Create and Train Neural Network Model

In [1]:

```
#Import All Required Packages
import os
import cv2
import time
import numpy as np
import tensorflow as tf
from tensorflow.keras.preprocessing.image import ImageDataGenerator
```

In [2]:

```
#Setting up paths
trainDir= "Dataset/train"
validDir= "Dataset/valid"
testDir= "Dataset/test"
```

In [3]:

```
#Generating Batches for training and validating
#Batches are created after preprocessing the images in folder with processing function for mobile net
trainBatch= ImageDataGenerator(rotation_range= 40, zoom_range=[0.15,1.4], preprocessing_function= tf.keras.applications.mobilenet.preprocess_input).flow_from_directory(directory= trainDir, shuffle=True, target_size=(224,224), batch_size = 32)
validBatch= ImageDataGenerator(rotation_range= 40, zoom_range=[0.15,1.4], preprocessing_function= tf.keras.applications.mobilenet.preprocess_input).flow_from_directory(directory= validDir, shuffle=True, target_size=(224,224), batch_size = 32)
```

```
Found 12757 images belonging to 10 classes.
Found 3000 images belonging to 10 classes.
```

In [4]:

```
#Download and save MobileNet Model
mobile= tf.keras.applications.MobileNet()
```

In [5]:

```
#Original Model layers and Summary
mobile.summary()
```

```
Model: "mobilenet_1.00_224"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_1 (InputLayer)         [(None, 224, 224, 3)]     0         
_________________________________________________________________
conv1_pad (ZeroPadding2D)    (None, 225, 225, 3)       0         
_________________________________________________________________
conv1 (Conv2D)               (None, 112, 112, 32)      864       
_________________________________________________________________
conv1_bn (BatchNormalization (None, 112, 112, 32)      128       
_________________________________________________________________
conv1_relu (ReLU)            (None, 112, 112, 32)      0         
_________________________________________________________________
conv_dw_1 (DepthwiseConv2D)  (None, 112, 112, 32)      288       
_________________________________________________________________
conv_dw_1_bn (BatchNormaliza (None, 112, 112, 32)      128       
_________________________________________________________________
conv_dw_1_relu (ReLU)        (None, 112, 112, 32)      0         
_________________________________________________________________
conv_pw_1 (Conv2D)           (None, 112, 112, 64)      2048      
_________________________________________________________________
conv_pw_1_bn (BatchNormaliza (None, 112, 112, 64)      256       
_________________________________________________________________
conv_pw_1_relu (ReLU)        (None, 112, 112, 64)      0         
_________________________________________________________________
conv_pad_2 (ZeroPadding2D)   (None, 113, 113, 64)      0         
_________________________________________________________________
conv_dw_2 (DepthwiseConv2D)  (None, 56, 56, 64)        576       
_________________________________________________________________
conv_dw_2_bn (BatchNormaliza (None, 56, 56, 64)        256       
_________________________________________________________________
conv_dw_2_relu (ReLU)        (None, 56, 56, 64)        0         
_________________________________________________________________
conv_pw_2 (Conv2D)           (None, 56, 56, 128)       8192      
_________________________________________________________________
conv_pw_2_bn (BatchNormaliza (None, 56, 56, 128)       512       
_________________________________________________________________
conv_pw_2_relu (ReLU)        (None, 56, 56, 128)       0         
_________________________________________________________________
conv_dw_3 (DepthwiseConv2D)  (None, 56, 56, 128)       1152      
_________________________________________________________________
conv_dw_3_bn (BatchNormaliza (None, 56, 56, 128)       512       
_________________________________________________________________
conv_dw_3_relu (ReLU)        (None, 56, 56, 128)       0         
_________________________________________________________________
conv_pw_3 (Conv2D)           (None, 56, 56, 128)       16384     
_________________________________________________________________
conv_pw_3_bn (BatchNormaliza (None, 56, 56, 128)       512       
_________________________________________________________________
conv_pw_3_relu (ReLU)        (None, 56, 56, 128)       0         
_________________________________________________________________
conv_pad_4 (ZeroPadding2D)   (None, 57, 57, 128)       0         
_________________________________________________________________
conv_dw_4 (DepthwiseConv2D)  (None, 28, 28, 128)       1152      
_________________________________________________________________
conv_dw_4_bn (BatchNormaliza (None, 28, 28, 128)       512       
_________________________________________________________________
conv_dw_4_relu (ReLU)        (None, 28, 28, 128)       0         
_________________________________________________________________
conv_pw_4 (Conv2D)           (None, 28, 28, 256)       32768     
_________________________________________________________________
conv_pw_4_bn (BatchNormaliza (None, 28, 28, 256)       1024      
_________________________________________________________________
conv_pw_4_relu (ReLU)        (None, 28, 28, 256)       0         
_________________________________________________________________
conv_dw_5 (DepthwiseConv2D)  (None, 28, 28, 256)       2304      
_________________________________________________________________
conv_dw_5_bn (BatchNormaliza (None, 28, 28, 256)       1024      
_________________________________________________________________
conv_dw_5_relu (ReLU)        (None, 28, 28, 256)       0         
_________________________________________________________________
conv_pw_5 (Conv2D)           (None, 28, 28, 256)       65536     
_________________________________________________________________
conv_pw_5_bn (BatchNormaliza (None, 28, 28, 256)       1024      
_________________________________________________________________
conv_pw_5_relu (ReLU)        (None, 28, 28, 256)       0         
_________________________________________________________________
conv_pad_6 (ZeroPadding2D)   (None, 29, 29, 256)       0         
_________________________________________________________________
conv_dw_6 (DepthwiseConv2D)  (None, 14, 14, 256)       2304      
_________________________________________________________________
conv_dw_6_bn (BatchNormaliza (None, 14, 14, 256)       1024      
_________________________________________________________________
conv_dw_6_relu (ReLU)        (None, 14, 14, 256)       0         
_________________________________________________________________
conv_pw_6 (Conv2D)           (None, 14, 14, 512)       131072    
_________________________________________________________________
conv_pw_6_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_pw_6_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_dw_7 (DepthwiseConv2D)  (None, 14, 14, 512)       4608      
_________________________________________________________________
conv_dw_7_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_dw_7_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pw_7 (Conv2D)           (None, 14, 14, 512)       262144    
_________________________________________________________________
conv_pw_7_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_pw_7_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_dw_8 (DepthwiseConv2D)  (None, 14, 14, 512)       4608      
_________________________________________________________________
conv_dw_8_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_dw_8_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pw_8 (Conv2D)           (None, 14, 14, 512)       262144    
_________________________________________________________________
conv_pw_8_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
```

```
conv_pw_8_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_dw_9 (DepthwiseConv2D)  (None, 14, 14, 512)       4608      
_________________________________________________________________
conv_dw_9_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_dw_9_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pw_9 (Conv2D)           (None, 14, 14, 512)       262144    
_________________________________________________________________
conv_pw_9_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_pw_9_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_dw_10 (DepthwiseConv2D) (None, 14, 14, 512)       4608      
_________________________________________________________________
conv_dw_10_bn (BatchNormaliz (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_dw_10_relu (ReLU)       (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pw_10 (Conv2D)          (None, 14, 14, 512)       262144    
_________________________________________________________________
conv_pw_10_bn (BatchNormaliz (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_pw_10_relu (ReLU)       (None, 14, 14, 512)       0         
_________________________________________________________________
conv_dw_11 (DepthwiseConv2D) (None, 14, 14, 512)       4608      
_________________________________________________________________
conv_dw_11_bn (BatchNormaliz (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_dw_11_relu (ReLU)       (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pw_11 (Conv2D)          (None, 14, 14, 512)       262144    
_________________________________________________________________
conv_pw_11_bn (BatchNormaliz (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_pw_11_relu (ReLU)       (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pad_12 (ZeroPadding2D)  (None, 15, 15, 512)       0         
_________________________________________________________________
conv_dw_12 (DepthwiseConv2D) (None, 7, 7, 512)         4608      
_________________________________________________________________
conv_dw_12_bn (BatchNormaliz (None, 7, 7, 512)         2048      
_________________________________________________________________
conv_dw_12_relu (ReLU)       (None, 7, 7, 512)         0         
_________________________________________________________________
conv_pw_12 (Conv2D)          (None, 7, 7, 1024)        524288    
_________________________________________________________________
conv_pw_12_bn (BatchNormaliz (None, 7, 7, 1024)        4096      
_________________________________________________________________
conv_pw_12_relu (ReLU)       (None, 7, 7, 1024)        0         
_________________________________________________________________
conv_dw_13 (DepthwiseConv2D) (None, 7, 7, 1024)        9216      
_________________________________________________________________
conv_dw_13_bn (BatchNormaliz (None, 7, 7, 1024)        4096      
_________________________________________________________________
conv_dw_13_relu (ReLU)       (None, 7, 7, 1024)        0         
```

```
_________________________________________________________________
conv_pw_13 (Conv2D)          (None, 7, 7, 1024)        1048576   
_________________________________________________________________
conv_pw_13_bn (BatchNormaliz (None, 7, 7, 1024)        4096      
_________________________________________________________________
conv_pw_13_relu (ReLU)       (None, 7, 7, 1024)        0         
_________________________________________________________________
global_average_pooling2d (Gl (None, 1024)              0         
_________________________________________________________________
reshape_1 (Reshape)          (None, 1, 1, 1024)        0         
_________________________________________________________________
dropout (Dropout)            (None, 1, 1, 1024)        0         
_________________________________________________________________
conv_preds (Conv2D)          (None, 1, 1, 1000)        1025000   
_________________________________________________________________
reshape_2 (Reshape)          (None, 1000)              0         
_________________________________________________________________
predictions (Activation)     (None, 1000)              0         
=================================================================
Total params: 4,253,864
Trainable params: 4,231,976
Non-trainable params: 21,888
_________________________________________________________________
```

