In [ ]:

```
import numpy as np
```

In [ ]:

```
import tensorflow as tf
```

**Data loading from csv file**

In [ ]:

```
with open("/content/drive/MyDrive/Colab Notebooks/dataset2/fer2013.csv") as f:
      content = f.readlines()

lines = np.array(content)
```

In [ ]:

```
num_of_instances = lines.size
print("number of instances: ",num_of_instances)
print("instance length: ",len(lines[1].split(",")[1].split(" ")))
```

```
number of instances:  35888
instance length:  2304
```

In [ ]:

```
num_classes = 7 #angry, disgust, fear, happy, sad, surprise, neutral
```

In [ ]:

```
x_train, y_train, x_test, y_test = [], [], [], []
```

In [ ]:

```
for i in range(1,num_of_instances):
  emotion, img, usage = lines[i].split(",")
  val = img.split(" ")
  pixels = np.array(val, 'float32')
  emotion = tf.keras.utils.to_categorical(emotion, num_classes)
  if 'Training' in usage:
    y_train.append(emotion)
    x_train.append(pixels)
  elif 'PublicTest' in usage:
    y_test.append(emotion)
    x_test.append(pixels)
```

In [ ]:

```
x_train = np.array(x_train, 'float32')
y_train = np.array(y_train, 'float32')
x_test = np.array(x_test, 'float32')
y_test = np.array(y_test, 'float32')
```

In [ ]:

```
x_train /= 255 #normalize inputs between [0, 1]
x_test /= 255

x_train = x_train.reshape(x_train.shape[0], 48, 48, 1)
x_train = x_train.astype('float32')
x_test = x_test.reshape(x_test.shape[0], 48, 48, 1)
x_test = x_test.astype('float32')
```

**Checking Dims**

In [ ]:

```
print(x_train.shape)
print(y_train.shape)
print(x_test.shape)
print(y_test.shape)
```

```
(28709, 48, 48, 1)
(28709, 7)
(3589, 48, 48, 1)
(3589, 7)
```

**Weigths initializer**

not used

In [ ]:

```
#initializer = tf.keras.initializers.RandomNormal(mean=0., stddev=0.00001, seed=1234646445567576789)
```

**vgg16 Model**

In [ ]:

```
# Build the model
emo_model = tf.keras.Sequential([
  tf.keras.layers.Conv2D(64,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.re
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Conv2D(64,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.re
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.MaxPool2D(pool_size =2, strides =2, padding ='same'),
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Conv2D(128,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.r
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Conv2D(128,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.r
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.MaxPool2D(pool_size =2, strides =2, padding ='same'),
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Conv2D(256,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.r
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Conv2D(256,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.r
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Conv2D(256,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.r
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.MaxPool2D(pool_size =2, strides =2, padding ='same'),
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Conv2D(512,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.r
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Conv2D(512,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.r
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Conv2D(512,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.r
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.MaxPool2D(pool_size =2, strides =2, padding ='same'),
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Conv2D(512,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.r
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Conv2D(512,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.r
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Conv2D(512,kernel_size =3, activation='relu', padding ='same', kernel_regularizer=tf.keras.r
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.MaxPool2D(pool_size =2, strides =2, padding ='same'),
  tf.keras.layers.BatchNormalization(),
  tf.keras.layers.Flatten(),
  tf.keras.layers.Dense(units = 4096, activation ='relu', kernel_initializer='he_normal'),
  tf.keras.layers.Dropout(0.5),
  tf.keras.layers.Dense(units = 4096, activation ='relu', kernel_initializer='he_normal'),
  tf.keras.layers.Dropout(0.5),
  tf.keras.layers.Dense(units = 1000, activation ='relu', kernel_initializer='he_normal'),
  tf.keras.layers.Dense(units = 7, activation ='softmax')
  ])
```

