NEURAL NETWORKS AND DEEP LEARNING ICP8

NAME : DASARI BHAVANI BHAGAVATHAMMA

STUDENT ID : 700759340

GITHUB LINK : https://github.com/Bhavani700759340/-NeuralNetworkAndDeepLearning_ICP8/tree/main

VIDEO LINK : https://drive.google.com/file/d/1bYmaz1pLvso7HGqkLVYnwjXI4VDF6Njm/view?usp=sharing

LeNet5 Code and output:

```
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 [==============================] - 6s 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)
```

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

```
lenet.summary()
```

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

 average_pooling2d (AverageP  (None, 16, 16, 6)        0
 ooling2D)

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

```
 average_pooling2d_1 (Averag  (None, 6, 6, 16)         0
 ePooling2D)

 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: 92,246
Trainable params: 92,246
Non-trainable params: 0
_________________________________________________________________
```

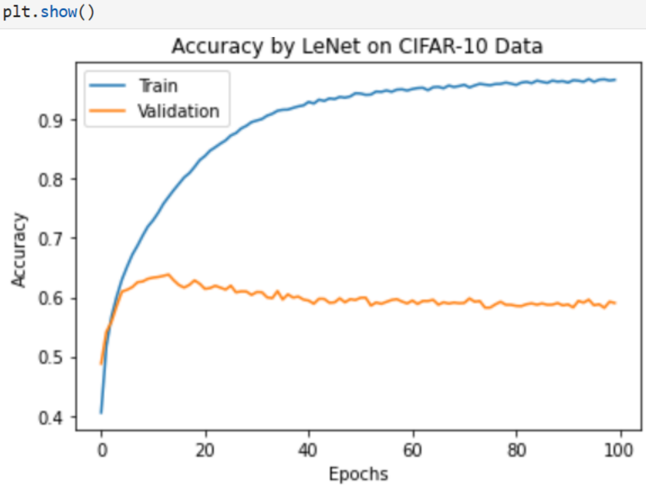
```
lenet.compile(optimizer='adam', loss=keras.losses.sparse_categorical_crossentropy, metrics=['accuracy'])
```

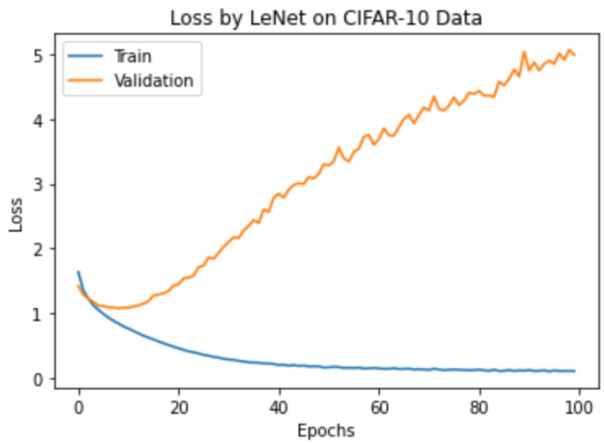
```
hist = lenet.fit(x_train, y_train, epochs=100, validation_data=(x_test, y_test),verbose=1)
```

```
Epoch 1/100
1563/1563 [==============================] - 19s 6ms/step - loss: 1.6343 - accuracy: 0.4051 - val_loss: 1.4179 - val_accuracy: 0.4879
Epoch 2/100
1563/1563 [==============================] - 9s 6ms/step - loss: 1.3498 - accuracy: 0.5170 - val_loss: 1.2812 - val_accuracy: 0.5415
Epoch 3/100
1563/1563 [==============================] - 8s 5ms/step - loss: 1.2189 - accuracy: 0.5675 - val_loss: 1.2239 - val_accuracy: 0.5587
```

```
Epoch 96/100
1563/1563 [==============================] - 8s 5ms/step - loss: 0.1112 - accuracy: 0.9635 - val_loss: 4.8539 - val_accuracy: 0.5863
Epoch 97/100
1563/1563 [==============================] - 8s 5ms/step - loss: 0.1035 - accuracy: 0.9671 - val_loss: 5.0162 - val_accuracy: 0.5881
Epoch 98/100
1563/1563 [==============================] - 8s 5ms/step - loss: 0.1029 - accuracy: 0.9678 - val_loss: 4.9166 - val_accuracy: 0.5819
Epoch 99/100
1563/1563 [==============================] - 10s 6ms/step - loss: 0.1059 - accuracy: 0.9658 - val_loss: 5.0741 - val_accuracy: 0.5924
Epoch 100/100
1563/1563 [==============================] - 8s 5ms/step - loss: 0.1006 - accuracy: 0.9670 - val_loss: 4.9955 - val_accuracy: 0.5902
```

```
# 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()
```

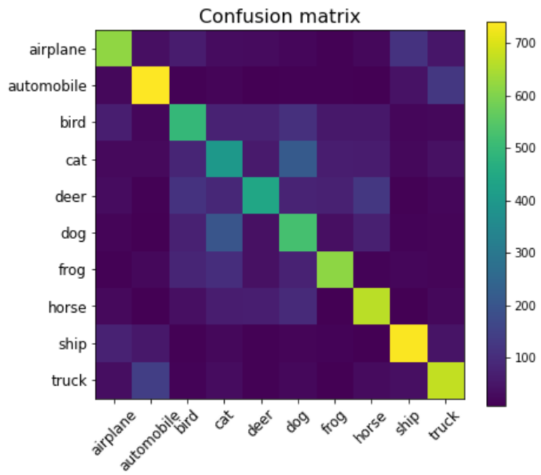





```
from sklearn.metrics import confusion_matrix
from sklearn.metrics import ConfusionMatrixDisplay
y_predictions= lenet.predict(x_test)
y_predictions.reshape(-1,)
y_predictions= np.argmax(y_predictions, axis=1)

confusion_matrix(y_test, y_predictions)
```

```
313/313 [==============================] - 1s 2ms/step
array([[618,  36,  64,  32,  28,  21,  11,  24, 115,  51],
       [ 24, 740,  12,  17,   7,  10,  12,   8,  43, 127],
       [ 69,  21, 495,  76,  77, 110,  53,  55,  21,  23],
       [ 25,  27,  83, 397,  61, 215,  67,  63,  23,  39],
       [ 32,  10, 114,  90, 441,  80,  75, 125,  12,  21],
       [ 18,   8,  75, 200,  39, 523,  38,  70,  13,  16],
       [ 12,  23,  82, 102,  40,  76, 615,  13,  21,  16],
       [ 25,   7,  37,  65,  68,  95,   8, 664,   8,  23],
       [ 77,  55,  11,  22,  12,  16,  14,   9, 737,  47],
       [ 33, 142,  13,  30,  11,  23,   9,  29,  38, 672]])
```