In [6]:

```
#Creating custom output for mobile net model
x = mobile.layers[-6].output
output = tf.keras.layers.Dense(units=10, activation='softmax')(x)
model = tf.keras.models.Model(inputs=mobile.input, outputs=output)
```

```
In [7]: #New model layers and summary
        model.summary()
```

```
Model: "functional_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_1 (InputLayer)         [(None, 224, 224, 3)]     0         
_________________________________________________________________
conv1_pad (ZeroPadding2D)    (None, 225, 225, 3)       0         
_________________________________________________________________
conv1 (Conv2D)               (None, 112, 112, 32)      864       
_________________________________________________________________
conv1_bn (BatchNormalization (None, 112, 112, 32)      128       
_________________________________________________________________
conv1_relu (ReLU)            (None, 112, 112, 32)      0         
_________________________________________________________________
conv_dw_1 (DepthwiseConv2D)  (None, 112, 112, 32)      288       
_________________________________________________________________
conv_dw_1_bn (BatchNormaliza (None, 112, 112, 32)      128       
_________________________________________________________________
conv_dw_1_relu (ReLU)        (None, 112, 112, 32)      0         
_________________________________________________________________
conv_pw_1 (Conv2D)           (None, 112, 112, 64)      2048      
_________________________________________________________________
conv_pw_1_bn (BatchNormaliza (None, 112, 112, 64)      256       
_________________________________________________________________
conv_pw_1_relu (ReLU)        (None, 112, 112, 64)      0         
_________________________________________________________________
conv_pad_2 (ZeroPadding2D)   (None, 113, 113, 64)      0         
_________________________________________________________________
conv_dw_2 (DepthwiseConv2D)  (None, 56, 56, 64)        576       
_________________________________________________________________
conv_dw_2_bn (BatchNormaliza (None, 56, 56, 64)        256       
_________________________________________________________________
conv_dw_2_relu (ReLU)        (None, 56, 56, 64)        0         
_________________________________________________________________
conv_pw_2 (Conv2D)           (None, 56, 56, 128)       8192      
_________________________________________________________________
conv_pw_2_bn (BatchNormaliza (None, 56, 56, 128)       512       
_________________________________________________________________
conv_pw_2_relu (ReLU)        (None, 56, 56, 128)       0         
_________________________________________________________________
conv_dw_3 (DepthwiseConv2D)  (None, 56, 56, 128)       1152      
_________________________________________________________________
conv_dw_3_bn (BatchNormaliza (None, 56, 56, 128)       512       
_________________________________________________________________
conv_dw_3_relu (ReLU)        (None, 56, 56, 128)       0         
_________________________________________________________________
conv_pw_3 (Conv2D)           (None, 56, 56, 128)       16384     
_________________________________________________________________
conv_pw_3_bn (BatchNormaliza (None, 56, 56, 128)       512       
_________________________________________________________________
conv_pw_3_relu (ReLU)        (None, 56, 56, 128)       0         
_________________________________________________________________
conv_pad_4 (ZeroPadding2D)   (None, 57, 57, 128)       0         
_________________________________________________________________
conv_dw_4 (DepthwiseConv2D)  (None, 28, 28, 128)       1152      
_________________________________________________________________
conv_dw_4_bn (BatchNormaliza (None, 28, 28, 128)       512       
_________________________________________________________________
conv_dw_4_relu (ReLU)        (None, 28, 28, 128)       0         
_________________________________________________________________
conv_pw_4 (Conv2D)           (None, 28, 28, 256)       32768     
_________________________________________________________________
conv_pw_4_bn (BatchNormaliza (None, 28, 28, 256)       1024      
_________________________________________________________________
conv_pw_4_relu (ReLU)        (None, 28, 28, 256)       0         
_________________________________________________________________
conv_dw_5 (DepthwiseConv2D)  (None, 28, 28, 256)       2304      
_________________________________________________________________
conv_dw_5_bn (BatchNormaliza (None, 28, 28, 256)       1024      
_________________________________________________________________
conv_dw_5_relu (ReLU)        (None, 28, 28, 256)       0         
_________________________________________________________________
conv_pw_5 (Conv2D)           (None, 28, 28, 256)       65536     
_________________________________________________________________
conv_pw_5_bn (BatchNormaliza (None, 28, 28, 256)       1024      
_________________________________________________________________
conv_pw_5_relu (ReLU)        (None, 28, 28, 256)       0         
_________________________________________________________________
conv_pad_6 (ZeroPadding2D)   (None, 29, 29, 256)       0         
_________________________________________________________________
conv_dw_6 (DepthwiseConv2D)  (None, 14, 14, 256)       2304      
_________________________________________________________________
conv_dw_6_bn (BatchNormaliza (None, 14, 14, 256)       1024      
_________________________________________________________________
conv_dw_6_relu (ReLU)        (None, 14, 14, 256)       0         
_________________________________________________________________
conv_pw_6 (Conv2D)           (None, 14, 14, 512)       131072    
_________________________________________________________________
conv_pw_6_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_pw_6_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_dw_7 (DepthwiseConv2D)  (None, 14, 14, 512)       4608      
_________________________________________________________________
conv_dw_7_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_dw_7_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pw_7 (Conv2D)           (None, 14, 14, 512)       262144    
_________________________________________________________________
conv_pw_7_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_pw_7_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_dw_8 (DepthwiseConv2D)  (None, 14, 14, 512)       4608      
_________________________________________________________________
conv_dw_8_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_dw_8_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pw_8 (Conv2D)           (None, 14, 14, 512)       262144    
_________________________________________________________________
conv_pw_8_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
```

```
conv_pw_8_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_dw_9 (DepthwiseConv2D)  (None, 14, 14, 512)       4608      
_________________________________________________________________
conv_dw_9_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_dw_9_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pw_9 (Conv2D)           (None, 14, 14, 512)       262144    
_________________________________________________________________
conv_pw_9_bn (BatchNormaliza (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_pw_9_relu (ReLU)        (None, 14, 14, 512)       0         
_________________________________________________________________
conv_dw_10 (DepthwiseConv2D) (None, 14, 14, 512)       4608      
_________________________________________________________________
conv_dw_10_bn (BatchNormaliz (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_dw_10_relu (ReLU)       (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pw_10 (Conv2D)          (None, 14, 14, 512)       262144    
_________________________________________________________________
conv_pw_10_bn (BatchNormaliz (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_pw_10_relu (ReLU)       (None, 14, 14, 512)       0         
_________________________________________________________________
conv_dw_11 (DepthwiseConv2D) (None, 14, 14, 512)       4608      
_________________________________________________________________
conv_dw_11_bn (BatchNormaliz (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_dw_11_relu (ReLU)       (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pw_11 (Conv2D)          (None, 14, 14, 512)       262144    
_________________________________________________________________
conv_pw_11_bn (BatchNormaliz (None, 14, 14, 512)       2048      
_________________________________________________________________
conv_pw_11_relu (ReLU)       (None, 14, 14, 512)       0         
_________________________________________________________________
conv_pad_12 (ZeroPadding2D)  (None, 15, 15, 512)       0         
_________________________________________________________________
conv_dw_12 (DepthwiseConv2D) (None, 7, 7, 512)         4608      
_________________________________________________________________
conv_dw_12_bn (BatchNormaliz (None, 7, 7, 512)         2048      
_________________________________________________________________
conv_dw_12_relu (ReLU)       (None, 7, 7, 512)         0         
_________________________________________________________________
conv_pw_12 (Conv2D)          (None, 7, 7, 1024)        524288    
_________________________________________________________________
conv_pw_12_bn (BatchNormaliz (None, 7, 7, 1024)        4096      
_________________________________________________________________
conv_pw_12_relu (ReLU)       (None, 7, 7, 1024)        0         
_________________________________________________________________
conv_dw_13 (DepthwiseConv2D) (None, 7, 7, 1024)        9216      
_________________________________________________________________
conv_dw_13_bn (BatchNormaliz (None, 7, 7, 1024)        4096      
_________________________________________________________________
conv_dw_13_relu (ReLU)       (None, 7, 7, 1024)        0         
```

```
________________________________________________________________
conv_pw_13 (Conv2D)          (None, 7, 7, 1024)        1048576
________________________________________________________________
conv_pw_13_bn (BatchNormaliz (None, 7, 7, 1024)        4096
________________________________________________________________
conv_pw_13_relu (ReLU)       (None, 7, 7, 1024)        0
________________________________________________________________
global_average_pooling2d (Gl (None, 1024)              0
________________________________________________________________
dense (Dense)                (None, 10)                10250
================================================================
Total params: 3,239,114
Trainable params: 3,217,226
Non-trainable params: 21,888
________________________________________________________________
```