In [ ]:

```
emo_model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 48, 48, 64)        640
_________________________________________________________________
batch_normalization (BatchNo (None, 48, 48, 64)        256
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 48, 48, 64)        36928
_________________________________________________________________
batch_normalization_1 (Batch (None, 48, 48, 64)        256
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 24, 24, 64)        0
```

| | | |
|---|---|---|
| batch_normalization_2 (Batch | (None, 24, 24, 64) | 256 |
| conv2d_2 (Conv2D) | (None, 24, 24, 128) | 73856 |
| batch_normalization_3 (Batch | (None, 24, 24, 128) | 512 |
| conv2d_3 (Conv2D) | (None, 24, 24, 128) | 147584 |
| batch_normalization_4 (Batch | (None, 24, 24, 128) | 512 |
| max_pooling2d_1 (MaxPooling2 | (None, 12, 12, 128) | 0 |
| batch_normalization_5 (Batch | (None, 12, 12, 128) | 512 |
| conv2d_4 (Conv2D) | (None, 12, 12, 256) | 295168 |
| batch_normalization_6 (Batch | (None, 12, 12, 256) | 1024 |
| conv2d_5 (Conv2D) | (None, 12, 12, 256) | 590080 |
| batch_normalization_7 (Batch | (None, 12, 12, 256) | 1024 |
| conv2d_6 (Conv2D) | (None, 12, 12, 256) | 590080 |
| batch_normalization_8 (Batch | (None, 12, 12, 256) | 1024 |
| max_pooling2d_2 (MaxPooling2 | (None, 6, 6, 256) | 0 |
| batch_normalization_9 (Batch | (None, 6, 6, 256) | 1024 |
| conv2d_7 (Conv2D) | (None, 6, 6, 512) | 1180160 |
| batch_normalization_10 (Batc | (None, 6, 6, 512) | 2048 |
| conv2d_8 (Conv2D) | (None, 6, 6, 512) | 2359808 |
| batch_normalization_11 (Batc | (None, 6, 6, 512) | 2048 |
| conv2d_9 (Conv2D) | (None, 6, 6, 512) | 2359808 |
| batch_normalization_12 (Batc | (None, 6, 6, 512) | 2048 |
| max_pooling2d_3 (MaxPooling2 | (None, 3, 3, 512) | 0 |
| batch_normalization_13 (Batc | (None, 3, 3, 512) | 2048 |
| conv2d_10 (Conv2D) | (None, 3, 3, 512) | 2359808 |
| batch_normalization_14 (Batc | (None, 3, 3, 512) | 2048 |
| conv2d_11 (Conv2D) | (None, 3, 3, 512) | 2359808 |
| batch_normalization_15 (Batc | (None, 3, 3, 512) | 2048 |
| conv2d_12 (Conv2D) | (None, 3, 3, 512) | 2359808 |
| batch_normalization_16 (Batc | (None, 3, 3, 512) | 2048 |
| max_pooling2d_4 (MaxPooling2 | (None, 2, 2, 512) | 0 |
| batch_normalization_17 (Batc | (None, 2, 2, 512) | 2048 |
| flatten (Flatten) | (None, 2048) | 0 |
| dense (Dense) | (None, 4096) | 8392704 |
| dropout (Dropout) | (None, 4096) | 0 |
| dense_1 (Dense) | (None, 4096) | 16781312 |
| dropout_1 (Dropout) | (None, 4096) | 0 |
| dense_2 (Dense) | (None, 1000) | 4097000 |
| dense_3 (Dense) | (None, 7) | 7007 |

```
Total params: 44,014,343
Trainable params: 44,002,951
Non-trainable params: 11,392
_________________________________________________________________
```

**Input Output test**

In [ ]:

```
predictions = emo_model(x_train[1:2]).numpy()
print(predictions)
```

```
[[0.14290261 0.14285195 0.1429394  0.14268515 0.14284706 0.14280333
  0.14297047]]
```

**Learning rate decay**

not used

In [ ]:

```
#lr_schedule = tf.keras.optimizers.schedules.ExponentialDecay(initial_learning_rate=0.1,decay_steps=100,decay_
```

**Optimizer Loss Function and Metrics**

In [ ]:

```
sgd = tf.keras.optimizers.SGD(
    learning_rate=0.0001, momentum=0.85, nesterov=True
)
loss_fn = tf.keras.losses.CategoricalCrossentropy(from_logits=True)
```

**Compiling**

In [ ]:

```
emo_model.compile(optimizer=sgd,
              loss=loss_fn,
              metrics=['accuracy'])
```

**Checkpoints**

In [ ]:

```
checkpoint_path = "/content/drive/MyDrive/Colab Notebooks/checkpoints/model5/cp.ckpt"

cp_callback = tf.keras.callbacks.ModelCheckpoint(filepath=checkpoint_path,monitor='accuracy', save_freq= 'epoc
```

