Cifar10_Image_Classification

May 1, 2020

0.1 Dataset Reading and Visulization

[1]:
```
import matplotlib.pyplot as plt
from keras.datasets import cifar10
import numpy as np
import time
import cv2
import pandas as pd

from typing import Tuple, Callable
import matplotlib.pyplot as plt
import keras
from keras.utils import to_categorical
from keras import layers
from keras import models
from keras import regularizers
from keras.applications.vgg16 import VGG16
from keras.applications.resnet import ResNet50
from keras.engine.training import Model
import functools
import os
import numpy as np
```

```
Using TensorFlow backend.
```

[3]:
```
(X_train, y_train), (X_test, y_test) = cifar10.load_data()
num_classes=len(np.unique(y_train))
y_train=y_train.reshape(-1)
y_test=y_test.reshape(-1)
Classes={0:'airplane',1:'automobile',2:'bird',3:'cat',4:'deer',5:'dog',6:
 ↪'frog',7:'horse',8:'ship',9:'truck'}
```

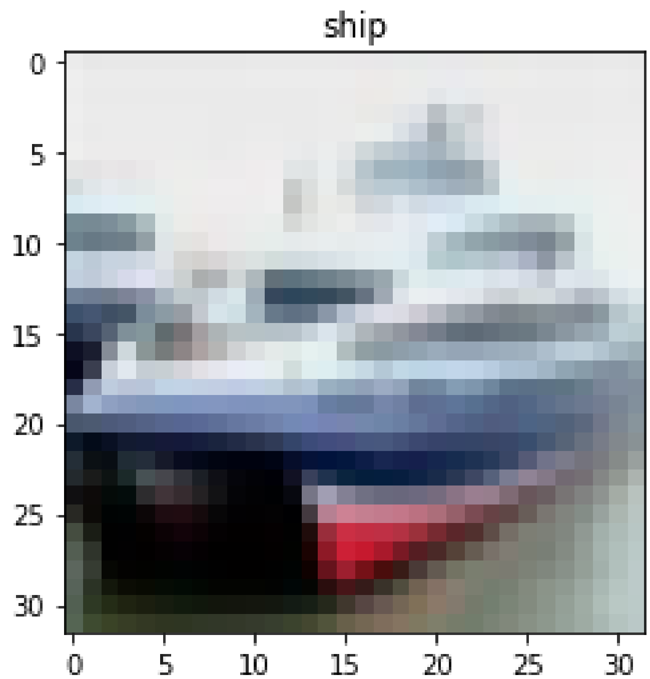
cifar-10 dataset consists of 50000 training images of digits and 10000 testing images. The dataset consists of 32*32*3 rgb images.

[4]:
```
print('Training Dataset shape:',X_train.shape)
print('Training labels shape:',y_train.shape)
```

```
print('Testing Dataset shape:',X_test.shape)
print('Testing labels shape:',y_test.shape)

print('Unique Labels:',np.unique(y_train))
```

```
Training Dataset shape: (50000, 32, 32, 3)
Training labels shape: (50000,)
Testing Dataset shape: (10000, 32, 32, 3)
Testing labels shape: (10000,)
Unique Labels: [0 1 2 3 4 5 6 7 8 9]
```

[5]:
```
# Visulizing Dataset one example.
plt.imshow(X_test[1])
plt.title(Classes[y_test[1]]);
```



Visualizing first 40 images from training dataset and their labels.

[6]:
```
plt.figure(figsize=(14,80))
for i in range (0,40):
    plt.subplot(40,10,i+1)
    img1=X_train[i]
    plt.imshow(img1)
    plt.title(Classes[y_train[i]])
    plt.axis('off')
plt.show()
```

[7]:
```python
train_X=X_train
test_X=X_test

print('X_train shape:',train_X.shape)
print('X_test shape:',test_X.shape)
```

```
X_train shape: (50000, 32, 32, 3)
X_test shape: (10000, 32, 32, 3)
```

[8]:
```python
train_y=to_categorical(y_train,num_classes)
test_y=to_categorical(y_test,num_classes)

print('y_train shape:',train_y.shape)
print('y_test shape:',test_y.shape)
```

```
y_train shape: (50000, 10)
y_test shape: (10000, 10)
```

0.2 Classification Method:

0.2.1 VGG:

[9]:
```python
def VGG_16(num_classes,img_size=(32,32,3)):
    initial_model: Model = VGG16(include_top=False, weights=None,input_shape=img_size)

    x = layers.Flatten()(initial_model.output)
    x = layers.Dense(256, activation='relu')(x)
```

```
    predictions = layers.Dense(num_classes, activation='softmax')(x)

    model = Model(initial_model.input, predictions)
    model.compile(loss='categorical_crossentropy', optimizer='adam',␣
↪metrics=['acc'])
    return model
```

[10]:
```
VGG_model=VGG_16(num_classes,img_size=(32,32,3))
VGG_model.summary()
```

```
WARNING:tensorflow:From C:\Users\afaq.ahmad\.conda\envs\tf_gpu\lib\site-
packages\keras\backend\tensorflow_backend.py:4070: The name tf.nn.max_pool is
deprecated. Please use tf.nn.max_pool2d instead.

Model: "model_1"
_________________________________________________________________
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_pool (MaxPooling2D)   (None, 4, 4, 256)         0
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 4, 4, 512)         1180160
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 4, 4, 512)         2359808
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 4, 4, 512)         2359808
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 2, 2, 512)         0
```

```
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 2, 2, 512)         2359808
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 2, 2, 512)         2359808
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 2, 2, 512)         2359808
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 1, 1, 512)         0
_________________________________________________________________
flatten_1 (Flatten)          (None, 512)               0
_________________________________________________________________
dense_1 (Dense)              (None, 256)               131328
_________________________________________________________________
dense_2 (Dense)              (None, 10)                2570
=================================================================
Total params: 14,848,586
Trainable params: 14,848,586
Non-trainable params: 0

_________________________________________________________________
```

[12]:
```
def get_callbacks_list():
    """Get callbacks for a model"""
    return [keras.callbacks.EarlyStopping(monitor='val_acc',patience=20),
        keras.callbacks.ReduceLROnPlateau(monitor='val_loss',factor=0.
 ↪2,patience=5)]
```

[13]:
```
history_vgg = VGG_model.fit(train_X,train_y,batch_size=128,epochs =␣
 ↪200,callbacks=get_callbacks_list(),validation_split=0.1)
```

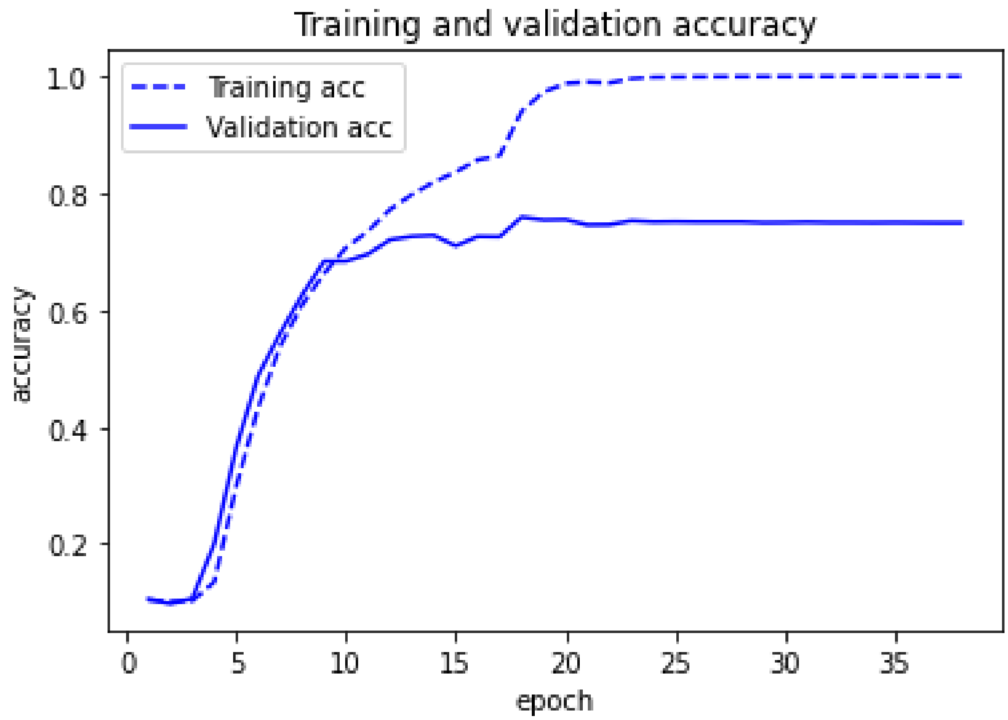
```
WARNING:tensorflow:From C:\Users\afaq.ahmad\.conda\envs\tf_gpu\lib\site-
packages\keras\backend\tensorflow_backend.py:422: The name tf.global_variables
is deprecated. Please use tf.compat.v1.global_variables instead.

Train on 45000 samples, validate on 5000 samples
Epoch 1/200
45000/45000 [==============================] - 57s 1ms/step - loss: 2.4082 -
acc: 0.1037 - val_loss: 2.3010 - val_acc: 0.1058
Epoch 2/200
45000/45000 [==============================] - 53s 1ms/step - loss: 2.3181 -
acc: 0.1017 - val_loss: 2.3037 - val_acc: 0.0976
Epoch 3/200
45000/45000 [==============================] - 54s 1ms/step - loss: 2.3031 -
acc: 0.1021 - val_loss: 2.3167 - val_acc: 0.1064
Epoch 4/200
45000/45000 [==============================] - 54s 1ms/step - loss: 2.2424 -
acc: 0.1347 - val_loss: 1.9479 - val_acc: 0.2002
Epoch 5/200
45000/45000 [==============================] - 54s 1ms/step - loss: 1.7903 -
```

