**Neural Networks and Deep Learning**
**Assignment-7**

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Github Link: https://github.com/pxc99740/neural_networks_assignment_7.git
Video Link: https://drive.google.com/drive/folders/1Benn6rUZWV1rPn-B-MmmKgJhRPR1yqpv

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras.optimizers import RMSprop, Adam
from sklearn.metrics import ConfusionMatrixDisplay
from sklearn.metrics import classification_report, confusion_matrix
import warnings
warnings.filterwarnings("ignore")
```

```
(x_train, y_train), (x_test, y_test)  = keras.datasets.cifar10.load_data()
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170498071/170498071 [==============================] - 4s 0us/step
```

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

```
y_train = y_train.reshape(-1,)
```

```
# Reshape converting 2D to 1D
y_test = y_test.reshape(-1,)
y_train = y_train.reshape(-1,)
```

```
# This code normalazation
x_train = x_train / 255.0
x_test = x_test / 255.0
```

```
x_train.shape
```

```
(50000, 32, 32, 3)
```

```
import tensorflow as tf
from tensorflow.keras import layers, models

lenet = models.Sequential([
    layers.Conv2D(6, kernel_size=5, strides=1, activation='relu', input_shape=(32,32,3), padding='same'), #C1
    layers.AveragePooling2D(pool_size=(2, 2)), #S1
    layers.Conv2D(16, kernel_size=5, strides=1, activation='relu', padding='valid'), #C2
    layers.AveragePooling2D(pool_size=(2, 2)), #S2
    layers.Conv2D(120, kernel_size=5, strides=1, activation='relu', padding='valid'), #C3
    layers.Flatten(), #Flatten
    layers.Dense(84, activation='relu'), #F1
    layers.Dense(10, activation='softmax') #Output layer
])
```

```python
lenet.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 32, 32, 6)         456

 average_pooling2d (Average  (None, 16, 16, 6)         0
 Pooling2D)

 conv2d_1 (Conv2D)           (None, 12, 12, 16)        2416

 average_pooling2d_1 (Avera  (None, 6, 6, 16)          0
 gePooling2D)

 conv2d_2 (Conv2D)           (None, 2, 2, 120)         48120

 flatten (Flatten)           (None, 480)               0

 dense (Dense)               (None, 84)                40404

 dense_1 (Dense)             (None, 10)                850

=================================================================
Total params: 92246 (360.34 KB)
Trainable params: 92246 (360.34 KB)
Non-trainable params: 0 (0.00 Byte)
```

```python
lenet.compile(optimizer='adam', loss=keras.losses.sparse_categorical_crossentropy, metrics=['accuracy'])
```

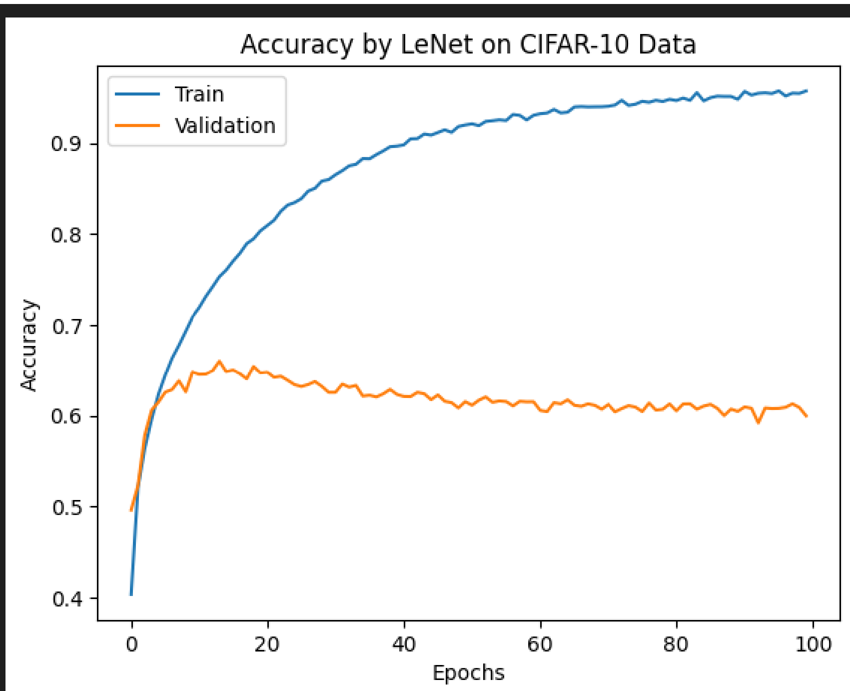
```python
hist = lenet.fit(x_train, y_train, epochs=100, validation_data=(x_test, y_test),verbose=1)
```

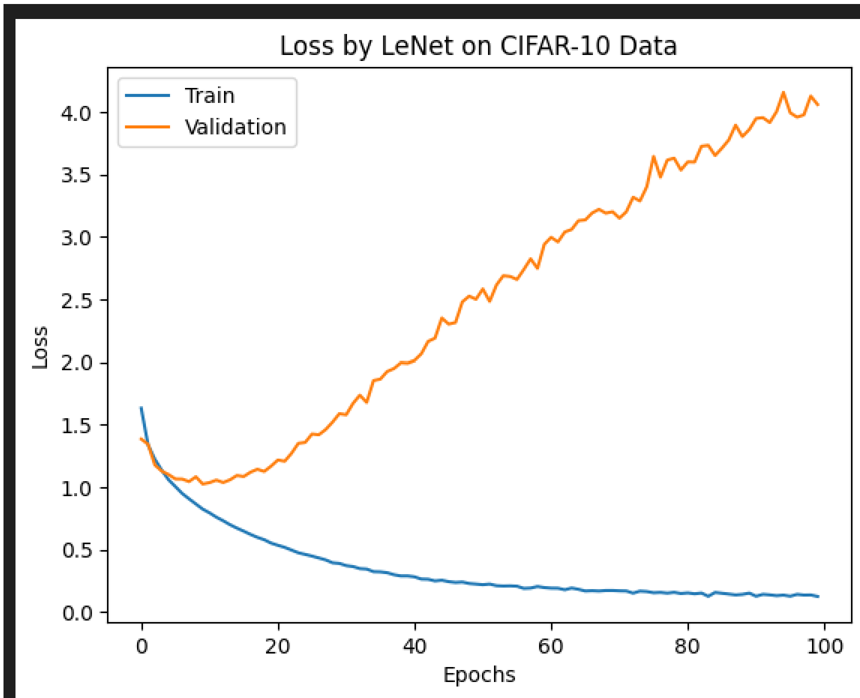
```
Epoch 1/100
1563/1563 [==============================] - 14s 6ms/step - loss: 1.6344 - accuracy: 0.4072 - val_loss: 1.3989 - val_accuracy: 0.4972
Epoch 2/100
1563/1563 [==============================] - 8s 5ms/step - loss: 1.3263 - accuracy: 0.5271 - val_loss: 1.2305 - val_accuracy: 0.5592
Epoch 3/100
1563/1563 [==============================] - 7s 4ms/step - loss: 1.1881 - accuracy: 0.5779 - val_loss: 1.2515 - val_accuracy: 0.5589
Epoch 4/100
1563/1563 [==============================] - 8s 5ms/step - loss: 1.1065 - accuracy: 0.6075 - val_loss: 1.1378 - val_accuracy: 0.6011
Epoch 5/100
1563/1563 [==============================] - 8s 5ms/step - loss: 1.0338 - accuracy: 0.6352 - val_loss: 1.1170 - val_accuracy: 0.6106
Epoch 6/100
1563/1563 [==============================] - 7s 5ms/step - loss: 0.9818 - accuracy: 0.6535 - val_loss: 1.0541 - val_accuracy: 0.6289
Epoch 7/100
1563/1563 [==============================] - 9s 5ms/step - loss: 0.9301 - accuracy: 0.6720 - val_loss: 1.0452 - val_accuracy: 0.6337
Epoch 8/100
1563/1563 [==============================] - 8s 5ms/step - loss: 0.8856 - accuracy: 0.6885 - val_loss: 1.0623 - val_accuracy: 0.6276
Epoch 9/100
1563/1563 [==============================] - 7s 5ms/step - loss: 0.8494 - accuracy: 0.7026 - val_loss: 1.0236 - val_accuracy: 0.6418
Epoch 10/100
1563/1563 [==============================] - 7s 5ms/step - loss: 0.8141 - accuracy: 0.7122 - val_loss: 1.0748 - val_accuracy: 0.6269
Epoch 11/100
1563/1563 [==============================] - 7s 5ms/step - loss: 0.7773 - accuracy: 0.7258 - val_loss: 1.0560 - val_accuracy: 0.6431
Epoch 12/100
1563/1563 [==============================] - 8s 5ms/step - loss: 0.7421 - accuracy: 0.7395 - val_loss: 1.0809 - val_accuracy: 0.6367
Epoch 13/100
...
1563/1563 [==============================] - 8s 5ms/step - loss: 0.1506 - accuracy: 0.9472 - val_loss: 3.6584 - val_accuracy: 0.6045
Epoch 71/100
1563/1563 [==============================] - 8s 5ms/step - loss: 0.1486 - accuracy: 0.9488 - val_loss: 3.7648 - val_accuracy: 0.6010
Epoch 72/100
1101/1563 [===================>.........] - ETA: 2s - loss: 0.1266 - accuracy: 0.9556
```

