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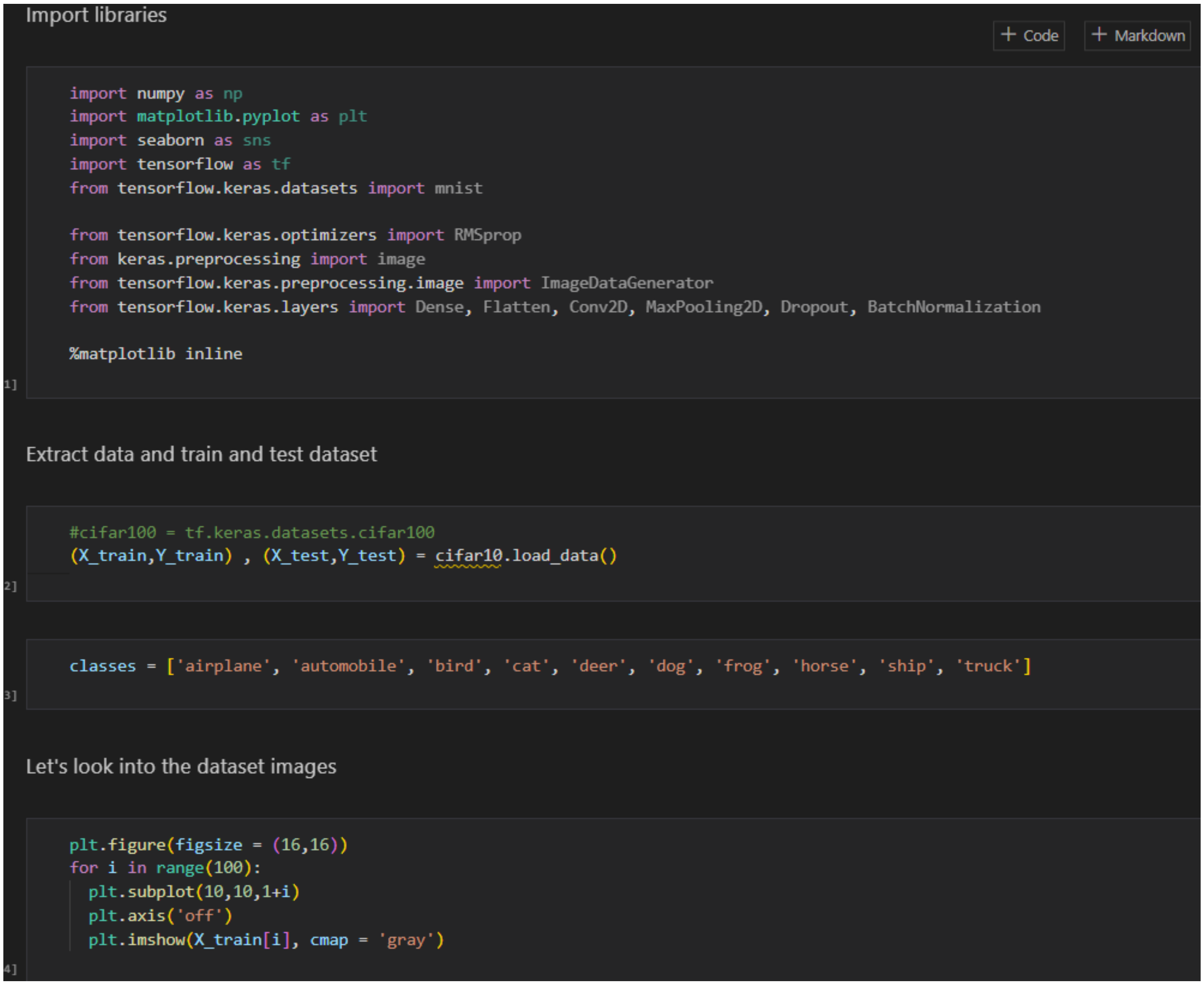
ASSIGNMENT 7

NEURAL NETWORKS AND DEEP LEARNING

Link for the recording: https://drive.google.com/file/d/18kIYGJuSqHEij35DlTnXYEnYH9qj9VDn/view?usp=drive_link



Import libraries

```
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import tensorflow as tf
from tensorflow.keras.datasets import mnist

from tensorflow.keras.optimizers import RMSprop
from keras.preprocessing import image
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras.layers import Dense, Flatten, Conv2D, MaxPooling2D, Dropout, BatchNormalization

%matplotlib inline
```

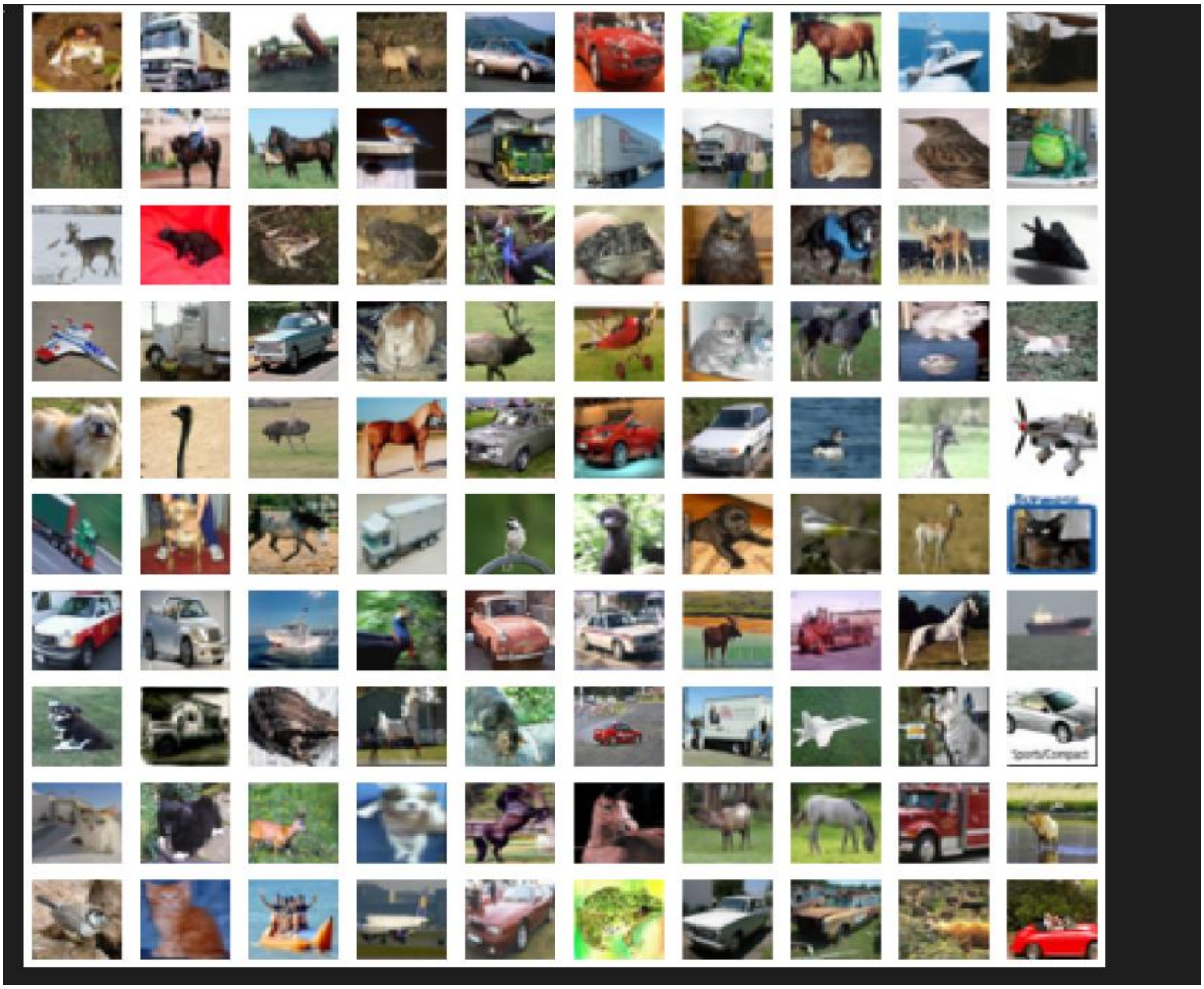
Extract data and train and test dataset

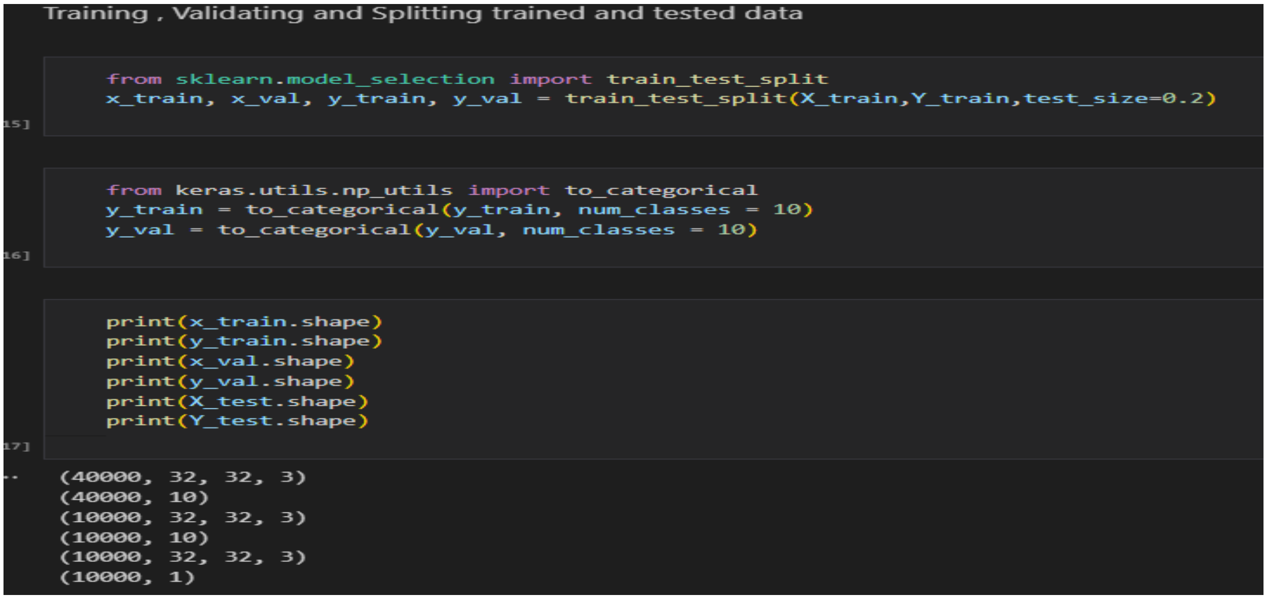
```
#cifar100 = tf.keras.datasets.cifar100
(X_train,Y_train) , (X_test,Y_test) = cifar10.load_data()
```

```
classes = ['airplane', 'automobile', 'bird', 'cat', 'deer', 'dog', 'frog', 'horse', 'ship', 'truck']
```

Let's look into the dataset images

```
plt.figure(figsize = (16,16))
for i in range(100):
    plt.subplot(10,10,1+i)
    plt.axis('off')
    plt.imshow(X_train[i], cmap = 'gray')
```





