\_block2\_out (Activation) (None, 7, 7, 2048) 0 conv5\_block2\_add[0][0]

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conv5\_block3\_1\_conv (Conv2D) (None, 7, 7, 512) 1049088 conv5\_block2\_out[0][0]

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conv5\_block3\_1\_bn (BatchNormali (None, 7, 7, 512) 2048 conv5\_block3\_1\_conv[0][0]

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conv5\_block3\_1\_relu (Activation (None, 7, 7, 512) 0 conv5\_block3\_1\_bn[0][0]

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conv5\_block3\_2\_conv (Conv2D) (None, 7, 7, 512) 2359808 conv5\_block3\_1\_relu[0][0]

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conv5\_block3\_2\_bn (BatchNormali (None, 7, 7, 512) 2048 conv5\_block3\_2\_conv[0][0]

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conv5\_block3\_2\_relu (Activation (None, 7, 7, 512) 0 conv5\_block3\_2\_bn[0][0]

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conv5\_block3\_3\_conv (Conv2D) (None, 7, 7, 2048) 1050624 conv5\_block3\_2\_relu[0][0]

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conv5\_block3\_3\_bn (BatchNormali (None, 7, 7, 2048) 8192 conv5\_block3\_3\_conv[0][0]

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conv5\_block3\_add (Add) (None, 7, 7, 2048) 0 conv5\_block2\_out[0][0]

conv5\_block3\_3\_bn[0][0]

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conv5\_block3\_out (Activation) (None, 7, 7, 2048) 0 conv5\_block3\_add[0][0]

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flatten\_5 (Flatten) (None, 100352) 0 conv5\_block3\_out[0][0]

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dense\_14 (Dense) (None, 197) 19769541 flatten\_5[0][0]

==================================================================================================

Total params: 43,357,253

Trainable params: 19,769,541

Non-trainable params: 23,587,712

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

### Training [Forward pass and Backpropagation]

#Compile with optimizer

resnet.compile(optimizer = Adam(learning\_rate=0.001), loss = 'categorical\_crossentropy', metrics = ['accuracy'])

early = EarlyStopping(monitor='val\_accuracy',min\_delta=0.01,patience=2,verbose=1,mode='auto')

#Training

resnet\_classifier = resnet.fit\_generator(train\_generator,epochs =30, validation\_data = validation\_generator, callbacks = [early]  )

**Epoch 1/30**

**255/255 [==============================] - 188s 726ms/step - loss: 25.5408 - accuracy: 0.0128 - val\_loss: 14.5744 - val\_accuracy: 0.0285**

**Epoch 2/30**

**255/255 [==============================] - 182s 716ms/step - loss: 13.3197 - accuracy: 0.0379 - val\_loss: 14.4397 - val\_accuracy: 0.0420**

**Epoch 3/30**

**255/255 [==============================] - 183s 718ms/step - loss: 12.8443 - accuracy: 0.0561 - val\_loss: 13.0493 - val\_accuracy: 0.0451**

**Epoch 4/30**

**255/255 [==============================] - 183s 718ms/step - loss: 12.7389 - accuracy: 0.0697 - val\_loss: 15.5320 - val\_accuracy: 0.0428**

**Epoch 00004: early stopping**

### Plot Accuracy and Loss

train\_loss = resnet\_classifier.history['loss']

val\_loss   = resnet\_classifier.history['val\_loss']

xc = resnet\_classifier.epoch

plt.title("Accuracy ValAccuracy Vs NumEpochs CNN")

plt.plot(xc,resnet\_classifier.history['accuracy'], label='train')

plt.plot(xc,resnet\_classifier.history['val\_accuracy'], label='test')

plt.legend()

plt.show()

plt.figure()

plt.title("Loss ValLoss Vs NumEpochs CNN")

plt.plot(xc, train\_loss,label='train')

plt.plot(xc, val\_loss,label='test')

plt.legend()

plt.show

### 

### As seen in the graph, training set accuracy continue to increase with each epoch. However, validation set accuracy doesn’t change after few epochs.

### 

### As seen above, training dataset loss shows a sharp drop after initial few epochs and then becomes constant. Validation dataset loss shows a marginal drop after few epochs and then starts to increase again.

### Evaluation

train\_acc = resnet.evaluate\_generator(train\_generator,steps = int(train\_generator.samples/BATCH\_SIZE))

val\_acc = resnet.evaluate\_generator(validation\_generator, steps = int(validation\_generator.samples/BATCH\_SIZE))

print(train\_acc[1])

print(val\_acc[1])

**0.07221949100494385**

**0.04282868653535843**

As seen, this model gives a very low training and validation accuracy of 7% and 4% respectively.

### Adding result to dataframe for comparison

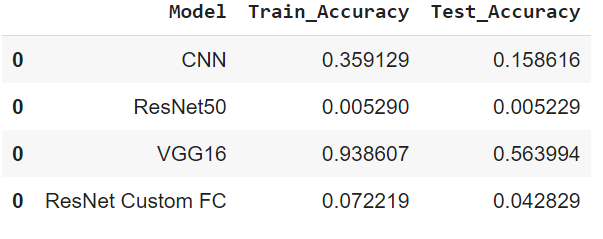
#Adding Performance metrics of Custom ResNet50 to the list

tempResultsDf = pd.DataFrame({'Model':['ResNet Custom FC'],  'Train\_Accuracy': train\_acc[1],'Test\_Accuracy': val\_acc[1]})

resultsDf = pd.concat([resultsDf, tempResultsDf])

resultsDf = resultsDf[['Model', 'Train\_Accuracy','Test\_Accuracy']]

resultsDf



1. **Save model for future use**

resnet.save('./resnet.h5')

resnet.save\_weights('./resnet\_weights.h5')

### InceptionResNetV2

### Creating the model

base\_model = InceptionResNetV2(include\_top=False, input\_shape = INPUT\_SIZE)