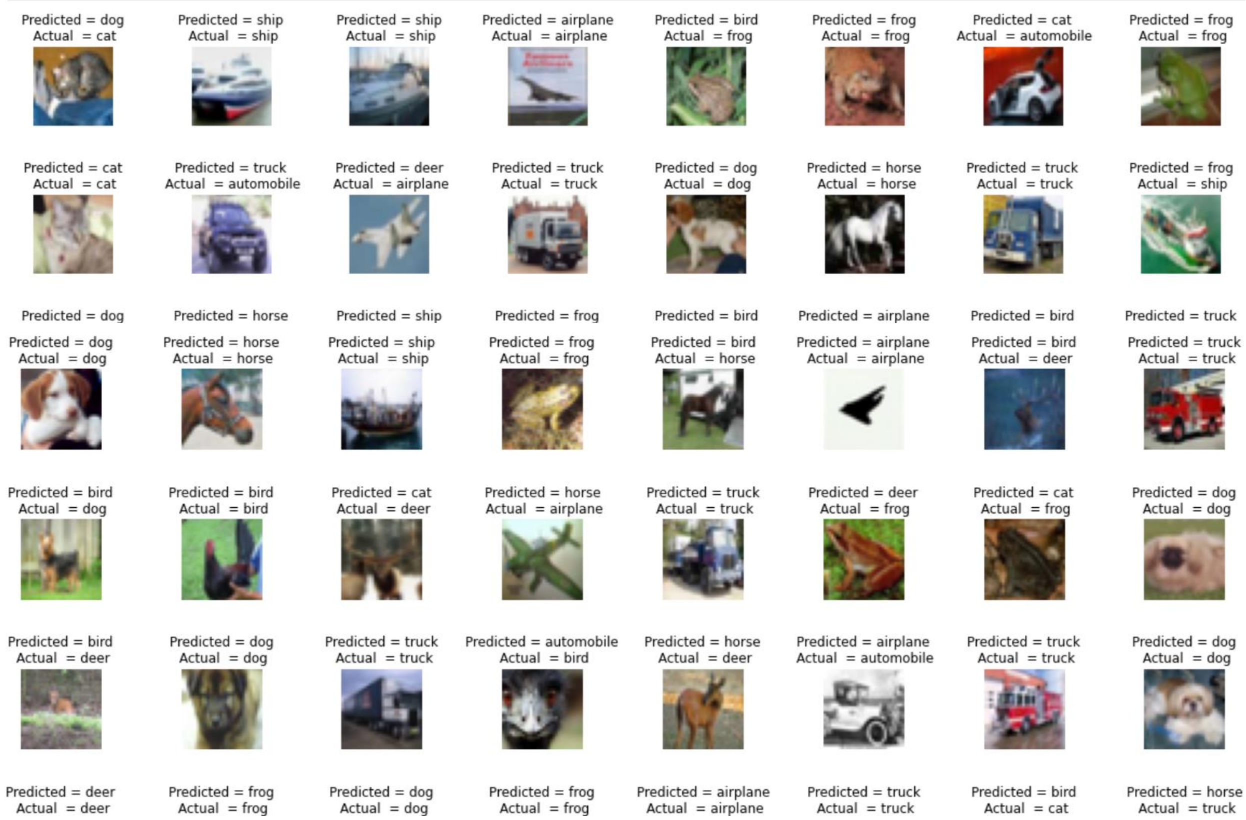
```
# confusion matrix and accuracy
from sklearn.metrics import confusion_matrix, accuracy_score
plt.figure(figsize=(7, 6))
plt.title('Confusion matrix', fontsize=16)
plt.imshow(confusion_matrix(y_test, y_predictions))
plt.xticks(np.arange(10), classes, rotation=45, fontsize=12)
plt.yticks(np.arange(10),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

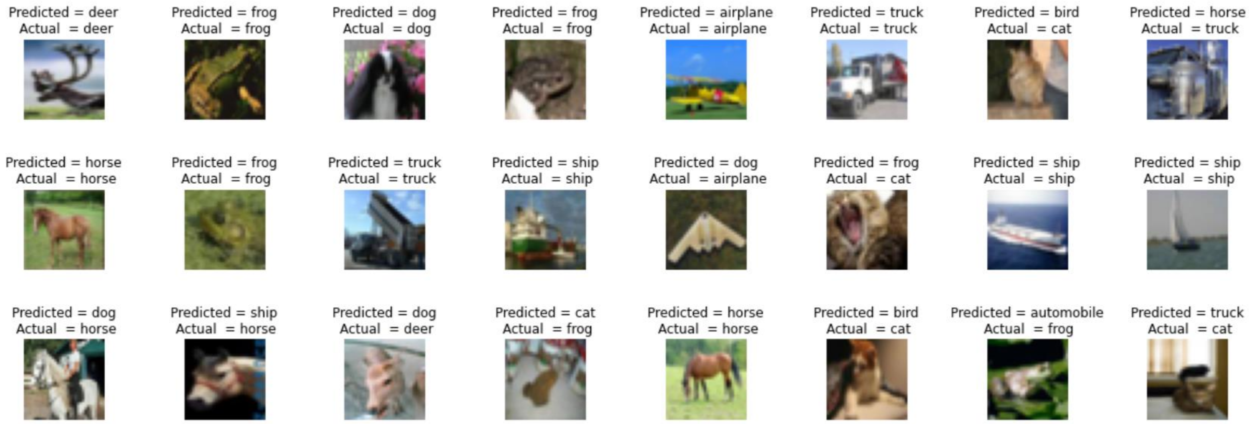