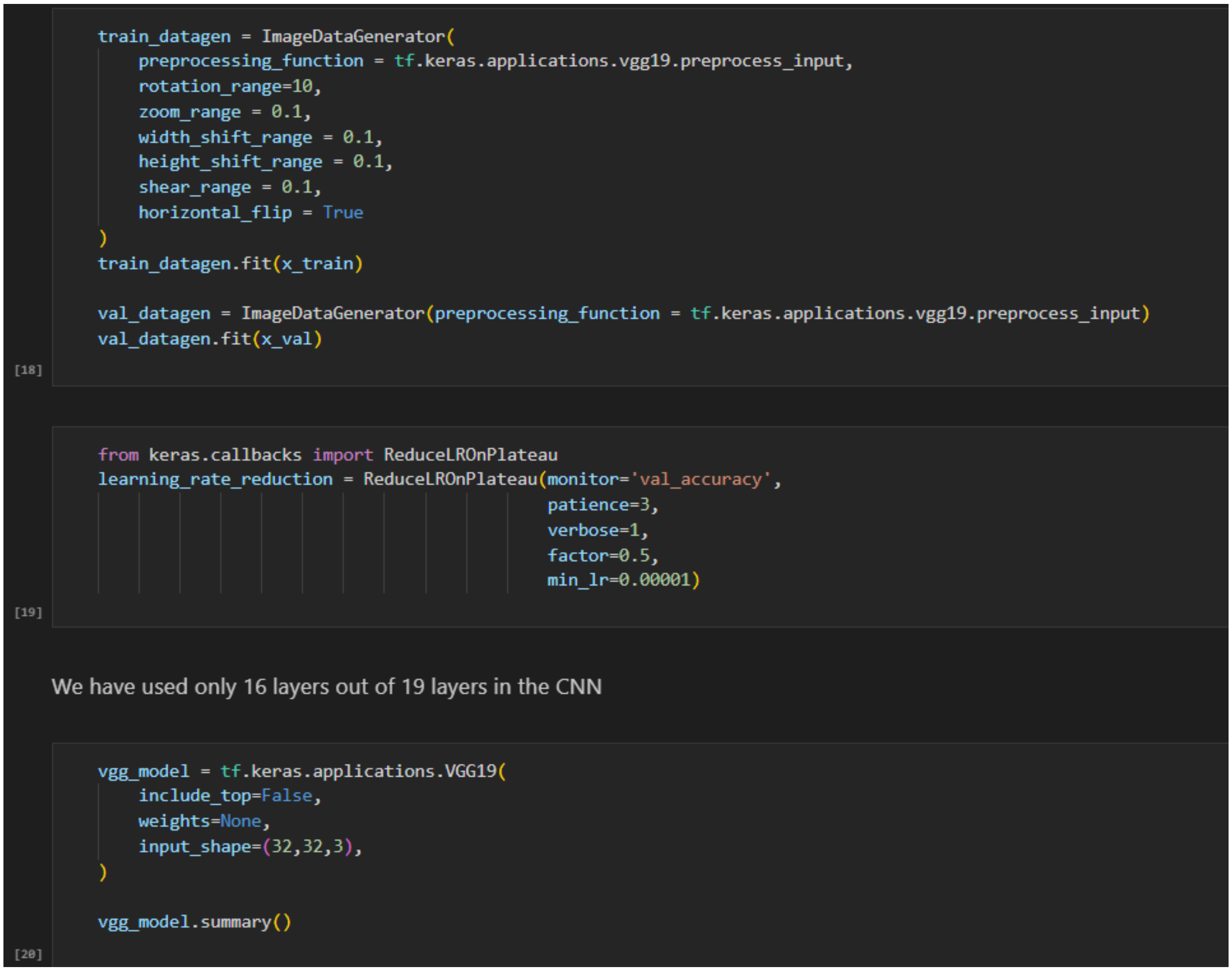
Training , Validating and Splitting trained and tested data

```
from sklearn.model_selection import train_test_split
x_train, x_val, y_train, y_val = train_test_split(X_train,Y_train,test_size=0.2)
```

```
from keras.utils.np_utils import to_categorical
y_train = to_categorical(y_train, num_classes = 10)
y_val = to_categorical(y_val, num_classes = 10)
```

```
print(x_train.shape)
print(y_train.shape)
print(x_val.shape)
print(y_val.shape)
print(X_test.shape)
print(Y_test.shape)
```

```
(40000, 32, 32, 3)
(40000, 10)
(10000, 32, 32, 3)
(10000, 10)
(10000, 32, 32, 3)
(10000, 1)
```



```
train_datagen = ImageDataGenerator(
    preprocessing_function = tf.keras.applications.vgg19.preprocess_input,
    rotation_range=10,
    zoom_range = 0.1,
    width_shift_range = 0.1,
    height_shift_range = 0.1,
    shear_range = 0.1,
    horizontal_flip = True
)
train_datagen.fit(x_train)

val_datagen = ImageDataGenerator(preprocessing_function = tf.keras.applications.vgg19.preprocess_input)
val_datagen.fit(x_val)
```

[18]

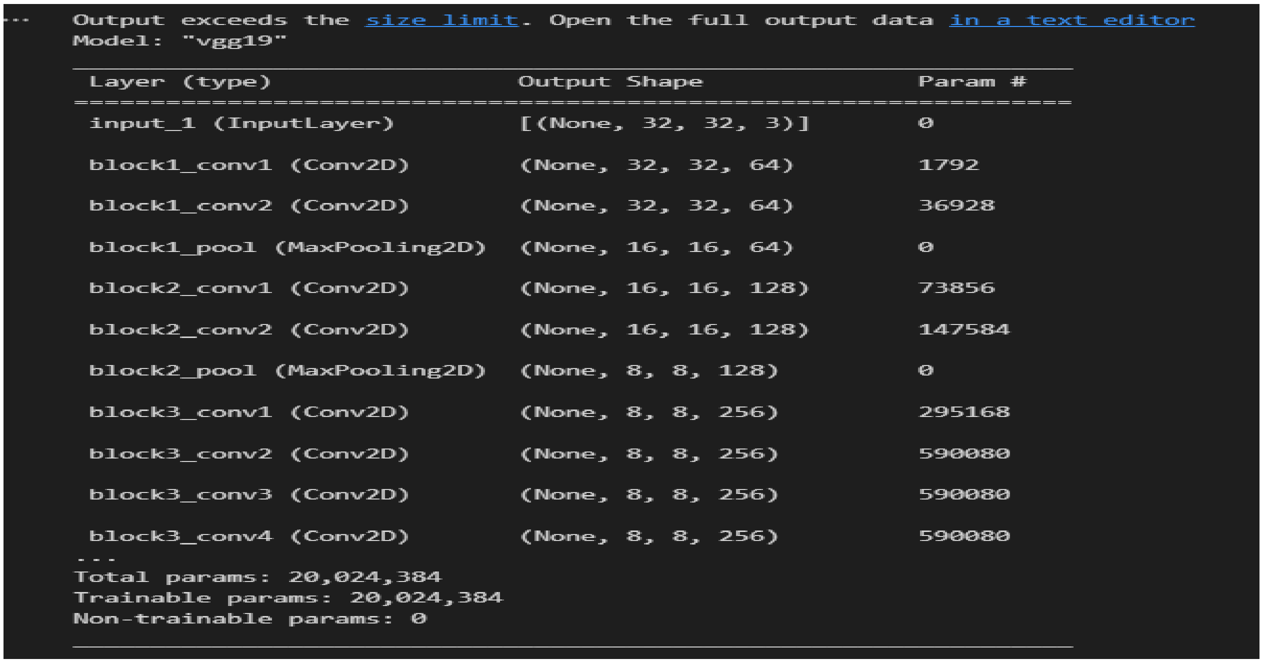
```
from keras.callbacks import ReduceLROnPlateau
learning_rate_reduction = ReduceLROnPlateau(monitor='val_accuracy',
                                            patience=3,
                                            verbose=1,
                                            factor=0.5,
                                            min_lr=0.00001)
```

[19]

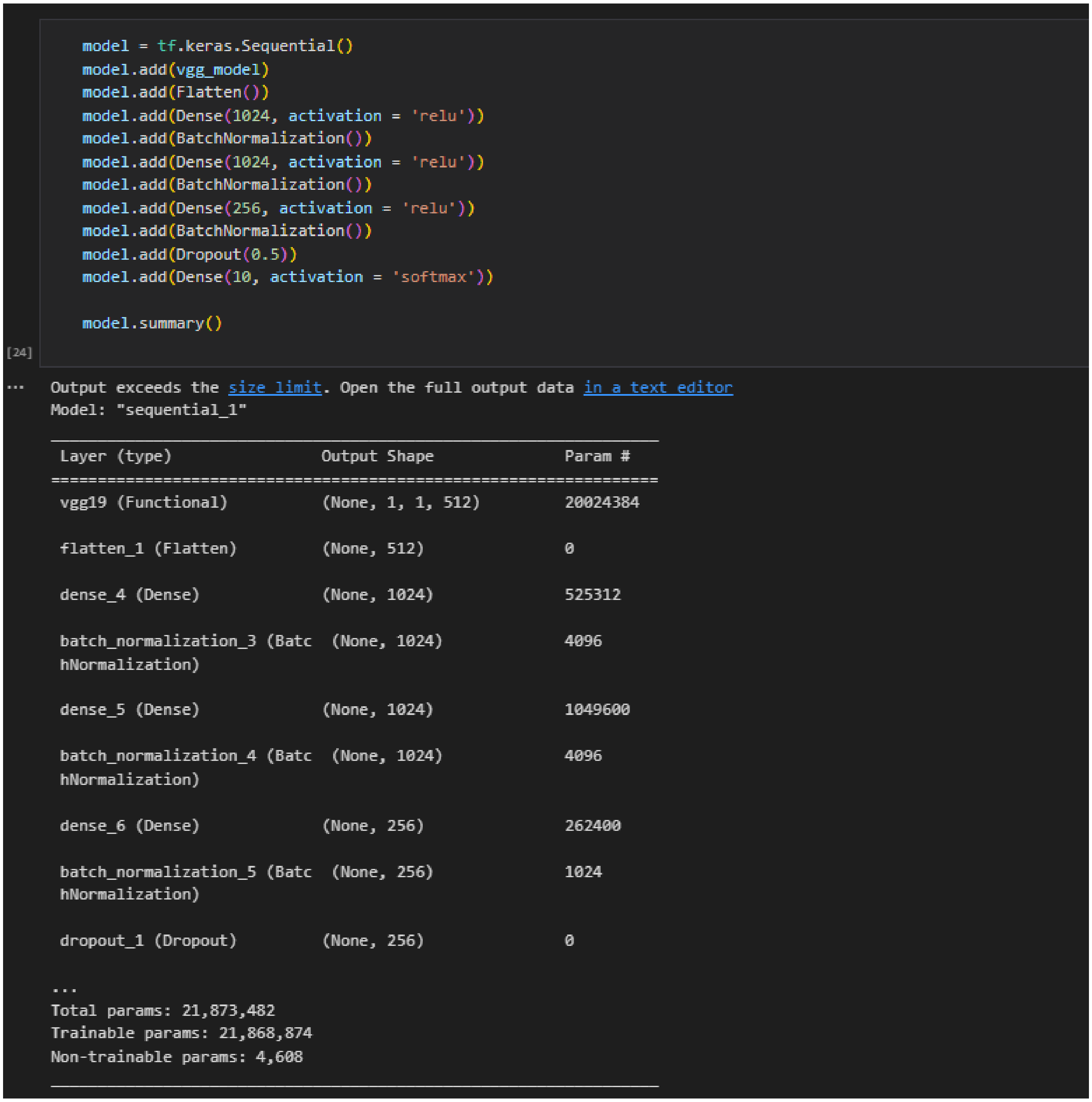
We have used only 16 layers out of 19 layers in the CNN

```
vgg_model = tf.keras.applications.VGG19(
    include_top=False,
    weights=None,
    input_shape=(32,32,3),
)

vgg_model.summary()
```