**Downloading data from** [**https://storage.googleapis.com/tensorflow/keras-applications/inception\_resnet\_v2/inception\_resnet\_v2\_weights\_tf\_dim\_ordering\_tf\_kernels\_notop.h5**](https://storage.googleapis.com/tensorflow/keras-applications/inception_resnet_v2/inception_resnet_v2_weights_tf_dim_ordering_tf_kernels_notop.h5)

**219062272/219055592 [==============================] - 2s 0us/step**

**219070464/219055592 [==============================] - 2s 0us/step**

classification\_model = tf.keras.Sequential([

    base\_model,

    tf.keras.layers.GlobalAveragePooling2D(),

    tf.keras.layers.Dense(128, activation='relu'),

    tf.keras.layers.BatchNormalization(),

    tf.keras.layers.Dropout(0.2),

    tf.keras.layers.Dense(197, activation='softmax')

])

### Summary of model

classification\_model.summary()

Model: "sequential\_1"

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Layer (type) Output Shape Param #

=================================================================

inception\_resnet\_v2 (Functio (None, 5, 5, 1536) 54336736

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

global\_average\_pooling2d (Gl (None, 1536) 0

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dense\_15 (Dense) (None, 128) 196736

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batch\_normalization\_203 (Bat (None, 128) 512

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dropout\_1 (Dropout) (None, 128) 0

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

dense\_16 (Dense) (None, 197) 25413

=================================================================

Total params: 54,559,397

Trainable params: 54,498,597

Non-trainable params: 60,800

1. **Define optimizer**

lr=0.001

classification\_model.compile(loss='categorical\_crossentropy', optimizer=Adam(lr=lr), metrics=['accuracy'])

1. **Early stopping and Model Checkpoint**

patience = 1

stop\_patience = 3

factor = 0.5

callbacks = [

    tf.keras.callbacks.ModelCheckpoint("classify\_model.h5", save\_best\_only=True, verbose = 0),

    tf.keras.callbacks.EarlyStopping(patience=stop\_patience, monitor='val\_loss', verbose=1),

    tf.keras.callbacks.ReduceLROnPlateau(monitor='val\_loss', factor=factor, patience=patience, verbose=1)

]

### Training [Forward pass and Backpropagation]

epochs = 30

history = classification\_model.fit(train\_generator, validation\_data=validation\_generator, epochs=epochs, callbacks=callbacks, verbose=1)

**Epoch 1/30**

**255/255 [==============================] - 219s 774ms/step - loss: 5.0064 - accuracy: 0.0424 - val\_loss: 4.8299 - val\_accuracy: 0.0622**

**Epoch 2/30**

**255/255 [==============================] - 193s 756ms/step - loss: 3.0798 - accuracy: 0.3256 - val\_loss: 3.7128 - val\_accuracy: 0.1919**

**Epoch 3/30**

**255/255 [==============================] - 192s 754ms/step - loss: 1.4914 - accuracy: 0.6661 - val\_loss: 1.6520 - val\_accuracy: 0.5869**

**Epoch 4/30**

**255/255 [==============================] - 193s 755ms/step - loss: 0.7913 - accuracy: 0.8196 - val\_loss: 1.7750 - val\_accuracy: 0.5655**

**Epoch 00004: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.**

**Epoch 5/30**

**255/255 [==============================] - 190s 745ms/step - loss: 0.3456 - accuracy: 0.9209 - val\_loss: 0.5200 - val\_accuracy: 0.8710**

**Epoch 6/30**

**255/255 [==============================] - 193s 753ms/step - loss: 0.2035 - accuracy: 0.9573 - val\_loss: 0.5306 - val\_accuracy: 0.8605**

**Epoch 00006: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.**

**Epoch 7/30**

**255/255 [==============================] - 191s 748ms/step - loss: 0.1194 - accuracy: 0.9773 - val\_loss: 0.3848 - val\_accuracy: 0.8965**

**Epoch 8/30**

**255/255 [==============================] - 193s 755ms/step - loss: 0.0785 - accuracy: 0.9877 - val\_loss: 0.3624 - val\_accuracy: 0.9042**

**Epoch 9/30**

**255/255 [==============================] - 193s 756ms/step - loss: 0.0683 - accuracy: 0.9882 - val\_loss: 0.3795 - val\_accuracy: 0.8957**

**Epoch 00009: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.**

**Epoch 10/30**

**161/255 [=================>............] - ETA: 50s - loss: 0.0471 - accuracy: 0.9930**

### Plot Accuracy and Loss for Training and Validation

train\_loss = history.history['loss']

val\_loss   = history.history['val\_loss']

xc = history.epoch

plt.title("Accuracy ValAccuracy Vs NumEpochs CNN")

plt.plot(xc,history.history['accuracy'], label='train')

plt.plot(xc,history.history['val\_accuracy'], label='test')

plt.legend()

plt.show()

plt.figure()

plt.title("Loss ValLoss Vs NumEpochs CNN")

plt.plot(xc, train\_loss,label='train')

plt.plot(xc, val\_loss,label='test')

plt.legend()

plt.show

### 

### As seen from the graph above, both training and validation accuracy continue to increase for initial epochs and then becomes constant after reaching near 100%. This shows that we could have probably trained model for lesser number of epochs.

### 

### As seen from the graph above, both training and validation loss continue to decrease for initial epochs and then becomes constant after reaching near 0. This shows that we could have probably trained model for lesser number of epochs.

### Evaluation

train\_acc = classification\_model.evaluate\_generator(train\_generator,steps = int(train\_generator.samples/BATCH\_SIZE))

val\_acc = classification\_model.evaluate\_generator(validation\_generator, steps = int(validation\_generator.samples/BATCH\_SIZE))

print(train\_acc[1])

print(val\_acc[1])

**0.9977854490280151**

**0.9172061681747437**

### Thus model works really great and shows a near perfect accuracy of 99.77% for training dataset, and very high accuracy of 91.7% for validation dataset.

