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 instrctions are given below. You have to write the code in the same cell which contains the instrction.
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 of 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.

In [3]:

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

We shared recordings.zip, please unzip those.

In [4]:

```
!wget --header="Host: doc-00-7s-docs.googleusercontent.com" --header="User-Agent: Mozilla/5.0 (Windows NT 10.0; W
in64; x64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/93.0.4577.63 Safari/537.36" --header="Accept: text/html,
application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*/*;q=0.8,application/signed-exchang
e;v=b3;q=0.9" --header="Accept-Language: en-IN,en-GB;q=0.9,en-US;q=0.8,en;q=0.7" --header="Cookie: AUTH_smvf2o367
eja801lv3hmgenqovh1tbcl_nonce=4m02l3olv6blg" --header="Connection: keep-alive" "https://doc-00-7s-docs.googleuser
content.com/docs/securesc/9csvdbmvo9gt489glsl99tqs7subbnk6/67mi270jjgtk4loba05f81a8t5423so6/1631524275000/0048451
6897554883881/01088116874641946513/17YGQheavMbM6aeHYjUcGssXfb7eQHo1z?e=download&authuser=0&nonce=4m02l3olv6blg&us
er=01088116874641946513&hash=9dha3qpbpilntebna8sqasvs3joc0m56" -c -O 'recordings.zip'
```

```
--2021-09-13 09:12:45--  https://doc-00-7s-docs.googleusercontent.com/docs/securesc/9csvdbmvo9gt489g
lsl99tqs7subbnk6/67mi270jjgtk4loba05f81a8t5423so6/1631524275000/00484516897554883881/010881168746419
46513/17YGQheavMbM6aeHYjUcGssXfb7eQHo1z?e=download&authuser=0&nonce=4m02l3olv6blg&user=0108811687464
1946513&hash=9dha3qpbpilntebna8sqasvs3joc0m56
Resolving doc-00-7s-docs.googleusercontent.com (doc-00-7s-docs.googleusercontent.com)... 74.125.69.1
32, 2607:f8b0:4001:c08::84
Connecting to doc-00-7s-docs.googleusercontent.com (doc-00-7s-docs.googleusercontent.com)|74.125.69.
132|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: unspecified [application/x-zip-compressed]
Saving to: ‘recordings.zip’

recordings.zip          [  <=>               ]   8.85M  35.1MB/s    in 0.3s

2021-09-13 09:12:46 (35.1 MB/s) - ‘recordings.zip’ saved [9282934]
```

In [5]:

```
import zipfile
with zipfile.ZipFile("/content/recordings.zip", 'r') as zip_ref:
    zip_ref.extractall()
```

In [6]:

```
import os
len(os.listdir("recordings")) #there are 2000 audi files
```

Out[6]:

```
2000
```

In [ ]:

```
#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"
```

In [7]:

```
all_files=[]
```

In [8]:

```
for i in os.listdir("/content/recordings"):
    a1="/content/recordings/" +str(i)
    all_files.append(a1)
```

In [9]:

```
len(all_files)
```

Out[9]:

```
2000
```

In [10]:

```
all_files[0]
```

Out[10]:

```
'/content/recordings/9_yweweler_13.wav'
```

Grader function 1

In [11]:

```
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()
```

Out[11]:

```
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

In [12]:

```
#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
all_files[17]
```

Out[12]:

```
'/content/recordings/9_nicolas_43.wav'
```

In [13]:

```
#creating labels
label=[]
import re
for i in all_files:
    x = int(re.findall('[0-9]+', i)[0])
    label.append(x)
```

In [14]:

```
len(label)  #labels are created
```

Out[14]:

```
2000
```

In [15]:

```
print(all_files[12])
print("*********")
print(label[12])
```

```
/content/recordings/5_jackson_31.wav
*********
5
```

In [16]:

```
df_audio=pd.DataFrame(list(zip(all_files, label)),columns =['path', 'label'])
df_audio.head(20)
```

Out[16]:

	path	label
0	/content/recordings/9_yweweler_13.wav	9
1	/content/recordings/0_theo_27.wav	0
2	/content/recordings/9_jackson_45.wav	9
3	/content/recordings/9_nicolas_19.wav	9
4	/content/recordings/4_theo_45.wav	4
5	/content/recordings/4_nicolas_10.wav	4
6	/content/recordings/0_nicolas_23.wav	0
7	/content/recordings/2_yweweler_29.wav	2
8	/content/recordings/6_theo_20.wav	6
9	/content/recordings/1_yweweler_47.wav	1
10	/content/recordings/8_theo_38.wav	8
11	/content/recordings/5_yweweler_21.wav	5
12	/content/recordings/5_jackson_31.wav	5
13	/content/recordings/1_yweweler_23.wav	1
14	/content/recordings/8_nicolas_42.wav	8
15	/content/recordings/7_nicolas_1.wav	7
16	/content/recordings/1_theo_21.wav	1
17	/content/recordings/9_nicolas_43.wav	9
18	/content/recordings/7_yweweler_28.wav	7
19	/content/recordings/9_theo_39.wav	9

In [17]:

```
df_audio.shape
```

Out[17]:

```
(2000, 2)
```

In [18]:

```
#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   int64 
dtypes: int64(1), object(1)
memory usage: 31.4+ KB
```

Grader function 2

In [19]:

```
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()
```

Out[19]:

```
True
```

In [20]:

```
from sklearn.utils import shuffle
df_audio = shuffle(df_audio, random_state=33)#don't change the random state
```

Train and Validation split

In [21]:

```
#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_train, X_test, y_train, y_test = train_test_split(all_files, label, test_size=0.30, random_state=45,stratify=la
bel)
```

In [22]:

```
print(type(X_train))
print(len(X_train))

print("*********")

print(type(y_train))
print(len(y_train))
```

```
<class 'list'>
1400
*********
<class 'list'>
1400
```

In [23]:

```
X_train[12]
```

Out[23]:

```
'/content/recordings/1_yweweler_25.wav'
```

In [24]:

```
print(type(X_test))
print(len(X_test))
print("*******")
print(type(y_test))
print(len(y_test))
```

```
<class 'list'>
600
*******
<class 'list'>
600
```

In [25]:

```
X_train=pd.DataFrame(X_train,columns=["path"])
y_train=pd.DataFrame(y_train,columns=['label'])
X_test=pd.DataFrame(X_test,columns=['path'])
y_test=pd.DataFrame(y_test,columns=["label"])
```

In [26]:

```
print(X_train.shape)
print(y_train.shape)
print("************")
print(X_test.shape)
print(y_test.shape)
```

```
(1400, 1)
(1400, 1)
************
(600, 1)
(600, 1)
```

In [27]:

```
print(type(y_train))
print(type(y_test))
```

```
<class 'pandas.core.frame.DataFrame'>
<class 'pandas.core.frame.DataFrame'>
```

Grader function 3

In [28]:

```
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()
```

Out[28]:

```
True
```

```
Preprocessing

All files are in the "WAV" format. We will read those raw data files using the librosa
```

In [29]:

```
print(X_train)
```

```
                                     path
0         /content/recordings/6_theo_24.wav
1     /content/recordings/1_yweweler_32.wav
2     /content/recordings/6_yweweler_45.wav
3      /content/recordings/5_jackson_49.wav
4      /content/recordings/0_jackson_24.wav
...                                     ...
1395   /content/recordings/2_nicolas_49.wav
1396  /content/recordings/8_yweweler_23.wav
1397   /content/recordings/0_nicolas_32.wav
1398    /content/recordings/3_nicolas_6.wav
1399       /content/recordings/2_theo_3.wav

[1400 rows x 1 columns]
```

In [30]:

```
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
```

In [31]:

```
X_train.path[0]
```

Out[31]:

```
'/content/recordings/6_theo_24.wav'
```

In [32]:

```
from tqdm import tqdm
x_train_ls_samples=[]
x_train_ls_duration=[]

for i in tqdm(X_train.path):
    s1,d1=load_wav(i)
    x_train_ls_samples.append(s1)
    x_train_ls_duration.append(d1)
```

```
100%|██████████| 1400/1400 [00:21<00:00, 65.76it/s]
```

In [33]:

```
X_train_processed=pd.DataFrame(list(zip(x_train_ls_samples, x_train_ls_duration)),columns =['raw_data', 'duration
'])
```

In [34]:

```
print(X_train_processed.shape)
print(type(X_train_processed))
print("*****")
print(X_train_processed.head(6))
```

```
(1400, 2)
<class 'pandas.core.frame.DataFrame'>
*****
                                            raw_data  duration
0  [0.00076898345, 0.0006697864, 0.00023488962, -...  0.499002
1  [5.9146714e-05, 6.741898e-05, 7.909497e-05, 9....  0.270159
2  [-0.0002240487, -0.00023717241, -0.00022053233...  0.255420
3  [0.01055219, 0.01332846, 0.014389632, 0.014420...  0.479909
4  [-0.010665349, -0.013037161, -0.01384184, -0.0...  0.642041
5  [-0.043248296, -0.028579358, -0.00053534476, 0...  0.474512
```

In [35]:

```
print(type(X_train_processed.raw_data[11]))
```

```
<class 'numpy.ndarray'>
```

In [36]:

```
x_test_ls_samples=[]
x_test_ls_duration=[]
for i in tqdm(X_test.path):
    s2,d2=load_wav(i)
    x_test_ls_samples.append(s2)
    x_test_ls_duration.append(d2)
```

```
100%|██████████| 600/600 [00:08<00:00, 70.44it/s]
```

In [37]:

```
X_test_processed=pd.DataFrame(list(zip(x_test_ls_samples, x_test_ls_duration)),columns =['raw_data', 'duration'])
```

In [38]:

```
print(X_test_processed.shape)
print("********")
print(X_test_processed.head(6))
```

