Pattern Recognition

Speech Emotion Recognition

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Loading the crema dataset using librosa.load() function and labeling them:

[1,0,0,0,0,0] being angry.

[0,1,0,0,0,0] being fear.

[0,0,1,0,0,0] being sad.

[0,0,0,1,0,0] being happy.

[0,0,0,0,1,0] being disgust.

[0,0,0,0,0,1] being neutral.

```
path = "Crema/"
dataset = []
rates = []
labels=[]
for filename in glob.glob(os.path.join(path, '*.wav')):
    if('ANG' in filename):
        labels.append([1,0,0,0,0,0])
    if('FEA' in filename):
        labels.append([0,1,0,0,0,0])
    if('SAD' in filename):
        labels.append([0,0,1,0,0,0])
    if('HAP' in filename):
        labels.append([0,0,0,1,0,0])
    if('DIS' in filename):
        labels.append([0,0,0,0,1,0])
    if('NEU' in filename):
        labels.append([0,0,0,0,0,1])
    samples, sample_rate = librosa.load(filename)
    #samplerate, data = wavfile.read(filename)
    dataset.append(samples)
    rates.append(sample_rate)

✓ 347.8s
```

Padding for the dataset to be of fixed length using np.pad() function:

```
max = 0
for i in range(len(dataset)):
    if max<len(dataset[i]):
        max = len(dataset[i])
for i in range(len(dataset)):
    dataset[i] =np.array(dataset[i])
    dataset[i]=np.pad(dataset[i],(0,max-len(dataset[i])),'constant')
```

Plotting the audio waveform:

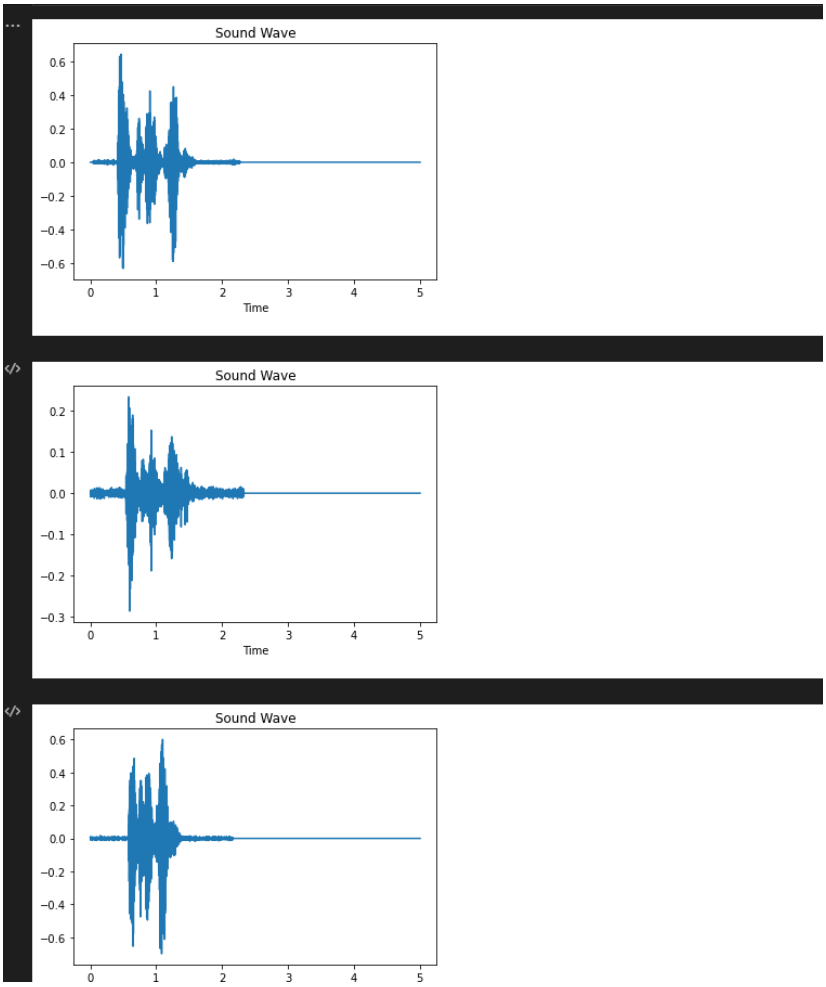
```
for i in range(len(dataset)):

    time = np.linspace(0,len(dataset[i]) / rates[i],num = len(dataset[i]))
    plt.figure(1)
    # title of the plot
    plt.title("Sound Wave")
    plt.xlabel("Time")
    plt.plot(time, dataset[i])
    plt.show()

    if np.max(dataset[i]) == 0:
        dataset[i] +=1
    Audio(dataset[i],rate = rates[i])
```