[20]



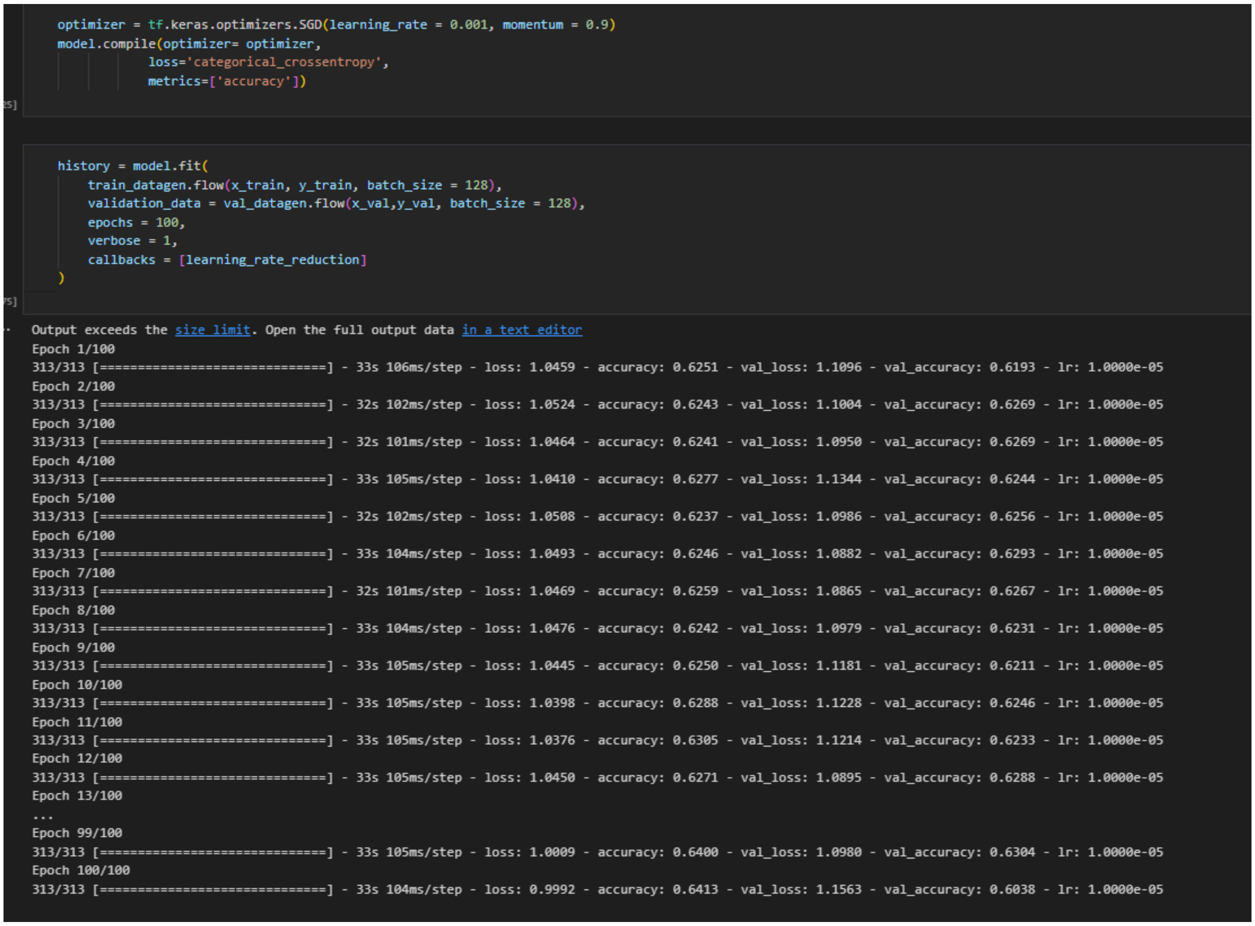
```
...  Output exceeds the size limit. Open the full output data in a text editor
     Model: "vgg19"
     _________________________________________________________________
      Layer (type)                Output Shape              Param #
     =================================================================
      input_1 (InputLayer)        [(None, 32, 32, 3)]       0

      block1_conv1 (Conv2D)       (None, 32, 32, 64)        1792

      block1_conv2 (Conv2D)       (None, 32, 32, 64)        36928

      block1_pool (MaxPooling2D)  (None, 16, 16, 64)        0

      block2_conv1 (Conv2D)       (None, 16, 16, 128)       73856

      block2_conv2 (Conv2D)       (None, 16, 16, 128)       147584

      block2_pool (MaxPooling2D)  (None, 8, 8, 128)         0

      block3_conv1 (Conv2D)       (None, 8, 8, 256)         295168

      block3_conv2 (Conv2D)       (None, 8, 8, 256)         590080

      block3_conv3 (Conv2D)       (None, 8, 8, 256)         590080

      block3_conv4 (Conv2D)       (None, 8, 8, 256)         590080
     ...
     Total params: 20,024,384
     Trainable params: 20,024,384
     Non-trainable params: 0
     _________________________________________________________________
```



```python
model = tf.keras.Sequential()
model.add(vgg_model)
model.add(Flatten())
model.add(Dense(1024, activation = 'relu'))
model.add(BatchNormalization())
model.add(Dense(1024, activation = 'relu'))
model.add(BatchNormalization())
model.add(Dense(256, activation = 'relu'))
model.add(BatchNormalization())
model.add(Dropout(0.5))
model.add(Dense(10, activation = 'softmax'))

model.summary()
```

[24]

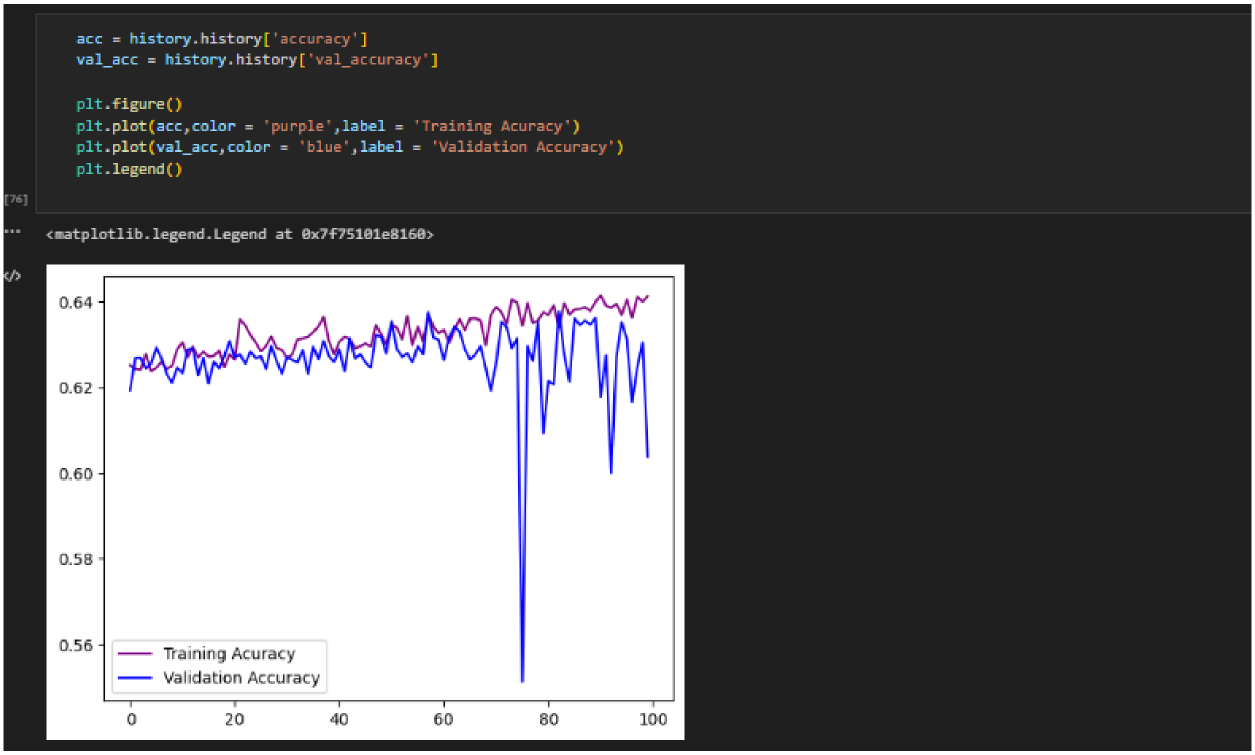
```
Output exceeds the size limit. Open the full output data in a text editor
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 vgg19 (Functional)          (None, 1, 1, 512)         20024384  
                                                                 
 flatten_1 (Flatten)         (None, 512)               0         
                                                                 
 dense_4 (Dense)             (None, 1024)              525312    
                                                                 
 batch_normalization_3 (Batc  (None, 1024)             4096      
 hNormalization)                                                 
                                                                 
 dense_5 (Dense)             (None, 1024)              1049600   
                                                                 
 batch_normalization_4 (Batc  (None, 1024)             4096      
 hNormalization)                                                 
                                                                 
 dense_6 (Dense)             (None, 256)               262400    
                                                                 
 batch_normalization_5 (Batc  (None, 256)              1024      
 hNormalization)                                                 
                                                                 
 dropout_1 (Dropout)         (None, 256)               0         
                                                                 
...
Total params: 21,873,482
Trainable params: 21,868,874
Non-trainable params: 4,608
_________________________________________________________________
```



```
optimizer = tf.keras.optimizers.SGD(learning_rate = 0.001, momentum = 0.9)
model.compile(optimizer= optimizer,
            loss='categorical_crossentropy',
            metrics=['accuracy'])
```