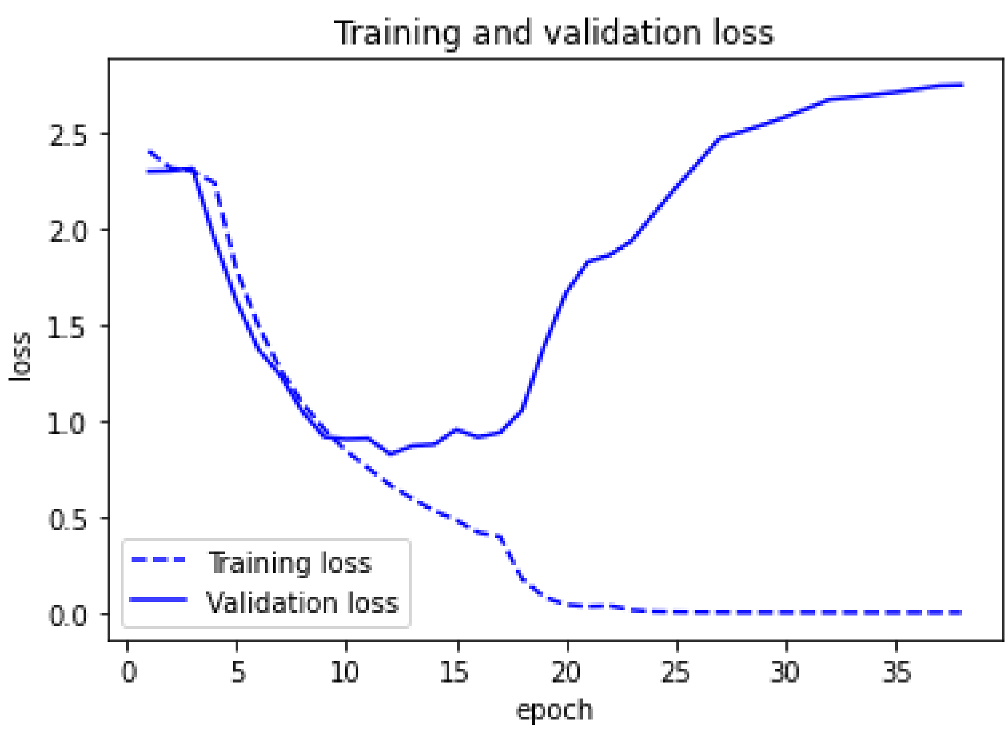
```
acc: 0.2976 - val_loss: 1.6247 - val_acc: 0.3642
Epoch 6/200
45000/45000 [==============================] - 54s 1ms/step - loss: 1.4971 -
acc: 0.4327 - val_loss: 1.3739 - val_acc: 0.4878
Epoch 7/200
45000/45000 [==============================] - 54s 1ms/step - loss: 1.2704 -
acc: 0.5380 - val_loss: 1.2387 - val_acc: 0.5602
Epoch 8/200
45000/45000 [==============================] - 55s 1ms/step - loss: 1.0946 -
acc: 0.6087 - val_loss: 1.0503 - val_acc: 0.6258
Epoch 9/200
45000/45000 [==============================] - 56s 1ms/step - loss: 0.9577 -
acc: 0.6625 - val_loss: 0.9165 - val_acc: 0.6836
Epoch 10/200
45000/45000 [==============================] - 57s 1ms/step - loss: 0.8435 -
acc: 0.7068 - val_loss: 0.9054 - val_acc: 0.6836
Epoch 11/200
45000/45000 [==============================] - 56s 1ms/step - loss: 0.7552 -
acc: 0.7347 - val_loss: 0.9092 - val_acc: 0.6956
Epoch 12/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.6654 -
acc: 0.7721 - val_loss: 0.8264 - val_acc: 0.7204
Epoch 13/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.5954 -
acc: 0.7978 - val_loss: 0.8701 - val_acc: 0.7262
Epoch 14/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.5328 -
acc: 0.8191 - val_loss: 0.8775 - val_acc: 0.7280
Epoch 15/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.4834 -
acc: 0.8367 - val_loss: 0.9546 - val_acc: 0.7098
Epoch 16/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.4192 -
acc: 0.8572 - val_loss: 0.9153 - val_acc: 0.7260
Epoch 17/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.3967 -
acc: 0.8645 - val_loss: 0.9393 - val_acc: 0.7256
Epoch 18/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.1773 -
acc: 0.9403 - val_loss: 1.0546 - val_acc: 0.7592
Epoch 19/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0833 -
acc: 0.9736 - val_loss: 1.3879 - val_acc: 0.7544
Epoch 20/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0424 -
acc: 0.9879 - val_loss: 1.6679 - val_acc: 0.7550
Epoch 21/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0327 -
```

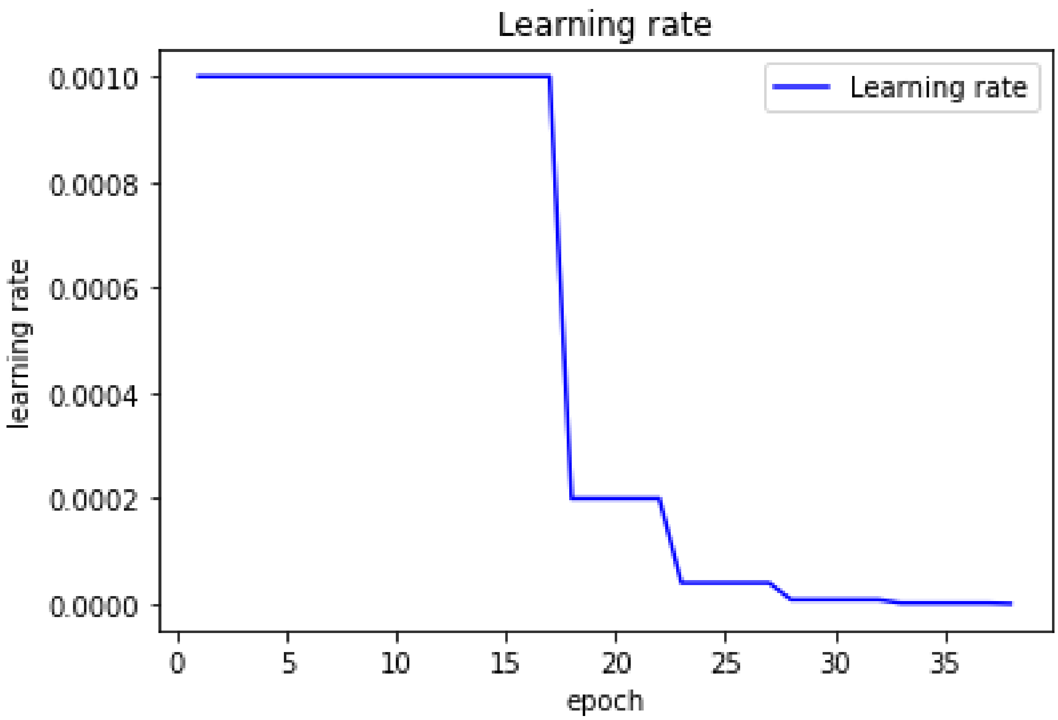
```
acc: 0.9904 - val_loss: 1.8288 - val_acc: 0.7458
Epoch 22/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0368 -
acc: 0.9889 - val_loss: 1.8648 - val_acc: 0.7462
Epoch 23/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0151 -
acc: 0.9961 - val_loss: 1.9392 - val_acc: 0.7530
Epoch 24/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0066 -
acc: 0.9985 - val_loss: 2.0793 - val_acc: 0.7510
Epoch 25/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0045 -
acc: 0.9990 - val_loss: 2.2155 - val_acc: 0.7514
Epoch 26/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0034 -
acc: 0.9993 - val_loss: 2.3429 - val_acc: 0.7510
Epoch 27/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0025 -
acc: 0.9995 - val_loss: 2.4738 - val_acc: 0.7510
Epoch 28/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0019 -
acc: 0.9996 - val_loss: 2.5077 - val_acc: 0.7510
Epoch 29/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0017 -
acc: 0.9996 - val_loss: 2.5452 - val_acc: 0.7498
Epoch 30/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0015 -
acc: 0.9997 - val_loss: 2.5853 - val_acc: 0.7500
Epoch 31/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0014 -
acc: 0.9998 - val_loss: 2.6291 - val_acc: 0.7506
Epoch 32/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0012 -
acc: 0.9998 - val_loss: 2.6763 - val_acc: 0.7500
Epoch 33/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0011 -
acc: 0.9998 - val_loss: 2.6872 - val_acc: 0.7500
Epoch 34/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0011 -
acc: 0.9998 - val_loss: 2.6996 - val_acc: 0.7498
Epoch 35/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0011 -
acc: 0.9998 - val_loss: 2.7133 - val_acc: 0.7500
Epoch 36/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0011 -
acc: 0.9999 - val_loss: 2.7295 - val_acc: 0.7498
Epoch 37/200
45000/45000 [==============================] - 54s 1ms/step - loss: 0.0010 -
```

```
acc: 0.9999 - val_loss: 2.7469 - val_acc: 0.7496
Epoch 38/200
45000/45000 [==============================] - 55s 1ms/step - loss: 0.0010 -
acc: 0.9999 - val_loss: 2.7509 - val_acc: 0.7496
```