```
print("Test accuracy:", accuracy_score(y_test, y_predictions))
```

```
Test accuracy: 0.5902
```

```
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)
```





AlexNet Code and Output:

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

```
#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(Dropout(0.1))
AlexNet.add(Dense(10,activation='softmax'))

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

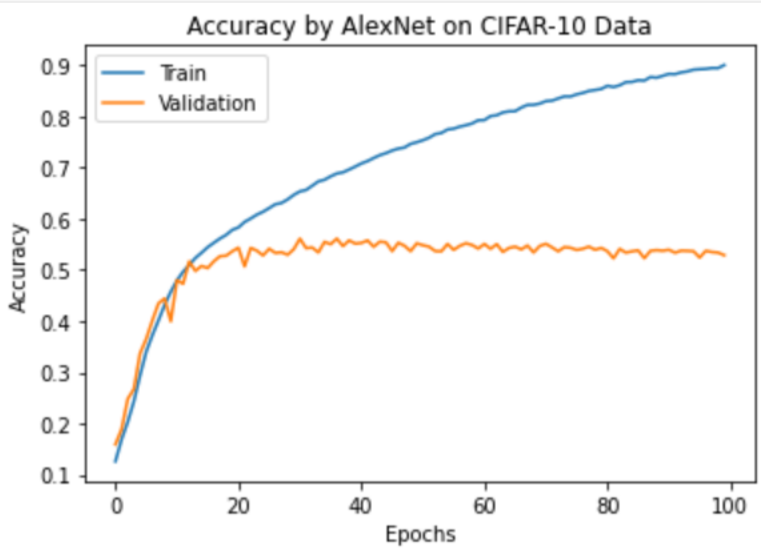
```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_3 (Conv2D)           (None, 8, 8, 16)          448

 max_pooling2d (MaxPooling2D  (None, 4, 4, 16)         0
 )

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

 max_pooling2d_1 (MaxPooling  (None, 2, 2, 60)         0
 2D)

 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 (MaxPooling  (None, 1, 1, 20)         0
 2D)
```

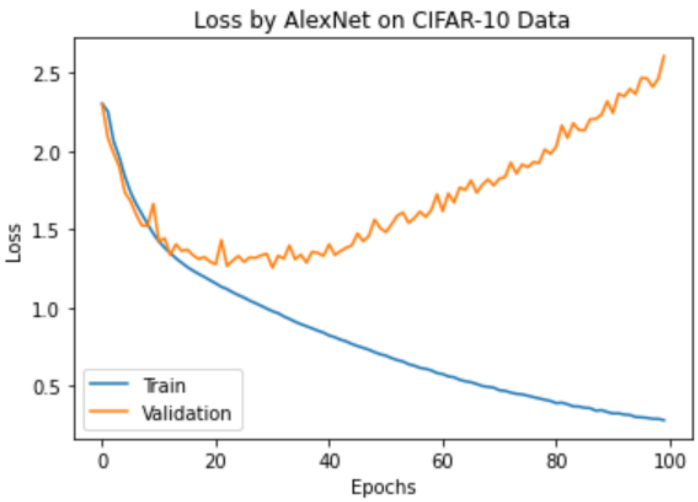
```
 flatten_1 (Flatten)         (None, 20)                0

 dense_2 (Dense)             (None, 200)               4200

 dropout (Dropout)           (None, 200)               0

 dense_3 (Dense)             (None, 200)               40200

 dropout_1 (Dropout)         (None, 200)               0

 dense_4 (Dense)             (None, 10)                2010

=================================================================
Total params: 125,028
Trainable params: 125,028
Non-trainable params: 0
_________________________________________________________________
```

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

```
Epoch 1/100
1563/1563 [==============================] - 13s 7ms/step - loss: 2.3008 - accuracy: 0.1261 - val_loss: 2.2969 - val_accuracy: 0.1592
Epoch 2/100
1563/1563 [==============================] - 10s 7ms/step - loss: 2.2508 - accuracy: 0.1689 - val_loss: 2.0838 - val_accuracy: 0.1888
Epoch 3/100
1563/1563 [==============================] - 10s 6ms/step - loss: 2.0630 - accuracy: 0.2030 - val_loss: 1.9858 - val_accuracy: 0.2479
Epoch 4/100
1563/1563 [==============================] - 11s 7ms/step - loss: 1.9620 - accuracy: 0.2432 - val_loss: 1.8994 - val_accuracy: 0.2673
Epoch 98/100
1563/1563 [==============================] - 11s 7ms/step - loss: 0.2925 - accuracy: 0.8944 - val_loss: 2.4082 - val_accuracy: 0.5349
Epoch 99/100
1563/1563 [==============================] - 10s 7ms/step - loss: 0.2918 - accuracy: 0.8943 - val_loss: 2.4604 - val_accuracy: 0.5338
Epoch 100/100
1563/1563 [==============================] - 11s 7ms/step - loss: 0.2835 - accuracy: 0.9001 - val_loss: 2.6043 - val_accuracy: 0.5287
```

```
# 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()
```