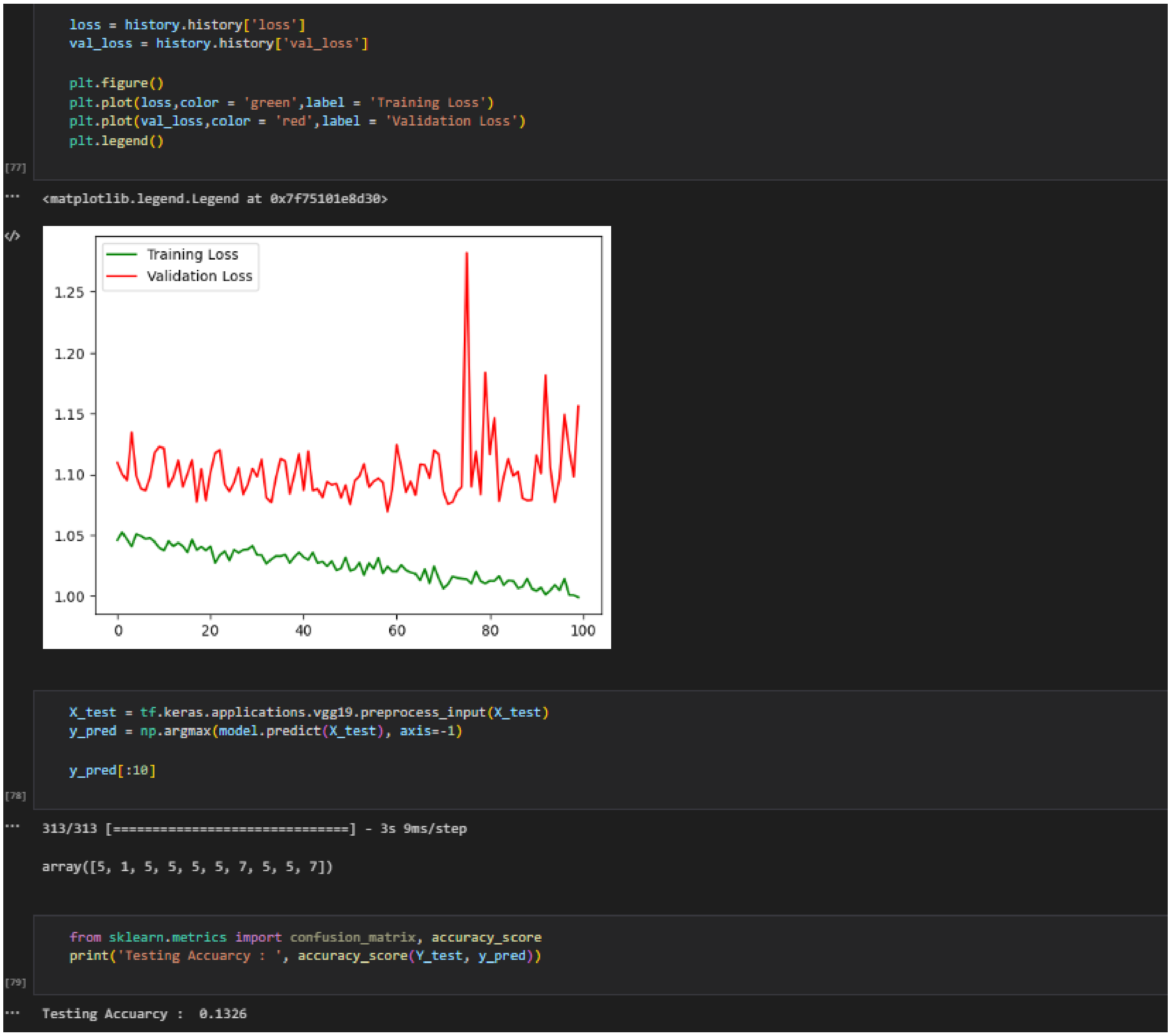
```
history = model.fit(
    train_datagen.flow(x_train, y_train, batch_size = 128),
    validation_data = val_datagen.flow(x_val,y_val, batch_size = 128),
    epochs = 100,
    verbose = 1,
    callbacks = [learning_rate_reduction]
)
```

```
Output exceeds the size limit. Open the full output data in a text editor
Epoch 1/100
313/313 [==============================] - 33s 106ms/step - loss: 1.0459 - accuracy: 0.6251 - val_loss: 1.1096 - val_accuracy: 0.6193 - lr: 1.0000e-05
Epoch 2/100
313/313 [==============================] - 32s 102ms/step - loss: 1.0524 - accuracy: 0.6243 - val_loss: 1.1004 - val_accuracy: 0.6269 - lr: 1.0000e-05
Epoch 3/100
313/313 [==============================] - 32s 101ms/step - loss: 1.0464 - accuracy: 0.6241 - val_loss: 1.0950 - val_accuracy: 0.6269 - lr: 1.0000e-05
Epoch 4/100
313/313 [==============================] - 33s 105ms/step - loss: 1.0410 - accuracy: 0.6277 - val_loss: 1.1344 - val_accuracy: 0.6244 - lr: 1.0000e-05
Epoch 5/100
313/313 [==============================] - 32s 102ms/step - loss: 1.0508 - accuracy: 0.6237 - val_loss: 1.0986 - val_accuracy: 0.6256 - lr: 1.0000e-05
Epoch 6/100
313/313 [==============================] - 33s 104ms/step - loss: 1.0493 - accuracy: 0.6246 - val_loss: 1.0882 - val_accuracy: 0.6293 - lr: 1.0000e-05
Epoch 7/100
313/313 [==============================] - 32s 101ms/step - loss: 1.0469 - accuracy: 0.6259 - val_loss: 1.0865 - val_accuracy: 0.6267 - lr: 1.0000e-05
Epoch 8/100
313/313 [==============================] - 33s 104ms/step - loss: 1.0476 - accuracy: 0.6242 - val_loss: 1.0979 - val_accuracy: 0.6231 - lr: 1.0000e-05
Epoch 9/100
313/313 [==============================] - 33s 105ms/step - loss: 1.0445 - accuracy: 0.6250 - val_loss: 1.1181 - val_accuracy: 0.6211 - lr: 1.0000e-05
Epoch 10/100
313/313 [==============================] - 33s 105ms/step - loss: 1.0398 - accuracy: 0.6288 - val_loss: 1.1228 - val_accuracy: 0.6246 - lr: 1.0000e-05
Epoch 11/100
313/313 [==============================] - 33s 105ms/step - loss: 1.0376 - accuracy: 0.6305 - val_loss: 1.1214 - val_accuracy: 0.6233 - lr: 1.0000e-05
Epoch 12/100
313/313 [==============================] - 33s 105ms/step - loss: 1.0450 - accuracy: 0.6271 - val_loss: 1.0895 - val_accuracy: 0.6288 - lr: 1.0000e-05
Epoch 13/100
...
Epoch 99/100
313/313 [==============================] - 33s 105ms/step - loss: 1.0009 - accuracy: 0.6400 - val_loss: 1.0980 - val_accuracy: 0.6304 - lr: 1.0000e-05
Epoch 100/100
313/313 [==============================] - 33s 104ms/step - loss: 0.9992 - accuracy: 0.6413 - val_loss: 1.1563 - val_accuracy: 0.6038 - lr: 1.0000e-05
```



```
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']

plt.figure()
plt.plot(acc,color = 'purple',label = 'Training Acuracy')
plt.plot(val_acc,color = 'blue',label = 'Validation Accuracy')
plt.legend()
```

```
<matplotlib.legend.Legend at 0x7f75101e8160>
```



```
    loss = history.history['loss']
    val_loss = history.history['val_loss']

    plt.figure()
    plt.plot(loss,color = 'green',label = 'Training Loss')
    plt.plot(val_loss,color = 'red',label = 'Validation Loss')
    plt.legend()
[77]
```

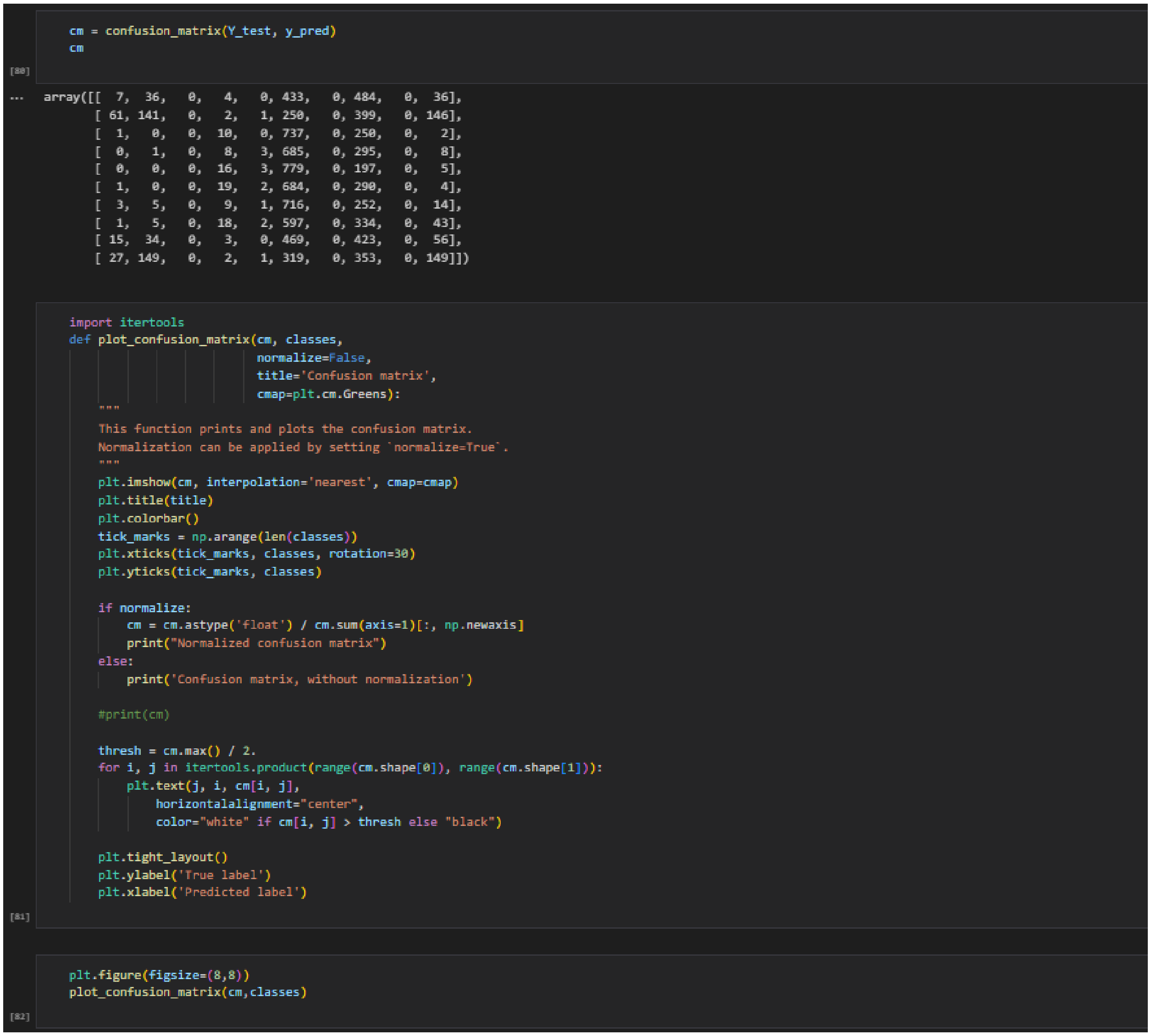
```
<matplotlib.legend.Legend at 0x7f75101e8d30>
```

```
    X_test = tf.keras.applications.vgg19.preprocess_input(X_test)
    y_pred = np.argmax(model.predict(X_test), axis=-1)

    y_pred[:10]
[78]
```

```
313/313 [==============================] - 3s 9ms/step

array([5, 1, 5, 5, 5, 5, 5, 7, 5, 5, 7])
```

```
    from sklearn.metrics import confusion_matrix, accuracy_score
    print('Testing Accuarcy : ', accuracy_score(Y_test, y_pred))
[79]
```

```
Testing Accuarcy :  0.1326
```



```
cm = confusion_matrix(Y_test, y_pred)
cm
```