Press Ctrl+Alt+Enter to execute cell

Example:



Splitting the data into 70% training and 30% testing

Then, splitting the training data into 95% training and 5% validation:

```
x_train,x_test,y_train,y_test = train_test_split(dataset,labels,test_size=0.3,random_state=123)
x_train,x_valid,y_train,y_valid = train_test_split(x_train,y_train,test_size=0.05,random_state=123)
print(np.shape(x_train))
print(np.shape(x_valid))
print(np.shape(x_valid))
```

✓ 14s

Data augmentation for the training dataset using pitch shift:

```
#data augmentation(pitch_shift) for 1D feautre space
x_train_pitch=np.zeros((4948*2,110361))
for i in range(0,len(x_train)):
    x_train_pitch[2*i]=x_train[i]
    x_train_pitch[2*i+1]=librosa.effects.pitch_shift(x_train[i],22050,n_steps=4,bins_per_octave=24)
print(np.shape(x_train_pitch))
```

✓ 1036.7s

```
(9896, 110361)
```

```
y_train_pitch=np.zeros((4948*2,6))
for i in range (0,len(y_train)):
    y_train_pitch[2*i]=y_train[i]
    y_train_pitch[2*i+1]=y_train[i]
```

Extracting the zero-crossing rate and energy 1D feature spaces using pyAudioAnalysis library , shortTermFeatures.featureExtraction function:

```
for i in range(len(x_train_pitch)):
    F, f_names = ShortTermFeatures.feature_extraction(x_train_pitch[i], 22050, 0.050*22050, 0.025*22050,'false')
    featurespace_x_train[2*i]=(F[0])
    featurespace_x_train[2*i+1]=(F[1])
for i in range(len(x_test)):
    F, f_names = ShortTermFeatures.feature_extraction(x_test[i], 22050, 0.050*22050, 0.025*22050,'false')
    featurespace_x_test[2*i]=(F[0])
    featurespace_x_test[2*i+1]=(F[1])
for i in range(len(x_valid)):
    F, f_names = ShortTermFeatures.feature_extraction(x_valid[i], 22050, 0.050*22050, 0.025*22050,'false')
    featurespace_x_valid[2*i]=(F[0])
    featurespace_x_valid[2*i+1]=(F[1])
✓ 3279.6s
```

Extracting the mel spectogram 2D feature space using librosa:

```
+ Code  + Markdown

specs_x_train = []
specs_x_test = []
specs_x_valid = []
for i in range(len(x_train)):
    S_x_train = librosa.feature.melspectrogram(y=x_train[i], sr=22050, n_mels=128,fmax=8000,hop_length=int(len(x_train[i])/128)+1)
    specs_x_train.append(S_x_train)
    #librosa.display.specshow(librosa.power_to_db(S, ref=np.max))
    #plt.show()
for i in range(len(x_test)):
    S_x_test = librosa.feature.melspectrogram(y=x_test[i], sr=22050, n_mels=128,fmax=8000,hop_length=int(len(x_test[i])/128)+1)
    specs_x_test.append(S_x_test)
    #librosa.display.specshow(librosa.power_to_db(S, ref=np.max))
    #plt.show()
for i in range(len(x_valid)):
    S_x_valid = librosa.feature.melspectrogram(y=x_valid[i], sr=22050, n_mels=128,fmax=8000,hop_length=int(len(x_valid[i])/128)+1)
    specs_x_valid.append(S_x_valid)
    #librosa.display.specshow(librosa.power_to_db(S, ref=np.max))
    #plt.show()

[180]  ✓ 58.2s                                                                    Python
```