**Data Augmentation**

In [ ]:

```
##### Include Little Data Augmentation
batch_size = 113 # try several values

train_DataGen = tf.keras.preprocessing.image.ImageDataGenerator(zoom_range=0.2,
                                                                width_shift_range=0.1,
                                                                height_shift_range = 0.1,
                                                                horizontal_flip=True)
train_set_conv = train_DataGen.flow(x_train, y_train, batch_size=batch_size) # train_lab is categorical
```

**Running ...**

last 30 epoch

In [ ]:

```
#history = emo_model.fit(train_set_conv,batch_size=batch_size,callbacks=[cp_callback] ,shuffle = True)
history = emo_model.fit(train_set_conv,epochs=30,steps_per_epoch=x_train.shape[0]/batch_size,validation_data=
```

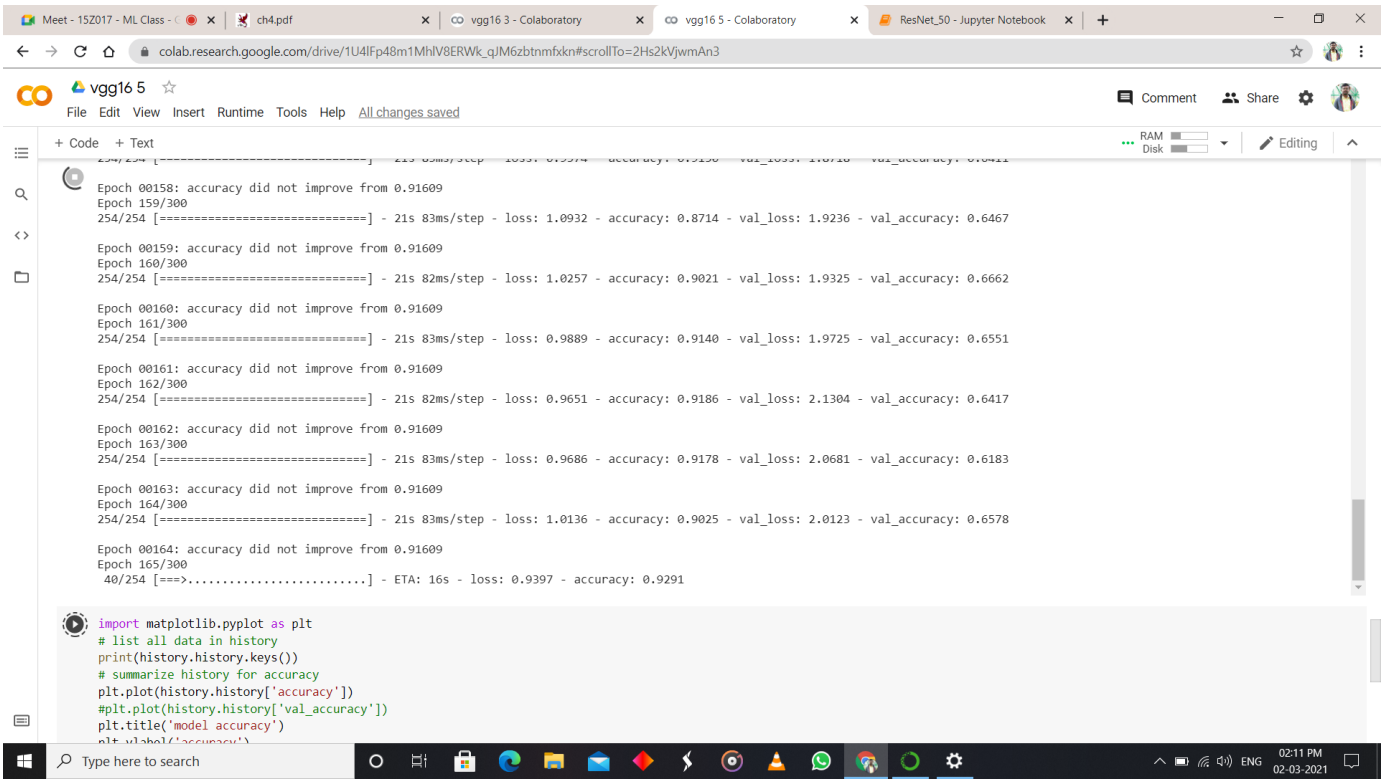
```
Epoch 1/30
254/254 [==============================] - 20s 78ms/step - loss: 0.5493 - accuracy: 0.9879 - val_loss: 2.5386
- val_accuracy: 0.6913

Epoch 00001: accuracy did not improve from 0.98823
Epoch 2/30
254/254 [==============================] - 20s 78ms/step - loss: 0.5491 - accuracy: 0.9875 - val_loss: 2.5364
- val_accuracy: 0.6910

Epoch 00002: accuracy did not improve from 0.98823
Epoch 3/30
254/254 [==============================] - 20s 78ms/step - loss: 0.5495 - accuracy: 0.9884 - val_loss: 2.5354
- val_accuracy: 0.6904
```

```
Epoch 00003: accuracy improved from 0.98823 to 0.98844, saving model to /content/drive/MyDrive/Colab Notebooks
/checkpoints/model5/cp.ckpt
Epoch 4/30
254/254 [==============================] - 21s 82ms/step - loss: 0.5474 - accuracy: 0.9886 - val_loss: 2.5387
- val_accuracy: 0.6910

Epoch 00004: accuracy improved from 0.98844 to 0.98861, saving model to /content/drive/MyDrive/Colab Notebooks
/checkpoints/model5/cp.ckpt
Epoch 5/30
254/254 [==============================] - 21s 82ms/step - loss: 0.5472 - accuracy: 0.9888 - val_loss: 2.5371
- val_accuracy: 0.6910

Epoch 00005: accuracy improved from 0.98861 to 0.98878, saving model to /content/drive/MyDrive/Colab Notebooks
/checkpoints/model5/cp.ckpt
Epoch 6/30
254/254 [==============================] - 21s 83ms/step - loss: 0.5472 - accuracy: 0.9885 - val_loss: 2.5446
- val_accuracy: 0.6924

Epoch 00006: accuracy did not improve from 0.98878
Epoch 7/30
254/254 [==============================] - 20s 79ms/step - loss: 0.5471 - accuracy: 0.9880 - val_loss: 2.5409