[80]

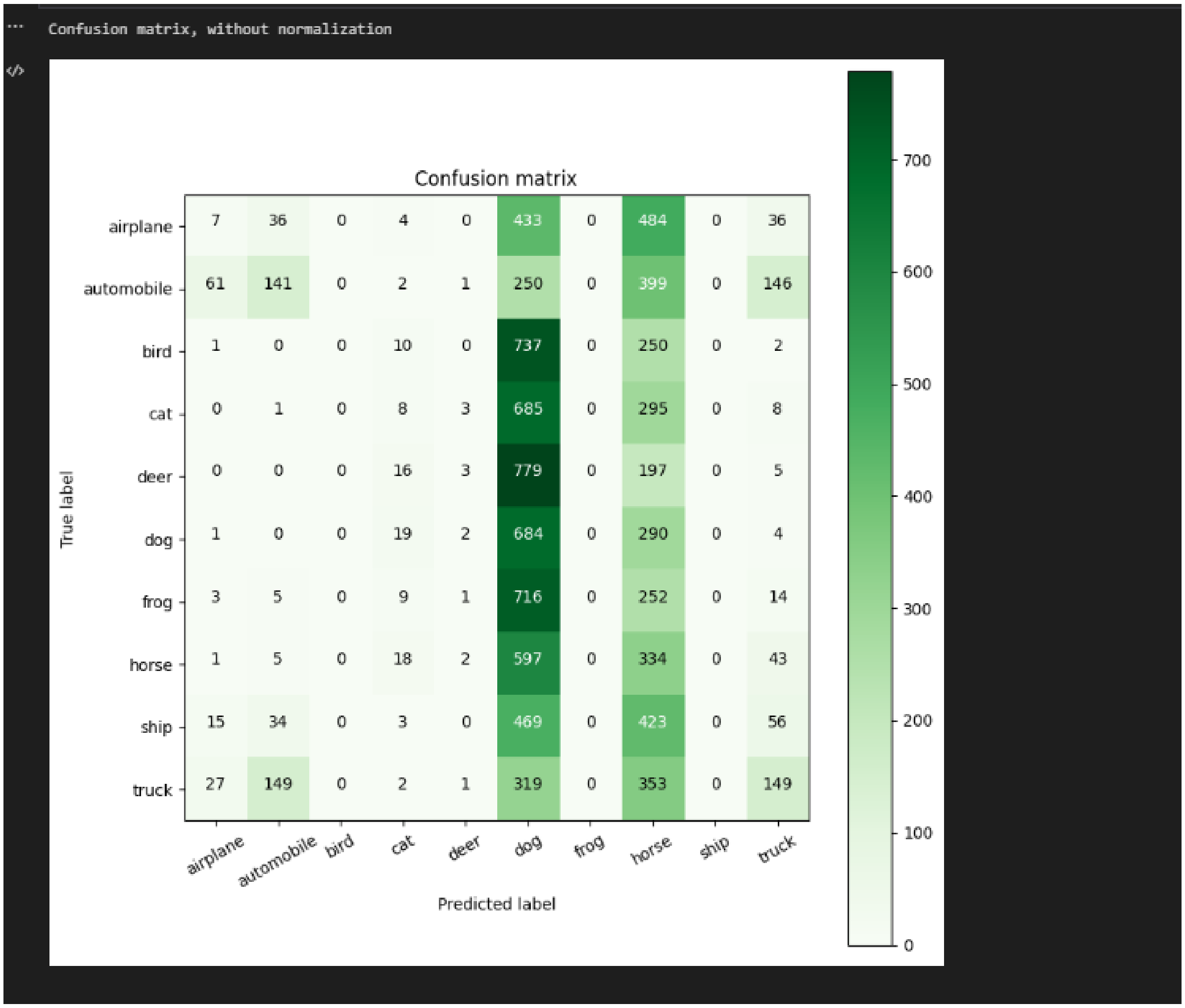
```
array([[  7,  36,   0,   4,   0, 433,   0, 484,   0,  36],
       [ 61, 141,   0,   2,   1, 250,   0, 399,   0, 146],
       [  1,   0,   0,  10,   0, 737,   0, 250,   0,   2],
       [  0,   1,   0,   8,   3, 685,   0, 295,   0,   8],
       [  0,   0,   0,  16,   3, 779,   0, 197,   0,   5],
       [  1,   0,   0,  19,   2, 684,   0, 290,   0,   4],
       [  3,   5,   0,   9,   1, 716,   0, 252,   0,  14],
       [  1,   5,   0,  18,   2, 597,   0, 334,   0,  43],
       [ 15,  34,   0,   3,   0, 469,   0, 423,   0,  56],
       [ 27, 149,   0,   2,   1, 319,   0, 353,   0, 149]])
```

```
import itertools
def plot_confusion_matrix(cm, classes,
                          normalize=False,
                          title='Confusion matrix',
                          cmap=plt.cm.Greens):
    """
    This function prints and plots the confusion matrix.
    Normalization can be applied by setting `normalize=True`.
    """
    plt.imshow(cm, interpolation='nearest', cmap=cmap)
    plt.title(title)
    plt.colorbar()
    tick_marks = np.arange(len(classes))
    plt.xticks(tick_marks, classes, rotation=30)
    plt.yticks(tick_marks, classes)

    if normalize:
        cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]
        print("Normalized confusion matrix")
    else:
        print('Confusion matrix, without normalization')

    #print(cm)

    thresh = cm.max() / 2.
    for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):
        plt.text(j, i, cm[i, j],
            horizontalalignment="center",
            color="white" if cm[i, j] > thresh else "black")

    plt.tight_layout()
    plt.ylabel('True label')
    plt.xlabel('Predicted label')
```

[81]

```
plt.figure(figsize=(8,8))
plot_confusion_matrix(cm,classes)
```

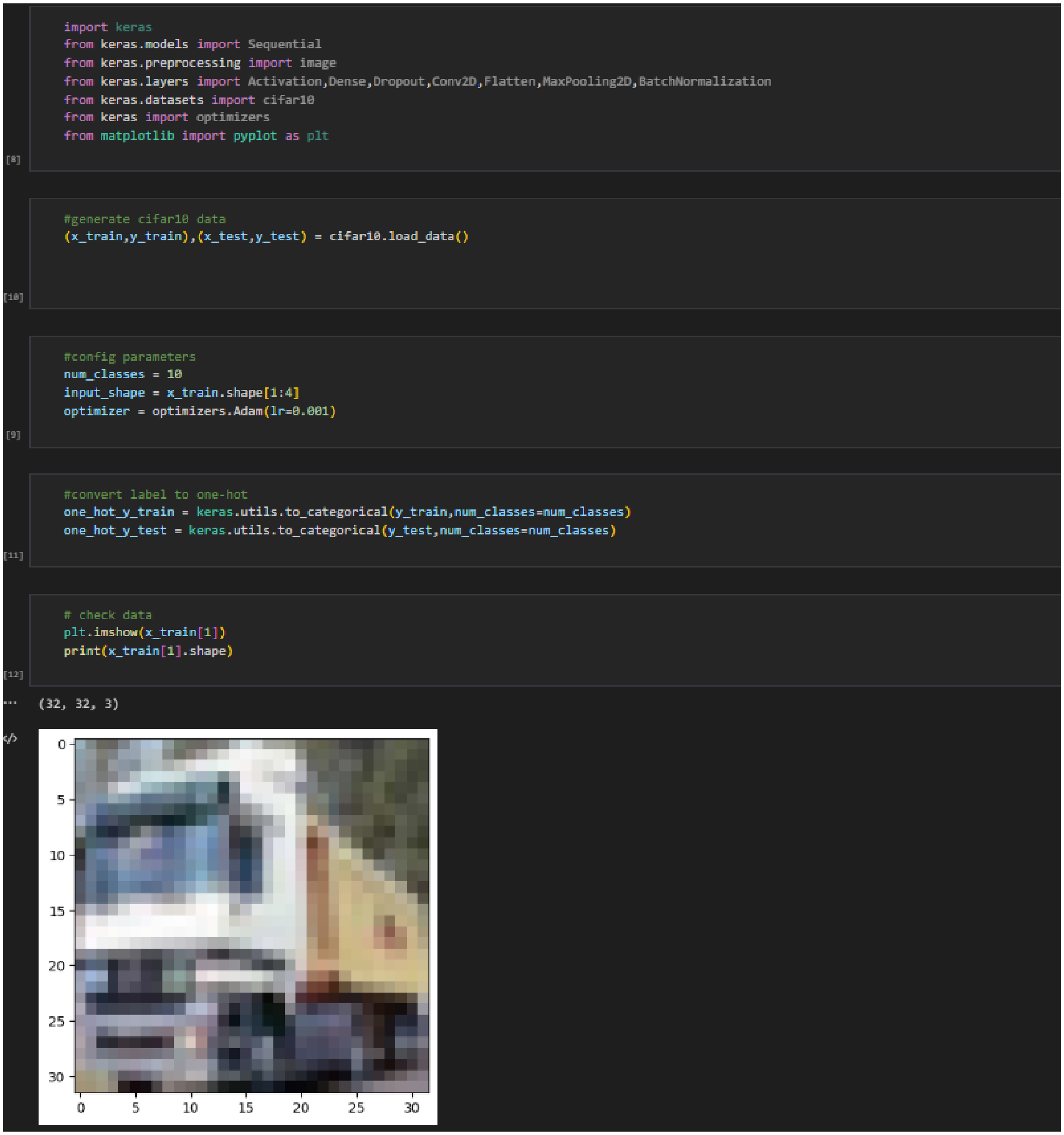
[82]



```
Confusion matrix, without normalization
```

Confusion matrix

True label \ Predicted label	airplane	automobile	bird	cat	deer	dog	frog	horse	ship	truck
airplane	7	36	0	4	0	433	0	484	0	36
automobile	61	141	0	2	1	250	0	399	0	146
bird	1	0	0	10	0	737	0	250	0	2
cat	0	1	0	8	3	685	0	295	0	8
deer	0	0	0	16	3	779	0	197	0	5
dog	1	0	0	19	2	684	0	290	0	4
frog	3	5	0	9	1	716	0	252	0	14
horse	1	5	0	18	2	597	0	334	0	43
ship	15	34	0	3	0	469	0	423	0	56
truck	27	149	0	2	1	319	0	353	0	149



```
import keras
from keras.models import Sequential
from keras.preprocessing import image
from keras.layers import Activation,Dense,Dropout,Conv2D,Flatten,MaxPooling2D,BatchNormalization
from keras.datasets import cifar10
from keras import optimizers
from matplotlib import pyplot as plt
```

[8]

```
#generate cifar10 data
(x_train,y_train),(x_test,y_test) = cifar10.load_data()
```

[10]

```
#config parameters
num_classes = 10
input_shape = x_train.shape[1:4]
optimizer = optimizers.Adam(lr=0.001)
```

[9]

