

## Spoken Digit Recognition

In this notebook, You will do Spoken Digit Recognition.

Input - speech signal, output - digit number

It contains

1. Reading the dataset. and Preprocess the data set. Detailed instructions are given below. You have to write the code in the same cell which contains the instruction.
2. Training the LSTM with RAW data
3. Converting to spectrogram and Training the LSTM network
4. Creating the augmented data and doing step 2 and 3 again.

Instructions:

1. Don't change any Grader Functions. Don't manipulate any Grader functions. If you manipulate any, it will be considered as plagiarised.
2. Please read the instructions on the code cells and markdown cells. We will explain what to write.
3. Please return outputs in the same format what we asked. Eg. Don't return List if we are asking for a numpy array.
4. Please read the external links that we are given so that you will learn the concept behind the code that you are writing.
5. We are giving instructions at each section if necessary, please follow them.

Every Grader function has to return True.

```
import numpy as np
import pandas as pd
import librosa
import os
from sklearn.metrics import f1_score
##if you need any imports you can do that here.
```

We shared recordings.zip, please unzip those.

```
#read the all file names in the recordings folder given by us
 #(if you get entire path, it is very useful in future)
#save those files names as list in "all_files"
#https://stackoverflow.com/questions/49685924/extract-google-drive-
zip-from-google-colab-notebook
!unzip /content/recordings.zip
```

Archive: /content/recordings.zip

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inflating: recordings/9\_nicolas\_28.wav  
inflating: recordings/9\_nicolas\_29.wav  
inflating: recordings/9\_nicolas\_3.wav  
inflating: recordings/9\_nicolas\_30.wav  
inflating: recordings/9\_nicolas\_31.wav  
inflating: recordings/9\_nicolas\_32.wav  
inflating: recordings/9\_nicolas\_33.wav  
inflating: recordings/9\_nicolas\_34.wav  
inflating: recordings/9\_nicolas\_35.wav  
inflating: recordings/9\_nicolas\_36.wav  
inflating: recordings/9\_nicolas\_37.wav  
inflating: recordings/9\_nicolas\_38.wav  
inflating: recordings/9\_nicolas\_39.wav  
inflating: recordings/9\_nicolas\_4.wav  
inflating: recordings/9\_nicolas\_40.wav  
inflating: recordings/9\_nicolas\_41.wav  
inflating: recordings/9\_nicolas\_42.wav  
inflating: recordings/9\_nicolas\_43.wav  
inflating: recordings/9\_nicolas\_44.wav  
inflating: recordings/9\_nicolas\_45.wav  
inflating: recordings/9\_nicolas\_46.wav  
inflating: recordings/9\_nicolas\_47.wav  
inflating: recordings/9\_nicolas\_48.wav  
inflating: recordings/9\_nicolas\_49.wav  
inflating: recordings/9\_nicolas\_5.wav  
inflating: recordings/9\_nicolas\_6.wav  
inflating: recordings/9\_nicolas\_7.wav

inflating: recordings/9\_nicolas\_8.wav  
inflating: recordings/9\_nicolas\_9.wav  
inflating: recordings/9\_theo\_0.wav  
inflating: recordings/9\_theo\_1.wav  
inflating: recordings/9\_theo\_10.wav  
inflating: recordings/9\_theo\_11.wav  
inflating: recordings/9\_theo\_12.wav  
inflating: recordings/9\_theo\_13.wav  
inflating: recordings/9\_theo\_14.wav  
inflating: recordings/9\_theo\_15.wav  
inflating: recordings/9\_theo\_16.wav  
inflating: recordings/9\_theo\_17.wav  
inflating: recordings/9\_theo\_18.wav  
inflating: recordings/9\_theo\_19.wav  
inflating: recordings/9\_theo\_2.wav  
inflating: recordings/9\_theo\_20.wav  
inflating: recordings/9\_theo\_21.wav  
inflating: recordings/9\_theo\_22.wav  
inflating: recordings/9\_theo\_23.wav  
inflating: recordings/9\_theo\_24.wav  
inflating: recordings/9\_theo\_25.wav  
inflating: recordings/9\_theo\_26.wav  
inflating: recordings/9\_theo\_27.wav  
inflating: recordings/9\_theo\_28.wav  
inflating: recordings/9\_theo\_29.wav  
inflating: recordings/9\_theo\_3.wav  
inflating: recordings/9\_theo\_30.wav  
inflating: recordings/9\_theo\_31.wav  
inflating: recordings/9\_theo\_32.wav  
inflating: recordings/9\_theo\_33.wav  
inflating: recordings/9\_theo\_34.wav  
inflating: recordings/9\_theo\_35.wav  
inflating: recordings/9\_theo\_36.wav  
inflating: recordings/9\_theo\_37.wav  
inflating: recordings/9\_theo\_38.wav  
inflating: recordings/9\_theo\_39.wav  
inflating: recordings/9\_theo\_4.wav  
inflating: recordings/9\_theo\_40.wav  
inflating: recordings/9\_theo\_41.wav  
inflating: recordings/9\_theo\_42.wav  
inflating: recordings/9\_theo\_43.wav  
inflating: recordings/9\_theo\_44.wav  
inflating: recordings/9\_theo\_45.wav  
inflating: recordings/9\_theo\_46.wav  
inflating: recordings/9\_theo\_47.wav  
inflating: recordings/9\_theo\_48.wav  
inflating: recordings/9\_theo\_49.wav  
inflating: recordings/9\_theo\_5.wav  
inflating: recordings/9\_theo\_6.wav  
inflating: recordings/9\_theo\_7.wav



inflating: recordings/9\_theo\_8.wav  
inflating: recordings/9\_theo\_9.wav  
inflating: recordings/9\_yweweler\_0.wav  
inflating: recordings/9\_yweweler\_1.wav  
inflating: recordings/9\_yweweler\_10.wav  
inflating: recordings/9\_yweweler\_11.wav  
inflating: recordings/9\_yweweler\_12.wav  
inflating: recordings/9\_yweweler\_13.wav  
inflating: recordings/9\_yweweler\_14.wav  
inflating: recordings/9\_yweweler\_15.wav  
inflating: recordings/9\_yweweler\_16.wav  
inflating: recordings/9\_yweweler\_17.wav  
inflating: recordings/9\_yweweler\_18.wav  
inflating: recordings/9\_yweweler\_19.wav  
inflating: recordings/9\_yweweler\_2.wav  
inflating: recordings/9\_yweweler\_20.wav  
inflating: recordings/9\_yweweler\_21.wav  
inflating: recordings/9\_yweweler\_22.wav  
inflating: recordings/9\_yweweler\_23.wav  
inflating: recordings/9\_yweweler\_24.wav  
inflating: recordings/9\_yweweler\_25.wav  
inflating: recordings/9\_yweweler\_26.wav  
inflating: recordings/9\_yweweler\_27.wav  
inflating: recordings/9\_yweweler\_28.wav  
inflating: recordings/9\_yweweler\_29.wav  
inflating: recordings/9\_yweweler\_3.wav  
inflating: recordings/9\_yweweler\_30.wav  
inflating: recordings/9\_yweweler\_31.wav  
inflating: recordings/9\_yweweler\_32.wav  
inflating: recordings/9\_yweweler\_33.wav  
inflating: recordings/9\_yweweler\_34.wav  
inflating: recordings/9\_yweweler\_35.wav  
inflating: recordings/9\_yweweler\_36.wav  
inflating: recordings/9\_yweweler\_37.wav  
inflating: recordings/9\_yweweler\_38.wav  
inflating: recordings/9\_yweweler\_39.wav  
inflating: recordings/9\_yweweler\_4.wav  
inflating: recordings/9\_yweweler\_40.wav  
inflating: recordings/9\_yweweler\_41.wav  
inflating: recordings/9\_yweweler\_42.wav  
inflating: recordings/9\_yweweler\_43.wav  
inflating: recordings/9\_yweweler\_44.wav  
inflating: recordings/9\_yweweler\_45.wav  
inflating: recordings/9\_yweweler\_46.wav  
inflating: recordings/9\_yweweler\_47.wav  
inflating: recordings/9\_yweweler\_48.wav  
inflating: recordings/9\_yweweler\_49.wav  
inflating: recordings/9\_yweweler\_5.wav  
inflating: recordings/9\_yweweler\_6.wav  
inflating: recordings/9\_yweweler\_7.wav

```

    inflating: recordings/9_yweweler_8.wav
    inflating: recordings/9_yweweler_9.wav

#all_files = os.listdir('recordings')
#!/usr/bin/python

import os, sys

# Open a file
path = "recordings"
all_files = os.listdir( path )

Grader function 1

def grader_files():
    temp = len(all_files)==2000
    temp1 = all([x[-3:]=="wav" for x in all_files])
    temp = temp and temp1
    return temp
grader_files()