- val_accuracy: 0.6930

Epoch 00007: accuracy did not improve from 0.98878
Epoch 8/30
254/254 [==============================] - 20s 79ms/step - loss: 0.5450 - accuracy: 0.9890 - val_loss: 2.5496
- val_accuracy: 0.6910

Epoch 00008: accuracy improved from 0.98878 to 0.98899, saving model to /content/drive/MyDrive/Colab Notebooks
/checkpoints/model5/cp.ckpt
Epoch 9/30
254/254 [==============================] - 21s 83ms/step - loss: 0.5440 - accuracy: 0.9889 - val_loss: 2.5501
- val_accuracy: 0.6896

Epoch 00009: accuracy did not improve from 0.98899
Epoch 10/30
254/254 [==============================] - 20s 80ms/step - loss: 0.5472 - accuracy: 0.9880 - val_loss: 2.5509
- val_accuracy: 0.6913

Epoch 00010: accuracy did not improve from 0.98899
Epoch 11/30
254/254 [==============================] - 20s 79ms/step - loss: 0.5449 - accuracy: 0.9884 - val_loss: 2.5505
- val_accuracy: 0.6921

Epoch 00011: accuracy did not improve from 0.98899
Epoch 12/30
254/254 [==============================] - 20s 80ms/step - loss: 0.5444 - accuracy: 0.9883 - val_loss: 2.5535
- val_accuracy: 0.6924

Epoch 00012: accuracy did not improve from 0.98899
Epoch 13/30
254/254 [==============================] - 20s 80ms/step - loss: 0.5434 - accuracy: 0.9887 - val_loss: 2.5627
- val_accuracy: 0.6930

Epoch 00013: accuracy did not improve from 0.98899
Epoch 14/30
254/254 [==============================] - 20s 79ms/step - loss: 0.5439 - accuracy: 0.9881 - val_loss: 2.5653
- val_accuracy: 0.6916

Epoch 00014: accuracy did not improve from 0.98899
Epoch 15/30
254/254 [==============================] - 20s 79ms/step - loss: 0.5428 - accuracy: 0.9884 - val_loss: 2.5677
- val_accuracy: 0.6932

Epoch 00015: accuracy did not improve from 0.98899
Epoch 16/30
254/254 [==============================] - 20s 79ms/step - loss: 0.5416 - accuracy: 0.9888 - val_loss: 2.5646
- val_accuracy: 0.6907

Epoch 00016: accuracy did not improve from 0.98899
Epoch 17/30
254/254 [==============================] - 20s 79ms/step - loss: 0.5418 - accuracy: 0.9885 - val_loss: 2.5652
- val_accuracy: 0.6896

Epoch 00017: accuracy did not improve from 0.98899
Epoch 18/30
254/254 [
```

```
254/254 [==============================] - 20s 80ms/step - loss: 0.5421 - accuracy: 0.9889 - val_loss: 2.5622
- val_accuracy: 0.6888

Epoch 00018: accuracy did not improve from 0.98899
Epoch 19/30