### Adding result to dataframe for comparison

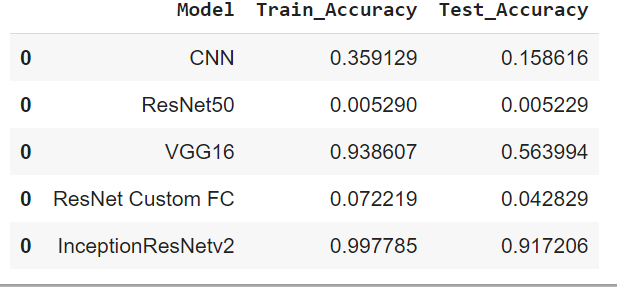
#Adding Performance metrics of InceptionResNetv2 to the list

tempResultsDf = pd.DataFrame({'Model':['InceptionResNetv2'],  'Train\_Accuracy': train\_acc[1],'Test\_Accuracy': val\_acc[1]})

resultsDf = pd.concat([resultsDf, tempResultsDf])

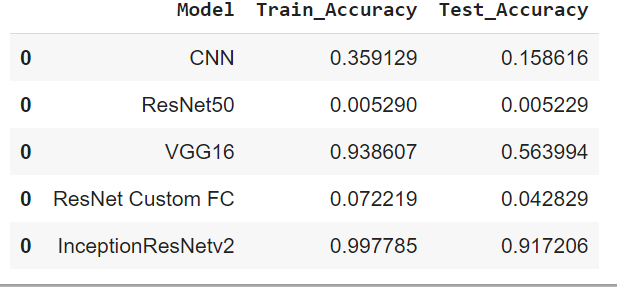
resultsDf = resultsDf[['Model', 'Train\_Accuracy','Test\_Accuracy']]

resultsDf



Comparing Models

resultsDf



**As seen from the table above, we tried different models for this classification problem.**

***InceptionResNetv2*gives the best accuracy. Therefore, it is our final selected model.**

final\_model = classification\_model

* **Pickle model for future use**

final\_model.save('./final\_model.h5')

Predictions

Let us use final model to predict some test car images

final\_model = keras.models.load\_model('final\_model.h5')

from google.colab import files

uploaded = files.upload()

**Saving test4.jpg to test4.jpg**

path = 'test1.jpg'

img = cv2.imread( path )

plt.grid(False)

plt.imshow(img)



from tensorflow.keras.utils import img\_to\_array, load\_img

import cv2

img = cv2.resize(img, (224,224),)

img.shape

**(224, 224, 3)**

pixels = img.astype('float32')

pixels /= 255.0

print(pixels.shape)

**(224, 224, 3)**

#Expanding the dimensions of the numpy array to match the dimension expected by

predict method

pixels = np.expand\_dims(pixels, axis=0)

print(pixels.shape)

**(1, 224, 224, 3)**

prediction = final\_model.predict(pixels)

prediction = np.argmax(prediction, axis = 1)

print(prediction)

**[135]**

predicted\_label = car\_names[car\_names['Class'] == prediction[0]]

print(predicted\_label)

**CarLabel Class**

**134 Hyundai Elantra Sedan 2007 135**

**Thus our model is able to make correct prediction.**

**Next Steps:**

For next milestone, we will work on following steps:

1. Try to fine tune our selected model to reduce variance.
2. Design a clickable UI which can automate tasks performed under milestone 1
3. Design a clickable UI which can automate tasks performed under milestone 2
4. Design a clickable UI based interface which can allow the user to browse & input the image, output the class and the bounding box or mask
5. Create final report

**Final Model Tuning**

For final model, we got training accuracy of 99.77% and validation accuracy of 91.72%. We tried different approaches to reduce variation.

1. Added L2 regularization

classification\_model = tf.keras.Sequential([

    base\_model,

    tf.keras.layers.GlobalAveragePooling2D(),

    tf.keras.layers.Dense(128, activation='relu', kernel\_regularizer='l2'),

    tf.keras.layers.BatchNormalization(),

    tf.keras.layers.Dropout(0.20),

    tf.keras.layers.Dense(197, activation='softmax')

])

**Epoch 1/20**

**255/255 [==============================] - 12463s 49s/step - loss: 5.7889 - accuracy: 0.0662 - val\_loss: 4.9012 - val\_accuracy: 0.0751**

**Epoch 2/20**

**255/255 [==============================] - 162s 635ms/step - loss: 3.0829 - accuracy: 0.3622 - val\_loss: 3.2536 - val\_accuracy: 0.3043**

**Epoch 3/20**

**255/255 [==============================] - 162s 633ms/step - loss: 1.7808 - accuracy: 0.6287 - val\_loss: 2.2073 - val\_accuracy: 0.5366**

**Epoch 4/20**

**255/255 [==============================] - 162s 634ms/step - loss: 1.1926 - accuracy: 0.7564 - val\_loss: 1.9011 - val\_accuracy: 0.5601**

**Epoch 5/20**

**255/255 [==============================] - 161s 631ms/step - loss: 0.8764 - accuracy: 0.8237 - val\_loss: 1.8182 - val\_accuracy: 0.5788**

**Epoch 6/20**

**255/255 [==============================] - 162s 633ms/step - loss: 0.7422 - accuracy: 0.8556 - val\_loss: 1.6738 - val\_accuracy: 0.6272**

**Epoch 7/20**

**255/255 [==============================] - 162s 634ms/step - loss: 0.6438 - accuracy: 0.8767 - val\_loss: 1.4621 - val\_accuracy: 0.6658**

**Epoch 8/20**

**255/255 [==============================] - 161s 631ms/step - loss: 0.5826 - accuracy: 0.8891 - val\_loss: 1.6377 - val\_accuracy: 0.6319**

**Epoch 00008: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.**

**Epoch 9/20**

**255/255 [==============================] - 160s 628ms/step - loss: 0.3303 - accuracy: 0.9486 - val\_loss: 0.6863 - val\_accuracy: 0.8447**

**Epoch 10/20**

**255/255 [==============================] - 161s 631ms/step - loss: 0.2142 - accuracy: 0.9650 - val\_loss: 0.6510 - val\_accuracy: 0.8450**