```python
import numpy as np
```

```python
# fix random seed for reproducibility
seed = 7
np.random.seed(seed)
```

```python
# summarize history for accuracy
plt.plot(hist.history['accuracy'])
plt.plot(hist.history['val_accuracy'])
plt.title("Accuracy by LeNet on CIFAR-10 Data")
plt.ylabel('Accuracy')
plt.xlabel('Epochs')
plt.legend(['Train', 'Validation'], loc='upper left')
plt.show()
# summarize history for loss
plt.plot(hist.history['loss'])
plt.plot(hist.history['val_loss'])
plt.title('Loss by LeNet on CIFAR-10 Data')
plt.ylabel('Loss')
plt.xlabel('Epochs')
plt.legend(['Train', 'Validation'])
plt.show()
```





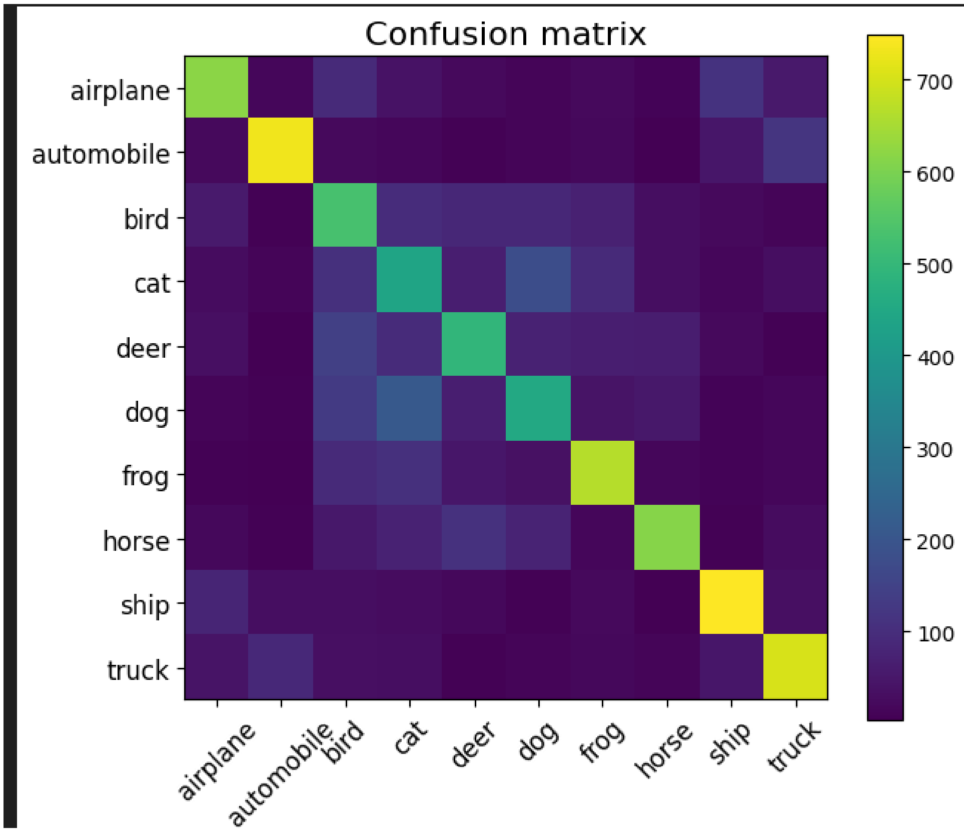

```python
from sklearn.metrics import confusion_matrix
from sklearn.metrics import ConfusionMatrixDisplay
y_predictions= lenet.predict(x_test)
y_predictions.reshape(-1,)
y_predictions= np.argmax(y_predictions, axis=1)

confusion_matrix(y_test, y_predictions)
```

```
313/313 [==============================] - 1s 2ms/step

array([[619,  15,  91,  40,  22,  14,  21,  11, 113,  54],
       [ 23, 731,  21,  16,   6,  12,  19,   5,  48, 119],
       [ 57,   6, 531,  97,  86,  87,  71,  30,  21,  14],
       [ 27,  12, 106, 439,  65, 179,  92,  32,  17,  31],
       [ 33,   3, 143,  95, 493,  73,  66,  64,  22,   8],
       [ 13,   8, 131, 211,  67, 453,  41,  50,  11,  15],
       [  8,   3,  92, 106,  48,  36, 666,  17,   9,  15],
       [ 19,   6,  50,  73, 110,  78,  17, 613,   6,  28],
       [ 80,  30,  30,  27,  19,   6,  21,   4, 748,  35],
       [ 43,  90,  34,  31,   7,  14,  18,  14,  47, 702]])
```