254/254 [==============================] - 20s 80ms/step - loss: 0.5417 - accuracy: 0.9887 - val_loss: 2.5604
- val_accuracy: 0.6916

Epoch 00019: accuracy did not improve from 0.98899
Epoch 20/30
254/254 [==============================] - 20s 80ms/step - loss: 0.5397 - accuracy: 0.9889 - val_loss: 2.5659
- val_accuracy: 0.6927

Epoch 00020: accuracy did not improve from 0.98899
Epoch 21/30
254/254 [==============================] - 21s 81ms/step - loss: 0.5413 - accuracy: 0.9884 - val_loss: 2.5648
- val_accuracy: 0.6924

Epoch 00021: accuracy did not improve from 0.98899
Epoch 22/30
254/254 [==============================] - 20s 78ms/step - loss: 0.5391 - accuracy: 0.9895 - val_loss: 2.5710
- val_accuracy: 0.6932

Epoch 00022: accuracy improved from 0.98899 to 0.98952, saving model to /content/drive/MyDrive/Colab Notebooks
/checkpoints/model5/cp.ckpt
Epoch 23/30
254/254 [==============================] - 21s 83ms/step - loss: 0.5389 - accuracy: 0.9887 - val_loss: 2.5733
- val_accuracy: 0.6938

Epoch 00023: accuracy did not improve from 0.98952
Epoch 24/30
254/254 [==============================] - 20s 78ms/step - loss: 0.5399 - accuracy: 0.9883 - val_loss: 2.5703
- val_accuracy: 0.6932

Epoch 00024: accuracy did not improve from 0.98952
Epoch 25/30
254/254 [==============================] - 20s 79ms/step - loss: 0.5391 - accuracy: 0.9886 - val_loss: 2.5571
- val_accuracy: 0.6932

Epoch 00025: accuracy did not improve from 0.98952
Epoch 26/30
254/254 [==============================] - 20s 78ms/step - loss: 0.5393 - accuracy: 0.9885 - val_loss: 2.5690
- val_accuracy: 0.6918

Epoch 00026: accuracy did not improve from 0.98952
Epoch 27/30
254/254 [==============================] - 20s 79ms/step - loss: 0.5384 - accuracy: 0.9886 - val_loss: 2.5758
- val_accuracy: 0.6907

Epoch 00027: accuracy did not improve from 0.98952
Epoch 28/30
254/254 [==============================] - 20s 79ms/step - loss: 0.5390 - accuracy: 0.9885 - val_loss: 2.5783
- val_accuracy: 0.6930

Epoch 00028: accuracy did not improve from 0.98952
Epoch 29/30
254/254 [==============================] - 20s 79ms/step - loss: 0.5370 - accuracy: 0.9887 - val_loss: 2.5797
- val_accuracy: 0.6938

Epoch 00029: accuracy did not improve from 0.98952
Epoch 30/30
254/254 [==============================] - 20s 78ms/step - loss: 0.5366 - accuracy: 0.9889 - val_loss: 2.5911
- val_accuracy: 0.6916

Epoch 00030: accuracy did not improve from 0.98952
```