**Epoch 11/20**

**255/255 [==============================] - 161s 633ms/step - loss: 0.1775 - accuracy: 0.9730 - val\_loss: 0.7043 - val\_accuracy: 0.8402**

**Epoch 00011: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.**

**Epoch 12/20**

**255/255 [==============================] - 161s 629ms/step - loss: 0.1347 - accuracy: 0.9832 - val\_loss: 0.8370 - val\_accuracy: 0.8064**

**Epoch 00012: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.**

**Epoch 13/20**

**255/255 [==============================] - 160s 628ms/step - loss: 0.0857 - accuracy: 0.9912 - val\_loss: 0.3929 - val\_accuracy: 0.9052**

**Epoch 14/20**

**255/255 [==============================] - 162s 635ms/step - loss: 0.0709 - accuracy: 0.9930 - val\_loss: 0.3856 - val\_accuracy: 0.9072**

**Epoch 15/20**

**255/255 [==============================] - 162s 633ms/step - loss: 0.0605 - accuracy: 0.9932 - val\_loss: 0.4006 - val\_accuracy: 0.9032**

**Epoch 00015: ReduceLROnPlateau reducing learning rate to 6.25000029685907e-05.**

**Epoch 16/20**

**255/255 [==============================] - 160s 629ms/step - loss: 0.0483 - accuracy: 0.9958 - val\_loss: 0.3652 - val\_accuracy: 0.9111**

**Epoch 17/20**

**255/255 [==============================] - 163s 638ms/step - loss: 0.0440 - accuracy: 0.9958 - val\_loss: 0.3718 - val\_accuracy: 0.9092**

**Epoch 00017: ReduceLROnPlateau reducing learning rate to 3.125000148429535e-05.**

**Epoch 18/20**

**255/255 [==============================] - 161s 633ms/step - loss: 0.0387 - accuracy: 0.9963 - val\_loss: 0.3618 - val\_accuracy: 0.9113**

**Epoch 19/20**

**255/255 [==============================] - 162s 636ms/step - loss: 0.0336 - accuracy: 0.9974 - val\_loss: 0.3576 - val\_accuracy: 0.9133**

**Epoch 20/20**

**255/255 [==============================] - 162s 633ms/step - loss: 0.0337 - accuracy: 0.9968 - val\_loss: 0.3616 - val\_accuracy: 0.9124**

**Epoch 00020: ReduceLROnPlateau reducing learning rate to 1.5625000742147677e-05.**

**CodeText**

print(train\_acc[1])

print(val\_acc[1])

**0.998031497001648**

**0.9073705077171326**

1. Added 1 additional layer

classification\_model = tf.keras.Sequential([

    base\_model,

    tf.keras.layers.GlobalAveragePooling2D(),

    tf.keras.layers.Dense(256, activation='relu'),

    tf.keras.layers.Dense(128, activation='relu'),

    tf.keras.layers.BatchNormalization(),

    tf.keras.layers.Dropout(0.20),

    tf.keras.layers.Dense(197, activation='softmax')

])

**Epoch 1/20**

**255/255 [==============================] - 181s 650ms/step - loss: 1.8494 - accuracy: 0.7157 - val\_loss: 1.6354 - val\_accuracy: 0.7091**

**Epoch 2/20**

**255/255 [==============================] - 164s 641ms/step - loss: 0.4688 - accuracy: 0.9128 - val\_loss: 1.4693 - val\_accuracy: 0.6673**

**Epoch 3/20**

**255/255 [==============================] - 163s 640ms/step - loss: 0.3327 - accuracy: 0.9261 - val\_loss: 1.1654 - val\_accuracy: 0.7326**

**Epoch 4/20**

**255/255 [==============================] - 162s 635ms/step - loss: 0.2844 - accuracy: 0.9278 - val\_loss: 1.2723 - val\_accuracy: 0.7077**

**Epoch 00004: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.**

**Epoch 5/20**

**255/255 [==============================] - 160s 628ms/step - loss: 0.1142 - accuracy: 0.9691 - val\_loss: 0.4884 - val\_accuracy: 0.8800**

**Epoch 6/20**

**255/255 [==============================] - 161s 631ms/step - loss: 0.0572 - accuracy: 0.9872 - val\_loss: 0.4386 - val\_accuracy: 0.8929**

**Epoch 7/20**

**255/255 [==============================] - 161s 631ms/step - loss: 0.0561 - accuracy: 0.9851 - val\_loss: 0.4896 - val\_accuracy: 0.8857**

**Epoch 00007: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.**

**Epoch 8/20**

**255/255 [==============================] - 160s 627ms/step - loss: 0.0338 - accuracy: 0.9917 - val\_loss: 0.3944 - val\_accuracy: 0.9072**

**Epoch 9/20**

**255/255 [==============================] - 161s 631ms/step - loss: 0.0240 - accuracy: 0.9939 - val\_loss: 0.4032 - val\_accuracy: 0.9047**

**Epoch 00009: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.**

**Epoch 10/20**

**255/255 [==============================] - 160s 627ms/step - loss: 0.0202 - accuracy: 0.9956 - val\_loss: 0.3805 - val\_accuracy: 0.9107**

**Epoch 11/20**

**255/255 [==============================] - 161s 632ms/step - loss: 0.0148 - accuracy: 0.9967 - val\_loss: 0.3840 - val\_accuracy: 0.9108**

**Epoch 00011: ReduceLROnPlateau reducing learning rate to 6.25000029685907e-05.**

**Epoch 12/20**

**255/255 [==============================] - 160s 627ms/step - loss: 0.0134 - accuracy: 0.9968 - val\_loss: 0.3789 - val\_accuracy: 0.9138**

**Epoch 13/20**

**255/255 [==============================] - 162s 634ms/step - loss: 0.0141 - accuracy: 0.9966 - val\_loss: 0.3768 - val\_accuracy: 0.9139**