Forming the Convolution neural network of 1D features:

```
featurespace_x_train =np.array(featurespace_x_train).reshape(4948*2,199,2)
featurespace_x_valid =np.array(featurespace_x_valid).reshape(261,199,2)
model = models.Sequential()

model.add(layers.Conv1D(16, kernel_size=3, activation='relu', input_shape=(199, 2)))
model.add(layers.Conv1D(16, kernel_size=3, activation='relu'))
model.add(layers.MaxPooling1D(pool_size=2,strides=None, padding='valid'))
model.add(layers.Conv1D(32, kernel_size=3, activation='relu'))
model.add(layers.Conv1D(32, kernel_size=3, activation='relu'))
model.add(layers.MaxPooling1D(pool_size=2,strides=None, padding='valid'))
model.add(layers.Conv1D(64, kernel_size=3, activation='relu'))
model.add(layers.Conv1D(64, kernel_size=3, activation='relu'))
model.add(layers.MaxPooling1D(pool_size=2,strides=None, padding='valid'))
model.add(layers.Conv1D(128, kernel_size=3, activation='relu'))
model.add(layers.Conv1D(128, kernel_size=3, activation='relu'))
model.add(layers.MaxPooling1D(pool_size=2,strides=None, padding='valid'))
model.add(layers.Flatten())
model.add(layers.Dense(128, activation='relu'))
model.add(layers.Dense(32, activation='relu'))
model.add(layers.Dense(6,activation='softmax'))
model.summary()
print(np.shape(np.array(x_train)))
print(np.shape(np.array(y_train)))
print(np.shape(np.array(x_valid)))
print(np.shape(np.array(y_valid)))
```

✓ 23s

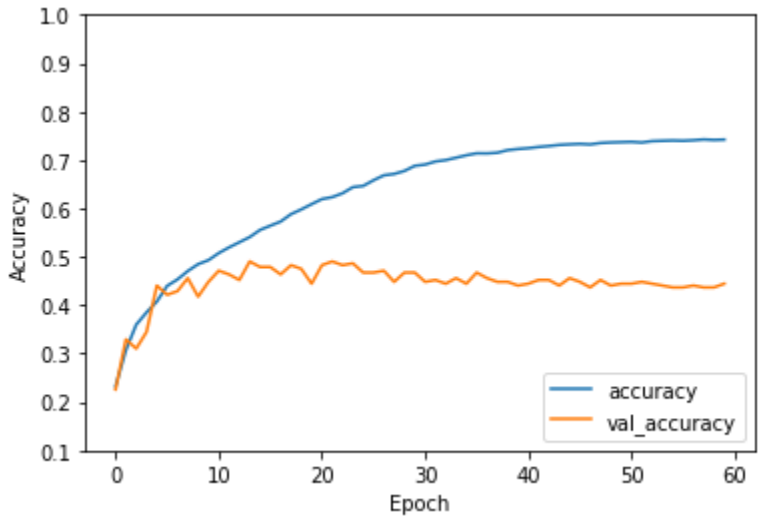
```
Model: "sequential_34"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv1d_259 (Conv1D)          (None, 197, 16)           112
_________________________________________________________________
conv1d_260 (Conv1D)          (None, 195, 16)           784
_________________________________________________________________
max_pooling1d_129 (MaxPoolin (None, 97, 16)            0
_________________________________________________________________
conv1d_261 (Conv1D)          (None, 95, 32)            1568
_________________________________________________________________
conv1d_262 (Conv1D)          (None, 93, 32)            3104
_________________________________________________________________
max_pooling1d_130 (MaxPoolin (None, 46, 32)            0
_________________________________________________________________
conv1d_263 (Conv1D)          (None, 44, 64)            6208
_________________________________________________________________
conv1d_264 (Conv1D)          (None, 42, 64)            12352
_________________________________________________________________
max_pooling1d_131 (MaxPoolin (None, 21, 64)            0
_________________________________________________________________
conv1d_265 (Conv1D)          (None, 19, 128)           24704
_________________________________________________________________
conv1d_266 (Conv1D)          (None, 17, 128)           49280
_________________________________________________________________
max_pooling1d_132 (MaxPoolin (None, 8, 128)            0
_________________________________________________________________
flatten_32 (Flatten)         (None, 1024)              0
_________________________________________________________________
dense_96 (Dense)             (None, 128)               131200
_________________________________________________________________
dense_97 (Dense)             (None, 32)                4128
_________________________________________________________________
dense_98 (Dense)             (None, 6)                 198
=================================================================
Total params: 233,638
Trainable params: 233,638
```