```
(600, 2)
********
                                            raw_data  duration
0  [-3.0896386e-05, 4.630324e-05, 0.0001238384, 0...  0.266259
1  [0.0001578252, 0.00016368195, 0.00016087637, 0...  0.282132
2  [-5.8392292e-08, 0.00026674374, 0.0003689947, ...  0.264036
3  [-0.0048882305, -0.0035996484, -0.0010624625, ...  0.818277
4  [-0.024412373, -0.0374546, -0.04497262, -0.045...  0.371020
5  [-0.00027326788, -4.2910684e-05, 8.124177e-05,...  0.222630
```

In [ ]:

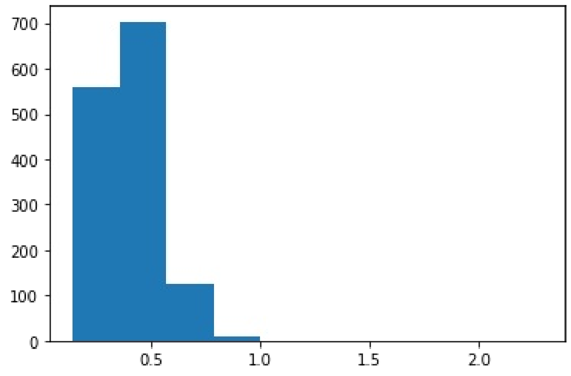
```
#use load_wav function that was written above to get every wave.
#save it in X_train_processed and X_test_processed
# X_train_processed/X_test_processed should be dataframes with two columns(raw_data, duration) with same index of
X_train/y_train
```

In [39]:

```
#plot the histogram of the duration for trian
import matplotlib.pyplot as plt
plt.hist(X_train_processed.duration)
```

Out[39]:

```
(array([559., 703., 126.,  10.,   1.,   0.,   0.,   0.,   0.,   1.]),
 array([0.14353741, 0.35746032, 0.57138322, 0.78530612, 0.99922902,
        1.21315193, 1.42707483, 1.64099773, 1.85492063, 2.06884354,
        2.28276644]),
 <a list of 10 Patch objects>)
```

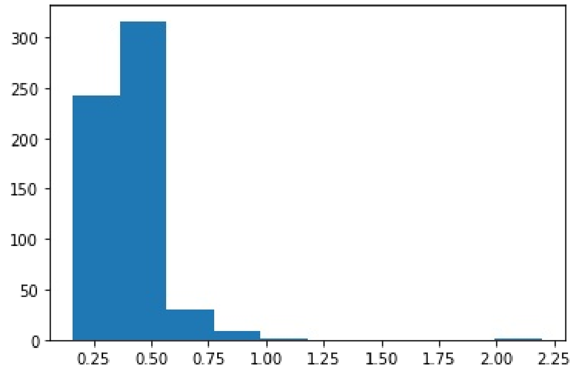


In [40]:

```
#plot the histogram of the duration for trian
plt.hist(X_test_processed.duration)
```

Out[40]:

```
(array([243., 316.,  30.,   9.,   1.,   0.,   0.,   0.,   0.,   1.]),
 array([0.16204082, 0.36542857, 0.56881633, 0.77220408, 0.97559184,
        1.17897959, 1.38236735, 1.5857551 , 1.78914286, 1.99253061,
        2.19591837]),
 <a list of 10 Patch objects>)
```



In [41]:

```
#print 0 to 100 percentile values with step size of 10 for train data duration.
for i in range(0,100+1,10):
    print(str(i)+"th percentile is",np.percentile(X_train_processed.duration,i))
```

```
0th percentile is 0.1435374149659864
10th percentile is 0.25989569160997733
20th percentile is 0.29777777777777775
30th percentile is 0.33037188208616775
40th percentile is 0.357859410430839
50th percentile is 0.3905215419501134
60th percentile is 0.41733333333333333
70th percentile is 0.44623582766439907
80th percentile is 0.4867392290249433
90th percentile is 0.5698140589569162
100th percentile is 2.282766439909297
```

In [42]:

```
##print 90 to 100 percentile values with step size of 1.
for i in range(90,100+1,1):
    print(str(i)+"th percentile is",np.percentile(X_train_processed.duration,i))
```

```
90th percentile is 0.5698140589569162
91th percentile is 0.5810512471655329
92th percentile is 0.5915356009070297
93th percentile is 0.6079006802721089
94th percentile is 0.6207873015873016
95th percentile is 0.6294943310657595
96th percentile is 0.6431455782312925
97th percentile is 0.6611179138321994
98th percentile is 0.6925750566893424
99th percentile is 0.7654394557823128
100th percentile is 2.282766439909297
```

Grader function 4

In [43]:

```
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()
```

Out[43]:

```
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 22
050. 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.
```

In [ ]:

```
## 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.
```

In [44]:

```
max_length  = 17640
```

In [45]:

```
X_train_pad_seq=np.zeros((len(X_train_processed),max_length))
X_test_pad_seq=np.zeros((len(X_test_processed), max_length))
X_train_mask=np.zeros((len(X_train_processed),max_length),dtype="bool")  #masked train numpy array
X_test_mask=np.zeros((len(X_test_processed), max_length),dtype="bool")  # masked test numpy array
```

In [46]:

```
print(X_train_mask.dtype)
print("*********")
print(X_test_mask.dtype)
```

```
bool
*********
bool
```

In [47]:

```
print(X_train_pad_seq.shape)
print(X_train_mask.shape)
print("***********")
print(X_test_pad_seq.shape)
print(X_test_mask.shape)
```

```
(1400, 17640)
(1400, 17640)
***********
(600, 17640)
(600, 17640)
```

In [48]:

```
len(X_train_processed.raw_data[999])
```

Out[48]:

```
12969
```

In [49]:

```
for i in range(len(X_train_processed)):
    for j  in range(len(X_train_processed.raw_data[i])):
        if j  < 17640:
            X_train_pad_seq[i][j]= X_train_processed.raw_data[i][j]
            X_train_mask[i][j]=1
```

In [50]:

```
for i in range(len(X_test_processed)):
    for j in range(len(X_test_processed.raw_data[i])):
        if j  < 17640:
            X_test_pad_seq[i][j]=X_test_processed.raw_data[i][j]
            X_test_mask[i][j]=1
```

In [51]:

```
X_test_mask
```

Out[51]:

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

In [52]:

```
import numpy as np
y_train=y_train.to_numpy()
y_test=y_test.to_numpy()
```

In [53]:

```
y_train.shape
```

Out[53]:

```
(1400, 1)
```

In [54]:

```
print(type(y_train))
```

```
<class 'numpy.ndarray'>
```

In [55]:

```
y_train=y_train.reshape(len(y_train))
y_test=y_test.reshape(len(y_test))
```

Grader function 5

In [56]:

```
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()
```

Out[56]:

```
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 us
e any number of LSTM cells. Please read LSTM documentation(https://www.tensorflow.org/api_docs/python/tf/k
eras/layers/LSTM) in tensorflow to know more about mask and also https://www.tensorflow.org/guide/keras/ma
sking_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).
3. Use tensorboard to plot the graphs of loss and metric(use micro F1 score as metric) and histograms of g
radients.
4. make sure that it won't overfit.
5. You are free to include any regularization
```

tensorboard callback for model 1

In [57]:

```
%load_ext tensorboard
```

In [58]:

```
!rm -rf ./logs/
import datetime
import os
```

In [ ]:

```
import tensorflow as tf
logdir1 = os.path.join("logs", datetime.datetime.now().strftime("%Y%m%d-%H%M%S"))
tensorboard_callback1= tf.keras.callbacks.TensorBoard(log_dir=logdir1, histogram_freq=1,write_graph=True,write_gr
ads=True)
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `TensorBoard` Callback.
```

micro f1 score callback

In [152]:

```
from sklearn.metrics import f1_score
class micro_f1_score1(tf.keras.callbacks.Callback):
    def on_train_begin(self, logs={}):
        self.metrics11={'f1_score': []}

    def on_epoch_end(self, epoch, logs={}):
        y_pred_final=[]
        for i in range(len(y_test)):
            a91=X_test_pad_seq11[i].T
            a92=np.reshape(X_test_mask[i],(1,17640))
            y_pred=np.argmax(self.model.predict((a91,a92)))
            y_pred_final.append(y_pred)

        from sklearn.metrics import f1_score
        f11=f1_score(y_test,y_pred_final,average='micro')



        self.metrics11["f1_score"].append(f11)

        if self.metrics11["f1_score"][epoch] > 0.10:
             print("micro f1 score has reached 0.10% so training is stopping")
             self.model.stop_training = True


        print("f1 score is ",self.metrics11["f1_score"][epoch])
```

In [153]:

```
f1_score1 = micro_f1_score1()
```

model1

In [154]:

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

In [155]:

```
## as discussed above, please write the LSTM
input_layer=Input(shape=(max_length,1),dtype="float32")
input_mask=Input(shape=(max_length),dtype="bool")
lstm_layer=LSTM(30, name="lstm_layer")(inputs = input_layer,mask = input_mask)
dense_layer=Dense(64, activation="relu")(lstm_layer)
output_layer=Dense(10,activation="softmax")(dense_layer)
model1=Model(inputs=[input_layer,input_mask], outputs=output_layer)
```

In [156]:

```
model1.summary()
```

```
Model: "model_3"
_________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
=================================================================================================
input_5 (InputLayer)            [(None, 17640, 1)]   0
_________________________________________________________________________________________________
input_6 (InputLayer)            [(None, 17640)]      0
_________________________________________________________________________________________________
lstm_layer (LSTM)               (None, 30)           3840        input_5[0][0]
                                                                 input_6[0][0]
_________________________________________________________________________________________________
dense_4 (Dense)                 (None, 64)           1984        lstm_layer[0][0]
_________________________________________________________________________________________________
dense_5 (Dense)                 (None, 10)           650         dense_4[0][0]
=================================================================================================
Total params: 6,474
Trainable params: 6,474
Non-trainable params: 0
_________________________________________________________________________________________________
```

In [ ]:

```
model1.compile(optimizer=tf.keras.optimizers.Adam(learning_rate=0.001),loss='SparseCategoricalCrossentropy',metri
cs=['accuracy'])
```

In [62]:

```
print(X_train_pad_seq.shape)
print(X_train_mask.shape)
print("***********")
print(X_test_pad_seq.shape)
print(X_test_mask.shape)
```

```
(1400, 17640)
(1400, 17640)
***********
(600, 17640)
(600, 17640)
```

In [63]:

```
X_train_pad_seq11=np.reshape(X_train_pad_seq,(1400,17640,1))
X_test_pad_seq11=np.reshape(X_test_pad_seq,(600,17640,1))
```

In [64]:

```
print(X_train_pad_seq11.shape)
print("*****")
print(X_test_pad_seq11.shape)
```

```
(1400, 17640, 1)
*****
(600, 17640, 1)
```

In [ ]:

```
#train your model
```

In [ ]:

```
model1.fit([X_train_pad_seq11,X_train_mask],y_train,
           epochs=2,batch_size=16,validation_data=([X_test_pad_seq11,X_test_mask],y_test),
            callbacks = [f1_score1,tensorboard_callback1])
```

```
Epoch 1/2
88/88 [==============================] - 145s 2s/step - loss: 2.3037 - accuracy: 0.0986 - val_loss:
2.3026 - val_accuracy: 0.1000
micro f1 score has reached 0.10% so training is stopping
f1 score is  0.10000000000000002
```

Out[ ]:

```
<keras.callbacks.History at 0x7f34a94e0110>
```

In [ ]:

```
logdir1
```

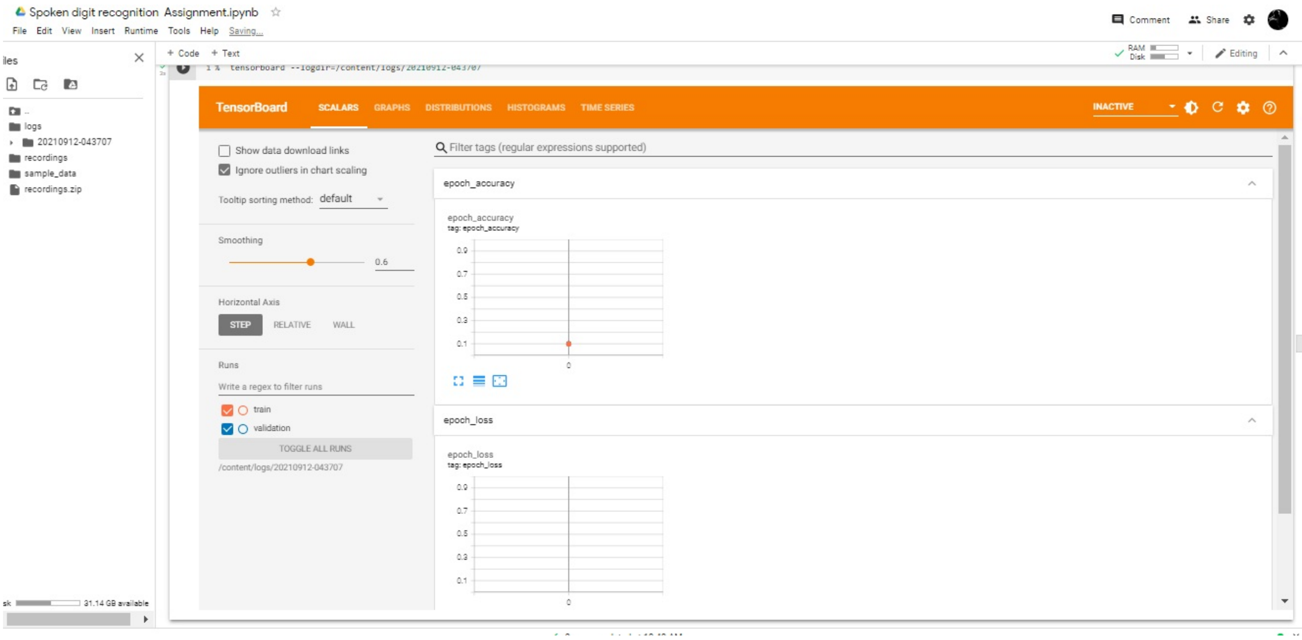
Out[ ]:

```
'logs/20210912-043707'
```

In [2]:

```
from IPython.display import Image
Image(filename=r'C:\Users\kingjames\Downloads\spoken image 1 final.png')
```

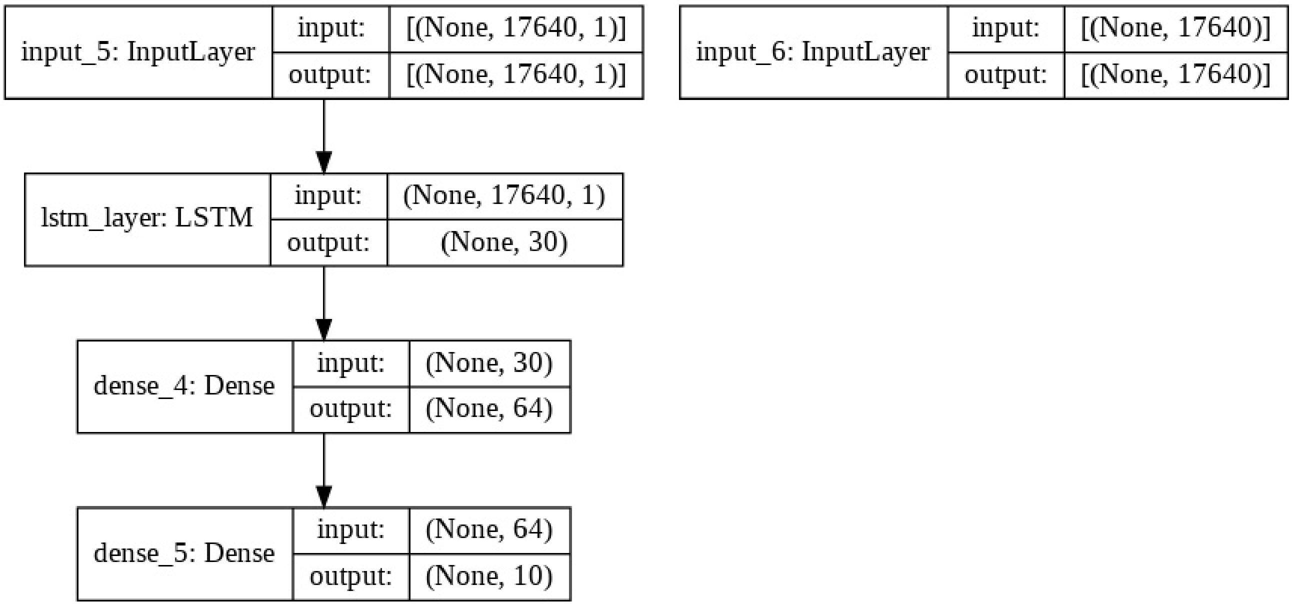
Out[2]:



In [157]:

```
from tensorflow.keras.utils import plot_model
plot_model(model1, to_file='model_plot.png', show_shapes=True, show_layer_names=True)
```

Out[157]:



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-dimensi
onal 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
```

In [59]:

```
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
```

In [60]:

```
print(X_train_pad_seq.shape)
print("*********")
print(X_test_pad_seq.shape)
```

```
(1400, 17640)
*********
(600, 17640)
```

In [65]:

```
print(X_train_pad_seq11.shape)
print("*********")
print(X_test_pad_seq11.shape)
```

```
(1400, 17640, 1)
*********
(600, 17640, 1)
```

In [ ]:

```
##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)
```

In [66]:

```
X_train_spectrogram=[]
```

In [67]:

```
for i in tqdm(X_train_pad_seq):
    spectogram=convert_to_spectrogram(i)
    X_train_spectrogram.append(spectogram)

X_train_spectrogram=np.array(X_train_spectrogram)
X_train_spectrogram.shape
```

```
100%|██████████| 1400/1400 [00:08<00:00, 155.63it/s]
```

Out[67]:

```
(1400, 64, 35)
```

In [68]:

```
X_test_spectrogram=[]
```

In [69]:

```
for i in tqdm(X_test_pad_seq):
    spectogram=convert_to_spectrogram(i)
    X_test_spectrogram.append(spectogram)

X_test_spectrogram=np.array(X_test_spectrogram)
X_test_spectrogram.shape
```

```
100%|██████████| 600/600 [00:03<00:00, 153.36it/s]
```

Out[69]:

```
(600, 64, 35)
```

In [70]:

```
X_train_spectogram=np.array(X_train_spectrogram)
X_train_spectogram.shape
```

Out[70]:

```
(1400, 64, 35)
```

Grader function 6

In [71]:

```
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()
```

Out[71]:

```
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 tim
e 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  (#., time_steps, features) average the output of every time step i.e, you s
hould get (#.,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 catego
rical cross entropy.
4. Use tensorboard to plot the graphs of loss and metric(use micro F1 score as metric) and histograms of g
radients.
5. make sure that it won't overfit.
6. You are free to include any regularization
```

tensorboard callback for model 2

In [81]:

```
logdir2 = os.path.join("logs", datetime.datetime.now().strftime("%Y%m%d-%H%M%S"))
tensorboard_callback2 = tf.keras.callbacks.TensorBoard(logdir2, histogram_freq=1,write_graph=True,write_grads=Tru
e)
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `TensorBoard` Callback.
```

micro f1 score for model 2

In [74]:

```
from sklearn.metrics import f1_score
class micro_f1_score2(tf.keras.callbacks.Callback):
    def on_train_begin(self, logs={}):
        self.metrics11={'f1_score': []}

    def on_epoch_end(self, epoch, logs={}):
        y_pred_final=[]
        for i in range(len(y_test)):
            b91=X_test_spectrogram[i]
            b92=np.reshape(b91,(1,64,35))  # here shape is differeent

            y_pred=np.argmax(self.model.predict((b92)))
            y_pred_final.append(y_pred)

        from sklearn.metrics import f1_score
        f11=f1_score(y_test,y_pred_final,average='micro')

        self.metrics11["f1_score"].append(f11)

        if self.metrics11["f1_score"][epoch] > 0.80:
             print("micro f1 score has reached 0.80% so training is stopping")
             self.model.stop_training = True



        print("f1 score is ",self.metrics11["f1_score"][epoch])
```