```python
# confusion matrix and accuracy
from sklearn.metrics import confusion_matrix, accuracy_score
plt.figure(figsize=(7, 6))
plt.title('Confusion matrix', fontsize=16)
plt.imshow(confusion_matrix(y_test, y_predictions))
plt.xticks(np.arange(10), classes, rotation=45, fontsize=12)
plt.yticks(np.arange(10), classes, fontsize=12)
plt.colorbar()
plt.show()
```



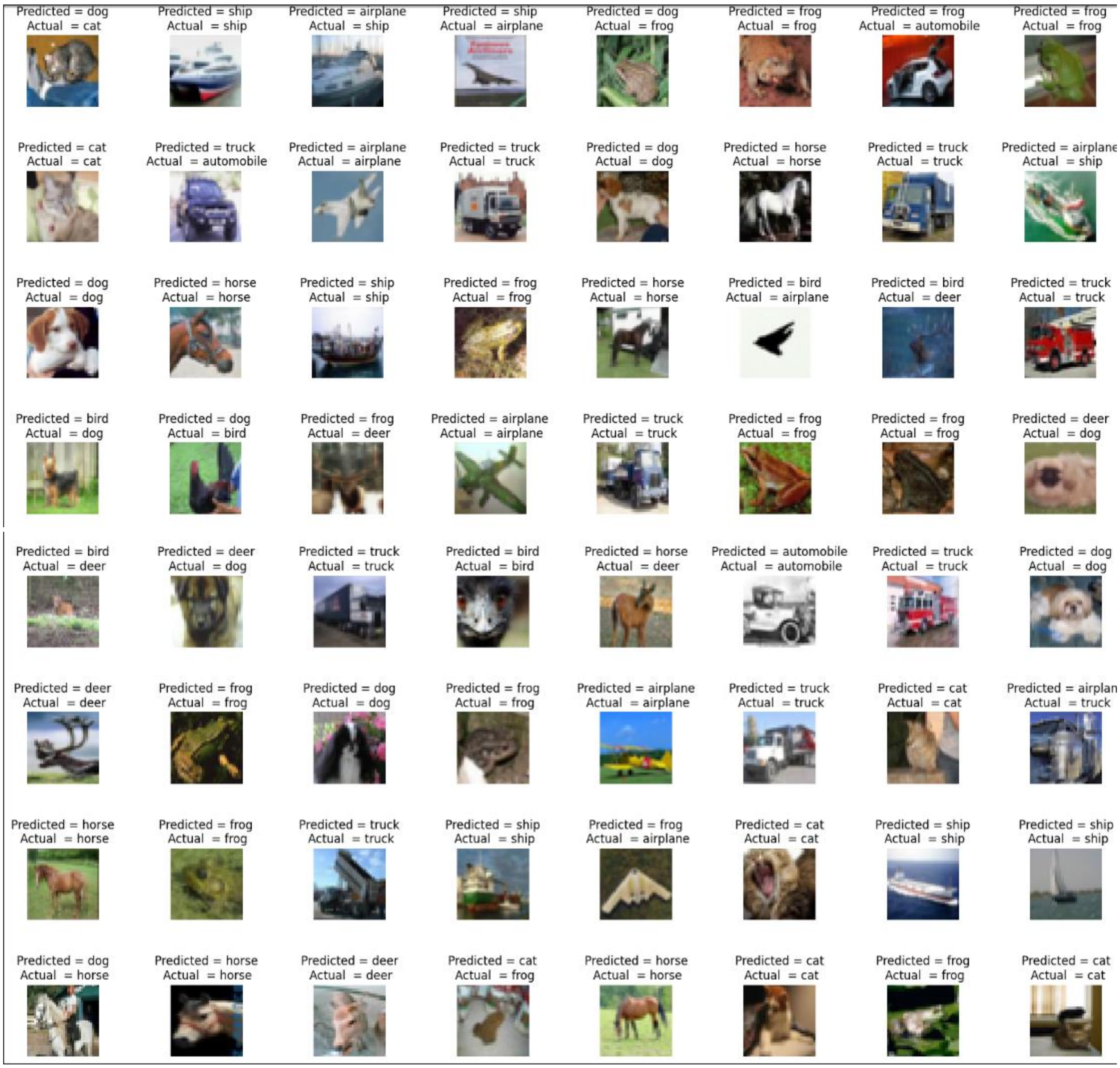

```python
print("Test accuracy:", accuracy_score(y_test, y_predictions))
```

```
Test accuracy: 0.5995
```

```python
L = 8
W = 8
fig, axes = plt.subplots(L, W, figsize = (20,20))
axes = axes.ravel() #

for i in np.arange(0, L * W):
    axes[i].imshow(x_test[i])
    axes[i].set_title("Predicted = {}\n Actual  = {}".format(classes[y_predictions[i]], classes[y_test[i]]))
    axes[i].axis('off')

plt.subplots_adjust(wspace=1)
```



Predicted = dog
Actual = cat
Predicted = ship
Actual = ship
Predicted = airplane
Actual = ship
Predicted = ship
Actual = airplane
Predicted = dog
Actual = frog
Predicted = frog
Actual = frog
Predicted = frog
Actual = automobile
Predicted = frog
Actual = frog
Predicted = cat
Actual = cat
Predicted = truck
Actual = automobile
Predicted = airplane
Actual = airplane
Predicted = truck
Actual = truck
Predicted = dog
Actual = dog
Predicted = horse
Actual = horse
Predicted = truck
Actual = truck
Predicted = airplane
Actual = ship
Predicted = dog
Actual = dog
Predicted = horse
Actual = horse
Predicted = ship
Actual = ship
Predicted = frog
Actual = frog
Predicted = horse
Actual = horse
Predicted = bird
Actual = airplane
Predicted = bird
Actual = deer
Predicted = truck
Actual = truck
Predicted = bird
Actual = dog
Predicted = dog
Actual = bird
Predicted = frog
Actual = deer
Predicted = airplane
Actual = airplane
Predicted = truck
Actual = truck
Predicted = frog
Actual = frog
Predicted = frog
Actual = frog
Predicted = deer
Actual = dog
Predicted = bird
Actual = deer
Predicted = deer
Actual = dog
Predicted = truck
Actual = truck
Predicted = bird
Actual = bird
Predicted = horse
Actual = deer
Predicted = automobile
Actual = automobile
Predicted = truck
Actual = truck
Predicted = dog
Actual = dog
Predicted = deer
Actual = deer
Predicted = frog
Actual = frog
Predicted = dog
Actual = dog
Predicted = frog
Actual = frog
Predicted = airplane
Actual = airplane
Predicted = truck
Actual = truck
Predicted = cat
Actual = cat
Predicted = airplan
Actual = truck
Predicted = horse
Actual = horse
Predicted = frog
Actual = frog
Predicted = truck
Actual = truck
Predicted = ship
Actual = ship
Predicted = frog
Actual = airplane
Predicted = cat
Actual = cat
Predicted = ship
Actual = ship
Predicted = ship
Actual = ship
Predicted = dog
Actual = horse
Predicted = horse
Actual = horse
Predicted = deer
Actual = deer
Predicted = cat
Actual = frog
Predicted = horse
Actual = horse
Predicted = cat
Actual = cat
Predicted = frog
Actual = frog
Predicted = cat
Actual = cat

```python
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Conv2D, Dropout, Flatten
from tensorflow.keras.optimizers import SGD, Adam
from tensorflow.keras.layers import Convolution2D as Conv2D
from tensorflow.keras.layers import MaxPooling2D
```

```python
#Define Alexnet Model
AlexNet = Sequential()
AlexNet.add(Conv2D(filters=16,kernel_size=(3,3),strides=(4,4),input_shape=(32,32,3), activation='relu'))
AlexNet.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
AlexNet.add(Conv2D(60,(5,5),padding='same',activation='relu'))
AlexNet.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
AlexNet.add(Conv2D(60,(3,3),padding='same',activation='relu'))
AlexNet.add(Conv2D(30,(3,3),padding='same',activation='relu'))
AlexNet.add(Conv2D(20,(3,3),padding='same',activation='relu'))
AlexNet.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
AlexNet.add(Flatten())
AlexNet.add(Dense(200, activation='relu'))
AlexNet.add(Dropout(0.1))
AlexNet.add(Dense(200, activation='relu'))
AlexNet.add(Dropout(0.1))
AlexNet.add(Dense(10,activation='softmax'))