```

True

Create a dataframe(name=df\_audio) with two columns(path, label).

You can get the label from the first letter of name.

Eg: 0\_jackson\_0 --> 0

0\_jackson\_43 --> 0

## Exploring the sound dataset

*#It is a good programming practise to explore the dataset that you are dealing with. This dataset is unique in itself because it has sounds as input*

*#<https://colab.research.google.com/github/Tyler-Hilbert/AudioProcessingInPythonWorkshop/blob/master/AudioProcessingInPython.ipynb>*

*#visualize the data and write code to play 2-3 sound samples in the notebook for better understanding.*

*#please go through the following reference video*

*<https://www.youtube.com/watch?v=37zCgCdV468>*

## Creating dataframe

```

# extract the labels from all_files
#Create a dataframe(name=df_audio) with two columns(path, label).
#You can get the label from the first letter of name.
#Eg: 0_jackson_0 --> 0
#0_jackson_43 --> 0
z=[ele.split('_') for ele in all_files]
extracted_label=[]

```

```

for i,j,k in z:
    #print(i,j,k)
    extracted_label.append(i)

extracted_label[:4]

['4', '4', '4', '0']

#Create a dataframe(name=df_audio) with two columns(path, label).
#You can get the label from the first letter of name.
#Eg: 0_jackson_0 --> 0
#0_jackson_43 --> 0
path = "recordings"
all_files = os.listdir(path)
#https://pandas.pydata.org/docs/reference/api/pandas.DataFrame.html
df_audio = pd.DataFrame()
df_audio['path'] = [path+'/' + i for i in all_files]
df_audio['label'] = extracted_label[:]

df_audio.head()

      path label
452  recordings/7_theo_12.wav      7
212  recordings/0_nicolas_49.wav     0
39   recordings/5_yweweler_28.wav     5
9    recordings/2_nicolas_16.wav      2
448  recordings/1_jackson_21.wav      1

#df_audio.to_csv('C:\\Users\\mural\\Desktop\\aaic assignments\\speech
recognition\\New folder\\file1_speech.csv')

#info
df_audio.info()

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 2000 entries, 0 to 1999
Data columns (total 2 columns):
 #   Column  Non-Null Count  Dtype
---  -
 0   path    2000 non-null     object
 1   label   2000 non-null     object
dtypes: object(2)
memory usage: 31.4+ KB

```

Grader function 2

```

def grader_df():
    flag_shape = df_audio.shape==(2000,2)
    flag_columns = all(df_audio.columns=='path', 'label')
    list_values = list(df_audio.label.value_counts())
    flag_label = len(list_values)==10
    flag_label2 = all([i==200 for i in list_values])

```

```

    final_flag = flag_shape and flag_columns and flag_label and
flag_label2
    return final_flag
grader_df()

True

from sklearn.utils import shuffle
df_audio = shuffle(df_audio, random_state=45)#don't change the random
state

#split the data into train and validation and save in X_train, X_test,
y_train, y_test
#use stratify sampling
#use random state of 45
#use test size of 30%
from sklearn.model_selection import train_test_split
x,y=df_audio['path'],df_audio['label']
X_train, X_test, y_train,
y_test=train_test_split(x,y,test_size=0.3,random_state=45,
                        stratify=y)

```

Grader function 3

```

def grader_split():
    flag_len = (len(X_train)==1400) and (len(X_test)==600) and
(len(y_train)==1400) and (len(y_test)==600)
    values_ytrain = list(y_train.value_counts())
    flag_ytrain = (len(values_ytrain)==10) and (all([i==140 for i in
values_ytrain]))
    values_ytest = list(y_test.value_counts())
    flag_ytest = (len(values_ytest)==10) and (all([i==60 for i in
values_ytest]))
    final_flag = flag_len and flag_ytrain and flag_ytest
    return final_flag
grader_split()

```

True

```

sample_rate = 22050
def load_wav(x, get_duration=True):
    '''This return the array values of audio with sampling rate of
22050 and Duration'''
    #loading the wav file with sampling rate of 22050
    samples, sample_rate = librosa.load(x, sr=22050)
    if get_duration:
        duration = librosa.get_duration(samples, sample_rate)
        return [samples, duration]
    else:
        return samples

#samples, sample_rate = librosa.load(str(train_audio_path)+filename)