In [75]:

```
f1_score2 = micro_f1_score2()
```

In [76]:

```
from tensorflow.keras.layers import Input, LSTM, Dense , GlobalAveragePooling1D, BatchNormalization , Dropout
```

In [77]:

```
input_layer=Input(shape=(64,35),dtype="float32")

lstm_layer = LSTM(25,name = "lstm_layer",return_sequences = True)(inputs = input_layer)

average_layer = GlobalAveragePooling1D(data_format='channels_first' )(lstm_layer)

dense_1_layer = Dense(64,activation="relu",name ="dense_1_layer")(average_layer)

output_layer = Dense(10,activation = "softmax",name = "output_layer")(dense_1_layer)

model2=Model(inputs=input_layer, outputs=output_layer)
```

In [78]:

```
model2.summary()
```

```
Model: "model"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_1 (InputLayer)         [(None, 64, 35)]          0         
_________________________________________________________________
lstm_layer (LSTM)            (None, 64, 25)            6100      
_________________________________________________________________
global_average_pooling1d (Gl (None, 64)                0         
_________________________________________________________________
dense_1_layer (Dense)        (None, 64)                4160      
_________________________________________________________________
output_layer (Dense)         (None, 10)                650       
=================================================================
Total params: 10,910
Trainable params: 10,910
Non-trainable params: 0
_________________________________________________________________
```

In [79]:

```
model2.compile(optimizer=tf.keras.optimizers.Adam(),loss='SparseCategoricalCrossentropy',metrics=['accuracy'])  # tf.keras.optimizers.SGD(
```

In [82]:

```
model2.fit(X_train_spectogram,y_train,
           epochs=200,
           batch_size=16,
           validation_data=(X_test_spectrogram,y_test),
           callbacks = [f1_score2,tensorboard_callback2])
```

```
Epoch 1/200
 3/88 [>.............................] - ETA: 21s - loss: 2.3014 - accuracy: 0.1250WARNING:tensorflo
w:Callback method `on_train_batch_begin` is slow compared to the batch time (batch time: 0.0082s vs
`on_train_batch_begin` time: 0.0295s). Check your callbacks.
WARNING:tensorflow:Callback method `on_train_batch_end` is slow compared to the batch time (batch ti
me: 0.0082s vs `on_train_batch_end` time: 0.0529s). Check your callbacks.
88/88 [==============================] - 9s 28ms/step - loss: 2.2564 - accuracy: 0.1686 - val_loss:
2.1609 - val_accuracy: 0.2083
f1 score is  0.20833333333333334
Epoch 2/200
88/88 [==============================] - 1s 16ms/step - loss: 1.9863 - accuracy: 0.2850 - val_loss:
1.8808 - val_accuracy: 0.3567
f1 score is  0.35666666666666674
Epoch 3/200
88/88 [==============================] - 1s 16ms/step - loss: 1.7237 - accuracy: 0.4229 - val_loss:
1.6363 - val_accuracy: 0.4783
f1 score is  0.47833333333333333
Epoch 4/200
88/88 [==============================] - 1s 16ms/step - loss: 1.5343 - accuracy: 0.4979 - val_loss:
1.4883 - val_accuracy: 0.4967
f1 score is  0.49666666666666665
Epoch 5/200
88/88 [==============================] - 1s 16ms/step - loss: 1.3456 - accuracy: 0.5736 - val_loss:
1.3176 - val_accuracy: 0.5583
f1 score is  0.5583333333333333
Epoch 6/200
88/88 [==============================] - 1s 16ms/step - loss: 1.2197 - accuracy: 0.6207 - val_loss:
1.2205 - val_accuracy: 0.5667
f1 score is  0.5666666666666667
Epoch 7/200
88/88 [==============================] - 1s 16ms/step - loss: 1.1438 - accuracy: 0.6450 - val_loss:
1.2257 - val_accuracy: 0.5900
f1 score is  0.59
Epoch 8/200
88/88 [==============================] - 1s 16ms/step - loss: 1.0499 - accuracy: 0.6721 - val_loss:
1.0681 - val_accuracy: 0.6700
f1 score is  0.67
Epoch 9/200
88/88 [==============================] - 1s 16ms/step - loss: 0.9650 - accuracy: 0.6829 - val_loss:
1.0003 - val_accuracy: 0.6667
f1 score is  0.6666666666666666
Epoch 10/200
88/88 [==============================] - 1s 15ms/step - loss: 0.9148 - accuracy: 0.7179 - val_loss:
0.9573 - val_accuracy: 0.7017
f1 score is  0.7016666666666667
Epoch 11/200
88/88 [==============================] - 1s 15ms/step - loss: 0.8592 - accuracy: 0.7271 - val_loss:
0.8920 - val_accuracy: 0.7233
f1 score is  0.7233333333333334
Epoch 12/200
88/88 [==============================] - 1s 16ms/step - loss: 0.8210 - accuracy: 0.7400 - val_loss:
0.8599 - val_accuracy: 0.7217
f1 score is  0.7216666666666668
Epoch 13/200
88/88 [==============================] - 1s 15ms/step - loss: 0.7769 - accuracy: 0.7443 - val_loss:
0.9231 - val_accuracy: 0.6633
f1 score is  0.6633333333333333
Epoch 14/200
88/88 [==============================] - 1s 15ms/step - loss: 0.7549 - accuracy: 0.7607 - val_loss:
0.7923 - val_accuracy: 0.7250
f1 score is  0.7250000000000001
Epoch 15/200
88/88 [==============================] - 1s 15ms/step - loss: 0.7032 - accuracy: 0.7650 - val_loss:
0.7176 - val_accuracy: 0.7583
f1 score is  0.7583333333333333
Epoch 16/200
88/88 [==============================] - 1s 16ms/step - loss: 0.6455 - accuracy: 0.7921 - val_loss:
0.6836 - val_accuracy: 0.7867
f1 score is  0.7866666666666666
Epoch 17/200
88/88 [==============================] - 1s 15ms/step - loss: 0.6608 - accuracy: 0.7664 - val_loss:
0.7011 - val_accuracy: 0.7433
f1 score is  0.7433333333333333
Epoch 18/200
88/88 [==============================] - 1s 15ms/step - loss: 0.6255 - accuracy: 0.7864 - val_loss:
```

```
0.6454 - val_accuracy: 0.7883
f1 score is  0.7883333333333333
Epoch 19/200
88/88 [==============================] - 1s 16ms/step - loss: 0.5875 - accuracy: 0.8136 - val_loss:
0.6374 - val_accuracy: 0.7933
f1 score is  0.7933333333333333
Epoch 20/200
88/88 [==============================] - 1s 16ms/step - loss: 0.5700 - accuracy: 0.8064 - val_loss:
0.6196 - val_accuracy: 0.7983
f1 score is  0.7983333333333333
Epoch 21/200
88/88 [==============================] - 1s 15ms/step - loss: 0.5517 - accuracy: 0.8121 - val_loss:
0.6218 - val_accuracy: 0.7750
f1 score is  0.775
Epoch 22/200
88/88 [==============================] - 1s 16ms/step - loss: 0.5342 - accuracy: 0.8336 - val_loss:
0.5848 - val_accuracy: 0.7983
f1 score is  0.7983333333333333
Epoch 23/200
88/88 [==============================] - 1s 16ms/step - loss: 0.5199 - accuracy: 0.8357 - val_loss:
0.5836 - val_accuracy: 0.7933
f1 score is  0.7933333333333333
Epoch 24/200
88/88 [==============================] - 1s 16ms/step - loss: 0.5051 - accuracy: 0.8264 - val_loss:
0.5600 - val_accuracy: 0.7933
f1 score is  0.7933333333333333
Epoch 25/200
88/88 [==============================] - 1s 16ms/step - loss: 0.5041 - accuracy: 0.8307 - val_loss:
0.6045 - val_accuracy: 0.7800
f1 score is  0.78
Epoch 26/200
88/88 [==============================] - 1s 15ms/step - loss: 0.4707 - accuracy: 0.8450 - val_loss:
0.6140 - val_accuracy: 0.7717
f1 score is  0.7716666666666666
Epoch 27/200
88/88 [==============================] - 1s 17ms/step - loss: 0.4973 - accuracy: 0.8429 - val_loss:
0.5449 - val_accuracy: 0.8167
micro f1 score has reached 0.80% so training is stopping
f1 score is  0.8166666666666667
```

Out[82]:

```
<keras.callbacks.History at 0x7fc9204c6b10>
```

In [85]:

```
logdir2
```

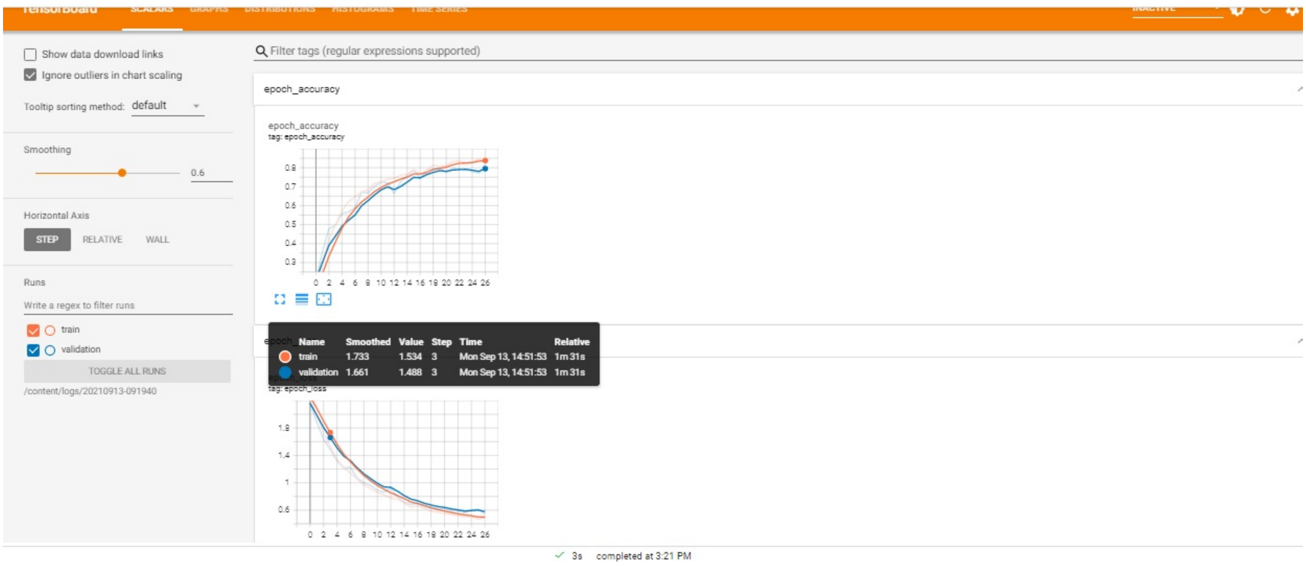
Out[85]:

```
'logs/20210913-091940'
```