AlexNet.compile(optimizer='SGD', loss=keras.losses.sparse_categorical_crossentropy, metrics=['accuracy'])
AlexNet.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_3 (Conv2D)           (None, 8, 8, 16)          448

 max_pooling2d (MaxPooling2  (None, 4, 4, 16)          0
 D)

 conv2d_4 (Conv2D)           (None, 4, 4, 60)          24060

 max_pooling2d_1 (MaxPoolin  (None, 2, 2, 60)          0
 g2D)

 conv2d_5 (Conv2D)           (None, 2, 2, 60)          32460

 conv2d_6 (Conv2D)           (None, 2, 2, 30)          16230

 conv2d_7 (Conv2D)           (None, 2, 2, 20)          5420

 max_pooling2d_2 (MaxPoolin  (None, 1, 1, 20)          0
 g2D)

 flatten_1 (Flatten)         (None, 20)                0

...
Total params: 125028 (488.39 KB)
Trainable params: 125028 (488.39 KB)
Non-trainable params: 0 (0.00 Byte)
```

```python
history1 = AlexNet.fit(x_train, y_train, epochs=100, validation_data=(x_test, y_test),verbose=1)
```

```
Epoch 1/100
1563/1563 [==============================] - 13s 6ms/step - loss: 2.3005 - accuracy: 0.1202 - val_loss: 2.2954 - val_accuracy: 0.1593
Epoch 2/100
1563/1563 [==============================] - 9s 6ms/step - loss: 2.2379 - accuracy: 0.1729 - val_loss: 2.0964 - val_accuracy: 0.2019
Epoch 3/100
1563/1563 [==============================] - 9s 6ms/step - loss: 2.0718 - accuracy: 0.2052 - val_loss: 2.0534 - val_accuracy: 0.2278
Epoch 4/100
1563/1563 [==============================] - 9s 6ms/step - loss: 1.9807 - accuracy: 0.2478 - val_loss: 2.0285 - val_accuracy: 0.2387
Epoch 5/100
1563/1563 [==============================] - 10s 6ms/step - loss: 1.8673 - accuracy: 0.2863 - val_loss: 1.7604 - val_accuracy: 0.3378
Epoch 6/100
1563/1563 [==============================] - 9s 6ms/step - loss: 1.7570 - accuracy: 0.3271 - val_loss: 1.7866 - val_accuracy: 0.3321
Epoch 7/100
1563/1563 [==============================] - 9s 6ms/step - loss: 1.6764 - accuracy: 0.3639 - val_loss: 1.6310 - val_accuracy: 0.3875
Epoch 8/100
1563/1563 [==============================] - 9s 6ms/step - loss: 1.6125 - accuracy: 0.3900 - val_loss: 1.6049 - val_accuracy: 0.3961
Epoch 9/100
1563/1563 [==============================] - 9s 6ms/step - loss: 1.5451 - accuracy: 0.4206 - val_loss: 1.5705 - val_accuracy: 0.4325
Epoch 10/100
1563/1563 [==============================] - 9s 5ms/step - loss: 1.4799 - accuracy: 0.4498 - val_loss: 1.6764 - val_accuracy: 0.3789
Epoch 11/100
1563/1563 [==============================] - 9s 6ms/step - loss: 1.4215 - accuracy: 0.4730 - val_loss: 1.3958 - val_accuracy: 0.4890
Epoch 12/100
1563/1563 [==============================] - 9s 6ms/step - loss: 1.3713 - accuracy: 0.4935 - val_loss: 1.3535 - val_accuracy: 0.5073
Epoch 13/100
...
Epoch 99/100
1563/1563 [==============================] - 9s 6ms/step - loss: 0.2739 - accuracy: 0.9039 - val_loss: 2.5997 - val_accuracy: 0.5227
Epoch 100/100
1563/1563 [==============================] - 9s 6ms/step - loss: 0.2681 - accuracy: 0.9057 - val_loss: 2.5864 - val_accuracy: 0.5327
```

```python
# summarize history for accuracy
plt.plot(history1.history['accuracy'])
plt.plot(history1.history['val_accuracy'])
plt.title("Accuracy by AlexNet on CIFAR-10 Data")
plt.ylabel('Accuracy')
plt.xlabel('Epochs')
plt.legend(['Train', 'Validation'], loc='upper left')
plt.show()
# summarize history for loss
plt.plot(history1.history['loss'])
plt.plot(history1.history['val_loss'])
plt.title('Loss by AlexNet on CIFAR-10 Data')
plt.ylabel('Loss')
plt.xlabel('Epochs')
plt.legend(['Train', 'Validation'])
plt.show()
```

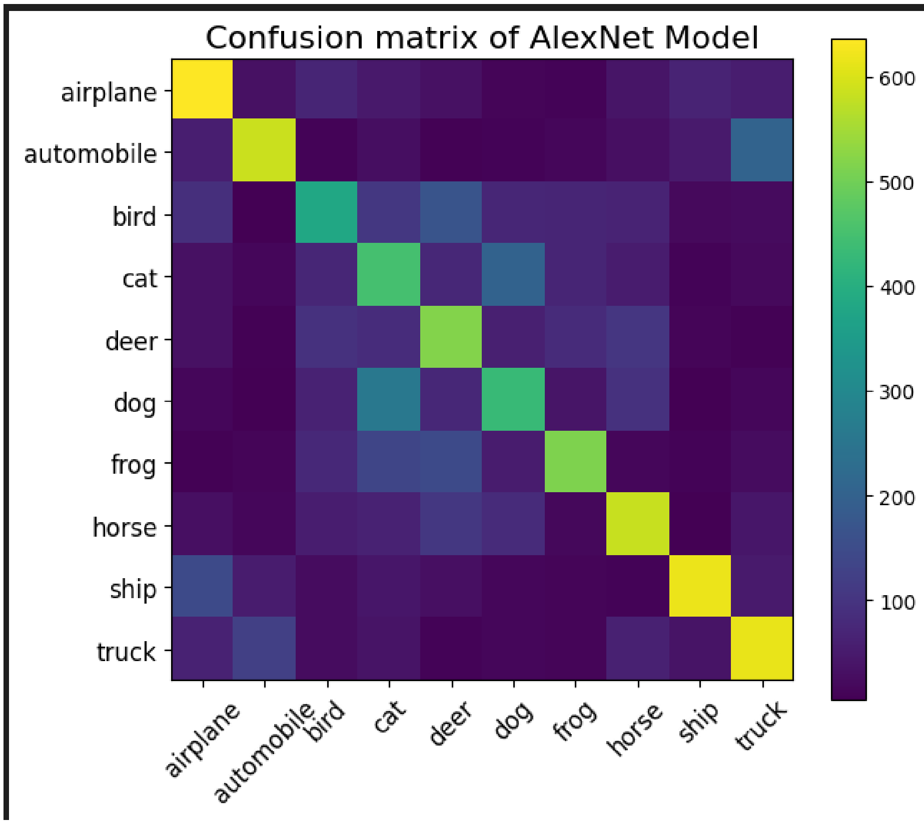
```python
y_predictions1 = AlexNet.predict(x_test)
y_predictions1.reshape(-1,)
y_predictions1= np.argmax(y_predictions1, axis=1)