Train the model:

```python
def scheduler(epoch,lr):
    if epoch < 10:
        return lr
    else:
        print(lr)
        return lr*tf.math.exp(-0.1)
model.compile(optimizer='adam',
              loss=tf.keras.losses.CategoricalCrossentropy(from_logits=True),
              metrics=['accuracy'])
#round(model.optimizer.lr.numpy(),5)
callback = tf.keras.callbacks.LearningRateScheduler(scheduler)
history = model.fit(np.array(featurespace_x_train), np.array(y_train_pitch), epochs=60,callbacks=[callback],batch_size = 128,
                    validation_data=(np.array(featurespace_x_valid), np.array(y_valid)))
```

✓ 193.5s

```
Epoch 1/60
78/78 [==============================] - 5s 51ms/step - loss: 1.7476 - accuracy: 0.2375 - val_loss: 1.6872 - val_accuracy: 0.2720
Epoch 2/60
78/78 [==============================] - 4s 47ms/step - loss: 1.6417 - accuracy: 0.3217 - val_loss: 1.5828 - val_accuracy: 0.3180
Epoch 3/60
78/78 [==============================] - 4s 47ms/step - loss: 1.5375 - accuracy: 0.3750 - val_loss: 1.4951 - val_accuracy: 0.3716
Epoch 4/60
78/78 [==============================] - 4s 48ms/step - loss: 1.4342 - accuracy: 0.4239 - val_loss: 1.4525 - val_accuracy: 0.4100
Epoch 5/60
78/78 [==============================] - 4s 51ms/step - loss: 1.3815 - accuracy: 0.4469 - val_loss: 1.3881 - val_accuracy: 0.4521
Epoch 6/60
78/78 [==============================] - 4s 51ms/step - loss: 1.3542 - accuracy: 0.4602 - val_loss: 1.3588 - val_accuracy: 0.4674
Epoch 7/60
78/78 [==============================] - 4s 49ms/step - loss: 1.3186 - accuracy: 0.4732 - val_loss: 1.3432 - val_accuracy: 0.4789
Epoch 8/60
78/78 [==============================] - 3s 41ms/step - loss: 1.3048 - accuracy: 0.4780 - val_loss: 1.3438 - val_accuracy: 0.4559
Epoch 9/60
78/78 [==============================] - 3s 38ms/step - loss: 1.2667 - accuracy: 0.4995 - val_loss: 1.3705 - val_accuracy: 0.4789
Epoch 10/60
78/78 [==============================] - 3s 37ms/step - loss: 1.2502 - accuracy: 0.5062 - val_loss: 1.3373 - val_accuracy: 0.5134
Epoch 11/60
0.0010000000474974513
78/78 [==============================] - 3s 41ms/step - loss: 1.2143 - accuracy: 0.5227 - val_loss: 1.3090 - val_accuracy: 0.5096
Epoch 12/60
0.0009048374486155808
78/78 [==============================] - 4s 46ms/step - loss: 1.1835 - accuracy: 0.5364 - val_loss: 1.3508 - val_accuracy: 0.5134
```



Evaluating the test data score of 1D features:

```
model.compile(optimizer='adam',
              loss=tf.keras.losses.CategoricalCrossentropy(from_logits=True),
              metrics=['accuracy'])
test_eval = model.evaluate(np.array(featurespace_x_test_final),np.array(y_test),verbose=1)
```

✓ 0.8s

Measuring F score and Convolutional matrix of 1D features:

```
predicted_classes = model.predict(featurespace_x_test_final)
predicted_classes = np.argmax(np.round(predicted_classes),axis=1)
y_test_final = np.argmax(np.round(y_test),axis=1)
f1_score(y_test_final, predicted_classes,average='macro')
```