In [3]:

```
from IPython.display import Image
Image(filename=r'C:\Users\kingjames\Downloads\spoken image 2 tensorboard.png')
```

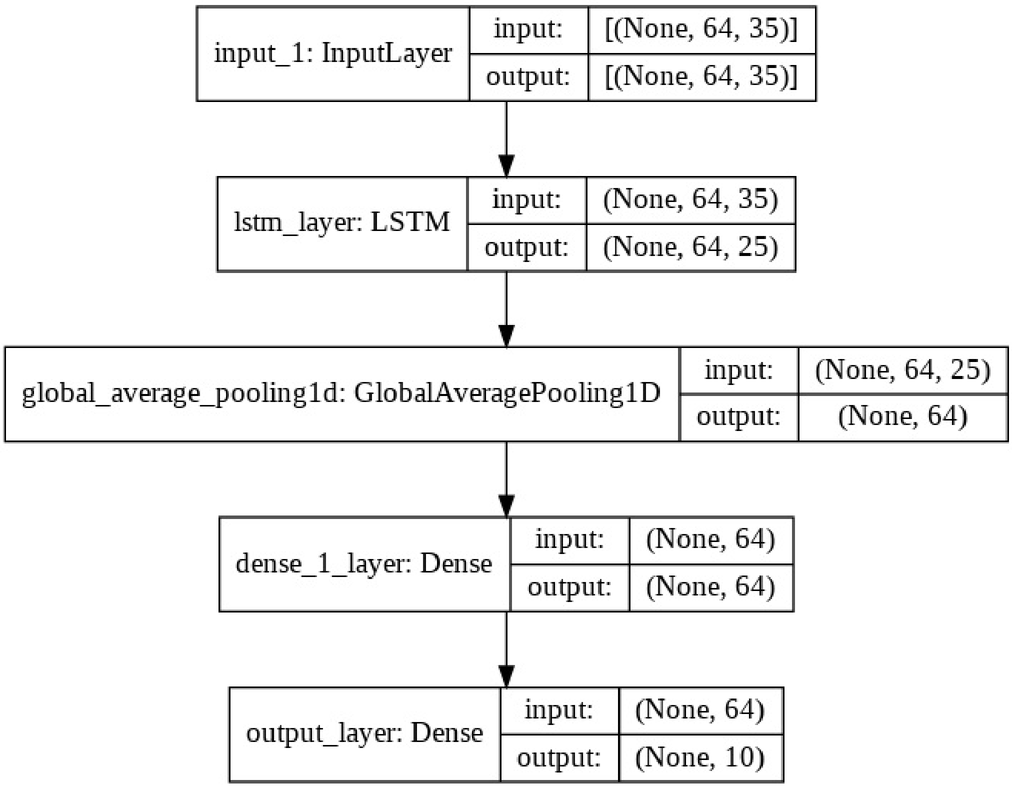
Out[3]:



In [90]:

```
from tensorflow.keras.utils import plot_model
plot_model(model2, to_file='model_plot.png', show_shapes=True, show_layer_names=True)
```

Out[90]:



3. data augmentation

```
Till now we have done with 2000 samples only. It is very less data. We are giving the process of generatin
g 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 stretc
hing 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 o
r down one half-step.
```

In [91]:

```
from sklearn.model_selection import train_test_split
X_train1, X_test1, y_train1, y_test1 = train_test_split(all_files, label, test_size=0.20, random_state=45,stratif
y=label)
```

In [92]:

```
print(len(X_train1))
```

1600

In [93]:

```
X_train1=pd.DataFrame(X_train1,columns=["path"])
y_train1=pd.DataFrame(y_train1,columns=['label'])
X_test1=pd.DataFrame(X_test1,columns=['path'])
y_test1=pd.DataFrame(y_test1,columns=["label"])
```

In [94]:

```
y_train1.label[0]
```

Out[94]:

8

In [95]:

```python
print(X_train1.shape)
print(X_train1.head(4))
```

```
(1600, 1)
                                    path
0      /content/recordings/8_theo_17.wav
1      /content/recordings/2_theo_14.wav
2  /content/recordings/7_yweweler_28.wav
3      /content/recordings/3_theo_13.wav
```

In [96]:

```python
print(y_train1.shape)
```

```
(1600, 1)
```

In [97]:

```python
print(X_test1.shape)
```

```
(400, 1)
```

augmentation

In [98]:

```python
## 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
```

In [99]:

```python
X_train_augmented = []  # we only augment train data only not test data
X_test_augmented=[]  #we dont augment test data, we only augment train data
```

In [100]:

```python
#train data
from tqdm import tqdm
for i in tqdm(range(len(X_train1))):
    a1=generate_augmented_data(X_train1.path[i]) #augmenting # for each point we are creating 9 duplicate point
    for j in a1:
        X_train_augmented.append(j)
```

```
100%|██████████| 1600/1600 [06:05<00:00,  4.37it/s]
```

In [101]:

```python
len(X_train_augmented)
```

Out[101]:

```
14400
```

In [102]:

```python
print(type(X_train_augmented))
```

```
<class 'list'>
```

In [103]:

```python
#creting samples for test data
for i in tqdm(X_test1.path):
    s2,d2=load_wav(i)  # here no augmenting just original point as it is
    X_test_augmented.append(s2)
```

```
100%|██████████| 400/400 [00:05<00:00, 66.72it/s]
```

In [104]:

```
len(X_test_augmented)
```

Out[104]:

```
400
```

Creating labels for augmented data

In [105]:

```
y_train_augmented=[]
y_test_augmented =[]
```

In [106]:

```
for i in y_train1.label:  #train
    for j in range(9):
        y_train_augmented.append(i)
```

In [107]:

```
len(y_train_augmented)
```

Out[107]:

```
14400
```

In [108]:

```
y_train_augmented=np.array(y_train_augmented)
```

In [109]:

```
for i in y_test1.label:  #test
    y_test_augmented.append(i)
```

In [110]:

```
len(y_test_augmented)
```

Out[110]:

```
400
```

In [111]:

```
y_test_augmented=np.array(y_test_augmented)
```

In [112]:

```
print(type(y_test_augmented))
```

```
<class 'numpy.ndarray'>
```

In [113]:

```
max_length=17640
```

In [114]:

```
X_train1_pad_seq_aug=np.zeros((len(X_train_augmented),max_length))
X_test1_pad_seq_aug=np.zeros((len(X_test_augmented), max_length))
X_train1_mask_aug=np.zeros((len(X_train_augmented),max_length),dtype="bool")  #masked train numpy array
X_test1_mask_aug=np.zeros((len(X_test_augmented), max_length),dtype="bool")  # masked test numpy array
```

In [115]:

```
print(X_train1_pad_seq_aug.shape)
print(X_test1_pad_seq_aug.shape)
print(X_train1_mask_aug.shape)
print(X_test1_mask_aug.shape)
```

```
(14400, 17640)
(400, 17640)
(14400, 17640)
(400, 17640)
```

In [116]:

```
for i in range(len(X_train_augmented)):
    for j  in range(len(X_train_augmented[i])):
        if j  < 17640:
            X_train1_pad_seq_aug[i][j]= X_train_augmented[i][j]
            X_train1_mask_aug[i][j]=1
```

In [117]:

```
X_train_augmented[0]
```

Out[117]:

```
array([0.00017661, 0.00019431, 0.00014904, ..., 0.00011464, 0.0004445 ,
       0.00030142], dtype=float32)
```

In [118]:

```
len(X_train_augmented[0])
```

Out[118]:

```
10856
```

In [119]:

```
X_train1_pad_seq_aug[0]
```

Out[119]:

```
array([0.00017661, 0.00019431, 0.00014904, ..., 0.        , 0.        ,
       0.        ])
```

In [120]:

```
len(X_train1_pad_seq_aug[0])
```

Out[120]:

```
17640
```

In [121]:

```
for i in range(len(X_test_augmented)):
    for j in range(len(X_test_augmented[i])):
        if j  < 17640:
            X_test1_pad_seq_aug[i][j]=X_test_augmented[i][j]
            X_test1_mask_aug[i][j]=1
```

In [122]:

```
X_train1_pad_seq_aug11=np.reshape(X_train1_pad_seq_aug,(14400,17640,1))
X_test1_pad_seq_aug11=np.reshape(X_test1_pad_seq_aug,(400,17640,1))
```

In [123]:

```
print(X_train1_pad_seq_aug11.shape)
print("************")
print(X_test1_pad_seq_aug11.shape)
```

```
(14400, 17640, 1)
************
(400, 17640, 1)
```

tensorboard callback for model 3

In [124]:

```
logdir3 = os.path.join("logs", datetime.datetime.now().strftime("%Y%m%d-%H%M%S"))
tensorboard_callback3 = tf.keras.callbacks.TensorBoard(logdir3, histogram_freq=1,write_graph=True,write_grads=Tru
e)
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `TensorBoard` Callback.
```

micro f1 score for model3

In [125]:

```
from sklearn.metrics import f1_score
class micro_f1_score3(tf.keras.callbacks.Callback):
    def on_train_begin(self, logs={}):
        self.metrics11={'f1_score': []}

    def on_epoch_end(self, epoch, logs={}):
        y_pred_final=[]
        for i in range(len(y_test_augmented)):
            c91=X_test1_pad_seq_aug11[i].T      #X_test1_pad_seq_aug11
            c92=np.reshape(X_test1_mask_aug[i],(1,17640))
            y_pred=np.argmax(self.model.predict((c91,c92)))
            y_pred_final.append(y_pred)

        from sklearn.metrics import f1_score
        f11=f1_score(y_test_augmented,y_pred_final,average='micro')



        self.metrics11["f1_score"].append(f11)

        if self.metrics11["f1_score"][epoch] > 0.10:
             print("micro f1 score has reached 0.10% so training is stopping")
             self.model.stop_training = True


        print("f1 score is ",self.metrics11["f1_score"][epoch])
```

