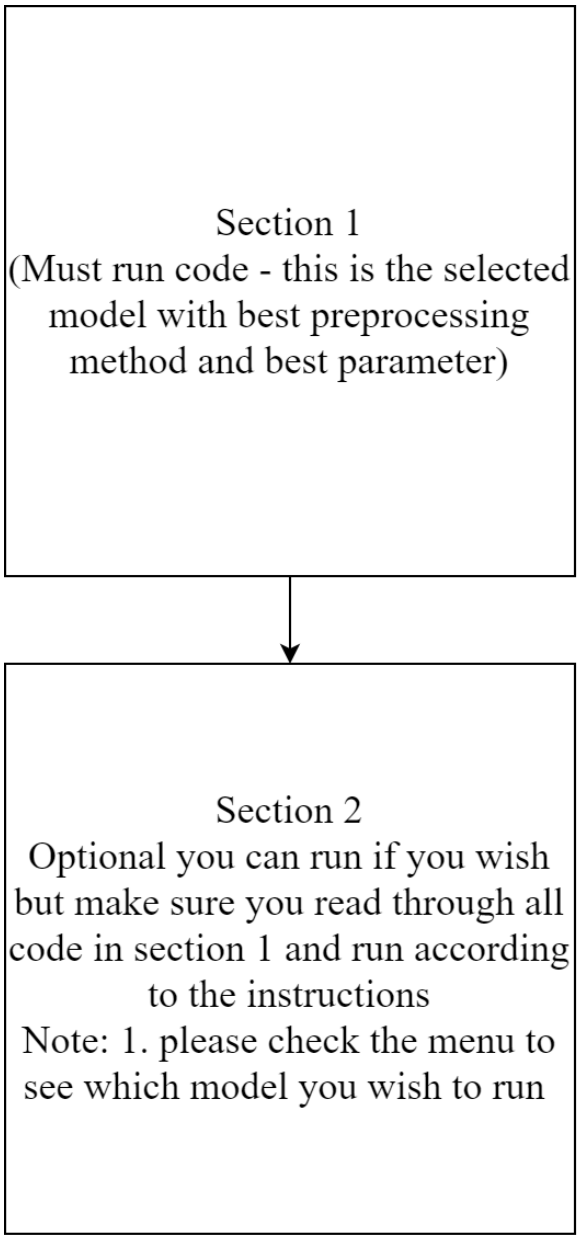
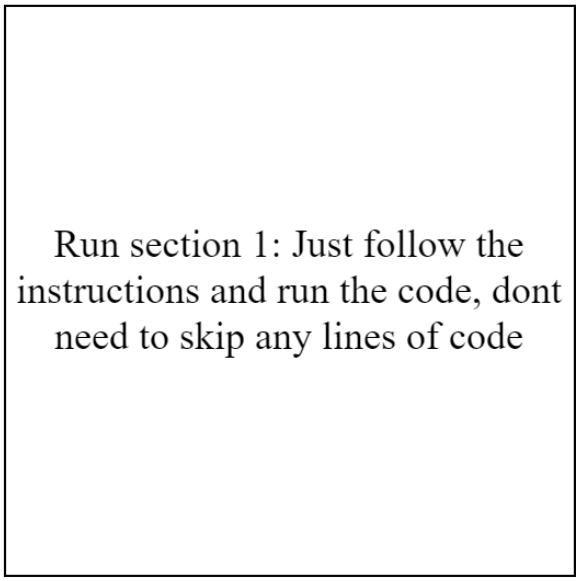


How to run for CNN, LR and SVM ipnyb file



How to run for Data Exploration ipnyb file

SECTION 1

IMPORT LIBRARIES

```
#libraries

from keras.datasets import cifar100
import matplotlib.pyplot as plt
```

```
import numpy as np
from keras.models import Sequential
from keras.layers.convolutional import Conv2D
from keras.layers.pooling import MaxPool2D
from keras.layers.core import Dense,Activation,Dropout,Flatten
from keras.utils import np_utils
from keras.preprocessing.image import ImageDataGenerator
import tensorflow as tf
from tensorflow.keras import datasets, layers, models, optimizers
import keras
from numpy import load
from numpy import asarray
from numpy import save
from tensorflow.keras.optimizers import RMSprop
import numpy as np
from numpy import mean
from sklearn.metrics import accuracy_score
from sklearn.metrics import confusion_matrix
import seaborn as sn
from keras.models import load_model
from sklearn.metrics import roc_curve, roc_auc_score
import matplotlib.pyplot as plt
```

SELECTED MODEL AND PREPROCESSING METHOD

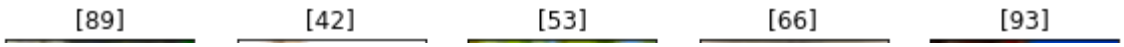
```
# Download dataset of CIFAR-100
(x_train,y_train),(x_test,y_test) = cifar100.load_data()

#print shape of the dataset
print('x_train shape:', x_train.shape)
print('x_test shape:', x_test.shape)
print('y_train shape:', y_train.shape)
print('y_test shape:', y_test.shape)

# print number of data set samples
print(x_train.shape[0], 'train set')
print(x_test.shape[0], 'test set')

# Data type for train and test set
print(type(x_test))
print(type(y_test[0]))
```

```
x_train shape: (50000, 32, 32, 3)
x_test shape: (10000, 32, 32, 3)
y_train shape: (50000, 1)
y_test shape: (10000, 1)
```

```
50000 train set
10000 test set
<class 'numpy.ndarray'>
<class 'numpy.ndarray'>
```

```
# Show sample random image 5x5
plt.figure(figsize=(10,10))
for i in range(25):
    rand_num=np.random.randint(0,100)
    cifar_image=plt.subplot(5,5,i+1)
    plt.imshow(x_train[rand_num])
    # Erase the value of x tick and y tick
    plt.xticks(color="None")
    plt.yticks(color="None")
    # remove the tick x-axis and y-axis
    plt.tick_params(length=0)
    # print label
    plt.title(y_train[rand_num])

plt.show()
```

```
C:\ProgramData\Anaconda3\lib\site-packages\matplotlib\text.py:1165: FutureWarning:
  if s != self._text:
```




```
%%time
#flipping image
#preprocess test dataset

Datagenerator = ImageDataGenerator()

x_train1 = Datagenerator.apply_transform(x=x_train, transform_parameters={'flip_horizontal':T
x_test1 = Datagenerator.apply_transform(x=x_test, transform_parameters={'flip_horizontal':Tru

#add back to original input image
x_train = np.concatenate((x_train,x_train1))
x_test = np.concatenate((x_test,x_test1))
#append the label twice because the fiiped images is the same images just being flipped, it h
y_train = np.concatenate((y_train,y_train))
y_test = np.concatenate((y_test,y_test))
```

```
Wall time: 192 ms
```

```
%%time
# Normalize taining and test set image to the range of 0-1
x_train = x_train.astype('float32')/255.0
x_test = x_test.astype('float32')/255.0

# convert the labels of y_train,y_test to One-Hot encoding
y_train = np_utils.to_categorical(y_train,100)
y_test = np_utils.to_categorical(y_test,100)
```

```
Wall time: 17.6 s
```

```
#split train into train and validation and keep test dataset as it is
from sklearn.model_selection import train_test_split
x_train, x_valid, y_train , y_valid = train_test_split(x_train, y_train,
                                                       train_size=0.70,
                                                       random_state=42,
                                                       stratify=y_train)
```

Do not run the following 2 cells, this is just evidence that we have run the cnn model befor eand extracted the features

```
# %%time
```

```
# intermediate_layer_model = keras.Model(model.input, model.get_layer(index = 10).output )

# intermediate_output_train = intermediate_layer_model.predict(x_train)
# intermediate_output_valid = intermediate_layer_model.predict(x_valid)
# intermediate_output_test = intermediate_layer_model.predict(x_test)

# %%time
# # save numpy array as npy file
# save('intermediate_output_train10.npy', intermediate_output_train)
# save('intermediate_output_valid10.npy', intermediate_output_valid)
# save('intermediate_output_test10.npy', intermediate_output_test)
```

Now we are using features as input for predicting image class i have submit together numpy array file .npy that consist of the features extracted from the cnn layers, there should be 3 .npy for you to run it consists of the features for train, valid and test set. alternatively you can import using collab if you are having trouble import using the following code using collab then run section [ctrl=F] search for this section - > "#ELU 10 epoch" at bottom of this ipnyb file it will run the cnn model again and will save the cnn feature in a .npy file

if you are importing using collab

```
# #https://drive.google.com/file/d/15ErTpnFRHNaQxc1k2t6UIfPv9FPj6Wlc/view?usp=sharing

# # Code to download file into Colaboratory:
# !pip install -U -q PyDrive
# from pydrive.auth import GoogleAuth
# from pydrive.drive import GoogleDrive
# from google.colab import auth
# from oauth2client.client import GoogleCredentials
# # Authenticate and create the PyDrive client.
# auth.authenticate_user()
# gauth = GoogleAuth()
# gauth.credentials = GoogleCredentials.get_application_default()
# drive = GoogleDrive(gauth)

# id = '15ErTpnFRHNaQxc1k2t6UIfPv9FPj6Wlc'
# downloaded = drive.CreateFile({'id':id})
# downloaded.GetContentFile('intermediate_output_train10.npy')
```

if you are importing using collab

```
# #https://drive.google.com/file/d/14u9i4YovLjBhg0V7iXJMDxru-K1cdbs4/view?usp=sharing

# # Code to download file into Colaboratory:
```

```
# !pip install -U -q PyDrive
# from pydrive.auth import GoogleAuth
# from pydrive.drive import GoogleDrive
# from google.colab import auth
# from oauth2client.client import GoogleCredentials
# # Authenticate and create the PyDrive client.
# auth.authenticate_user()
# # gauth = GoogleAuth()
# gauth.credentials = GoogleCredentials.get_application_default()
# drive = GoogleDrive(gauth)

# id = '14u9i4YovLjBhg0V7iXJMDxru-K1cdbs4'
# downloaded = drive.CreateFile({'id':id})
# downloaded.GetContentFile('intermediate_output_valid10.npy')
```

if you are importing using collab

```
# #https://drive.google.com/file/d/13xadJZ3cb85rmR6nEWhix8dhj9F0EHQB/view?usp=sharing

# # Code to download file into Colaboratory:
# !pip install -U -q PyDrive
# from pydrive.auth import GoogleAuth
# from pydrive.drive import GoogleDrive
# from google.colab import auth
# from oauth2client.client import GoogleCredentials
# # Authenticate and create the PyDrive client.
# auth.authenticate_user()
# gauth = GoogleAuth()
# gauth.credentials = GoogleCredentials.get_application_default()
# drive = GoogleDrive(gauth)

# id = '13xadJZ3cb85rmR6nEWhix8dhj9F0EHQB'
# downloaded = drive.CreateFile({'id':id})
# downloaded.GetContentFile('intermediate_output_test10.npy')
```

use this if you are running on jupyter locate to the file the npy that you have saved there should be 3 - 1 for training 1 for validation 1 for testing

```
%%time
# load array of the features - because for our final model - if we use feature extraction it
intermediate_output_train = load('intermediate_output_train10.npy')
intermediate_output_valid = load('intermediate_output_valid10.npy')
intermediate_output_test = load('intermediate_output_test10.npy')
```

```
Wall time: 1.45 s
```

```
%%time
# Create Convolution neural network (this cnn network is with Dropout)
model = Sequential()

#1st convolutional layer
model.add(Conv2D(32,(3,3),padding='same',input_shape=(8,8,64)))
model.add(Activation('elu'))
model.add(Conv2D(32,(3,3),padding='same'))
model.add(Activation('elu'))
model.add(MaxPool2D(pool_size=(2,2)))
model.add(Dropout(0.25))

#2nd convolutional layer
model.add(Conv2D(64,(3,3),padding='same'))
model.add(Activation('elu'))
model.add(Conv2D(64,(3,3),padding='same'))
model.add(Activation('elu'))
model.add(MaxPool2D(pool_size=(2,2)))
model.add(Dropout(0.25))

#dense layer
model.add(Flatten())
model.add(Dense(512))
model.add(Activation('elu'))
model.add(Dropout(0.5))
model.add(Dense(100,activation='softmax'))


#use adam optimiser
model.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])

model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_8 (Conv2D)            (None, 8, 8, 32)          18464
_________________________________________________________________
activation_10 (Activation)   (None, 8, 8, 32)          0
_________________________________________________________________
conv2d_9 (Conv2D)            (None, 8, 8, 32)          9248
_________________________________________________________________
activation_11 (Activation)   (None, 8, 8, 32)          0
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 4, 4, 32)          0
_________________________________________________________________
dropout_6 (Dropout)          (None, 4, 4, 32)          0
_________________________________________________________________
conv2d_10 (Conv2D)           (None, 4, 4, 64)          18496
_________________________________________________________________
activation_12 (Activation)   (None, 4, 4, 64)          0
```

```
_________________________________________________________________
conv2d_11 (Conv2D)           (None, 4, 4, 64)          36928     
_________________________________________________________________
activation_13 (Activation)   (None, 4, 4, 64)          0         
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 2, 2, 64)          0         
_________________________________________________________________
dropout_7 (Dropout)          (None, 2, 2, 64)          0         
_________________________________________________________________
flatten_2 (Flatten)          (None, 256)               0         
_________________________________________________________________
dense_4 (Dense)              (None, 512)               131584    
_________________________________________________________________
activation_14 (Activation)   (None, 512)               0         
_________________________________________________________________
dropout_8 (Dropout)          (None, 512)               0         
_________________________________________________________________
dense_5 (Dense)              (None, 100)               51300     
=================================================================
Total params: 266,020
Trainable params: 266,020
Non-trainable params: 0
_________________________________________________________________
Wall time: 69.7 ms
```

Here training begins

```
%%time
# Train the model
epochs = 20 #here we run 20 epoch because the best model is run using 20 epochs
num_predictions = 20
batchsize = 128

for i in range(epochs):
  print("Epoch {}/{}".format(i+1, epochs))

  model.fit(intermediate_output_train, y_train,
            batch_size=batchsize,
            epochs=1,
            validation_data=(intermediate_output_valid, y_valid),
            shuffle=True)


json_string = model.to_json()
open('group32_pretrained_model.json',"w").write(json_string)

# export model weight to a h5 file
model.save_weights('group32_pretrained_model_weights.h5')


model.save('group32_pretrained_model.h5')
```

```
Epoch 1/20
547/547 [==============================] - 53s 97ms/step - loss: 3.4274 - accuracy: 0.1
Epoch 2/20
547/547 [==============================] - 56s 102ms/step - loss: 2.8368 - accuracy: 0.
Epoch 3/20
547/547 [==============================] - 54s 99ms/step - loss: 2.6575 - accuracy: 0.3
Epoch 4/20
547/547 [==============================] - 55s 100ms/step - loss: 2.5514 - accuracy: 0.
Epoch 5/20
547/547 [==============================] - 57s 103ms/step - loss: 2.4808 - accuracy: 0.
Epoch 6/20
547/547 [==============================] - 51s 92ms/step - loss: 2.4165 - accuracy: 0.3
Epoch 7/20
547/547 [==============================] - 51s 93ms/step - loss: 2.3742 - accuracy: 0.3
Epoch 8/20
547/547 [==============================] - 50s 91ms/step - loss: 2.3381 - accuracy: 0.3
Epoch 9/20
547/547 [==============================] - 51s 93ms/step - loss: 2.3016 - accuracy: 0.3
Epoch 10/20
547/547 [==============================] - 56s 102ms/step - loss: 2.2810 - accuracy: 0.
Epoch 11/20
547/547 [==============================] - 54s 99ms/step - loss: 2.2530 - accuracy: 0.3
Epoch 12/20
547/547 [==============================] - 52s 95ms/step - loss: 2.2293 - accuracy: 0.4
Epoch 13/20
547/547 [==============================] - 51s 94ms/step - loss: 2.2061 - accuracy: 0.4
Epoch 14/20
547/547 [==============================] - 52s 95ms/step - loss: 2.1873 - accuracy: 0.4
Epoch 15/20
547/547 [==============================] - 54s 98ms/step - loss: 2.1742 - accuracy: 0.4
Epoch 16/20
547/547 [==============================] - 51s 94ms/step - loss: 2.1664 - accuracy: 0.4
Epoch 17/20
547/547 [==============================] - 50s 92ms/step - loss: 2.1480 - accuracy: 0.4
Epoch 18/20
547/547 [==============================] - 50s 92ms/step - loss: 2.1269 - accuracy: 0.4
Epoch 19/20
547/547 [==============================] - 51s 93ms/step - loss: 2.1156 - accuracy: 0.4
Epoch 20/20
547/547 [==============================] - 51s 93ms/step - loss: 2.0993 - accuracy: 0.4
Wall time: 17min 32s
```

```
# Evaluate the Model
evaluate = model.evaluate(intermediate_output_test, y_test, verbose=1)
print("Model Accuracy: {}".format(evaluate[1]))
```

```
625/625 [==============================] - 7s 11ms/step - loss: 2.0775 - accuracy: 0.43
Model Accuracy: 0.4364500045776367
```

```
# Evaluate the Model
evaluate = model.evaluate(intermediate_output_valid, y_valid, verbose=1)
```

```
print("Model Accuracy: {}".format(evaluate[1]))
```

```
938/938 [==============================] - 10s 10ms/step - loss: 2.0401 - accuracy: 0.4
Model Accuracy: 0.4474666714668274
```

cross validation

uncomment only if you want to run cross validation

```
# %%time
# from sklearn.model_selection import StratifiedKFold

# # define 10-fold cross validation test harness
# seed = 7
# kfold = StratifiedKFold(n_splits=10, shuffle=True, random_state=seed)
# cross_validation_scores = []

# # implement k-folds
# for train, test in kfold.split(x_train, np.array([np.argmax(x) for x in y_train])):

#   ################
#   # Create Model#
#   ################
#   model = Sequential()

#   # layer 1
#   model.add(Conv2D(32,(3,3),padding='same',input_shape=(8,8,64)))
#   model.add(Activation('elu'))
#   model.add(Conv2D(32,(3,3),padding='same'))
#   model.add(Activation('elu'))
#   model.add(MaxPool2D(pool_size=(2,2)))
#   model.add(Dropout(0.25))

#   # Layer 2
#   model.add(Conv2D(64,(3,3),padding='same'))
#   model.add(Activation('elu'))
#   model.add(Conv2D(64,(3,3),padding='same'))
#   model.add(Activation('elu'))
#   model.add(MaxPool2D(pool_size=(2,2)))
#   model.add(Dropout(0.25))

# #   # Convolutional Layer 3
# #   model.add(Conv2D(512, (3, 3), padding='same'))
# #   # Batch Normalization
# #   model.add(BatchNormalization())
# #   model.add(Activation('elu'))
# #   model.add(Conv2D(512, (3, 3)))
```

```
    # #   model.add(Activation('elu'))
    # #   model.add(MaxPooling2D(pool_size=(2, 2)))
    # #   model.add(Dropout(0.25))

    #   # Dense Layer
    # #   model.add(Flatten())
    # #   model.add(Dense(1024))
    # #   # Batch Normalization
    # #   model.add(BatchNormalization())
    # #   model.add(Activation('elu'))
    # #   model.add(Dropout(0.5))
    # #   model.add(Dense(num_classes))
    # #   model.add(Activation('softmax'))
    #   model.add(Flatten())
    #   model.add(Dense(512))
    #   model.add(Activation('elu'))
    #   model.add(Dropout(0.5))
    #   model.add(Dense(100,activation='softmax'))



    #   # Let's train the model using ADAM
    #   model.compile(loss='categorical_crossentropy',
    #                 optimizer='adam',
    #                 metrics=['accuracy'])


    #   # fit Model  #


    #   # Train the model
    #   epochs = 20
    #   num_predictions = 20
    #   batchsize = 128

    #   for i in range(epochs):
    #     print("Epoch {}/{}".format(i+1, epochs))

    #     model.fit(intermediate_output_train, y_train,
    #               batch_size=batchsize,
    #               epochs=1,
    #               validation_data=(intermediate_output_valid, y_valid),
    #               shuffle=True)


    #   #####EVALUATION#####

    #   # Evaluate the Model
    #   score = model.evaluate(intermediate_output_test, y_test, verbose=0)
    #   print("Model Accuracy: {}".format(score[1]))
    #   cross_validation_scores.append(score[1])
```

```
# # print the average score
# print(np.mean(np.array(cross_validation_scores)))
```

```
Epoch 1/20
547/547 [==============================] - 17s 29ms/step - loss: 3.4275 - accuracy: 0
Epoch 2/20
547/547 [==============================] - 27s 29ms/step - loss: 2.8439 - accuracy: 0
Epoch 3/20
547/547 [==============================] - 27s 29ms/step - loss: 2.6567 - accuracy: 0
Epoch 4/20
547/547 [==============================] - 27s 29ms/step - loss: 2.5432 - accuracy: 0
Epoch 5/20
547/547 [==============================] - 27s 29ms/step - loss: 2.4722 - accuracy: 0
Epoch 6/20
547/547 [==============================] - 27s 29ms/step - loss: 2.4181 - accuracy: 0
Epoch 7/20
547/547 [==============================] - 27s 29ms/step - loss: 2.3661 - accuracy: 0
Epoch 8/20
547/547 [==============================] - 27s 29ms/step - loss: 2.3353 - accuracy: 0
Epoch 9/20
547/547 [==============================] - 27s 28ms/step - loss: 2.3033 - accuracy: 0
Epoch 10/20
547/547 [==============================] - 27s 29ms/step - loss: 2.2734 - accuracy: 0
Epoch 11/20
547/547 [==============================] - 27s 28ms/step - loss: 2.2531 - accuracy: 0
Epoch 12/20
547/547 [==============================] - 27s 28ms/step - loss: 2.2223 - accuracy: 0
Epoch 13/20
547/547 [==============================] - 28s 31ms/step - loss: 2.2105 - accuracy: 0
Epoch 14/20
547/547 [==============================] - 27s 29ms/step - loss: 2.1930 - accuracy: 0
Epoch 15/20
547/547 [==============================] - 27s 28ms/step - loss: 2.1705 - accuracy: 0
Epoch 16/20
547/547 [==============================] - 27s 29ms/step - loss: 2.1584 - accuracy: 0
Epoch 17/20
547/547 [==============================] - 27s 28ms/step - loss: 2.1461 - accuracy: 0
Epoch 18/20
547/547 [==============================] - 27s 29ms/step - loss: 2.1318 - accuracy: 0
Epoch 19/20
547/547 [==============================] - 27s 29ms/step - loss: 2.1234 - accuracy: 0
Epoch 20/20
547/547 [==============================] - 28s 29ms/step - loss: 2.1048 - accuracy: 0
Model Accuracy: 0.43779999017715454
Epoch 1/20
547/547 [==============================] - 16s 29ms/step - loss: 3.4314 - accuracy: 0
Epoch 2/20
547/547 [==============================] - 27s 29ms/step - loss: 2.8428 - accuracy: 0
Epoch 3/20
547/547 [==============================] - 27s 28ms/step - loss: 2.6571 - accuracy: 0
```

```
Epoch 4/20
547/547 [==============================] - 27s 29ms/step - loss: 2.5527 - accuracy: 0
Epoch 5/20
547/547 [==============================] - 27s 28ms/step - loss: 2.4764 - accuracy: 0
Epoch 6/20
547/547 [==============================] - 28s 29ms/step - loss: 2.4174 - accuracy: 0
Epoch 7/20
547/547 [==============================] - 27s 28ms/step - loss: 2.3807 - accuracy: 0
Epoch 8/20
547/547 [==============================] - 27s 29ms/step - loss: 2.3421 - accuracy: 0
Epoch 9/20
```

```
# # CNN Cross validation Accuracy

# test_accuracy = np.mean(cross_validation_scores)
# print('average test_accuracy of cross-valiudation is {0:.4f}'.format(mean(test_accuracy)))
```

```
average test_accuracy of cross-valiudation is 0.4354
```