[14]:
```
def draw_training_info_plots(_history):
    """Draw loss graphs at the training and validation stage"""
    acc = _history.history['acc']
    val_acc = _history.history['val_acc']
    loss = _history.history['loss']
    val_loss = _history.history['val_loss']

    epochs_plot = range(1, len(acc) + 1)
    plt.plot(epochs_plot, acc, 'b--', label='Training acc')
    plt.plot(epochs_plot, val_acc, 'b', label='Validation acc')
    plt.title('Training and validation accuracy')
    plt.xlabel('epoch')
    plt.ylabel('accuracy')
    plt.legend()
    plt.figure()

    plt.plot(epochs_plot, loss, 'b--', label='Training loss')
    plt.plot(epochs_plot, val_loss, 'b', label='Validation loss')
    plt.title('Training and validation loss')
    plt.xlabel('epoch')
    plt.ylabel('loss')
    plt.legend()
    plt.show()

    if 'lr' in _history.history:
        learning_rate = _history.history['lr']
        plt.plot(epochs_plot, learning_rate, 'b', label='Learning rate')
        plt.title('Learning rate')
        plt.xlabel('epoch')
        plt.ylabel('learning rate')
        plt.legend()
        plt.show()
    return

draw_training_info_plots(history_vgg)
```


Training and validation accuracy
Training acc
Validation acc
accuracy
epoch
1.0
0.8
0.6
0.4
0.2
0
5
10
15
20
25
30
35


Training and validation loss
Training loss
Validation loss
loss
epoch
2.5
2.0
1.5
1.0
0.5
0.0
0
5
10
15
20
25
30
35




```
[15]: print('Accuracy:',VGG_model.evaluate(test_X,test_y,verbose=0)[1])
```

```
Accuracy: 0.7437999844551086
```

Classification Score and Confusion Metric

```
[16]: predictions = VGG_model.predict(test_X)

from sklearn.metrics import classification_report
print("EVALUATION ON TESTING DATA")
print(classification_report(y_test, np.argmax(predictions,axis=1)))
```

```
EVALUATION ON TESTING DATA
              precision    recall  f1-score   support

           0       0.76      0.79      0.77      1000
           1       0.88      0.88      0.88      1000
           2       0.64      0.63      0.63      1000
           3       0.52      0.59      0.55      1000
           4       0.72      0.66      0.69      1000
           5       0.63      0.67      0.65      1000
           6       0.82      0.80      0.81      1000
           7       0.79      0.77      0.78      1000
           8       0.86      0.83      0.85      1000
           9       0.86      0.82      0.84      1000
```

```
    accuracy                           0.74     10000
   macro avg       0.75      0.74      0.75     10000
weighted avg       0.75      0.74      0.75     10000
```

[27]:
```
from sklearn.metrics import confusion_matrix
import pandas as pd
print ("Confusion matrix")
pd.DataFrame(confusion_matrix(y_test,np.
 ↪argmax(predictions,axis=1)),columns=list(np.array(list(Classes.items()))[:
 ↪,1]),index=list(np.array(list(Classes.items()))[:,1]))
```

```
Confusion matrix
```

[27]:

	airplane	automobile	bird	cat	deer	dog	frog	horse	ship	truck
airplane	790	13	59	26	16	3	5	17	50	21
automobile	10	880	1	10	1	2	6	2	29	59
bird	67	1	627	78	81	64	46	20	11	5
cat	23	6	72	591	52	167	43	30	10	6
deer	18	1	82	70	658	45	53	67	5	1
dog	6	2	44	182	33	673	10	42	3	5
frog	3	3	62	71	30	24	795	5	3	4
horse	15	1	23	52	43	75	4	772	2	13
ship	73	28	14	21	1	5	6	6	832	14
truck	41	65	3	30	3	6	2	13	17	820

[28]:
```
VGG_model.save('VGG_model_cifar10.h5')
```

0.2.2 Resnet:

[29]:
```
def Resnet_50(num_classes,img_size=(32,32,3)):
    initial_model: Model = ResNet50(include_top=False,␣
 ↪weights=None,input_shape=img_size)
```

```
    x = layers.Flatten()(initial_model.output)
    x = layers.Dense(256, activation='relu')(x)
    predictions = layers.Dense(num_classes, activation='softmax')(x)

    model = Model(initial_model.input, predictions)
    model.compile(loss='categorical_crossentropy', optimizer='adam',␣
↪metrics=['acc'])
    return model
```