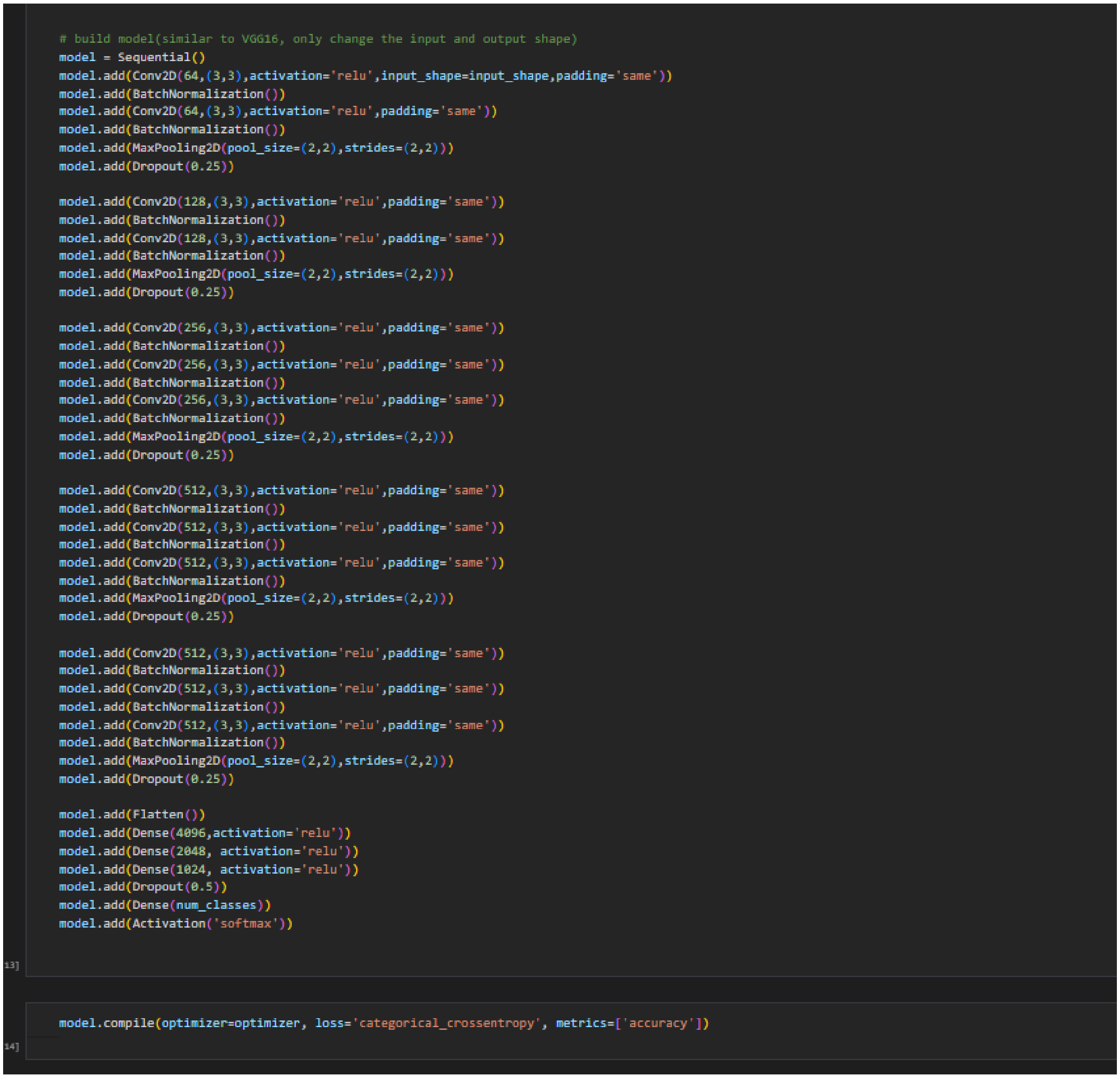
```
#convert label to one-hot
one_hot_y_train = keras.utils.to_categorical(y_train,num_classes=num_classes)
one_hot_y_test = keras.utils.to_categorical(y_test,num_classes=num_classes)
```

[11]

```
# check data
plt.imshow(x_train[1])
print(x_train[1].shape)
```

[12]

```
(32, 32, 3)
```

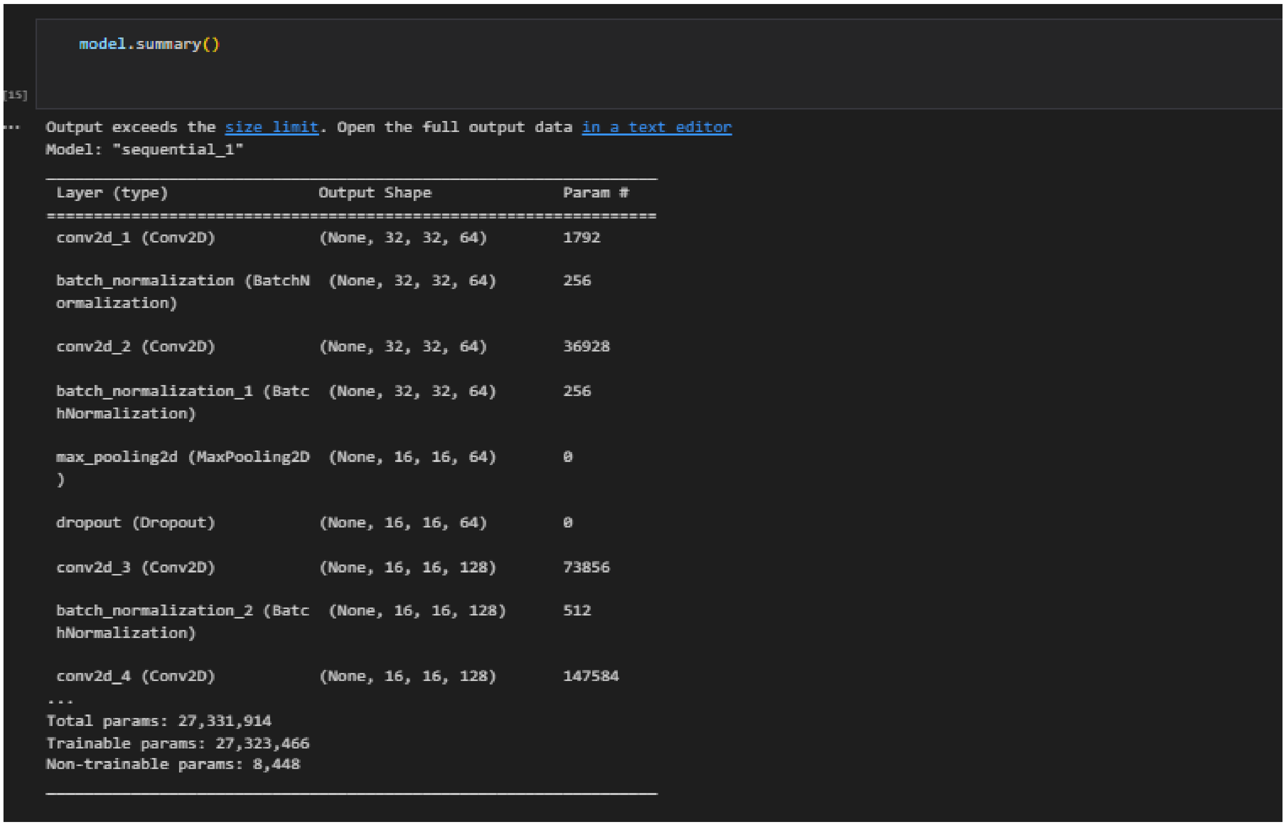


```
# build model(similar to VGG16, only change the input and output shape)
model = Sequential()
model.add(Conv2D(64,(3,3),activation='relu',input_shape=input_shape,padding='same'))
model.add(BatchNormalization())
model.add(Conv2D(64,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
model.add(Dropout(0.25))

model.add(Conv2D(128,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(Conv2D(128,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
model.add(Dropout(0.25))

model.add(Conv2D(256,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(Conv2D(256,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(Conv2D(256,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
model.add(Dropout(0.25))

model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
model.add(Dropout(0.25))

model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
model.add(Dropout(0.25))

model.add(Flatten())
model.add(Dense(4096,activation='relu'))
model.add(Dense(2048, activation='relu'))
model.add(Dense(1024, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes))
model.add(Activation('softmax'))
```

13]

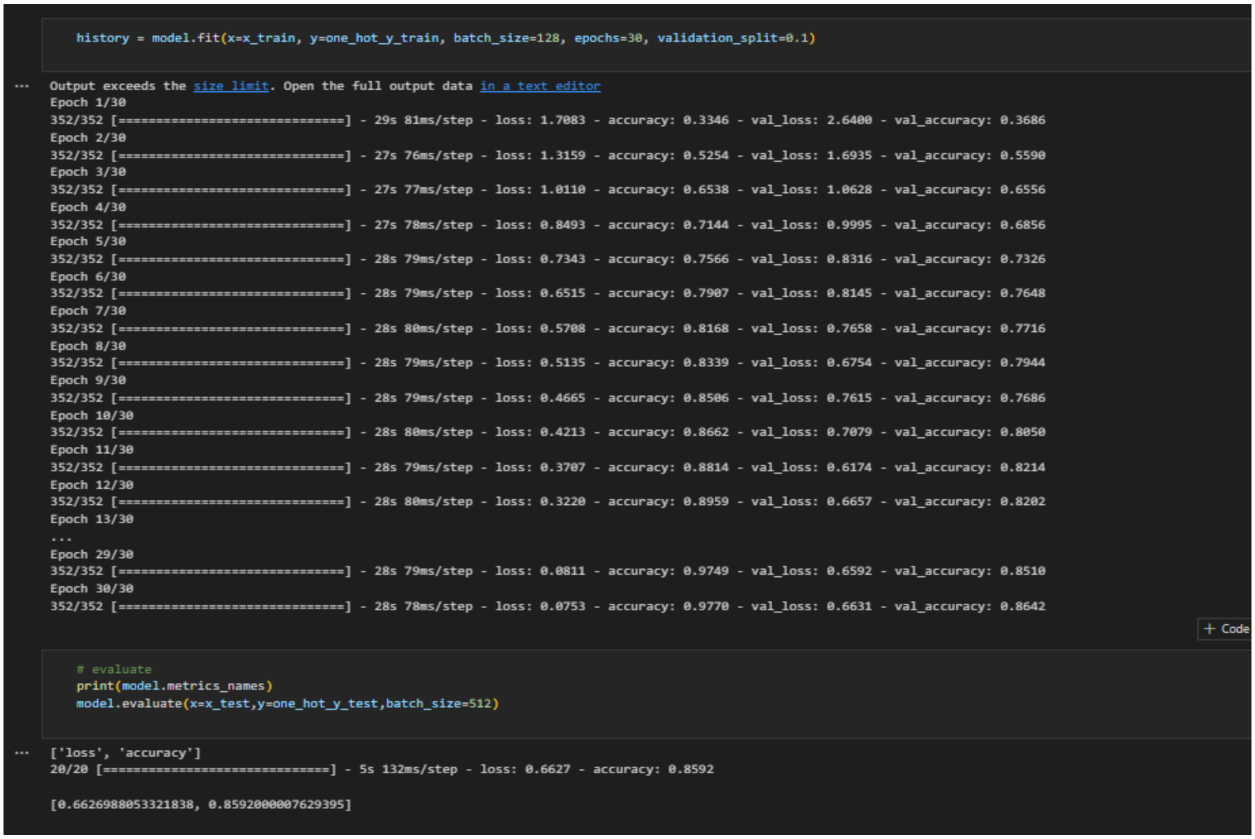
```
model.compile(optimizer=optimizer, loss='categorical_crossentropy', metrics=['accuracy'])
```