In [126]:

```
f1_score3 = micro_f1_score3()
```

Model -3 (Augmented)

In [127]:

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

In [128]:

```
## as discussed above, please write the LSTM
input_layer=Input(shape=(max_length,1),dtype="float32")
input_mask=Input(shape=(max_length),dtype="bool")
lstm_layer=LSTM(30, name="lstm_layer")(inputs = input_layer,mask = input_mask)
dense_layer=Dense(64, activation="relu")(lstm_layer)
output_layer=Dense(10,activation="softmax")(dense_layer)
model3=Model(inputs=[input_layer,input_mask], outputs=output_layer)
```

In [131]:

```
model3.compile(optimizer=tf.keras.optimizers.Adam(),loss='SparseCategoricalCrossentropy',metrics=['accuracy'])
```

In [132]:

```
model3.fit([X_train1_pad_seq_aug11,X_train1_mask_aug],y_train_augmented,
           epochs=2,
           batch_size=16,
           validation_data=([X_test1_pad_seq_aug11,X_test1_mask_aug],y_test_augmented),
           callbacks = [f1_score3,tensorboard_callback3])
```

```
Epoch 1/2
  1/900 [..............................] - ETA: 1:13:33 - loss: 2.3037 - accuracy: 0.0625ERROR:tenso
rflow:Failed to start profiler: Another profiler is running.
900/900 [==============================] - 1062s 1s/step - loss: 2.3032 - accuracy: 0.0986 - val_los
s: 2.3026 - val_accuracy: 0.1000
micro f1 score has reached 0.10% so training is stopping
f1 score is  0.10000000000000002
```

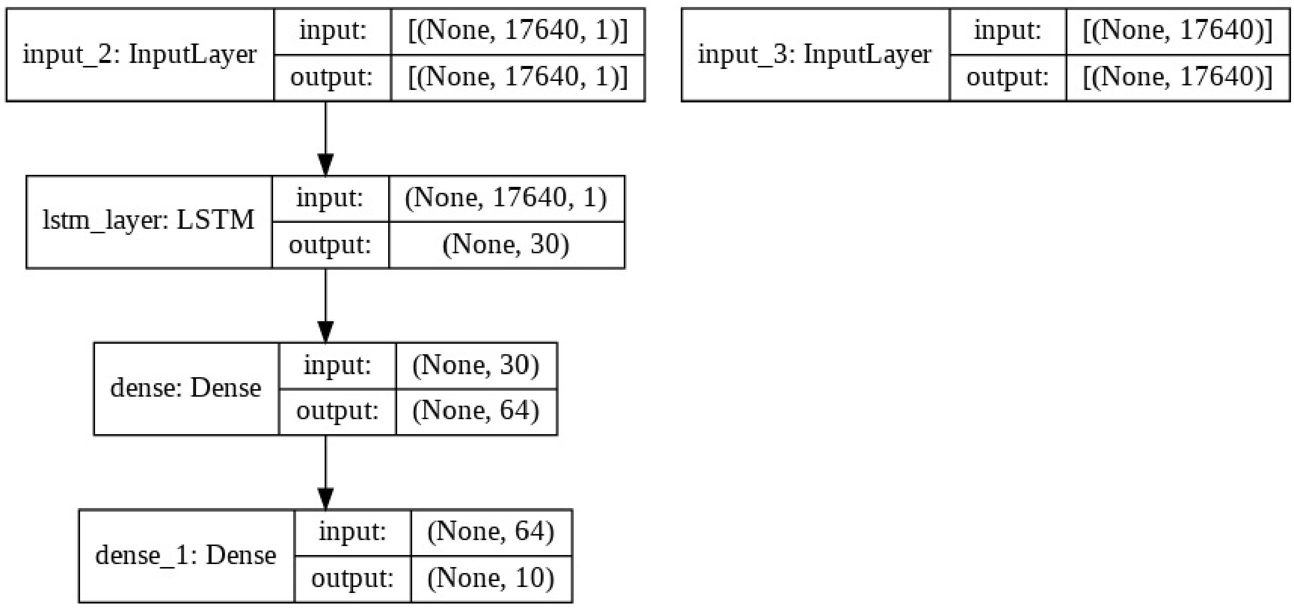
Out[132]:

```
<keras.callbacks.History at 0x7fc8c3426d50>
```

In [135]:

```
from tensorflow.keras.utils import plot_model
plot_model(model3, to_file='model_plot.png', show_shapes=True, show_layer_names=True)
```

Out[135]:



In [133]:

```
logdir3
```

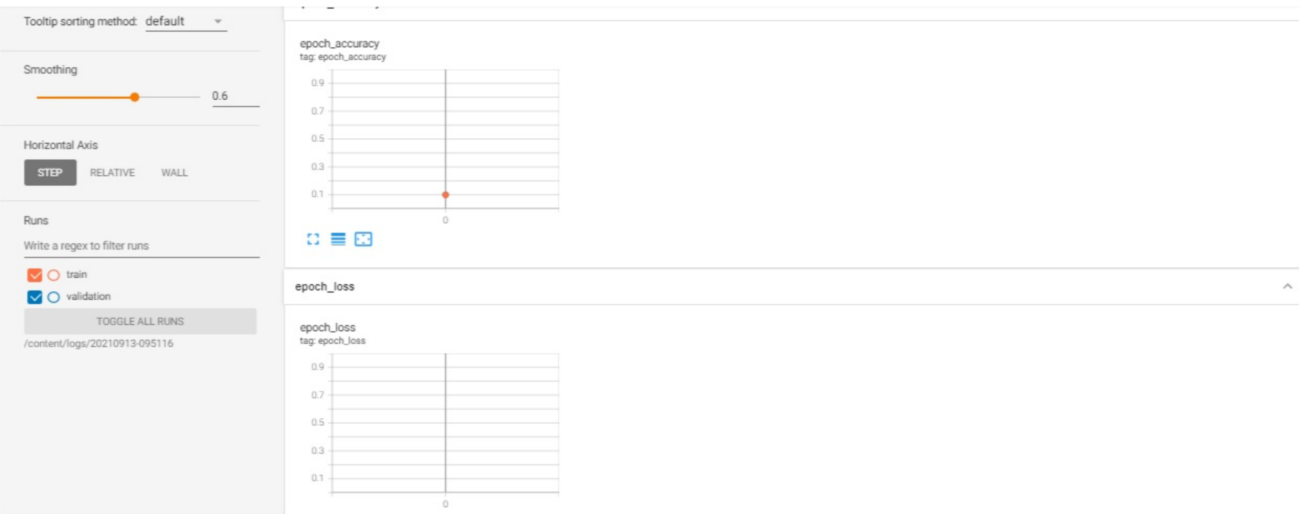
Out[133]:

```
'logs/20210913-095116'
```

In [4]:

```
from IPython.display import Image
Image(filename=r'C:\Users\kingjames\Downloads\spoken digit 3 tensorboard.png')
```

Out[4]:



model 4

converting augmented data into spectrogram then applying model

In [136]:

```
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
```

In [137]:

```
X_train_spectrogram_aug=[]
X_test_spectrogram_aug=[]
```

In [138]:

```
for i in tqdm(X_train1_pad_seq_aug):
    spectogram=convert_to_spectrogram(i)
    X_train_spectrogram_aug.append(spectogram)

X_train_spectrogram_aug=np.array(X_train_spectrogram_aug)
X_train_spectrogram_aug.shape
```

```
100%|██████████| 14400/14400 [01:37<00:00, 148.22it/s]
```

Out[138]:

```
(14400, 64, 35)
```

In [139]:

```
for i in tqdm(X_test1_pad_seq_aug):
    spectogram=convert_to_spectrogram(i)
    X_test_spectrogram_aug.append(spectogram)

X_test_spectrogram_aug=np.array(X_test_spectrogram_aug)
X_test_spectrogram_aug.shape
```

```
100%|██████████| 400/400 [00:02<00:00, 150.68it/s]
```

Out[139]:

```
(400, 64, 35)
```

In [ ]:

```

```

micro f1 score for model 4

In [140]:

```
from sklearn.metrics import f1_score
class micro_f1_score4(tf.keras.callbacks.Callback):
    def on_train_begin(self, logs={}):
        self.metrics11={'f1_score': []}

    def on_epoch_end(self, epoch, logs={}):
        y_pred_final=[]
        for i in range(len(y_test_augmented)):
            b91=X_test_spectrogram_aug[i]
            b92=np.reshape(b91,(1,64,35))  # here shape is differeent

            y_pred=np.argmax(self.model.predict((b92)))
            y_pred_final.append(y_pred)

        from sklearn.metrics import f1_score
        f11=f1_score(y_test_augmented,y_pred_final,average='micro')

        self.metrics11["f1_score"].append(f11)

        if self.metrics11["f1_score"][epoch] > 0.80:
             print("micro f1 score has reached 0.80% so training is stopping")
             self.model.stop_training = True



        print("f1 score is ",self.metrics11["f1_score"][epoch])
```

In [141]:

```
f1_score4 = micro_f1_score4()
```

In [ ]:

```

```

tensorboard callback for model 4

In [142]:

```
logdir4 = os.path.join("logs", datetime.datetime.now().strftime("%Y%m%d-%H%M%S"))
tensorboard_callback4 = tf.keras.callbacks.TensorBoard(logdir4, histogram_freq=1,write_graph=True,write_grads=Tru
e)
```

```
WARNING:tensorflow:`write_grads` will be ignored in TensorFlow 2.0 for the `TensorBoard` Callback.
ERROR:tensorflow:Failed to start profiler: Another profiler is running.
```