[33]:
```
Resnet_model=Resnet_50(num_classes,img_size=(32,32,3))
Resnet_model.summary()
```

```
Model: "model_3"
________________________________________________________________________________
__________________
Layer (type)                    Output Shape         Param #     Connected to
================================================================================
==================
input_3 (InputLayer)            (None, 32, 32, 3)    0
________________________________________________________________________________
__________________
conv1_pad (ZeroPadding2D)       (None, 38, 38, 3)    0           input_3[0][0]
________________________________________________________________________________
__________________
conv1_conv (Conv2D)             (None, 16, 16, 64)   9472        conv1_pad[0][0]
________________________________________________________________________________
__________________
conv1_bn (BatchNormalization)   (None, 16, 16, 64)   256
conv1_conv[0][0]
________________________________________________________________________________
__________________
conv1_relu (Activation)         (None, 16, 16, 64)   0           conv1_bn[0][0]
________________________________________________________________________________
__________________
pool1_pad (ZeroPadding2D)       (None, 18, 18, 64)   0
conv1_relu[0][0]
________________________________________________________________________________
__________________
pool1_pool (MaxPooling2D)       (None, 8, 8, 64)     0           pool1_pad[0][0]
________________________________________________________________________________
__________________
conv2_block1_1_conv (Conv2D)    (None, 8, 8, 64)     4160
pool1_pool[0][0]
________________________________________________________________________________
__________________
conv2_block1_1_bn (BatchNormali (None, 8, 8, 64)     256
conv2_block1_1_conv[0][0]
```

```
--------------------------------------------------------------------------------
------------------
conv2_block1_1_relu (Activation (None, 8, 8, 64)     0
conv2_block1_1_bn[0][0]

--------------------------------------------------------------------------------
------------------
conv2_block1_2_conv (Conv2D)    (None, 8, 8, 64)     36928
conv2_block1_1_relu[0][0]

--------------------------------------------------------------------------------
------------------
conv2_block1_2_bn (BatchNormali (None, 8, 8, 64)     256
conv2_block1_2_conv[0][0]

--------------------------------------------------------------------------------
------------------
conv2_block1_2_relu (Activation (None, 8, 8, 64)     0
conv2_block1_2_bn[0][0]

--------------------------------------------------------------------------------
------------------
conv2_block1_0_conv (Conv2D)    (None, 8, 8, 256)    16640
pool1_pool[0][0]

--------------------------------------------------------------------------------
------------------
conv2_block1_3_conv (Conv2D)    (None, 8, 8, 256)    16640
conv2_block1_2_relu[0][0]

--------------------------------------------------------------------------------
------------------
conv2_block1_0_bn (BatchNormali (None, 8, 8, 256)    1024
conv2_block1_0_conv[0][0]

--------------------------------------------------------------------------------
------------------
conv2_block1_3_bn (BatchNormali (None, 8, 8, 256)    1024
conv2_block1_3_conv[0][0]

--------------------------------------------------------------------------------
------------------
conv2_block1_add (Add)          (None, 8, 8, 256)    0
conv2_block1_0_bn[0][0]
conv2_block1_3_bn[0][0]

--------------------------------------------------------------------------------
------------------
conv2_block1_out (Activation)   (None, 8, 8, 256)    0
conv2_block1_add[0][0]

--------------------------------------------------------------------------------
------------------
conv2_block2_1_conv (Conv2D)    (None, 8, 8, 64)     16448
conv2_block1_out[0][0]

--------------------------------------------------------------------------------
------------------
conv2_block2_1_bn (BatchNormali (None, 8, 8, 64)     256
```

```
conv2_block2_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block2_1_relu (Activation (None, 8, 8, 64)     0
conv2_block2_1_bn[0][0]
__________________________________________________________________________________________________
conv2_block2_2_conv (Conv2D)    (None, 8, 8, 64)     36928
conv2_block2_1_relu[0][0]
__________________________________________________________________________________________________
conv2_block2_2_bn (BatchNormali (None, 8, 8, 64)     256
conv2_block2_2_conv[0][0]
__________________________________________________________________________________________________
conv2_block2_2_relu (Activation (None, 8, 8, 64)     0
conv2_block2_2_bn[0][0]
__________________________________________________________________________________________________
conv2_block2_3_conv (Conv2D)    (None, 8, 8, 256)    16640
conv2_block2_2_relu[0][0]
__________________________________________________________________________________________________
conv2_block2_3_bn (BatchNormali (None, 8, 8, 256)    1024
conv2_block2_3_conv[0][0]
__________________________________________________________________________________________________
conv2_block2_add (Add)          (None, 8, 8, 256)    0
conv2_block1_out[0][0]
conv2_block2_3_bn[0][0]
__________________________________________________________________________________________________
conv2_block2_out (Activation)   (None, 8, 8, 256)    0
conv2_block2_add[0][0]
__________________________________________________________________________________________________
conv2_block3_1_conv (Conv2D)    (None, 8, 8, 64)     16448
conv2_block2_out[0][0]
__________________________________________________________________________________________________
conv2_block3_1_bn (BatchNormali (None, 8, 8, 64)     256
conv2_block3_1_conv[0][0]
__________________________________________________________________________________________________
conv2_block3_1_relu (Activation (None, 8, 8, 64)     0
conv2_block3_1_bn[0][0]
__________________________________________________________________________________________________
```

```
conv2_block3_2_conv (Conv2D)    (None, 8, 8, 64)     36928
conv2_block3_1_relu[0][0]

__________________________________________________________________________________
__________________
conv2_block3_2_bn (BatchNormali (None, 8, 8, 64)     256
conv2_block3_2_conv[0][0]

__________________________________________________________________________________
__________________
conv2_block3_2_relu (Activation (None, 8, 8, 64)     0
conv2_block3_2_bn[0][0]

__________________________________________________________________________________
__________________
conv2_block3_3_conv (Conv2D)    (None, 8, 8, 256)    16640
conv2_block3_2_relu[0][0]

__________________________________________________________________________________
__________________
conv2_block3_3_bn (BatchNormali (None, 8, 8, 256)    1024
conv2_block3_3_conv[0][0]

__________________________________________________________________________________
__________________
conv2_block3_add (Add)          (None, 8, 8, 256)    0
conv2_block2_out[0][0]
conv2_block3_3_bn[0][0]

__________________________________________________________________________________
__________________
conv2_block3_out (Activation)   (None, 8, 8, 256)    0
conv2_block3_add[0][0]

__________________________________________________________________________________
__________________
conv3_block1_1_conv (Conv2D)    (None, 4, 4, 128)    32896
conv2_block3_out[0][0]

__________________________________________________________________________________
__________________
conv3_block1_1_bn (BatchNormali (None, 4, 4, 128)    512
conv3_block1_1_conv[0][0]

__________________________________________________________________________________
__________________
conv3_block1_1_relu (Activation (None, 4, 4, 128)    0
conv3_block1_1_bn[0][0]

__________________________________________________________________________________
__________________
conv3_block1_2_conv (Conv2D)    (None, 4, 4, 128)    147584
conv3_block1_1_relu[0][0]

__________________________________________________________________________________
__________________
conv3_block1_2_bn (BatchNormali (None, 4, 4, 128)    512
conv3_block1_2_conv[0][0]

__________________________________________________________________________________
```

```
__________________
conv3_block1_2_relu (Activation (None, 4, 4, 128)    0
conv3_block1_2_bn[0][0]
________________________________________________________________________________
__________________
conv3_block1_0_conv (Conv2D)    (None, 4, 4, 512)    131584
conv2_block3_out[0][0]
________________________________________________________________________________
__________________
conv3_block1_3_conv (Conv2D)    (None, 4, 4, 512)    66048
conv3_block1_2_relu[0][0]
________________________________________________________________________________
__________________
conv3_block1_0_bn (BatchNormali (None, 4, 4, 512)    2048
conv3_block1_0_conv[0][0]
________________________________________________________________________________
__________________
conv3_block1_3_bn (BatchNormali (None, 4, 4, 512)    2048
conv3_block1_3_conv[0][0]
________________________________________________________________________________
__________________
conv3_block1_add (Add)          (None, 4, 4, 512)    0
conv3_block1_0_bn[0][0]
conv3_block1_3_bn[0][0]
________________________________________________________________________________
__________________
conv3_block1_out (Activation)   (None, 4, 4, 512)    0
conv3_block1_add[0][0]
________________________________________________________________________________
__________________
conv3_block2_1_conv (Conv2D)    (None, 4, 4, 128)    65664
conv3_block1_out[0][0]
________________________________________________________________________________
__________________
conv3_block2_1_bn (BatchNormali (None, 4, 4, 128)    512
conv3_block2_1_conv[0][0]
________________________________________________________________________________
__________________
conv3_block2_1_relu (Activation (None, 4, 4, 128)    0
conv3_block2_1_bn[0][0]
________________________________________________________________________________
__________________
conv3_block2_2_conv (Conv2D)    (None, 4, 4, 128)    147584
conv3_block2_1_relu[0][0]
________________________________________________________________________________
__________________
conv3_block2_2_bn (BatchNormali (None, 4, 4, 128)    512
conv3_block2_2_conv[0][0]
```

```
______________________________________________________________________________
__________________
conv3_block2_2_relu (Activation (None, 4, 4, 128)    0
conv3_block2_2_bn[0][0]
______________________________________________________________________________
__________________
conv3_block2_3_conv (Conv2D)    (None, 4, 4, 512)    66048
conv3_block2_2_relu[0][0]
______________________________________________________________________________
__________________
conv3_block2_3_bn (BatchNormali (None, 4, 4, 512)    2048
conv3_block2_3_conv[0][0]
______________________________________________________________________________
__________________
conv3_block2_add (Add)          (None, 4, 4, 512)    0
conv3_block1_out[0][0]
conv3_block2_3_bn[0][0]
______________________________________________________________________________
__________________
conv3_block2_out (Activation)   (None, 4, 4, 512)    0
conv3_block2_add[0][0]
______________________________________________________________________________
__________________
conv3_block3_1_conv (Conv2D)    (None, 4, 4, 128)    65664
conv3_block2_out[0][0]
______________________________________________________________________________
__________________
conv3_block3_1_bn (BatchNormali (None, 4, 4, 128)    512
conv3_block3_1_conv[0][0]
______________________________________________________________________________
__________________
conv3_block3_1_relu (Activation (None, 4, 4, 128)    0
conv3_block3_1_bn[0][0]
______________________________________________________________________________
__________________
conv3_block3_2_conv (Conv2D)    (None, 4, 4, 128)    147584
conv3_block3_1_relu[0][0]
______________________________________________________________________________
__________________
conv3_block3_2_bn (BatchNormali (None, 4, 4, 128)    512
conv3_block3_2_conv[0][0]
______________________________________________________________________________
__________________
conv3_block3_2_relu (Activation (None, 4, 4, 128)    0
conv3_block3_2_bn[0][0]
______________________________________________________________________________
__________________
conv3_block3_3_conv (Conv2D)    (None, 4, 4, 512)    66048
```

```
conv3_block3_2_relu[0][0]
________________________________________________________________________________
__________________
conv3_block3_3_bn (BatchNormali (None, 4, 4, 512)    2048
conv3_block3_3_conv[0][0]
________________________________________________________________________________
__________________
conv3_block3_add (Add)          (None, 4, 4, 512)    0
conv3_block2_out[0][0]
conv3_block3_3_bn[0][0]
________________________________________________________________________________
__________________
conv3_block3_out (Activation)   (None, 4, 4, 512)    0
conv3_block3_add[0][0]
________________________________________________________________________________
__________________
conv3_block4_1_conv (Conv2D)    (None, 4, 4, 128)    65664
conv3_block3_out[0][0]
________________________________________________________________________________
__________________
conv3_block4_1_bn (BatchNormali (None, 4, 4, 128)    512
conv3_block4_1_conv[0][0]
________________________________________________________________________________
__________________
conv3_block4_1_relu (Activation (None, 4, 4, 128)    0
conv3_block4_1_bn[0][0]
________________________________________________________________________________
__________________
conv3_block4_2_conv (Conv2D)    (None, 4, 4, 128)    147584
conv3_block4_1_relu[0][0]
________________________________________________________________________________
__________________
conv3_block4_2_bn (BatchNormali (None, 4, 4, 128)    512
conv3_block4_2_conv[0][0]
________________________________________________________________________________
__________________
conv3_block4_2_relu (Activation (None, 4, 4, 128)    0
conv3_block4_2_bn[0][0]
________________________________________________________________________________
__________________
conv3_block4_3_conv (Conv2D)    (None, 4, 4, 512)    66048
conv3_block4_2_relu[0][0]
________________________________________________________________________________
__________________
conv3_block4_3_bn (BatchNormali (None, 4, 4, 512)    2048
conv3_block4_3_conv[0][0]
________________________________________________________________________________
__________________
```

```
conv3_block4_add (Add)          (None, 4, 4, 512)    0
conv3_block3_out[0][0]
conv3_block4_3_bn[0][0]
________________________________________________________________________________
__________________
conv3_block4_out (Activation)   (None, 4, 4, 512)    0
conv3_block4_add[0][0]
________________________________________________________________________________
__________________
conv4_block1_1_conv (Conv2D)    (None, 2, 2, 256)    131328
conv3_block4_out[0][0]
________________________________________________________________________________
__________________
conv4_block1_1_bn (BatchNormali (None, 2, 2, 256)    1024
conv4_block1_1_conv[0][0]
________________________________________________________________________________
__________________
conv4_block1_1_relu (Activation (None, 2, 2, 256)    0
conv4_block1_1_bn[0][0]
________________________________________________________________________________
__________________
conv4_block1_2_conv (Conv2D)    (None, 2, 2, 256)    590080
conv4_block1_1_relu[0][0]
________________________________________________________________________________
__________________
conv4_block1_2_bn (BatchNormali (None, 2, 2, 256)    1024