Here is the part for prediction

get test score result

if you choose to train the model do not uncomment the line that downloads the model, but if you wish to run form the model file then uncomment the line that import the model file

```
%%time
#model = load_model('group32_pretrained_model.h5')


y_test_pred = model.predict(intermediate_output_test)
y_test_pred=np.argmax(y_test_pred, axis=1)
y_test=np.argmax(y_test, axis=1) #if you having trouble running comment this line
print("accuracy on test set:")
print(accuracy_score(y_test, y_test_pred))
from sklearn.metrics import classification_report
print(classification_report(y_test, y_test_pred))
```

```
accuracy on test set:
0.43645
              precision    recall  f1-score   support

           0       0.73      0.66      0.69       200
           1       0.56      0.58      0.57       200
           2       0.33      0.33      0.33       200
           3       0.23      0.18      0.20       200
           4       0.15      0.39      0.22       200
           5       0.36      0.34      0.35       200
```

6	0.36	0.58	0.45	200
7	0.63	0.42	0.50	200
8	0.58	0.62	0.60	200
9	0.58	0.57	0.58	200
10	0.30	0.27	0.28	200
11	0.25	0.20	0.22	200
12	0.44	0.46	0.45	200
13	0.24	0.57	0.34	200
14	0.36	0.29	0.32	200
15	0.32	0.27	0.29	200
16	0.46	0.56	0.50	200
17	0.47	0.70	0.57	200
18	0.47	0.42	0.44	200
19	0.33	0.40	0.36	200
20	0.67	0.65	0.66	200
21	0.49	0.64	0.55	200
22	0.55	0.38	0.45	200
23	0.71	0.69	0.70	200
24	0.66	0.69	0.67	200
25	0.25	0.42	0.32	200
26	0.54	0.30	0.39	200
27	0.26	0.37	0.31	200
28	0.67	0.65	0.66	200
29	0.36	0.34	0.35	200
30	0.36	0.50	0.42	200
31	0.28	0.39	0.32	200
32	0.52	0.24	0.33	200
33	0.44	0.54	0.49	200
34	0.43	0.32	0.36	200
35	0.27	0.11	0.16	200
36	0.49	0.48	0.49	200
37	0.36	0.30	0.33	200
38	0.24	0.37	0.29	200
39	0.67	0.53	0.59	200
40	0.41	0.26	0.32	200
41	0.59	0.62	0.61	200
42	0.57	0.41	0.48	200
43	0.40	0.51	0.45	200
44	0.30	0.20	0.24	200
45	0.29	0.31	0.30	200
46	0.22	0.29	0.25	200
47	0.58	0.46	0.51	200
48	0.57	0.78	0.66	200
49	0.53	0.67	0.59	200
50	0.19	0.18	0.19	200
51	0.21	0.56	0.30	200
52	0.51	0.66	0.58	200
53	0.62	0.80	0.69	200
54	0.55	0.62	0.59	200

plot confusion matrix, look at data exploration ipnyb file if you want to understand more about the labels according to the indices, you can run cm[class_index] if you want to find out confusion matrix for a particular class

```
%%time
```

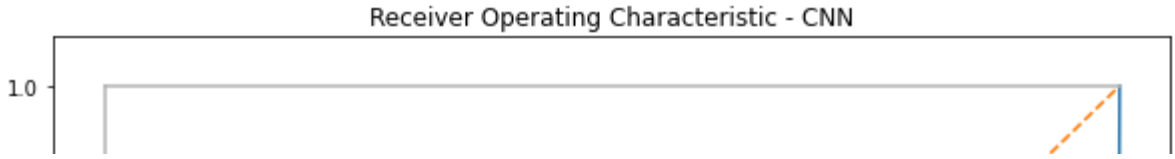
```
np.set_printoptions(threshold=np.inf)

cm = confusion_matrix(y_test, y_test_pred)
print(cm)
```

```
[[132   2   1   0   0   0   0   1   0   0   2   0   0   0   0   0   0   0
    0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0
    1   0   0   0   0   0   0   0   0   0   3   0   0   0   0   0   0  14
    4   0   0   9   0   0   0   1   1   0   0   0   0   0   0   0   7   0
    0   0   0   0   0   1   0   0   0   0   0  10   0   0   0   0   0   0
    0   2   8   0   0   0   0   0   0   0]
 [  0 117   0   0   0   0   1   0   0   0   1   0   0   1   0   0   0   0
    4   2   0   0   0   0   0   0   0   0   1   0   0   1   1   2   1   0
    0   0   0   0   0   0   0   0   0   3   0   0   1   0   0   7   0   6
    4   0   0   3   0   0   0   1   4   0   1   0   0   0   0   0   2   0
    0   3   2   0   0   1   0   0   1   0   2   1   2   0   1   0   0   3
    0   7   6   2   0   1   0   0   0   4]
 [  0   0  65   1   0   1   1   0   6   1   0  13   0   1   2   2   0   0
    0   3   0   1   0   0   0   5   1   0   0   0   0   0   3   0   0   3
    8   0   2   1   1   1   0   0   0   2  19   0   2   0   3   6   0   2
    4   0   0   3   0   0   0   1   0   0   1   1   0   0   0   0   0   0
    0   0   0   0   0   3   1   0   0   0   1   0   6   0   0   3   0   4
    0   0   2   0   2   0   0   1   8   3]
 [  0   0   0  36  32   0   2   0   0   0   0   0   0   0   0   1   0   1
    0  13   0  18   0   0   0   1   0   0   0   2   0  18   0   1   1   0
    5   1   0   0   0   0   1   6   0   0   1   0   0   0   3   7   0   0
    0   2   2   0   0   0   0   0   0   2   3   1   2   0   0   0   0   0
   11   0   5   9   3   0   0   0   4   0   0   1   0   0   0   0   0   0
    2   0   0   0   0   1   0   2   0   0]
 [  0   0   0   6  78   0   0   0   0   0   0   0   0   1   0   1   1   0
    0   2   0   3   1   0   0   0   3  14   1   0   2   3   0   1   2   1
    0   0   4   0   1   0   1   6   0   1   2   0   0   0   7  11   0   0
    0   1   0   0   0   0   0   0   0   7   2   0   3   0   0   0   0   0
    3   0   3   1   0   6   1   0   1   0   0   0   0   0   1   0   6   3
    1   1   0   1   0   2   0   1   3   0]
 [  0   2   2   0   1  67   2   0   1   1   1   0   2   3   0   0   4   0
    0   1   8   0   0   0   0  39   0   0   0   0   0   0   0   1   0   0
    0   1   0   2   2   0   0   0   0   2   2   0   0   2   0   0   0   1
    1   0   0   1   2   0   3   0   0   0   0   0   0   0   1   0   0   0
    0   0   0   0   0   0   0   0   0   2   0   0  28   0   1   2   0   0
    0   3   0   2   5   0   0   0   0   2]
 [  0   0   0   1   2   0 116   7   0   0   0   0   0   0   6   1   1   0
    2   0   1   0   0   0   3   0   0   0   0   3   0   1   0   0   0   0
    0   0   1   0   0   1   2   8   0   7   0   1   1   0   3   1   0   0
    4   0   2   0   0   1   0   0   1   0   0   0   0   0   0   0   0   0
    0   0   0   0   0   0   1   4   2   0   9   0   0   0   0   0   2   5
    0   0   0   0   0   0   0   0   0   0]
 [  0   0   2   0   2   0   9  84   2   1   0   0   0   1  13   0   0   0
    7   0   0   0   0   0  22   0   3   1   0   1   0   0   0   0   0   0
    0   0   0   0   1   9   0   0   1   1   1   0   1   0   0   0   0   0
    2   0   0   1   1   2   0   0   0   0   0   0   0   0   1   0   1   0
    2   0   3   0   0   1   6  11   0   0   0   4   0   0   0   0   0   1
    1   0   0   1   0   0   0   0   0   0]
 [  0   0   0   0   1   3   1   2 124   0   0   2   1   1   0   0   0   0
```

```
  1   1   2   0   1   0   0   2   0   2   0   0   0   0   0   2   0   0
  0   1   2   3   0   5   0   0   0   5   1   0  14   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   1   2   0   1   0   0   1   6   0   0   1   9
  0   0   1   0   0   0   0   1   0   0]
[ 1   0   1   0   0   2   0   0   0 115   0   2   2   1   0   0  11   2
  1   0   2   2   0   0   0   2   0   0   7   2   0   3   1   0   0   0
  0   0   0   0   3   0   0   0   1   2   1   0   0   0   0   0   0   0
  2   0   0   1   0   0   0   0   0   0   0   0   0   0   0   5   0   0
  0   0   0   0   0   0   0   0   0   0   0   4   7   2   3   0   0   1
```

plot ROC curve

```
#y_score1 = clf_tree.predict_proba(X_test)[:,1]
#y_score2 = model.predict(x_test)[:,1]

#false_positive_rate1, true_positive_rate1, threshold1 = roc_curve(y_test, y_score1)
false_positive_rate2, true_positive_rate2, threshold2 = roc_curve(y_test, y_test_pred, pos_la


plt.subplots(1, figsize=(10,10))
plt.title('Receiver Operating Characteristic - CNN')
plt.plot(false_positive_rate2, true_positive_rate2)
plt.plot([0, 1], ls="--")
plt.plot([0, 0], [1, 0] , c=".7"), plt.plot([1, 1] , c=".7")
plt.ylabel('True Positive Rate')
plt.xlabel('False Positive Rate')
plt.show()
```



SECTION 2 Evidences of hyperparameter tuning and testing on different preprocessing method. If you want to run this section be sure that you have run the above code - from loading data to preprocessing the data and convert labels to one hot encoding

MENU OF WHAT IS UNDER SECTION 2 Hyperparameter tuning

1. SGD
2. ELU activation function
3. Changing to RMSProp optimiser (with momemtum)
4. RELU activation function and adam optimiser
5. ELU 10 epoch Testing with different preprocessing methods
6. Flipping image and add back to original image data and based on previous cnn model (best model parameter - ELU activation function , adam optimiser and with feature extraction) we export CNN model's intermediate layer and use that as the input layer and test on the accuracy
7. divide by 255 only
8. Just import data with no preprocessing
9. Feature extraction - Extract mean of all colour pixels (take all 3 colour value R,G,B and divide by 3)
10. Normalise divide by 255 and PCA
11. subsample 10 % of the training , validation and testing data and conduct CP reconstruction , tucker's reconstruction to compress image and compare with original data ands see whether there is improvements
12. use CNN as the model to evaluate performance of CP and tucker reconstruction, we will pick to use this method if only it increases the accuracy of the model
13. test on cpr
14. test on tucker decomposition
15. compare with original data

BELOW ARE ALL HYPERPARAMETER TUNING AND TEST ON DIFFERENT PREPROCESSING METHODS

All codes below serve as evidences but if you wish to run you can uncomment all codes under a section to run the code

SGD

```
# #libraries

# from keras.datasets import cifar100
# import matplotlib.pyplot as plt
# import numpy as np
# from keras.models import Sequential
# from keras.layers.convolutional import Conv2D
# from keras.layers.pooling import MaxPool2D
# from keras.layers.core import Dense,Activation,Dropout,Flatten
# from keras.utils import np_utils

# import tensorflow as tf
# from tensorflow.keras import datasets, layers, models, optimizers

# # Download dataset of CIFAR-100 (Canadian Institute for Advanced Research)
# (x_train,y_train),(x_test,y_test) = cifar100.load_data()

# #print shapre of training and test dataset
# print('x_train shape:', x_train.shape)
# print('x_test shape:', x_test.shape)
# print('y_train shape:', y_train.shape)
# print('y_test shape:', y_test.shape)

# # print number of data set samples
# print(x_train.shape[0], 'train set')
# print(x_test.shape[0], 'test set')

# # Data type for train and test set
# print(type(x_test))
# print(type(y_test[0]))
```

```
x_train shape: (50000, 32, 32, 3)
```

```
x_test shape: (10000, 32, 32, 3)
y_train shape: (50000, 1)
y_test shape: (10000, 1)
50000 train set
10000 test set
<class 'numpy.ndarray'>
<class 'numpy.ndarray'>
```

```
# # Show sample random image 5x5
# plt.figure(figsize=(10,10))
# for i in range(25):
#     rand_num=np.random.randint(0,100)
#     cifar_image=plt.subplot(5,5,i+1)
#     plt.imshow(x_train[rand_num])
#     # Erase the value of x tick and y tick
#     plt.xticks(color="None")
#     plt.yticks(color="None")
#     # remove the tick x-axis and y-axis
#     plt.tick_params(length=0)
#     # print label
#     plt.title(y_train[rand_num])

# plt.show()
```

```
C:\ProgramData\Anaconda3\lib\site-packages\matplotlib\text.py:1165: FutureWarning:
  if s != self._text:
```


```
# %%time
# #flipping image
# #preprocess test dataset
# from keras.preprocessing.image import ImageDataGenerator
# Datagenerator = ImageDataGenerator()

# x_train1 = Datagenerator.apply_transform(x=x_train, transform_parameters={'flip_horizontal'
# x_test1 = Datagenerator.apply_transform(x=x_test, transform_parameters={'flip_horizontal':T


# x_train = np.concatenate((x_train,x_train1))
# x_test = np.concatenate((x_test,x_test1))
# y_train = np.concatenate((y_train,y_train))
# y_test = np.concatenate((y_test,y_test))


    Wall time: 3.99 s
```

```
# %%time
# # Normalize taining and test set image to the range of 0-1
# x_train = x_train.astype('float32')/255.0
# x_test = x_test.astype('float32')/255.0

# # convert the labels of y_train,y_test to One-Hot encoding
# y_train = np_utils.to_categorical(y_train,100)
# y_test = np_utils.to_categorical(y_test,100)


    Wall time: 24.7 s


# from sklearn.model_selection import train_test_split
# x_train, x_valid, y_train , y_valid = train_test_split(x_train, y_train,
#                                                        train_size=0.70,
#                                                        random_state=42,
#                                                        stratify=y_train)


# %%time
# from tensorflow.keras.optimizers import RMSprop
# # Create Convolution neural network (CNN layer with Dropout)
# model = Sequential()
```

```
# model.add(Conv2D(32,(3,3),padding='same',input_shape=(32,32,3)))
# model.add(Activation('relu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))



# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('relu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))


# #use adam optimiser
# model.compile(optimizer='SGD',loss='categorical_crossentropy',metrics=['accuracy'])

# model.summary()
```

```
Model: "sequential_5"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_11 (Conv2D)           (None, 32, 32, 32)        896
_________________________________________________________________
activation_13 (Activation)   (None, 32, 32, 32)        0
_________________________________________________________________
conv2d_12 (Conv2D)           (None, 32, 32, 32)        9248
_________________________________________________________________
activation_14 (Activation)   (None, 32, 32, 32)        0
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 16, 16, 32)        0
_________________________________________________________________
dropout_6 (Dropout)          (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_13 (Conv2D)           (None, 16, 16, 64)        18496
_________________________________________________________________
activation_15 (Activation)   (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_14 (Conv2D)           (None, 16, 16, 64)        36928
_________________________________________________________________
activation_16 (Activation)   (None, 16, 16, 64)        0
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 8, 8, 64)          0
```

```
dropout_7 (Dropout)          (None, 8, 8, 64)          0
_________________________________________________________________
flatten_2 (Flatten)          (None, 4096)              0
_________________________________________________________________
dense_4 (Dense)              (None, 512)               2097664
_________________________________________________________________
activation_17 (Activation)   (None, 512)               0
_________________________________________________________________
dropout_8 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_5 (Dense)              (None, 100)               51300
=================================================================
Total params: 2,214,532
Trainable params: 2,214,532
Non-trainable params: 0
_________________________________________________________________
Wall time: 3.1 s
```

```
# %%time
# # Train the model
# epochs = 10
# num_predictions = 20
# batchsize = 128

# for i in range(epochs):
#   print("Epoch {}/{}".format(i+1, epochs))

#   model.fit(x_train, y_train,
#             batch_size=batchsize,
#             epochs=1,
#             validation_data=(x_valid, y_valid),
#             shuffle=True)


# json_string = model.to_json()
# open('cifar100_trial150epochfollowingseniorSGD.json',"w").write(json_string)

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn50epochfollowingseFsgd
niorSGD.h5')


# model.save('normalcnn50epochfollowingseniorSGD.h5')
```

```
Epoch 1/10
547/547 [==============================] - 1266s 2s/step - loss: 4.6049 - accuracy: 0.0
Epoch 2/10
547/547 [==============================] - 1295s 2s/step - loss: 4.5988 - accuracy: 0.0
Epoch 3/10
547/547 [==============================] - 1187s 2s/step - loss: 4.5560 - accuracy: 0.0
Epoch 4/10
547/547 [==============================] - 1064s 2s/step - loss: 4.4379 - accuracy: 0.0
Epoch 5/10
```

```
547/547 [==============================] - 1047s 2s/step - loss: 4.3498 - accuracy: 0.0
Epoch 6/10
547/547 [==============================] - 1008s 2s/step - loss: 4.2717 - accuracy: 0.0
Epoch 7/10
547/547 [==============================] - 1134s 2s/step - loss: 4.1843 - accuracy: 0.0
Epoch 8/10
547/547 [==============================] - 1250s 2s/step - loss: 4.1068 - accuracy: 0.0
Epoch 9/10
547/547 [==============================] - 1480s 3s/step - loss: 4.0371 - accuracy: 0.0
Epoch 10/10
547/547 [==============================] - 1431s 3s/step - loss: 3.9789 - accuracy: 0.0
Wall time: 3h 25min 37s
```

```
# # Evaluate the Model
# evaluate = model.evaluate(x_test, y_test, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
625/625 [==============================] - 157s 226ms/step - loss: 3.8223 - accuracy: 0
Model Accuracy: 0.12714999914169312
```

```
# # Evaluate the Model
# evaluate = model.evaluate(x_valid, y_valid, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
938/938 [==============================] - 203s 213ms/step - loss: 3.8139 - accuracy: 0
Model Accuracy: 0.12996666133403778
```

get test score result

```
# %%time
# from sklearn.metrics import accuracy_score
# y_test_pred = model.predict(x_test)
# y_test_pred=np.argmax(y_test_pred, axis=1)
# y_test=np.argmax(y_test, axis=1)
# print("accuracy on test set:")
# print(accuracy_score(y_test, y_test_pred))
# from sklearn.metrics import classification_report
# print(classification_report(y_test, y_test_pred))
```

```
accuracy on test set:
0.0168
C:\ProgramData\Anaconda3\lib\site-packages\sklearn\metrics\_classification.py:1245: U
  _warn_prf(average, modifier, msg_start, len(result))
              precision    recall  f1-score   support

           0       0.00      0.00      0.00       200
```