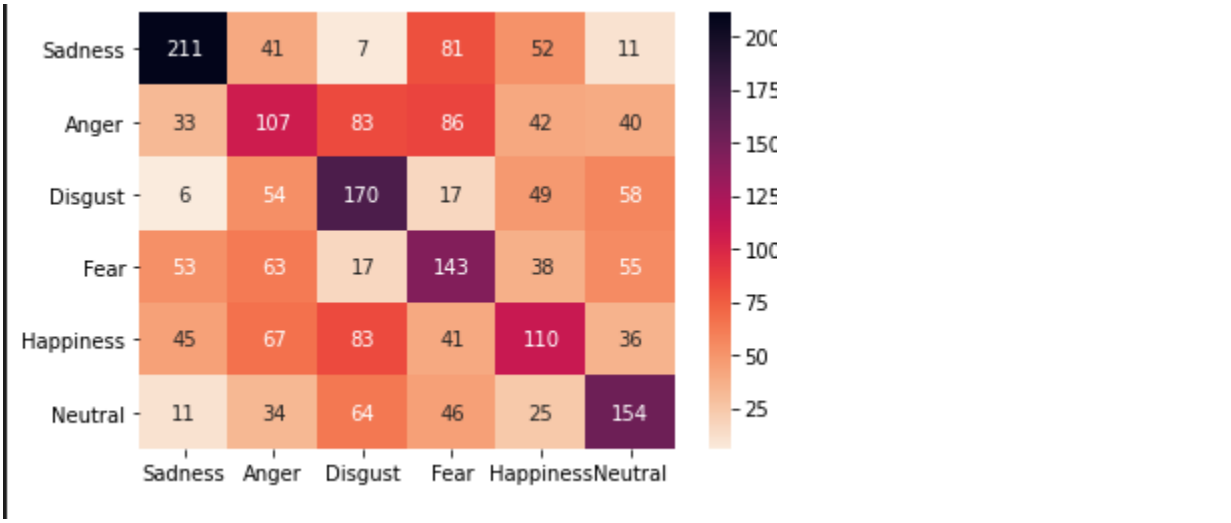
✓ 0.5s Python

```
0.3701431364517073
```

+ Code + Markdown

```
x_testcnn=np.array(featurespace_x_test_final).reshape(len(featurespace_x_test_final),199,2)
y_pred = model.predict(x_testcnn)
matrix = confusion_matrix(np.array(y_test).argmax(axis=1), y_pred.argmax(axis=1))
ax = sn.heatmap(matrix, annot=True, fmt="d", cmap = 'rocket_r', xticklabels = [ 'Sadness','Anger', 'Disgust', 'Fear', 'Happiness', 'Neutral'], yticklabels = ['Sadness','Anger', 'Disgust', 'Fear', 'Happi
```

✓ 1.2s Python



Most confusing classes are anger with fear.

Forming the Convolution neural network pf 2D features:

```
specs_x_train =np.array(specs_x_train).reshape(4948,128, 128,1)
specs_x_valid =np.array(specs_x_valid).reshape(261,128, 128,1)
model2D = models.Sequential()

model2D.add(layers.Conv2D(16, kernel_size=(5,5), activation='relu', input_shape=(128, 128,1)))
model2D.add(layers.Conv2D(16, kernel_size=(3,3), activation='relu'))
model2D.add(layers.MaxPooling2D(pool_size=(2,2),strides=2, padding='valid'))
model2D.add(layers.Conv2D(32, kernel_size=(3,3), activation='relu'))
model2D.add(layers.Conv2D(32, kernel_size=(3,3), activation='relu'))
model2D.add(layers.MaxPooling2D(pool_size=(2,2),strides=2, padding='valid'))
model2D.add(layers.Conv2D(64, kernel_size=(3,3), activation='relu'))
model2D.add(layers.Conv2D(64, kernel_size=(3,3), activation='relu'))
model2D.add(layers.MaxPooling2D(pool_size=(2,2),strides=None, padding='valid'))
model2D.add(layers.Conv2D(128, kernel_size=(3,3), activation='relu'))
model2D.add(layers.Conv2D(128, kernel_size=(3,3), activation='relu'))
model2D.add(layers.MaxPooling2D(pool_size=(2,2),strides=None, padding='valid'))

model2D.add(layers.Flatten())
model2D.add(layers.Dense(256, activation='relu'))
model2D.add(layers.Dense(64, activation='relu'))
model2D.add(layers.Dense(6,activation='softmax'))
model2D.summary()
print(np.shape(np.array(specs_x_train)))
print(np.shape(np.array(y_train)))
print(np.shape(np.array(specs_x_valid)))
print(np.shape(np.array(y_valid)))
```