**Epoch 14/20**

**255/255 [==============================] - 162s 634ms/step - loss: 0.0122 - accuracy: 0.9969 - val\_loss: 0.3785 - val\_accuracy: 0.9159**

**Epoch 00014: ReduceLROnPlateau reducing learning rate to 3.125000148429535e-05.**

**Epoch 15/20**

**255/255 [==============================] - 160s 628ms/step - loss: 0.0112 - accuracy: 0.9972 - val\_loss: 0.3782 - val\_accuracy: 0.9152**

**Epoch 00015: ReduceLROnPlateau reducing learning rate to 1.5625000742147677e-05.**

**Epoch 16/20**

**255/255 [==============================] - 160s 629ms/step - loss: 0.0112 - accuracy: 0.9971 - val\_loss: 0.3782 - val\_accuracy: 0.9148**

**Epoch 00016: ReduceLROnPlateau reducing learning rate to 7.812500371073838e-06.**

**Epoch 00016: early stopping**

print(train\_acc[1])

print(val\_acc[1])

**0.9985235929489136**

**0.9147161245346069**

1. Added 2 additional layers

classification\_model = tf.keras.Sequential([

    base\_model,

    tf.keras.layers.GlobalAveragePooling2D(),

    tf.keras.layers.Dense(256, activation='relu'),

    tf.keras.layers.Dense(128, activation='relu'),

    tf.keras.layers.Dense(64, activation='relu'),

    tf.keras.layers.BatchNormalization(),

    tf.keras.layers.Dropout(0.20),

    tf.keras.layers.Dense(197, activation='softmax')

])

**Epoch 1/25**

**255/255 [==============================] - 190s 745ms/step - loss: 0.0982 - accuracy: 0.9819 - val\_loss: 0.3994 - val\_accuracy: 0.8879**

**Epoch 2/25**

**255/255 [==============================] - 190s 746ms/step - loss: 0.0859 - accuracy: 0.9866 - val\_loss: 0.3909 - val\_accuracy: 0.8964**

**Epoch 3/25**

**255/255 [==============================] - 191s 747ms/step - loss: 0.0760 - accuracy: 0.9888 - val\_loss: 0.4057 - val\_accuracy: 0.8889**

**Epoch 00003: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.**

**Epoch 4/25**

**255/255 [==============================] - 189s 739ms/step - loss: 0.0626 - accuracy: 0.9929 - val\_loss: 0.3721 - val\_accuracy: 0.8978**

**Epoch 5/25**

**255/255 [==============================] - 189s 742ms/step - loss: 0.0544 - accuracy: 0.9930 - val\_loss: 0.3717 - val\_accuracy: 0.8996**

**Epoch 6/25**

**255/255 [==============================] - 190s 742ms/step - loss: 0.0520 - accuracy: 0.9939 - val\_loss: 0.3848 - val\_accuracy: 0.8965**

**Epoch 00006: ReduceLROnPlateau reducing learning rate to 6.25000029685907e-05.**

**Epoch 7/25**

**255/255 [==============================] - 189s 741ms/step - loss: 0.0447 - accuracy: 0.9948 - val\_loss: 0.3703 - val\_accuracy: 0.8994**

**Epoch 8/25**

**255/255 [==============================] - 191s 747ms/step - loss: 0.0435 - accuracy: 0.9951 - val\_loss: 0.3731 - val\_accuracy: 0.8990**

**Epoch 00008: ReduceLROnPlateau reducing learning rate to 3.125000148429535e-05.**

**Epoch 9/25**

**255/255 [==============================] - 187s 735ms/step - loss: 0.0411 - accuracy: 0.9957 - val\_loss: 0.3665 - val\_accuracy: 0.8994**

**Epoch 10/25**

**255/255 [==============================] - 189s 742ms/step - loss: 0.0400 - accuracy: 0.9962 - val\_loss: 0.3626 - val\_accuracy: 0.9005**

**Epoch 11/25**

**255/255 [==============================] - 192s 754ms/step - loss: 0.0383 - accuracy: 0.9942 - val\_loss: 0.3633 - val\_accuracy: 0.9032**

**Epoch 00011: ReduceLROnPlateau reducing learning rate to 1.5625000742147677e-05.**

**Epoch 12/25**

**255/255 [==============================] - 190s 746ms/step - loss: 0.0361 - accuracy: 0.9962 - val\_loss: 0.3610 - val\_accuracy: 0.9015**

**Epoch 13/25**

**255/255 [==============================] - 191s 748ms/step - loss: 0.0321 - accuracy: 0.9972 - val\_loss: 0.3613 - val\_accuracy: 0.9014**

**Epoch 00013: ReduceLROnPlateau reducing learning rate to 7.812500371073838e-06.**

**Epoch 14/25**

**255/255 [==============================] - 189s 740ms/step - loss: 0.0338 - accuracy: 0.9972 - val\_loss: 0.3619 - val\_accuracy: 0.9014**

**Epoch 00014: ReduceLROnPlateau reducing learning rate to 3.906250185536919e-06.**

**Epoch 15/25**

**255/255 [==============================] - 188s 737ms/step - loss: 0.0320 - accuracy: 0.9967 - val\_loss: 0.3620 - val\_accuracy: 0.9016**

**Epoch 00015: ReduceLROnPlateau reducing learning rate to 1.9531250927684596e-06.**

**Epoch 00015: early stopping**

print(train\_acc[1])

print(val\_acc[1])

**0.9976624250411987**

**0.9016434550285339**

1. Added 1 additional layer after Batch Normalization

classification\_model = tf.keras.Sequential([

    base\_model,

    tf.keras.layers.GlobalAveragePooling2D(),

    tf.keras.layers.Dense(128, activation='relu'),

    tf.keras.layers.BatchNormalization(),

    tf.keras.layers.Dense(128, activation='relu'),

    tf.keras.layers.Dropout(0.20),

    tf.keras.layers.Dense(197, activation='softmax')

])