1	0.00	0.00	0.00	200
2	0.00	0.00	0.00	200
3	0.00	0.00	0.00	200
4	0.00	0.00	0.00	200
5	0.00	0.00	0.00	200
6	0.06	0.01	0.01	200
7	0.00	0.00	0.00	200
8	0.00	0.00	0.00	200
9	0.00	0.00	0.00	200
10	0.00	0.00	0.00	200
11	0.00	0.00	0.00	200
12	0.00	0.00	0.00	200
13	0.00	0.00	0.00	200
14	0.00	0.00	0.00	200
15	0.00	0.00	0.00	200
16	0.00	0.00	0.00	200
17	0.00	0.00	0.00	200
18	0.00	0.00	0.00	200
19	0.00	0.00	0.00	200
20	0.02	0.71	0.03	200
21	0.00	0.00	0.00	200
22	0.00	0.00	0.00	200
23	0.00	0.00	0.00	200
24	0.01	0.17	0.01	200
25	0.00	0.00	0.00	200
26	0.01	0.03	0.02	200
27	0.00	0.00	0.00	200
28	0.00	0.00	0.00	200
29	0.00	0.00	0.00	200
30	0.10	0.48	0.16	200
31	0.00	0.00	0.00	200
32	0.00	0.00	0.00	200
33	0.00	0.00	0.00	200
34	0.03	0.03	0.03	200
35	0.00	0.00	0.00	200
36	0.00	0.00	0.00	200
37	0.00	0.00	0.00	200
38	0.00	0.00	0.00	200
39	0.01	0.01	0.01	200
40	0.00	0.00	0.00	200
41	0.01	0.04	0.01	200
42	0.00	0.00	0.00	200
43	0.00	0.00	0.00	200
44	0.00	0.00	0.00	200
45	0.00	0.00	0.00	200
46	0.00	0.00	0.00	200
47	0.00	0.00	0.00	200
48	0.00	0.00	0.00	200
49	0.00	0.00	0.00	200
50	0.00	0.00	0.00	200
51	0.00	0.00	0.00	200

plot confusion matrix

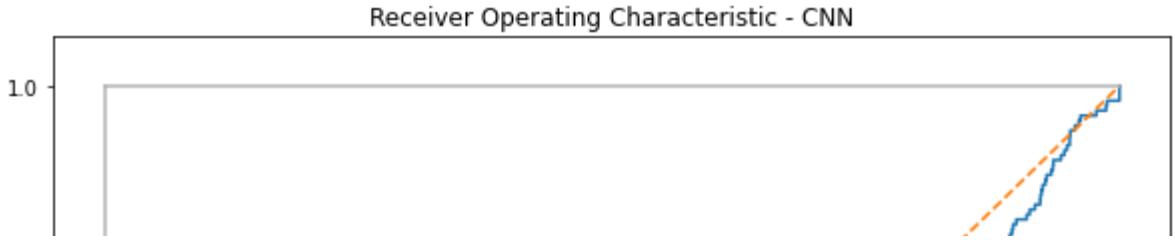
```
# from sklearn.metrics import confusion_matrix
```

```
# %%time

# cm = confusion_matrix(y_test, y_test_pred )
# print(cm)
```

```
[[0 0 1 ... 0 0 0]
 [0 0 0 ... 0 0 0]
 [0 1 0 ... 0 1 0]
 ...
 [0 0 1 ... 0 0 0]
 [0 0 1 ... 0 0 0]
 [0 0 1 ... 0 0 0]]
Wall time: 509 ms
```

plot graph

```
# from sklearn.metrics import roc_curve, roc_auc_score
# import matplotlib.pyplot as plt
# #y_score1 = clf_tree.predict_proba(X_test)[:,1]
# y_score2 = model.predict(x_test)[:,1]

# #false_positive_rate1, true_positive_rate1, threshold1 = roc_curve(y_test, y_score1)
# false_positive_rate2, true_positive_rate2, threshold2 = roc_curve(y_test, y_score2, pos_lab


# plt.subplots(1, figsize=(10,10))
# plt.title('Receiver Operating Characteristic - CNN')
# plt.plot(false_positive_rate2, true_positive_rate2)
# plt.plot([0, 1], ls="--")
# plt.plot([0, 0], [1, 0] , c=".7"), plt.plot([1, 1] , c=".7")
# plt.ylabel('True Positive Rate')
# plt.xlabel('False Positive Rate')
# plt.show()
```



ELU activation function

```
# %%time
# from tensorflow.keras.optimizers import RMSprop
# # Create Convolution neural network (CNN layer with Dropout)
# model = Sequential()

# model.add(Conv2D(32,(3,3),padding='same',input_shape=(32,32,3)))
# model.add(Activation('elu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))



# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('elu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))


# #use adam optimiser
# model.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])

# model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 32, 32, 32)        896
_________________________________________________________________
```

```
activation (Activation)      (None, 32, 32, 32)        0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 32, 32, 32)        9248
_________________________________________________________________
activation_1 (Activation)    (None, 32, 32, 32)        0
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 16, 16, 32)        0
_________________________________________________________________
dropout (Dropout)            (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 16, 16, 64)        18496
_________________________________________________________________
activation_2 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 16, 16, 64)        36928
_________________________________________________________________
activation_3 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 8, 8, 64)          0
_________________________________________________________________
dropout_1 (Dropout)          (None, 8, 8, 64)          0
_________________________________________________________________
flatten (Flatten)            (None, 4096)              0
_________________________________________________________________
dense (Dense)                (None, 512)               2097664
_________________________________________________________________
activation_4 (Activation)    (None, 512)               0
_________________________________________________________________
dropout_2 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_1 (Dense)              (None, 100)               51300
=================================================================
Total params: 2,214,532
Trainable params: 2,214,532
Non-trainable params: 0
_________________________________________________________________
Wall time: 1.76 s
```

```
# %%time
# # Train the model
# epochs = 10
# num_predictions = 20
# batchsize = 128

# for i in range(epochs):
#   print("Epoch {}/{}".format(i+1, epochs))

#   model.fit(x_train, y_train,
#             batch_size=batchsize,
#             epochs=1,
#             validation_data=(x_valid, y_valid),
#             shuffle=True)
```

```
# json_string = model.to_json()
# open('cifar100_trial150epochfollowingsenior.json',"w").write(json_string)

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn50epochfollowingsenior.h5')


# model.save('normalcnn50epochfollowingsenior.h5')
```

```
Epoch 1/10
547/547 [==============================] - 905s 2s/step - loss: 3.6546 - accuracy: 0.15
Epoch 2/10
547/547 [==============================] - 1266s 2s/step - loss: 2.9578 - accuracy: 0.2
Epoch 3/10
547/547 [==============================] - 1496s 3s/step - loss: 2.7237 - accuracy: 0.3
Epoch 4/10
547/547 [==============================] - 1343s 2s/step - loss: 2.5759 - accuracy: 0.3
Epoch 5/10
547/547 [==============================] - 1323s 2s/step - loss: 2.4589 - accuracy: 0.3
Epoch 6/10
547/547 [==============================] - 1156s 2s/step - loss: 2.3753 - accuracy: 0.3
Epoch 7/10
547/547 [==============================] - 1148s 2s/step - loss: 2.2911 - accuracy: 0.4
Epoch 8/10
547/547 [==============================] - 1140s 2s/step - loss: 2.2129 - accuracy: 0.4
Epoch 9/10
547/547 [==============================] - 1600s 3s/step - loss: 2.1514 - accuracy: 0.4
Epoch 10/10
547/547 [==============================] - 1620s 3s/step - loss: 2.0822 - accuracy: 0.4
Wall time: 3h 39min 34s
```

```
# # Evaluate the Model
# evaluate = model.evaluate(x_test, y_test, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
625/625 [==============================] - 152s 227ms/step - loss: 2.4059 - accuracy: 0
Model Accuracy: 0.3923499882221222
```

```
# # Evaluate the Model
# evaluate = model.evaluate(x_valid, y_valid, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
938/938 [==============================] - 166s 176ms/step - loss: 2.3339 - accuracy: 0
Model Accuracy: 0.4117000102996826
```

get test score result

```
# %%time
# from sklearn.metrics import accuracy_score
# y_test_pred = model.predict(x_test)
# y_test_pred=np.argmax(y_test_pred, axis=1)
# y_test=np.argmax(y_test, axis=1)
# print("accuracy on test set:")
# print(accuracy_score(y_test, y_test_pred))
# from sklearn.metrics import classification_report
# print(classification_report(y_test, y_test_pred))
```

```
accuracy on test set:
0.34445
              precision    recall  f1-score   support

           0       0.64      0.43      0.51       200
           1       0.37      0.60      0.46       200
           2       0.32      0.18      0.23       200
           3       0.21      0.12      0.15       200
           4       0.26      0.12      0.17       200
           5       0.30      0.40      0.34       200
           6       0.44      0.29      0.35       200
           7       0.38      0.33      0.35       200
           8       0.58      0.43      0.50       200
           9       0.56      0.51      0.53       200
          10       0.24      0.24      0.24       200
          11       0.29      0.14      0.19       200
          12       0.34      0.30      0.32       200
          13       0.29      0.25      0.27       200
          14       0.49      0.13      0.21       200
          15       0.26      0.06      0.10       200
          16       0.46      0.41      0.43       200
          17       0.31      0.60      0.41       200
          18       0.26      0.28      0.27       200
          19       0.23      0.09      0.12       200
          20       0.79      0.56      0.66       200
          21       0.31      0.60      0.41       200
          22       0.85      0.17      0.28       200
          23       0.27      0.81      0.40       200
          24       0.37      0.65      0.47       200
          25       0.29      0.21      0.24       200
          26       0.42      0.33      0.37       200
          27       0.19      0.38      0.25       200
          28       0.52      0.65      0.58       200
          29       0.30      0.21      0.25       200
          30       0.26      0.48      0.34       200
          31       0.18      0.39      0.25       200
          32       0.31      0.23      0.26       200
          33       0.29      0.49      0.36       200
          34       0.26      0.29      0.27       200
          35       0.19      0.09      0.12       200
          36       0.25      0.36      0.30       200
          37       0.22      0.32      0.26       200
          38       0.19      0.23      0.20       200
          39       0.53      0.24      0.33       200
          40       0.51      0.20      0.29       200
          41       0.67      0.46      0.54       200
```

```
42       0.44      0.41      0.42       200
43       0.28      0.56      0.37       200
44       0.27      0.10      0.14       200
45       0.23      0.19      0.21       200
46       0.32      0.15      0.21       200
47       0.66      0.29      0.41       200
48       0.61      0.67      0.63       200
49       0.39      0.43      0.41       200
50       0.00      0.00      0.00       200
51       0.40      0.22      0.28       200
52       0.44      0.66      0.53       200
53       0.49      0.61      0.54       200
54       0.52      0.56      0.53       200
```

plot confusion matrix

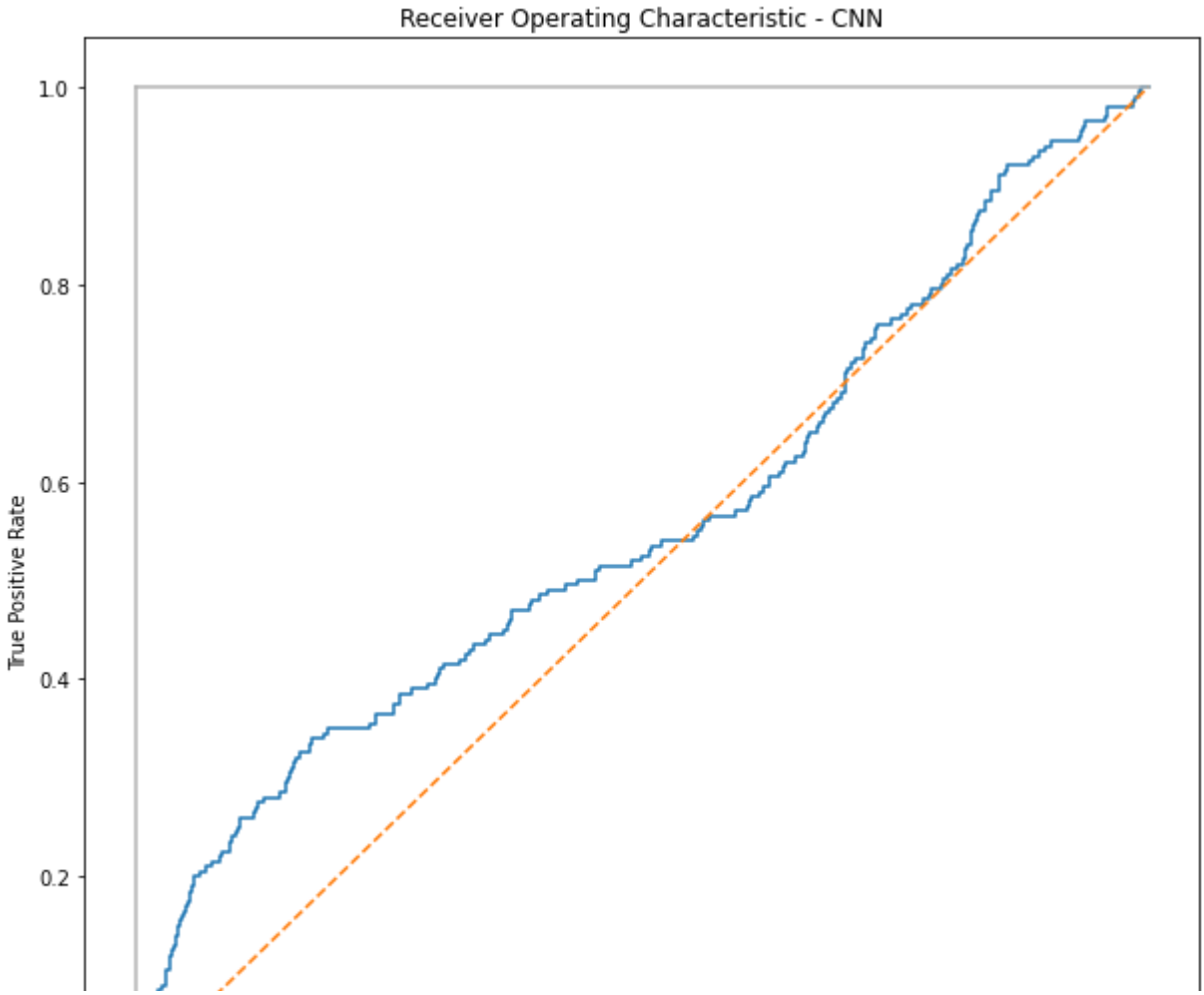
```
# from sklearn.metrics import confusion_matrix


# %%time

# cm = confusion_matrix(y_test, y_test_pred )
# print(cm)
```

```
[[ 86   8   0 ...   0   0   0]
 [  0 121   0 ...   1   0   1]
 [  0  13  36 ...   5   0   0]
 ...
 [  0   0   0 ... 105   1   0]
 [  1   1   8 ...   6  17   1]
 [  1   3   1 ...   0   0  28]]
Wall time: 909 ms
```

ROC curve

```
# from sklearn.metrics import roc_curve, roc_auc_score
# import matplotlib.pyplot as plt
# #y_score1 = clf_tree.predict_proba(X_test)[:,1]
# y_score2 = model.predict(x_test)[:,1]

# #false_positive_rate1, true_positive_rate1, threshold1 = roc_curve(y_test, y_score1)
# false_positive_rate2, true_positive_rate2, threshold2 = roc_curve(y_test, y_score2, pos_lab


# plt.subplots(1, figsize=(10,10))
# plt.title('Receiver Operating Characteristic - CNN')
# plt.plot(false_positive_rate2, true_positive_rate2)
# plt.plot([0, 1], ls="--")
# plt.plot([0, 0], [1, 0] , c=".7"), plt.plot([1, 1] , c=".7")
# plt.ylabel('True Positive Rate')
```

```
# plt.xlabel('False Positive Rate')
# plt.show()
```



Changing to RMSProp optimiser (with momemtum)

0.0 0.2 0.4 0.6 0.8 1.0

```
# %%time
# from tensorflow.keras.optimizers import RMSprop
# # Create Convolution neural network (CNN layer with Dropout)
# model = Sequential()

# model.add(Conv2D(32,(3,3),padding='same',input_shape=(32,32,3)))
# model.add(Activation('relu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
```

```
# model.add(Dropout(0.25))

# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('relu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))


# # initiate RMSprop optimizer
# opt = RMSprop(lr=0.0001, decay=1e-6)


# #use adam optimiser
# model.compile(optimizer=opt,loss='categorical_crossentropy',metrics=['accuracy'])

# model.summary()
```

```
Model: "sequential_16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_64 (Conv2D)           (None, 32, 32, 32)        896
_________________________________________________________________
activation_80 (Activation)   (None, 32, 32, 32)        0
_________________________________________________________________
conv2d_65 (Conv2D)           (None, 32, 32, 32)        9248
_________________________________________________________________
activation_81 (Activation)   (None, 32, 32, 32)        0
_________________________________________________________________
max_pooling2d_32 (MaxPooling (None, 16, 16, 32)        0
_________________________________________________________________
dropout_48 (Dropout)         (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_66 (Conv2D)           (None, 16, 16, 64)        18496
_________________________________________________________________
activation_82 (Activation)   (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_67 (Conv2D)           (None, 16, 16, 64)        36928
_________________________________________________________________
activation_83 (Activation)   (None, 16, 16, 64)        0
_________________________________________________________________
max_pooling2d_33 (MaxPooling (None, 8, 8, 64)          0
_________________________________________________________________
dropout_49 (Dropout)         (None, 8, 8, 64)          0
_________________________________________________________________
flatten_16 (Flatten)         (None, 4096)              0
_________________________________________________________________
dense_32 (Dense)             (None, 512)               2097664
_________________________________________________________________
activation_84 (Activation)   (None, 512)               0
_________________________________________________________________
dropout_50 (Dropout)         (None, 512)               0
_________________________________________________________________
```

```
dense_33 (Dense)             (None, 100)               51300
=================================================================
Total params: 2,214,532
Trainable params: 2,214,532
Non-trainable params: 0
_________________________________________________________________
Wall time: 98.2 ms
```

```
# %%time
# # Train the model
# epochs = 10
# num_predictions = 20
# batchsize = 128

# for i in range(epochs):
#   print("Epoch {}/{}".format(i+1, epochs))

#   model.fit(x_train, y_train,
#             batch_size=batchsize,
#             epochs=1,
#             validation_data=(x_valid, y_valid),
#             shuffle=True)


# json_string = model.to_json()
# open('cifar100_trial150epochfollowingsenior.json',"w").write(json_string)

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn50epochfollowingsenior.h5')


# model.save('normalcnn50epochfollowingsenior.h5')
```

```
Epoch 1/10
782/782 [==============================] - 430s 549ms/step - loss: 4.3512 - accuracy: 0
Epoch 2/10
782/782 [==============================] - 425s 543ms/step - loss: 3.9213 - accuracy: 0
Epoch 3/10
782/782 [==============================] - 405s 518ms/step - loss: 3.6627 - accuracy: 0
Epoch 4/10
782/782 [==============================] - 398s 510ms/step - loss: 3.4966 - accuracy: 0
Epoch 5/10
782/782 [==============================] - 397s 509ms/step - loss: 3.3617 - accuracy: 0
Epoch 6/10
782/782 [==============================] - 397s 509ms/step - loss: 3.2526 - accuracy: 0
Epoch 7/10
782/782 [==============================] - 416s 532ms/step - loss: 3.1552 - accuracy: 0
Epoch 8/10
782/782 [==============================] - 409s 523ms/step - loss: 3.0714 - accuracy: 0
Epoch 9/10
782/782 [==============================] - 401s 513ms/step - loss: 3.0000 - accuracy: 0
Epoch 10/10
782/782 [==============================] - 404s 517ms/step - loss: 2.9300 - accuracy: 0
Wall time: 1h 8min 23s
```

```
# # Evaluate the Model
# evaluate = model.evaluate(x_test, y_test, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
625/625 [==============================] - 18s 28ms/step - loss: 2.8126 - accuracy: 0.3
Model Accuracy: 0.30605000257492065
```

```
# # Evaluate the Model
# evaluate = model.evaluate(x_valid, y_valid, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
938/938 [==============================] - 213s 223ms/step - loss: 2.6495 - accuracy: 0
Model Accuracy: 0.3441999852657318
```

get test score result

```
# %%time
# from sklearn.metrics import accuracy_score
# y_test_pred = model.predict(x_test)
# y_test_pred=np.argmax(y_test_pred, axis=1)
# y_test=np.argmax(y_test, axis=1)
# print("accuracy on test set:")
# print(accuracy_score(y_test, y_test_pred))
# from sklearn.metrics import classification_report
# print(classification_report(y_test, y_test_pred))
```

```
accuracy on test set:
0.3115
              precision    recall  f1-score   support

           0       0.54      0.59      0.57       200
           1       0.41      0.39      0.40       200
           2       0.25      0.23      0.24       200
           3       0.21      0.11      0.14       200
           4       0.22      0.10      0.14       200
           5       0.24      0.28      0.26       200
           6       0.30      0.30      0.30       200
           7       0.32      0.37      0.34       200
           8       0.35      0.39      0.37       200
           9       0.52      0.38      0.44       200
          10       0.23      0.04      0.07       200
          11       0.29      0.12      0.17       200
          12       0.29      0.32      0.30       200
          13       0.23      0.28      0.25       200
```

14	0.19	0.24	0.22	200
15	0.24	0.12	0.16	200
16	0.34	0.25	0.29	200
17	0.44	0.54	0.48	200
18	0.29	0.21	0.24	200
19	0.21	0.14	0.17	200
20	0.38	0.53	0.44	200
21	0.29	0.60	0.39	200
22	0.27	0.27	0.27	200
23	0.47	0.59	0.52	200
24	0.36	0.65	0.46	200
25	0.26	0.20	0.23	200
26	0.19	0.27	0.22	200
27	0.22	0.24	0.23	200
28	0.44	0.35	0.39	200
29	0.43	0.21	0.29	200
30	0.29	0.40	0.33	200
31	0.26	0.22	0.24	200
32	0.44	0.20	0.28	200
33	0.31	0.39	0.35	200
34	0.21	0.20	0.20	200
35	0.20	0.17	0.18	200
36	0.24	0.39	0.29	200
37	0.22	0.23	0.22	200
38	0.21	0.19	0.20	200
39	0.31	0.20	0.24	200
40	0.35	0.20	0.25	200
41	0.54	0.54	0.54	200
42	0.23	0.31	0.26	200
43	0.28	0.46	0.35	200
44	0.28	0.17	0.21	200
45	0.20	0.10	0.13	200
46	0.21	0.12	0.15	200
47	0.54	0.34	0.42	200
48	0.32	0.67	0.44	200
49	0.35	0.33	0.34	200
50	0.14	0.07	0.09	200
51	0.16	0.14	0.15	200
52	0.43	0.79	0.56	200
53	0.39	0.65	0.48	200
54	0.40	0.51	0.45	200

plot confusion matrix

```
# from sklearn.metrics import confusion_matrix


# %%time

# cm = confusion_matrix(y_test, y_test_pred )
# print(cm)
```

```
[[119   4   0 ...   0   1   0]
 [  1  78   1 ...   0   0   0]
```

```
 [  9   2  46 ...   2  14   1]
 ...
 [  0   0   1 ...  54   1   0]
 [  0   2  14 ...   5  36   2]
 [  6   1   2 ...   0   0  33]]
Wall time: 1min 30s
```

```
# from sklearn.metrics import roc_curve, roc_auc_score
# import matplotlib.pyplot as plt
# #y_score1 = clf_tree.predict_proba(X_test)[:,1]
# y_score2 = model.predict(x_test)[:,1]

# #false_positive_rate1, true_positive_rate1, threshold1 = roc_curve(y_test, y_score1)
# false_positive_rate2, true_positive_rate2, threshold2 = roc_curve(y_test, y_score2, pos_lab


# plt.subplots(1, figsize=(10,10))
# plt.title('Receiver Operating Characteristic - CNN')
# plt.plot(false_positive_rate2, true_positive_rate2)
# plt.plot([0, 1], ls="--")
# plt.plot([0, 0], [1, 0] , c=".7"), plt.plot([1, 1] , c=".7")
# plt.ylabel('True Positive Rate')
# plt.xlabel('False Positive Rate')
# plt.show()
```