✓ 0.7s

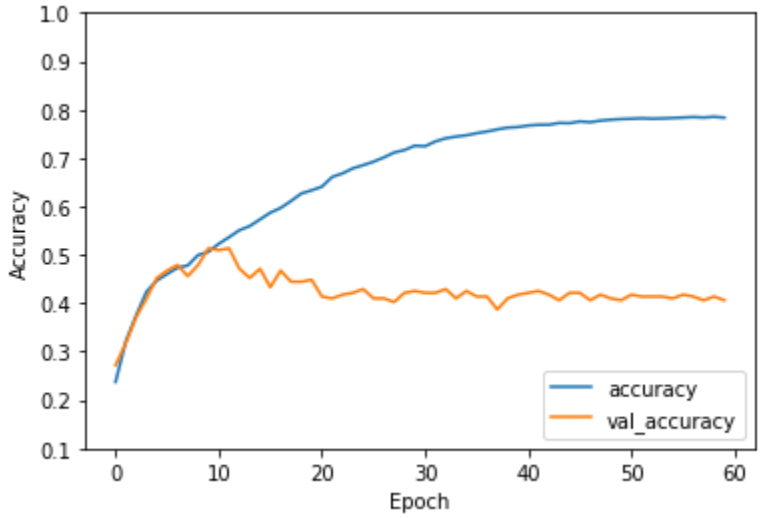
```
Model: "sequential_36"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_38 (Conv2D)           (None, 124, 124, 16)      416
_________________________________________________________________
conv2d_39 (Conv2D)           (None, 122, 122, 16)      2320
_________________________________________________________________
max_pooling2d_19 (MaxPooling (None, 61, 61, 16)        0
_________________________________________________________________
conv2d_40 (Conv2D)           (None, 59, 59, 32)        4640
_________________________________________________________________
conv2d_41 (Conv2D)           (None, 57, 57, 32)        9248
```

Train the model:

```python
def scheduler(epoch,lr):
    if epoch < 10:
        return lr
    else:
        print(lr)
        return lr*tf.math.exp(-0.1)
model2D.compile(optimizer='adam',
                loss=tf.keras.losses.CategoricalCrossentropy(from_logits=True),
                metrics=['accuracy'])
callback = tf.keras.callbacks.LearningRateScheduler(scheduler)
history2D = model2D.fit(np.array(specs_x_train), np.array(y_train), epochs=50,callbacks=[callback],batch_size = 128,
                    validation_data=(np.array(specs_x_valid), np.array(y_valid)))
```

✓ 3557.6s

```
Epoch 1/50
C:\Users\YAHYA IHAB\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.9_qbz5n2kfra8p0\LocalCache\local-packages\Python39\site-packages\te
"`categorical_crossentropy` received `from_logits=True`, but the `output` argument was produced by a sigmoid or softmax activation and thus does
  warnings.warn(
39/39 [==============================] - 93s 2s/step - loss: 1.6727 - accuracy: 0.3211 - val_loss: 1.8053 - val_accuracy: 0.3180
Epoch 2/50
39/39 [==============================] - 90s 2s/step - loss: 1.5359 - accuracy: 0.3723 - val_loss: 1.5197 - val_accuracy: 0.3946
Epoch 3/50
39/39 [==============================] - 88s 2s/step - loss: 1.4478 - accuracy: 0.4068 - val_loss: 1.4773 - val_accuracy: 0.4368
Epoch 4/50
39/39 [==============================] - 87s 2s/step - loss: 1.4298 - accuracy: 0.4224 - val_loss: 1.4822 - val_accuracy: 0.3870
Epoch 5/50
39/39 [==============================] - 85s 2s/step - loss: 1.3952 - accuracy: 0.4339 - val_loss: 1.4037 - val_accuracy: 0.4368
Epoch 6/50
39/39 [==============================] - 85s 2s/step - loss: 1.3406 - accuracy: 0.4545 - val_loss: 1.3947 - val_accuracy: 0.4406
Epoch 7/50
39/39 [==============================] - 82s 2s/step - loss: 1.3135 - accuracy: 0.4697 - val_loss: 1.3858 - val_accuracy: 0.4636
Epoch 8/50
39/39 [==============================] - 69s 2s/step - loss: 1.2993 - accuracy: 0.4790 - val_loss: 1.5243 - val_accuracy: 0.4598
Epoch 9/50
39/39 [==============================] - 68s 2s/step - loss: 1.2679 - accuracy: 0.4885 - val_loss: 1.3754 - val_accuracy: 0.4368
Epoch 10/50
39/39 [==============================] - 68s 2s/step - loss: 1.2081 - accuracy: 0.5224 - val_loss: 1.4637 - val_accuracy: 0.4559
Epoch 11/50
0.0010000000474974513
39/39 [==============================] - 68s 2s/step - loss: 1.1956 - accuracy: 0.5356 - val_loss: 1.4935 - val_accuracy: 0.4866
```