conv4_block1_2_conv[0][0]
________________________________________________________________________________
__________________
conv4_block1_2_relu (Activation (None, 2, 2, 256)    0
conv4_block1_2_bn[0][0]
________________________________________________________________________________
__________________
conv4_block1_0_conv (Conv2D)    (None, 2, 2, 1024)   525312
conv3_block4_out[0][0]
________________________________________________________________________________
__________________
conv4_block1_3_conv (Conv2D)    (None, 2, 2, 1024)   263168
conv4_block1_2_relu[0][0]
________________________________________________________________________________
__________________
conv4_block1_0_bn (BatchNormali (None, 2, 2, 1024)   4096
conv4_block1_0_conv[0][0]
________________________________________________________________________________
__________________
conv4_block1_3_bn (BatchNormali (None, 2, 2, 1024)   4096
conv4_block1_3_conv[0][0]
________________________________________________________________________________
```

```
__________________
conv4_block1_add (Add)          (None, 2, 2, 1024)   0
conv4_block1_0_bn[0][0]
conv4_block1_3_bn[0][0]
________________________________________________________________________________
__________________
conv4_block1_out (Activation)   (None, 2, 2, 1024)   0
conv4_block1_add[0][0]
________________________________________________________________________________
__________________
conv4_block2_1_conv (Conv2D)    (None, 2, 2, 256)    262400
conv4_block1_out[0][0]
________________________________________________________________________________
__________________
conv4_block2_1_bn (BatchNormali (None, 2, 2, 256)    1024
conv4_block2_1_conv[0][0]
________________________________________________________________________________
__________________
conv4_block2_1_relu (Activation (None, 2, 2, 256)    0
conv4_block2_1_bn[0][0]
________________________________________________________________________________
__________________
conv4_block2_2_conv (Conv2D)    (None, 2, 2, 256)    590080
conv4_block2_1_relu[0][0]
________________________________________________________________________________
__________________
conv4_block2_2_bn (BatchNormali (None, 2, 2, 256)    1024
conv4_block2_2_conv[0][0]
________________________________________________________________________________
__________________
conv4_block2_2_relu (Activation (None, 2, 2, 256)    0
conv4_block2_2_bn[0][0]
________________________________________________________________________________
__________________
conv4_block2_3_conv (Conv2D)    (None, 2, 2, 1024)   263168
conv4_block2_2_relu[0][0]
________________________________________________________________________________
__________________
conv4_block2_3_bn (BatchNormali (None, 2, 2, 1024)   4096
conv4_block2_3_conv[0][0]
________________________________________________________________________________
__________________
conv4_block2_add (Add)          (None, 2, 2, 1024)   0
conv4_block1_out[0][0]
conv4_block2_3_bn[0][0]
________________________________________________________________________________
__________________
conv4_block2_out (Activation)   (None, 2, 2, 1024)   0
```

```
conv4_block2_add[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block3_1_conv (Conv2D)    (None, 2, 2, 256)    262400
conv4_block2_out[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block3_1_bn (BatchNormali (None, 2, 2, 256)    1024
conv4_block3_1_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block3_1_relu (Activation (None, 2, 2, 256)    0
conv4_block3_1_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block3_2_conv (Conv2D)    (None, 2, 2, 256)    590080
conv4_block3_1_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block3_2_bn (BatchNormali (None, 2, 2, 256)    1024
conv4_block3_2_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block3_2_relu (Activation (None, 2, 2, 256)    0
conv4_block3_2_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block3_3_conv (Conv2D)    (None, 2, 2, 1024)   263168
conv4_block3_2_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block3_3_bn (BatchNormali (None, 2, 2, 1024)   4096
conv4_block3_3_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block3_add (Add)          (None, 2, 2, 1024)   0
conv4_block2_out[0][0]
conv4_block3_3_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block3_out (Activation)   (None, 2, 2, 1024)   0
conv4_block3_add[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block4_1_conv (Conv2D)    (None, 2, 2, 256)    262400
conv4_block3_out[0][0]
--------------------------------------------------------------------------------
------------------
```

```
conv4_block4_1_bn (BatchNormali (None, 2, 2, 256)    1024
conv4_block4_1_conv[0][0]
-----------------------------------------------------------------------------------------------
conv4_block4_1_relu (Activation (None, 2, 2, 256)    0
conv4_block4_1_bn[0][0]
-----------------------------------------------------------------------------------------------
conv4_block4_2_conv (Conv2D)    (None, 2, 2, 256)    590080
conv4_block4_1_relu[0][0]
-----------------------------------------------------------------------------------------------
conv4_block4_2_bn (BatchNormali (None, 2, 2, 256)    1024
conv4_block4_2_conv[0][0]
-----------------------------------------------------------------------------------------------
conv4_block4_2_relu (Activation (None, 2, 2, 256)    0
conv4_block4_2_bn[0][0]
-----------------------------------------------------------------------------------------------
conv4_block4_3_conv (Conv2D)    (None, 2, 2, 1024)   263168
conv4_block4_2_relu[0][0]
-----------------------------------------------------------------------------------------------
conv4_block4_3_bn (BatchNormali (None, 2, 2, 1024)   4096
conv4_block4_3_conv[0][0]
-----------------------------------------------------------------------------------------------
conv4_block4_add (Add)          (None, 2, 2, 1024)   0
conv4_block3_out[0][0]
conv4_block4_3_bn[0][0]
-----------------------------------------------------------------------------------------------
conv4_block4_out (Activation)   (None, 2, 2, 1024)   0
conv4_block4_add[0][0]
-----------------------------------------------------------------------------------------------
conv4_block5_1_conv (Conv2D)    (None, 2, 2, 256)    262400
conv4_block4_out[0][0]
-----------------------------------------------------------------------------------------------
conv4_block5_1_bn (BatchNormali (None, 2, 2, 256)    1024
conv4_block5_1_conv[0][0]
-----------------------------------------------------------------------------------------------
conv4_block5_1_relu (Activation (None, 2, 2, 256)    0
conv4_block5_1_bn[0][0]
-------------------------------------------------------------------------------
```

```
__________________
conv4_block5_2_conv (Conv2D)    (None, 2, 2, 256)    590080
conv4_block5_1_relu[0][0]
________________________________________________________________________________
__________________
conv4_block5_2_bn (BatchNormali (None, 2, 2, 256)    1024
conv4_block5_2_conv[0][0]
________________________________________________________________________________
__________________
conv4_block5_2_relu (Activation (None, 2, 2, 256)    0
conv4_block5_2_bn[0][0]
________________________________________________________________________________
__________________
conv4_block5_3_conv (Conv2D)    (None, 2, 2, 1024)   263168
conv4_block5_2_relu[0][0]
________________________________________________________________________________
__________________
conv4_block5_3_bn (BatchNormali (None, 2, 2, 1024)   4096
conv4_block5_3_conv[0][0]
________________________________________________________________________________
__________________
conv4_block5_add (Add)          (None, 2, 2, 1024)   0
conv4_block4_out[0][0]
conv4_block5_3_bn[0][0]
________________________________________________________________________________
__________________
conv4_block5_out (Activation)   (None, 2, 2, 1024)   0
conv4_block5_add[0][0]
________________________________________________________________________________
__________________
conv4_block6_1_conv (Conv2D)    (None, 2, 2, 256)    262400
conv4_block5_out[0][0]
________________________________________________________________________________
__________________
conv4_block6_1_bn (BatchNormali (None, 2, 2, 256)    1024
conv4_block6_1_conv[0][0]
________________________________________________________________________________
__________________
conv4_block6_1_relu (Activation (None, 2, 2, 256)    0
conv4_block6_1_bn[0][0]
________________________________________________________________________________
__________________
conv4_block6_2_conv (Conv2D)    (None, 2, 2, 256)    590080
conv4_block6_1_relu[0][0]
________________________________________________________________________________
__________________
conv4_block6_2_bn (BatchNormali (None, 2, 2, 256)    1024
conv4_block6_2_conv[0][0]
```

```
--------------------------------------------------------------------------------
------------------
conv4_block6_2_relu (Activation (None, 2, 2, 256)    0
conv4_block6_2_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block6_3_conv (Conv2D)    (None, 2, 2, 1024)   263168
conv4_block6_2_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block6_3_bn (BatchNormali (None, 2, 2, 1024)   4096
conv4_block6_3_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block6_add (Add)          (None, 2, 2, 1024)   0
conv4_block5_out[0][0]
conv4_block6_3_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv4_block6_out (Activation)   (None, 2, 2, 1024)   0
conv4_block6_add[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block1_1_conv (Conv2D)    (None, 1, 1, 512)    524800
conv4_block6_out[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block1_1_bn (BatchNormali (None, 1, 1, 512)    2048
conv5_block1_1_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block1_1_relu (Activation (None, 1, 1, 512)    0
conv5_block1_1_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block1_2_conv (Conv2D)    (None, 1, 1, 512)    2359808
conv5_block1_1_relu[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block1_2_bn (BatchNormali (None, 1, 1, 512)    2048
conv5_block1_2_conv[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block1_2_relu (Activation (None, 1, 1, 512)    0
conv5_block1_2_bn[0][0]
--------------------------------------------------------------------------------
------------------
conv5_block1_0_conv (Conv2D)    (None, 1, 1, 2048)   2099200
```

```
conv4_block6_out[0][0]
__________________________________________________________________________________________________
conv5_block1_3_conv (Conv2D)    (None, 1, 1, 2048)   1050624
conv5_block1_2_relu[0][0]
__________________________________________________________________________________________________
conv5_block1_0_bn (BatchNormali (None, 1, 1, 2048)   8192
conv5_block1_0_conv[0][0]
__________________________________________________________________________________________________
conv5_block1_3_bn (BatchNormali (None, 1, 1, 2048)   8192
conv5_block1_3_conv[0][0]
__________________________________________________________________________________________________
conv5_block1_add (Add)          (None, 1, 1, 2048)   0
conv5_block1_0_bn[0][0]
conv5_block1_3_bn[0][0]
__________________________________________________________________________________________________
conv5_block1_out (Activation)   (None, 1, 1, 2048)   0
conv5_block1_add[0][0]
__________________________________________________________________________________________________
conv5_block2_1_conv (Conv2D)    (None, 1, 1, 512)    1049088
conv5_block1_out[0][0]
__________________________________________________________________________________________________
conv5_block2_1_bn (BatchNormali (None, 1, 1, 512)    2048
conv5_block2_1_conv[0][0]
__________________________________________________________________________________________________
conv5_block2_1_relu (Activation (None, 1, 1, 512)    0
conv5_block2_1_bn[0][0]
__________________________________________________________________________________________________
conv5_block2_2_conv (Conv2D)    (None, 1, 1, 512)    2359808
conv5_block2_1_relu[0][0]
__________________________________________________________________________________________________
conv5_block2_2_bn (BatchNormali (None, 1, 1, 512)    2048
conv5_block2_2_conv[0][0]
__________________________________________________________________________________________________
conv5_block2_2_relu (Activation (None, 1, 1, 512)    0
conv5_block2_2_bn[0][0]
__________________________________________________________________________________________________
```

```
conv5_block2_3_conv (Conv2D)    (None, 1, 1, 2048)   1050624
conv5_block2_2_relu[0][0]
________________________________________________________________________________
__________________
conv5_block2_3_bn (BatchNormali (None, 1, 1, 2048)   8192
conv5_block2_3_conv[0][0]
________________________________________________________________________________
__________________
conv5_block2_add (Add)          (None, 1, 1, 2048)   0
conv5_block1_out[0][0]
conv5_block2_3_bn[0][0]
________________________________________________________________________________
__________________
conv5_block2_out (Activation)   (None, 1, 1, 2048)   0
conv5_block2_add[0][0]
________________________________________________________________________________
__________________
conv5_block3_1_conv (Conv2D)    (None, 1, 1, 512)    1049088
conv5_block2_out[0][0]
________________________________________________________________________________
__________________
conv5_block3_1_bn (BatchNormali (None, 1, 1, 512)    2048
conv5_block3_1_conv[0][0]
________________________________________________________________________________
__________________
conv5_block3_1_relu (Activation (None, 1, 1, 512)    0
conv5_block3_1_bn[0][0]
________________________________________________________________________________
__________________
conv5_block3_2_conv (Conv2D)    (None, 1, 1, 512)    2359808
conv5_block3_1_relu[0][0]
________________________________________________________________________________
__________________
conv5_block3_2_bn (BatchNormali (None, 1, 1, 512)    2048
conv5_block3_2_conv[0][0]
________________________________________________________________________________
__________________
conv5_block3_2_relu (Activation (None, 1, 1, 512)    0
conv5_block3_2_bn[0][0]
________________________________________________________________________________
__________________
conv5_block3_3_conv (Conv2D)    (None, 1, 1, 2048)   1050624
conv5_block3_2_relu[0][0]
________________________________________________________________________________
__________________
conv5_block3_3_bn (BatchNormali (None, 1, 1, 2048)   8192
conv5_block3_3_conv[0][0]
________________________________________________________________________________
```

```
------------------
conv5_block3_add (Add)          (None, 1, 1, 2048)   0
conv5_block2_out[0][0]
conv5_block3_3_bn[0][0]

________________________________________________________________________________
------------------
conv5_block3_out (Activation)   (None, 1, 1, 2048)   0
conv5_block3_add[0][0]

________________________________________________________________________________
------------------
flatten_3 (Flatten)             (None, 2048)         0
conv5_block3_out[0][0]

________________________________________________________________________________
------------------
dense_5 (Dense)                 (None, 256)          524544      flatten_3[0][0]
________________________________________________________________________________
------------------
dense_6 (Dense)                 (None, 10)           2570        dense_5[0][0]
================================================================================
==================
Total params: 24,114,826
Trainable params: 24,061,706
Non-trainable params: 53,120

________________________________________________________________________________
------------------
```