In [ ]:

```

```

In [143]:

```
from tensorflow.keras.layers import Input, LSTM, Dense , GlobalAveragePooling1D
```

In [144]:

```
## as discussed above, please write the LSTM
input_layer=Input(shape=(64,35),dtype="float32")
lstm_layer=LSTM(30, name="lstm_layer",return_sequences = True)(inputs = input_layer)
average_layer = GlobalAveragePooling1D(data_format='channels_last')(lstm_layer)
dense_layer=Dense(64, activation="relu")(average_layer)
output_layer=Dense(10,activation="softmax")(dense_layer)
model4=Model(inputs=input_layer, outputs=output_layer)
```

In [145]:

```
model4.summary()
```

```
Model: "model_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_4 (InputLayer)         [(None, 64, 35)]          0         
_________________________________________________________________
lstm_layer (LSTM)            (None, 64, 30)            7920      
_________________________________________________________________
global_average_pooling1d_1 ( (None, 30)                0         
_________________________________________________________________
dense_2 (Dense)              (None, 64)                1984      
_________________________________________________________________
dense_3 (Dense)              (None, 10)                650       
=================================================================
Total params: 10,554
Trainable params: 10,554
Non-trainable params: 0
_________________________________________________________________
```

In [146]:

```
model4.compile(optimizer=tf.keras.optimizers.Adam(),loss='SparseCategoricalCrossentropy',metrics=['accuracy'])
```

In [147]:

```
model4.fit(X_train_spectrogram_aug,y_train_augmented,
           epochs=200,
           batch_size=32,
           validation_data=(X_test_spectrogram_aug,y_test_augmented),
           callbacks = [f1_score4,tensorboard_callback4])
```

```
Epoch 1/200
  1/450 [..............................] - ETA: 13:06 - loss: 2.3978 - accuracy: 0.0625ERROR:tensorf
low:Failed to start profiler: Another profiler is running.
  3/450 [..............................] - ETA: 50s - loss: 2.3281 - accuracy: 0.1458WARNING:tensorf
low:Callback method `on_train_batch_end` is slow compared to the batch time (batch time: 0.0056s vs
`on_train_batch_end` time: 0.0400s). Check your callbacks.
450/450 [==============================] - 9s 16ms/step - loss: 2.0025 - accuracy: 0.2858 - val_loss
: 1.7273 - val_accuracy: 0.3925
f1 score is  0.3925
Epoch 2/200
450/450 [==============================] - 6s 14ms/step - loss: 1.6506 - accuracy: 0.4149 - val_loss
: 1.4878 - val_accuracy: 0.4825
f1 score is  0.4825
Epoch 3/200
450/450 [==============================] - 6s 14ms/step - loss: 1.4641 - accuracy: 0.4940 - val_loss
: 1.2557 - val_accuracy: 0.5625
f1 score is  0.5625
```

```
Epoch 4/200
450/450 [==============================] - 6s 14ms/step - loss: 1.3198 - accuracy: 0.5504 - val_loss
: 1.1412 - val_accuracy: 0.5925
f1 score is  0.5925
Epoch 5/200
450/450 [==============================] - 6s 14ms/step - loss: 1.2090 - accuracy: 0.5815 - val_loss
: 1.0452 - val_accuracy: 0.6475
f1 score is  0.6475
Epoch 6/200
450/450 [==============================] - 6s 14ms/step - loss: 1.1217 - accuracy: 0.6153 - val_loss
: 1.0220 - val_accuracy: 0.6700
f1 score is  0.67
Epoch 7/200
450/450 [==============================] - 6s 14ms/step - loss: 1.0743 - accuracy: 0.6297 - val_loss
: 0.9430 - val_accuracy: 0.6950
f1 score is  0.695
Epoch 8/200
450/450 [==============================] - 6s 14ms/step - loss: 1.0210 - accuracy: 0.6495 - val_loss
: 0.9407 - val_accuracy: 0.6950
f1 score is  0.695
Epoch 9/200
450/450 [==============================] - 6s 14ms/step - loss: 0.9940 - accuracy: 0.6623 - val_loss
: 0.9421 - val_accuracy: 0.6800
f1 score is  0.68
Epoch 10/200
450/450 [==============================] - 6s 14ms/step - loss: 0.9557 - accuracy: 0.6717 - val_loss
: 0.9663 - val_accuracy: 0.6800
f1 score is  0.68
Epoch 11/200
450/450 [==============================] - 6s 14ms/step - loss: 0.9343 - accuracy: 0.6819 - val_loss
: 0.8469 - val_accuracy: 0.7125
f1 score is  0.7125
Epoch 12/200
450/450 [==============================] - 6s 14ms/step - loss: 0.9010 - accuracy: 0.6887 - val_loss
: 0.8230 - val_accuracy: 0.7225
f1 score is  0.7225
Epoch 13/200
450/450 [==============================] - 6s 14ms/step - loss: 0.8750 - accuracy: 0.6976 - val_loss
: 0.8548 - val_accuracy: 0.7100
f1 score is  0.7100000000000001
Epoch 14/200
450/450 [==============================] - 6s 14ms/step - loss: 0.8595 - accuracy: 0.7047 - val_loss
: 0.8706 - val_accuracy: 0.7100
f1 score is  0.7100000000000001
Epoch 15/200
450/450 [==============================] - 6s 14ms/step - loss: 0.8516 - accuracy: 0.7046 - val_loss
: 0.8159 - val_accuracy: 0.7075
f1 score is  0.7075
Epoch 16/200
450/450 [==============================] - 6s 14ms/step - loss: 0.8373 - accuracy: 0.7088 - val_loss
: 0.8677 - val_accuracy: 0.7100
f1 score is  0.7100000000000001
Epoch 17/200
450/450 [==============================] - 6s 14ms/step - loss: 0.8070 - accuracy: 0.7186 - val_loss
: 0.8344 - val_accuracy: 0.7150
f1 score is  0.715
Epoch 18/200
450/450 [==============================] - 6s 14ms/step - loss: 0.7988 - accuracy: 0.7213 - val_loss
: 0.8308 - val_accuracy: 0.7025
f1 score is  0.7025
Epoch 19/200
450/450 [==============================] - 6s 14ms/step - loss: 0.7838 - accuracy: 0.7340 - val_loss
: 0.7841 - val_accuracy: 0.7600
f1 score is  0.76
Epoch 20/200
450/450 [==============================] - 6s 14ms/step - loss: 0.7764 - accuracy: 0.7306 - val_loss
: 0.7877 - val_accuracy: 0.7325
f1 score is  0.7325
Epoch 21/200
450/450 [==============================] - 6s 14ms/step - loss: 0.7810 - accuracy: 0.7296 - val_loss
: 0.7788 - val_accuracy: 0.7375
f1 score is  0.7375
Epoch 22/200
450/450 [==============================] - 6s 14ms/step - loss: 0.7668 - accuracy: 0.7341 - val_loss
: 0.7682 - val_accuracy: 0.7375
f1 score is  0.7375
Epoch 23/200
450/450 [==============================] - 6s 14ms/step - loss: 0.7414 - accuracy: 0.7453 - val_loss
: 0.7362 - val_accuracy: 0.7500
f1 score is  0.75
Epoch 24/200
450/450 [==============================] - 6s 14ms/step - loss: 0.7256 - accuracy: 0.7483 - val_loss
: 0.7111 - val_accuracy: 0.7275
```

```
f1 score is  0.7275000000000001
Epoch 25/200
450/450 [==============================] - 6s 14ms/step - loss: 0.7131 - accuracy: 0.7556 - val_loss
: 0.7290 - val_accuracy: 0.7600
f1 score is  0.76
Epoch 26/200
450/450 [==============================] - 6s 14ms/step - loss: 0.7107 - accuracy: 0.7511 - val_loss
: 0.7314 - val_accuracy: 0.7400
f1 score is  0.74
Epoch 27/200
450/450 [==============================] - 6s 14ms/step - loss: 0.7037 - accuracy: 0.7544 - val_loss
: 0.7619 - val_accuracy: 0.7525
f1 score is  0.7525
Epoch 28/200
450/450 [==============================] - 6s 14ms/step - loss: 0.7209 - accuracy: 0.7490 - val_loss
: 0.7481 - val_accuracy: 0.7625
f1 score is  0.7625
Epoch 29/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6936 - accuracy: 0.7608 - val_loss
: 0.7030 - val_accuracy: 0.7475
f1 score is  0.7475
Epoch 30/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6816 - accuracy: 0.7599 - val_loss
: 0.7513 - val_accuracy: 0.7525
f1 score is  0.7525
Epoch 31/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6758 - accuracy: 0.7674 - val_loss
: 0.7365 - val_accuracy: 0.7525
f1 score is  0.7525
Epoch 32/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6657 - accuracy: 0.7722 - val_loss
: 0.8480 - val_accuracy: 0.7025
f1 score is  0.7025
Epoch 33/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6544 - accuracy: 0.7721 - val_loss
: 0.7338 - val_accuracy: 0.7475
f1 score is  0.7475
Epoch 34/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6641 - accuracy: 0.7713 - val_loss
: 0.7110 - val_accuracy: 0.7575
f1 score is  0.7575
Epoch 35/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6373 - accuracy: 0.7774 - val_loss
: 0.6806 - val_accuracy: 0.7625
f1 score is  0.7625
Epoch 36/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6353 - accuracy: 0.7819 - val_loss
: 0.6856 - val_accuracy: 0.7850
f1 score is  0.785
Epoch 37/200
450/450 [==============================] - 7s 15ms/step - loss: 0.6336 - accuracy: 0.7806 - val_loss
: 0.8374 - val_accuracy: 0.7450
f1 score is  0.745
Epoch 38/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6402 - accuracy: 0.7760 - val_loss
: 0.8018 - val_accuracy: 0.7275
f1 score is  0.7275000000000001
Epoch 39/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6472 - accuracy: 0.7758 - val_loss
: 0.6636 - val_accuracy: 0.7625
f1 score is  0.7625
Epoch 40/200
450/450 [==============================] - 7s 15ms/step - loss: 0.6374 - accuracy: 0.7799 - val_loss
: 0.6517 - val_accuracy: 0.7725
f1 score is  0.7725000000000001
Epoch 41/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6287 - accuracy: 0.7876 - val_loss
: 0.7390 - val_accuracy: 0.7650
f1 score is  0.765
Epoch 42/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6243 - accuracy: 0.7815 - val_loss
: 0.6568 - val_accuracy: 0.7800
f1 score is  0.78
Epoch 43/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6021 - accuracy: 0.7944 - val_loss
: 0.6693 - val_accuracy: 0.7700
f1 score is  0.7699999999999999
Epoch 44/200
450/450 [==============================] - 6s 14ms/step - loss: 0.6022 - accuracy: 0.7909 - val_loss
: 0.6307 - val_accuracy: 0.7925
f1 score is  0.7925
Epoch 45/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5935 - accuracy: 0.7943 - val_loss
```

```
: 0.6509 - val_accuracy: 0.7875
f1 score is  0.7875
Epoch 46/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5899 - accuracy: 0.7976 - val_loss
: 0.6443 - val_accuracy: 0.7975
f1 score is  0.7975
Epoch 47/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5811 - accuracy: 0.7947 - val_loss
: 0.6572 - val_accuracy: 0.7950
f1 score is  0.795
Epoch 48/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5680 - accuracy: 0.8065 - val_loss
: 0.6398 - val_accuracy: 0.7700
f1 score is  0.7699999999999999
Epoch 49/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5695 - accuracy: 0.8017 - val_loss
: 0.6376 - val_accuracy: 0.7775
f1 score is  0.7775
Epoch 50/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5521 - accuracy: 0.8088 - val_loss
: 0.7267 - val_accuracy: 0.7650
f1 score is  0.765
Epoch 51/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5435 - accuracy: 0.8162 - val_loss
: 0.6176 - val_accuracy: 0.7850
f1 score is  0.785
Epoch 52/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5497 - accuracy: 0.8076 - val_loss
: 0.6516 - val_accuracy: 0.7875
f1 score is  0.7875
Epoch 53/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5451 - accuracy: 0.8081 - val_loss
: 0.6421 - val_accuracy: 0.7875
f1 score is  0.7875
Epoch 54/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5406 - accuracy: 0.8141 - val_loss
: 0.6391 - val_accuracy: 0.7850
f1 score is  0.785
Epoch 55/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5359 - accuracy: 0.8153 - val_loss
: 0.6962 - val_accuracy: 0.7800
f1 score is  0.78
Epoch 56/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5296 - accuracy: 0.8138 - val_loss
: 0.6540 - val_accuracy: 0.7800
f1 score is  0.78
Epoch 57/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5198 - accuracy: 0.8214 - val_loss
: 0.6553 - val_accuracy: 0.7825
f1 score is  0.7825
Epoch 58/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5183 - accuracy: 0.8228 - val_loss
: 0.6900 - val_accuracy: 0.7400
f1 score is  0.74
Epoch 59/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5137 - accuracy: 0.8199 - val_loss
: 0.6327 - val_accuracy: 0.7900
f1 score is  0.79
Epoch 60/200
450/450 [==============================] - 6s 14ms/step - loss: 0.5159 - accuracy: 0.8183 - val_loss
: 0.6558 - val_accuracy: 0.7800
f1 score is  0.78
Epoch 61/200
450/450 [==============================] - 7s 15ms/step - loss: 0.5073 - accuracy: 0.8247 - val_loss
: 0.6550 - val_accuracy: 0.8025
micro f1 score has reached 0.80% so training is stopping
f1 score is  0.8025
```