**Epoch 1/25**

**255/255 [==============================] - 212s 755ms/step - loss: 2.1494 - accuracy: 0.5803 - val\_loss: 1.3532 - val\_accuracy: 0.6718**

**Epoch 2/25**

**255/255 [==============================] - 191s 751ms/step - loss: 0.5785 - accuracy: 0.8374 - val\_loss: 1.2510 - val\_accuracy: 0.6851**

**Epoch 3/25**

**255/255 [==============================] - 190s 745ms/step - loss: 0.4462 - accuracy: 0.8680 - val\_loss: 0.9357 - val\_accuracy: 0.7510**

**Epoch 4/25**

**255/255 [==============================] - 190s 746ms/step - loss: 0.3684 - accuracy: 0.8867 - val\_loss: 1.0145 - val\_accuracy: 0.7447**

**Epoch 00004: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.**

**Epoch 5/25**

**255/255 [==============================] - 189s 740ms/step - loss: 0.1473 - accuracy: 0.9552 - val\_loss: 0.4592 - val\_accuracy: 0.8785**

**Epoch 6/25**

**255/255 [==============================] - 190s 745ms/step - loss: 0.1031 - accuracy: 0.9691 - val\_loss: 0.5824 - val\_accuracy: 0.8595**

**Epoch 00006: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.**

**Epoch 7/25**

**255/255 [==============================] - 189s 740ms/step - loss: 0.0659 - accuracy: 0.9810 - val\_loss: 0.4346 - val\_accuracy: 0.8896**

**Epoch 8/25**

**255/255 [==============================] - 190s 745ms/step - loss: 0.0525 - accuracy: 0.9853 - val\_loss: 0.4293 - val\_accuracy: 0.8947**

**Epoch 9/25**

**255/255 [==============================] - 190s 746ms/step - loss: 0.0439 - accuracy: 0.9896 - val\_loss: 0.4344 - val\_accuracy: 0.8938**

**Epoch 00009: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.**

**Epoch 10/25**

**255/255 [==============================] - 191s 748ms/step - loss: 0.0304 - accuracy: 0.9924 - val\_loss: 0.4108 - val\_accuracy: 0.8989**

**Epoch 11/25**

**255/255 [==============================] - 191s 747ms/step - loss: 0.0302 - accuracy: 0.9932 - val\_loss: 0.4131 - val\_accuracy: 0.9004**

**Epoch 00011: ReduceLROnPlateau reducing learning rate to 6.25000029685907e-05.**

**Epoch 12/25**

**255/255 [==============================] - 190s 744ms/step - loss: 0.0263 - accuracy: 0.9942 - val\_loss: 0.4059 - val\_accuracy: 0.9032**

**Epoch 13/25**

**255/255 [==============================] - 192s 751ms/step - loss: 0.0252 - accuracy: 0.9941 - val\_loss: 0.4084 - val\_accuracy: 0.9036**

**Epoch 00013: ReduceLROnPlateau reducing learning rate to 3.125000148429535e-05.**

**Epoch 14/25**

**255/255 [==============================] - 189s 743ms/step - loss: 0.0223 - accuracy: 0.9942 - val\_loss: 0.4065 - val\_accuracy: 0.9051**

**Epoch 00014: ReduceLROnPlateau reducing learning rate to 1.5625000742147677e-05.**

**Epoch 15/25**

**255/255 [==============================] - 189s 741ms/step - loss: 0.0188 - accuracy: 0.9959 - val\_loss: 0.4067 - val\_accuracy: 0.9047**

**Epoch 00015: ReduceLROnPlateau reducing learning rate to 7.812500371073838e-06.**

**Epoch 00015: early stopping**

print(train\_acc[1])

print(val\_acc[1])

**0.9972932934761047**

**0.904631495475769**

1. Keep 1 layer and increase dropout to 25%

classification\_model = tf.keras.Sequential([

    base\_model,

    tf.keras.layers.GlobalAveragePooling2D(),

    tf.keras.layers.Dense(128, activation='relu'),

    tf.keras.layers.BatchNormalization(),

    tf.keras.layers.Dropout(0.25),

    tf.keras.layers.Dense(197, activation='softmax')

])

print(train\_acc[1])

print(val\_acc[1])

**0.9979084730148315**

**0.9109810590744019**

1. Keep 1 layer and decrease dropout to 15%

**Epoch 1/20**

**255/255 [==============================] - 214s 759ms/step - loss: 1.0674 - accuracy: 0.8652 - val\_loss: 1.1154 - val\_accuracy: 0.8023**

**Epoch 2/20**

**255/255 [==============================] - 189s 742ms/step - loss: 0.2601 - accuracy: 0.9494 - val\_loss: 0.9886 - val\_accuracy: 0.7881**

**Epoch 3/20**

**255/255 [==============================] - 189s 739ms/step - loss: 0.1824 - accuracy: 0.9637 - val\_loss: 0.9440 - val\_accuracy: 0.7969**

**Epoch 4/20**

**255/255 [==============================] - 189s 740ms/step - loss: 0.1481 - accuracy: 0.9677 - val\_loss: 0.8737 - val\_accuracy: 0.8028**

**Epoch 5/20**

**255/255 [==============================] - 188s 736ms/step - loss: 0.1312 - accuracy: 0.9686 - val\_loss: 1.0381 - val\_accuracy: 0.7796**

**Epoch 00005: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.**

**Epoch 6/20**

**255/255 [==============================] - 186s 728ms/step - loss: 0.0584 - accuracy: 0.9866 - val\_loss: 0.5209 - val\_accuracy: 0.8836**

**Epoch 7/20**

**255/255 [==============================] - 189s 741ms/step - loss: 0.0354 - accuracy: 0.9924 - val\_loss: 0.4613 - val\_accuracy: 0.8934**

**Epoch 8/20**

**255/255 [==============================] - 188s 738ms/step - loss: 0.0338 - accuracy: 0.9918 - val\_loss: 0.5103 - val\_accuracy: 0.8832**