In [8]:

```
#Compile the model
model.compile(optimizer= tf.keras.optimizers.Adam(lr=0.0001), loss='categorical_crossentropy', metrics= ['accuracy'])
```

In [9]:

```
#Fine Tune the model to predict requred classes
for i in range(0,25):
    print("Epoch Completed: {}".format(i*10))
    model.fit(x= trainBatch, validation_data= validBatch, epochs= 10, verbose=
2)

    #Save the model
    model.save('model\mainModel{}.h5'.format(i))
```

```
Epoch Completed: 0
Epoch 1/10
WARNING:tensorflow:Callbacks method `on_train_batch_end` is slow compared to
the batch time (batch time: 0.0312s vs `on_train_batch_end` time: 0.1250s). C
heck your callbacks.
399/399 - 194s - loss: 0.8252 - accuracy: 0.7358 - val_loss: 0.3533 - val_acc
uracy: 0.8907
Epoch 2/10
399/399 - 197s - loss: 0.2691 - accuracy: 0.9149 - val_loss: 0.1884 - val_acc
uracy: 0.9397
Epoch 3/10
399/399 - 195s - loss: 0.1889 - accuracy: 0.9387 - val_loss: 0.1254 - val_acc
uracy: 0.9573
Epoch 4/10
399/399 - 188s - loss: 0.1409 - accuracy: 0.9556 - val_loss: 0.1132 - val_acc
uracy: 0.9637
Epoch 5/10
399/399 - 190s - loss: 0.1181 - accuracy: 0.9628 - val_loss: 0.1145 - val_acc
uracy: 0.9620
Epoch 6/10
399/399 - 190s - loss: 0.1014 - accuracy: 0.9669 - val_loss: 0.0820 - val_acc
uracy: 0.9690
Epoch 7/10
399/399 - 189s - loss: 0.0941 - accuracy: 0.9697 - val_loss: 0.0747 - val_acc
uracy: 0.9733
Epoch 8/10
399/399 - 189s - loss: 0.0818 - accuracy: 0.9740 - val_loss: 0.0644 - val_acc
uracy: 0.9777
Epoch 9/10
399/399 - 190s - loss: 0.0762 - accuracy: 0.9727 - val_loss: 0.0665 - val_acc
uracy: 0.9783
Epoch 10/10
399/399 - 188s - loss: 0.0719 - accuracy: 0.9761 - val_loss: 0.0611 - val_acc
uracy: 0.9780
Epoch Completed: 10
Epoch 1/10
399/399 - 193s - loss: 0.0696 - accuracy: 0.9771 - val_loss: 0.0534 - val_acc
uracy: 0.9797
Epoch 2/10
399/399 - 190s - loss: 0.0630 - accuracy: 0.9787 - val_loss: 0.0490 - val_acc
uracy: 0.9843
Epoch 3/10
399/399 - 190s - loss: 0.0621 - accuracy: 0.9800 - val_loss: 0.0651 - val_acc
uracy: 0.9787
Epoch 4/10
399/399 - 189s - loss: 0.0555 - accuracy: 0.9823 - val_loss: 0.0556 - val_acc
uracy: 0.9833
Epoch 5/10
399/399 - 190s - loss: 0.0584 - accuracy: 0.9808 - val_loss: 0.0432 - val_acc
uracy: 0.9853
Epoch 6/10
399/399 - 190s - loss: 0.0502 - accuracy: 0.9830 - val_loss: 0.0518 - val_acc
uracy: 0.9840
Epoch 7/10
399/399 - 187s - loss: 0.0472 - accuracy: 0.9840 - val_loss: 0.0510 - val_acc
uracy: 0.9820
Epoch 8/10
```

```
399/399 - 187s - loss: 0.0523 - accuracy: 0.9819 - val_loss: 0.0370 - val_acc
uracy: 0.9863
Epoch 9/10
399/399 - 193s - loss: 0.0496 - accuracy: 0.9827 - val_loss: 0.0432 - val_acc
uracy: 0.9853
Epoch 10/10
399/399 - 189s - loss: 0.0417 - accuracy: 0.9862 - val_loss: 0.0378 - val_acc
uracy: 0.9867
Epoch Completed: 20
Epoch 1/10
399/399 - 190s - loss: 0.0454 - accuracy: 0.9857 - val_loss: 0.0448 - val_acc
uracy: 0.9843
Epoch 2/10
399/399 - 189s - loss: 0.0413 - accuracy: 0.9864 - val_loss: 0.0310 - val_acc
uracy: 0.9900
Epoch 3/10
399/399 - 189s - loss: 0.0449 - accuracy: 0.9849 - val_loss: 0.0354 - val_acc
uracy: 0.9883
Epoch 4/10
399/399 - 197s - loss: 0.0415 - accuracy: 0.9851 - val_loss: 0.0343 - val_acc
uracy: 0.9867
Epoch 5/10
399/399 - 187s - loss: 0.0385 - accuracy: 0.9875 - val_loss: 0.0226 - val_acc
uracy: 0.9913
Epoch 6/10
399/399 - 187s - loss: 0.0368 - accuracy: 0.9864 - val_loss: 0.0340 - val_acc
uracy: 0.9870
Epoch 7/10
399/399 - 186s - loss: 0.0388 - accuracy: 0.9873 - val_loss: 0.0291 - val_acc
uracy: 0.9897
Epoch 8/10
399/399 - 186s - loss: 0.0361 - accuracy: 0.9882 - val_loss: 0.0192 - val_acc
uracy: 0.9933
Epoch 9/10
399/399 - 188s - loss: 0.0344 - accuracy: 0.9870 - val_loss: 0.0397 - val_acc
uracy: 0.9877
Epoch 10/10
399/399 - 188s - loss: 0.0329 - accuracy: 0.9886 - val_loss: 0.0249 - val_acc
uracy: 0.9893
Epoch Completed: 30
Epoch 1/10
399/399 - 188s - loss: 0.0349 - accuracy: 0.9882 - val_loss: 0.0377 - val_acc
uracy: 0.9877
Epoch 2/10
399/399 - 187s - loss: 0.0341 - accuracy: 0.9889 - val_loss: 0.0295 - val_acc
uracy: 0.9903
Epoch 3/10
399/399 - 186s - loss: 0.0309 - accuracy: 0.9886 - val_loss: 0.0246 - val_acc
uracy: 0.9907
Epoch 4/10
399/399 - 187s - loss: 0.0374 - accuracy: 0.9883 - val_loss: 0.0306 - val_acc
uracy: 0.9907
Epoch 5/10
399/399 - 187s - loss: 0.0323 - accuracy: 0.9896 - val_loss: 0.0288 - val_acc
uracy: 0.9910
Epoch 6/10
399/399 - 187s - loss: 0.0301 - accuracy: 0.9889 - val_loss: 0.0320 - val_acc
```