RELU activation function and adam optimiser

```
# %%time
# from tensorflow.keras.optimizers import RMSprop
# # Create Convolution neural network (CNN layer with Dropout)
# model = Sequential()

# model.add(Conv2D(32,(3,3),padding='same',input_shape=(32,32,3)))
# model.add(Activation('relu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('relu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))


# #use adam optimiser
# model.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])

# model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d (Conv2D)              (None, 32, 32, 32)        896       
_________________________________________________________________
activation (Activation)      (None, 32, 32, 32)        0
```

```
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 32, 32, 32)        9248
_________________________________________________________________
activation_1 (Activation)    (None, 32, 32, 32)        0
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 16, 16, 32)        0
_________________________________________________________________
dropout (Dropout)            (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 16, 16, 64)        18496
_________________________________________________________________
activation_2 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 16, 16, 64)        36928
_________________________________________________________________
activation_3 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 8, 8, 64)          0
_________________________________________________________________
dropout_1 (Dropout)          (None, 8, 8, 64)          0
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 8, 8, 64)          36928
_________________________________________________________________
activation_4 (Activation)    (None, 8, 8, 64)          0
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 8, 8, 64)          36928
_________________________________________________________________
activation_5 (Activation)    (None, 8, 8, 64)          0
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 4, 4, 64)          0
_________________________________________________________________
dropout_2 (Dropout)          (None, 4, 4, 64)          0
_________________________________________________________________
flatten (Flatten)            (None, 1024)              0
_________________________________________________________________
dense (Dense)                (None, 512)               524800
_________________________________________________________________
activation_6 (Activation)    (None, 512)               0
_________________________________________________________________
dropout_3 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_1 (Dense)              (None, 100)               51300
=================================================================
Total params: 715,524
Trainable params: 715,524
Non-trainable params: 0
_________________________________________________________________
Wall time: 1.8 s
```

```
# %%time
# # Train the model
# epochs = 10
# num_predictions = 20
# batchsize = 128

# for i in range(epochs):
```

```
#   print("Epoch {}/{}".format(i+1, epochs))

#   model.fit(x_train, y_train,
#             batch_size=batchsize,
#             epochs=1,
#             validation_data=(x_valid, y_valid),
#             shuffle=True)


# json_string = model.to_json()
# open('cifar100_trial150epochfollowingsenior.json',"w").write(json_string)

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn50epochfollowingsenior.h5')


# model.save('normalcnn50epochfollowingsenior.h5')
```

```
Epoch 1/10
547/547 [==============================] - 830s 1s/step - loss: 4.1917 - accuracy: 0.05
Epoch 2/10
547/547 [==============================] - 859s 2s/step - loss: 3.6494 - accuracy: 0.13
Epoch 3/10
547/547 [==============================] - 878s 2s/step - loss: 3.3354 - accuracy: 0.18
Epoch 4/10
547/547 [==============================] - 877s 2s/step - loss: 3.1303 - accuracy: 0.22
Epoch 5/10
547/547 [==============================] - 872s 2s/step - loss: 2.9631 - accuracy: 0.25
Epoch 6/10
547/547 [==============================] - 892s 2s/step - loss: 2.8379 - accuracy: 0.28
Epoch 7/10
547/547 [==============================] - 1003s 2s/step - loss: 2.7322 - accuracy: 0.3
Epoch 8/10
547/547 [==============================] - 934s 2s/step - loss: 2.6536 - accuracy: 0.31
Epoch 9/10
547/547 [==============================] - 943s 2s/step - loss: 2.5773 - accuracy: 0.33
Epoch 10/10
547/547 [==============================] - 942s 2s/step - loss: 2.5136 - accuracy: 0.34
Wall time: 2h 32min 22s
```

```
# # Evaluate the Model
# evaluate = model.evaluate(x_test, y_test, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
625/625 [==============================] - 93s 143ms/step - loss: 2.4710 - accuracy: 0.
Model Accuracy: 0.36500000953674316
```

get test score result

```
# %%time
# from sklearn.metrics import accuracy_score
# y_test_pred = model.predict(x_test)
# y_test_pred=np.argmax(y_test_pred, axis=1)
# y_test=np.argmax(y_test, axis=1)

# print("CNN feature extraction - accuracy on test set:")
# print(accuracy_score(y_test, y_test_pred))
# from sklearn.metrics import classification_report
# print(classification_report(y_test, y_test_pred))
```

```
CNN feature extraction - accuracy on test set:
0.36005
              precision    recall  f1-score   support

           0       0.67      0.64      0.66       200
           1       0.39      0.41      0.40       200
           2       0.30      0.20      0.24       200
           3       0.25      0.10      0.14       200
           4       0.10      0.27      0.15       200
           5       0.33      0.39      0.35       200
           6       0.50      0.35      0.42       200
           7       0.40      0.43      0.42       200
           8       0.47      0.40      0.43       200
           9       0.57      0.41      0.48       200
          10       0.24      0.23      0.24       200
          11       0.33      0.14      0.20       200
          12       0.53      0.29      0.37       200
          13       0.31      0.28      0.30       200
          14       0.20      0.17      0.18       200
          15       0.37      0.14      0.20       200
          16       0.50      0.42      0.46       200
          17       0.42      0.55      0.48       200
          18       0.51      0.27      0.35       200
          19       0.30      0.12      0.18       200
          20       0.69      0.71      0.70       200
          21       0.23      0.76      0.36       200
          22       0.39      0.24      0.30       200
          23       0.39      0.72      0.51       200
          24       0.47      0.70      0.57       200
          25       0.29      0.20      0.24       200
          26       0.30      0.32      0.31       200
          27       0.18      0.33      0.23       200
          28       0.47      0.51      0.49       200
          29       0.44      0.31      0.36       200
          30       0.37      0.35      0.36       200
          31       0.26      0.28      0.27       200
          32       0.40      0.31      0.35       200
          33       0.38      0.32      0.35       200
          34       0.38      0.24      0.30       200
          35       0.21      0.23      0.22       200
          36       0.28      0.47      0.35       200
          37       0.29      0.27      0.28       200
          38       0.18      0.26      0.21       200
          39       0.37      0.42      0.39       200
          40       0.35      0.20      0.26       200
```

```
41       0.59      0.57      0.58       200
42       0.30      0.28      0.29       200
43       0.22      0.44      0.29       200
44       0.20      0.12      0.15       200
45       0.26      0.22      0.24       200
46       0.21      0.12      0.15       200
47       0.52      0.41      0.46       200
48       0.51      0.68      0.58       200
49       0.41      0.61      0.49       200
50       0.20      0.12      0.15       200
51       0.22      0.19      0.20       200
52       0.44      0.84      0.58       200
53       0.46      0.67      0.55       200
54       0.55      0.46      0.50       200
```

plot confusion matrix

```
# from sklearn.metrics import confusion_matrix


# %%time

# y_test_pred =model.predict(x_test)
# y_test_pred =np.argmax(y_test_pred, axis=1)

# cm = confusion_matrix(y_test, y_test_pred )
# print(cm)
```

```
[[128   4   2 ...   0   1   0]
 [  1  82   0 ...   0   1   1]
 [  1   4  39 ...   0  16   0]
 ...
 [  0   0   0 ...  40   0   0]
 [  1   1   8 ...   1  37   2]
 [  0   1   0 ...   0   0  47]]
Wall time: 2min 30s
```

ELU 10 epoch

```
# %%time
# from tensorflow.keras.optimizers import RMSprop
# # Create Convolution neural network (CNN layer with Dropout)
# model = Sequential()

# model.add(Conv2D(32,(3,3),padding='same',input_shape=(32,32,3)))
# model.add(Activation('elu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(MaxPool2D(pool_size=(2,2)))
```

```
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))



# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('elu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))


# #use adam optimiser
# model.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])

# model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d (Conv2D)              (None, 32, 32, 32)        896       
_________________________________________________________________
activation (Activation)      (None, 32, 32, 32)        0         
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 32, 32, 32)        9248      
_________________________________________________________________
activation_1 (Activation)    (None, 32, 32, 32)        0         
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 16, 16, 32)        0         
_________________________________________________________________
dropout (Dropout)            (None, 16, 16, 32)        0         
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 16, 16, 64)        18496     
_________________________________________________________________
activation_2 (Activation)    (None, 16, 16, 64)        0         
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 16, 16, 64)        36928     
_________________________________________________________________
activation_3 (Activation)    (None, 16, 16, 64)        0         
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 8, 8, 64)          0         
_________________________________________________________________
dropout_1 (Dropout)          (None, 8, 8, 64)          0         
_________________________________________________________________
flatten (Flatten)            (None, 4096)              0         
_________________________________________________________________
```

```
dense (Dense)                (None, 512)               2097664
_________________________________________________________________
activation_4 (Activation)    (None, 512)               0
_________________________________________________________________
dropout_2 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_1 (Dense)              (None, 100)               51300
=================================================================
Total params: 2,214,532
Trainable params: 2,214,532
Non-trainable params: 0
_________________________________________________________________
Wall time: 1.76 s
```

```
# %%time
# # Train the model
# epochs = 10
# num_predictions = 20
# batchsize = 128

# for i in range(epochs):
#   print("Epoch {}/{}".format(i+1, epochs))

#   model.fit(x_train, y_train,
#             batch_size=batchsize,
#             epochs=1,
#             validation_data=(x_valid, y_valid),
#             shuffle=True)


# json_string = model.to_json()
# open('cifar100_trial150epochfollowingsenior.json',"w").write(json_string)

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn50epochfollowingsenior.h5')


# model.save('normalcnn50epochfollowingsenior.h5')
```

```
Epoch 1/10
547/547 [==============================] - 905s 2s/step - loss: 3.6546 - accuracy: 0.15
Epoch 2/10
547/547 [==============================] - 1266s 2s/step - loss: 2.9578 - accuracy: 0.2
Epoch 3/10
547/547 [==============================] - 1496s 3s/step - loss: 2.7237 - accuracy: 0.3
Epoch 4/10
547/547 [==============================] - 1343s 2s/step - loss: 2.5759 - accuracy: 0.3
Epoch 5/10
547/547 [==============================] - 1323s 2s/step - loss: 2.4589 - accuracy: 0.3
Epoch 6/10
547/547 [==============================] - 1156s 2s/step - loss: 2.3753 - accuracy: 0.3
Epoch 7/10
547/547 [==============================] - 1148s 2s/step - loss: 2.2911 - accuracy: 0.4
```

```
Epoch 8/10
547/547 [==============================] - 1140s 2s/step - loss: 2.2129 - accuracy: 0.4
Epoch 9/10
547/547 [==============================] - 1600s 3s/step - loss: 2.1514 - accuracy: 0.4
Epoch 10/10
547/547 [==============================] - 1620s 3s/step - loss: 2.0822 - accuracy: 0.4
Wall time: 3h 39min 34s
```

code below is just to illustrate the result using this preprocessing method

```
# # Evaluate the Model
# evaluate = model.evaluate(x_valid, y_valid, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
938/938 [==============================] - 166s 176ms/step - loss: 2.3339 - accuracy: 0
Model Accuracy: 0.4117000102996826
```

get test score result

plot confusion matrix

```
# from sklearn.metrics import confusion_matrix
```

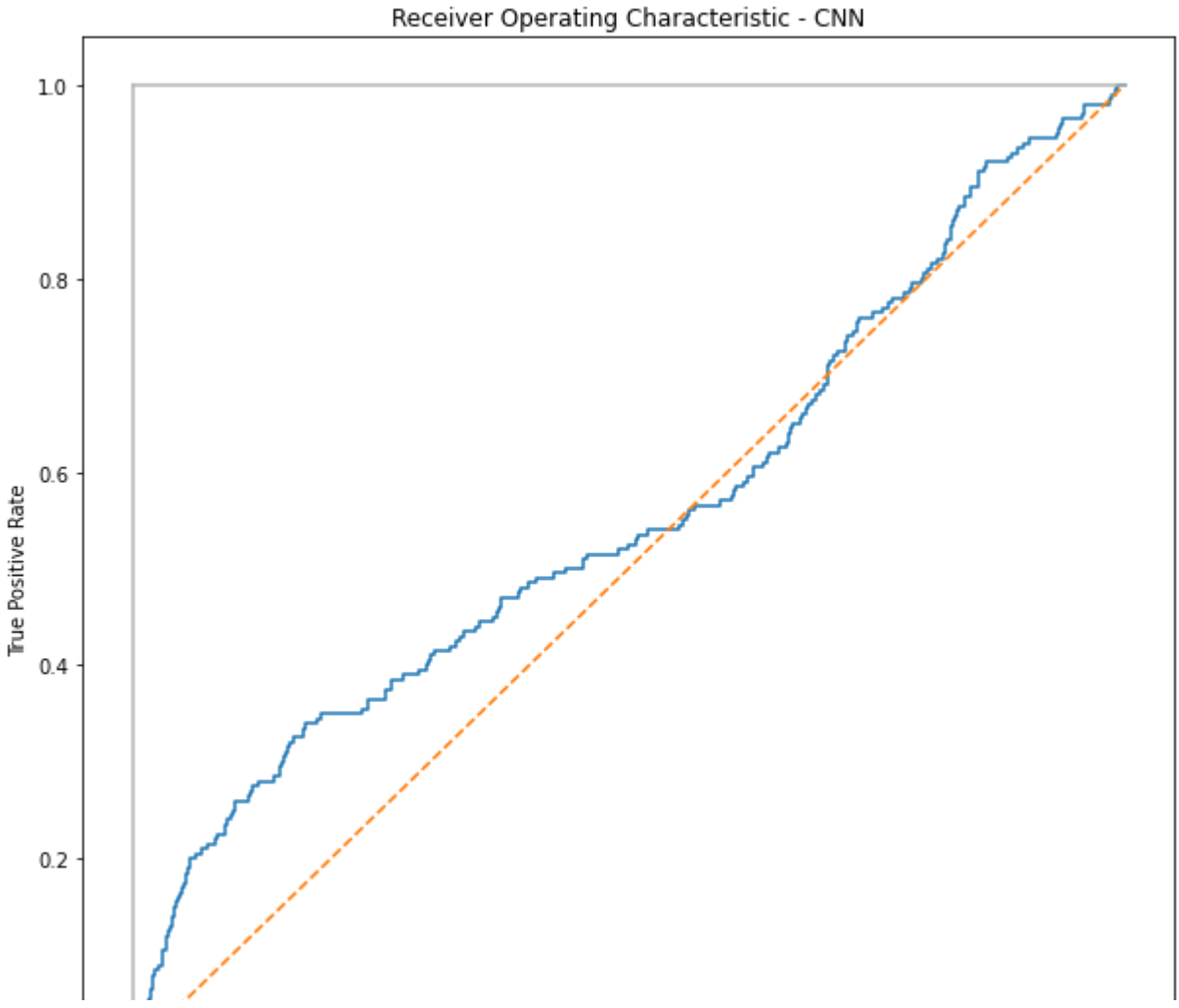
```
# %%time

# # y_test_pred =model.predict(x_test)
# # y_test_pred =np.argmax(y_test_pred, axis=1)

# cm = confusion_matrix(y_test, y_test_pred )
# print(cm)
```

```
[[ 86   8   0 ...   0   0   0]
 [  0 121   0 ...   1   0   1]
 [  0  13  36 ...   5   0   0]
 ...
 [  0   0   0 ... 105   1   0]
 [  1   1   8 ...   6  17   1]
 [  1   3   1 ...   0   0  28]]
Wall time: 909 ms
```

ROC curve

```
# from sklearn.metrics import roc_curve, roc_auc_score
```

```
# import matplotlib.pyplot as plt
# #y_score1 = clf_tree.predict_proba(X_test)[:,1]
# y_score2 = model.predict(x_test)[:,1]

# #false_positive_rate1, true_positive_rate1, threshold1 = roc_curve(y_test, y_score1)
# false_positive_rate2, true_positive_rate2, threshold2 = roc_curve(y_test, y_score2, pos_lab


# plt.subplots(1, figsize=(10,10))
# plt.title('Receiver Operating Characteristic - CNN')
# plt.plot(false_positive_rate2, true_positive_rate2)
# plt.plot([0, 1], ls="--")
# plt.plot([0, 0], [1, 0] , c=".7"), plt.plot([1, 1] , c=".7")
# plt.ylabel('True Positive Rate')
# plt.xlabel('False Positive Rate')
# plt.show()
```



Here is just showing different preprocessing method that we have tested

INCLUDING FEATURE EXTRACTION

Flipping image and add back to original image data and based on previous cnn model (best model parameter - ELU activation function , adam optimiser and with feature extraction) we export CNN model's intermediate layer and use that as the input layer and test on the accuracy

from the previous cnn model we extract the features in layer no 10 (after max pooling) and compare the result

```
# %%time
# import keras
# intermediate_layer_model = keras.Model(model.input, model.get_layer(index = 10).output )

# intermediate_output_train = intermediate_layer_model.predict(x_train)
# intermediate_output_valid = intermediate_layer_model.predict(x_valid)
# intermediate_output_test = intermediate_layer_model.predict(x_test)
```

```
Wall time: 3min 6s
```

```
# %%time
# # save numpy array as npy file
# from numpy import asarray
# from numpy import save
# save('intermediate_output_train10.npy', intermediate_output_train)
# save('intermediate_output_valid10.npy', intermediate_output_valid)
# save('intermediate_output_test10.npy', intermediate_output_test)
```

```
Wall time: 4.11 s
```

```
# %%time
# from numpy import load
# # load array
# intermediate_output_train = load('intermediate_output_train10.npy')
# intermediate_output_valid = load('intermediate_output_valid10.npy')
# intermediate_output_test = load('intermediate_output_test10.npy')
```

```
Wall time: 820 ms
```

below just to show results obtained using the features from cnn layer

```
# %%time
# from tensorflow.keras.optimizers import RMSprop
# # Create Convolution neural network (CNN layer with Dropout)
# model = Sequential()

# model.add(Conv2D(32,(3,3),padding='same',input_shape=(8,8,64)))
# model.add(Activation('elu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))



# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('elu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))


# #use adam optimiser
# model.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])

# model.summary()
```

```
Model: "sequential_3"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_12 (Conv2D)           (None, 8, 8, 32)          18464     
_________________________________________________________________
activation_15 (Activation)   (None, 8, 8, 32)          0         
_________________________________________________________________
conv2d_13 (Conv2D)           (None, 8, 8, 32)          9248      
_________________________________________________________________
activation_16 (Activation)   (None, 8, 8, 32)          0         
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 4, 4, 32)          0         
_________________________________________________________________
dropout_9 (Dropout)          (None, 4, 4, 32)          0         
_________________________________________________________________
conv2d_14 (Conv2D)           (None, 4, 4, 64)          18496     
_________________________________________________________________
```

```
activation_17 (Activation)   (None, 4, 4, 64)          0
_________________________________________________________________
conv2d_15 (Conv2D)           (None, 4, 4, 64)          36928
_________________________________________________________________
activation_18 (Activation)   (None, 4, 4, 64)          0
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 2, 2, 64)          0
_________________________________________________________________
dropout_10 (Dropout)         (None, 2, 2, 64)          0
_________________________________________________________________
flatten_3 (Flatten)          (None, 256)               0
_________________________________________________________________
dense_6 (Dense)              (None, 512)               131584
_________________________________________________________________
activation_19 (Activation)   (None, 512)               0
_________________________________________________________________
dropout_11 (Dropout)         (None, 512)               0
_________________________________________________________________
dense_7 (Dense)              (None, 100)               51300
=================================================================
Total params: 266,020
Trainable params: 266,020
Non-trainable params: 0
_________________________________________________________________
Wall time: 63.4 ms
```

```
# %%time
# # Train the model
# epochs = 10
# num_predictions = 10
# batchsize = 128

# for i in range(epochs):
#   print("Epoch {}/{}".format(i+1, epochs))

#   model.fit(intermediate_output_train, y_train,
#             batch_size=batchsize,
#             epochs=1,
#             validation_data=(intermediate_output_valid, y_valid),
#             shuffle=True)


# json_string = model.to_json()
# open('cifar100_trial20epochfollowingsenior20FEATUREEXTRACTION.json',"w").write(json_string)

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn20epochfollowingseniorFEATUREEXTRACTION.h5')


# model.save('normalcnn20epochfollowingseniorFEATUREEXTRACTION.h5')
```

```
Epoch 1/10
547/547 [==============================] - 57s 103ms/step - loss: 3.2455 - accuracy: 0.
```

```
Epoch 2/10
547/547 [==============================] - 55s 100ms/step - loss: 2.8066 - accuracy: 0.
Epoch 3/10
547/547 [==============================] - 56s 103ms/step - loss: 2.6407 - accuracy: 0.
Epoch 4/10
547/547 [==============================] - 55s 101ms/step - loss: 2.5324 - accuracy: 0.
Epoch 5/10
547/547 [==============================] - 50s 92ms/step - loss: 2.4672 - accuracy: 0.3
Epoch 6/10
547/547 [==============================] - 52s 95ms/step - loss: 2.4124 - accuracy: 0.3
Epoch 7/10
547/547 [==============================] - 50s 92ms/step - loss: 2.3595 - accuracy: 0.3
Epoch 8/10
547/547 [==============================] - 51s 94ms/step - loss: 2.3267 - accuracy: 0.3
Epoch 9/10
547/547 [==============================] - 50s 91ms/step - loss: 2.2961 - accuracy: 0.3
Epoch 10/10
547/547 [==============================] - 51s 93ms/step - loss: 2.2784 - accuracy: 0.3
Wall time: 8min 49s
```

```
# # Evaluate the Model
# evaluate = model.evaluate(intermediate_output_test, y_test, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
625/625 [==============================] - 8s 12ms/step - loss: 2.1691 - accuracy: 0.42
Model Accuracy: 0.42114999890327454
```

```
# # Evaluate the Model
# evaluate = model.evaluate(intermediate_output_valid, y_valid, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
938/938 [==============================] - 10s 10ms/step - loss: 2.1340 - accuracy: 0.4
Model Accuracy: 0.4260333478450775
```