**Epoch 00008: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.**

**Epoch 9/20**

**255/255 [==============================] - 186s 730ms/step - loss: 0.0221 - accuracy: 0.9951 - val\_loss: 0.4445 - val\_accuracy: 0.9013**

**Epoch 10/20**

**255/255 [==============================] - 189s 742ms/step - loss: 0.0158 - accuracy: 0.9952 - val\_loss: 0.4359 - val\_accuracy: 0.9004**

**Epoch 11/20**

**255/255 [==============================] - 190s 743ms/step - loss: 0.0123 - accuracy: 0.9974 - val\_loss: 0.4518 - val\_accuracy: 0.8974**

**Epoch 00011: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.**

**Epoch 12/20**

**255/255 [==============================] - 188s 735ms/step - loss: 0.0111 - accuracy: 0.9968 - val\_loss: 0.4405 - val\_accuracy: 0.9005**

**Epoch 00012: ReduceLROnPlateau reducing learning rate to 6.25000029685907e-05.**

**Epoch 13/20**

**255/255 [==============================] - 188s 739ms/step - loss: 0.0093 - accuracy: 0.9973 - val\_loss: 0.4349 - val\_accuracy: 0.9027**

**Epoch 14/20**

**255/255 [==============================] - 189s 742ms/step - loss: 0.0090 - accuracy: 0.9977 - val\_loss: 0.4347 - val\_accuracy: 0.9027**

**Epoch 15/20**

**255/255 [==============================] - 189s 741ms/step - loss: 0.0085 - accuracy: 0.9971 - val\_loss: 0.4355 - val\_accuracy: 0.9044**

**Epoch 00015: ReduceLROnPlateau reducing learning rate to 3.125000148429535e-05.**

**Epoch 16/20**

**255/255 [==============================] - 187s 733ms/step - loss: 0.0086 - accuracy: 0.9975 - val\_loss: 0.4333 - val\_accuracy: 0.9041**

**Epoch 17/20**

**255/255 [==============================] - 187s 730ms/step - loss: 0.0070 - accuracy: 0.9982 - val\_loss: 0.4330 - val\_accuracy: 0.9047**

**Epoch 18/20**

**255/255 [==============================] - 189s 737ms/step - loss: 0.0068 - accuracy: 0.9975 - val\_loss: 0.4335 - val\_accuracy: 0.9052**

**Epoch 00018: ReduceLROnPlateau reducing learning rate to 1.5625000742147677e-05.**

**Epoch 19/20**

**255/255 [==============================] - 187s 735ms/step - loss: 0.0074 - accuracy: 0.9975 - val\_loss: 0.4336 - val\_accuracy: 0.9052**

**Epoch 00019: ReduceLROnPlateau reducing learning rate to 7.812500371073838e-06.**

**Epoch 20/20**

**255/255 [==============================] - 190s 743ms/step - loss: 0.0059 - accuracy: 0.9982 - val\_loss: 0.4340 - val\_accuracy: 0.9051**

**Epoch 00020: ReduceLROnPlateau reducing learning rate to 3.906250185536919e-06.**

**Epoch 00020: early stopping**

print(train\_acc[1])

print(val\_acc[1])

**0.998031497001648**

**0.9050049781799316**

1. Keep 1 layer and decrease dropout to 15%

classification\_model = tf.keras.Sequential([

    base\_model,

    tf.keras.layers.GlobalAveragePooling2D(),

    tf.keras.layers.Dense(128, activation='relu'),

    tf.keras.layers.BatchNormalization(),

    tf.keras.layers.Dropout(0.15),

    tf.keras.layers.Dense(197, activation='softmax')

])

Epoch 1/20

255/255 [==============================] - 6167s 24s/step - loss: 4.6427 - accuracy: 0.0732 - val\_loss: 4.7016 - val\_accuracy: 0.0624

Epoch 2/20

255/255 [==============================] - 187s 731ms/step - loss: 2.6085 - accuracy: 0.4381 - val\_loss: 3.2084 - val\_accuracy: 0.2502

Epoch 3/20

255/255 [==============================] - 185s 724ms/step - loss: 1.2336 - accuracy: 0.7225 - val\_loss: 1.8304 - val\_accuracy: 0.5743

Epoch 4/20

255/255 [==============================] - 184s 723ms/step - loss: 0.6837 - accuracy: 0.8362 - val\_loss: 1.5504 - val\_accuracy: 0.6253

Epoch 5/20

255/255 [==============================] - 182s 714ms/step - loss: 0.4596 - accuracy: 0.8864 - val\_loss: 1.4041 - val\_accuracy: 0.6272

Epoch 6/20

255/255 [==============================] - 185s 725ms/step - loss: 0.3434 - accuracy: 0.9110 - val\_loss: 0.8972 - val\_accuracy: 0.7687

Epoch 7/20

255/255 [==============================] - 182s 715ms/step - loss: 0.2779 - accuracy: 0.9279 - val\_loss: 0.8614 - val\_accuracy: 0.7747

Epoch 8/20

255/255 [==============================] - 187s 732ms/step - loss: 0.2316 - accuracy: 0.9349 - val\_loss: 1.3778 - val\_accuracy: 0.6507

Epoch 00008: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.

Epoch 9/20

255/255 [==============================] - 184s 722ms/step - loss: 0.1083 - accuracy: 0.9725 - val\_loss: 0.4502 - val\_accuracy: 0.8785

Epoch 10/20

255/255 [==============================] - 187s 732ms/step - loss: 0.0624 - accuracy: 0.9861 - val\_loss: 0.3728 - val\_accuracy: 0.8948

Epoch 11/20

255/255 [==============================] - 189s 740ms/step - loss: 0.0505 - accuracy: 0.9889 - val\_loss: 0.4187 - val\_accuracy: 0.8917

Epoch 00011: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.