Evaluating the test data score of 2D features:

```
specs_x_test =np.array(specs_x_test).reshape(2233,128, 128,1)
model2D.compile(optimizer='adam',
                loss=tf.keras.losses.CategoricalCrossentropy(from_logits=True),
                metrics=['accuracy'])
test_eval2D = model2D.evaluate(np.array(specs_x_test),np.array(y_test),verbose=1)
```

✓ 6.4s

```
C:\Users\YAHYA IHAB\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.9_qbz5n2kfra8p0\LocalCache\local-packages\Python39\site-packages\tensorflow\python\keras\back
"`categorical_crossentropy` received `from_logits=True`, but the `output` argument was produced by a sigmoid or softmax activation and thus does not represent logits. Was
  warnings.warn(
70/70 [==============================] - 6s 86ms/step - loss: 4.6242 - accuracy: 0.4751
```

Measuring F score and Convolutional matrix of 2D features:

```
predicted_classes2D = model2D.predict(specs_x_test)
predicted_classes2D = np.argmax(np.round(predicted_classes2D),axis=1)
y_test_final2D = np.argmax(np.round(y_test),axis=1)
f1_score(y_test_final2D, predicted_classes2D,average='macro')
```

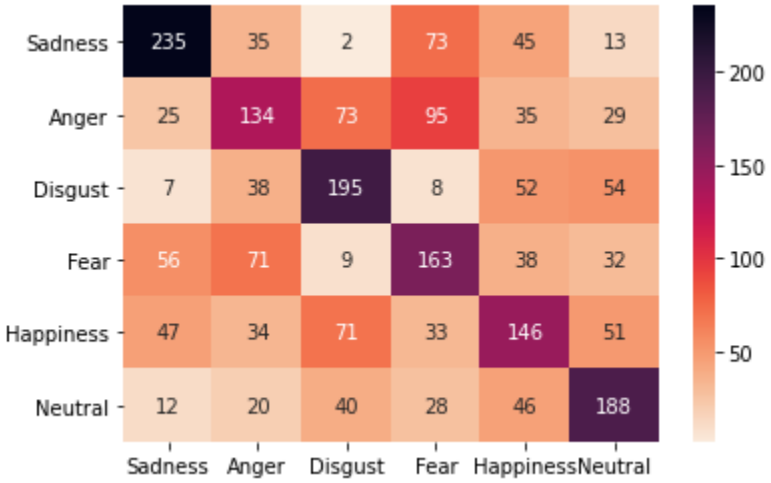
✓ 6.1s

```
0.4509914511275676
```

+ Code + Markdown

```
x_testcnn2D=np.array(specs_x_test).reshape(len(specs_x_test),128,128,1)
y_pred2D = model2D.predict(x_testcnn2D)
matrix2D = confusion_matrix(np.array(y_test).argmax(axis=1), y_pred2D.argmax(axis=1))
ax2D = sn.heatmap(matrix2D, annot=True, fmt="d", cmap = 'rocket_r', xticklabels = [ 'Sadness','Anger', 'Disgust', 'Fear', 'Happiness', 'Neutral'], yticklabels = ['Sadness','Anger', 'Disgust', 'Fear',
```

✓ 6.7s



Most confusing classes are anger with fear.