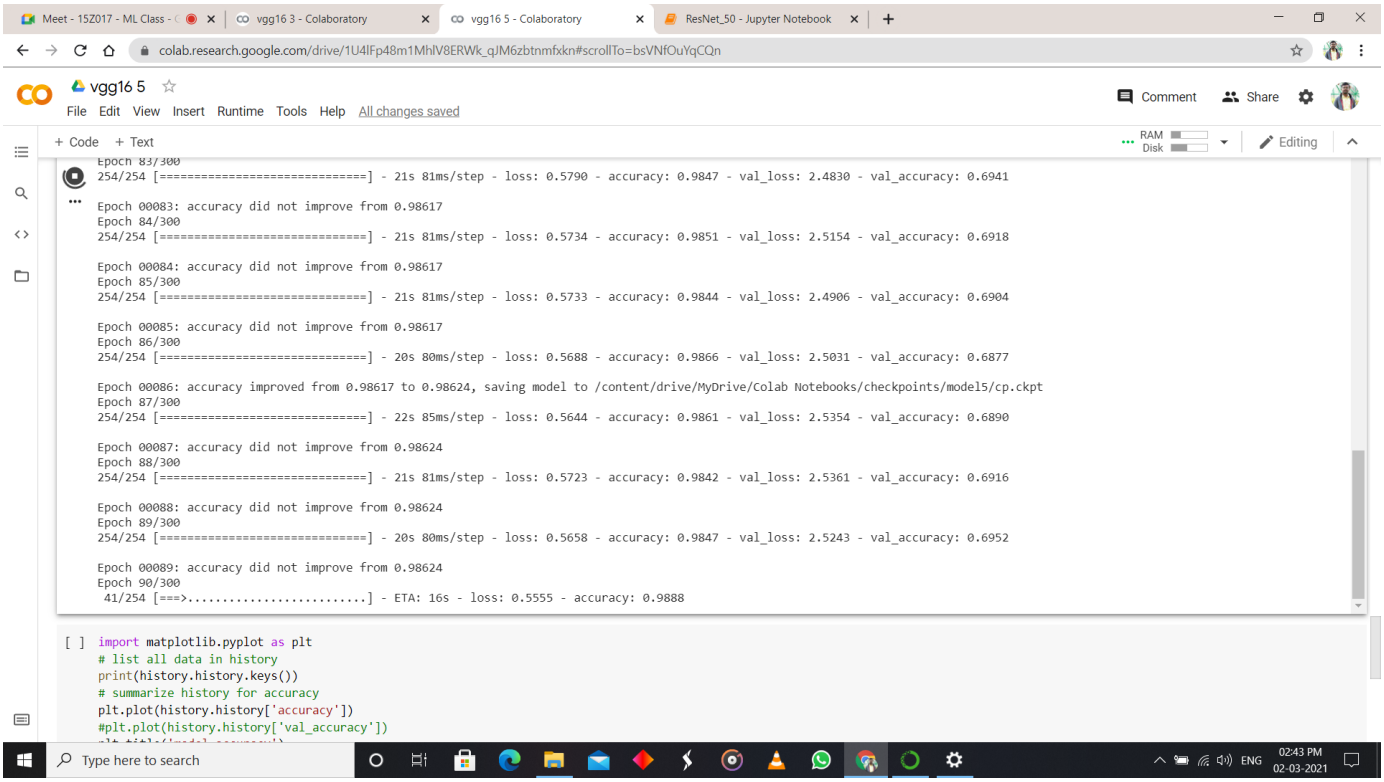
**First 165 epoch**

learing rate 0.01



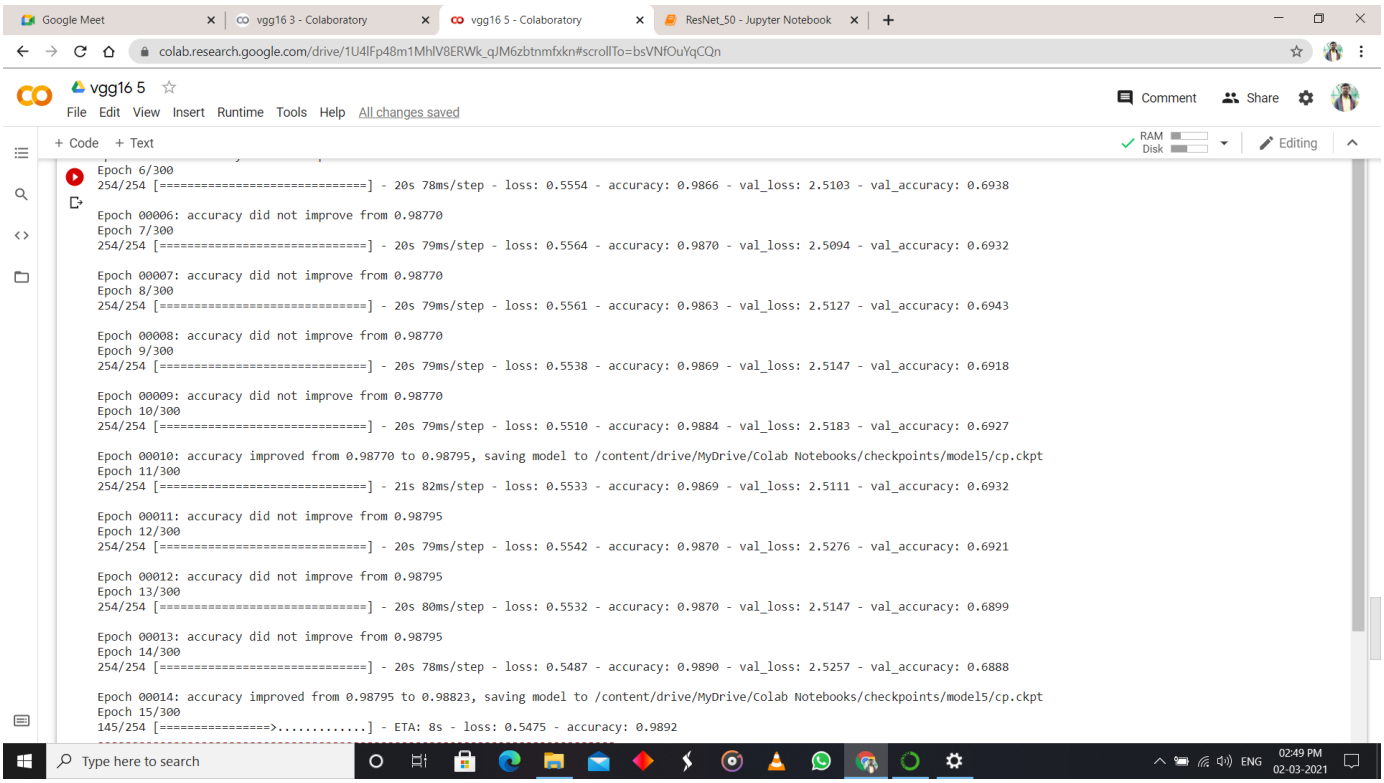

**Second 90 epoch**

learing rate 0.001




**Third 15 epoch**

learing rate 0.0001

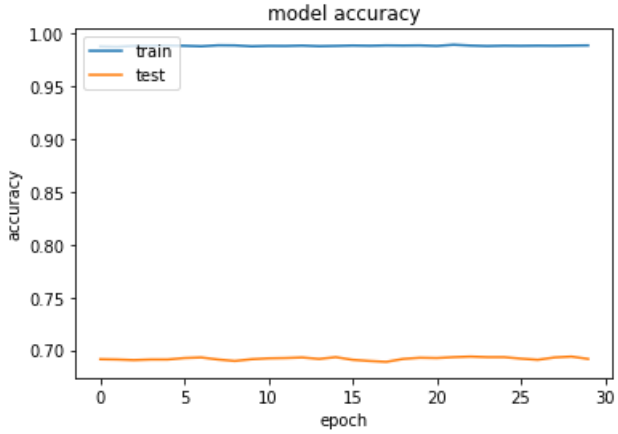


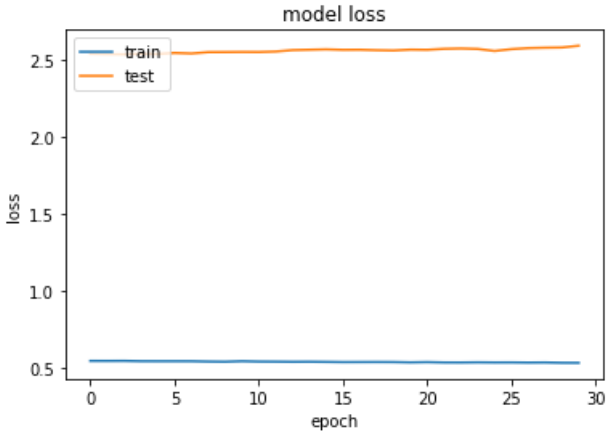

**Train Test performance in last 30 epoch**

In [ ]:

```
import matplotlib.pyplot as plt
# list all data in history
print(history.history.keys())
# summarize history for accuracy
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('model accuracy')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend(['train',"test"], loc='upper left')
plt.show()
# summarize history for loss
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('model loss')
plt.ylabel('loss')
plt.xlabel('epoch')
plt.legend(['train',"test"], loc='upper left')
plt.show()
```

```
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy'])
```




**Train Test results**

In [ ]:

```