Epoch 12/20

255/255 [==============================] - 188s 735ms/step - loss: 0.0374 - accuracy: 0.9919 - val\_loss: 0.3541 - val\_accuracy: 0.9061

Epoch 13/20

255/255 [==============================] - 191s 749ms/step - loss: 0.0276 - accuracy: 0.9939 - val\_loss: 0.3443 - val\_accuracy: 0.9087

Epoch 14/20

255/255 [==============================] - 186s 730ms/step - loss: 0.0209 - accuracy: 0.9958 - val\_loss: 0.3580 - val\_accuracy: 0.9073

Epoch 00014: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.

Epoch 15/20

255/255 [==============================] - 188s 735ms/step - loss: 0.0231 - accuracy: 0.9948 - val\_loss: 0.3346 - val\_accuracy: 0.9141

Epoch 16/20

255/255 [==============================] - 187s 735ms/step - loss: 0.0170 - accuracy: 0.9963 - val\_loss: 0.3387 - val\_accuracy: 0.9147

Epoch 00016: ReduceLROnPlateau reducing learning rate to 6.25000029685907e-05.

Epoch 17/20

255/255 [==============================] - 190s 743ms/step - loss: 0.0159 - accuracy: 0.9971 - val\_loss: 0.3312 - val\_accuracy: 0.9168

Epoch 18/20

255/255 [==============================] - 186s 730ms/step - loss: 0.0126 - accuracy: 0.9975 - val\_loss: 0.3306 - val\_accuracy: 0.9154

Epoch 19/20

255/255 [==============================] - 185s 726ms/step - loss: 0.0123 - accuracy: 0.9975 - val\_loss: 0.3323 - val\_accuracy: 0.9151

Epoch 00019: ReduceLROnPlateau reducing learning rate to 3.125000148429535e-05.

Epoch 20/20

255/255 [==============================] - 185s 725ms/step - loss: 0.0103 - accuracy: 0.9975 - val\_loss: 0.3309 - val\_accuracy: 0.9152

Epoch 00020: ReduceLROnPlateau reducing learning rate to 1.5625000742147677e-05

print(train\_acc[1])

print(val\_acc[1])

**0.9986466765403748**

**0.9150896668434143**

1. Keep 1 layer with 256 neurons and 20% dropout

classification\_model = tf.keras.Sequential([

    base\_model,

    tf.keras.layers.GlobalAveragePooling2D(),

    tf.keras.layers.Dense(256, activation='relu'),

    tf.keras.layers.BatchNormalization(),

    tf.keras.layers.Dropout(0.20),

    tf.keras.layers.Dense(197, activation='softmax')

])

**Epoch 1/20**

**255/255 [==============================] - 209s 735ms/step - loss: 0.9082 - accuracy: 0.8531 - val\_loss: 1.2007 - val\_accuracy: 0.7589**

**Epoch 2/20**

**255/255 [==============================] - 186s 728ms/step - loss: 0.2712 - accuracy: 0.9416 - val\_loss: 2.2045 - val\_accuracy: 0.5580**

**Epoch 00002: ReduceLROnPlateau reducing learning rate to 0.0005000000237487257.**

**Epoch 3/20**

**255/255 [==============================] - 192s 754ms/step - loss: 0.0894 - accuracy: 0.9810 - val\_loss: 0.4741 - val\_accuracy: 0.8861**

**Epoch 4/20**

**255/255 [==============================] - 193s 759ms/step - loss: 0.0443 - accuracy: 0.9894 - val\_loss: 0.5016 - val\_accuracy: 0.8819**

**Epoch 00004: ReduceLROnPlateau reducing learning rate to 0.0002500000118743628.**

**Epoch 5/20**

**255/255 [==============================] - 194s 759ms/step - loss: 0.0305 - accuracy: 0.9937 - val\_loss: 0.4325 - val\_accuracy: 0.9036**

**Epoch 6/20**

**255/255 [==============================] - 194s 761ms/step - loss: 0.0269 - accuracy: 0.9937 - val\_loss: 0.4283 - val\_accuracy: 0.9011**

**Epoch 7/20**

**255/255 [==============================] - 193s 758ms/step - loss: 0.0200 - accuracy: 0.9959 - val\_loss: 0.4143 - val\_accuracy: 0.9060**

**Epoch 8/20**

**255/255 [==============================] - 189s 741ms/step - loss: 0.0209 - accuracy: 0.9952 - val\_loss: 0.4454 - val\_accuracy: 0.9021**

**Epoch 00008: ReduceLROnPlateau reducing learning rate to 0.0001250000059371814.**

**Epoch 9/20**

**255/255 [==============================] - 185s 725ms/step - loss: 0.0155 - accuracy: 0.9966 - val\_loss: 0.3985 - val\_accuracy: 0.9111**

**Epoch 10/20**

**255/255 [==============================] - 189s 741ms/step - loss: 0.0129 - accuracy: 0.9971 - val\_loss: 0.3972 - val\_accuracy: 0.9126**

**Epoch 11/20**

**255/255 [==============================] - 186s 728ms/step - loss: 0.0113 - accuracy: 0.9972 - val\_loss: 0.4021 - val\_accuracy: 0.9120**

**Epoch 00011: ReduceLROnPlateau reducing learning rate to 6.25000029685907e-05.**

**Epoch 12/20**

**255/255 [==============================] - 187s 735ms/step - loss: 0.0091 - accuracy: 0.9975 - val\_loss: 0.3997 - val\_accuracy: 0.9118**

**Epoch 00012: ReduceLROnPlateau reducing learning rate to 3.125000148429535e-05.**

**Epoch 13/20**

**255/255 [==============================] - 185s 724ms/step - loss: 0.0086 - accuracy: 0.9972 - val\_loss: 0.3986 - val\_accuracy: 0.9131**

**Epoch 00013: ReduceLROnPlateau reducing learning rate to 1.5625000742147677e-05.**

**Epoch 00013: early stopping**

print(train\_acc[1])

print(val\_acc[1])

**0.9976624250411987**

**0.9129731059074402**

**Thus, maximum validation accuracy that we could extract from this model is 91.72%**