[34]:
```
def get_callbacks_list():
    """Get callbacks for a model"""
    return [keras.callbacks.EarlyStopping(monitor='val_acc',patience=20),
        keras.callbacks.ReduceLROnPlateau(monitor='val_loss',factor=0.
↪2,patience=5)]
```

[35]:
```
history_resnet = Resnet_model.fit(train_X,train_y,batch_size=256,epochs =␣
↪200,callbacks=get_callbacks_list(),validation_split=0.1)
```

```
Train on 45000 samples, validate on 5000 samples
Epoch 1/200
45000/45000 [==============================] - 62s 1ms/step - loss: 1.9366 -
acc: 0.3421 - val_loss: 2.1362 - val_acc: 0.2084
Epoch 2/200
45000/45000 [==============================] - 53s 1ms/step - loss: 1.3817 -
acc: 0.5038 - val_loss: 1.4493 - val_acc: 0.4808
Epoch 3/200
45000/45000 [==============================] - 53s 1ms/step - loss: 1.1794 -
acc: 0.5789 - val_loss: 1.4986 - val_acc: 0.4886
Epoch 4/200
45000/45000 [==============================] - 53s 1ms/step - loss: 1.0378 -
acc: 0.6325 - val_loss: 1.4795 - val_acc: 0.4996
```

```
Epoch 5/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.9305 -
acc: 0.6705 - val_loss: 1.3818 - val_acc: 0.5426
Epoch 6/200
45000/45000 [==============================] - 52s 1ms/step - loss: 0.8244 -
acc: 0.7084 - val_loss: 2.0437 - val_acc: 0.4354
Epoch 7/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.7393 -
acc: 0.7425 - val_loss: 1.6434 - val_acc: 0.5270
Epoch 8/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.6523 -
acc: 0.7735 - val_loss: 1.3320 - val_acc: 0.5888
Epoch 9/200
45000/45000 [==============================] - 52s 1ms/step - loss: 0.6042 -
acc: 0.7881 - val_loss: 1.3096 - val_acc: 0.5904
Epoch 10/200
45000/45000 [==============================] - 52s 1ms/step - loss: 0.5203 -
acc: 0.8195 - val_loss: 1.6008 - val_acc: 0.5514
Epoch 11/200
45000/45000 [==============================] - 52s 1ms/step - loss: 0.4639 -
acc: 0.8380 - val_loss: 1.5592 - val_acc: 0.5674
Epoch 12/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.4640 -
acc: 0.8374 - val_loss: 1.3299 - val_acc: 0.6206
Epoch 13/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.3746 -
acc: 0.8674 - val_loss: 1.6018 - val_acc: 0.5824
Epoch 14/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.3349 -
acc: 0.8828 - val_loss: 1.4178 - val_acc: 0.5998
Epoch 15/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.1106 -
acc: 0.9642 - val_loss: 1.2826 - val_acc: 0.7016
Epoch 16/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.0281 -
acc: 0.9919 - val_loss: 1.5703 - val_acc: 0.6926
Epoch 17/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.0120 -
acc: 0.9967 - val_loss: 1.9534 - val_acc: 0.6930
Epoch 18/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.0098 -
acc: 0.9972 - val_loss: 2.0684 - val_acc: 0.7010
Epoch 19/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.0155 -
acc: 0.9950 - val_loss: 2.1089 - val_acc: 0.6812
Epoch 20/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.0169 -
acc: 0.9944 - val_loss: 2.0313 - val_acc: 0.6960
```