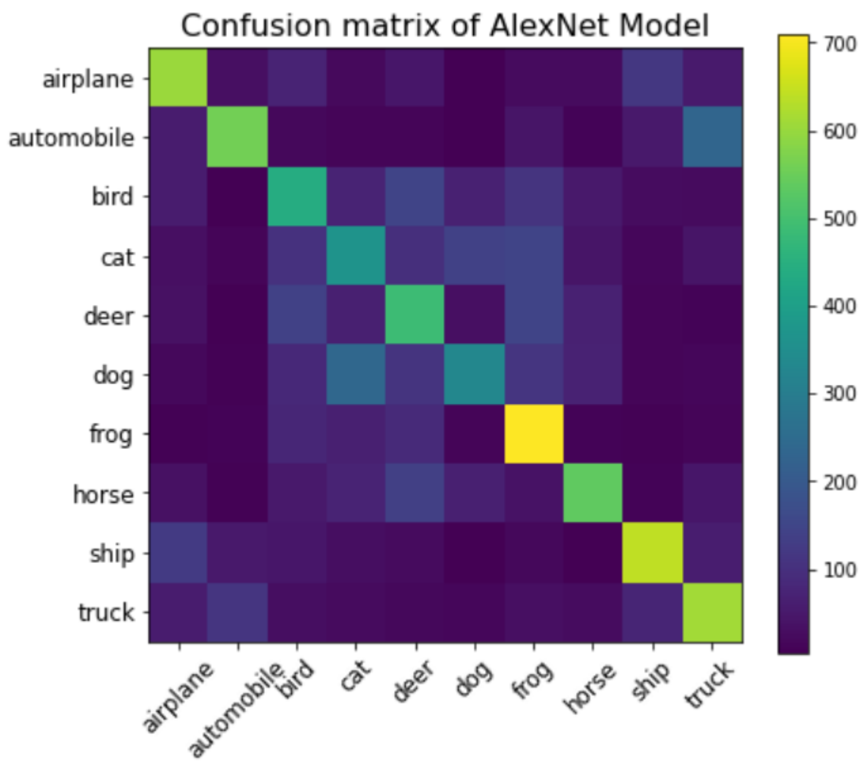



```
y_predictions1 = AlexNet.predict(x_test)
y_predictions1.reshape(-1,)
y_predictions1= np.argmax(y_predictions1, axis=1)

confusion_matrix(y_test, y_predictions1)
```

```
313/313 [==============================] - 1s 2ms/step
array([[602,  33,  72,  21,  47,   4,  25,  24, 118,  54],
       [ 56, 560,  19,  13,  13,   4,  42,  11,  50, 232],
       [ 56,   3, 441,  74, 148,  69, 110,  50,  26,  23],
       [ 31,  13, 104, 367,  97, 139, 148,  43,  15,  43],
       [ 34,   4, 139,  64, 488,  32, 149,  68,  12,  10],
       [ 18,   6,  85, 240, 110, 331, 112,  70,  13,  15],
       [  8,   9,  78,  66,  88,  14, 709,   9,   7,  12],
       [ 34,   7,  51,  74, 138,  65,  38, 538,   9,  46],
       [123,  51,  45,  29,  25,   3,  19,   5, 641,  59],
       [ 58, 111,  28,  24,  19,  16,  33,  26,  75, 610]])
```

]:

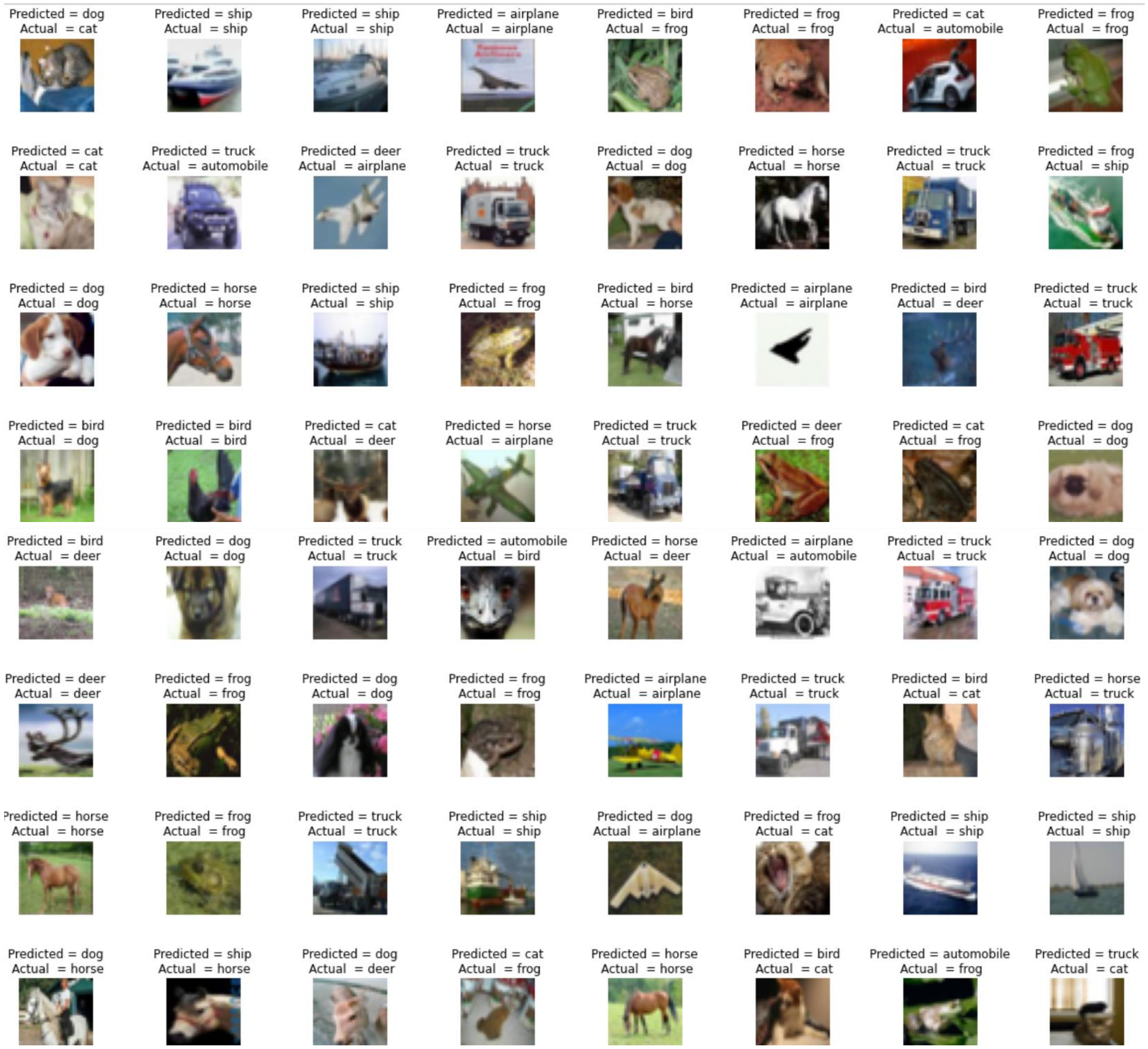
```
# confusion matrix and accuracy
plt.figure(figsize=(7, 6))
plt.title('Confusion matrix of AlexNet Model', fontsize=16)
plt.imshow(confusion_matrix(y_test, y_predictions1))
plt.xticks(np.arange(10), classes, rotation=45, fontsize=12)
plt.yticks(np.arange(10), classes, fontsize=12)
plt.colorbar()
plt.show()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




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