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uracy: 0.9893
Epoch 7/10
399/399 - 188s - loss: 0.0302 - accuracy: 0.9897 - val_loss: 0.0240 - val_acc
uracy: 0.9920
Epoch 8/10
399/399 - 191s - loss: 0.0293 - accuracy: 0.9911 - val_loss: 0.0249 - val_acc
uracy: 0.9900
Epoch 9/10
399/399 - 188s - loss: 0.0302 - accuracy: 0.9883 - val_loss: 0.0147 - val_acc
uracy: 0.9957
Epoch 10/10
399/399 - 188s - loss: 0.0279 - accuracy: 0.9905 - val_loss: 0.0314 - val_acc
uracy: 0.9893
Epoch Completed: 40
Epoch 1/10
399/399 - 188s - loss: 0.0283 - accuracy: 0.9901 - val_loss: 0.0260 - val_acc
uracy: 0.9903
Epoch 2/10
399/399 - 186s - loss: 0.0261 - accuracy: 0.9910 - val_loss: 0.0504 - val_acc
uracy: 0.9860
Epoch 3/10
399/399 - 187s - loss: 0.0342 - accuracy: 0.9889 - val_loss: 0.0233 - val_acc
uracy: 0.9927
Epoch 4/10
399/399 - 187s - loss: 0.0259 - accuracy: 0.9912 - val_loss: 0.0294 - val_acc
uracy: 0.9903
Epoch 5/10
399/399 - 187s - loss: 0.0221 - accuracy: 0.9924 - val_loss: 0.0191 - val_acc
uracy: 0.9923
Epoch 6/10
399/399 - 188s - loss: 0.0251 - accuracy: 0.9911 - val_loss: 0.0194 - val_acc
uracy: 0.9937
Epoch 7/10
399/399 - 188s - loss: 0.0230 - accuracy: 0.9922 - val_loss: 0.0197 - val_acc
uracy: 0.9927
Epoch 8/10
399/399 - 188s - loss: 0.0261 - accuracy: 0.9915 - val_loss: 0.0203 - val_acc
uracy: 0.9943
Epoch 9/10
399/399 - 186s - loss: 0.0292 - accuracy: 0.9903 - val_loss: 0.0175 - val_acc
uracy: 0.9933
Epoch 10/10
399/399 - 186s - loss: 0.0241 - accuracy: 0.9916 - val_loss: 0.0291 - val_acc
uracy: 0.9910
Epoch Completed: 50
Epoch 1/10
399/399 - 187s - loss: 0.0266 - accuracy: 0.9910 - val_loss: 0.0130 - val_acc
uracy: 0.9957
Epoch 2/10
399/399 - 186s - loss: 0.0209 - accuracy: 0.9929 - val_loss: 0.0258 - val_acc
uracy: 0.9897
Epoch 3/10
399/399 - 188s - loss: 0.0209 - accuracy: 0.9924 - val_loss: 0.0267 - val_acc
uracy: 0.9900
Epoch 4/10
399/399 - 187s - loss: 0.0230 - accuracy: 0.9912 - val_loss: 0.0180 - val_acc
uracy: 0.9947
```

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Epoch 5/10
399/399 - 189s - loss: 0.0261 - accuracy: 0.9916 - val_loss: 0.0251 - val_acc
uracy: 0.9927
Epoch 6/10
399/399 - 189s - loss: 0.0244 - accuracy: 0.9922 - val_loss: 0.0169 - val_acc
uracy: 0.9940
Epoch 7/10
399/399 - 193s - loss: 0.0215 - accuracy: 0.9929 - val_loss: 0.0132 - val_acc
uracy: 0.9940
Epoch 8/10
399/399 - 190s - loss: 0.0236 - accuracy: 0.9920 - val_loss: 0.0224 - val_acc
uracy: 0.9923
Epoch 9/10
399/399 - 189s - loss: 0.0230 - accuracy: 0.9925 - val_loss: 0.0167 - val_acc
uracy: 0.9943
Epoch 10/10
399/399 - 188s - loss: 0.0233 - accuracy: 0.9916 - val_loss: 0.0212 - val_acc
uracy: 0.9933
Epoch Completed: 60
Epoch 1/10
399/399 - 188s - loss: 0.0222 - accuracy: 0.9929 - val_loss: 0.0155 - val_acc
uracy: 0.9953
Epoch 2/10
399/399 - 188s - loss: 0.0233 - accuracy: 0.9919 - val_loss: 0.0150 - val_acc
uracy: 0.9953
Epoch 3/10
399/399 - 187s - loss: 0.0195 - accuracy: 0.9930 - val_loss: 0.0177 - val_acc
uracy: 0.9937
Epoch 4/10
399/399 - 188s - loss: 0.0203 - accuracy: 0.9934 - val_loss: 0.0090 - val_acc
uracy: 0.9967
Epoch 5/10
399/399 - 189s - loss: 0.0167 - accuracy: 0.9944 - val_loss: 0.0188 - val_acc
uracy: 0.9923
Epoch 6/10
399/399 - 187s - loss: 0.0215 - accuracy: 0.9926 - val_loss: 0.0198 - val_acc
uracy: 0.9917
Epoch 7/10
399/399 - 187s - loss: 0.0235 - accuracy: 0.9923 - val_loss: 0.0245 - val_acc
uracy: 0.9917
Epoch 8/10
399/399 - 189s - loss: 0.0216 - accuracy: 0.9933 - val_loss: 0.0143 - val_acc
uracy: 0.9947
Epoch 9/10
399/399 - 188s - loss: 0.0159 - accuracy: 0.9933 - val_loss: 0.0241 - val_acc
uracy: 0.9923
Epoch 10/10
399/399 - 189s - loss: 0.0287 - accuracy: 0.9892 - val_loss: 0.0179 - val_acc
uracy: 0.9927
Epoch Completed: 70
Epoch 1/10
399/399 - 188s - loss: 0.0176 - accuracy: 0.9938 - val_loss: 0.0129 - val_acc
uracy: 0.9950
Epoch 2/10
399/399 - 187s - loss: 0.0198 - accuracy: 0.9929 - val_loss: 0.0118 - val_acc
uracy: 0.9960
Epoch 3/10
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399/399 - 188s - loss: 0.0235 - accuracy: 0.9918 - val_loss: 0.0213 - val_acc
uracy: 0.9927
Epoch 4/10
399/399 - 188s - loss: 0.0221 - accuracy: 0.9926 - val_loss: 0.0142 - val_acc
uracy: 0.9943
Epoch 5/10
399/399 - 191s - loss: 0.0162 - accuracy: 0.9946 - val_loss: 0.0278 - val_acc
uracy: 0.9913
Epoch 6/10
399/399 - 213s - loss: 0.0221 - accuracy: 0.9929 - val_loss: 0.0139 - val_acc
uracy: 0.9960
Epoch 7/10
399/399 - 189s - loss: 0.0201 - accuracy: 0.9940 - val_loss: 0.0209 - val_acc
uracy: 0.9937
Epoch 8/10
399/399 - 188s - loss: 0.0170 - accuracy: 0.9943 - val_loss: 0.0171 - val_acc
uracy: 0.9943
Epoch 9/10
399/399 - 188s - loss: 0.0189 - accuracy: 0.9940 - val_loss: 0.0123 - val_acc
uracy: 0.9947
Epoch 10/10
399/399 - 188s - loss: 0.0203 - accuracy: 0.9929 - val_loss: 0.0198 - val_acc
uracy: 0.9950
Epoch Completed: 80
Epoch 1/10
399/399 - 188s - loss: 0.0185 - accuracy: 0.9942 - val_loss: 0.0184 - val_acc
uracy: 0.9953
Epoch 2/10
399/399 - 187s - loss: 0.0177 - accuracy: 0.9934 - val_loss: 0.0198 - val_acc
uracy: 0.9943
Epoch 3/10
399/399 - 188s - loss: 0.0185 - accuracy: 0.9942 - val_loss: 0.0143 - val_acc
uracy: 0.9950
Epoch 4/10
399/399 - 187s - loss: 0.0178 - accuracy: 0.9940 - val_loss: 0.0112 - val_acc
uracy: 0.9953
Epoch 5/10
399/399 - 189s - loss: 0.0235 - accuracy: 0.9923 - val_loss: 0.0094 - val_acc
uracy: 0.9967
Epoch 6/10
399/399 - 190s - loss: 0.0155 - accuracy: 0.9947 - val_loss: 0.0150 - val_acc
uracy: 0.9957
Epoch 7/10
399/399 - 189s - loss: 0.0170 - accuracy: 0.9945 - val_loss: 0.0142 - val_acc
uracy: 0.9937
Epoch 8/10
399/399 - 190s - loss: 0.0151 - accuracy: 0.9948 - val_loss: 0.0140 - val_acc
uracy: 0.9947
Epoch 9/10
399/399 - 189s - loss: 0.0200 - accuracy: 0.9928 - val_loss: 0.0115 - val_acc
uracy: 0.9943
Epoch 10/10
399/399 - 190s - loss: 0.0187 - accuracy: 0.9936 - val_loss: 0.0145 - val_acc
uracy: 0.9947
Epoch Completed: 90
Epoch 1/10
399/399 - 190s - loss: 0.0185 - accuracy: 0.9931 - val_loss: 0.0156 - val_acc
```