get test score result

```
# %%time
# from sklearn.metrics import accuracy_score
# y_test_pred = model.predict(intermediate_output_test)
# y_test_pred=np.argmax(y_test_pred, axis=1)
# y_test=np.argmax(y_test, axis=1)
# print("accuracy on test set:")
# print(accuracy_score(y_test, y_test_pred))
# from sklearn.metrics import classification_report
# print(classification_report(y_test, y_test_pred))
```

```
accuracy on test set:
0.42115
```

	precision	recall	f1-score	support
0	0.59	0.63	0.61	200
1	0.51	0.61	0.56	200
2	0.32	0.35	0.33	200
3	0.22	0.24	0.23	200
4	0.21	0.29	0.25	200
5	0.38	0.30	0.34	200
6	0.53	0.40	0.45	200
7	0.50	0.42	0.46	200
8	0.59	0.62	0.60	200
9	0.42	0.59	0.49	200
10	0.41	0.17	0.24	200
11	0.18	0.24	0.21	200
12	0.42	0.45	0.43	200
13	0.44	0.18	0.26	200
14	0.24	0.24	0.24	200
15	0.24	0.39	0.30	200
16	0.49	0.53	0.51	200
17	0.58	0.58	0.58	200
18	0.40	0.38	0.39	200
19	0.30	0.27	0.28	200
20	0.70	0.58	0.64	200
21	0.66	0.44	0.53	200
22	0.42	0.34	0.38	200
23	0.58	0.80	0.67	200
24	0.60	0.62	0.61	200
25	0.39	0.28	0.33	200
26	0.50	0.34	0.41	200
27	0.30	0.45	0.36	200
28	0.55	0.60	0.57	200
29	0.34	0.33	0.33	200
30	0.40	0.34	0.36	200
31	0.26	0.32	0.29	200
32	0.40	0.23	0.29	200
33	0.45	0.51	0.48	200
34	0.29	0.40	0.34	200
35	0.22	0.28	0.25	200
36	0.37	0.52	0.43	200
37	0.31	0.45	0.37	200
38	0.26	0.30	0.28	200
39	0.62	0.59	0.61	200
40	0.41	0.24	0.30	200
41	0.57	0.63	0.60	200
42	0.44	0.53	0.48	200
43	0.49	0.47	0.48	200
44	0.28	0.20	0.23	200
45	0.20	0.34	0.25	200
46	0.39	0.21	0.28	200
47	0.56	0.43	0.49	200
48	0.59	0.78	0.67	200
49	0.53	0.67	0.59	200
50	0.18	0.13	0.15	200
51	0.29	0.47	0.35	200
52	0.46	0.79	0.58	200

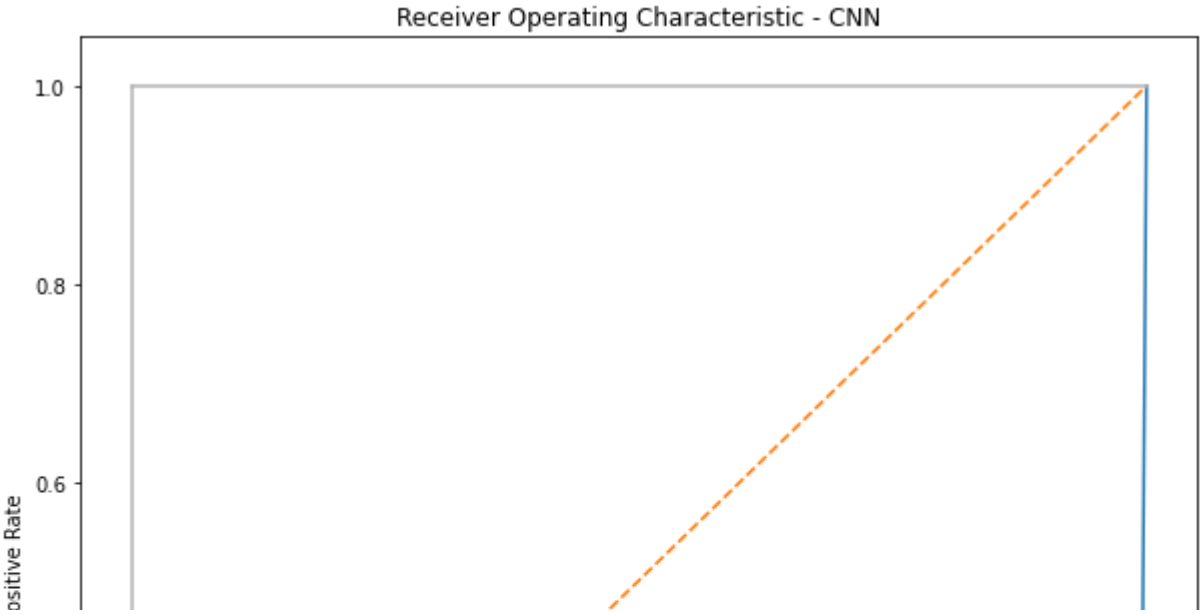
```
53        0.77      0.49      0.60        200
```

plot confusion matrix

```
# from sklearn.metrics import confusion_matrix



# %%time

# cm = confusion_matrix(y_test, y_test_pred)
# print(cm)
```

```
[[126   4   2 ...   0   1   0]
 [  0 123   0 ...   1   0   3]
 [  1   1  71 ...   1   5   0]
 ...
 [  0   0   0 ...  64   0   0]
 [  4   0   8 ...   0  23   3]
 [  0   1   1 ...   0   0  61]]
Wall time: 19.1 ms
```

```
# from sklearn.metrics import roc_curve, roc_auc_score
# import matplotlib.pyplot as plt
# #y_score1 = clf_tree.predict_proba(X_test)[:,1]
# #y_score2 = model.predict(x_test)[:,1]

# #false_positive_rate1, true_positive_rate1, threshold1 = roc_curve(y_test, y_score1)
# false_positive_rate2, true_positive_rate2, threshold2 = roc_curve(y_test, y_test_pred, pos_



# plt.subplots(1, figsize=(10,10))
# plt.title('Receiver Operating Characteristic - CNN')
# plt.plot(false_positive_rate2, true_positive_rate2)
# plt.plot([0, 1], ls="--")
# plt.plot([0, 0], [1, 0] , c=".7"), plt.plot([1, 1] , c=".7")
# plt.ylabel('True Positive Rate')
# plt.xlabel('False Positive Rate')
# plt.show()
```



divide by 255 only

```
# #libraries
# from keras.datasets import cifar100
# import matplotlib.pyplot as plt
# import numpy as np
# from keras.models import Sequential
# from keras.layers.convolutional import Conv2D
# from keras.layers.pooling import MaxPool2D
# from keras.layers.core import Dense,Activation,Dropout,Flatten
# from keras.utils import np_utils

# import tensorflow as tf
# from tensorflow.keras import datasets, layers, models, optimizers

# # Download dataset of CIFAR-100 (Canadian Institute for Advanced Research)
# (x_train,y_train),(x_test,y_test) = cifar100.load_data()

# #print shapre of training and test dataset
# print('x_train shape:', x_train.shape)
# print('x_test shape:', x_test.shape)
# print('y_train shape:', y_train.shape)
# print('y_test shape:', y_test.shape)

# # print number of data set samples
# print(x_train.shape[0], 'train set')
# print(x_test.shape[0], 'test set')

#  # Data type for train and test set
# print(type(x_test))
# print(type(y_test[0]))
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-100-python.tar.gz
169009152/169001437 [==============================] - 4s 0us/step
169017344/169001437 [==============================] - 4s 0us/step
x_train shape: (50000, 32, 32, 3)
x_test shape: (10000, 32, 32, 3)
y_train shape: (50000, 1)
y_test shape: (10000, 1)
50000 train set
10000 test set
<class 'numpy.ndarray'>
<class 'numpy.ndarray'>
```

```
# # Show sample random image 5x5
# plt.figure(figsize=(10,10))
# for i in range(25):
#     rand_num=np.random.randint(0,100)
#     cifar_image=plt.subplot(5,5,i+1)
#     plt.imshow(x_train[rand_num])
#     # Erase the value of x tick and y tick
#     plt.xticks(color="None")
#     plt.yticks(color="None")
#     # remove the tick x-axis and y-axis
#     plt.tick_params(length=0)
#     # print label
#     plt.title(y_train[rand_num])

# plt.show()
```

```
/usr/local/lib/python3.7/dist-packages/matplotlib/text.py:1165: FutureWarning: ele
  if s != self._text:
```


```
# #flipping image
# %%time
# #preprocess test dataset
# from keras.preprocessing.image import ImageDataGenerator
# Datagenerator = ImageDataGenerator()
# x_train = Datagenerator.apply_transform(x=x_train, transform_parameters={'flip_horizontal':
# x_test = Datagenerator.apply_transform(x=x_test, transform_parameters={'flip_horizontal':Tr
```

```
CPU times: user 404 µs, sys: 0 ns, total: 404 µs
Wall time: 437 µs
```

```
# %%time
# # Normalize taining and test set image to the range of 0-1
# x_train = x_train.astype('float32')/255.0

# x_test = x_test.astype('float32')/255.0

#  # convert the labels of y_train,y_test to One-Hot encoding
# y_train = np_utils.to_categorical(y_train,100)
# y_test = np_utils.to_categorical(y_test,100)
```

```
CPU times: user 217 ms, sys: 185 ms, total: 402 ms
Wall time: 416 ms
```

```
# from sklearn.model_selection import train_test_split
# x_train, x_valid, y_train , y_valid = train_test_split(x_train, y_train,
#                                                        train_size=0.70,
#                                                        random_state=42,
#                                                        stratify=y_train)



# %%time
```

```
# # Create Convolution neural network (CNN layer with Dropout)
# model = Sequential()

# model.add(Conv2D(32,(3,3),padding='same',input_shape=(32,32,3)))
# model.add(Activation('relu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('relu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))

#  #use adam optimiser
# model.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])

# model.summary()

# # Training(Epoch 100 will take over 8 hours using GPU on Google Colab)
# history = model.fit(x_train,y_train,batch_size=128,epochs=10,verbose=1)

# # export model into a json file
# json_string = model.to_json()
# open('cifar100_trial1.json',"w").write(json_string)

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn.h5')

# # Evaluate CNN model
# score = model.evaluate(x_valid,y_valid,verbose=0)
# print('Test loss:',score[0])
# print('Test accuracy:',score[1])
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 32, 32, 32)        896
_________________________________________________________________
activation (Activation)      (None, 32, 32, 32)        0
_________________________________________________________________
```

```
conv2d_1 (Conv2D)            (None, 32, 32, 32)        9248
_________________________________________________________________
activation_1 (Activation)    (None, 32, 32, 32)        0
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 16, 16, 32)        0
_________________________________________________________________
dropout (Dropout)            (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 16, 16, 64)        18496
_________________________________________________________________
activation_2 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 16, 16, 64)        36928
_________________________________________________________________
activation_3 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 8, 8, 64)          0
_________________________________________________________________
dropout_1 (Dropout)          (None, 8, 8, 64)          0
_________________________________________________________________
flatten (Flatten)            (None, 4096)              0
_________________________________________________________________
dense (Dense)                (None, 512)               2097664
_________________________________________________________________
activation_4 (Activation)    (None, 512)               0
_________________________________________________________________
dropout_2 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_1 (Dense)              (None, 100)               51300
=================================================================
Total params: 2,214,532
Trainable params: 2,214,532
Non-trainable params: 0
_________________________________________________________________
Epoch 1/10
274/274 [==============================] - 170s 618ms/step - loss: 4.2423 - accuracy:
Epoch 2/10
274/274 [==============================] - 169s 616ms/step - loss: 3.6434 - accuracy:
Epoch 3/10
274/274 [==============================] - 169s 615ms/step - loss: 3.2716 - accuracy:
Epoch 4/10
274/274 [==============================] - 169s 618ms/step - loss: 3.0317 - accuracy:
Epoch 5/10
274/274 [==============================] - 170s 621ms/step - loss: 2.8463 - accuracy:
Epoch 6/10
274/274 [==============================] - 170s 621ms/step - loss: 2.6921 - accuracy:
Epoch 7/10
274/274 [==============================] - 169s 617ms/step - loss: 2.5454 - accuracy:
Epoch 8/10
274/274 [==============================] - 169s 618ms/step - loss: 2.4249 - accuracy:
```

get test score result

```
# %%time
# from sklearn.metrics import accuracy_score
```

```
# y_test_pred = model.predict(x_test)
# y_test_pred=np.argmax(y_test_pred, axis=1)
# y_test=np.argmax(y_test, axis=1)

# print("CNN feature extraction - accuracy on test set:")
# print(accuracy_score(y_test, y_test_pred))
# from sklearn.metrics import classification_report
# print(classification_report(y_test, y_test_pred))
```

```
CNN feature extraction - accuracy on test set:
0.4086
              precision    recall  f1-score   support

           0       0.54      0.70      0.61       100
           1       0.49      0.46      0.47       100
           2       0.22      0.36      0.27       100
           3       0.28      0.19      0.23       100
           4       0.23      0.17      0.20       100
           5       0.34      0.38      0.36       100
           6       0.45      0.49      0.47       100
           7       0.47      0.39      0.43       100
           8       0.58      0.53      0.55       100
           9       0.66      0.51      0.58       100
          10       0.27      0.26      0.26       100
          11       0.30      0.24      0.27       100
          12       0.40      0.34      0.37       100
          13       0.58      0.34      0.43       100
          14       0.41      0.29      0.34       100
          15       0.28      0.21      0.24       100
          16       0.46      0.42      0.44       100
          17       0.58      0.56      0.57       100
          18       0.35      0.28      0.31       100
          19       0.33      0.31      0.32       100
          20       0.66      0.73      0.70       100
          21       0.53      0.59      0.56       100
          22       0.68      0.25      0.36       100
          23       0.49      0.54      0.51       100
          24       0.48      0.72      0.58       100
          25       0.36      0.31      0.33       100
          26       0.53      0.24      0.33       100
          27       0.22      0.45      0.30       100
          28       0.57      0.66      0.61       100
          29       0.37      0.34      0.36       100
          30       0.39      0.30      0.34       100
          31       0.32      0.45      0.38       100
          32       0.56      0.27      0.36       100
          33       0.42      0.50      0.46       100
          34       0.31      0.37      0.34       100
          35       0.25      0.12      0.16       100
          36       0.21      0.46      0.29       100
          37       0.33      0.36      0.34       100
          38       0.18      0.29      0.22       100
          39       0.50      0.42      0.46       100
          40       0.44      0.41      0.42       100
          41       0.66      0.69      0.67       100
          42       0.34      0.36      0.35       100
```

```
43       0.28      0.54      0.37       100
44       0.20      0.29      0.24       100
45       0.27      0.19      0.22       100
46       0.35      0.26      0.30       100
47       0.53      0.51      0.52       100
48       0.55      0.75      0.64       100
49       0.52      0.40      0.45       100
50       0.17      0.15      0.16       100
51       0.35      0.34      0.35       100
52       0.49      0.69      0.57       100
53       0.45      0.75      0.56       100
54       0.38      0.63      0.47       100
```

plot confusion matrix

```
# from sklearn.metrics import confusion_matrix


# %%time

# y_test_pred =model.predict(x_test)
# y_test_pred =np.argmax(y_test_pred, axis=1)

# cm = confusion_matrix(y_test, y_test_pred )
# print(cm)
```

```
[[70  2  1 ...  0  0  0]
 [ 2 46  0 ...  0  0  0]
 [ 1  1 36 ...  1  6  1]
 ...
 [ 0  0  1 ... 24  0  0]
 [ 2  2 11 ...  1 16  2]
 [ 1  0  2 ...  0  0 32]]
CPU times: user 21 s, sys: 349 ms, total: 21.3 s
Wall time: 11.3 s
```

Just import data with no preprocessing

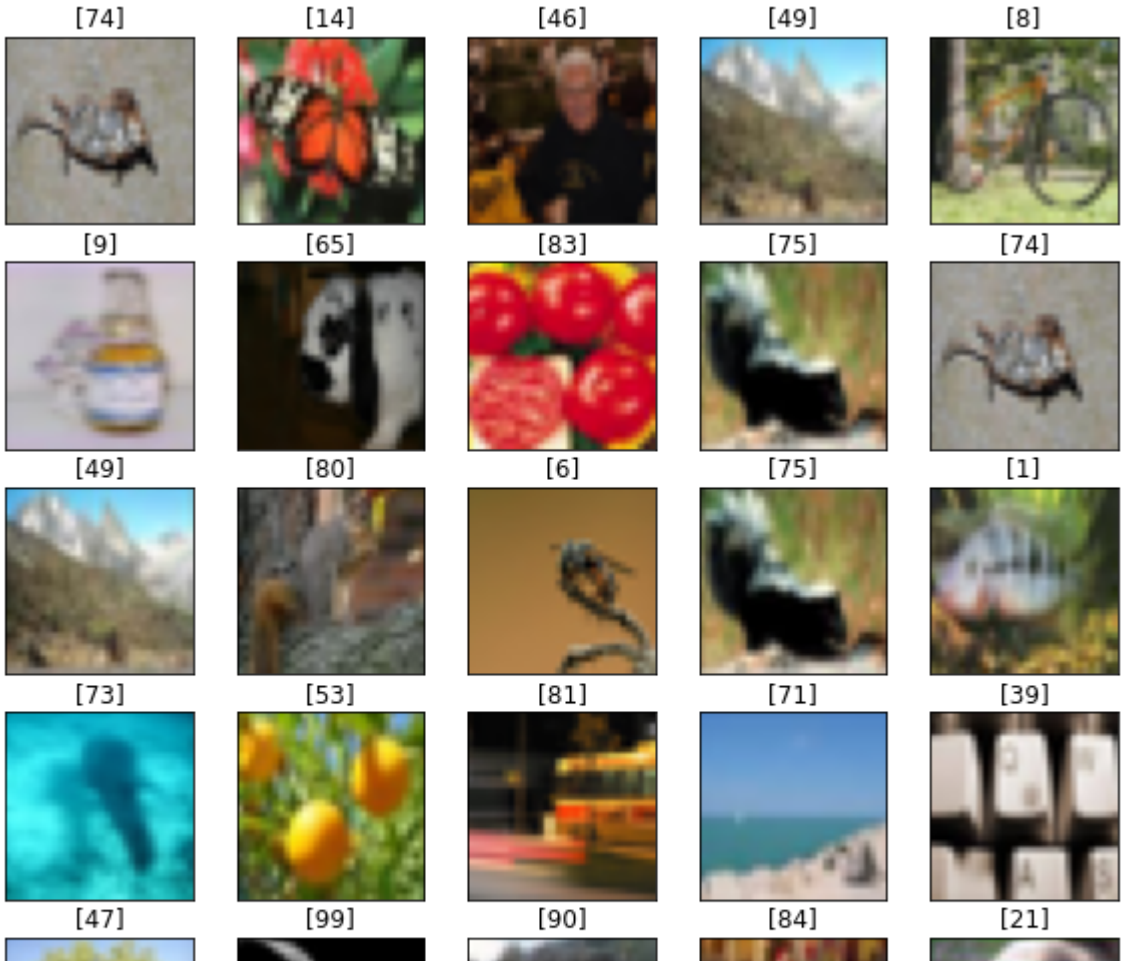
```
# #libraries
# from keras.datasets import cifar100
# import matplotlib.pyplot as plt
# import numpy as np
# from keras.models import Sequential
# from keras.layers.convolutional import Conv2D
# from keras.layers.pooling import MaxPool2D
# from keras.layers.core import Dense,Activation,Dropout,Flatten
# from keras.utils import np_utils

# import tensorflow as tf
```

```
# from tensorflow.keras import datasets, layers, models, optimizers

# # Download dataset of CIFAR-100 (Canadian Institute for Advanced Research)
# (x_train,y_train),(x_test,y_test) = cifar100.load_data()

# #print shapre of training and test dataset
# print('x_train shape:', x_train.shape)
# print('x_test shape:', x_test.shape)
# print('y_train shape:', y_train.shape)
# print('y_test shape:', y_test.shape)

# # print number of data set samples
# print(x_train.shape[0], 'train set')
# print(x_test.shape[0], 'test set')

# # Data type for train and test set
# print(type(x_test))
# print(type(y_test[0]))
```

```
x_train shape: (50000, 32, 32, 3)
x_test shape: (10000, 32, 32, 3)
y_train shape: (50000, 1)
y_test shape: (10000, 1)
50000 train set
10000 test set
<class 'numpy.ndarray'>
<class 'numpy.ndarray'>
```

```
# # Show sample random image 5x5
# plt.figure(figsize=(10,10))
# for i in range(25):
#     rand_num=np.random.randint(0,100)
#     cifar_image=plt.subplot(5,5,i+1)
#     plt.imshow(x_train[rand_num])
#     # Erase the value of x tick and y tick
#     plt.xticks(color="None")
#     plt.yticks(color="None")
#     # remove the tick x-axis and y-axis
#     plt.tick_params(length=0)
#     # print label
#     plt.title(y_train[rand_num])

# plt.show()
```

```
/usr/local/lib/python3.7/dist-packages/matplotlib/text.py:1165: FutureWarning: ele
  if s != self._text:
```




```
# # convert the labels of y_train,y_test to One-Hot encoding
# y_train = np_utils.to_categorical(y_train,100)
# y_test = np_utils.to_categorical(y_test,100)

# # Create Convolution neural network (CNN layer with Dropout)
# model = Sequential()

# model.add(Conv2D(32,(3,3),padding='same',input_shape=(32,32,3)))
# model.add(Activation('relu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))
```

```
# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('relu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))

#  #use adam optimiser
# model.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])

# model.summary()

# # Training(Epoch 100 will take over 8 hours using GPU on Google Colab)
# history = model.fit(x_train,y_train,batch_size=128,epochs=10,verbose=1)

# # export model into a json file
# json_string = model.to_json()
# open('cifar100_trial1.json',"w").write(json_string)

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn.h5')

# # Evaluate CNN model
# score = model.evaluate(x_test,y_test,verbose=0)
# print('Test loss:',score[0])
# print('Test accuracy:',score[1])
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_4 (Conv2D)            (None, 32, 32, 32)        896
_________________________________________________________________
activation_5 (Activation)    (None, 32, 32, 32)        0
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 32, 32, 32)        9248
_________________________________________________________________
activation_6 (Activation)    (None, 32, 32, 32)        0
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 16, 16, 32)        0
_________________________________________________________________
dropout_3 (Dropout)          (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 16, 16, 64)        18496
_________________________________________________________________
activation_7 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_7 (Conv2D)            (None, 16, 16, 64)        36928
_________________________________________________________________
activation_8 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 8, 8, 64)          0
_________________________________________________________________
```

```
dropout_4 (Dropout)          (None, 8, 8, 64)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 4096)              0
_________________________________________________________________
dense_2 (Dense)              (None, 512)               2097664
_________________________________________________________________
activation_9 (Activation)    (None, 512)               0
_________________________________________________________________
dropout_5 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_3 (Dense)              (None, 100)               51300
=================================================================
Total params: 2,214,532
Trainable params: 2,214,532
Non-trainable params: 0
_________________________________________________________________
Epoch 1/10
391/391 [==============================] - 237s 604ms/step - loss: 5.1291 - accuracy:
Epoch 2/10
391/391 [==============================] - 236s 603ms/step - loss: 4.1865 - accuracy:
Epoch 3/10
391/391 [==============================] - 235s 602ms/step - loss: 3.8095 - accuracy:
Epoch 4/10
391/391 [==============================] - 236s 605ms/step - loss: 3.5364 - accuracy:
Epoch 5/10
391/391 [==============================] - 236s 603ms/step - loss: 3.3200 - accuracy:
Epoch 6/10
391/391 [==============================] - 236s 604ms/step - loss: 3.1444 - accuracy:
Epoch 7/10
391/391 [==============================] - 237s 606ms/step - loss: 2.9820 - accuracy:
Epoch 8/10
391/391 [==============================] - 237s 606ms/step - loss: 2.8433 - accuracy:
```