```

```

#use load_wav function that was written above to get every wave.
#save it in X_train_processed and X_test_processed
# X_train_processed/X_test_processed should be dataframes with two
columns(raw_data, duration) with same index of X_train/y_train

#X_train_processed=load_wav(X_train,get_duration=True)

samples_train,duration_train=[],[]

for value in X_train:
    z=load_wav(value, get_duration=True)
    samples_train.append(z[0]) #z[0] means samples
    duration_train.append(z[1]) #z[1] means duration

samples_test,duration_test=[],[]

for value in X_test:
    z=load_wav(value, get_duration=True)
    samples_test.append(z[0]) #z[0] means samples
    duration_test.append(z[1]) #z[1] means duration

#https://pandas.pydata.org/docs/reference/api/pandas.DataFrame.html
d = {'raw_data' : samples_train,'duration':duration_train}
d1 = {'raw_data' : samples_test,'duration':duration_test}

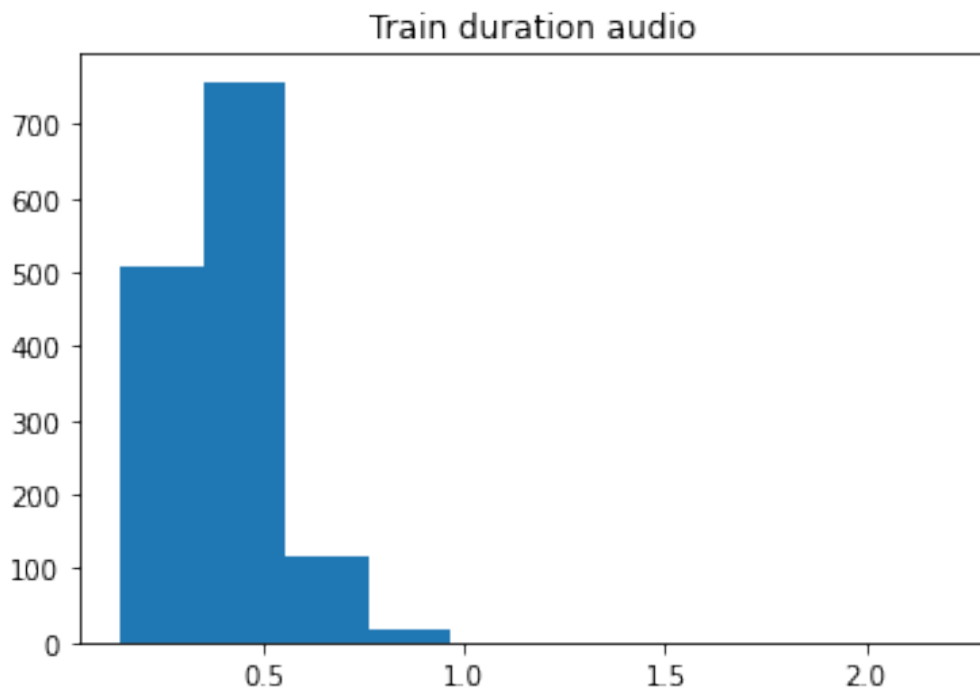
X_train_processed=pd.DataFrame(data=d)
X_test_processed=pd.DataFrame(data=d1)

#https://www.w3schools.com/python/matplotlib_histograms.asp
#plot the histogram of the duration for train
import matplotlib.pyplot as plt
plt.hist(X_train_processed['duration'])

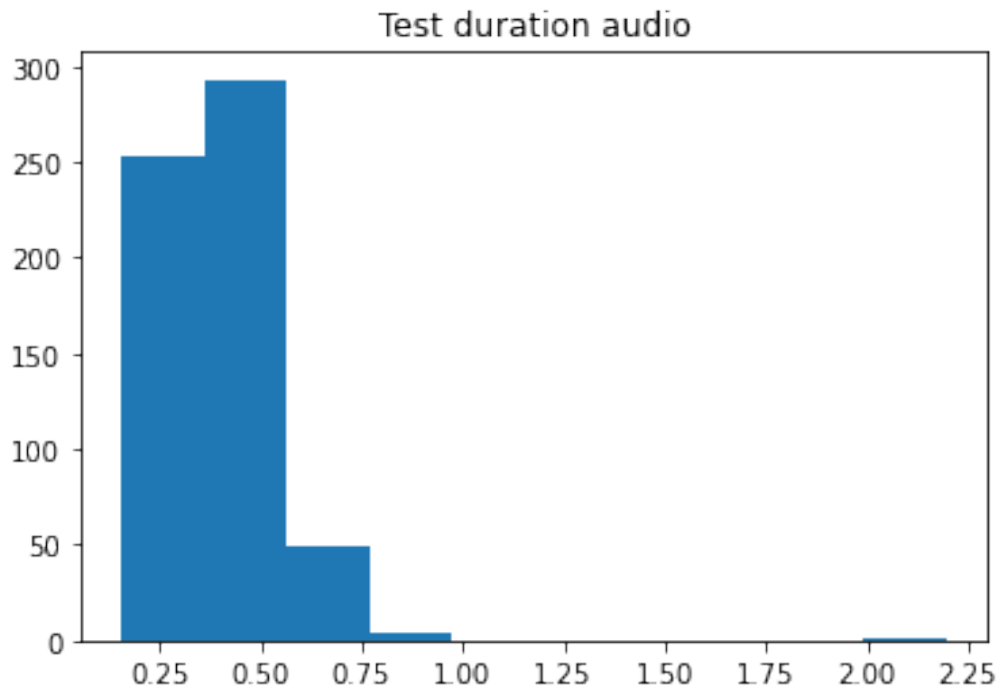
# displaying the title
plt.title("Train duration audio")

plt.show()

```



```
#plot the histogram of the duration for trian  
#https://www.w3schools.com/python/matplotlib_histograms.asp  
#plot the histogram of the duration for trian  
import matplotlib.pyplot as plt  
plt.hist(X_test_processed['duration'])  
  
# displaying the title  
plt.title("Test duration audio")  
  
plt.show()
```



*#print 0 to 100 percentile values with step size of 10 for train data duration.*

*#percentile cal*

*#step1 difference=max\_val-min\_val*

*#step2 boundary for ex: low=0.25\*diff,high=0.75\*diff*

*#step3 low<values<high*

*#diff=max(X\_train\_processed['duration'])-*

*min(X\_train\_processed['duration'])*

*#low=0\*diff*

*#high=1\*diff*

*#perc\_list=[]*

*#for val in X\_train\_processed['duration']:*

*# if val>=low and val<=high:*

*# perc\_list.append(val)*

*# Python Program illustrating*

*# numpy.percentile() method*

*#<https://www.geeksforgeeks.org/numpy-percentile-in-python/>*

*import numpy as np*

*# 1D array*

*arr = X\_train\_processed['duration']*

*for i in range(11):*

*print(str(10\*i)+"th percentile of train data*

*duration:",np.percentile(arr, 10\*i))*

```
0th percentile of train data duration: 0.1435374149659864
10th percentile of train data duration: 0.25955102040816325
20th percentile of train data duration: 0.30090702947845804
30th percentile of train data duration: 0.33424489795918366
40th percentile of train data duration: 0.36048979591836733
50th percentile of train data duration: 0.38913832199546483
60th percentile of train data duration: 0.41645351473922904
70th percentile of train data duration: 0.44658503401360544
80th percentile of train data duration: 0.4860589569160998
90th percentile of train data duration: 0.5600952380952383
100th percentile of train data duration: 2.282766439909297
```

```
##print 90 to 100 percentile values with step size of 1.
# Python Program illustrating
# numpy.percentile() method
#https://www.geeksforgeeks.org/numpy-percentile-in-python/
import numpy as np
```

```
# 1D array
arr = X_test_processed['duration']
for i in range(90,101):
    print(str(i)+"th percentile of test data
duration:",np.percentile(arr,i))
```

```
90th percentile of test data duration: 0.544716553287982
91th percentile of test data duration: 0.5567482993197282
92th percentile of test data duration: 0.5777215419501134
93th percentile of test data duration: 0.590251247165533
94th percentile of test data duration: 0.6082149659863944
95th percentile of test data duration: 0.6250657596371881
96th percentile of test data duration: 0.6432907029478456
97th percentile of test data duration: 0.6647850340136054
98th percentile of test data duration: 0.6897750566893422
99th percentile of test data duration: 0.7362893424036279
100th percentile of test data duration: 2.195918367346939
```

Grader function 4

```
def grader_processed():
    flag_columns = (all(X_train_processed.columns==['raw_data',
'duration'])) and (all(X_test_processed.columns==['raw_data',
'duration']))
    flag_shape = (X_train_processed.shape ==(1400, 2)) and
(X_test_processed.shape==(600,2))
    return flag_columns and flag_shape
grader_processed()
```

True



Based on our analysis 99 percentile values are less than 0.8sec so we will limit maximum length of X\_train\_processed and X\_test\_processed to 0.8 sec. It is similar to pad\_sequence for a text dataset.

While loading the audio files, we are using sampling rate of 22050 so one sec will give array of length 22050. so, our maximum length is  $0.8 * 22050 = 17640$  Pad with Zero if length of sequence is less than 17640 else Truncate the number.