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uracy: 0.9947
Epoch 2/10
399/399 - 190s - loss: 0.0145 - accuracy: 0.9946 - val_loss: 0.0232 - val_acc
uracy: 0.9930
Epoch 3/10
399/399 - 193s - loss: 0.0186 - accuracy: 0.9942 - val_loss: 0.0127 - val_acc
uracy: 0.9947
Epoch 4/10
399/399 - 191s - loss: 0.0141 - accuracy: 0.9955 - val_loss: 0.0079 - val_acc
uracy: 0.9977
Epoch 5/10
399/399 - 194s - loss: 0.0217 - accuracy: 0.9921 - val_loss: 0.0107 - val_acc
uracy: 0.9960
Epoch 6/10
399/399 - 190s - loss: 0.0178 - accuracy: 0.9939 - val_loss: 0.0174 - val_acc
uracy: 0.9943
Epoch 7/10
399/399 - 188s - loss: 0.0137 - accuracy: 0.9951 - val_loss: 0.0203 - val_acc
uracy: 0.9940
Epoch 8/10
399/399 - 191s - loss: 0.0177 - accuracy: 0.9938 - val_loss: 0.0187 - val_acc
uracy: 0.9957
Epoch 9/10
399/399 - 190s - loss: 0.0196 - accuracy: 0.9939 - val_loss: 0.0234 - val_acc
uracy: 0.9937
Epoch 10/10
399/399 - 190s - loss: 0.0177 - accuracy: 0.9938 - val_loss: 0.0194 - val_acc
uracy: 0.9943
Epoch Completed: 100
Epoch 1/10
399/399 - 189s - loss: 0.0169 - accuracy: 0.9944 - val_loss: 0.0102 - val_acc
uracy: 0.9963
Epoch 2/10
399/399 - 189s - loss: 0.0122 - accuracy: 0.9963 - val_loss: 0.0052 - val_acc
uracy: 0.9980
Epoch 3/10
399/399 - 189s - loss: 0.0177 - accuracy: 0.9945 - val_loss: 0.0151 - val_acc
uracy: 0.9960
Epoch 4/10
399/399 - 189s - loss: 0.0143 - accuracy: 0.9949 - val_loss: 0.0092 - val_acc
uracy: 0.9970
Epoch 5/10
399/399 - 189s - loss: 0.0151 - accuracy: 0.9958 - val_loss: 0.0090 - val_acc
uracy: 0.9967
Epoch 6/10
399/399 - 189s - loss: 0.0139 - accuracy: 0.9953 - val_loss: 0.0121 - val_acc
uracy: 0.9967
Epoch 7/10
399/399 - 188s - loss: 0.0168 - accuracy: 0.9942 - val_loss: 0.0117 - val_acc
uracy: 0.9963
Epoch 8/10
399/399 - 188s - loss: 0.0178 - accuracy: 0.9937 - val_loss: 0.0131 - val_acc
uracy: 0.9943
Epoch 9/10
399/399 - 190s - loss: 0.0145 - accuracy: 0.9949 - val_loss: 0.0107 - val_acc
uracy: 0.9970
Epoch 10/10
```

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399/399 - 190s - loss: 0.0136 - accuracy: 0.9949 - val_loss: 0.0141 - val_acc
uracy: 0.9950
Epoch Completed: 110
Epoch 1/10
399/399 - 193s - loss: 0.0179 - accuracy: 0.9942 - val_loss: 0.0087 - val_acc
uracy: 0.9963
Epoch 2/10
399/399 - 224s - loss: 0.0129 - accuracy: 0.9955 - val_loss: 0.0125 - val_acc
uracy: 0.9950
Epoch 3/10
399/399 - 229s - loss: 0.0160 - accuracy: 0.9952 - val_loss: 0.0083 - val_acc
uracy: 0.9963
Epoch 4/10
399/399 - 225s - loss: 0.0125 - accuracy: 0.9958 - val_loss: 0.0143 - val_acc
uracy: 0.9940
Epoch 5/10
399/399 - 217s - loss: 0.0151 - accuracy: 0.9955 - val_loss: 0.0108 - val_acc
uracy: 0.9967
Epoch 6/10
399/399 - 217s - loss: 0.0140 - accuracy: 0.9958 - val_loss: 0.0113 - val_acc
uracy: 0.9967
Epoch 7/10
399/399 - 214s - loss: 0.0163 - accuracy: 0.9947 - val_loss: 0.0059 - val_acc
uracy: 0.9980
Epoch 8/10
399/399 - 216s - loss: 0.0120 - accuracy: 0.9961 - val_loss: 0.0108 - val_acc
uracy: 0.9953
Epoch 9/10
399/399 - 215s - loss: 0.0195 - accuracy: 0.9934 - val_loss: 0.0143 - val_acc
uracy: 0.9960
Epoch 10/10
399/399 - 218s - loss: 0.0144 - accuracy: 0.9955 - val_loss: 0.0151 - val_acc
uracy: 0.9953
Epoch Completed: 120
Epoch 1/10
399/399 - 211s - loss: 0.0154 - accuracy: 0.9945 - val_loss: 0.0071 - val_acc
uracy: 0.9980
Epoch 2/10
399/399 - 192s - loss: 0.0121 - accuracy: 0.9958 - val_loss: 0.0083 - val_acc
uracy: 0.9970
Epoch 3/10
399/399 - 190s - loss: 0.0125 - accuracy: 0.9955 - val_loss: 0.0087 - val_acc
uracy: 0.9970
Epoch 4/10
399/399 - 192s - loss: 0.0147 - accuracy: 0.9952 - val_loss: 0.0089 - val_acc
uracy: 0.9967
Epoch 5/10
399/399 - 189s - loss: 0.0140 - accuracy: 0.9957 - val_loss: 0.0069 - val_acc
uracy: 0.9973
Epoch 6/10
399/399 - 188s - loss: 0.0161 - accuracy: 0.9944 - val_loss: 0.0094 - val_acc
uracy: 0.9980
Epoch 7/10
399/399 - 198s - loss: 0.0159 - accuracy: 0.9944 - val_loss: 0.0116 - val_acc
uracy: 0.9967
Epoch 8/10
399/399 - 228s - loss: 0.0136 - accuracy: 0.9955 - val_loss: 0.0099 - val_acc
```