confusion_matrix(y_test, y_predictions1)
```

```
313/313 [==============================] - 1s 2ms/step

array([[636,  32,  69,  48,  32,  13,   9,  41,  66,  54],
       [ 57, 585,  10,  28,   8,  11,  15,  31,  50, 205],
       [ 90,   4, 381, 106, 169,  71,  70,  66,  21,  22],
       [ 33,  16,  73, 449,  75, 202,  70,  53,  10,  19],
       [ 32,   8,  93,  83, 519,  59,  82, 105,  12,   7],
       [ 14,   6,  64, 257,  75, 429,  40,  95,   4,  16],
       [  7,  12,  78, 136, 146,  53, 515,  16,  11,  26],
       [ 31,  14,  54,  65, 107,  82,  17, 582,   6,  42],
       [147,  52,  26,  42,  30,  15,  13,   9, 617,  49],
       [ 65, 124,  24,  37,   9,  16,  12,  62,  37, 614]])
```

```python
# confusion matrix and accuracy
plt.figure(figsize=(7, 6))
plt.title('Confusion matrix of AlexNet Model', fontsize=16)
plt.imshow(confusion_matrix(y_test, y_predictions1))
plt.xticks(np.arange(10), classes, rotation=45, fontsize=12)
plt.yticks(np.arange(10), classes, fontsize=12)
plt.colorbar()
plt.show()
```



```python
print("Test accuracy by AlexNet:", accuracy_score(y_test, y_predictions))
```

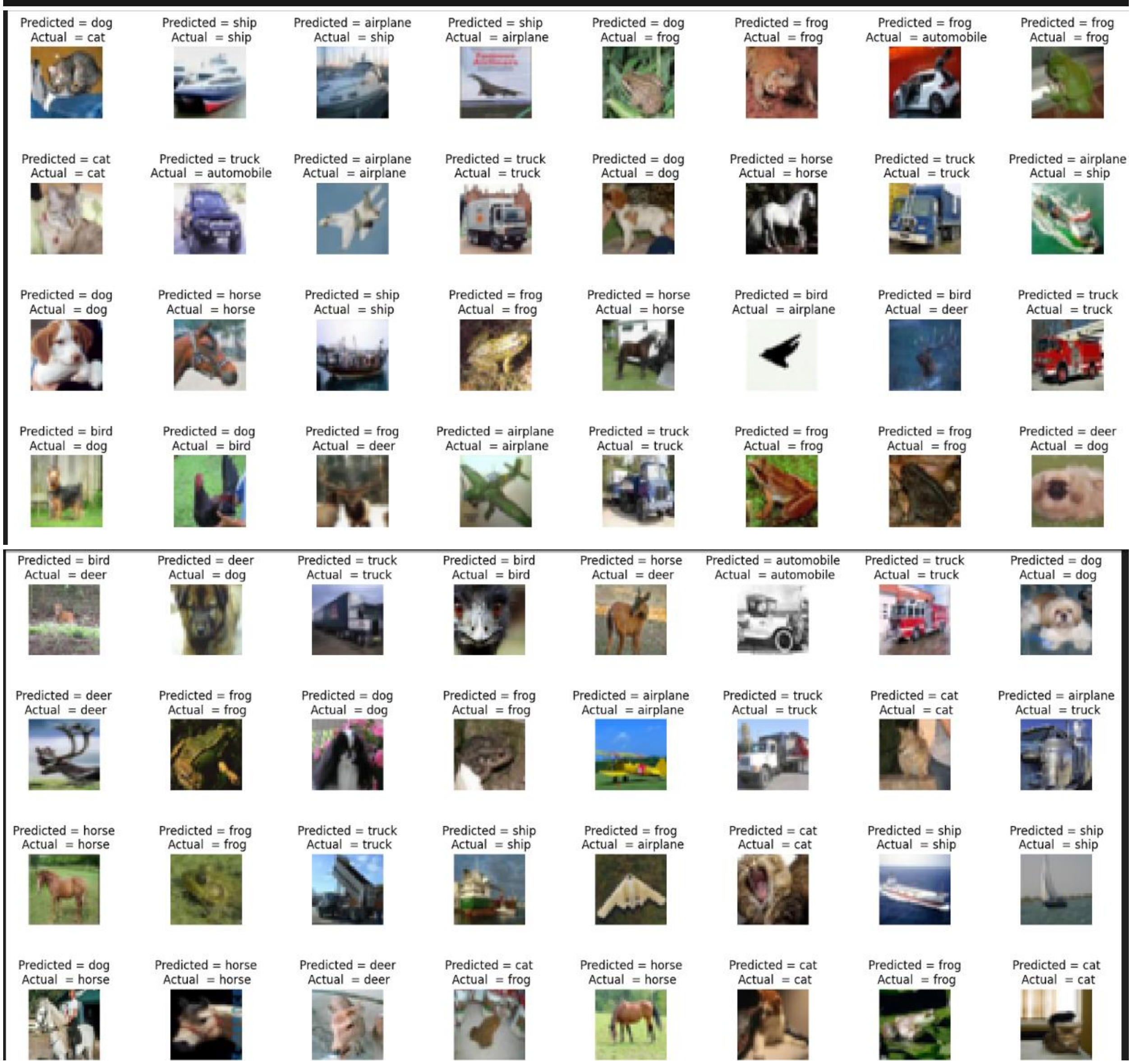
```
Test accuracy by AlexNet: 0.5995
```

+ Code + Markdown

```python
L = 8
W = 8
fig, axes = plt.subplots(L, W, figsize = (20,20))
axes = axes.ravel() #

for i in np.arange(0, L * W):
    axes[i].imshow(x_test[i])
    axes[i].set_title("Predicted = {}\n Actual  = {}".format(classes[y_predictions[i]], classes[y_test[i]]))
    axes[i].axis('off')

plt.subplots_adjust(wspace=1)
```



3.VGG 16

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

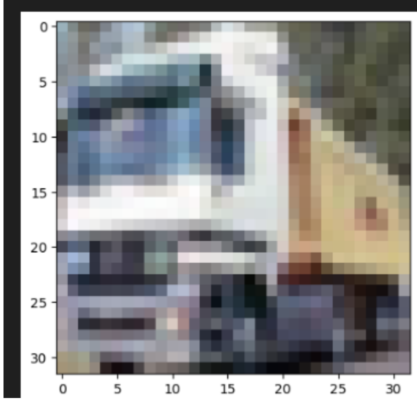
```
# generate cifar10 data
(x_train,y_train),(x_test,y_test) = cifar10.load_data()
```

```
# config parameters
num_classes = 10
input_shape = x_train.shape[1:4]
optimizer = optimizers.Adam(lr=0.0003)
```

```
# 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)
```

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

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



```python
# 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(Conv2D(64,(3,3),activation='relu',padding='same'))
model.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
model.add(Conv2D(128,(3,3),activation='relu',padding='same'))
model.add(Conv2D(128,(3,3),activation='relu',padding='same'))
model.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
model.add(Conv2D(256,(3,3),activation='relu',padding='same'))
model.add(Conv2D(256,(3,3),activation='relu',padding='same'))
model.add(Conv2D(256,(3,3),activation='relu',padding='same'))
model.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
model.add(Flatten())
model.add(Dense(4096,activation='relu'))
model.add(Dense(4096,activation='relu'))
model.add(Dense(num_classes))
model.add(Activation('softmax'))
```

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