Also create a masking vector for train and test.

masking vector value = 1 if it is real value, 0 if it is pad value. Masking vector data type must be bool.

```
max_length = 17640
```

```
## as discussed above, Pad with Zero if length of sequence is less  
than 17640 else Truncate the number.
```

```
## save in the X_train_pad_seq, X_test_pad_seq
```

```
## also Create masking vector X_train_mask, X_test_mask
```

```
## all the X_train_pad_seq, X_test_pad_seq, X_train_mask, X_test_mask  
will be numpy arrays mask vector dtype must be bool.
```

```
#https://stackoverflow.com/questions/42598630/why-cant-i-use-  
preprocessing-module-in-keras
```

```
import tensorflow as tf
```

```
import keras
```

```
from keras import preprocessing
```

```
from tensorflow.keras.preprocessing.sequence import pad_sequences
```

```
train_sequences=X_train_processed.raw_data
```

```
test_sequences=X_test_processed.raw_data
```

```
max_length = 17640
```

```
X_train_pad_seq=
```

```
preprocessing.sequence.pad_sequences(train_sequences,maxlen=max_length
```

```
,
```

```
dtype =
```

```
'float32',padding='post',truncating='post')
```

```
X_test_pad_seq=
```

```
preprocessing.sequence.pad_sequences(test_sequences,maxlen=max_length
```

```
,
```

```
dtype =
```

```
'float32',padding='post',truncating='post')
```

```
#masking vector
```

```
#https://www.youtube.com/watch?v=sjIzRpVXd30
```

```
train_mask = X_train_pad_seq>0
```

```
test_mask = X_test_pad_seq>0
```

```

X_train_mask=train_mask
X_test_mask=test_mask

X_train_mask

array([[False, False, False, ..., False, False, False],
       [ True,  True,  True, ..., False, False, False],
       [ True,  True,  True, ..., False, False, False],
       ...,
       [ True,  True,  True, ..., False, False, False],
       [False, False, False, ..., False, False, False],
       [ True,  True,  True, ..., False, False, False]])

#X_train_pad_seq1 = np.expand_dims(X_train_pad_seq, -1)
#X_test_pad_seq1 = np.expand_dims(X_test_pad_seq, -1)

```

Grader function 5

```

def grader_padoutput():
    flag_padshape = (X_train_pad_seq.shape==(1400, 17640)) and
(X_test_pad_seq.shape==(600, 17640)) and (y_train.shape==(1400,))
    flag_maskshape = (X_train_mask.shape==(1400, 17640)) and
(X_test_mask.shape==(600, 17640)) and (y_test.shape==(600,))
    flag_dtype = (X_train_mask.dtype==bool) and
(X_test_mask.dtype==bool)
    return flag_padshape and flag_maskshape and flag_dtype
grader_padoutput()

```

True

## 1. Giving Raw data directly.

Now we have

Train data: X\_train\_pad\_seq, X\_train\_mask and y\_train

Test data: X\_test\_pad\_seq, X\_test\_mask and y\_test

We will create a LSTM model which takes this input.

Task:

1. Create an LSTM network which takes "X\_train\_pad\_seq" as input, "X\_train\_mask" as mask input. You can use any number of LSTM cells. Please read LSTM documentation([https://www.tensorflow.org/api\\_docs/python/tf/keras/layers/LSTM](https://www.tensorflow.org/api_docs/python/tf/keras/layers/LSTM)) in tensorflow to know more about mask and also [https://www.tensorflow.org/guide/keras/masking\\_and\\_padding](https://www.tensorflow.org/guide/keras/masking_and_padding)
2. Get the final output of the LSTM and give it to Dense layer of any size and then give it to Dense layer of size 10(because we have 10 outputs) and then compile with the sparse categorical cross entropy( because we are not converting it to one hot vectors). Also check the datatype of class labels(y\_values) and make sure that you convert your class labels to integer datatype before fitting in the model.

3. While defining your model make sure that you pass both the input layer and mask input layer as input to lstm layer as follows
4. Use tensorboard to plot the graphs of loss and metric(use custom micro F1 score as metric) and histograms of gradients. You can write your code for computing F1 score using this link
5. make sure that it won't overfit.
6. You are free to include any regularization

```
y_train = y_train.values.astype('int')
y_test = y_test.values.astype('int')
```

```
X_train_pad_seq = X_train_pad_seq
X_test_pad_seq = X_test_pad_seq
```

Call backs

<https://towardsdatascience.com/custom-callback-functions-for-transformers-ae65e30c094f>

<https://imgur.com/8YULUcu>

```
import numpy as np
import tensorflow as tf
from tensorflow.keras.callbacks import Callback
from sklearn.metrics import f1_score
```

```
class Metrics(Callback):
    def __init__(self, train_data, validation_data):
        self.validation_data = validation_data
        self.train_data = train_data
    def on_epoch_end(self, epoch, logs={}):

        train_predict =
np.argmax(tf.nn.softmax(self.model.predict(self.train_data[0])),1)
        train_targ = self.train_data[1]
        train_f1 = f1_score(train_targ, train_predict,
average='micro')
        logs['train_f1'] = train_f1

        val_predict =
np.argmax(tf.nn.softmax(self.model.predict(self.validation_data[0])),1
)
        val_targ = self.validation_data[1]
        val_f1 = f1_score(val_targ, val_predict, average='micro')
        logs['val_f1'] = val_f1

        print (f'- val_f1: {round(val_f1,4)} ')
        print (f'- train_f1: {round(train_f1,4)} ')
        return val_f1, train_f1
```

```

class F1Score(tf.keras.callbacks.Callback):
    def __init__(self, train_data, validation_data):
        super().__init__()
        self.train_data = train_data
        self.validation_data = validation_data
        self.history = {}
        self.history['val_f1_score'] = []

    def on_epoch_end(self, epochs, logs = {}):
        train_preds =
np.argmax(self.model.predict(self.train_data[0]), axis = 1)
        train_f1_score = f1_score(self.train_data[1], train_preds,
average='micro')
        #train_f1_score = np.round(train_f1_score, 4)

        test_preds =
np.argmax(self.model.predict(self.validation_data[0]), axis = 1)
        test_f1_score = f1_score(self.validation_data[1], test_preds,
average='micro')
        #test_f1_score = np.round(test_f1_score, 4)
        self.history['val_f1_score'].append(test_f1_score)

        print(f" train- f1_score: {train_f1_score} - val_f1_score:
{test_f1_score}")

from tensorflow.keras.callbacks import EarlyStopping
earlystop = EarlyStopping(monitor='val_loss', min_delta=0, patience=1,
verbose=1)

from tensorflow.keras.layers import Input, LSTM, Dense
from tensorflow.keras.models import Model
import tensorflow as tf

## as discussed above, please write the architecture of the model.
## you will have two input layers in your model (data input layer and
mask input layer)
## make sure that you have defined the data type of masking layer as
bool

import datetime

%load_ext tensorboard
# Clear any logs from previous runs
!rm -rf ./logs/

#callbacks
log_dir = os.path.join("logs", 'fits',

```

```
datetime.datetime.now().strftime("%Y%m%d-%H%M%S"))
tensorboard_callback =
tf.keras.callbacks.TensorBoard(log_dir=log_dir,histogram_freq=1,write_
graph=True)
```

*#creating the first model*

```
tf.keras.backend.clear_session()
in_put = Input(shape = (17640,1)) #array of max len is 17640 and
having 1 dimension from X_train padded
x_mask = Input(shape = (17640), dtype = 'bool') #mask have 17640
maxlen
layer_1= tf.keras.layers.LSTM(10)(in_put, mask = x_mask)
```

*# Usage in a Keras layer:*

*#<https://keras.io/api/layers/initializers/>*

```
GlorotNormal_initializer = tf.keras.initializers.GlorotNormal()
HeNormal_initializer = tf.keras.initializers.HeNormal()
```

```
layer_2 = tf.keras.layers.Dense(20, activation = 'relu',
kernel_initializer = GlorotNormal_initializer)(layer_1)
out = tf.keras.layers.Dense(10, activation = 'softmax',
kernel_initializer = HeNormal_initializer)(layer_2)
```

```
model1 = Model(inputs = [in_put, x_mask], outputs = out)
```

*#printing the summary of model*

```
model1.summary()
```

Model: "model"

Layer (type)	Output Shape	Param #
Connected to		
=====	=====	=====
input_1 (InputLayer)	[(None, 17640, 1)]	0 []
input_2 (InputLayer)	[(None, 17640)]	0 []
lstm (LSTM)	(None, 10)	480
['input_1[0][0]',		
'input_2[0][0]']		

dense (Dense)	(None, 20)	220
['lstm[0][0]']		
dense_1 (Dense)	(None, 10)	210
['dense[0][0]']		

```
=====
Total params: 910
Trainable params: 910
Non-trainable params: 0
```