Out[147]:

```
<keras.callbacks.History at 0x7fc8c00dea10>
```

In [148]:

```
logdir4
```

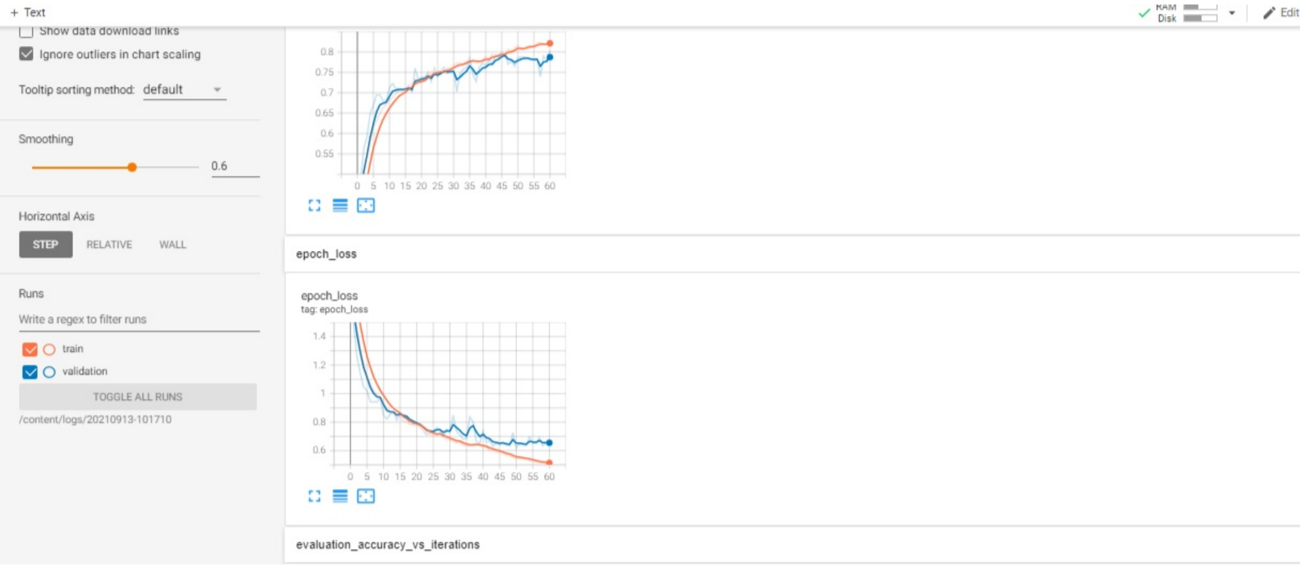
Out[148]:

```
'logs/20210913-101710'
```

In [5]:

```python
from IPython.display import Image
Image(filename=r'C:\Users\kingjames\Downloads\spoken model 4 tensorboard.png')
```

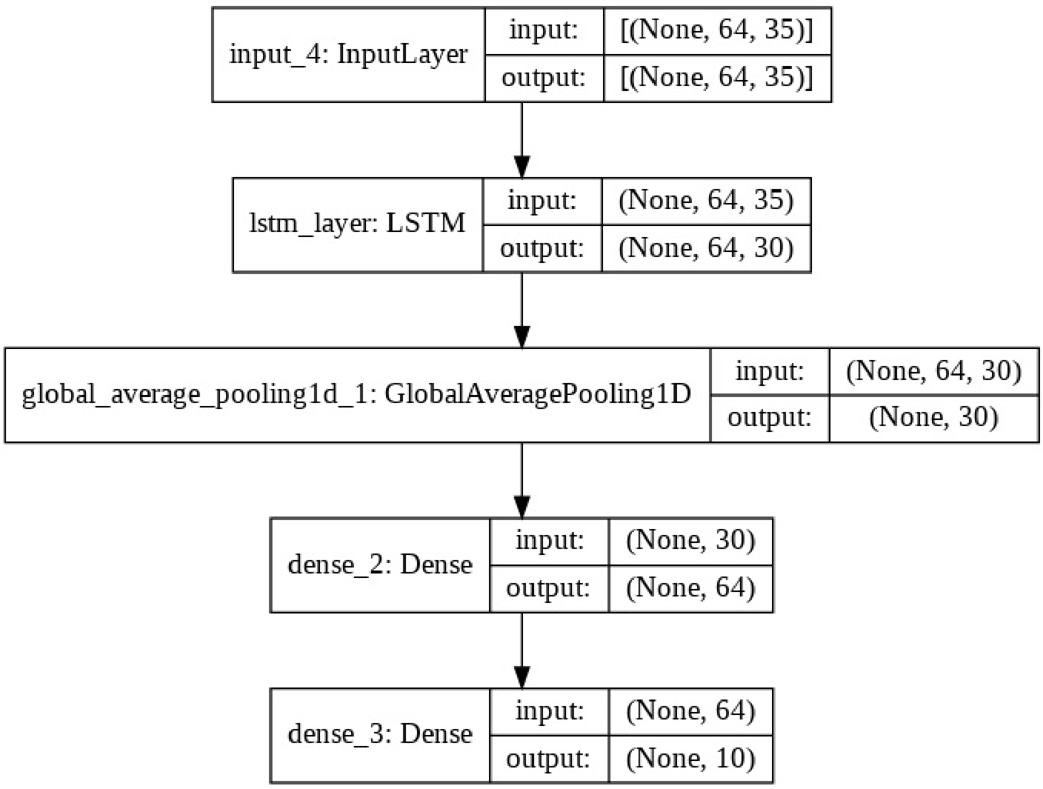
Out[5]:



In [151]:

```python
from tensorflow.keras.utils import plot_model
plot_model(model4, to_file='model_plot.png', show_shapes=True, show_layer_names=True)
```

Out[151]:



observations

1] Here the data is audio which has wav format. so we use librosa libarary to get vector for every audio file ,with sampling rate 22050. sampling rate is basically number of observation taken per second here we took 22050.

2] then we each audio file must be same length so he we observaed that 99.99% of the audo file have 0.8 sec of duaration . for 1 sec we have 22050 sampling rate for 0.8 sec we have 17640sampling rate

3] So each audio file is of length 17640.if it is less than 17640 we pad with 0 . If it is more than 17640 we truncate it .

4] then we feed it to lstm model. here we ahve 4 model. first model we directly feed it to the lstm and got desired accuracy.

5] second model we convert audio file to spectogram and then feed it to the lstm model. third model we did data augmentation for each file we have created 9 files and then feed it to the lstm model. and in fourth model we convert augemnted data to spectogram and then feed it to the model and got desired f1 score.

In [ ]:

```

```