```python
# check model
model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_8 (Conv2D)           (None, 32, 32, 64)        1792

 conv2d_9 (Conv2D)           (None, 32, 32, 64)        36928

 max_pooling2d_3 (MaxPoolin  (None, 16, 16, 64)        0
 g2D)

 conv2d_10 (Conv2D)          (None, 16, 16, 128)       73856

 conv2d_11 (Conv2D)          (None, 16, 16, 128)       147584

 max_pooling2d_4 (MaxPoolin  (None, 8, 8, 128)         0
 g2D)

 conv2d_12 (Conv2D)          (None, 8, 8, 256)         295168
```

```
 conv2d_13 (Conv2D)          (None, 8, 8, 256)         590080

 conv2d_14 (Conv2D)          (None, 8, 8, 256)         590080

 max_pooling2d_5 (MaxPoolin  (None, 4, 4, 256)         0
...
Total params: 33638218 (128.32 MB)
Trainable params: 33638218 (128.32 MB)
Non-trainable params: 0 (0.00 Byte)
```

```python
# train
model.fit(x=x_train,y=one_hot_y_train,batch_size=128,epochs=10)
```

```
Epoch 1/10
391/391 [==============================] - 36s 68ms/step - loss: 2.3356 - accuracy: 0.0983
Epoch 2/10
391/391 [==============================] - 23s 59ms/step - loss: 2.3027 - accuracy: 0.0959
Epoch 3/10
391/391 [==============================] - 23s 58ms/step - loss: 2.3027 - accuracy: 0.0961
Epoch 4/10
391/391 [==============================] - 23s 59ms/step - loss: 2.3027 - accuracy: 0.0975
Epoch 5/10
391/391 [==============================] - 23s 59ms/step - loss: 2.3027 - accuracy: 0.0969
Epoch 6/10
391/391 [==============================] - 23s 59ms/step - loss: 2.3027 - accuracy: 0.0957
Epoch 7/10
391/391 [==============================] - 23s 58ms/step - loss: 2.3027 - accuracy: 0.0967
Epoch 8/10
391/391 [==============================] - 23s 59ms/step - loss: 2.3027 - accuracy: 0.0959
Epoch 9/10
391/391 [==============================] - 23s 59ms/step - loss: 2.3027 - accuracy: 0.0982
Epoch 10/10
391/391 [==============================] - 23s 59ms/step - loss: 2.3027 - accuracy: 0.0981
```

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

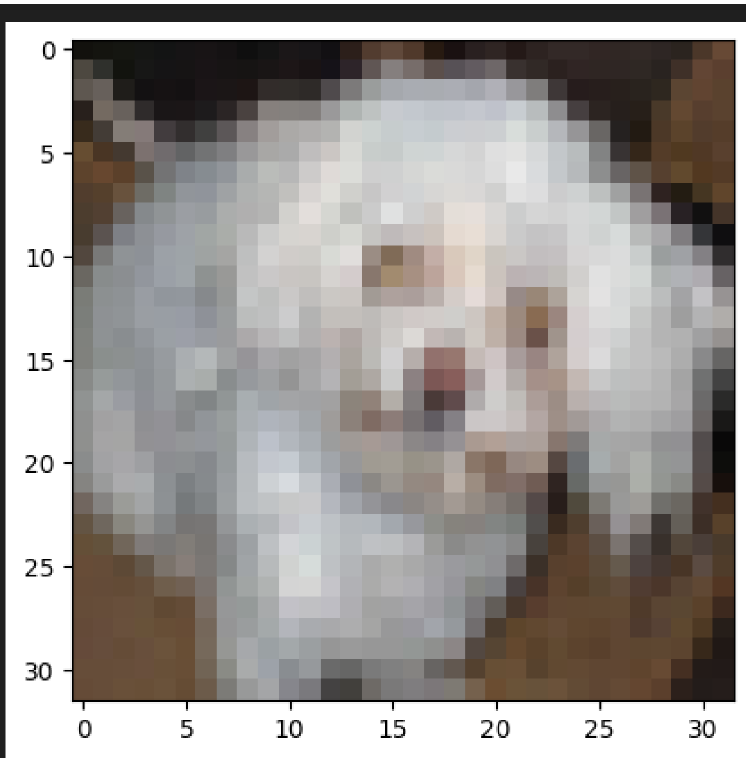
```
['loss', 'accuracy']
20/20 [==============================] - 7s 162ms/step - loss: 2.3026 - accuracy: 0.1000

[2.3025965690612793, 0.10000000149011612]
```

```python
# predict
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 640ms/step
predict class: 9
expected class: 5
```




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

4.VGG19Model

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

from keras.datasets import cifar10
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

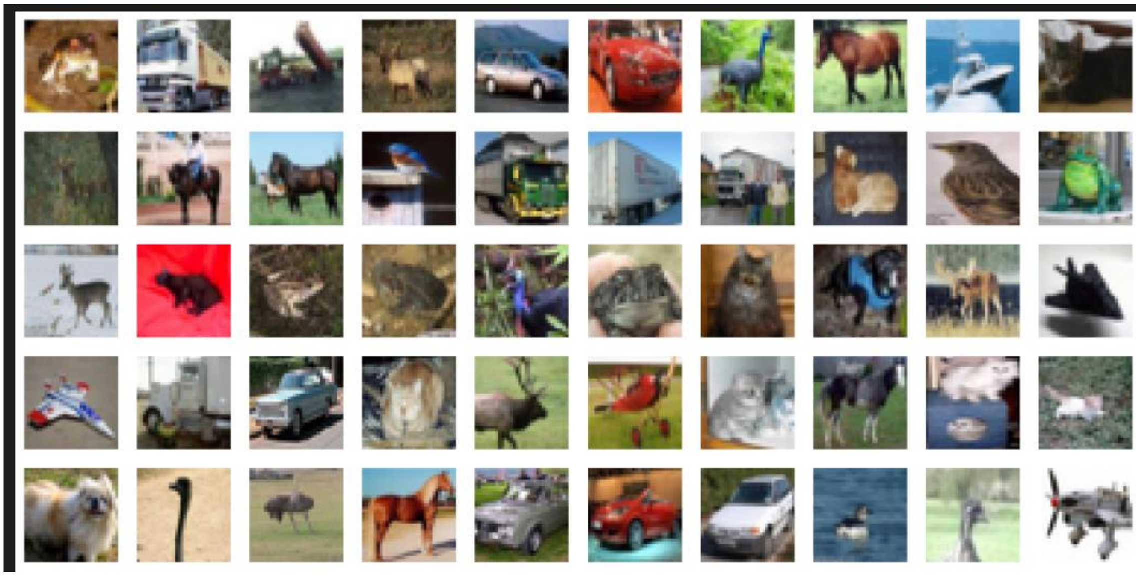
```
cifar100 = tf.keras.datasets.cifar100
(X_train,Y_train) , (X_test,Y_test) = cifar10.load_data()
```

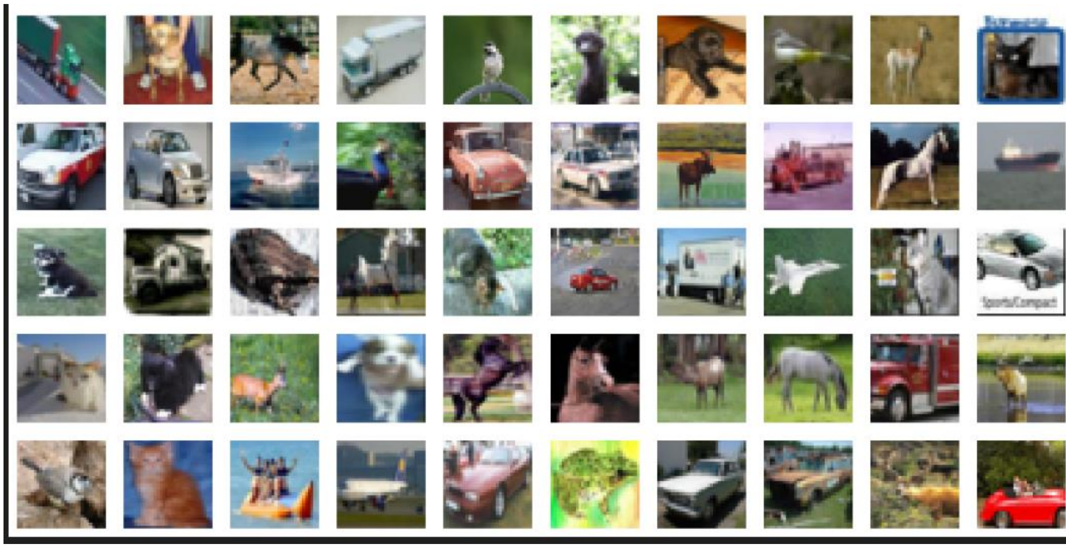
```
classes = ['airplane', 'automobile', 'bird', 'cat', 'deer', 'dog', 'frog', 'horse', 'ship', 'truck']
```