---

```
#train your model
#model1.fit([X_train_pad_seq,X_train_mask],y_train_int,.....)

#https://machinelearningmastery.com/adam-optimization-algorithm-for-deep-learning/
#Adam Configuration Parameters
#alpha. Also referred to as the learning rate or step size.
#The proportion that weights are updated (e.g. 0.001).
#Larger values (e.g. 0.3) results in faster initial learning before the rate is updated.
#Smaller values (e.g. 1.0E-5) slow learning right down during training

model1.compile(optimizer = tf.keras.optimizers.Adam(0.001), loss =
'sparse_categorical_crossentropy')

callback = [F1Score([X_train_pad_seq, X_train_mask], y_train),
([X_test_pad_seq, X_test_mask], y_test)),
earlystop,tensorboard_callback]

model1.fit([X_train_pad_seq, X_train_mask], y_train, validation_data =
([X_test_pad_seq, X_test_mask], y_test),
batch_size = 80, epochs = 2, callbacks = callback)

Epoch 1/2
18/18 [=====] - ETA: 0s - loss: 2.3029
train- f1_score: 0.10000000000000002 - val_f1_score:
0.10000000000000002
18/18 [=====] - 319s 18s/step - loss: 2.3029
- val_loss: 2.3026
Epoch 2/2
18/18 [=====] - ETA: 0s - loss: 2.3027
train- f1_score: 0.10000000000000002 - val_f1_score:
0.10000000000000002
```

```
18/18 [=====] - 310s 18s/step - loss: 2.3027  
- val_loss: 2.3026
```

```
<keras.callbacks.History at 0x7f25c537f250>
```

```
%tensorboard --logdir logs/fits
```

```
Reusing TensorBoard on port 6006 (pid 608), started 0:00:48 ago. (Use  
'!kill 608' to kill it.)
```

```
<IPython.core.display.Javascript object>
```

## 2. Converting into spectrogram and giving spectrogram data as input

We can use librosa to convert raw data into spectrogram. A spectrogram shows the features in a two-dimensional representation with the intensity of a frequency at a point in time i.e we are converting Time domain to frequency domain. you can read more about this in <https://pnsn.org/spectrograms/what-is-a-spectrogram>

```
def convert_to_spectrogram(raw_data):  
    '''converting to spectrogram'''  
    spectrum = librosa.feature.melspectrogram(y=raw_data,  
sr=sample_rate, n_mels=64)  
    logmel_spectrum = librosa.power_to_db(S=spectrum, ref=np.max)  
    return logmel_spectrum
```

```
##use convert_to_spectrogram and convert every raw sequence in  
X_train_pad_seq and X_test_pad_seq.  
## save those all in the X_train_spectrogram and X_test_spectrogram  
( These two arrays must be numpy arrays)  
#reducing the dimensions back  
#https://www.geeksforgeeks.org/using-numpy-to-convert-array-elements-  
to-float-type/  
#https://stackoverflow.com/questions/49586458/parametererror-data-  
must-be-floating-point-librosa  
#convert dtype to float otherwise it shows audio should be in floating  
point
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:7:  
DeprecationWarning: `np.float` is a deprecated alias for the builtin  
`float`. To silence this warning, use `float` by itself. Doing this  
will not modify any behavior and is safe. If you specifically wanted  
the numpy scalar type, use `np.float64` here.
```

```
Deprecated in NumPy 1.20; for more details and guidance:  
https://numpy.org/devdocs/release/1.20.0-notes.html#deprecations
```

```
import sys
```

```
/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:8:  
DeprecationWarning: `np.float` is a deprecated alias for the builtin  
`float`. To silence this warning, use `float` by itself. Doing this  
will not modify any behavior and is safe. If you specifically wanted  
the numpy scalar type, use `np.float64` here.
```

```
Deprecated in NumPy 1.20; for more details and guidance:
```

<https://numpy.org/devdocs/release/1.20.0-notes.html#deprecations>

```
X_train_spectrogram = []
for raw_ele in X_train_pad_seq:
    X_train_spectrogram.append(convert_to_spectrogram(raw_ele))
X_train_spectrogram = np.array(X_train_spectrogram)

X_test_spectrogram = []
for raw_ele in X_test_pad_seq:
    X_test_spectrogram.append(convert_to_spectrogram(raw_ele))
X_test_spectrogram = np.array(X_test_spectrogram)
```

Grader function 6

```
def grader_spectrogram():
    flag_shape = (X_train_spectrogram.shape==(1400,64, 35)) and
(X_test_spectrogram.shape == (600, 64, 35))
    return flag_shape
grader_spectrogram()
```

True

Now we have

Train data: X\_train\_spectrogram and y\_train

Test data: X\_test\_spectrogram and y\_test

We will create a LSTM model which takes this input.

Task:

1. Create an LSTM network which takes "X\_train\_spectrogram" as input and has to return output at every time step.
2. Average the output of every time step and give this to the Dense layer of any size. (ex: Output from LSTM will be (None, time\_steps, features) average the output of every time step i.e, you should get (None,time\_steps) and then pass to dense layer )
3. give the above output to Dense layer of size 10( output layer) and train the network with sparse categorical cross entropy.
4. Use tensorboard to plot the graphs of loss and metric(use custom micro F1 score as metric) and histograms of gradients. You can write your code for computing F1 score using this link
5. make sure that it won't overfit.
6. You are free to include any regularization

*#<https://classroom.appliedroots.com/v2/faqs/3DALB9LQ/>*

*# write the architecture of the model*

*#print model.summary and make sure that it is following point 2 mentioned above*

*tf.keras.backend.clear\_session()*



```

in_put = Input(shape = (64,35,))
layer_1 = LSTM(192, return_sequences = True)(in_put)
#https://www.tensorflow.org/api_docs/python/tf/math/reduce_mean
#https://stackoverflow.com/questions/65185733/how-to-apply-average-
pooling-at-each-time-step-of-lstm-output
layer_2 = tf.reduce_mean(layer_1, axis = -1)

```

```

# Usage in a Keras layer:
#https://keras.io/api/layers/initializers/
GlorotNormal_initializer = tf.keras.initializers.GlorotNormal()
HeNormal_initializer = tf.keras.initializers.HeNormal()
layer_3 = Dense(192, activation = 'relu', kernel_initializer =
GlorotNormal_initializer)(layer_2)
out_put = Dense(10, activation = 'softmax', kernel_initializer =
GlorotNormal_initializer )(layer_3)

```

```

model2 = Model(inputs = in_put, outputs = out_put)
#printing the model summary
model2.summary()

```

Model: "model"

Layer (type)	Output Shape	Param #
input_1 (InputLayer)	[(None, 64, 35)]	0
lstm (LSTM)	(None, 64, 192)	175104
tf.math.reduce_mean (TFOpLa mbda)	(None, 64)	0
dense (Dense)	(None, 192)	12480
dense_1 (Dense)	(None, 10)	1930

```

=====
Total params: 189,514
Trainable params: 189,514
Non-trainable params: 0
=====

```

```

#compile and fit your model.
#model2.fit([X_train_spectrogram],y_train_int,.....)