14]



```python
model.summary()
```

```
Output exceeds the size limit. Open the full output data in a text editor
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_1 (Conv2D)           (None, 32, 32, 64)        1792

 batch_normalization (BatchN  (None, 32, 32, 64)       256
 ormalization)

 conv2d_2 (Conv2D)           (None, 32, 32, 64)        36928

 batch_normalization_1 (Batc  (None, 32, 32, 64)       256
 hNormalization)

 max_pooling2d (MaxPooling2D  (None, 16, 16, 64)       0
 )

 dropout (Dropout)           (None, 16, 16, 64)        0

 conv2d_3 (Conv2D)           (None, 16, 16, 128)       73856

 batch_normalization_2 (Batc  (None, 16, 16, 128)      512
 hNormalization)

 conv2d_4 (Conv2D)           (None, 16, 16, 128)       147584
...
Total params: 27,331,914
Trainable params: 27,323,466
Non-trainable params: 8,448
_________________________________________________________________
```

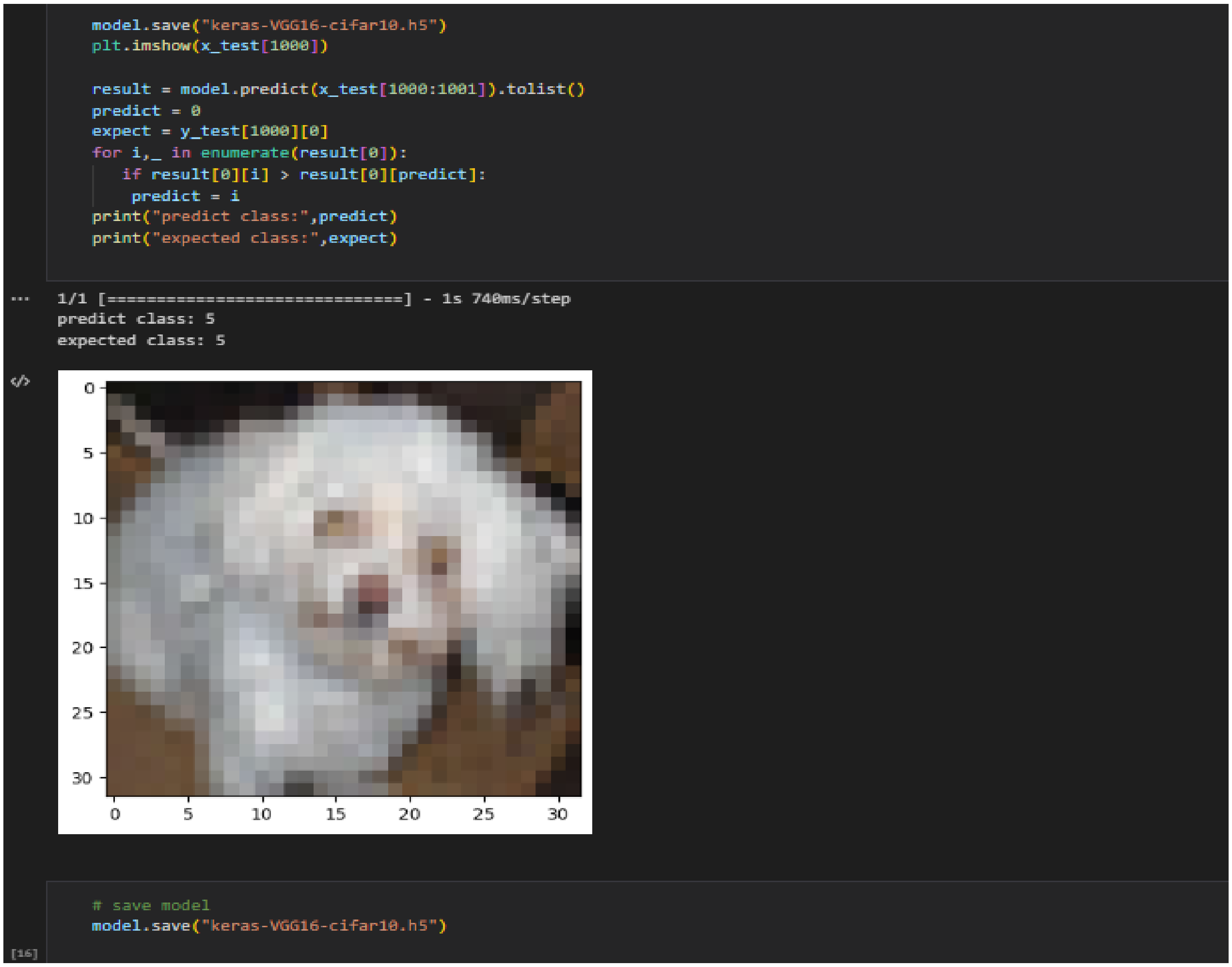


```python
history = model.fit(x=x_train, y=one_hot_y_train, batch_size=128, epochs=30, validation_split=0.1)
```

```
Output exceeds the size limit. Open the full output data in a text editor
Epoch 1/30
352/352 [==============================] - 29s 81ms/step - loss: 1.7083 - accuracy: 0.3346 - val_loss: 2.6400 - val_accuracy: 0.3686
Epoch 2/30
352/352 [==============================] - 27s 76ms/step - loss: 1.3159 - accuracy: 0.5254 - val_loss: 1.6935 - val_accuracy: 0.5590
Epoch 3/30
352/352 [==============================] - 27s 77ms/step - loss: 1.0110 - accuracy: 0.6538 - val_loss: 1.0628 - val_accuracy: 0.6556
Epoch 4/30
352/352 [==============================] - 27s 78ms/step - loss: 0.8493 - accuracy: 0.7144 - val_loss: 0.9995 - val_accuracy: 0.6856
Epoch 5/30
352/352 [==============================] - 28s 79ms/step - loss: 0.7343 - accuracy: 0.7566 - val_loss: 0.8316 - val_accuracy: 0.7326
Epoch 6/30
352/352 [==============================] - 28s 79ms/step - loss: 0.6515 - accuracy: 0.7907 - val_loss: 0.8145 - val_accuracy: 0.7648
Epoch 7/30
352/352 [==============================] - 28s 80ms/step - loss: 0.5708 - accuracy: 0.8168 - val_loss: 0.7658 - val_accuracy: 0.7716
Epoch 8/30
352/352 [==============================] - 28s 79ms/step - loss: 0.5135 - accuracy: 0.8339 - val_loss: 0.6754 - val_accuracy: 0.7944
Epoch 9/30
352/352 [==============================] - 28s 79ms/step - loss: 0.4665 - accuracy: 0.8506 - val_loss: 0.7615 - val_accuracy: 0.7686
Epoch 10/30
352/352 [==============================] - 28s 80ms/step - loss: 0.4213 - accuracy: 0.8662 - val_loss: 0.7079 - val_accuracy: 0.8050
Epoch 11/30
352/352 [==============================] - 28s 79ms/step - loss: 0.3707 - accuracy: 0.8814 - val_loss: 0.6174 - val_accuracy: 0.8214
Epoch 12/30
352/352 [==============================] - 28s 80ms/step - loss: 0.3220 - accuracy: 0.8959 - val_loss: 0.6657 - val_accuracy: 0.8202
Epoch 13/30
...
Epoch 29/30
352/352 [==============================] - 28s 79ms/step - loss: 0.0811 - accuracy: 0.9749 - val_loss: 0.6592 - val_accuracy: 0.8510
Epoch 30/30
352/352 [==============================] - 28s 78ms/step - loss: 0.0753 - accuracy: 0.9770 - val_loss: 0.6631 - val_accuracy: 0.8642
```

```python
# evaluate
print(model.metrics_names)
model.evaluate(x=x_test,y=one_hot_y_test,batch_size=512)
```

```
['loss', 'accuracy']
20/20 [==============================] - 5s 132ms/step - loss: 0.6627 - accuracy: 0.8592

[0.6626988053321838, 0.8592000007629395]
```

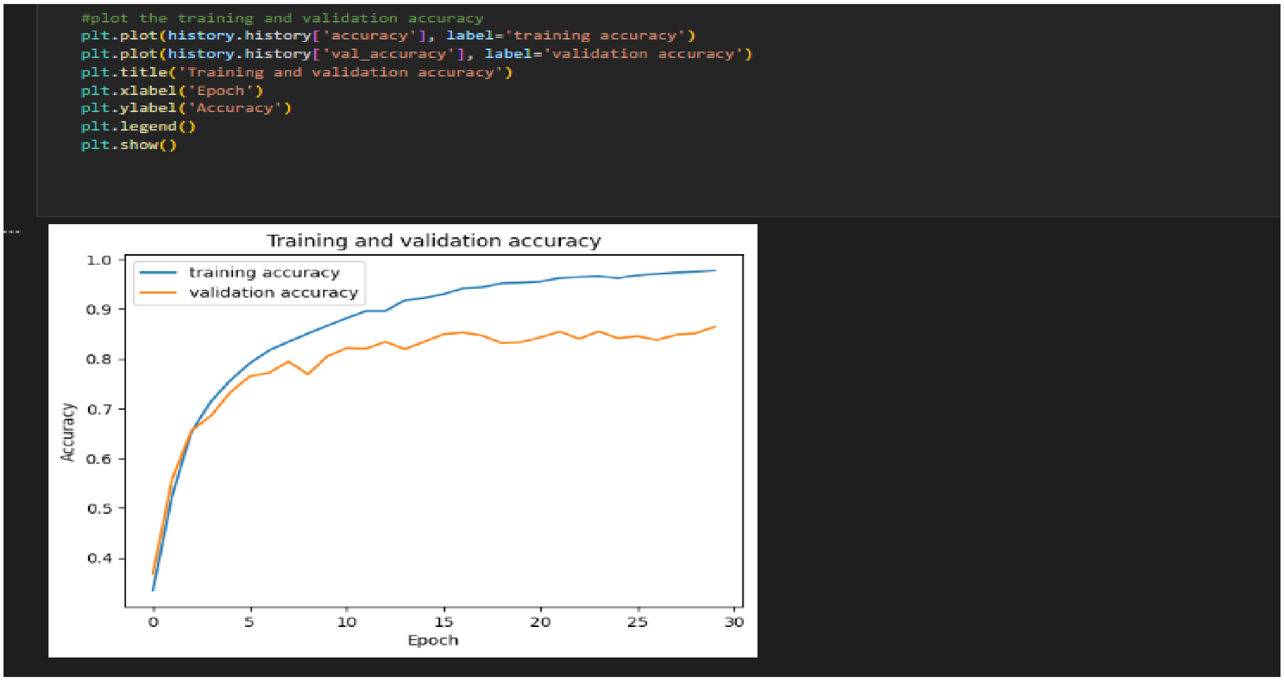


```
model.save("keras-VGG16-cifar10.h5")
plt.imshow(x_test[1000])

result = model.predict(x_test[1000:1001]).tolist()
predict = 0
expect = y_test[1000][0]
for i,_ in enumerate(result[0]):
    if result[0][i] > result[0][predict]:
      predict = i
print("predict class:",predict)
print("expected class:",expect)
```