```
# X_train = X_train.astype('float32')
# X_test = X_test.astype('float32')
# X_train = X_train / 255.0
# X_test = X_test / 255.0
```

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 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)
```

```python
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)
```

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

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

```python
vgg_model = tf.keras.applications.VGG19(
    include_top=False,
    weights="imagenet",
    input_shape=(32,32,3),
)

vgg_model.summary()
```

```
Model: "vgg19"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 input_3 (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: 20024384 (76.39 MB)
Trainable params: 20024384 (76.39 MB)
Non-trainable params: 0 (0.00 Byte)
```

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

model.summary()
```

```
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 vgg19 (Functional)          (None, 1, 1, 512)         20024384

 flatten_3 (Flatten)         (None, 512)               0

 dense_10 (Dense)            (None, 1024)              525312

 dense_11 (Dense)            (None, 1024)              1049600

 dense_12 (Dense)            (None, 256)               262400

 dense_13 (Dense)            (None, 10)                2570

=================================================================
Total params: 21864266 (83.41 MB)
Trainable params: 21864266 (83.41 MB)
Non-trainable params: 0 (0.00 Byte)
```

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

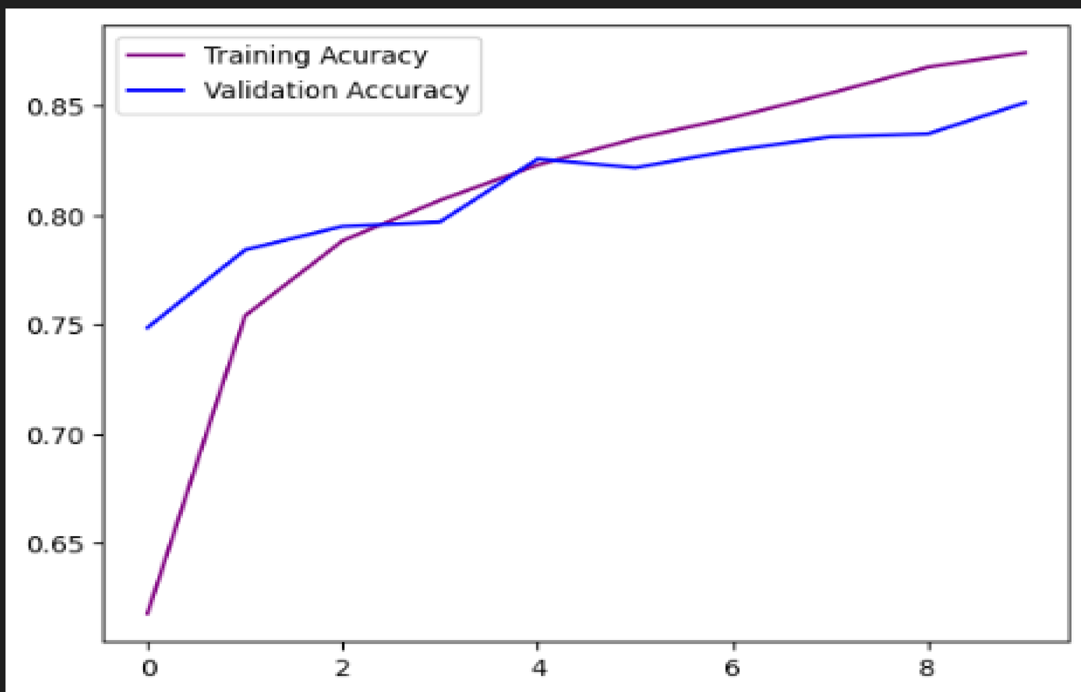
```python
history = model.fit(
    train_datagen.flow(x_train, y_train, batch_size = 128),
    validation_data = val_datagen.flow(x_val,y_val, batch_size = 128),
    epochs = 10,
    verbose = 1,
    callbacks = [learning_rate_reduction]
)
```

```
313/313 [==============================] - 38s 112ms/step - loss: 1.1032 - accuracy: 0.6178 - val_loss: 0.7488 - val_accuracy: 0.7486 - lr: 0.0010
Epoch 2/10
313/313 [==============================] - 34s 107ms/step - loss: 0.7297 - accuracy: 0.7541 - val_loss: 0.6326 - val_accuracy: 0.7842 - lr: 0.0010
Epoch 3/10
313/313 [==============================] - 34s 107ms/step - loss: 0.6273 - accuracy: 0.7884 - val_loss: 0.6150 - val_accuracy: 0.7950 - lr: 0.0010
Epoch 4/10
313/313 [==============================] - 34s 107ms/step - loss: 0.5704 - accuracy: 0.8069 - val_loss: 0.5969 - val_accuracy: 0.7970 - lr: 0.0010
Epoch 5/10
313/313 [==============================] - 34s 108ms/step - loss: 0.5160 - accuracy: 0.8231 - val_loss: 0.5143 - val_accuracy: 0.8258 - lr: 0.0010
Epoch 6/10
313/313 [==============================] - 34s 109ms/step - loss: 0.4794 - accuracy: 0.8351 - val_loss: 0.5276 - val_accuracy: 0.8218 - lr: 0.0010
Epoch 7/10
313/313 [==============================] - 35s 112ms/step - loss: 0.4492 - accuracy: 0.8448 - val_loss: 0.5124 - val_accuracy: 0.8297 - lr: 0.0010
Epoch 8/10
313/313 [==============================] - 33s 106ms/step - loss: 0.4173 - accuracy: 0.8559 - val_loss: 0.4892 - val_accuracy: 0.8359 - lr: 0.0010
Epoch 9/10
313/313 [==============================] - 33s 104ms/step - loss: 0.3871 - accuracy: 0.8678 - val_loss: 0.4836 - val_accuracy: 0.8373 - lr: 0.0010
Epoch 10/10
313/313 [==============================] - 33s 106ms/step - loss: 0.3677 - accuracy: 0.8744 - val_loss: 0.4372 - val_accuracy: 0.8516 - lr: 0.0010
```