train_score = emo_model.evaluate(x_train, y_train, verbose=0)
print('Train loss:', train_score[0])
print('Train accuracy:', 100*train_score[1])

test_score = emo_model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', test_score[0])
print('Test accuracy:', 100*test_score[1])
```

```
Train loss: 0.5329243540763855
Train accuracy: 99.08391237258911
Test loss: 2.5911366939544678
Test accuracy: 69.155752658844
```

**Real world Test**

In [ ]:

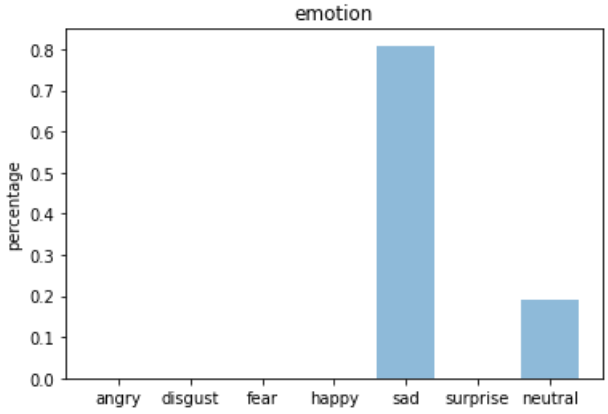
```
def emotion_analysis(emotions):
    objects = ('angry', 'disgust', 'fear', 'happy', 'sad', 'surprise', 'neutral')
    y_pos = np.arange(len(objects))

    plt.bar(y_pos, emotions, align='center', alpha=0.5)
    plt.xticks(y_pos, objects)
    plt.ylabel('percentage')
    plt.title('emotion')

    plt.show()
```

In [ ]:

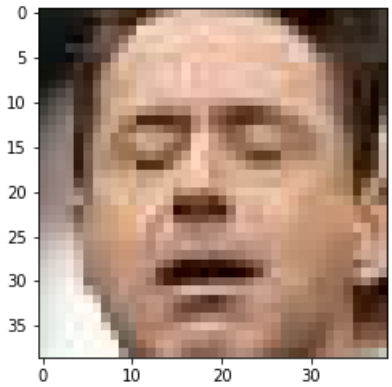
```
from keras.preprocessing import image
from keras.preprocessing.image import ImageDataGenerator

file = '/content/drive/MyDrive/Colab Notebooks/test/test6.png'
true_image = image.load_img(file)
img = image.load_img(file, grayscale=True, target_size=(48, 48))

x = image.img_to_array(img)
x = np.expand_dims(x, axis = 0)
```

```
x /= 255

custom = emo_model.predict(x)
emotion_analysis(custom[0])
print(custom[0])

x = np.array(x, 'float32')
x = x.reshape([48, 48]);

plt.gray()
plt.imshow(true_image)
plt.show()
```

```
/usr/local/lib/python3.7/dist-packages/keras_preprocessing/image/utils.py:107: UserWarning: grayscale is depre
cated. Please use color_mode = "grayscale"
  warnings.warn('grayscale is deprecated. Please use '
```




```
[7.3928933e-04 9.5471400e-08 2.1783708e-05 2.7109706e-06 8.0887306e-01
 5.0759081e-07 1.9036256e-01]
```




**Saving model**

In [ ]:

```
print(emo_model.save('/content/drive/MyDrive/Colab Notebooks/checkpoints/SuccessModel1'))
```

```
INFO:tensorflow:Assets written to: /content/drive/MyDrive/Colab Notebooks/checkpoints/SuccessModel1/assets
None
```