get test score result

```
# %%time
# from sklearn.metrics import accuracy_score
# y_test_pred = model.predict(x_test)
# y_test_pred=np.argmax(y_test_pred, axis=1)
# y_test=np.argmax(y_test, axis=1)

# print("CNN feature extraction - accuracy on test set:")
# print(accuracy_score(y_test, y_test_pred))
# from sklearn.metrics import classification_report
# print(classification_report(y_test, y_test_pred))
```

```
CNN feature extraction - accuracy on test set:
0.3532
              precision    recall  f1-score   support

           0       0.56      0.66      0.61       100
           1       0.41      0.41      0.41       100
           2       0.35      0.19      0.25       100
           3       0.25      0.25      0.25       100
```

4	0.16	0.16	0.16	100
5	0.40	0.27	0.32	100
6	0.48	0.26	0.34	100
7	0.43	0.30	0.35	100
8	0.57	0.46	0.51	100
9	0.56	0.54	0.55	100
10	0.33	0.31	0.32	100
11	0.30	0.13	0.18	100
12	0.44	0.34	0.38	100
13	0.44	0.14	0.21	100
14	0.37	0.28	0.32	100
15	0.42	0.16	0.23	100
16	0.74	0.29	0.42	100
17	0.52	0.52	0.52	100
18	0.27	0.31	0.29	100
19	0.39	0.21	0.27	100
20	0.76	0.67	0.71	100
21	0.29	0.61	0.39	100
22	0.51	0.22	0.31	100
23	0.32	0.60	0.42	100
24	0.61	0.60	0.60	100
25	0.32	0.36	0.34	100
26	0.34	0.25	0.29	100
27	0.13	0.39	0.19	100
28	0.66	0.59	0.62	100
29	0.41	0.36	0.38	100
30	0.28	0.33	0.30	100
31	0.26	0.36	0.30	100
32	0.46	0.37	0.41	100
33	0.19	0.60	0.29	100
34	0.29	0.16	0.21	100
35	0.36	0.10	0.16	100
36	0.39	0.25	0.30	100
37	0.35	0.18	0.24	100
38	0.26	0.23	0.25	100
39	0.27	0.13	0.17	100
40	0.50	0.29	0.37	100
41	0.71	0.57	0.63	100
42	0.16	0.47	0.24	100
43	0.17	0.35	0.23	100
44	0.13	0.07	0.09	100
45	0.23	0.20	0.22	100
46	0.24	0.25	0.24	100
47	0.47	0.44	0.46	100
48	0.81	0.63	0.71	100
49	0.56	0.44	0.49	100
50	0.22	0.06	0.09	100
51	0.22	0.25	0.23	100
52	0.48	0.56	0.52	100
53	0.53	0.42	0.47	100
54	0.65	0.33	0.44	100

plot confusion matrix

```
# from sklearn.metrics import confusion_matrix
```

```
# %%time

# y_test_pred =model.predict(x_test)
# y_test_pred =np.argmax(y_test_pred, axis=1)

# cm = confusion_matrix(y_test, y_test_pred )
# print(cm)
```

```
[[66  3  0 ...  0  0  0]
 [ 1 41  0 ...  0  0  2]
 [ 2  1 19 ...  1 10  0]
 ...
 [ 0  1  0 ... 29  1  0]
 [ 1  0  2 ...  2 27  0]
 [ 0  0  1 ...  0  0 21]]
CPU times: user 20.8 s, sys: 285 ms, total: 21.1 s
Wall time: 20.6 s
```

Feature extraction - Extract mean of all colour pixels (take all 3 colour value R,G,B and divide by 3)

```
# #libraries
# from keras.datasets import cifar100
# import matplotlib.pyplot as plt
# import numpy as np
# from keras.models import Sequential
# from keras.layers.convolutional import Conv2D
# from keras.layers.pooling import MaxPool2D
# from keras.layers.core import Dense,Activation,Dropout,Flatten
# from keras.utils import np_utils

# import tensorflow as tf
# from tensorflow.keras import datasets, layers, models, optimizers

# # Download dataset of CIFAR-100 (Canadian Institute for Advanced Research)
# (x_train,y_train),(x_test,y_test) = cifar100.load_data()

# #print shapre of training and test dataset
# print('x_train shape:', x_train.shape)
# print('x_test shape:', x_test.shape)
# print('y_train shape:', y_train.shape)
# print('y_test shape:', y_test.shape)

# # print number of data set samples
# print(x_train.shape[0], 'train set')
```

```
# print(x_test.shape[0], 'test set')

# # Data type for train and test set
# print(type(x_test))
# print(type(y_test[0]))
```

```
x_train shape: (50000, 32, 32, 3)
x_test shape: (10000, 32, 32, 3)
y_train shape: (50000, 1)
y_test shape: (10000, 1)
50000 train set
10000 test set
<class 'numpy.ndarray'>
<class 'numpy.ndarray'>
```

```
# # Show sample random image 5x5
# plt.figure(figsize=(10,10))
# for i in range(25):
#     rand_num=np.random.randint(0,100)
#     cifar_image=plt.subplot(5,5,i+1)
#     plt.imshow(x_train[rand_num])
#     # Erase the value of x tick and y tick
#     plt.xticks(color="None")
#     plt.yticks(color="None")
#     # remove the tick x-axis and y-axis
#     plt.tick_params(length=0)
#     # print label
#     plt.title(y_train[rand_num])

# plt.show()
```

```
C:\ProgramData\Anaconda3\lib\site-packages\matplotlib\text.py:1165: FutureWarning: elem
  if s != self._text:
```


```
# %%time
# #flipping image
# #preprocess test dataset
# from keras.preprocessing.image import ImageDataGenerator
# Datagenerator = ImageDataGenerator()

# x_train1 = Datagenerator.apply_transform(x=x_train, transform_parameters={'flip_horizontal'
# x_test1 = Datagenerator.apply_transform(x=x_test, transform_parameters={'flip_horizontal':T


# x_train = np.concatenate((x_train,x_train1))
# x_test = np.concatenate((x_test,x_test1))
# y_train = np.concatenate((y_train,y_train))
# y_test = np.concatenate((y_test,y_test))


    Wall time: 205 ms


# %%time
# # Normalize taining and test set image to the range of 0-1
# x_train = x_train.astype('float32')/255.0
# x_test = x_test.astype('float32')/255.0

# # convert the labels of y_train,y_test to One-Hot encoding
# y_train = np_utils.to_categorical(y_train,100)
# y_test = np_utils.to_categorical(y_test,100)


    Wall time: 1.73 s


# %%time
# from sklearn.model_selection import train_test_split
# x_train, x_valid, y_train , y_valid = train_test_split(x_train, y_train,
#                                                        train_size=0.70,
```

```
#                                                     random_state=42,
#                                                     stratify=y_train)
```

```
Wall time: 15 s
```

if you havent install

```
!pip install numpy
```

```
Requirement already satisfied: numpy in c:\programdata\anaconda3\lib\site-packages (1.1
```

```
# %%time
# import numpy
# feature_x_train = numpy.zeros((len(x_train),32,32))

# for a in range(len(x_train)-1):
#   for b in range(31):
#     for c in range(31):
#       #for d in range(2):
#       feature_x_train[a][b][c] = ((x_train[a][b][c][0] + x_train[a][b][c][1] + x_train[a][b

# feature_x_train = feature_x_train.reshape(list(feature_x_train.shape) + [1])


# feature_x_valid = numpy.zeros((len(x_valid),32,32))

# for a in range(len(x_valid)-1):
#   for b in range(31):
#     for c in range(31):
#       #for d in range(2):
#       feature_x_valid[a][b][c] = ((x_valid[a][b][c][0] + x_valid[a][b][c][1] + x_valid[a][b
# feature_x_valid = feature_x_valid.reshape(list(feature_x_valid.shape) + [1])


# feature_x_test = numpy.zeros((len(x_test),32,32))

# for a in range(len(x_test)-1):
#   for b in range(31):
#     for c in range(31):
#       #for d in range(2):
#       feature_x_test[a][b][c] = ((x_test[a][b][c][0] + x_test[a][b][c][1] + x_test[a][b][c]

# feature_x_test = feature_x_test.reshape(list(feature_x_test.shape) + [1])
```

```
Wall time: 24min 52s
```

```
# %%time
# # Create Convolution neural network (CNN layer with Dropout)
```

```
# model = Sequential()

# model.add(Conv2D(32,(3,3),padding='same',input_shape=(32,32,1)))
# model.add(Activation('relu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('relu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))

#  #use adam optimiser
# model.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])

# model.summary()

# # Training(Epoch 100 will take over 8 hours using GPU on Google Colab)
# history = model.fit(feature_x_train,y_train,batch_size=128,epochs=10,verbose=1)

# # export model into a json file
# json_string = model.to_json()
# open('cifar100_trial1.json',"w").write(json_string)

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn.h5')

# # Evaluate CNN model
# score = model.evaluate(feature_x_valid,y_valid,verbose=0)
# print('Test loss:',score[0])
# print('Test accuracy:',score[1])
```

```
Model: "sequential_4"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_13 (Conv2D)           (None, 32, 32, 32)        320
_________________________________________________________________
activation_15 (Activation)   (None, 32, 32, 32)        0
_________________________________________________________________
conv2d_14 (Conv2D)           (None, 32, 32, 32)        9248
```

```
activation_16 (Activation)   (None, 32, 32, 32)        0
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 16, 16, 32)        0
_________________________________________________________________
dropout_9 (Dropout)          (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_15 (Conv2D)           (None, 16, 16, 64)        18496
_________________________________________________________________
activation_17 (Activation)   (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_16 (Conv2D)           (None, 16, 16, 64)        36928
_________________________________________________________________
activation_18 (Activation)   (None, 16, 16, 64)        0
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 8, 8, 64)          0
_________________________________________________________________
dropout_10 (Dropout)         (None, 8, 8, 64)          0
_________________________________________________________________
flatten_3 (Flatten)          (None, 4096)              0
_________________________________________________________________
dense_6 (Dense)              (None, 512)               2097664
_________________________________________________________________
activation_19 (Activation)   (None, 512)               0
_________________________________________________________________
dropout_11 (Dropout)         (None, 512)               0
_________________________________________________________________
dense_7 (Dense)              (None, 100)               51300
=================================================================
Total params: 2,213,956
Trainable params: 2,213,956
Non-trainable params: 0
_________________________________________________________________
Epoch 1/10
547/547 [==============================] - 238s 433ms/step - loss: 4.3643 - accuracy:
Epoch 2/10
547/547 [==============================] - 237s 433ms/step - loss: 3.8269 - accuracy:
Epoch 3/10
547/547 [==============================] - 237s 433ms/step - loss: 3.4394 - accuracy:
Epoch 4/10
547/547 [==============================] - 236s 431ms/step - loss: 3.1983 - accuracy:
Epoch 5/10
547/547 [==============================] - 234s 427ms/step - loss: 3.0452 - accuracy:
Epoch 6/10
547/547 [==============================] - 234s 428ms/step - loss: 2.9275 - accuracy:
Epoch 7/10
547/547 [==============================] - 232s 425ms/step - loss: 2.8376 - accuracy:
Epoch 8/10
547/547 [==============================] - 233s 427ms/step - loss: 2.7467 - accuracy:
```

get test score result

```
# %%time
# from sklearn.metrics import accuracy_score
# y_test_pred = model.predict(feature_x_test)
```

```
# y_test_pred=np.argmax(y_test_pred, axis=1)
# y_test=np.argmax(y_test, axis=1)

# print("CNN feature extraction - accuracy on test set:")
# print(accuracy_score(y_test, y_test_pred))
# from sklearn.metrics import classification_report
# print(classification_report(y_test, y_test_pred))
```

```
CNN feature extraction - accuracy on test set:
0.3368
              precision    recall  f1-score   support

           0       0.52      0.62      0.57       200
           1       0.38      0.47      0.42       200
           2       0.19      0.14      0.16       200
           3       0.28      0.12      0.16       200
           4       0.14      0.17      0.15       200
           5       0.28      0.28      0.28       200
           6       0.31      0.27      0.29       200
           7       0.32      0.34      0.33       200
           8       0.33      0.56      0.41       200
           9       0.60      0.52      0.56       200
          10       0.30      0.25      0.27       200
          11       0.38      0.13      0.19       200
          12       0.40      0.30      0.35       200
          13       0.30      0.27      0.28       200
          14       0.31      0.19      0.23       200
          15       0.25      0.14      0.18       200
          16       0.43      0.47      0.45       200
          17       0.47      0.57      0.52       200
          18       0.28      0.17      0.22       200
          19       0.24      0.27      0.25       200
          20       0.69      0.67      0.68       200
          21       0.39      0.48      0.43       200
          22       0.44      0.41      0.42       200
          23       0.61      0.49      0.55       200
          24       0.49      0.69      0.58       200
          25       0.34      0.34      0.34       200
          26       0.30      0.28      0.29       200
          27       0.15      0.38      0.21       200
          28       0.62      0.55      0.58       200
          29       0.58      0.28      0.38       200
          30       0.30      0.24      0.27       200
          31       0.28      0.33      0.30       200
          32       0.37      0.22      0.28       200
          33       0.31      0.50      0.38       200
          34       0.15      0.07      0.10       200
          35       0.21      0.10      0.13       200
          36       0.36      0.32      0.34       200
          37       0.31      0.29      0.30       200
          38       0.20      0.28      0.23       200
          39       0.72      0.38      0.49       200
          40       0.47      0.34      0.39       200
          41       0.48      0.55      0.51       200
          42       0.17      0.49      0.26       200
          43       0.17      0.21      0.19       200
```

```
44       0.18      0.11      0.14       200
45       0.21      0.12      0.15       200
46       0.27      0.21      0.24       200
47       0.34      0.53      0.41       200
48       0.43      0.77      0.55       200
49       0.62      0.29      0.39       200
50       0.39      0.06      0.10       200
51       0.21      0.37      0.27       200
52       0.49      0.57      0.53       200
53       0.39      0.43      0.41       200
54       0.45      0.41      0.43       200
```

plot confusion matrix

```
# from sklearn.metrics import confusion_matrix


# %%time

# y_test_pred =model.predict(feature_x_test)
# y_test_pred =np.argmax(y_test_pred, axis=1)

# cm = confusion_matrix(y_test, y_test_pred )
# print(cm)
```

```
[[124   3   0 ...   2   0   0]
 [  2  93   1 ...   0   0   1]
 [  1   4  29 ...   6   5   1]
 ...
 [  0   1   1 ...  37   0   1]
 [  0   2   8 ...   2  19   3]
 [  0   1   1 ...   0   0  98]]
Wall time: 21.1 s
```

Normalise divide by 255 and PCA

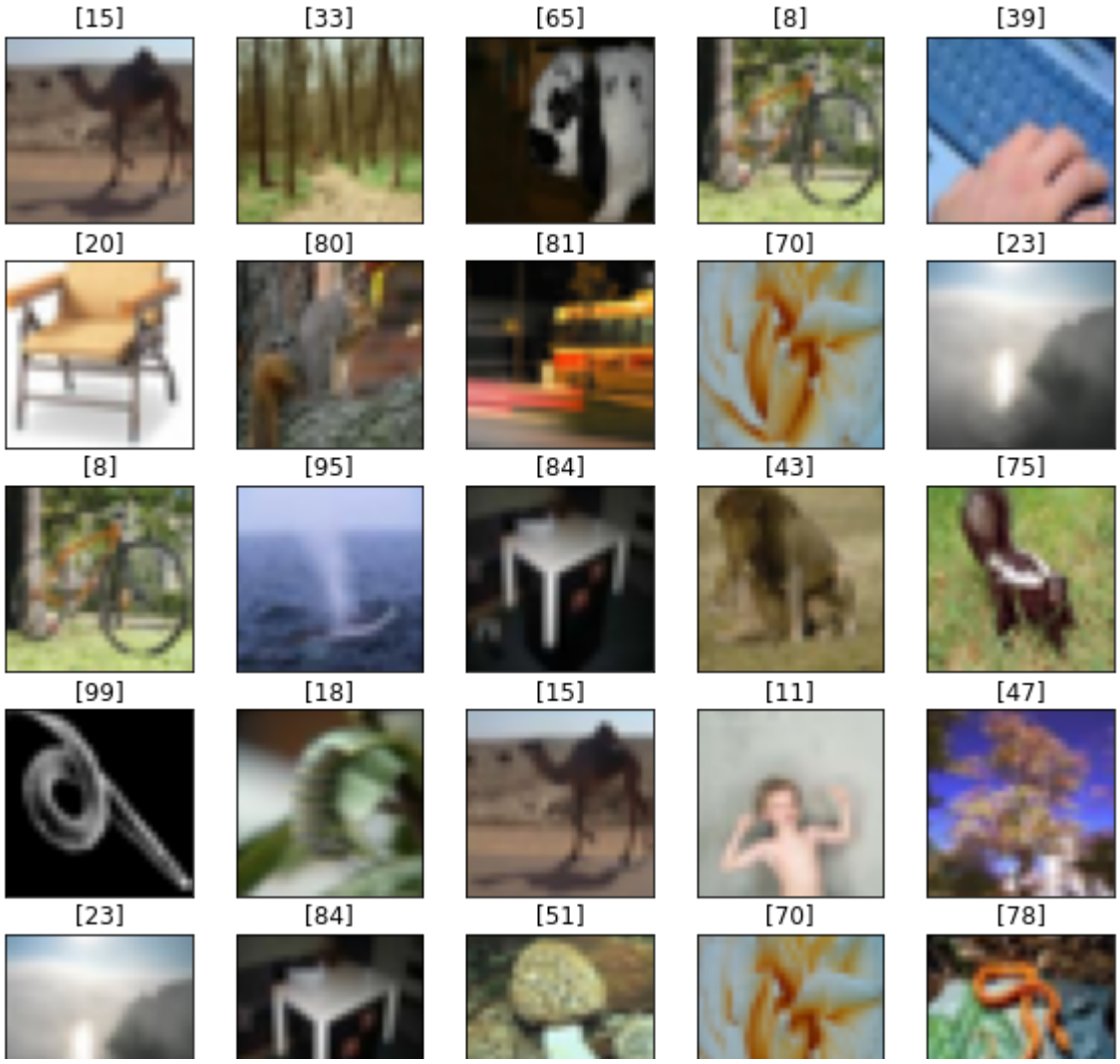
```
# #libraries
# from keras.datasets import cifar100
# import matplotlib.pyplot as plt
# import numpy as np
# from keras.models import Sequential
# from keras.layers.convolutional import Conv2D
# from keras.layers.pooling import MaxPool2D
# from keras.layers.core import Dense,Activation,Dropout,Flatten
# from keras.utils import np_utils

# import tensorflow as tf
# from tensorflow.keras import datasets, layers, models, optimizers
```

```
# # Download dataset of CIFAR-100 (Canadian Institute for Advanced Research)
# (x_train,y_train),(x_test,y_test) = cifar100.load_data()

# #print shapre of training and test dataset
# print('x_train shape:', x_train.shape)
# print('x_test shape:', x_test.shape)
# print('y_train shape:', y_train.shape)
# print('y_test shape:', y_test.shape)

# # print number of data set samples
# print(x_train.shape[0], 'train set')
# print(x_test.shape[0], 'test set')

# # Data type for train and test set
# print(type(x_test))
# print(type(y_test[0]))
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-100-python.tar.gz
169009152/169001437 [==============================] - 2s 0us/step
169017344/169001437 [==============================] - 2s 0us/step
x_train shape: (50000, 32, 32, 3)
x_test shape: (10000, 32, 32, 3)
y_train shape: (50000, 1)
y_test shape: (10000, 1)
50000 train set
10000 test set
<class 'numpy.ndarray'>
<class 'numpy.ndarray'>
```

```
# # Show sample random image 5x5
# plt.figure(figsize=(10,10))
# for i in range(25):
#     rand_num=np.random.randint(0,100)
#     cifar_image=plt.subplot(5,5,i+1)
#     plt.imshow(x_train[rand_num])
#     # Erase the value of x tick and y tick
#     plt.xticks(color="None")
#     plt.yticks(color="None")
#     # remove the tick x-axis and y-axis
#     plt.tick_params(length=0)
#     # print label
#     plt.title(y_train[rand_num])

# plt.show()
```

```
/usr/local/lib/python3.7/dist-packages/matplotlib/text.py:1165: FutureWarning: ele
  if s != self._text:
```




```
# #flipping image
# %%time
# #preprocess test dataset
# from keras.preprocessing.image import ImageDataGenerator
# Datagenerator = ImageDataGenerator()

# x_train1 = Datagenerator.apply_transform(x=x_train, transform_parameters={'flip_horizontal'
# x_test1 = Datagenerator.apply_transform(x=x_test, transform_parameters={'flip_horizontal':T


# x_train = np.concatenate((x_train,x_train1))
# x_test = np.concatenate((x_test,x_test1))
# y_train = np.concatenate((y_train,y_train))
# y_test = np.concatenate((y_test,y_test))


    CPU times: user 147 ms, sys: 161 ms, total: 308 ms
    Wall time: 327 ms


# %%time
```

```
# # Normalize taining and test set image to the range of 0-1
# x_train1 = x_train.astype('float32')/255.0

# x_test1 = x_test.astype('float32')/255.0

# #https://www.kdnuggets.com/2020/05/dataset-splitting-best-practices-python.html
#  # convert the labels of y_train,y_test to One-Hot encoding
# y_train = np_utils.to_categorical(y_train,100)
# y_test = np_utils.to_categorical(y_test,100)
```

```
CPU times: user 322 ms, sys: 509 ms, total: 832 ms
Wall time: 829 ms
```

```
# %%time
# #resize data before clustering
# no_samples, nx, ny, nz = x_train1.shape
# x_train = x_train1.reshape((no_samples,nx*ny*nz))
# no_samples, nx, ny, nz = x_test1.shape
# x_test = x_test1.reshape((no_samples,nx*ny*nz))
```

```
CPU times: user 879 ms, sys: 508 ms, total: 1.39 s
Wall time: 1.4 s
```