```
Test accuracy by AlexNet: 0.5902
```

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

Vgg16 Code and Output:

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

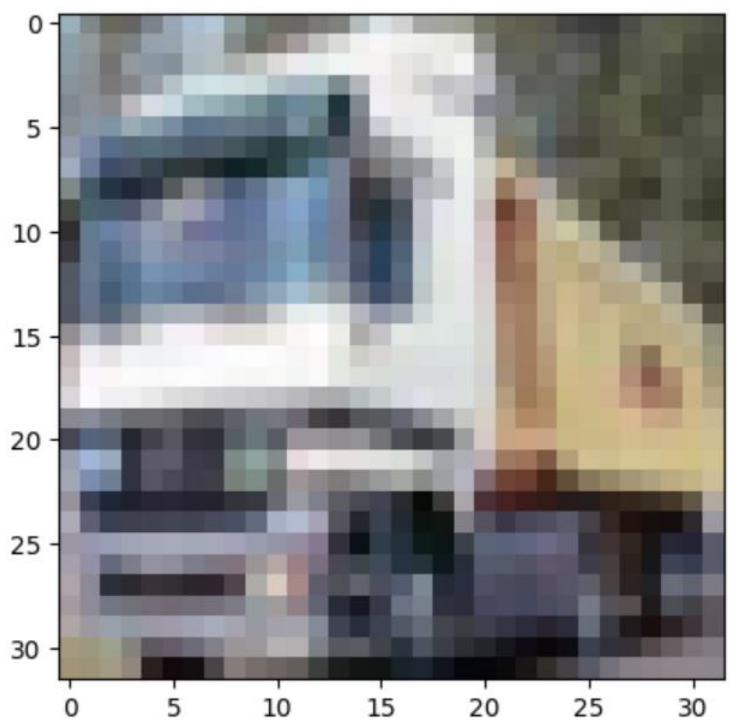
```
#generate cifar10 data
(x_train,y_train),(x_test,y_test) = cifar10.load_data()
```

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

```
#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(BatchNormalization())
model.add(Conv2D(64,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
model.add(MaxPooling2D(pool_size=(2,2),strides=(2,2)))
model.add(Dropout(0.25))

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

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

model.add(Conv2D(512,(3,3),activation='relu',padding='same'))
model.add(BatchNormalization())
```

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

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

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

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

```
model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d_1 (Conv2D)           (None, 32, 32, 64)        1792      
                                                                 
 batch_normalization (BatchN  (None, 32, 32, 64)       256       
 ormalization)                                                   
                                                                 
 conv2d_2 (Conv2D)           (None, 32, 32, 64)        36928     
                                                                 
 batch_normalization_1 (Batc  (None, 32, 32, 64)       256       
 hNormalization)                                                 
                                                                 
 max_pooling2d (MaxPooling2D  (None, 16, 16, 64)       0         
 )                                                               
                                                                 
 dropout (Dropout)           (None, 16, 16, 64)        0         
```

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

```
Epoch 1/30
352/352 [==============================] - 29s 81ms/step - loss: 1.7083 - accuracy: 0.3346 - val_loss: 2.6400 - val_accuracy: 0.3686
Epoch 2/30
352/352 [==============================] - 27s 76ms/step - loss: 1.3159 - accuracy: 0.5254 - val_loss: 1.6935 - val_accuracy: 0.5590
```

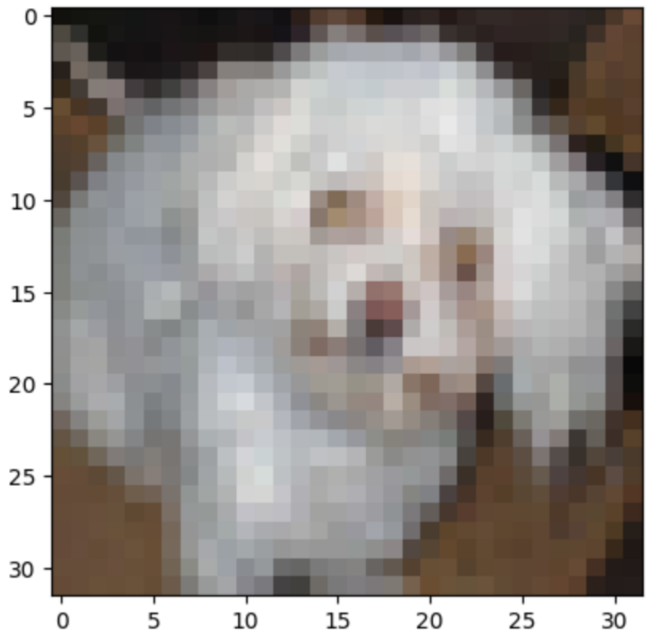
```
Epoch 27/30
352/352 [==============================] - 28s 78ms/step - loss: 0.0962 - accuracy: 0.9703 - val_loss: 0.7319 - val_accuracy: 0.8376
Epoch 28/30
352/352 [==============================] - 28s 78ms/step - loss: 0.0871 - accuracy: 0.9728 - val_loss: 0.7403 - val_accuracy: 0.8480
Epoch 29/30
352/352 [==============================] - 28s 79ms/step - loss: 0.0811 - accuracy: 0.9749 - val_loss: 0.6592 - val_accuracy: 0.8510
Epoch 30/30
352/352 [==============================] - 28s 78ms/step - loss: 0.0753 - accuracy: 0.9770 - val_loss: 0.6631 - val_accuracy: 0.8642
```

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