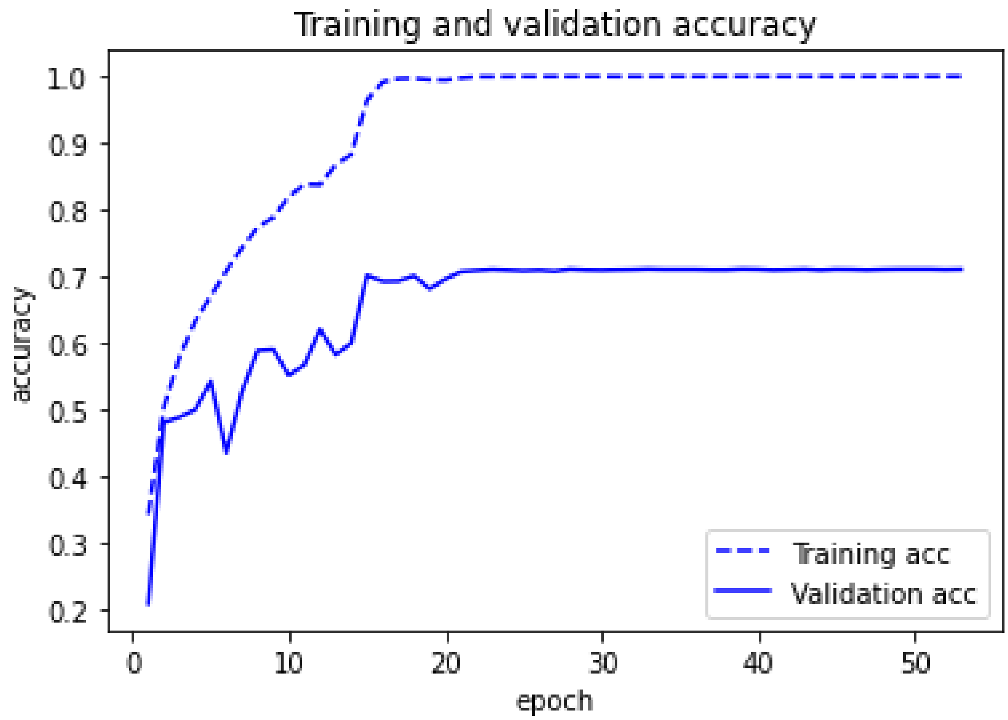
```
Epoch 21/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.0084 -
acc: 0.9975 - val_loss: 1.9724 - val_acc: 0.7072
Epoch 22/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.0027 -
acc: 0.9995 - val_loss: 2.1115 - val_acc: 0.7088
Epoch 23/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.0021 -
acc: 0.9996 - val_loss: 2.2299 - val_acc: 0.7104
Epoch 24/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.0018 -
acc: 0.9997 - val_loss: 2.2782 - val_acc: 0.7094
Epoch 25/200
45000/45000 [==============================] - 52s 1ms/step - loss: 0.0014 -
acc: 0.9998 - val_loss: 2.3991 - val_acc: 0.7084
Epoch 26/200
45000/45000 [==============================] - 53s 1ms/step - loss: 0.0012 -
acc: 0.9998 - val_loss: 2.4482 - val_acc: 0.7092
Epoch 27/200
45000/45000 [==============================] - 53s 1ms/step - loss: 9.1392e-04 -
acc: 0.9999 - val_loss: 2.4611 - val_acc: 0.7078
Epoch 28/200
45000/45000 [==============================] - 53s 1ms/step - loss: 9.9718e-04 -
acc: 0.9998 - val_loss: 2.4836 - val_acc: 0.7108
Epoch 29/200
45000/45000 [==============================] - 53s 1ms/step - loss: 8.1524e-04 -
acc: 0.9999 - val_loss: 2.5028 - val_acc: 0.7096
Epoch 30/200
45000/45000 [==============================] - 53s 1ms/step - loss: 8.3314e-04 -
acc: 0.9999 - val_loss: 2.5280 - val_acc: 0.7092
Epoch 31/200
45000/45000 [==============================] - 53s 1ms/step - loss: 8.5586e-04 -
acc: 0.9998 - val_loss: 2.5388 - val_acc: 0.7098
Epoch 32/200
45000/45000 [==============================] - 53s 1ms/step - loss: 8.3775e-04 -
acc: 0.9998 - val_loss: 2.5427 - val_acc: 0.7102
Epoch 33/200
45000/45000 [==============================] - 53s 1ms/step - loss: 8.4652e-04 -
acc: 0.9998 - val_loss: 2.5437 - val_acc: 0.7110
Epoch 34/200
45000/45000 [==============================] - 53s 1ms/step - loss: 7.1219e-04 -
acc: 0.9999 - val_loss: 2.5610 - val_acc: 0.7104
Epoch 35/200
45000/45000 [==============================] - 53s 1ms/step - loss: 7.4927e-04 -
acc: 0.9999 - val_loss: 2.5669 - val_acc: 0.7104
Epoch 36/200
45000/45000 [==============================] - 53s 1ms/step - loss: 7.0004e-04 -
acc: 0.9999 - val_loss: 2.5757 - val_acc: 0.7104
```

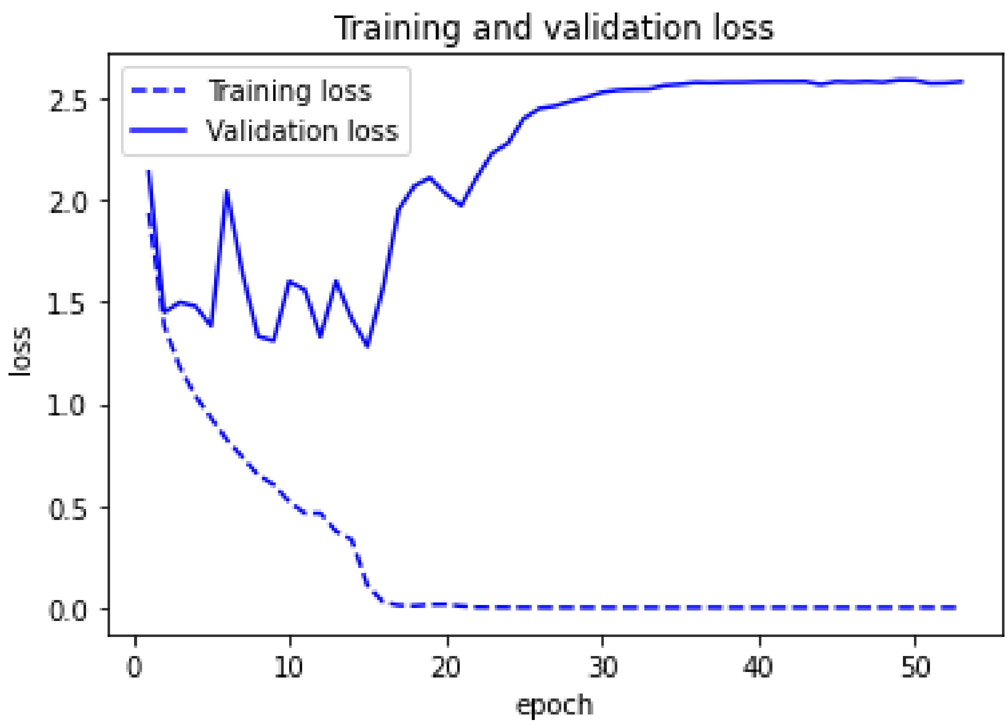
```
Epoch 37/200
45000/45000 [==============================] - 53s 1ms/step - loss: 9.4168e-04 -
acc: 0.9998 - val_loss: 2.5738 - val_acc: 0.7098
Epoch 38/200
45000/45000 [==============================] - 53s 1ms/step - loss: 7.1098e-04 -
acc: 0.9999 - val_loss: 2.5766 - val_acc: 0.7098
Epoch 39/200
45000/45000 [==============================] - 53s 1ms/step - loss: 6.6225e-04 -
acc: 0.9999 - val_loss: 2.5768 - val_acc: 0.7110
Epoch 40/200
45000/45000 [==============================] - 52s 1ms/step - loss: 7.7483e-04 -
acc: 0.9999 - val_loss: 2.5791 - val_acc: 0.7106
Epoch 41/200
45000/45000 [==============================] - 52s 1ms/step - loss: 7.9943e-04 -
acc: 0.9998 - val_loss: 2.5801 - val_acc: 0.7094
Epoch 42/200
45000/45000 [==============================] - 52s 1ms/step - loss: 8.3066e-04 -
acc: 0.9998 - val_loss: 2.5799 - val_acc: 0.7100
Epoch 43/200
45000/45000 [==============================] - 52s 1ms/step - loss: 7.5625e-04 -
acc: 0.9999 - val_loss: 2.5809 - val_acc: 0.7108
Epoch 44/200
45000/45000 [==============================] - 52s 1ms/step - loss: 7.3131e-04 -
acc: 0.9999 - val_loss: 2.5657 - val_acc: 0.7094
Epoch 45/200
45000/45000 [==============================] - 52s 1ms/step - loss: 6.7855e-04 -
acc: 0.9999 - val_loss: 2.5800 - val_acc: 0.7106
Epoch 46/200
45000/45000 [==============================] - 52s 1ms/step - loss: 7.6205e-04 -
acc: 0.9998 - val_loss: 2.5773 - val_acc: 0.7104
Epoch 47/200
45000/45000 [==============================] - 52s 1ms/step - loss: 7.2198e-04 -
acc: 0.9999 - val_loss: 2.5805 - val_acc: 0.7096
Epoch 48/200
45000/45000 [==============================] - 52s 1ms/step - loss: 7.8620e-04 -
acc: 0.9999 - val_loss: 2.5765 - val_acc: 0.7104
Epoch 49/200
45000/45000 [==============================] - 52s 1ms/step - loss: 9.1242e-04 -
acc: 0.9998 - val_loss: 2.5878 - val_acc: 0.7108
Epoch 50/200
45000/45000 [==============================] - 52s 1ms/step - loss: 7.4463e-04 -
acc: 0.9999 - val_loss: 2.5868 - val_acc: 0.7108
Epoch 51/200
45000/45000 [==============================] - 53s 1ms/step - loss: 6.5927e-04 -
acc: 0.9999 - val_loss: 2.5712 - val_acc: 0.7108
Epoch 52/200
45000/45000 [==============================] - 52s 1ms/step - loss: 7.2061e-04 -
acc: 0.9999 - val_loss: 2.5727 - val_acc: 0.7102
```