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uracy: 0.9957
Epoch 9/10
399/399 - 184s - loss: 0.0133 - accuracy: 0.9955 - val_loss: 0.0163 - val_acc
uracy: 0.9947
Epoch 10/10
399/399 - 198s - loss: 0.0116 - accuracy: 0.9959 - val_loss: 0.0053 - val_acc
uracy: 0.9973
Epoch Completed: 130
Epoch 1/10
399/399 - 217s - loss: 0.0169 - accuracy: 0.9942 - val_loss: 0.0183 - val_acc
uracy: 0.9933
Epoch 2/10
399/399 - 211s - loss: 0.0142 - accuracy: 0.9959 - val_loss: 0.0113 - val_acc
uracy: 0.9953
Epoch 3/10
399/399 - 215s - loss: 0.0130 - accuracy: 0.9951 - val_loss: 0.0112 - val_acc
uracy: 0.9963
Epoch 4/10
399/399 - 214s - loss: 0.0135 - accuracy: 0.9957 - val_loss: 0.0173 - val_acc
uracy: 0.9937
Epoch 5/10
399/399 - 214s - loss: 0.0120 - accuracy: 0.9967 - val_loss: 0.0144 - val_acc
uracy: 0.9947
Epoch 6/10
399/399 - 194s - loss: 0.0144 - accuracy: 0.9951 - val_loss: 0.0131 - val_acc
uracy: 0.9957
Epoch 7/10
399/399 - 193s - loss: 0.0160 - accuracy: 0.9946 - val_loss: 0.0137 - val_acc
uracy: 0.9953
Epoch 8/10
399/399 - 214s - loss: 0.0127 - accuracy: 0.9957 - val_loss: 0.0074 - val_acc
uracy: 0.9967
Epoch 9/10
399/399 - 217s - loss: 0.0155 - accuracy: 0.9941 - val_loss: 0.0158 - val_acc
uracy: 0.9947
Epoch 10/10
399/399 - 218s - loss: 0.0162 - accuracy: 0.9951 - val_loss: 0.0138 - val_acc
uracy: 0.9960
Epoch Completed: 140
Epoch 1/10
399/399 - 214s - loss: 0.0143 - accuracy: 0.9948 - val_loss: 0.0128 - val_acc
uracy: 0.9953
Epoch 2/10
399/399 - 215s - loss: 0.0130 - accuracy: 0.9958 - val_loss: 0.0086 - val_acc
uracy: 0.9977
Epoch 3/10
399/399 - 215s - loss: 0.0131 - accuracy: 0.9956 - val_loss: 0.0081 - val_acc
uracy: 0.9973
Epoch 4/10
399/399 - 215s - loss: 0.0161 - accuracy: 0.9944 - val_loss: 0.0143 - val_acc
uracy: 0.9937
Epoch 5/10
399/399 - 214s - loss: 0.0124 - accuracy: 0.9955 - val_loss: 0.0089 - val_acc
uracy: 0.9963
Epoch 6/10
399/399 - 190s - loss: 0.0128 - accuracy: 0.9949 - val_loss: 0.0047 - val_acc
uracy: 0.9987
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Epoch 7/10
399/399 - 191s - loss: 0.0134 - accuracy: 0.9954 - val_loss: 0.0165 - val_acc
uracy: 0.9943
Epoch 8/10
399/399 - 198s - loss: 0.0131 - accuracy: 0.9953 - val_loss: 0.0073 - val_acc
uracy: 0.9980
Epoch 9/10
399/399 - 190s - loss: 0.0118 - accuracy: 0.9957 - val_loss: 0.0120 - val_acc
uracy: 0.9950
Epoch 10/10
399/399 - 186s - loss: 0.0132 - accuracy: 0.9950 - val_loss: 0.0073 - val_acc
uracy: 0.9970
Epoch Completed: 150
Epoch 1/10
399/399 - 183s - loss: 0.0109 - accuracy: 0.9964 - val_loss: 0.0087 - val_acc
uracy: 0.9967
Epoch 2/10
399/399 - 183s - loss: 0.0156 - accuracy: 0.9942 - val_loss: 0.0082 - val_acc
uracy: 0.9983
Epoch 3/10
399/399 - 185s - loss: 0.0110 - accuracy: 0.9960 - val_loss: 0.0136 - val_acc
uracy: 0.9943
Epoch 4/10
399/399 - 186s - loss: 0.0125 - accuracy: 0.9960 - val_loss: 0.0107 - val_acc
uracy: 0.9953
Epoch 5/10
399/399 - 187s - loss: 0.0117 - accuracy: 0.9955 - val_loss: 0.0102 - val_acc
uracy: 0.9967
Epoch 6/10
399/399 - 186s - loss: 0.0106 - accuracy: 0.9964 - val_loss: 0.0057 - val_acc
uracy: 0.9980
Epoch 7/10
399/399 - 189s - loss: 0.0119 - accuracy: 0.9956 - val_loss: 0.0087 - val_acc
uracy: 0.9967
Epoch 8/10
399/399 - 188s - loss: 0.0102 - accuracy: 0.9967 - val_loss: 0.0199 - val_acc
uracy: 0.9947
Epoch 9/10
399/399 - 187s - loss: 0.0134 - accuracy: 0.9962 - val_loss: 0.0165 - val_acc
uracy: 0.9940
Epoch 10/10
399/399 - 189s - loss: 0.0107 - accuracy: 0.9969 - val_loss: 0.0107 - val_acc
uracy: 0.9963
Epoch Completed: 160
Epoch 1/10
399/399 - 189s - loss: 0.0133 - accuracy: 0.9951 - val_loss: 0.0090 - val_acc
uracy: 0.9967
Epoch 2/10
399/399 - 189s - loss: 0.0094 - accuracy: 0.9963 - val_loss: 0.0197 - val_acc
uracy: 0.9957
Epoch 3/10
399/399 - 190s - loss: 0.0112 - accuracy: 0.9960 - val_loss: 0.0104 - val_acc
uracy: 0.9963
Epoch 4/10
399/399 - 189s - loss: 0.0143 - accuracy: 0.9957 - val_loss: 0.0078 - val_acc
uracy: 0.9970
Epoch 5/10
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399/399 - 189s - loss: 0.0137 - accuracy: 0.9955 - val_loss: 0.0192 - val_acc
uracy: 0.9947
Epoch 6/10
399/399 - 188s - loss: 0.0122 - accuracy: 0.9965 - val_loss: 0.0144 - val_acc
uracy: 0.9953
Epoch 7/10
399/399 - 192s - loss: 0.0106 - accuracy: 0.9974 - val_loss: 0.0096 - val_acc
uracy: 0.9967
Epoch 8/10
399/399 - 190s - loss: 0.0107 - accuracy: 0.9962 - val_loss: 0.0122 - val_acc
uracy: 0.9973
Epoch 9/10
399/399 - 188s - loss: 0.0114 - accuracy: 0.9962 - val_loss: 0.0075 - val_acc
uracy: 0.9973
Epoch 10/10
399/399 - 188s - loss: 0.0133 - accuracy: 0.9955 - val_loss: 0.0096 - val_acc
uracy: 0.9970
Epoch Completed: 170
Epoch 1/10
399/399 - 189s - loss: 0.0118 - accuracy: 0.9964 - val_loss: 0.0114 - val_acc
uracy: 0.9973
Epoch 2/10
399/399 - 187s - loss: 0.0103 - accuracy: 0.9969 - val_loss: 0.0146 - val_acc
uracy: 0.9943
Epoch 3/10
399/399 - 189s - loss: 0.0113 - accuracy: 0.9961 - val_loss: 0.0124 - val_acc
uracy: 0.9977
Epoch 4/10
399/399 - 189s - loss: 0.0126 - accuracy: 0.9958 - val_loss: 0.0171 - val_acc
uracy: 0.9957
Epoch 5/10
399/399 - 187s - loss: 0.0112 - accuracy: 0.9966 - val_loss: 0.0137 - val_acc
uracy: 0.9950
Epoch 6/10
399/399 - 189s - loss: 0.0101 - accuracy: 0.9963 - val_loss: 0.0078 - val_acc
uracy: 0.9970
Epoch 7/10
399/399 - 189s - loss: 0.0107 - accuracy: 0.9960 - val_loss: 0.0066 - val_acc
uracy: 0.9973
Epoch 8/10
399/399 - 189s - loss: 0.0147 - accuracy: 0.9958 - val_loss: 0.0107 - val_acc
uracy: 0.9970
Epoch 9/10
399/399 - 188s - loss: 0.0105 - accuracy: 0.9962 - val_loss: 0.0090 - val_acc
uracy: 0.9967
Epoch 10/10
399/399 - 190s - loss: 0.0128 - accuracy: 0.9957 - val_loss: 0.0138 - val_acc
uracy: 0.9957
Epoch Completed: 180
Epoch 1/10
399/399 - 189s - loss: 0.0092 - accuracy: 0.9966 - val_loss: 0.0053 - val_acc
uracy: 0.9970
Epoch 2/10
399/399 - 189s - loss: 0.0117 - accuracy: 0.9953 - val_loss: 0.0100 - val_acc
uracy: 0.9967
Epoch 3/10
399/399 - 187s - loss: 0.0137 - accuracy: 0.9959 - val_loss: 0.0132 - val_acc
```

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uracy: 0.9947
Epoch 4/10
399/399 - 188s - loss: 0.0091 - accuracy: 0.9971 - val_loss: 0.0137 - val_acc
uracy: 0.9960
Epoch 5/10
399/399 - 189s - loss: 0.0096 - accuracy: 0.9968 - val_loss: 0.0065 - val_acc
uracy: 0.9977
Epoch 6/10
399/399 - 191s - loss: 0.0105 - accuracy: 0.9961 - val_loss: 0.0172 - val_acc
uracy: 0.9943
Epoch 7/10
399/399 - 190s - loss: 0.0122 - accuracy: 0.9961 - val_loss: 0.0180 - val_acc
uracy: 0.9937
Epoch 8/10
399/399 - 189s - loss: 0.0133 - accuracy: 0.9958 - val_loss: 0.0077 - val_acc
uracy: 0.9973