```
['loss', 'accuracy']
20/20 [==============================] - 5s 132ms/step - loss: 0.6627 - accuracy: 0.8592
[0.6626988053321838, 0.8592000007629395]
```

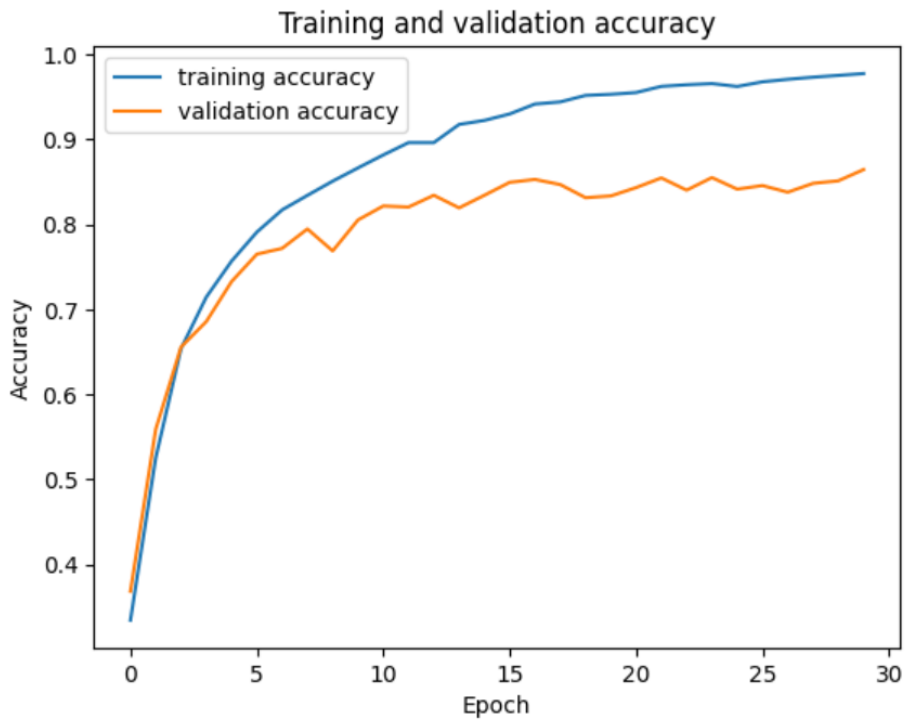
```
model.save("keras-VGG16-cifar10.h5")
plt.imshow(x_test[1000])

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

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

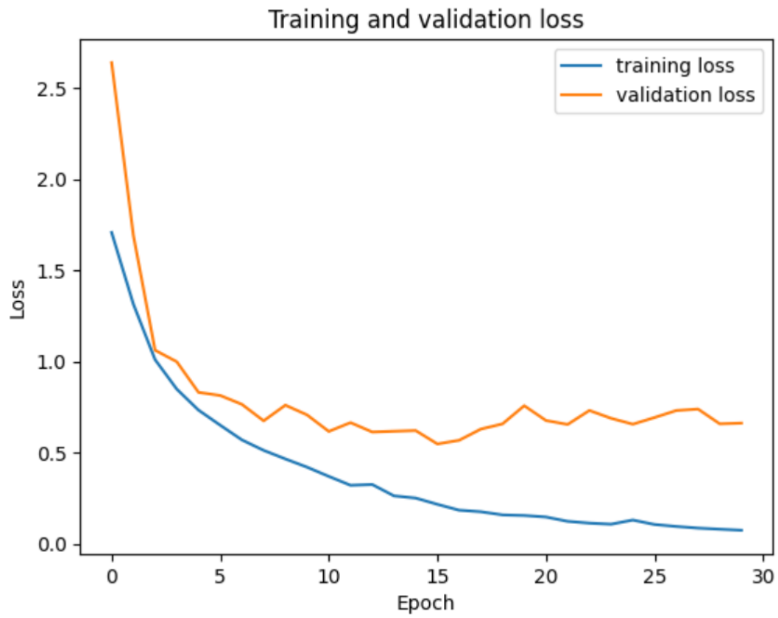



```python
# save model
model.save("keras-VGG16-cifar10.h5")
```