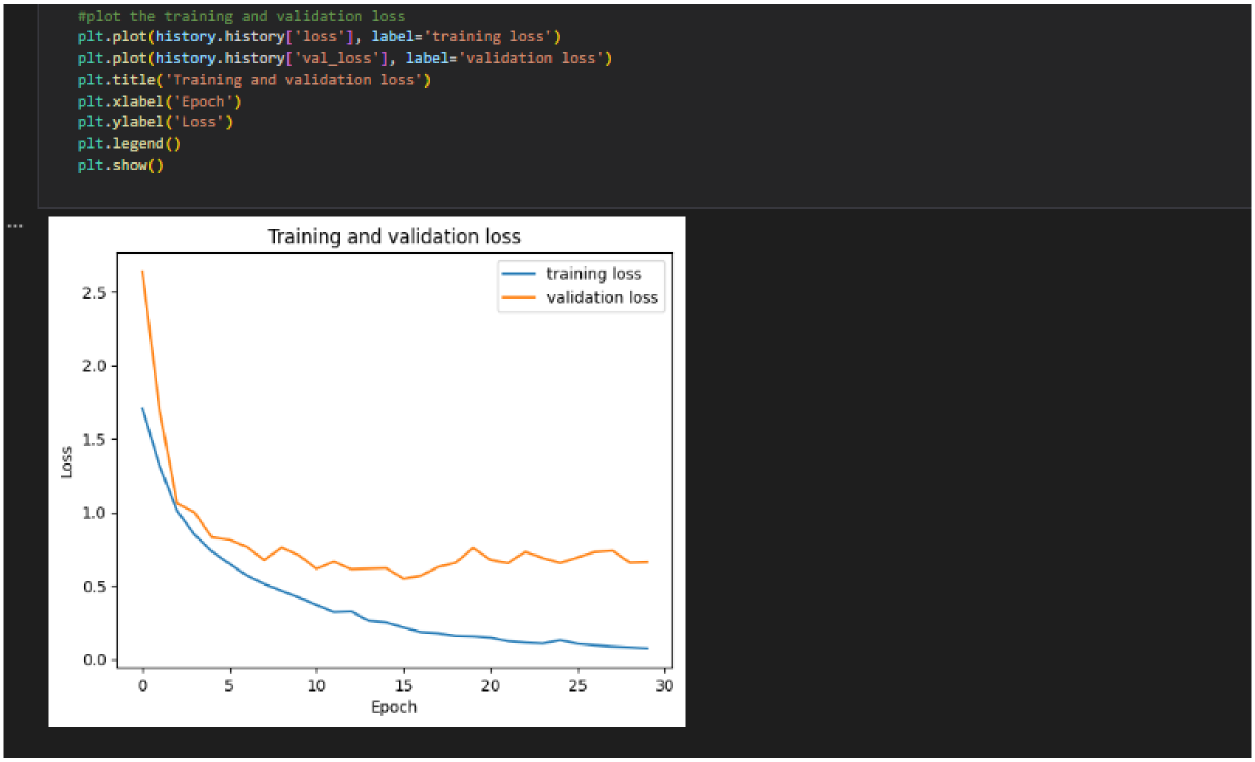
```
1/1 [==============================] - 1s 740ms/step
predict class: 5
expected class: 5
```

```
# save model
model.save("keras-VGG16-cifar10.h5")
```

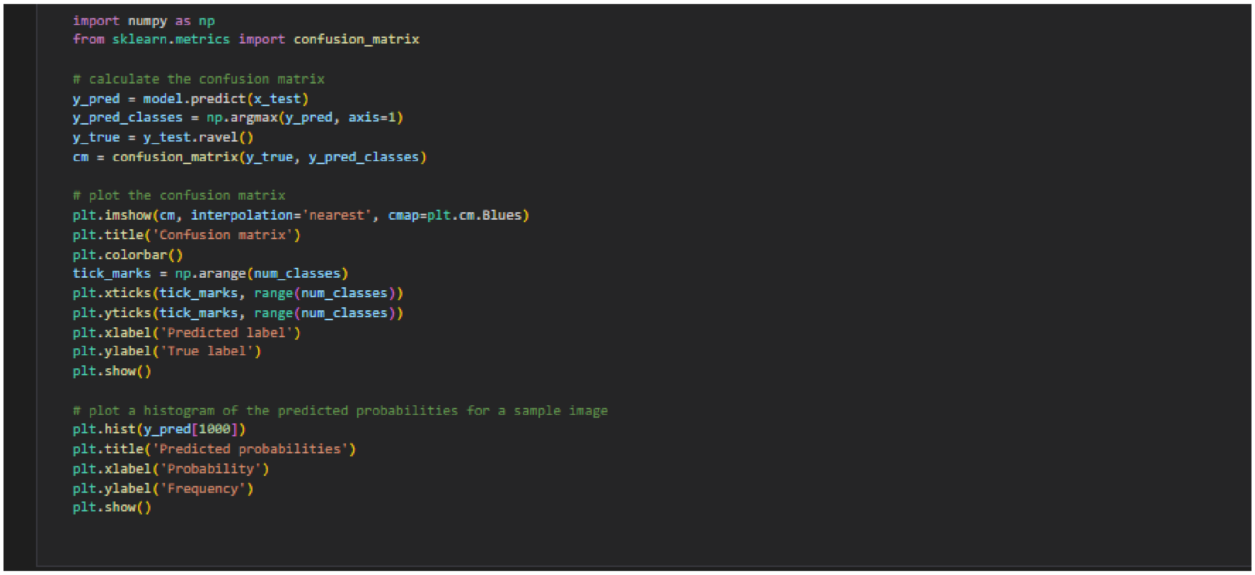
[16]



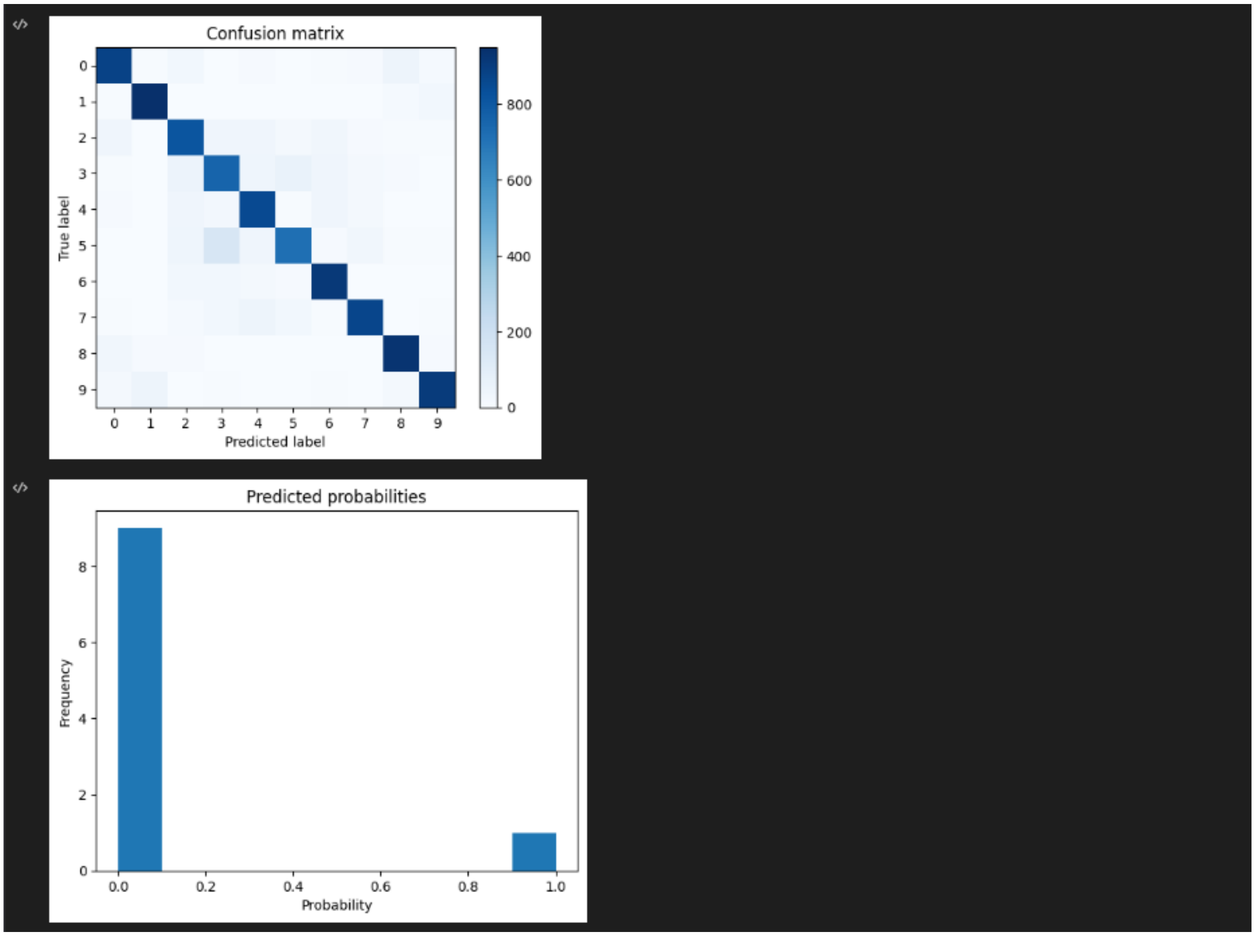
```
#plot the training and validation accuracy
plt.plot(history.history['accuracy'], label='training accuracy')
plt.plot(history.history['val_accuracy'], label='validation accuracy')
plt.title('Training and validation accuracy')
plt.xlabel('Epoch')
plt.ylabel('Accuracy')
plt.legend()
plt.show()
```



```
#plot the training and validation loss
plt.plot(history.history['loss'], label='training loss')
plt.plot(history.history['val_loss'], label='validation loss')
plt.title('Training and validation loss')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()
plt.show()
```



```
import numpy as np
from sklearn.metrics import confusion_matrix

# calculate the confusion matrix
y_pred = model.predict(x_test)
y_pred_classes = np.argmax(y_pred, axis=1)
y_true = y_test.ravel()
cm = confusion_matrix(y_true, y_pred_classes)

# plot the confusion matrix
plt.imshow(cm, interpolation='nearest', cmap=plt.cm.Blues)
plt.title('Confusion matrix')
plt.colorbar()
tick_marks = np.arange(num_classes)
plt.xticks(tick_marks, range(num_classes))
plt.yticks(tick_marks, range(num_classes))
plt.xlabel('Predicted label')
plt.ylabel('True label')
plt.show()

# plot a histogram of the predicted probabilities for a sample image
plt.hist(y_pred[1000])
plt.title('Predicted probabilities')
plt.xlabel('Probability')
plt.ylabel('Frequency')
plt.show()
```


Confusion matrix
True label
0
1
2
3
4
5
6
7
8
9
Predicted label
0
1
2
3
4
5
6
7
8
9
800
600
400
200
0
Predicted probabilities
Frequency
8
6
4
2
0
Probability
0.0
0.2
0.4
0.6
0.8
1.0