```python
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()
```

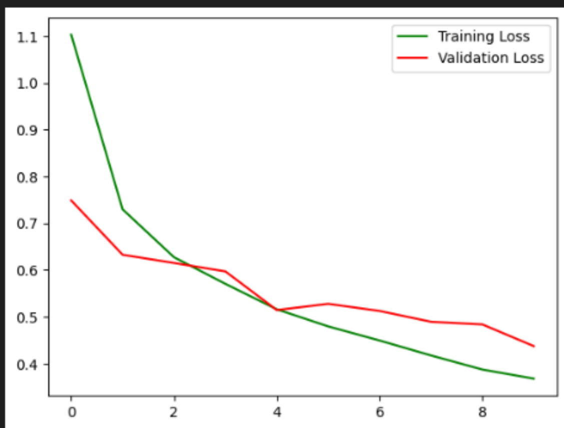
```
<matplotlib.legend.Legend at 0x7f9ed4129930>
```



```
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()
```

```
<matplotlib.legend.Legend at 0x7f9ed55d68f0>
```




```
x_test = tf.keras.applications.vgg19.preprocess_input(X_test)
y_pred = np.argmax(model.predict(x_test), axis=-1)
y_pred[:10]
```

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

array([3, 8, 8, 0, 6, 6, 1, 6, 3, 1])
```

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

```
array([[892,   4,  19,   5,  10,   2,   2,  12,  36,  18],
       [ 12, 885,   1,   1,   0,   2,   3,   2,  11,  83],
       [ 35,   1, 826,  19,  48,  19,  35,   9,   5,   3],
       [  5,   3,  36, 700,  32, 145,  39,  19,   6,  15],
       [ 12,   1,  37,  27, 834,  15,  29,  40,   4,   1],
       [  3,   1,  28, 105,  22, 793,  11,  34,   1,   2],
       [ 10,   2,  28,  38,  15,  11, 884,   1,   7,   4],
       [  5,   0,  13,  21,  25,  30,   1, 898,   2,   5],
       [ 29,  15,   5,   1,   3,   1,   0,   0, 923,  23],
       [ 15,  16,   3,  15,   1,   1,   1,   7,  12, 929]])
```

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

```
Testing Accuarcy :  0.8564
```

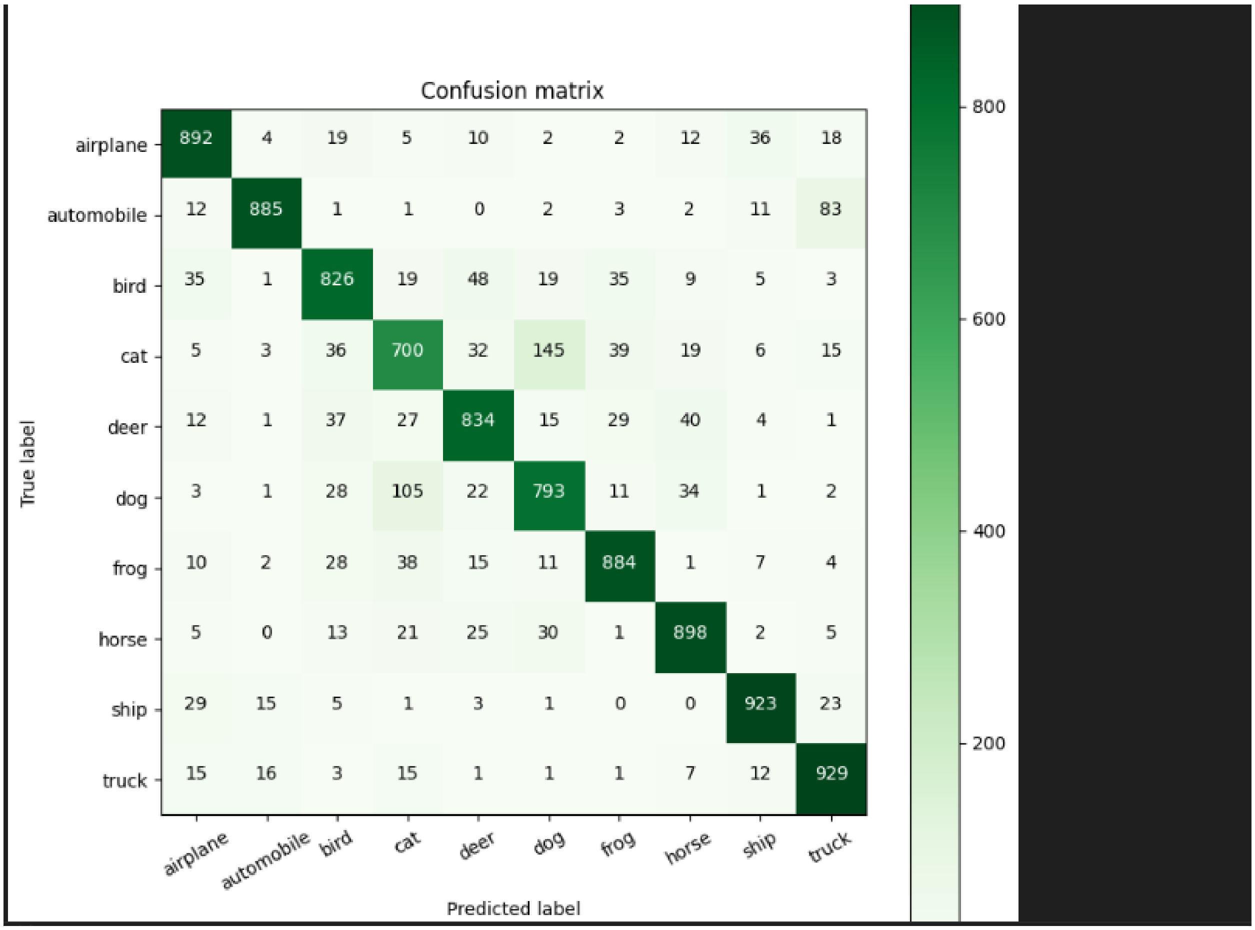
```python
import itertools
def plot_confusion_matrix(cm, classes,
                          normalize=False,
                          title='Confusion matrix',
                          cmap=plt.cm.Greens):
    """
    This function prints and plots the confusion matrix.
    Normalization can be applied 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")
```

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


Confusion matrix
True label
Predicted label
airplane
automobile
bird
cat
deer
dog
frog
horse
ship
truck
892 4 19 5 10 2 2 12 36 18
12 885 1 1 0 2 3 2 11 83
35 1 826 19 48 19 35 9 5 3
5 3 36 700 32 145 39 19 6 15
12 1 37 27 834 15 29 40 4 1
3 1 28 105 22 793 11 34 1 2
10 2 28 38 15 11 884 1 7 4
5 0 13 21 25 30 1 898 2 5
29 15 5 1 3 1 0 0 923 23
15 16 3 15 1 1 1 7 12 929
800
600
400
200