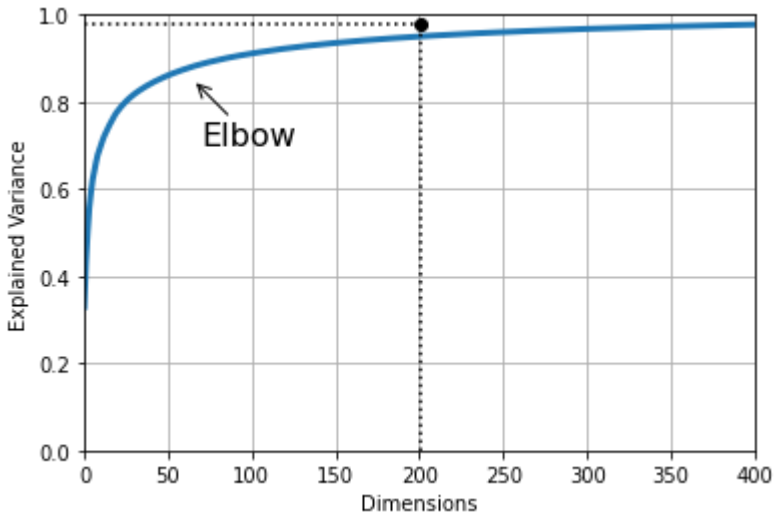
```
# %%time
# #split training into training and validation set
# from sklearn.model_selection import train_test_split
# x_train, x_valid, y_train , y_valid = train_test_split(x_train, y_train,
#                                                        train_size=0.70,
#                                                        random_state=42,
#                                                        stratify=y_train)
```

```
CPU times: user 10.9 s, sys: 1.43 s, total: 12.3 s
Wall time: 11.3 s
```

```
# %%time
# #references lab week 6
# from sklearn.decomposition import PCA
# # Make an instance of the Model
# variance_score = 0.98 #we picked high variance score because the higher the explained varia
# pca_model = PCA()

# pca_model.fit(x_train) #fit the data according to our PCA instance
# cumsum = np.cumsum(pca_model.explained_variance_ratio_)
# d = np.argmax(cumsum >= 0.95) + 1
# print(d)

# print("Number of components before applying PCA  = " + str(x_train1.shape[0]))
# print("Number of components after applying PCA 0.98 = " + str(pca_model.n_components_))
```

```
201
Number of components before applying PCA  = 100000
Number of components after applying PCA 0.98 = 3072
CPU times: user 3min 21s, sys: 5.2 s, total: 3min 26s
Wall time: 1min 48s
```

```
# # Plot explained variance vs number of dimensions
# plt.figure(figsize=(6,4))
# plt.plot(cumsum, linewidth=3)
# plt.axis([0, 400, 0, 1])
# plt.xlabel("Dimensions")
# plt.ylabel("Explained Variance")
# plt.plot([d, d], [0, 0.98], "k:")
# plt.plot([0, d], [0.98, 0.98], "k:")
# plt.plot(d, 0.98, "ko")
# plt.annotate("Elbow", xy=(65, 0.85), xytext=(70, 0.7),
#              arrowprops=dict(arrowstyle="->"), fontsize=16)
# plt.grid(True)
# plt.show()
```




```
# %%time
# x_train_clustered = pca_model.fit_transform(x_train)

# x_valid_clustered = pca_model.transform(x_valid)

# x_test_clustered = pca_model.transform(x_test)
```

```
CPU times: user 3min 49s, sys: 5.18 s, total: 3min 54s
Wall time: 2min 2s
```

```
# %%time
# #reshape
# x_train_clustered = x_train_clustered.reshape(x_train_clustered.shape[0],32,32,3)
# x_valid_clustered = x_valid_clustered.reshape(x_valid_clustered.shape[0],32,32,3)
# x_test_clustered = x_test_clustered.reshape(x_test_clustered.shape[0],32,32,3)
```

```
CPU times: user 26 µs, sys: 1 µs, total: 27 µs
Wall time: 32.7 µs
```

```
# %%time
# # Create Convolution neural network (CNN layer with Dropout)
# model = Sequential()

# model.add(Conv2D(32,(3,3),padding='same',input_shape=(32,32,3)))
# model.add(Activation('relu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('relu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('relu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))

#  #use adam optimiser
# model.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])

# model.summary()

# # Training(Epoch 100 will take over 8 hours using GPU on Google Colab)
# history = model.fit(np.array(x_train_clustered),y_train,batch_size=128,epochs=10,verbose=1)

# # export model into a json file
# json_string = model.to_json()
# open('cifar100_trial1.json',"w").write(json_string)

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn.h5')

# # Evaluate CNN model
# score = model.evaluate(x_valid_clustered,y_valid,verbose=0)
```

```
# print('Test loss:',score[0])
# print('Test accuracy:',score[1])
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 32, 32, 32)        896
_________________________________________________________________
activation (Activation)      (None, 32, 32, 32)        0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 32, 32, 32)        9248
_________________________________________________________________
activation_1 (Activation)    (None, 32, 32, 32)        0
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 16, 16, 32)        0
_________________________________________________________________
dropout (Dropout)            (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 16, 16, 64)        18496
_________________________________________________________________
activation_2 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 16, 16, 64)        36928
_________________________________________________________________
activation_3 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 8, 8, 64)          0
_________________________________________________________________
dropout_1 (Dropout)          (None, 8, 8, 64)          0
_________________________________________________________________
flatten (Flatten)            (None, 4096)              0
_________________________________________________________________
dense (Dense)                (None, 512)               2097664
_________________________________________________________________
activation_4 (Activation)    (None, 512)               0
_________________________________________________________________
dropout_2 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_1 (Dense)              (None, 100)               51300
=================================================================
Total params: 2,214,532
Trainable params: 2,214,532
Non-trainable params: 0
_________________________________________________________________
Epoch 1/10
547/547 [==============================] - 385s 702ms/step - loss: 4.1916 - accuracy:
Epoch 2/10
547/547 [==============================] - 384s 702ms/step - loss: 3.7766 - accuracy:
Epoch 3/10
547/547 [==============================] - 381s 697ms/step - loss: 3.6232 - accuracy:
Epoch 4/10
547/547 [==============================] - 380s 695ms/step - loss: 3.5263 - accuracy:
Epoch 5/10
547/547 [==============================] - 384s 702ms/step - loss: 3.4532 - accuracy:
```

```
Epoch 6/10
547/547 [==============================] - 387s 708ms/step - loss: 3.4004 - accuracy:
Epoch 7/10
547/547 [==============================] - 387s 707ms/step - loss: 3.3534 - accuracy:
Epoch 8/10
547/547 [==============================] - 385s 704ms/step - loss: 3.3208 - accuracy:
```

get test score result

```
# %%time
# from sklearn.metrics import accuracy_score
# y_test_pred = model.predict(x_test_clustered)
# y_test_pred=np.argmax(y_test_pred, axis=1)
# y_test=np.argmax(y_test, axis=1)

# print("CNN feature extraction - accuracy on test set:")
# print(accuracy_score(y_test, y_test_pred))
# from sklearn.metrics import classification_report
# print(classification_report(y_test, y_test_pred))
```

```
CNN feature extraction - accuracy on test set:
0.2313
              precision    recall  f1-score   support

           0       0.56      0.50      0.53       200
           1       0.25      0.38      0.30       200
           2       0.08      0.17      0.11       200
           3       0.15      0.06      0.09       200
           4       0.13      0.07      0.09       200
           5       0.12      0.10      0.10       200
           6       0.22      0.17      0.19       200
           7       0.24      0.28      0.26       200
           8       0.19      0.33      0.24       200
           9       0.42      0.28      0.34       200
          10       0.10      0.04      0.05       200
          11       0.04      0.01      0.02       200
          12       0.31      0.13      0.18       200
          13       0.19      0.10      0.13       200
          14       0.22      0.14      0.18       200
          15       0.12      0.15      0.13       200
          16       0.29      0.22      0.25       200
          17       0.29      0.36      0.32       200
          18       0.28      0.26      0.27       200
          19       0.23      0.03      0.05       200
          20       0.34      0.36      0.35       200
          21       0.22      0.37      0.27       200
          22       0.32      0.17      0.22       200
          23       0.40      0.40      0.40       200
          24       0.30      0.56      0.39       200
          25       0.24      0.07      0.11       200
          26       0.23      0.11      0.15       200
          27       0.13      0.10      0.11       200
          28       0.33      0.16      0.22       200
```

```
29       0.35      0.11      0.17       200
30       0.26      0.34      0.29       200
31       0.13      0.19      0.16       200
32       0.46      0.10      0.16       200
33       0.18      0.34      0.24       200
34       0.12      0.08      0.09       200
35       0.12      0.03      0.05       200
36       0.17      0.33      0.22       200
37       0.11      0.10      0.10       200
38       0.09      0.10      0.10       200
39       0.46      0.36      0.40       200
40       0.25      0.17      0.20       200
41       0.22      0.47      0.30       200
42       0.19      0.38      0.25       200
43       0.22      0.35      0.27       200
44       0.22      0.05      0.08       200
45       0.13      0.12      0.12       200
46       0.15      0.17      0.16       200
47       0.29      0.29      0.29       200
48       0.23      0.41      0.29       200
49       0.25      0.34      0.29       200
50       0.00      0.00      0.00       200
51       0.14      0.12      0.12       200
52       0.29      0.73      0.41       200
53       0.38      0.61      0.47       200
54       0.29      0.51      0.37       200
```

plot confusion matrix

```
# from sklearn.metrics import confusion_matrix


# %%time

# y_test_pred =model.predict(x_test_clustered)
# y_test_pred =np.argmax(y_test_pred, axis=1)

# cm = confusion_matrix(y_test, y_test_pred )
# print(cm)
```

```
[[100   4   2 ...   0   0   0]
 [  0  75   6 ...   1   1   2]
 [  4   3  35 ...   1   6   0]
 ...
 [  0   0   3 ...  45   0   2]
 [  3   4  19 ...   2  10   1]
 [  0   1   1 ...   0   1  60]]
CPU times: user 47.6 s, sys: 779 ms, total: 48.4 s
Wall time: 41 s
```

subsample 10 % of the training , validation and testing data and conduct CP reconstruction , tucker's reconstruction to compress image and compare with original data ands see whether there is improvements

The following code are learned from :
http://tensorly.org/stable/auto_examples/decomposition/plot_image_compression.html

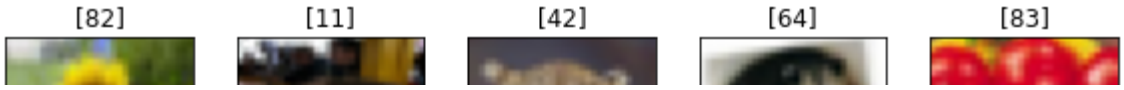
```
# #libraries
# from keras.datasets import cifar100
# import matplotlib.pyplot as plt
# import numpy as np
# from keras.models import Sequential
# from keras.layers.convolutional import Conv2D
# from keras.layers.pooling import MaxPool2D
# from keras.layers.core import Dense,Activation,Dropout,Flatten
# from keras.utils import np_utils

# import tensorflow as tf
# from tensorflow.keras import datasets, layers, models, optimizers

# # Download dataset of CIFAR-100 (Canadian Institute for Advanced Research)
# (x_train,y_train),(x_test,y_test) = cifar100.load_data()

# #print shapre of training and test dataset
# print('x_train shape:', x_train.shape)
# print('x_test shape:', x_test.shape)
# print('y_train shape:', y_train.shape)
# print('y_test shape:', y_test.shape)

# # print number of data set samples
# print(x_train.shape[0], 'train set')
# print(x_test.shape[0], 'test set')

# # Data type for train and test set
# print(type(x_test))
# print(type(y_test[0]))
```

```
x_train shape: (50000, 32, 32, 3)
x_test shape: (10000, 32, 32, 3)
y_train shape: (50000, 1)
y_test shape: (10000, 1)
```

```
50000 train set
10000 test set
<class 'numpy.ndarray'>
<class 'numpy.ndarray'>
```

```
# # Show sample random image 5x5
# plt.figure(figsize=(10,10))
# for i in range(25):
#     rand_num=np.random.randint(0,100)
#     cifar_image=plt.subplot(5,5,i+1)
#     plt.imshow(x_train[rand_num])
#     # Erase the value of x tick and y tick
#     plt.xticks(color="None")
#     plt.yticks(color="None")
#     # remove the tick x-axis and y-axis
#     plt.tick_params(length=0)
#     # print label
#     plt.title(y_train[rand_num])

# plt.show()
```

```
/usr/local/lib/python3.7/dist-packages/matplotlib/text.py:1165: FutureWarning: ele
  if s != self._text:
```




```
# %%time
# #flipping image
# #preprocess test dataset
# from keras.preprocessing.image import ImageDataGenerator
# Datagenerator = ImageDataGenerator()

# x_train1 = Datagenerator.apply_transform(x=x_train, transform_parameters={'flip_horizontal'
# x_test1 = Datagenerator.apply_transform(x=x_test, transform_parameters={'flip_horizontal':T


# x_train = np.concatenate((x_train,x_train1))
# x_test = np.concatenate((x_test,x_test1))
# y_train = np.concatenate((y_train,y_train))
# y_test = np.concatenate((y_test,y_test))
```

```
CPU times: user 105 ms, sys: 96.1 ms, total: 202 ms
Wall time: 210 ms
```

```
# %%time
# # Normalize taining and test set image to the range of 0-1
# x_train = x_train.astype('float32')/255.0
# x_test = x_test.astype('float32')/255.0
```

```
# # convert the labels of y_train,y_test to One-Hot encoding
# y_train = np_utils.to_categorical(y_train,100)
# y_test = np_utils.to_categorical(y_test,100)
```

if you havent install

```
# !pip install tensorly
```

```
Requirement already satisfied: tensorly in /usr/local/lib/python3.7/dist-packages (0.6.
Requirement already satisfied: scipy in /usr/local/lib/python3.7/dist-packages (from te
Requirement already satisfied: numpy in /usr/local/lib/python3.7/dist-packages (from te
Requirement already satisfied: nose in /usr/local/lib/python3.7/dist-packages (from ten
```

```
# from sklearn.model_selection import train_test_split
# x_train, x_valid, y_train , y_valid = train_test_split(x_train, y_train,
```

```
#                                                     train_size=0.70,
#                                                     random_state=42,
#                                                     stratify=y_train)
```

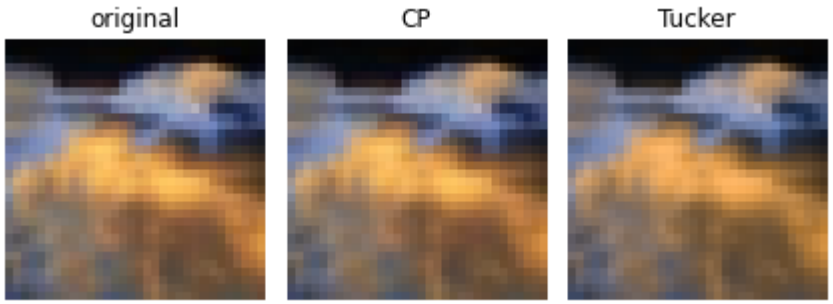
subsampling 10%

```
# %%time

# from sklearn.model_selection import train_test_split
# x_train_sample1, x_train_sample2, y_train_sample1 , y_train_sample2 = train_test_split(x_tr
#                                                     train_size=0.10,
#                                                     random_state=42,
#                                                     stratify=y_train)

# x_valid_sample1, x_valid_sample2, y_valid_sample1 , y_valid_sample2 = train_test_split(x_va
#                                                     train_size=0.10,
#                                                     random_state=42,
#                                                     stratify=y_valid)


# x_test_sample1, x_test_sample2, y_test_sample1 , y_test_sample2 = train_test_split(x_test,
#                                                     train_size=0.10,
#                                                     random_state=42,
#                                                     stratify=y_test)
```

```
CPU times: user 10.1 s, sys: 1.08 s, total: 11.2 s
Wall time: 10.2 s
```

```
# import matplotlib.pyplot as plt
# import tensorly as tl
# import numpy as np
# from scipy.misc import face
# from scipy.ndimage import zoom
# from tensorly.decomposition import parafac
# from tensorly.decomposition import tucker
# from math import ceil


# random_state = 12345

# #image = tl.tensor(zoom(x_train_sample1[1], (0.3, 0.3, 1)), dtype='float64')
# image = np.float64(x_train_sample1[1])
# def to_image(tensor):
#     """A convenience function to convert from a float dtype back to uint8"""
#     img = tl.to_numpy(tensor)
#     img -= img.min()
#     img /= img.max()
#     img *= 255
#     return img.astype(np.uint8)
```

```
# # Rank of the CP decomposition
# cp_ranking = 25
# # Rank of the Tucker decomposition
# tucker_ranking = [100, 100, 2]

# # Perform the CP decomposition
# weights, factors = parafac(image, rank=cp_ranking, init='random', tol=10e-6)
# # Reconstruct the image from the factors
# cp_r = tl.cp_to_tensor((weights, factors))

# # Tucker decomposition
# core, tucker_f = tucker(image, rank=tucker_ranking, init='random', tol=10e-5, random_state=
# tucker_reconstruction = tl.tucker_to_tensor((core, tucker_f))

# # Plotting the original and reconstruction from the decompositions
# fig = plt.figure()
# ax = fig.add_subplot(1, 3, 1)
# ax.set_axis_off()
# ax.imshow(to_image(image))
# ax.set_title('original')

# ax = fig.add_subplot(1, 3, 2)
# ax.set_axis_off()
# ax.imshow(to_image(cp_r))
# ax.set_title('CP')

# ax = fig.add_subplot(1, 3, 3)
# ax.set_axis_off()
# ax.imshow(to_image(tucker_reconstruction))
# ax.set_title('Tucker')

# plt.tight_layout()
# plt.show()
```