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

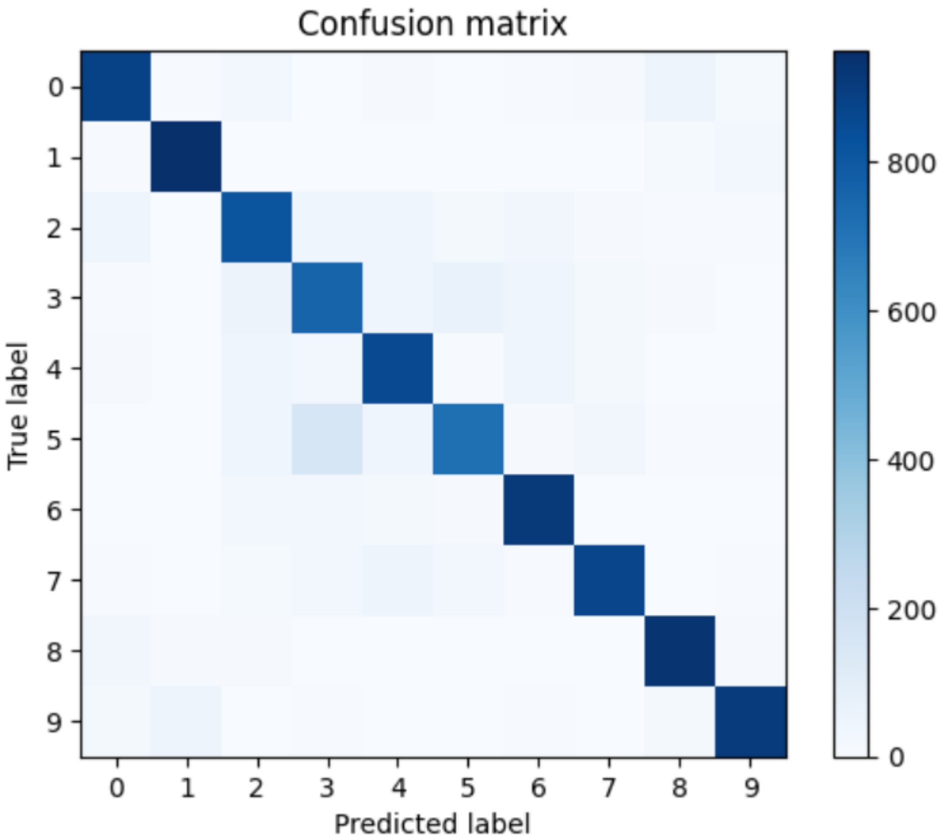


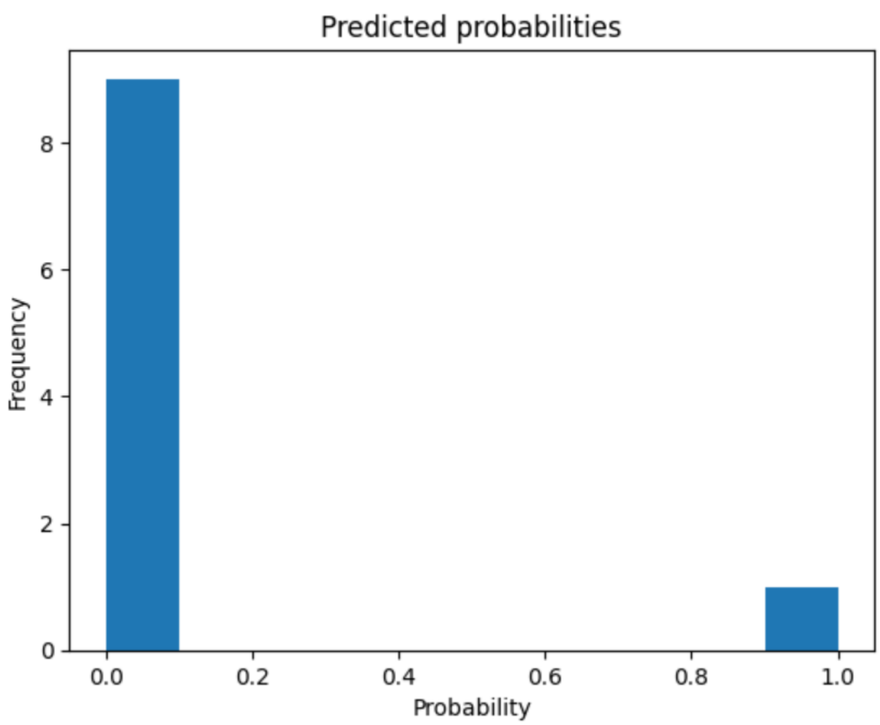

```
#plot the training and validation loss
plt.plot(history.history['loss'], label='training loss')
plt.plot(history.history['val_loss'], label='validation loss')
plt.title('Training and validation loss')
plt.xlabel('Epoch')
plt.ylabel('Loss')
plt.legend()
plt.show()
```




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

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

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

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

```
313/313 [==============================] - 3s 8ms/step
```





VGG19Model Code and Output:

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

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

%matplotlib inline
```

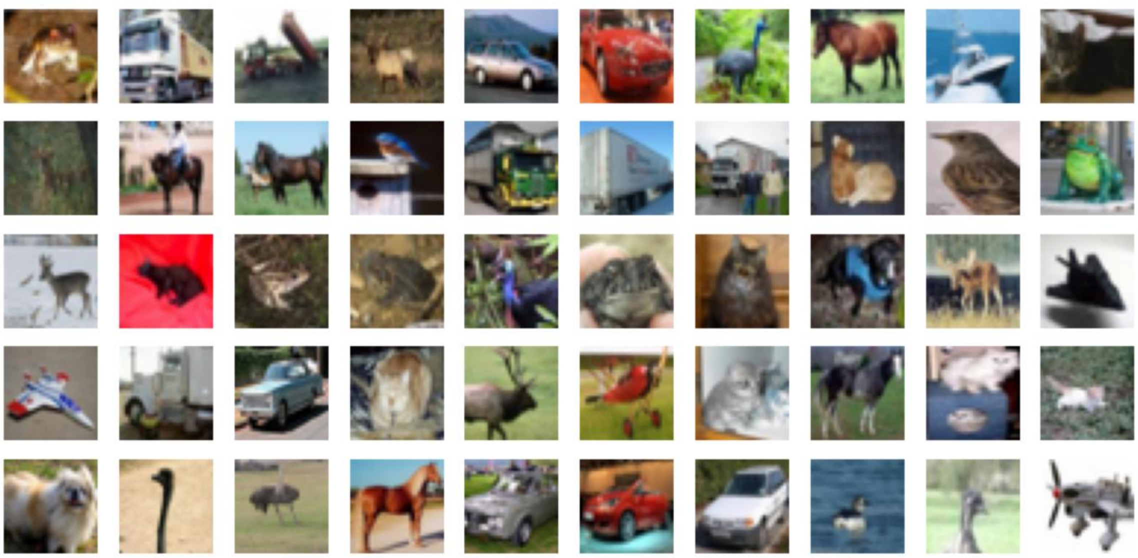
Extract data and train and test dataset

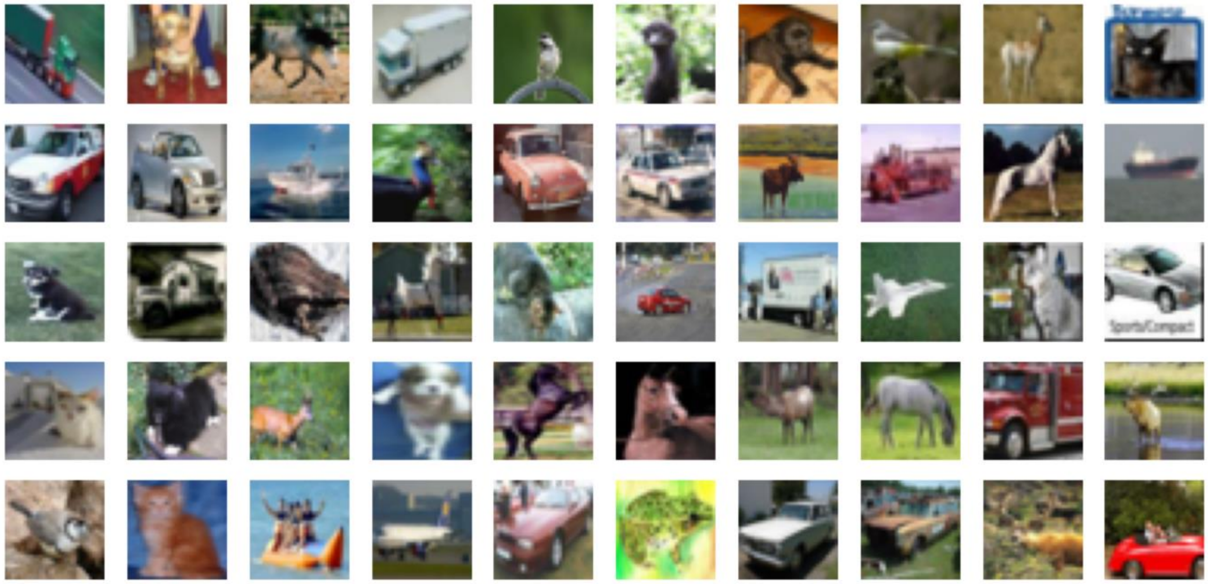
```
cifar100 = tf.keras.datasets.cifar100
(X_train,Y_train) , (X_test,Y_test) = cifar10.load_data()
```

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

Let's look into the dataset images

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





Training , Validating and Splitting trained and tested data

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

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

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

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

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

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