```

```

class F1ScoreCB(tf.keras.callbacks.Callback):
    def __init__(self, train_data, test_data):
        super().__init__()
        self.train_data = train_data
        self.test_data = test_data
        self.history = {}
        self.history['val_f1_score'] = []

```

```

def on_epoch_end(self, epochs, logs = {}):
    train_preds =
np.argmax(self.model.predict(self.train_data[0]), axis = -1)
    train_f1_score = f1_score(self.train_data[1], train_preds,
average='micro')
    train_f1_score = np.round(train_f1_score, 4)

    test_preds = np.argmax(self.model.predict(self.test_data[0]),
axis = -1)
    test_f1_score = f1_score(self.test_data[1], test_preds,
average='micro')
    test_f1_score = np.round(test_f1_score, 4)
    self.history['val_f1_score'].append(test_f1_score)

    print(f" - f1_score: {train_f1_score} - val_f1_score:
{test_f1_score}")

```

```

%load_ext tensorboard
# Clear any logs from previous runs
!rm -rf ./logs/

```

The tensorboard extension is already loaded. To reload it, use:

```
%reload_ext tensorboard
```

```
Metrics((X_train_spectrogram, y_train),(X_test_spectrogram, y_test))
```

```
<__main__.Metrics at 0x7f25c465c790>
```

```
#https://machinelearningmastery.com/adam-optimization-algorithm-for-deep-learning/
```

```
#Adam Configuration Parameters
```

```
#alpha. Also referred to as the learning rate or step size.
```

```
#The proportion that weights are updated (e.g. 0.001).
```

```
#Larger values (e.g. 0.3) results in faster initial learning before the rate is updated.
```

```
#Smaller values (e.g. 1.0E-5) slow learning right down during training
```

```
#https://www.tensorflow.org/api\_docs/python/tf/keras/optimizers/Adam
```

```
model2.compile(optimizer = tf.keras.optimizers.Adam(0.0005), loss =
'sparse_categorical_crossentropy')
```

```
callback = [F1Score((X_train_spectrogram, y_train),
(X_test_spectrogram, y_test)),
earlystop,tensorboard_callback]
```

```
model2.fit(X_train_spectrogram, y_train, validation_data =
(X_test_spectrogram, y_test),
batch_size = 16, epochs = 20, callbacks = callback)
```

Epoch 1/20  
88/88 [=====] - ETA: 0s - loss: 2.2444 train-  
f1\_score: 0.30642857142857144 - val\_f1\_score: 0.30666666666666664  
88/88 [=====] - 15s 150ms/step - loss: 2.2444  
- val\_loss: 2.0909  
Epoch 2/20  
88/88 [=====] - ETA: 0s - loss: 1.8316 train-  
f1\_score: 0.5321428571428571 - val\_f1\_score: 0.5383333333333333  
88/88 [=====] - 13s 149ms/step - loss: 1.8316  
- val\_loss: 1.5893  
Epoch 3/20  
88/88 [=====] - ETA: 0s - loss: 1.4786 train-  
f1\_score: 0.6107142857142858 - val\_f1\_score: 0.5766666666666667  
88/88 [=====] - 12s 139ms/step - loss: 1.4786  
- val\_loss: 1.3443  
Epoch 4/20  
88/88 [=====] - ETA: 0s - loss: 1.2745 train-  
f1\_score: 0.6792857142857143 - val\_f1\_score: 0.6566666666666666  
88/88 [=====] - 12s 135ms/step - loss: 1.2745  
- val\_loss: 1.2094  
Epoch 5/20  
88/88 [=====] - ETA: 0s - loss: 1.1066 train-  
f1\_score: 0.7107142857142857 - val\_f1\_score: 0.7  
88/88 [=====] - 12s 138ms/step - loss: 1.1066  
- val\_loss: 1.0381  
Epoch 6/20  
88/88 [=====] - ETA: 0s - loss: 0.9961 train-  
f1\_score: 0.7428571428571429 - val\_f1\_score: 0.74  
88/88 [=====] - 12s 140ms/step - loss: 0.9961  
- val\_loss: 0.9336  
Epoch 7/20  
88/88 [=====] - ETA: 0s - loss: 0.8953 train-  
f1\_score: 0.7614285714285713 - val\_f1\_score: 0.7516666666666667  
88/88 [=====] - 12s 139ms/step - loss: 0.8953  
- val\_loss: 0.8563  
Epoch 8/20  
88/88 [=====] - ETA: 0s - loss: 0.8214 train-  
f1\_score: 0.775 - val\_f1\_score: 0.7783333333333333  
88/88 [=====] - 16s 178ms/step - loss: 0.8214  
- val\_loss: 0.7802  
Epoch 9/20  
88/88 [=====] - ETA: 0s - loss: 0.7348 train-  
f1\_score: 0.797142857142857 - val\_f1\_score: 0.7866666666666666  
88/88 [=====] - 12s 138ms/step - loss: 0.7348  
- val\_loss: 0.7325  
Epoch 10/20  
88/88 [=====] - ETA: 0s - loss: 0.6685 train-  
f1\_score: 0.7685714285714286 - val\_f1\_score: 0.7733333333333333  
88/88 [=====] - 12s 138ms/step - loss: 0.6685  
- val\_loss: 0.7320

```

Epoch 11/20
88/88 [=====] - ETA: 0s - loss: 0.6297 train-
f1_score: 0.8171428571428572 - val_f1_score: 0.8283333333333334
88/88 [=====] - 12s 142ms/step - loss: 0.6297
- val_loss: 0.6369
Epoch 12/20
88/88 [=====] - ETA: 0s - loss: 0.6040 train-
f1_score: 0.8185714285714286 - val_f1_score: 0.8016666666666666
88/88 [=====] - 12s 137ms/step - loss: 0.6040
- val_loss: 0.6288
Epoch 13/20
88/88 [=====] - ETA: 0s - loss: 0.5574 train-
f1_score: 0.8399999999999999 - val_f1_score: 0.83
88/88 [=====] - 12s 142ms/step - loss: 0.5574
- val_loss: 0.5780
Epoch 14/20
88/88 [=====] - ETA: 0s - loss: 0.5416 train-
f1_score: 0.8492857142857143 - val_f1_score: 0.8483333333333335
88/88 [=====] - 12s 142ms/step - loss: 0.5416
- val_loss: 0.5482
Epoch 15/20
88/88 [=====] - ETA: 0s - loss: 0.4957 train-
f1_score: 0.8407142857142856 - val_f1_score: 0.845
88/88 [=====] - 12s 136ms/step - loss: 0.4957
- val_loss: 0.5361
Epoch 16/20
88/88 [=====] - ETA: 0s - loss: 0.5034 train-
f1_score: 0.8392857142857143 - val_f1_score: 0.8383333333333334
88/88 [=====] - 12s 142ms/step - loss: 0.5034
- val_loss: 0.5260
Epoch 17/20
88/88 [=====] - ETA: 0s - loss: 0.4581 train-
f1_score: 0.8721428571428571 - val_f1_score: 0.865
88/88 [=====] - 12s 138ms/step - loss: 0.4581
- val_loss: 0.4842
Epoch 18/20
88/88 [=====] - ETA: 0s - loss: 0.4373 train-
f1_score: 0.8642857142857143 - val_f1_score: 0.8433333333333335
88/88 [=====] - 12s 138ms/step - loss: 0.4373
- val_loss: 0.4987
Epoch 18: early stopping

```

```
<keras.callbacks.History at 0x7f25c464ae50>
```

```

#model2.compile(optimizer = tf.keras.optimizers.Adam(0.0006), loss =
'sparse_categorical_crossentropy')
#cb = [Metrics((X_train_spectrogram, y_train),(X_test_spectrogram,
y_test)),
#earlystop,tensorboard_callback]

```

```
#model2.fit(X_train_spectrogram, y_train, validation_data =
(X_test_spectrogram, y_test),
            #batch_size = 16, epochs = 15, callbacks = cb)
```

```
%tensorboard --logdir logs/fits
```

Reusing TensorBoard on port 6006 (pid 608), started 0:55:49 ago. (Use '!kill 608' to kill it.)

```
<IPython.core.display.Javascript object>
```

### 3. Data augmentation with raw features

Till now we have done with 2000 samples only. It is very less data. We are giving the process of generating augmented data below.