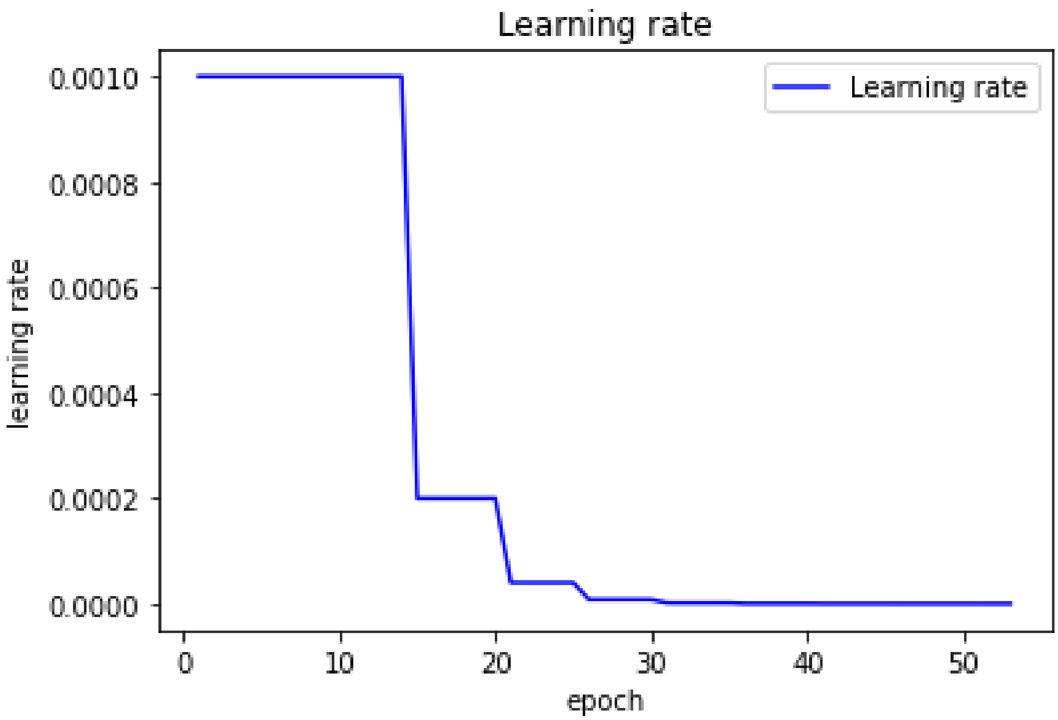
```
Epoch 53/200
45000/45000 [==============================] - 52s 1ms/step - loss: 7.2549e-04 -
acc: 0.9999 - val_loss: 2.5795 - val_acc: 0.7106
```

[36]:

```
def draw_training_info_plots(_history):
    """Draw loss graphs at the training and validation stage"""
    acc = _history.history['acc']
    val_acc = _history.history['val_acc']
    loss = _history.history['loss']
    val_loss = _history.history['val_loss']

    epochs_plot = range(1, len(acc) + 1)
    plt.plot(epochs_plot, acc, 'b--', label='Training acc')
    plt.plot(epochs_plot, val_acc, 'b', label='Validation acc')
    plt.title('Training and validation accuracy')
    plt.xlabel('epoch')
    plt.ylabel('accuracy')
    plt.legend()
    plt.figure()

    plt.plot(epochs_plot, loss, 'b--', label='Training loss')
    plt.plot(epochs_plot, val_loss, 'b', label='Validation loss')
    plt.title('Training and validation loss')
    plt.xlabel('epoch')
    plt.ylabel('loss')
    plt.legend()
    plt.show()

    if 'lr' in _history.history:
        learning_rate = _history.history['lr']
        plt.plot(epochs_plot, learning_rate, 'b', label='Learning rate')
        plt.title('Learning rate')
        plt.xlabel('epoch')
        plt.ylabel('learning rate')
        plt.legend()
        plt.show()
    return

draw_training_info_plots(history_resnet)
```


Training and validation accuracy
accuracy
epoch
Training acc
Validation acc


Training and validation loss
loss
epoch
Training loss
Validation loss



[37]:
```
print('Accuracy:',Resnet_model.evaluate(test_X,test_y,verbose=0)[1])
```

Accuracy: 0.70169997215271

Classification Score and Confusion Metric

[38]:
```
predictions = Resnet_model.predict(test_X)

from sklearn.metrics import classification_report
print("EVALUATION ON TESTING DATA")
print(classification_report(y_test, np.argmax(predictions,axis=1)))
```

EVALUATION ON TESTING DATA

	precision	recall	f1-score	support
0	0.74	0.77	0.75	1000
1	0.79	0.82	0.81	1000
2	0.62	0.58	0.60	1000
3	0.50	0.52	0.51	1000
4	0.65	0.66	0.65	1000
5	0.61	0.60	0.60	1000
6	0.77	0.77	0.77	1000
7	0.74	0.75	0.74	1000
8	0.84	0.81	0.82	1000
9	0.77	0.75	0.76	1000

```
    accuracy                           0.70     10000
   macro avg       0.70      0.70      0.70     10000
weighted avg       0.70      0.70      0.70     10000
```

[39]:
```
from sklearn.metrics import confusion_matrix
import pandas as pd
print ("Confusion matrix")
pd.DataFrame(confusion_matrix(y_test,np.
↪argmax(predictions,axis=1)),columns=list(np.array(list(Classes.items()))[:
↪,1]),index=list(np.array(list(Classes.items()))[:,1]))
```

```
Confusion matrix
```

[39]:

	airplane	automobile	bird	cat	deer	dog	frog	horse	ship	\
airplane	765	22	54	19	25	11	6	11	52	
automobile	17	816	13	11	3	9	7	3	31	
bird	73	9	581	78	92	56	54	35	11	
cat	24	13	66	523	63	173	63	46	10	
deer	20	5	70	72	656	28	51	85	7	
dog	11	7	48	197	45	597	27	51	8	
frog	7	7	48	61	46	40	767	10	5	
horse	19	4	28	52	62	57	8	748	2	
ship	66	35	19	16	12	7	4	3	811	
truck	37	109	14	15	5	7	11	17	32	

	truck
airplane	35
automobile	90
bird	11
cat	19
deer	6
dog	9
frog	9
horse	20
ship	27
truck	753

[40]:
```
Resnet_model.save('Resnet_model_cifar10.h5')
```

[ ]:
```
```

[ ]:
```
```