```
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

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

vgg_model.summary()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/vgg19/vgg19_weights_tf_dim_ordering_tf_kernels_notop.h5
80142336/80134624 [==============================] - 1s 0us/step
Model: "vgg19"
_________________________________________________________________
Layer (type)                Output Shape              Param #
=================================================================
input_1 (InputLayer)        [(None, 32, 32, 3)]       0

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

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

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

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

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

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

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

```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 = 'relu'))
model.add(Dense(10, activation = 'softmax'))

model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
vgg19 (Functional)           (None, 1, 1, 512)         20024384  
_________________________________________________________________
flatten (Flatten)            (None, 512)               0         
_________________________________________________________________
dense (Dense)                (None, 1024)              525312    
_________________________________________________________________
dense_1 (Dense)              (None, 1024)              1049600   
_________________________________________________________________
dense_2 (Dense)              (None, 256)               262400    
_________________________________________________________________
dense_3 (Dense)              (None, 10)                2570      
=================================================================
Total params: 21,864,266
Trainable params: 21,864,266
Non-trainable params: 0
```

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

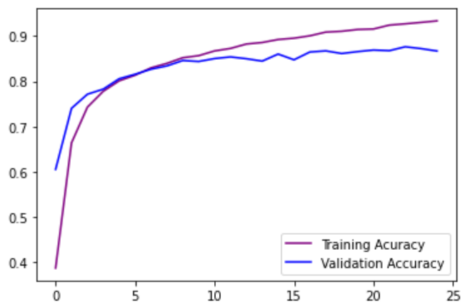
```
history = model.fit(
    train_datagen.flow(x_train, y_train, batch_size = 128),
    validation_data = val_datagen.flow(x_val,y_val, batch_size = 128),
    epochs = 25,
    verbose = 1,
    callbacks = [learning_rate_reduction]
)
```

```
Epoch 1/25
313/313 [==============================] - 84s 165ms/step - loss: 1.6671 - accuracy: 0.3875 - val_loss: 1.1241 - val_accuracy: 0.6056
Epoch 2/25
313/313 [==============================] - 50s 159ms/step - loss: 0.9631 - accuracy: 0.6640 - val_loss: 0.7466 - val_accuracy: 0.7404
Epoch 3/25
313/313 [==============================] - 50s 160ms/step - loss: 0.7464 - accuracy: 0.7430 - val_loss: 0.6792 - val_accuracy: 0.7716
```

```
Epoch 24/25
313/313 [==============================] - 50s 159ms/step - loss: 0.1964 - accuracy: 0.9304 - val_loss: 0.4461 - val_accuracy: 0.8724
Epoch 25/25
313/313 [==============================] - 50s 159ms/step - loss: 0.1879 - accuracy: 0.9337 - val_loss: 0.4827 - val_accuracy: 0.8671
```

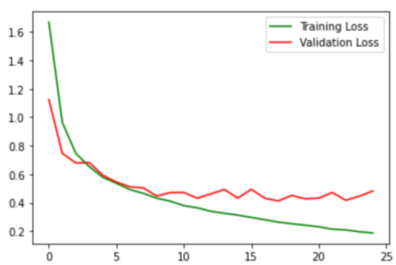
```
acc = history.history['accuracy']
val_acc = history.history['val_accuracy']

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 0x7fc5601fe610>
```




```
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 0x7fc5bd878ad0>
```




```
x_test = tf.keras.applications.vgg19.preprocess_input(X_test)
y_pred = model.predict_classes(x_test)
y_pred[:10]
```

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

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

```
Testing Accuarcy :  0.8591
```

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

```
array([[882,  11,  20,   1,  12,   1,   5,   9,  43,  16],
       [  5, 944,   0,   2,   0,   1,   2,   0,   8,  38],
       [ 22,   3, 800,  11,  54,  30,  56,   9,  10,   5],
       [ 10,   7,  42, 536,  57, 228,  74,  26,   6,  14],
       [  6,   1,  22,   5, 884,  20,  35,  23,   2,   2],
       [  5,   4,   9,  54,  36, 845,  19,  26,   0,   2],
       [  5,   1,  11,   7,  16,  10, 941,   3,   3,   3],
       [  4,   1,  12,   7,  31,  28,   8, 902,   2,   5],
       [ 25,  16,   1,   1,   4,   0,   4,   1, 929,  19],
       [  6,  41,   1,   2,   4,   0,   6,   2,  10, 928]])
```

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

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

    #print(cm)

    thresh = cm.max() / 2.
    for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):
        plt.text(j, i, cm[i, j],
```

```
             horizontalalignment="center",
             color="white" if cm[i, j] > thresh else "black")

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

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

```
Confusion matrix, without normalization
```