There are two types of augmentation:

1. time stretching - Time stretching either increases or decreases the length of the file. For time stretching we move the file 30% faster or slower
2. pitch shifting - pitch shifting moves the frequencies higher or lower. For pitch shifting we shift up or down one half-step.

```
## generating augmented data.
```

```
def generate_augmented_data(file_path):
    augmented_data = []
    samples = load_wav(file_path, get_duration=False)
    for time_value in [0.7, 1, 1.3]:
        for pitch_value in [-1, 0, 1]:
            time_stretch_data = librosa.effects.time_stretch(samples,
rate=time_value)
            final_data =
librosa.effects.pitch_shift(time_stretch_data, sr=sample_rate,
n_steps=pitch_value)
            augmented_data.append(final_data)
    return augmented_data
```

### Follow the steps

1. Split data 'df\_audio' into train and test (80-20 split)
2. We have 2000 data points(1600 train points, 400 test points)

```
from sklearn.model_selection import train_test_split
```

```
X_train, X_test, y_train,
y_test=train_test_split(df_audio['path'],df_audio['label'],random_stat
e = 32321,test_size=0.2,stratify=df_audio['label'])
```

1. Do augmentation only on X\_train, pass each point of X\_train to generate\_augmented\_data function. After augmentation we will get 14400 train

points. Make sure that you are augmenting the corresponding class labels (y\_train) also.

2. Preprocess your X\_test using load\_wav function.
3. Convert the augmented\_train\_data and test\_data to numpy arrays.
4. Perform padding and masking on augmented\_train\_data and test\_data.
5. After padding define the model similar to model 1 and fit the data

Note - While fitting your model on the augmented data for model 3 you might face Resource exhaust error. One simple hack to avoid that is save the augmented\_train\_data, augment\_y\_train, test\_data and y\_test to Drive or into your local system. Then restart the runtime so that now you can train your model with full RAM capacity. Upload these files again in the new runtime session perform padding and masking and then fit your model.

*#Data augmentation on train data and preprocessing on test data*

```
train_augmented_data = []  
train_augmented_labels = []
```

```
for path, label in zip(X_train.values, y_train.values):  
    aug_data = generate_augmented_data(path)
```

```
#train_augmented_data.extend(aug_data)#https://www.programiz.com/  
python-programming/methods/list/extend  
#append() adds a single element to the end of the list while .  
extend() can add multiple individual elements to the end of the list  
train_augmented_data+=aug_data
```

```
train_augmented_labels.extend(label*9)#https://www.programiz.com/  
python-programming/methods/list/extend
```

```
X_train_processed = pd.DataFrame({'raw_data' : train_augmented_data,  
'label' : train_augmented_labels})
```

```
#X_train_processed=pd.read_csv('/content/final_preprocessed_sound_model  
13_train1.csv')
```

```
#X_test_processed=pd.read_csv('/content/final_preprocessed_sound_model  
3_test.csv')
```

```
test_data, test_duration=[], []
```

```
for path in X_test:  
    z=load_wav(path, get_duration=True)  
    test_data.append(z[0]) #z[0] means samples  
    test_duration.append(z[1]) #z[1] means duration
```

```

X_test_processed = pd.DataFrame({'raw_data' : test_data, 'label' :
y_test})

#https://stackoverflow.com/questions/42598630/why-cant-i-use-
preprocessing-module-in-keras
import tensorflow as tf
import keras
from keras import preprocessing
from tensorflow.keras.preprocessing.sequence import pad_sequences

train_sequences=X_train_processed.raw_data
test_sequences=X_test_processed.raw_data
max_length = 17640

X_train_pad_seq3=
preprocessing.sequence.pad_sequences(X_train_processed.raw_data,maxlen=
=max_length ,
dtype =
'float32',padding='post',truncating='post')

X_test_pad_seq3=
preprocessing.sequence.pad_sequences(X_test_processed.raw_data,maxlen=
max_length ,
dtype =
'float32',padding='post',truncating='post')

#saving the dataframe
#X_train_processed.to_csv(r'final_preprocessed_sound_model3_train1.csv
')
#X_test_processed.to_csv(r'final_preprocessed_sound_model3_test.csv')
#from google.colab import files
#files.download('final_preprocessed_sound_model3_train1.csv')
#files.download('final_preprocessed_sound_model3_test.csv')

y_train3 = X_train_processed.label.values.astype('int')
y_test3 = X_test_processed.label.values.astype('int')

X_train_mask3 = X_train_pad_seq3>0
X_test_mask3 = X_test_pad_seq3>0

#creating the first model
tf.keras.backend.clear_session()
in_put = Input(shape = (17640,1)) #array of max len is 17640 and
having 1 dimension from X_train padded
x_mask = Input(shape = (17640), dtype = 'bool') #mask have 17640
maxlen
layer_1= tf.keras.layers.LSTM(10)(in_put, mask = x_mask)

# Usage in a Keras layer:
#https://keras.io/api/layers/initializers/
GlorotNormal_initializer = tf.keras.initializers.GlorotNormal()

```

```
HeNormal_initializer = tf.keras.initializers.HeNormal()
```

```
layer_2 = tf.keras.layers.Dense(20, activation = 'relu',  
kernel_initializer = GlorotNormal_initializer)(layer_1)  
out = tf.keras.layers.Dense(10, activation = 'softmax',  
kernel_initializer = GlorotNormal_initializer)(layer_2)
```

```
model3 = Model(inputs = [in_put, x_mask], outputs = out)  
#printing the summary of model  
model3.summary()
```

Model: "model"

Layer (type) Connected to	Output Shape	Param #	
=====			
input_1 (InputLayer)	[(None, 17640, 1)]	0	[]
input_2 (InputLayer)	[(None, 17640)]	0	[]
lstm (LSTM) ['input_1[0][0]', 'input_2[0][0]']	(None, 10)	480	
dense (Dense) ['lstm[0][0]']	(None, 20)	220	
dense_1 (Dense) ['dense[0][0]']	(None, 10)	210	
=====			
Total params: 910			
Trainable params: 910			
Non-trainable params: 0			



```

#tf.keras.backend.clear_session()
#inp = Input(shape = (17640,1))
#inp_mask = Input(shape = (17640), dtype = 'bool')

#x = LSTM(10)(inp, mask = inp_mask)

#x = Dense(20, activation = 'relu', kernel_initializer = 'he_normal')
(x)
#out = Dense(10, activation = 'softmax', kernel_initializer =
'glorot_normal')(x)

#model3 = Model(inputs = [inp, inp_mask], outputs = out)

```

```

model3.compile(optimizer = tf.keras.optimizers.Adam(0.001), loss =
'sparse_categorical_crossentropy')

```

```

callback = [F1Score([X_train_pad_seq3, X_train_mask3], y_train3),
([X_test_pad_seq3, X_test_mask3], y_test3)),
earlystop,tensorboard_callback]

```

```

model3.fit([X_train_pad_seq3, X_train_mask3], y_train3,
validation_data = ([X_test_pad_seq3, X_test_mask3], y_test3),
batch_size = 380, epochs = 10, callbacks = callback)

```

Epoch 1/10

38/38 [=====] - ETA: 0s - loss: 2.3026

train- f1\_score: 0.10208333333333333 - val\_f1\_score:

0.10749999999999998

38/38 [=====] - 1380s 37s/step - loss: 2.3026

- val\_loss: 2.3026

Epoch 2/10

38/38 [=====] - ETA: 0s - loss: 2.3026

train- f1\_score: 0.09763888888888889 - val\_f1\_score:

0.100000000000000002

38/38 [=====] - 1284s 34s/step - loss: 2.3026

- val\_loss: 2.3025

Epoch 3/10

38/38 [=====] - ETA: 0s - loss: 2.3024

train- f1\_score: 0.10895833333333334 - val\_f1\_score: 0.1225

38/38 [=====] - 1321s 35s/step - loss: 2.3024

- val\_loss: 2.3022

Epoch 4/10

38/38 [=====] - ETA: 0s - loss: 2.3022

train- f1\_score: 0.09402777777777778 - val\_f1\_score: 0.1125

38/38 [=====] - 1271s 34s/step - loss: 2.3022

- val\_loss: 2.3016

Epoch 5/10

38/38 [=====] - ETA: 0s - loss: 2.3013

```

train- f1_score: 0.10000000000000002 - val_f1_score:
0.10000000000000002
38/38 [=====] - 1323s 35s/step - loss: 2.3013
- val_loss: 2.3000
Epoch 6/10
38/38 [=====] - ETA: 0s - loss: 2.3023
train- f1_score: 0.11472222222222223 - val_f1_score: 0.0975
38/38 [=====] - 1319s 35s/step - loss: 2.3023
- val_loss: 2.3019
Epoch 6: early stopping
<keras.callbacks.History at 0x7f25c3bffa35>

```

```
%tensorboard --logdir logs/fits
```

```

Reusing TensorBoard on port 6006 (pid 608), started 3:25:23 ago. (Use
'!kill 608' to kill it.)

```

```
<IPython.core.display.Javascript object>
```

#### 4. Data augmentation with spectrogram data

1. use `convert_to_spectrogram` and convert the padded data from train and test data to spectrogram data.
2. The shape of train data will be 14400 x 64 x 35 and shape of test\_data will be 400 x 64 x 35
3. Define the model similar to model 2 and fit the data

```

def convert_to_spectrogram(raw_data):
    '''converting to spectrogram'''
    spectrum = librosa.feature.melspectrogram(y=raw_data,
sr=sample_rate, n_mels=64)
    logmel_spectrum = librosa.power_to_db(S=spectrum, ref=np.max)
    return logmel_spectrum

```

```

X_train_spectrogram4 = []
for raw_ele in X_train_pad_seq3:
    X_train_spectrogram4.append(convert_to_spectrogram(raw_ele))
X_train_spectrogram4 = np.array(X_train_spectrogram4)

```

```

X_test_spectrogram4 = []
for raw_ele in X_test_pad_seq3:
    X_test_spectrogram4.append(convert_to_spectrogram(raw_ele))
X_test_spectrogram4 = np.array(X_test_spectrogram4)

```

```

y_train4 = y_train3
y_test4 = y_test3

```

```

#https://classroom.appliedroots.com/v2/faqs/3DALB9LQ/
# write the architecture of the model

```

```
#print model.summary and make sure that it is following point 2
mentioned above
tf.keras.backend.clear_session()
in_put = Input(shape = (64,35,))
layer_1 = LSTM(192, return_sequences = True)(in_put)
#https://www.tensorflow.org/api_docs/python/tf/math/reduce_mean
#https://stackoverflow.com/questions/65185733/how-to-apply-average-
pooling-at-each-time-step-of-lstm-output
layer_2 = tf.reduce_mean(layer_1, axis = -1)
```

```
# Usage in a Keras layer:
#https://keras.io/api/layers/initializers/
GlorotNormal_initializer = tf.keras.initializers.GlorotNormal()
HeNormal_initializer = tf.keras.initializers.HeNormal()
layer_3 = Dense(192, activation = 'relu', kernel_initializer =
GlorotNormal_initializer)(layer_2)
out_put = Dense(10, activation = 'softmax', kernel_initializer =
GlorotNormal_initializer )(layer_3)
```

```
model4 = Model(inputs = in_put, outputs = out_put)
```

```
#printing the model summary
```

```
model4.summary()
```

```
Model: "model"
```

Layer (type)	Output Shape	Param #
input_1 (InputLayer)	[(None, 64, 35)]	0
lstm (LSTM)	(None, 64, 192)	175104
tf.math.reduce_mean (TFOpLambda)	(None, 64)	0
dense (Dense)	(None, 192)	12480
dense_1 (Dense)	(None, 10)	1930
Total params: 189,514		
Trainable params: 189,514		
Non-trainable params: 0		

```
from tensorflow.keras.callbacks import EarlyStopping
earlystop = EarlyStopping(monitor='val_loss', min_delta=0, patience=1,
verbose=1)
```

```
import datetime

%load_ext tensorboard
# Clear any logs from previous runs
!rm -rf ./logs/

#callbacks
log_dir = os.path.join("logs", 'fits',
datetime.datetime.now().strftime("%Y%m%d-%H%M%S"))
tensorboard_callback =
tf.keras.callbacks.TensorBoard(log_dir=log_dir,histogram_freq=1,write_
graph=True)
```

The tensorboard extension is already loaded. To reload it, use:

```
%reload_ext tensorboard
```

```
#https://www.tensorflow.org/api\_docs/python/tf/keras/optimizers/Adam
model4.compile(optimizer = tf.keras.optimizers.Adam(0.0005), loss =
'sparse_categorical_crossentropy')
cb = [F1ScoreCB((X_train_spectrogram4, y_train4),
(X_test_spectrogram4, y_test4)),
earlystop,tensorboard_callback]
```

```
model4.fit(X_train_spectrogram4, y_train4, validation_data =
(X_test_spectrogram4, y_test4),
batch_size = 16, epochs = 10, callbacks = cb)
```

```
Epoch 1/10
900/900 [=====] - ETA: 0s - loss: 1.4326 -
f1_score: 0.6973 - val_f1_score: 0.745
900/900 [=====] - 108s 118ms/step - loss:
1.4326 - val_loss: 0.8009
Epoch 2/10
900/900 [=====] - ETA: 0s - loss: 0.7676 -
f1_score: 0.7817 - val_f1_score: 0.82
900/900 [=====] - 102s 114ms/step - loss:
0.7676 - val_loss: 0.5476
Epoch 3/10
900/900 [=====] - ETA: 0s - loss: 0.6206 -
f1_score: 0.8064 - val_f1_score: 0.805
900/900 [=====] - 101s 113ms/step - loss:
0.6206 - val_loss: 0.5138
Epoch 4/10
900/900 [=====] - ETA: 0s - loss: 0.5475 -
f1_score: 0.8258 - val_f1_score: 0.87
900/900 [=====] - 103s 114ms/step - loss:
0.5475 - val_loss: 0.4397
Epoch 5/10
900/900 [=====] - ETA: 0s - loss: 0.5059 -
f1_score: 0.8376 - val_f1_score: 0.8675
```

```
900/900 [=====] - 102s 113ms/step - loss:
0.5059 - val_loss: 0.4243
Epoch 6/10
900/900 [=====] - ETA: 0s - loss: 0.4729 -
f1_score: 0.8365 - val_f1_score: 0.8525
900/900 [=====] - 102s 113ms/step - loss:
0.4729 - val_loss: 0.4511
Epoch 6: early stopping
<keras.callbacks.History at 0x7f25c1267990>
```

```
%tensorboard --logdir logs/fits
```

```
Reusing TensorBoard on port 6006 (pid 608), started 3:48:21 ago. (Use
'!kill 608' to kill it.)
```

```
<IPython.core.display.Javascript object>
```

#Inferences:

- 1) In model 1 and model 3 as the data does not convert into time domain frequency so that model does not learn and generate a low f1 score.
- 2) In model 2 and model 4 as the data converted into Time Domain frequency spectrograms so that model learns and generate a high f1 score. Also average of time step frequency reduce the dimensionality and it reaches optimality in less Time.
- 3) Data augmentation helps to model do not overfitting on the data.