cp and tucker decomposition

```
# %%time
# import matplotlib.pyplot as plt
# import tensorly as tl
```

```
# import numpy as np
# from scipy.misc import face
# from scipy.ndimage import zoom
# from tensorly.decomposition import parafac
# from tensorly.decomposition import tucker
# from math import ceil

# x_train_cpr = []
# x_train_t = []
# x_validate_cpr = []
# x_validate_t = []
# x_test_cpr = []
# x_test_t = []

# random_state = 12345

# for i in range(len(x_train_sample1)):
#   #image = tl.tensor(zoom(x_train_sample1[i], (0.3, 0.3, 1)), dtype='float64')
#   image = np.float64(x_train_sample1[i])
#   def to_image(tensor):
#       """A convenience function to convert from a float dtype back to uint8"""
#       img = tl.to_numpy(tensor)
#       img -= img.min()
#       img /= img.max()
#       img *= 255
#       return img.astype(np.uint8)

#   # Rank of the CP decomposition
#   cp_ranking = 25
#   # Rank of the Tucker decomposition
#   tucker_ranking = [100, 100, 2]

#   # Perform the CP decomposition
#   weights, factors = parafac(image, rank=cp_ranking, init='random', tol=10e-6)
#   # Reconstruct the image from the factors
#   cp_r = tl.cp_to_tensor((weights, factors))

#   # Tucker decomposition
#   core, tucker_f = tucker(image, rank=tucker_ranking, init='random', tol=10e-5, random_stat
#   tucker_reconstruction = tl.tucker_to_tensor((core, tucker_f))
#   x_train_cpr.append(cp_r)
#   x_train_t.append(tucker_reconstruction)
```

```
/usr/local/lib/python3.7/dist-packages/tensorly/backend/core.py:910: RuntimeWarning: in
  S = np.where(np.abs(S) <= np.finfo(S.dtype).eps, 0, np.sqrt(S))
/usr/local/lib/python3.7/dist-packages/tensorly/backend/core.py:911: RuntimeWarning: di
  V = np.dot(matrix.T.conj(), U * np.where(np.abs(S) <= np.finfo(S.dtype).eps, 0, 1/S)[
CPU times: user 1h 35min 37s, sys: 1h 18min 12s, total: 2h 53min 49s
Wall time: 1h 28min 24s
```

```
# %%time

# for i in range(len(x_valid_sample1)):
#   #image = tl.tensor(zoom(x_valid_sample1[i], (0.3, 0.3, 1)), dtype='float64')
#   image = np.float64(x_valid_sample1[i])
#   def to_image(tensor):
#       """A convenience function to convert from a float dtype back to uint8"""
#       img = tl.to_numpy(tensor)
#       img -= img.min()
#       img /= img.max()
#       img *= 255
#       return img.astype(np.uint8)

#   # Rank of the CP decomposition
#   cp_ranking = 25
#   # Rank of the Tucker decomposition
#   tucker_ranking = [100, 100, 2]

#   # Perform the CP decomposition
#   weights, factors = parafac(image, rank=cp_ranking, init='random', tol=10e-6)
#   # Reconstruct the image from the factors
#   cp_r = tl.cp_to_tensor((weights, factors))

#   # Tucker decomposition
#   core, tucker_f = tucker(image, rank=tucker_ranking, init='random', tol=10e-5, random_stat
#   tucker_reconstruction = tl.tucker_to_tensor((core, tucker_f))
#   x_validate_cpr.append(cp_r)
#   x_validate_t.append(tucker_reconstruction)



# for i in range(len(x_test_sample1)):
#   #image = tl.tensor(zoom(x_test_sample1[i], (0.3, 0.3, 1)), dtype='float64')
#   image = np.float64(x_test_sample1[i])
#   def to_image(tensor):
#       """A convenience function to convert from a float dtype back to uint8"""
#       img = tl.to_numpy(tensor)
#       img -= img.min()
#       img /= img.max()
#       img *= 255
#       return img.astype(np.uint8)

#   # Rank of the CP decomposition
#   cp_ranking = 25
#   # Rank of the Tucker decomposition
#   tucker_ranking = [100, 100, 2]

#   # Perform the CP decomposition
#   weights, factors = parafac(image, rank=cp_ranking, init='random', tol=10e-6)
#   # Reconstruct the image from the factors
```

```
#   cp_r = tl.cp_to_tensor((weights, factors))

#   # Tucker decomposition
#   core, tucker_f = tucker(image, rank=tucker_ranking, init='random', tol=10e-5, random_stat
#   tucker_reconstruction = tl.tucker_to_tensor((core, tucker_f))
#   x_test_cpr.append(cp_r)
#   x_test_t.append(tucker_reconstruction)
```

```
/usr/local/lib/python3.7/dist-packages/tensorly/backend/core.py:910: RuntimeWarning: in
  S = np.where(np.abs(S) <= np.finfo(S.dtype).eps, 0, np.sqrt(S))
/usr/local/lib/python3.7/dist-packages/tensorly/backend/core.py:911: RuntimeWarning: di
  V = np.dot(matrix.T.conj(), U * np.where(np.abs(S) <= np.finfo(S.dtype).eps, 0, 1/S)[
CPU times: user 1h 6min 32s, sys: 54min 55s, total: 2h 1min 28s
Wall time: 1h 1min 45s
```

```
# x_train_cpr = np.asarray(x_train_cpr)
# x_train_t = np.asarray(x_train_t)
# x_validate_cpr = np.asarray(x_validate_cpr)
# x_validate_t = np.asarray(x_validate_t)
# x_test_cpr = np.asarray(x_test_cpr)
# x_test_t = np.asarray(x_test_t)
```

use CNN as the model to evaluate performance of CP and tucker reconstruction, we will pick to use this method if only it increases the accuracy of the model

test on cpr

```
# %%time
# from tensorflow.keras.optimizers import RMSprop
# # Create Convolution neural network (CNN layer with Dropout)
# model = Sequential()

# model.add(Conv2D(32,(3,3),padding='same',input_shape=(32,32,3)))
# model.add(Activation('elu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('elu'))
```

```
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('elu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))


# #use adam optimiser
# model.compile(optimizer='adam',loss='categorical_crossentropy',metrics=['accuracy'])

# model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_4 (Conv2D)            (None, 32, 32, 32)        896
_________________________________________________________________
activation_5 (Activation)    (None, 32, 32, 32)        0
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 32, 32, 32)        9248
_________________________________________________________________
activation_6 (Activation)    (None, 32, 32, 32)        0
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 16, 16, 32)        0
_________________________________________________________________
dropout_3 (Dropout)          (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 16, 16, 64)        18496
_________________________________________________________________
activation_7 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_7 (Conv2D)            (None, 16, 16, 64)        36928
_________________________________________________________________
activation_8 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 8, 8, 64)          0
_________________________________________________________________
dropout_4 (Dropout)          (None, 8, 8, 64)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 4096)              0
_________________________________________________________________
dense_2 (Dense)              (None, 512)               2097664
_________________________________________________________________
activation_9 (Activation)    (None, 512)               0
_________________________________________________________________
dropout_5 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_3 (Dense)              (None, 100)               51300
```

```
=================================================================
Total params: 2,214,532
Trainable params: 2,214,532
Non-trainable params: 0
_________________________________________________________________
CPU times: user 111 ms, sys: 3.95 ms, total: 115 ms
Wall time: 105 ms
```

```
# %%time
# # Train the model
# epochs = 10
# num_predictions = 20
# batchsize = 128

# for i in range(epochs):
#   print("Epoch {}/{}".format(i+1, epochs))

#   model.fit(x_train_cpr, y_train_sample1,
#             batch_size=batchsize,
#             epochs=1,
#             validation_data=(x_validate_cpr, y_valid_sample1),
#             shuffle=True)


# json_string = model.to_json()
# open('cifar100_trial1CPDecomposition.json',"w").write(json_string)

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn50CPDecomposition.h5')


# model.save('normalcnnCPDecomposition.h5')
```

```
Epoch 1/10
55/55 [==============================] - 40s 712ms/step - loss: 9.1560 - accuracy: 0.00
Epoch 2/10
55/55 [==============================] - 39s 708ms/step - loss: 5.3988 - accuracy: 0.00
Epoch 3/10
55/55 [==============================] - 39s 707ms/step - loss: 5.3191 - accuracy: 0.01
Epoch 4/10
55/55 [==============================] - 39s 711ms/step - loss: 5.1999 - accuracy: 0.01
Epoch 5/10
55/55 [==============================] - 39s 705ms/step - loss: 4.8433 - accuracy: 0.03
Epoch 6/10
55/55 [==============================] - 39s 714ms/step - loss: 4.4041 - accuracy: 0.07
Epoch 7/10
55/55 [==============================] - 39s 716ms/step - loss: 3.9516 - accuracy: 0.12
Epoch 8/10
55/55 [==============================] - 39s 718ms/step - loss: 3.5331 - accuracy: 0.18
Epoch 9/10
55/55 [==============================] - 42s 765ms/step - loss: 3.1843 - accuracy: 0.24
Epoch 10/10
55/55 [==============================] - 39s 711ms/step - loss: 2.8883 - accuracy: 0.29
```

```
CPU times: user 12min 11s, sys: 16.3 s, total: 12min 27s
Wall time: 7min 25s
```

```
# # Evaluate the Model
# evaluate = model.evaluate(x_test_cpr, y_test_sample1, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
63/63 [==============================] - 3s 43ms/step - loss: 3.8656 - accuracy: 0.1545
Model Accuracy: 0.15449999272823334
```

```
# # Evaluate the Model
# evaluate = model.evaluate(x_validate_cpr, y_valid_sample1, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
94/94 [==============================] - 4s 45ms/step - loss: 3.7979 - accuracy: 0.1570
Model Accuracy: 0.15700000524520874
```

test on tucker decomposition

```
# %%time
# from tensorflow.keras.optimizers import RMSprop
# # Create Convolution neural network (CNN layer with Dropout)
# model = Sequential()

# model.add(Conv2D(32,(3,3),padding='same',input_shape=(32,32,3)))
# model.add(Activation('elu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('elu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))
```

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

# model.summary()
```

```
Model: "sequential_3"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_12 (Conv2D)           (None, 32, 32, 32)        896
_________________________________________________________________
activation_15 (Activation)   (None, 32, 32, 32)        0
_________________________________________________________________
conv2d_13 (Conv2D)           (None, 32, 32, 32)        9248
_________________________________________________________________
activation_16 (Activation)   (None, 32, 32, 32)        0
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 16, 16, 32)        0
_________________________________________________________________
dropout_9 (Dropout)          (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_14 (Conv2D)           (None, 16, 16, 64)        18496
_________________________________________________________________
activation_17 (Activation)   (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_15 (Conv2D)           (None, 16, 16, 64)        36928
_________________________________________________________________
activation_18 (Activation)   (None, 16, 16, 64)        0
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 8, 8, 64)          0
_________________________________________________________________
dropout_10 (Dropout)         (None, 8, 8, 64)          0
_________________________________________________________________
flatten_3 (Flatten)          (None, 4096)              0
_________________________________________________________________
dense_6 (Dense)              (None, 512)               2097664
_________________________________________________________________
activation_19 (Activation)   (None, 512)               0
_________________________________________________________________
dropout_11 (Dropout)         (None, 512)               0
_________________________________________________________________
dense_7 (Dense)              (None, 100)               51300
=================================================================
Total params: 2,214,532
Trainable params: 2,214,532
Non-trainable params: 0
_________________________________________________________________
CPU times: user 166 ms, sys: 27.4 ms, total: 193 ms
Wall time: 158 ms
```

```
# %%time
# # Train the model
```

```
# epochs = 10
# num_predictions = 20
# batchsize = 128

# for i in range(epochs):
#   print("Epoch {}/{}".format(i+1, epochs))

#   model.fit(x_train_t, y_train_sample1,
#             batch_size=batchsize,
#             epochs=1,
#             validation_data=(x_validate_t, y_valid_sample1),
#             shuffle=True)


# json_string = model.to_json()
# open('cifar100_trial150epochfollowingseniorELUDECOMPOSITIONTUCKER.json',"w").write(json_str

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn50epochfollowingseniorrELUDECOMPOSITIONTUCKER.h5')


# model.save('normalcnn50epochfollowingseniorrELUDECOMPOSITIONTUCKER.h5')
```

```
Epoch 1/10
55/55 [==============================] - 38s 685ms/step - loss: 10.0878 - accuracy: 0.0
Epoch 2/10
55/55 [==============================] - 37s 683ms/step - loss: 5.1436 - accuracy: 0.01
Epoch 3/10
55/55 [==============================] - 38s 682ms/step - loss: 4.7722 - accuracy: 0.03
Epoch 4/10
55/55 [==============================] - 38s 686ms/step - loss: 4.4094 - accuracy: 0.06
Epoch 5/10
55/55 [==============================] - 38s 691ms/step - loss: 4.0367 - accuracy: 0.10
Epoch 6/10
55/55 [==============================] - 39s 716ms/step - loss: 3.6940 - accuracy: 0.15
Epoch 7/10
55/55 [==============================] - 39s 703ms/step - loss: 3.4397 - accuracy: 0.19
Epoch 8/10
55/55 [==============================] - 39s 707ms/step - loss: 3.0753 - accuracy: 0.25
Epoch 9/10
55/55 [==============================] - 39s 707ms/step - loss: 2.8579 - accuracy: 0.29
Epoch 10/10
55/55 [==============================] - 38s 696ms/step - loss: 2.5387 - accuracy: 0.35
CPU times: user 12min 2s, sys: 14.3 s, total: 12min 16s
Wall time: 6min 35s
```

```
# # Evaluate the Model

# evaluate = model.evaluate(x_test_t, y_test_sample1, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
63/63 [==============================] - 3s 44ms/step - loss: 4.2408 - accuracy: 0.1545
Model Accuracy: 0.15449999272823334
```

```
# # Evaluate the Model
# evaluate = model.evaluate(x_validate_t, y_valid_sample1, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
94/94 [==============================] - 4s 43ms/step - loss: 4.1902 - accuracy: 0.1527
Model Accuracy: 0.15266667306423187
```

compare with original data

```
# #libraries
# from keras.datasets import cifar100
# import matplotlib.pyplot as plt
# import numpy as np
# from keras.models import Sequential
# from keras.layers.convolutional import Conv2D
# from keras.layers.pooling import MaxPool2D
# from keras.layers.core import Dense,Activation,Dropout,Flatten
# from keras.utils import np_utils

# import tensorflow as tf
# from tensorflow.keras import datasets, layers, models, optimizers

# # Download dataset of CIFAR-100 (Canadian Institute for Advanced Research)
# (x_train,y_train),(x_test,y_test) = cifar100.load_data()

# #print shapre of training and test dataset
# print('x_train shape:', x_train.shape)
# print('x_test shape:', x_test.shape)
# print('y_train shape:', y_train.shape)
# print('y_test shape:', y_test.shape)

# # print number of data set samples
# print(x_train.shape[0], 'train set')
# print(x_test.shape[0], 'test set')

# # Data type for train and test set
# print(type(x_test))
# print(type(y_test[0]))
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-100-python.tar.gz
```

```
169009152/169001437 [==============================] - 2s 0us/step
169017344/169001437 [==============================] - 2s 0us/step
x_train shape: (50000, 32, 32, 3)
x_test shape: (10000, 32, 32, 3)
y_train shape: (50000, 1)
y_test shape: (10000, 1)
50000 train set
10000 test set
<class 'numpy.ndarray'>
<class 'numpy.ndarray'>
```

```
# # Show sample random image 5x5
# plt.figure(figsize=(10,10))
# for i in range(25):
#     rand_num=np.random.randint(0,100)
#     cifar_image=plt.subplot(5,5,i+1)
#     plt.imshow(x_train[rand_num])
#     # Erase the value of x tick and y tick
#     plt.xticks(color="None")
#     plt.yticks(color="None")
#     # remove the tick x-axis and y-axis
#     plt.tick_params(length=0)
#     # print label
#     plt.title(y_train[rand_num])

# plt.show()
```

```
/usr/local/lib/python3.7/dist-packages/matplotlib/text.py:1165: FutureWarning: ele
  if s != self._text:
```


```
# %%time
# #flipping image
# #preprocess test dataset
# from keras.preprocessing.image import ImageDataGenerator
# Datagenerator = ImageDataGenerator()

# x_train1 = Datagenerator.apply_transform(x=x_train, transform_parameters={'flip_horizontal'
# x_test1 = Datagenerator.apply_transform(x=x_test, transform_parameters={'flip_horizontal':T


# x_train = np.concatenate((x_train,x_train1))
# x_test = np.concatenate((x_test,x_test1))
# y_train = np.concatenate((y_train,y_train))
# y_test = np.concatenate((y_test,y_test))
```

```
CPU times: user 88.8 ms, sys: 103 ms, total: 191 ms
Wall time: 199 ms
```

```
%%time
# Normalize taining and test set image to the range of 0-1
x_train = x_train.astype('float32')/255.0
x_test = x_test.astype('float32')/255.0




# # convert the labels of y_train,y_test to One-Hot encoding
# y_train = np_utils.to_categorical(y_train,100)
# y_test = np_utils.to_categorical(y_test,100)


# from sklearn.model_selection import train_test_split
# x_train, x_valid, y_train , y_valid = train_test_split(x_train, y_train,
#                                                        train_size=0.70,
#                                                        random_state=42,
#                                                        stratify=y_train)
```

subsampling 10% of training, validation and testing data

```
# %%time

# from sklearn.model_selection import train_test_split
# x_train_sample1, x_train_sample2, y_train_sample1 , y_train_sample2 = train_test_split(x_tr
#                                                     train_size=0.10,
#                                                     random_state=42,
#                                                     stratify=y_train)

# x_valid_sample1, x_valid_sample2, y_valid_sample1 , y_valid_sample2 = train_test_split(x_va
#                                                     train_size=0.10,
#                                                     random_state=42,
#                                                     stratify=y_valid)


# x_test_sample1, x_test_sample2, y_test_sample1 , y_test_sample2 = train_test_split(x_test,
#                                                     train_size=0.10,
#                                                     random_state=42,
#                                                     stratify=y_test)
```

```
CPU times: user 12.6 s, sys: 990 ms, total: 13.6 s
Wall time: 11.9 s
```

```
# %%time
# from tensorflow.keras.optimizers import RMSprop
# # Create Convolution neural network (CNN layer with Dropout)
# model = Sequential()

# model.add(Conv2D(32,(3,3),padding='same',input_shape=(32,32,3)))
# model.add(Activation('elu'))
# model.add(Conv2D(32,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(Conv2D(64,(3,3),padding='same'))
# model.add(Activation('elu'))
# model.add(MaxPool2D(pool_size=(2,2)))
# model.add(Dropout(0.25))

# model.add(Flatten())
# model.add(Dense(512))
# model.add(Activation('elu'))
# model.add(Dropout(0.5))
# model.add(Dense(100,activation='softmax'))


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

```
# model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 32, 32, 32)        896
_________________________________________________________________
activation (Activation)      (None, 32, 32, 32)        0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 32, 32, 32)        9248
_________________________________________________________________
activation_1 (Activation)    (None, 32, 32, 32)        0
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 16, 16, 32)        0
_________________________________________________________________
dropout (Dropout)            (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 16, 16, 64)        18496
_________________________________________________________________
activation_2 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 16, 16, 64)        36928
_________________________________________________________________
activation_3 (Activation)    (None, 16, 16, 64)        0
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 8, 8, 64)          0
_________________________________________________________________
dropout_1 (Dropout)          (None, 8, 8, 64)          0
_________________________________________________________________
flatten (Flatten)            (None, 4096)              0
_________________________________________________________________
dense (Dense)                (None, 512)               2097664
_________________________________________________________________
activation_4 (Activation)    (None, 512)               0
_________________________________________________________________
dropout_2 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_1 (Dense)              (None, 100)               51300
=================================================================
Total params: 2,214,532
Trainable params: 2,214,532
Non-trainable params: 0
_________________________________________________________________
CPU times: user 154 ms, sys: 23.9 ms, total: 178 ms
Wall time: 423 ms
```

```
# %%time
# # Train the model
# epochs = 10
# num_predictions = 20
# batchsize = 128

# for i in range(epochs):
```

```
#   print("Epoch {}/{}".format(i+1, epochs))

#   model.fit(x_train_sample1, y_train_sample1,
#             batch_size=batchsize,
#             epochs=1,
#             validation_data=(x_valid_sample1, y_valid_sample1),
#             shuffle=True)


# json_string = model.to_json()
# open('cifar100_trial150epochfollowingseniorNODECOMPOSITION.json',"w").write(json_string)

# # export model weight to a h5 file
# model.save_weights('cifar100_cnn50epochfollowingseniorNODECOMPOSITION.h5')


# model.save('normalcnn50epochfollowingseniorNODECOMPOSITION.h5')
```

```
Epoch 1/10
55/55 [==============================] - 45s 806ms/step - loss: 8.5262 - accuracy: 0.01
Epoch 2/10
55/55 [==============================] - 44s 796ms/step - loss: 4.9307 - accuracy: 0.02
Epoch 3/10
55/55 [==============================] - 44s 809ms/step - loss: 4.3854 - accuracy: 0.06
Epoch 4/10
55/55 [==============================] - 45s 810ms/step - loss: 3.9876 - accuracy: 0.10
Epoch 5/10
55/55 [==============================] - 45s 813ms/step - loss: 3.6838 - accuracy: 0.15
Epoch 6/10
55/55 [==============================] - 44s 804ms/step - loss: 3.4057 - accuracy: 0.20
Epoch 7/10
55/55 [==============================] - 44s 809ms/step - loss: 3.1115 - accuracy: 0.24
Epoch 8/10
55/55 [==============================] - 44s 801ms/step - loss: 2.8365 - accuracy: 0.30
Epoch 9/10
55/55 [==============================] - 44s 796ms/step - loss: 2.5631 - accuracy: 0.35
Epoch 10/10
55/55 [==============================] - 44s 802ms/step - loss: 2.3520 - accuracy: 0.39
CPU times: user 13min 50s, sys: 13.1 s, total: 14min 3s
Wall time: 13min 41s
```

```
# # Evaluate the Model
# evaluate = model.evaluate(x_test_sample1, y_test_sample1, verbose=1)
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
63/63 [==============================] - 3s 53ms/step - loss: 4.1561 - accuracy: 0.1700
Model Accuracy: 0.17000000178813934
```

```
# # Evaluate the Model
# evaluate = model.evaluate(x_valid_sample1, y_valid_sample1, verbose=1)
```

```
# print("Model Accuracy: {}".format(evaluate[1]))
```

```
94/94 [==============================] - 5s 52ms/step - loss: 4.0825 - accuracy: 0.1640
Model Accuracy: 0.164000004529953
```