Epoch 9/10
399/399 - 188s - loss: 0.0137 - accuracy: 0.9955 - val_loss: 0.0114 - val_acc
uracy: 0.9963
Epoch 10/10
399/399 - 188s - loss: 0.0108 - accuracy: 0.9962 - val_loss: 0.0099 - val_acc
uracy: 0.9960
Epoch Completed: 190
Epoch 1/10
399/399 - 189s - loss: 0.0087 - accuracy: 0.9973 - val_loss: 0.0080 - val_acc
uracy: 0.9963
Epoch 2/10
399/399 - 189s - loss: 0.0081 - accuracy: 0.9974 - val_loss: 0.0105 - val_acc
uracy: 0.9967
Epoch 3/10
399/399 - 189s - loss: 0.0136 - accuracy: 0.9956 - val_loss: 0.0074 - val_acc
uracy: 0.9980
Epoch 4/10
399/399 - 187s - loss: 0.0089 - accuracy: 0.9967 - val_loss: 0.0082 - val_acc
uracy: 0.9967
Epoch 5/10
399/399 - 188s - loss: 0.0107 - accuracy: 0.9966 - val_loss: 0.0117 - val_acc
uracy: 0.9977
Epoch 6/10
399/399 - 189s - loss: 0.0113 - accuracy: 0.9971 - val_loss: 0.0108 - val_acc
uracy: 0.9967
Epoch 7/10
399/399 - 246s - loss: 0.0090 - accuracy: 0.9972 - val_loss: 0.0064 - val_acc
uracy: 0.9973
Epoch 8/10
399/399 - 246s - loss: 0.0112 - accuracy: 0.9956 - val_loss: 0.0315 - val_acc
uracy: 0.9907
Epoch 9/10
399/399 - 247s - loss: 0.0101 - accuracy: 0.9973 - val_loss: 0.0060 - val_acc
uracy: 0.9977
Epoch 10/10
399/399 - 209s - loss: 0.0090 - accuracy: 0.9969 - val_loss: 0.0115 - val_acc
uracy: 0.9953
Epoch Completed: 200
Epoch 1/10
399/399 - 212s - loss: 0.0116 - accuracy: 0.9961 - val_loss: 0.0142 - val_acc
uracy: 0.9953
```

```
Epoch 2/10
399/399 - 203s - loss: 0.0155 - accuracy: 0.9944 - val_loss: 0.0036 - val_acc
uracy: 0.9987
Epoch 3/10
399/399 - 203s - loss: 0.0092 - accuracy: 0.9967 - val_loss: 0.0062 - val_acc
uracy: 0.9973
Epoch 4/10
399/399 - 209s - loss: 0.0109 - accuracy: 0.9966 - val_loss: 0.0140 - val_acc
uracy: 0.9953
Epoch 5/10
399/399 - 207s - loss: 0.0110 - accuracy: 0.9961 - val_loss: 0.0049 - val_acc
uracy: 0.9980
Epoch 6/10
399/399 - 208s - loss: 0.0104 - accuracy: 0.9965 - val_loss: 0.0062 - val_acc
uracy: 0.9983
Epoch 7/10
399/399 - 209s - loss: 0.0070 - accuracy: 0.9976 - val_loss: 0.0080 - val_acc
uracy: 0.9967
Epoch 8/10
399/399 - 208s - loss: 0.0092 - accuracy: 0.9969 - val_loss: 0.0071 - val_acc
uracy: 0.9973
Epoch 9/10
399/399 - 204s - loss: 0.0128 - accuracy: 0.9958 - val_loss: 0.0067 - val_acc
uracy: 0.9983
Epoch 10/10
399/399 - 203s - loss: 0.0105 - accuracy: 0.9963 - val_loss: 0.0114 - val_acc
uracy: 0.9960
Epoch Completed: 210
Epoch 1/10
399/399 - 202s - loss: 0.0104 - accuracy: 0.9962 - val_loss: 0.0060 - val_acc
uracy: 0.9973
Epoch 2/10
399/399 - 202s - loss: 0.0093 - accuracy: 0.9969 - val_loss: 0.0069 - val_acc
uracy: 0.9973
Epoch 3/10
399/399 - 204s - loss: 0.0115 - accuracy: 0.9967 - val_loss: 0.0161 - val_acc
uracy: 0.9950
Epoch 4/10
399/399 - 204s - loss: 0.0112 - accuracy: 0.9965 - val_loss: 0.0079 - val_acc
uracy: 0.9977
Epoch 5/10
399/399 - 203s - loss: 0.0113 - accuracy: 0.9955 - val_loss: 0.0093 - val_acc
uracy: 0.9953
Epoch 6/10
399/399 - 205s - loss: 0.0072 - accuracy: 0.9975 - val_loss: 0.0153 - val_acc
uracy: 0.9933
Epoch 7/10
399/399 - 203s - loss: 0.0100 - accuracy: 0.9968 - val_loss: 0.0141 - val_acc
uracy: 0.9963
Epoch 8/10
399/399 - 204s - loss: 0.0086 - accuracy: 0.9968 - val_loss: 0.0086 - val_acc
uracy: 0.9977
Epoch 9/10
399/399 - 204s - loss: 0.0095 - accuracy: 0.9972 - val_loss: 0.0088 - val_acc
uracy: 0.9970
Epoch 10/10
399/399 - 205s - loss: 0.0100 - accuracy: 0.9969 - val_loss: 0.0075 - val_acc
```

```
uracy: 0.9970
Epoch Completed: 220
Epoch 1/10
399/399 - 215s - loss: 0.0112 - accuracy: 0.9965 - val_loss: 0.0090 - val_acc
uracy: 0.9980
Epoch 2/10
399/399 - 209s - loss: 0.0112 - accuracy: 0.9967 - val_loss: 0.0196 - val_acc
uracy: 0.9957
Epoch 3/10
399/399 - 207s - loss: 0.0107 - accuracy: 0.9969 - val_loss: 0.0040 - val_acc
uracy: 0.9983
Epoch 4/10
399/399 - 207s - loss: 0.0086 - accuracy: 0.9969 - val_loss: 0.0092 - val_acc
uracy: 0.9973
Epoch 5/10
399/399 - 206s - loss: 0.0063 - accuracy: 0.9975 - val_loss: 0.0084 - val_acc
uracy: 0.9973
Epoch 6/10
399/399 - 206s - loss: 0.0116 - accuracy: 0.9962 - val_loss: 0.0084 - val_acc
uracy: 0.9963
Epoch 7/10
399/399 - 210s - loss: 0.0116 - accuracy: 0.9961 - val_loss: 0.0101 - val_acc
uracy: 0.9967
Epoch 8/10
399/399 - 209s - loss: 0.0117 - accuracy: 0.9964 - val_loss: 0.0151 - val_acc
uracy: 0.9950
Epoch 9/10
399/399 - 209s - loss: 0.0097 - accuracy: 0.9969 - val_loss: 0.0147 - val_acc
uracy: 0.9953
Epoch 10/10
399/399 - 209s - loss: 0.0107 - accuracy: 0.9966 - val_loss: 0.0181 - val_acc
uracy: 0.9953
Epoch Completed: 230
Epoch 1/10
399/399 - 211s - loss: 0.0099 - accuracy: 0.9965 - val_loss: 0.0099 - val_acc
uracy: 0.9953
Epoch 2/10
399/399 - 207s - loss: 0.0085 - accuracy: 0.9971 - val_loss: 0.0078 - val_acc
uracy: 0.9970
Epoch 3/10
399/399 - 207s - loss: 0.0109 - accuracy: 0.9963 - val_loss: 0.0115 - val_acc
uracy: 0.9960
Epoch 4/10
399/399 - 206s - loss: 0.0084 - accuracy: 0.9974 - val_loss: 0.0098 - val_acc
uracy: 0.9963
Epoch 5/10
399/399 - 205s - loss: 0.0065 - accuracy: 0.9976 - val_loss: 0.0076 - val_acc
uracy: 0.9973
Epoch 6/10
399/399 - 204s - loss: 0.0079 - accuracy: 0.9966 - val_loss: 0.0072 - val_acc
uracy: 0.9977
Epoch 7/10
399/399 - 206s - loss: 0.0139 - accuracy: 0.9956 - val_loss: 0.0054 - val_acc
uracy: 0.9980
Epoch 8/10
399/399 - 207s - loss: 0.0106 - accuracy: 0.9967 - val_loss: 0.0163 - val_acc
uracy: 0.9950
```

```
Epoch 9/10
399/399 - 210s - loss: 0.0093 - accuracy: 0.9964 - val_loss: 0.0076 - val_acc
uracy: 0.9973
Epoch 10/10
399/399 - 210s - loss: 0.0121 - accuracy: 0.9964 - val_loss: 0.0081 - val_acc
uracy: 0.9963
Epoch Completed: 240
Epoch 1/10
399/399 - 207s - loss: 0.0115 - accuracy: 0.9960 - val_loss: 0.0055 - val_acc
uracy: 0.9977
Epoch 2/10
399/399 - 205s - loss: 0.0101 - accuracy: 0.9966 - val_loss: 0.0081 - val_acc
uracy: 0.9967
Epoch 3/10
399/399 - 208s - loss: 0.0113 - accuracy: 0.9961 - val_loss: 0.0046 - val_acc
uracy: 0.9983
Epoch 4/10
399/399 - 211s - loss: 0.0095 - accuracy: 0.9972 - val_loss: 0.0083 - val_acc
uracy: 0.9967
Epoch 5/10
399/399 - 204s - loss: 0.0077 - accuracy: 0.9975 - val_loss: 0.0059 - val_acc
uracy: 0.9983
Epoch 6/10
399/399 - 202s - loss: 0.0053 - accuracy: 0.9980 - val_loss: 0.0055 - val_acc
uracy: 0.9977
Epoch 7/10
399/399 - 206s - loss: 0.0065 - accuracy: 0.9976 - val_loss: 0.0062 - val_acc
uracy: 0.9980
Epoch 8/10
399/399 - 205s - loss: 0.0061 - accuracy: 0.9978 - val_loss: 0.0115 - val_acc
uracy: 0.9967
Epoch 9/10
399/399 - 205s - loss: 0.0108 - accuracy: 0.9966 - val_loss: 0.0029 - val_acc
uracy: 0.9993
Epoch 10/10
399/399 - 205s - loss: 0.0118 - accuracy: 0.9962 - val_loss: 0.0125 - val_acc
uracy: 0.9963
```

Testing Trained Model

In [10]:

```
#import packages for visualizing performance of trained model with confusion m
atrix
import pandas as pd
import seaborn as sn
import matplotlib.pyplot as plt
```

In [11]:

```
#load trained Model
model= tf.keras.models.load_model('model\mainModel24.h5')
```

In [12]:

```
#initialize prediction array
cm= np.zeros([10,10])
lables = ["Zero","One","Two","Three","Four","Five","ThumbsUp","Ok","SpiderMan"
,"Rock"]
```

In [13]:

```
#preprocessing the image, Same as done to create batches
def preProcess(image):
    image= np.array(image)
    resized= cv2.resize(image, (224,224))
    resized= cv2.cvtColor(resized, cv2.COLOR_BGR2RGB)
    filtered= tf.keras.applications.mobilenet.preprocess_input(resized)
    reshaped= filtered.reshape(-1,224,224,3)
    return reshaped
```

In [14]:

```
#Access all class folder images and start predicting
count = 0
for subs in os.listdir(testDir):
    print(lables[count])
    for images in os.listdir(os.path.join(testDir, subs)):
        img = cv2.imread(os.path.join(testDir, subs, images), -1)
        prosimg = preProcess(img)
        pred = model.predict(prosimg)
        cm[count][np.argmax(pred[0])] = cm[count][np.argmax(pred[0])] + 1
    count = count + 1
```

```
Zero
One
Two
Three
Four
Five
ThumbsUp
Ok
SpiderMan
Rock
```

In [15]:

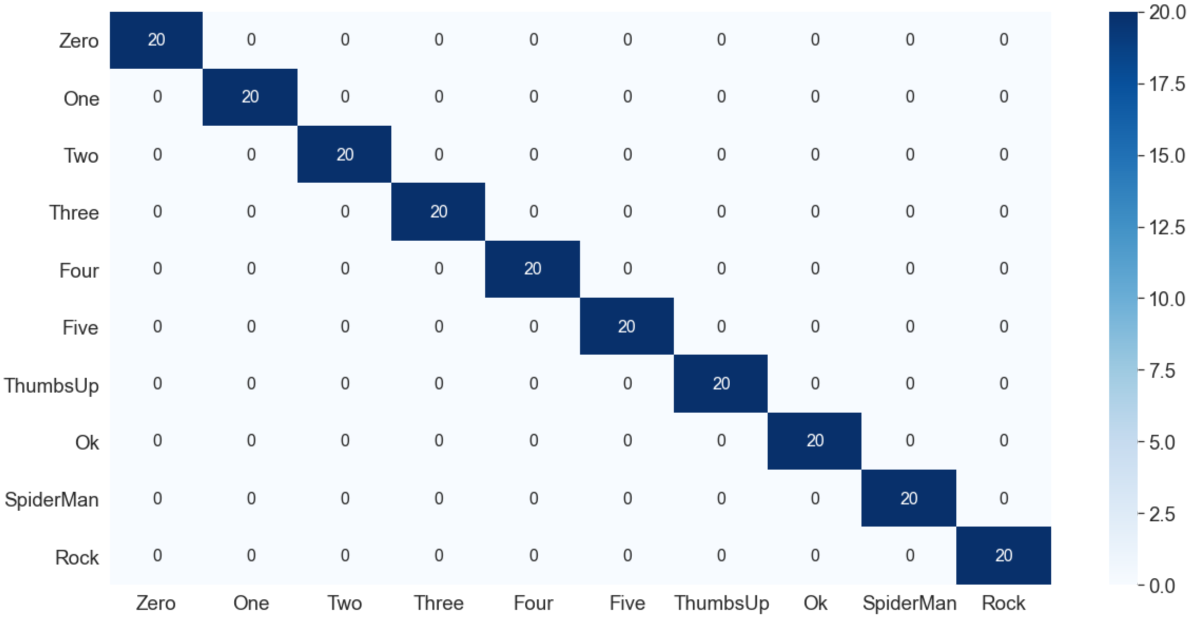
```
#Array Containing Confusion Matrix
cm
```

Out[15]:

```
array([[20.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.],
       [ 0., 20.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.],
       [ 0.,  0., 20.,  0.,  0.,  0.,  0.,  0.,  0.,  0.],
       [ 0.,  0.,  0., 20.,  0.,  0.,  0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0., 20.,  0.,  0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.,  0., 20.,  0.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.,  0.,  0., 20.,  0.,  0.,  0.],
       [ 0.,  0.,  0.,  0.,  0.,  0.,  0., 20.,  0.,  0.],
       [ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0., 20.,  0.],
       [ 0.,  0.,  0.,  0.,  0.,  0.,  0.,  0.,  0., 20.]])
```

In [16]:

```
#Setup Confusion Matrix and display
df_cm = pd.DataFrame(cm, lables, lables)
plt.figure(figsize=(20,10))
sn.set(font_scale=1.7) # for label size
sn.heatmap(df_cm, annot=True, annot_kws={"size": 16}, cmap='Blues', fmt='g') # font size
plt.show()
```



	Zero	One	Two	Three	Four	Five	ThumbsUp	Ok	SpiderMan	Rock
Zero	20	0	0	0	0	0	0	0	0	0
One	0	20	0	0	0	0	0	0	0	0
Two	0	0	20	0	0	0	0	0	0	0
Three	0	0	0	20	0	0	0	0	0	0
Four	0	0	0	0	20	0	0	0	0	0
Five	0	0	0	0	0	20	0	0	0	0
ThumbsUp	0	0	0	0	0	0	20	0	0	0
Ok	0	0	0	0	0	0	0	20	0	0
SpiderMan	0	0	0	0	0	0	0	0	20	0
Rock	0	0	0	0	0	0	0	0	0	20

Convert h5 model to tflite

In [17]:

```
model= tf.keras.models.load_model('model/mainModel24.h5')
```

In [18]:

```
converter= tf.lite.TFLiteConverter.from_keras_model(model)
tf_model= converter.convert()
with open('model\mainModel.tflite', 'wb') as f:
    f.write(tf_model)
```

```
WARNING:tensorflow:From D:\Software\Anaconda\lib\site-packages\tensorflow\pyt
hon\training\tracking\tracking.py:111: Model.state_updates (from tensorflow.p
ython.keras.engine.training) is deprecated and will be removed in a future ve
rsion.
Instructions for updating:
This property should not be used in TensorFlow 2.0, as updates are applied au
tomatically.
WARNING:tensorflow:From D:\Software\Anaconda\lib\site-packages\tensorflow\pyt
hon\training\tracking\tracking.py:111: Layer.updates (from tensorflow.python.
keras.engine.base_layer) is deprecated and will be removed in a future versio
n.
Instructions for updating:
This property should not be used in TensorFlow 2.0, as updates are applied au
tomatically.
INFO:tensorflow:Assets written to: C:\Users\abhir\AppData\Local\Temp\tmpl6f9
jj0\assets
```

Testing Model with live video

In [19]:
```
#The value in the bracket can change as per the camera in use
vid= cv2.VideoCapture(1)
```

In [20]:
```
interpreter= tf.lite.Interpreter(model_path= 'model/mainModel.tflite')
interpreter.allocate_tensors()
input_details= interpreter.get_input_details()
output_details= interpreter.get_output_details()
```

In [21]:
```
while True:
    ret, frame= vid.read()
    if ret==0:
        print("No Camera Detected, try changing port number")
        break

    shape_fr = frame.shape
    start_pt = (int(shape_fr[1]/16),int(shape_fr[0]/4))
    end_pt = (int(shape_fr[1]/2-shape_fr[1]/16),int(shape_fr[0] - shape_fr[0]/
4))

    roi = frame[int(shape_fr[0]/4):int(shape_fr[0] - shape_fr[0]/4),int(shape_
fr[1]/16):int(shape_fr[1]/2-shape_fr[1]/16)]
    processFrame= preProcess(roi)
    frame = cv2.rectangle(frame, start_pt, end_pt, (255,0,0), 2)

#     interpreter.set_tensor(input_details[0]['index'], processFrame)
#     interpreter.invoke()
#     pred= interpreter.get_tensor(output_details[0]['index'])

    pred= model.predict(processFrame)

    gest = lables[np.argmax(pred[0])]
    cv2.putText(frame, gest, (50,50), cv2.FONT_HERSHEY_COMPLEX, 1, (0,255,0),
2)
    cv2.imshow('Video', frame)
    if cv2.waitKey(1) & 0xFF == ord('q'):
        break

vid.release()
cv2.destroyAllWindows()
```

In [ ]: