A report submitted for EMBEDDED SYSTEM project component

Respiratory Sounds Diagnosis using Artificial Intelligence

by

VIDWATH JAGADEESH M

17BMD0062

IV Year - B.TECH BIOMEDICAL ENGINEERING

SCHOOL OF ELECTRONICS ENGINEERING

Vellore – 632014, Tamil Nadu, India

www.vit.ac.in

FALL SEMESTER 2020 - 21

SCHOOL OF ELECTRONICS ENGINEERING

J Component Project

EMBEDDED SYSTE IN MEDICAL APPLICATION (ECE-4024)

It is certified that the project entitled “Respiratory Sounds Diagnosis Using Artificial Intelligence” is the Bonafide work for J component EMBEDDED SYSTE IN MEDICAL APPLICATION of by the following students

17BMD0062- VIDWATH JAGADEESH M

17BMD0008- DIGVIJAY YADAV

Of Electrical engineering branch under my supervision in E2 slot during the Fall semester -2018-19 at V.I.T. University, Vellore-632 014.

Faculty Signature:

Date:

1. INTRODUCTION

1.1 ABSTRACT

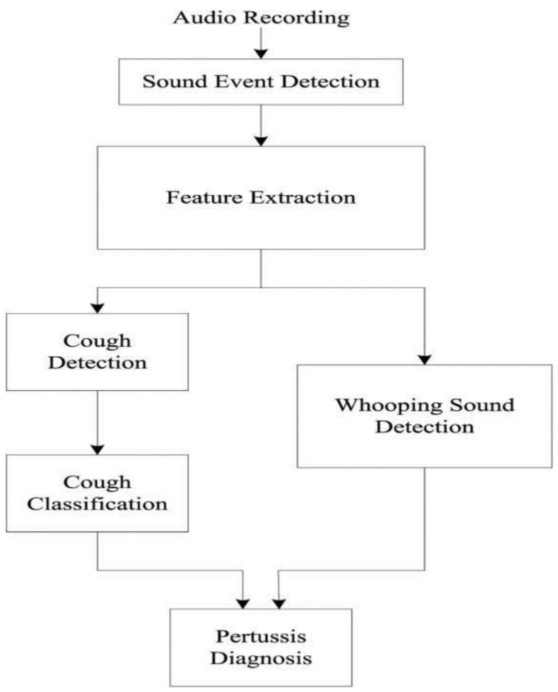
This project focuses on creating a contactless based analysis and classification of respiratory sounds. This apparatus uses the mobile microphone recording to limiting the exposure of subject to be tested. This was done taking into account COVID-19. This methodology uses the conversion of audio signals from the microphone into its respective spectrum using MFCC's which is stored and this data is trained with the other clips and normal sounds to differentiate and give result to the specific diagnosis.

1.2 OBJECTIVE

- To collect data without contact and limit exposure to individuals
- To test the robustness of the neural network on the data sets recorded.
- To achieve high accuracy to identify and diagnose the condition.

2.1 Working

• Proposed algorithm



1. We got the microphone based recorded audio of various conditions related to respiratory system such as pertussis, bronchiectasis etc. (Reichert, 2008)
2. With the present data we divided the data based on the condition and created the MFCC's (Mel-frequency cepstral coefficients). The MFCC feature extraction technique basically includes windowing the signal, applying the DFT, taking the log of the magnitude, and then warping the frequencies on a Mel scale, followed by applying the inverse DCT. (Pramono RXA, 2016)
3. MFCC's help in converting the audio format to visual format which is easier for analysis in the convoluted neural network.
4. Splitting was done in 80:20 form, with 80% of data stored in training data which would be used by Neural Network model to understand about the dataset.
5. Data of Asthma and LRTI were removed for missing data.
6. Mobile-Net model was tried at first, however due to its poor performance in detecting diseases clearly it was removed.

CODE:

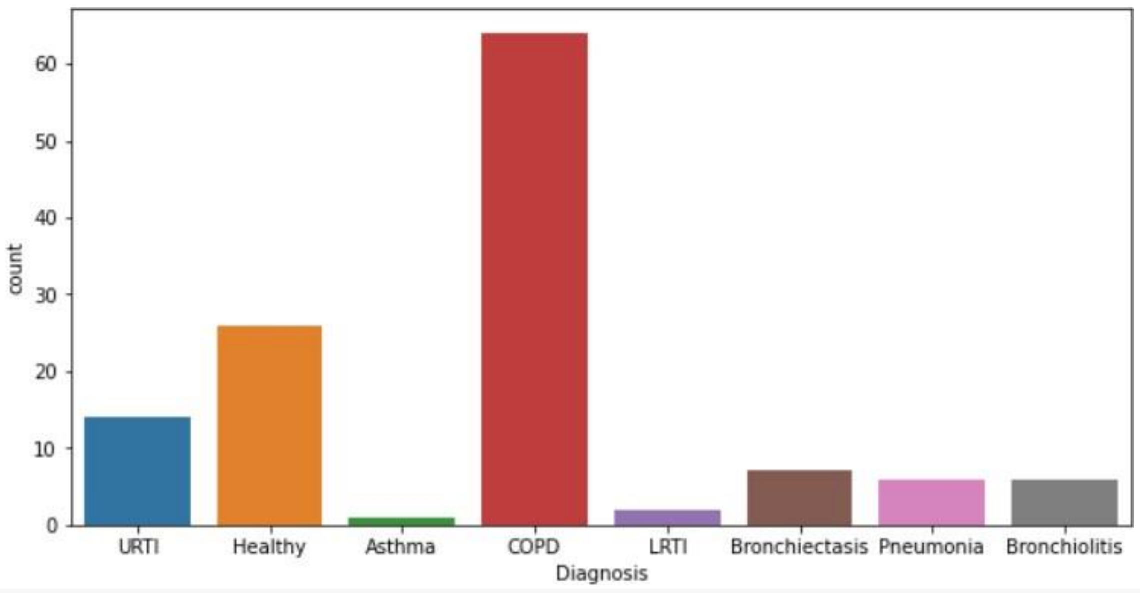
```
# This Python 3 environment comes with many helpful analytics libraries installed
# It is defined by the kaggle/python Docker image: https://github.com/kaggle/docker-python
# For example, here's several helpful packages to load

import numpy as np # linear algebra
import pandas as pd # data processing, CSV file I/O (e.g. pd.read_csv)

# Input data files are available in the read-only "../input/" directory
# For example, running this (by clicking run or pressing Shift+Enter) will list all files un
der the input directory

import os
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv1D, Conv2D, MaxPooling2D, MaxPooling1D, Dense, Fla
tten, Dropout, SeparableConv1D
import matplotlib.pyplot as plt
import seaborn as sns


# You can write up to 5GB to the current directory (/kaggle/working/) that gets preserved as
output when you create a version using "Save & Run All"
# You can also write temporary files to /kaggle/temp/, but they won't be saved outside of th
e current session
```

```
diagnosis_df = pd.read_csv('../input/respiratory-sound-database/Respiratory_Sound_Databas
e/Respiratory_Sound_Database/patient_diagnosis.csv', names=['Patient number', 'Diagnosi
s'])
diagnosis_df.head(4)
```

	Patient number	Diagnosis
0	101	URTI
1	102	Healthy
2	103	Asthma
3	104	COPD

```
plt.figure(figsize=(10,5))
sns.countplot(diagnosis_df['Diagnosis'])
```

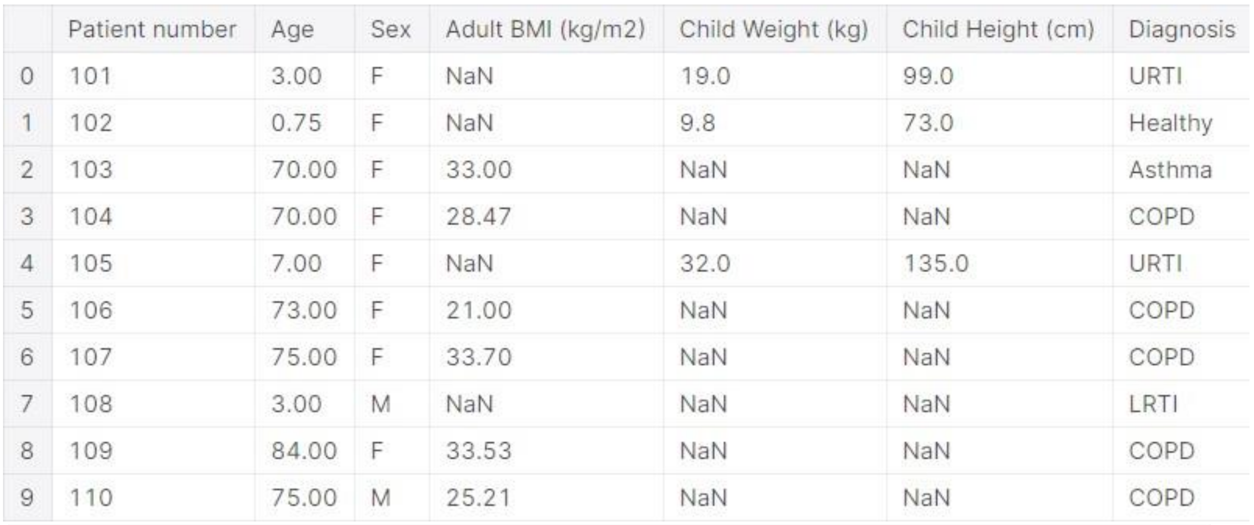
```
<matplotlib.axes._subplots.AxesSubplot at 0x7fb46f656290>
```



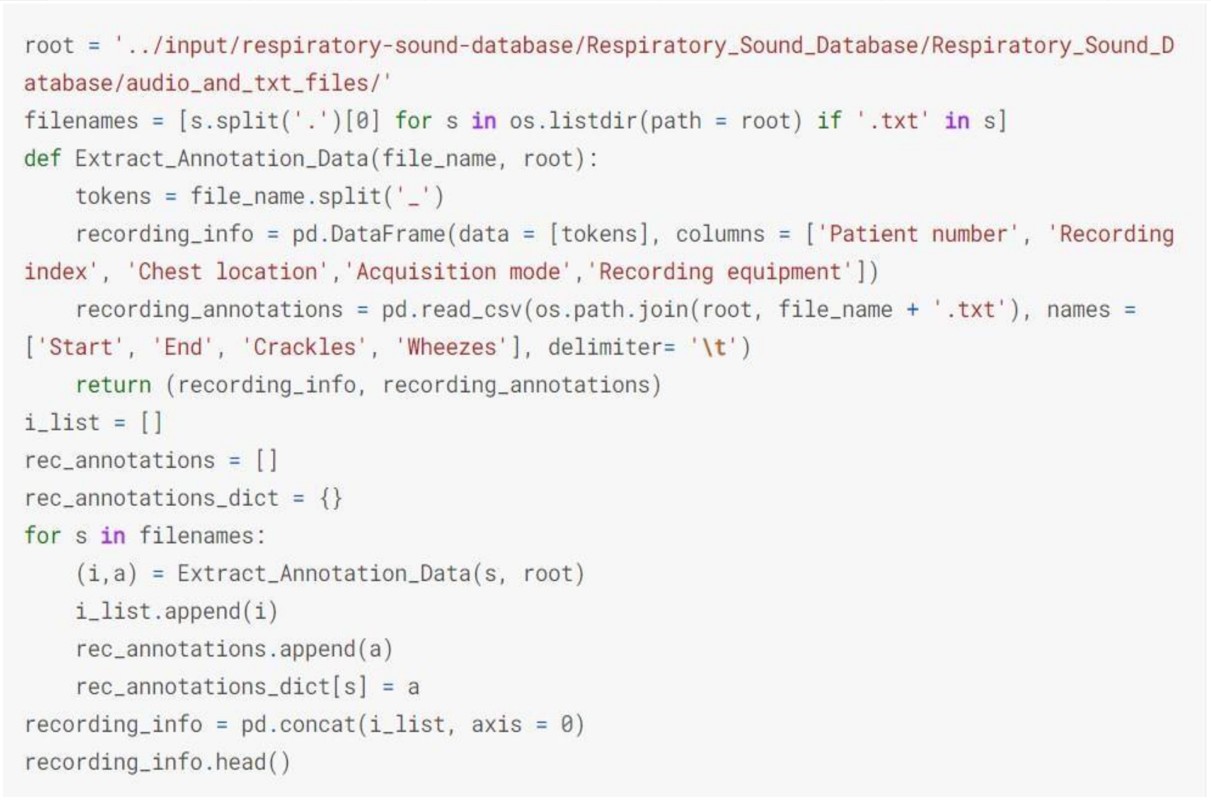
```
df_no_diagnosis = pd.read_csv('../input/respiratory-sound-database/demographic_info.txt',
names =
                  ['Patient number', 'Age', 'Sex' , 'Adult BMI (kg/m2)', 'Child Weight (k
g)' , 'Child Height (cm)'],
                  delimiter = ' ')
df_no_diagnosis.head(5)
```

	Patient number	Age	Sex	Adult BMI (kg/m2)	Child Weight (kg)	Child Height (cm)
0	101	3.00	F	NaN	19.0	99.0
1	102	0.75	F	NaN	9.8	73.0
2	103	70.00	F	33.00	NaN	NaN
3	104	70.00	F	28.47	NaN	NaN
4	105	7.00	F	NaN	32.0	135.0

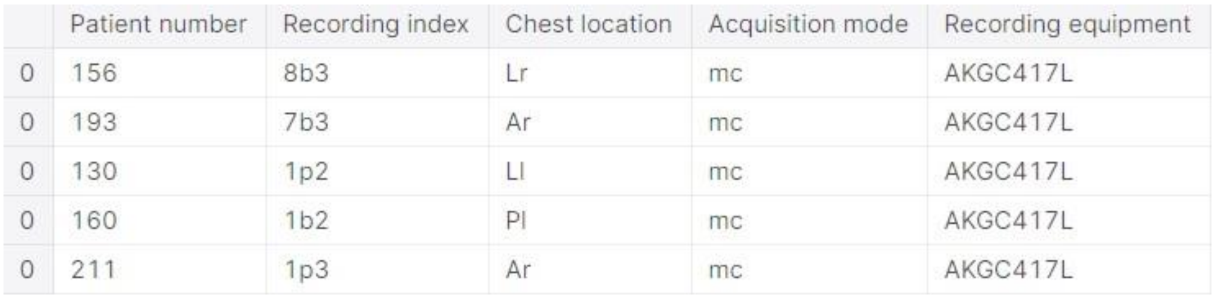
```
df =  df_no_diagnosis.join(diagnosis_df.set_index('Patient number'), on = 'Patient numbe
r', how = 'left')
df.head(10)
```



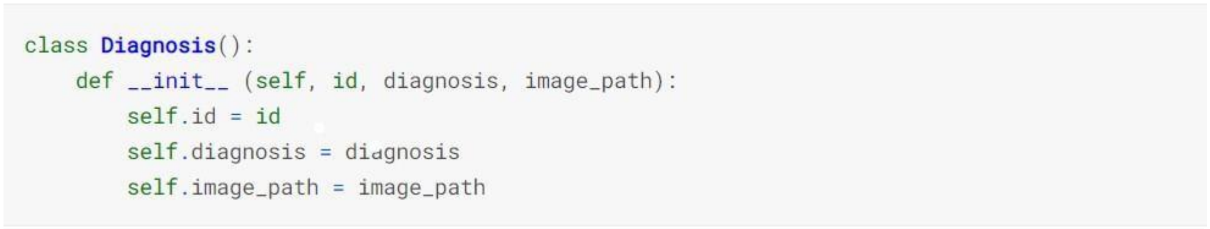
	Patient number	Age	Sex	Adult BMI (kg/m2)	Child Weight (kg)	Child Height (cm)	Diagnosis
0	101	3.00	F	NaN	19.0	99.0	URTI
1	102	0.75	F	NaN	9.8	73.0	Healthy
2	103	70.00	F	33.00	NaN	NaN	Asthma
3	104	70.00	F	28.47	NaN	NaN	COPD
4	105	7.00	F	NaN	32.0	135.0	URTI
5	106	73.00	F	21.00	NaN	NaN	COPD
6	107	75.00	F	33.70	NaN	NaN	COPD
7	108	3.00	M	NaN	NaN	NaN	LRTI
8	109	84.00	F	33.53	NaN	NaN	COPD
9	110	75.00	M	25.21	NaN	NaN	COPD



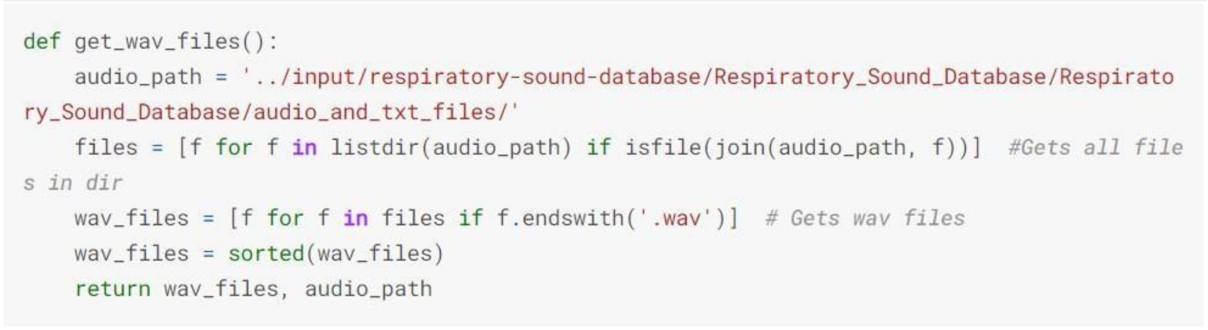
```
root = '../input/respiratory-sound-database/Respiratory_Sound_Database/Respiratory_Sound_D
atabase/audio_and_txt_files/'
filenames = [s.split('.')[0] for s in os.listdir(path = root) if '.txt' in s]
def Extract_Annotation_Data(file_name, root):
    tokens = file_name.split('_')
    recording_info = pd.DataFrame(data = [tokens], columns = ['Patient number', 'Recording
index', 'Chest location','Acquisition mode','Recording equipment'])
    recording_annotations = pd.read_csv(os.path.join(root, file_name + '.txt'), names =
['Start', 'End', 'Crackles', 'Wheezes'], delimiter= '\t')
    return (recording_info, recording_annotations)
i_list = []
rec_annotations = []
rec_annotations_dict = {}
for s in filenames:
    (i,a) = Extract_Annotation_Data(s, root)
    i_list.append(i)
    rec_annotations.append(a)
    rec_annotations_dict[s] = a
recording_info = pd.concat(i_list, axis = 0)
recording_info.head()
```



	Patient number	Recording index	Chest location	Acquisition mode	Recording equipment
0	156	8b3	Lr	mc	AKGC417L
0	193	7b3	Ar	mc	AKGC417L
0	130	1p2	Ll	mc	AKGC417L
0	160	1b2	Pl	mc	AKGC417L
0	211	1p3	Ar	mc	AKGC417L



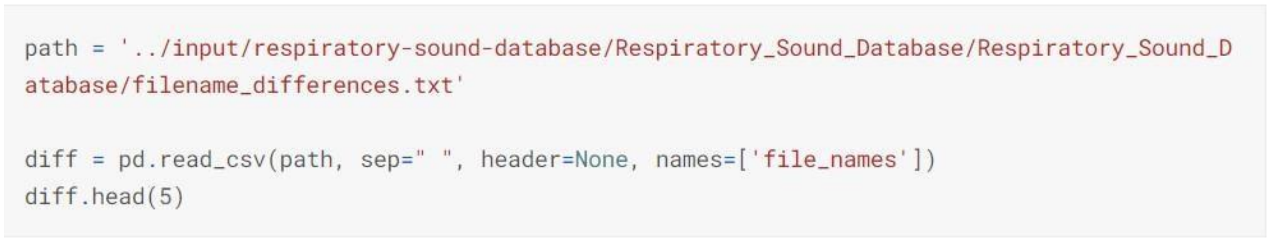
```
class Diagnosis():
    def __init__ (self, id, diagnosis, image_path):
        self.id = id
        self.diagnosis = diagnosis
        self.image_path = image_path
```



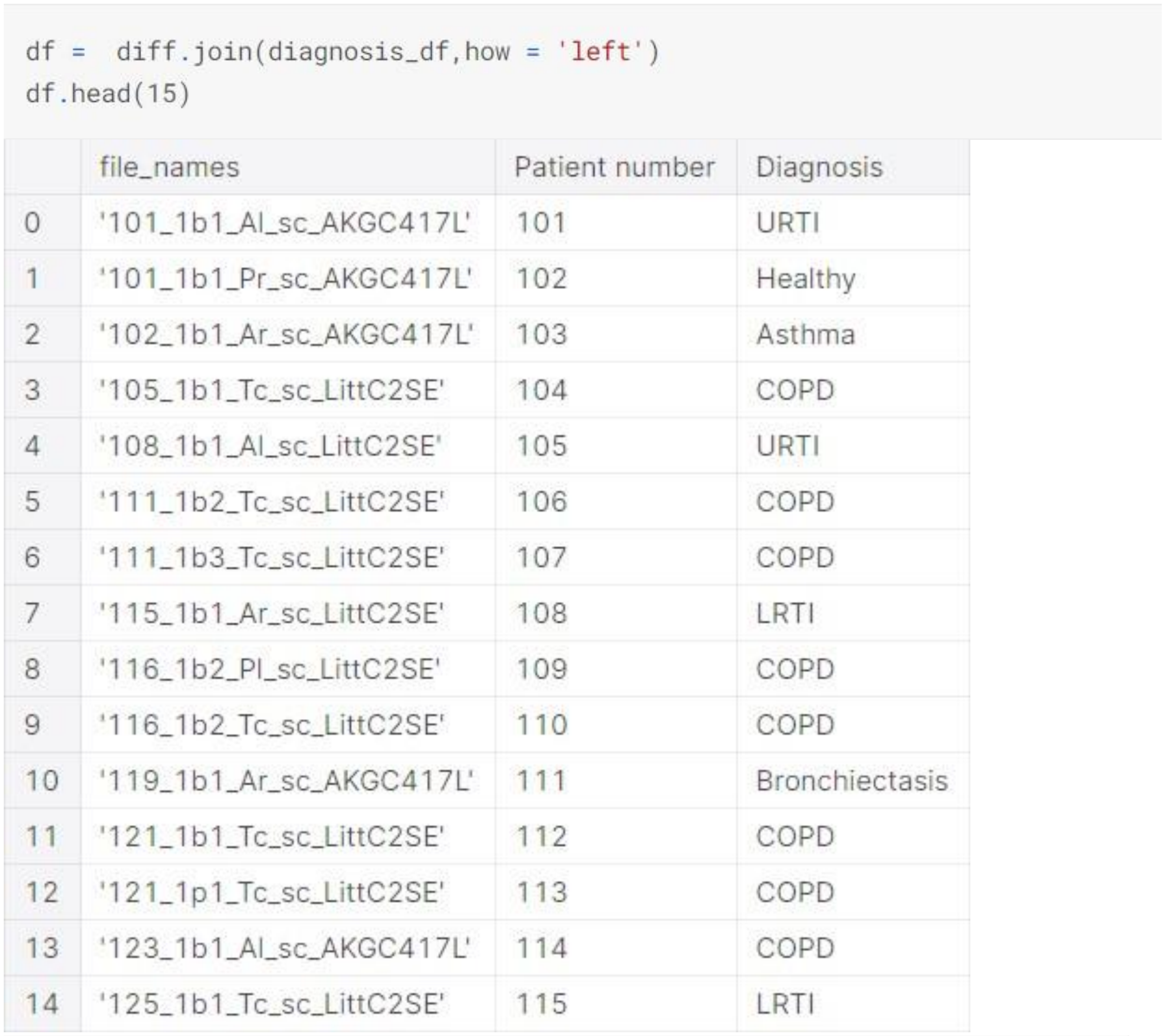
```
def get_wav_files():
    audio_path = '../input/respiratory-sound-database/Respiratory_Sound_Database/Respirato
ry_Sound_Database/audio_and_txt_files/'
    files = [f for f in listdir(audio_path) if isfile(join(audio_path, f))]  #Gets all file
s in dir
    wav_files = [f for f in files if f.endswith('.wav')]  # Gets wav files
    wav_files = sorted(wav_files)
    return wav_files, audio_path
```

```python
def diagnosis_data():
    diagnosis = pd.read_csv('../input/respiratory-sound-database/Respiratory_Sound_Database/Respiratory_Sound_Database/patient_diagnosis.csv')

    wav_files, audio_path = get_wav_files()
    diag_dict = { 101 : "URTI"}
    diagnosis_list = []

    for index , row in diagnosis.iterrows():
        diag_dict[row[0]] = row[1]

    c = 0
    for f in wav_files:
        diagnosis_list.append(Diagnosis(c, diag_dict[int(f[:3])], audio_path+f))
        c+=1

    return diagnosis_list
```

```python
import librosa
import librosa.display

def audio_features(filename):
    sound, sample_rate = librosa.load(filename)
    stft = np.abs(librosa.stft(sound))

    mfccs = np.mean(librosa.feature.mfcc(y=sound, sr=sample_rate, n_mfcc=40),axis=1)
    chroma = np.mean(librosa.feature.chroma_stft(S=stft, sr=sample_rate),axis=1)
    mel = np.mean(librosa.feature.melspectrogram(sound, sr=sample_rate),axis=1)
    contrast = np.mean(librosa.feature.spectral_contrast(S=stft, sr=sample_rate),axis=1)
    tonnetz = np.mean(librosa.feature.tonnetz(y=librosa.effects.harmonic(sound), sr=sample_rate),axis=1)

    concat = np.concatenate((mfccs,chroma,mel,contrast,tonnetz))
    return concat

def data_points():
    labels = []
    images = []

    to_hot_one = {"COPD":0, "Healthy":1, "URTI":2, "Bronchiectasis":3, "Pneumonia":4, "Bronchiolitis":5, "Asthma":6, "LRTI":7}

    #count = 0
    for f in diagnosis_data():
        #print(count)
        labels.append(to_hot_one[f.diagnosis])
        images.append(audio_features(f.image_path))
        #count+=1

    return np.array(labels), np.array(images)
```

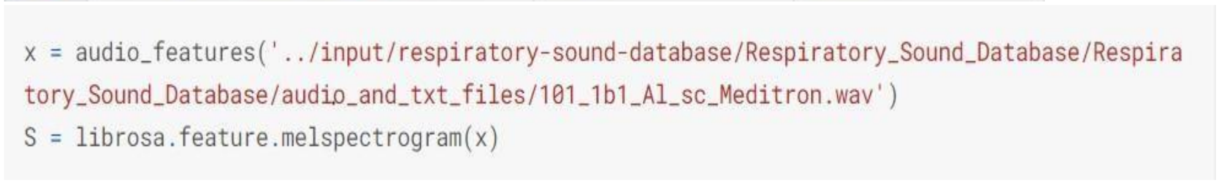


```
path = '../input/respiratory-sound-database/Respiratory_Sound_Database/Respiratory_Sound_D
atabase/filename_differences.txt'

diff = pd.read_csv(path, sep=" ", header=None, names=['file_names'])
diff.head(5)
```



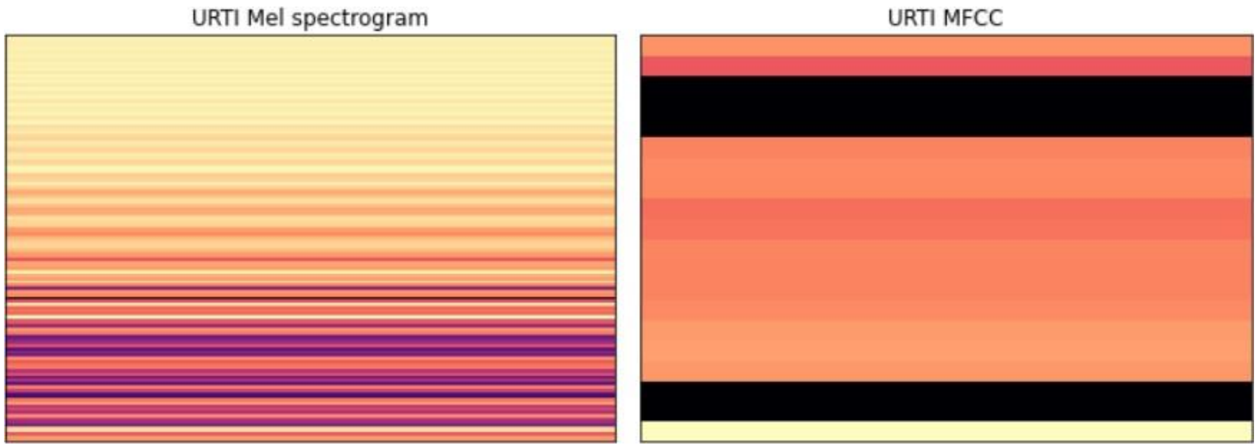
```
df =  diff.join(diagnosis_df,how = 'left')
df.head(15)
```

	file_names	Patient number	Diagnosis
0	'101_1b1_Al_sc_AKGC417L'	101	URTI
1	'101_1b1_Pr_sc_AKGC417L'	102	Healthy
2	'102_1b1_Ar_sc_AKGC417L'	103	Asthma
3	'105_1b1_Tc_sc_LittC2SE'	104	COPD
4	'108_1b1_Al_sc_LittC2SE'	105	URTI
5	'111_1b2_Tc_sc_LittC2SE'	106	COPD
6	'111_1b3_Tc_sc_LittC2SE'	107	COPD
7	'115_1b1_Ar_sc_LittC2SE'	108	LRTI
8	'116_1b2_Pl_sc_LittC2SE'	109	COPD
9	'116_1b2_Tc_sc_LittC2SE'	110	COPD
10	'119_1b1_Ar_sc_AKGC417L'	111	Bronchiectasis
11	'121_1b1_Tc_sc_LittC2SE'	112	COPD
12	'121_1p1_Tc_sc_LittC2SE'	113	COPD
13	'123_1b1_Al_sc_AKGC417L'	114	COPD
14	'125_1b1_Tc_sc_LittC2SE'	115	LRTI



```
x = audio_features('../input/respiratory-sound-database/Respiratory_Sound_Database/Respira
tory_Sound_Database/audio_and_txt_files/101_1b1_Al_sc_Meditron.wav')
S = librosa.feature.melspectrogram(x)
```

```
plt.figure(figsize=(10, 7))
plt.subplot(2,2,1)
librosa.display.specshow(librosa.power_to_db(S, ref=np.max))
plt.title('URTI Mel spectrogram')
plt.tight_layout()

T = librosa.feature.mfcc(x)
plt.subplot(2,2,2)
librosa.display.specshow(librosa.power_to_db(T, ref=np.max))
plt.title('URTI MFCC')
plt.tight_layout()
```

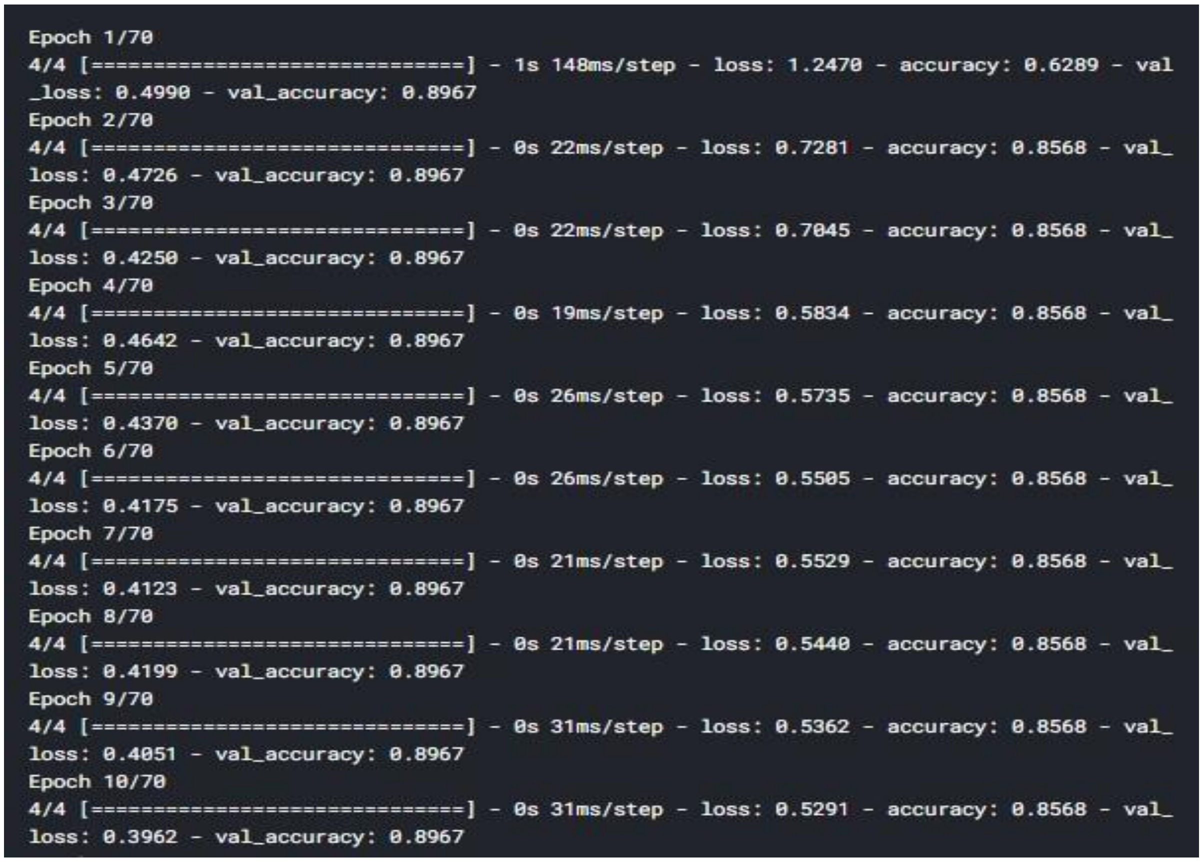


```
from sklearn.model_selection import train_test_split

def preprocessing(labels, images):

  # Remove Asthma and LRTI
    images = np.delete(images, np.where((labels == 7) | (labels == 6))[0], axis=0)
    labels = np.delete(labels, np.where((labels == 7) | (labels == 6))[0], axis=0)

  # Split data
    X_train, X_test, y_train, y_test = train_test_split(images, labels, test_size=0.2, ran
dom_state=10)

  # Hot one encode the labels
    y_train = to_categorical(y_train)
    y_test = to_categorical(y_test)

  # Format new data
    y_train = np.reshape(y_train, (y_train.shape[0], 6))
    X_train = np.reshape(X_train, (X_train.shape[0], X_train.shape[1], 1))
    y_test = np.reshape(y_test, (y_test.shape[0], 6))
    X_test = np.reshape(X_test, (X_test.shape[0], X_train.shape[1],  1))

    return X_train, X_test, y_train, y_test
```

```
from os import listdir
from os.path import isfile, join
from tensorflow.keras.utils import plot_model,to_categorical

labels, images = data_points()
X_train, X_test, y_train, y_test = preprocessing(labels, images)
```

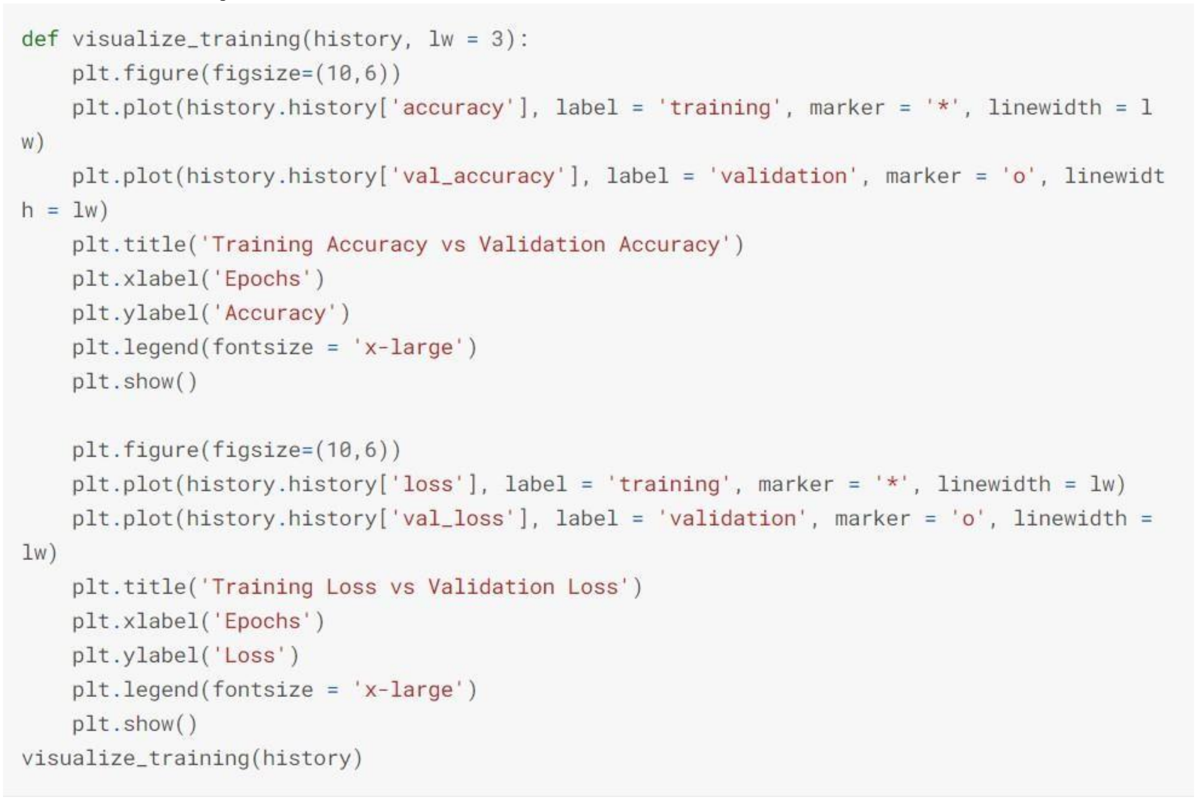
Depthwise Separable CNN model

```
model = Sequential()
model.add(Conv1D(64, kernel_size=5, activation='relu', input_shape=(193, 1)))

model.add(Conv1D(128, kernel_size=5, activation='relu'))
model.add(MaxPooling1D(2))

model.add(SeparableConv1D(256, kernel_size=5, activation='relu'))
model.add(MaxPooling1D(2))

model.add(SeparableConv1D(256, kernel_size=5, activation='relu'))
model.add(MaxPooling1D(2))

model.add(Dropout(0.5))
model.add(Flatten())

model.add(Dense(512, activation='relu'))
model.add(Dense(6, activation='softmax'))

model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
history = model.fit(X_train, y_train, validation_data=(X_test, y_test), epochs=70, batch_s
ize=200, verbose=1)
```

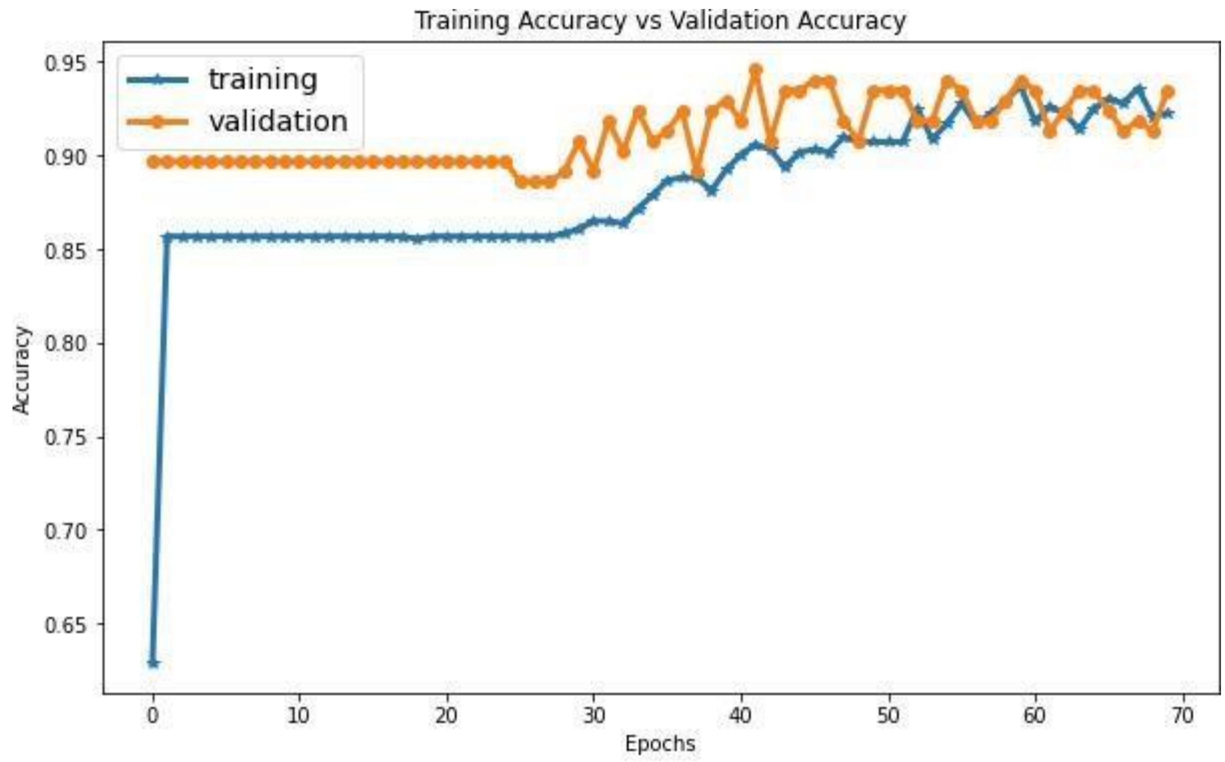


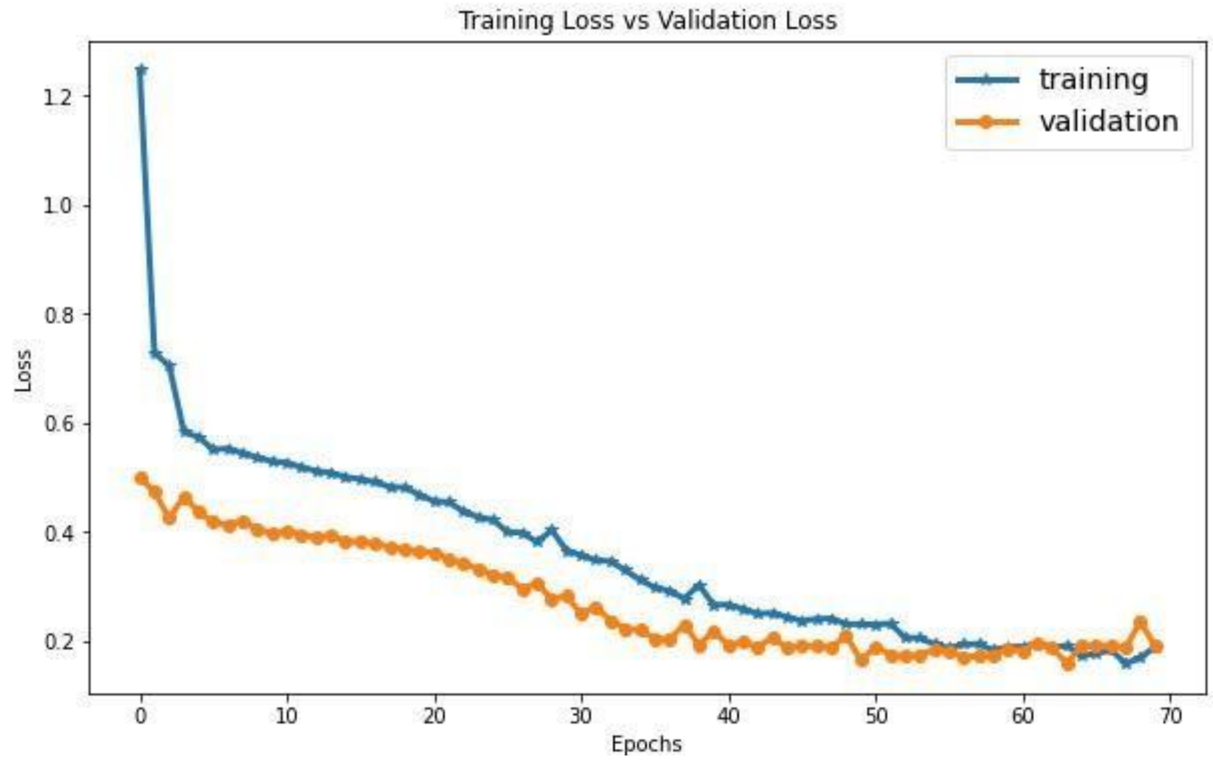
```
Epoch 1/70
4/4 [==============================] - 1s 148ms/step - loss: 1.2470 - accuracy: 0.6289 - val
_loss: 0.4990 - val_accuracy: 0.8967
Epoch 2/70
4/4 [==============================] - 0s 22ms/step - loss: 0.7281 - accuracy: 0.8568 - val_
loss: 0.4726 - val_accuracy: 0.8967
Epoch 3/70
4/4 [==============================] - 0s 22ms/step - loss: 0.7045 - accuracy: 0.8568 - val_
loss: 0.4250 - val_accuracy: 0.8967
Epoch 4/70
4/4 [==============================] - 0s 19ms/step - loss: 0.5834 - accuracy: 0.8568 - val_
loss: 0.4642 - val_accuracy: 0.8967
Epoch 5/70
4/4 [==============================] - 0s 26ms/step - loss: 0.5735 - accuracy: 0.8568 - val_
loss: 0.4370 - val_accuracy: 0.8967
Epoch 6/70
4/4 [==============================] - 0s 26ms/step - loss: 0.5505 - accuracy: 0.8568 - val_
loss: 0.4175 - val_accuracy: 0.8967
Epoch 7/70
4/4 [==============================] - 0s 21ms/step - loss: 0.5529 - accuracy: 0.8568 - val_
loss: 0.4123 - val_accuracy: 0.8967
Epoch 8/70
4/4 [==============================] - 0s 21ms/step - loss: 0.5440 - accuracy: 0.8568 - val_
loss: 0.4199 - val_accuracy: 0.8967
Epoch 9/70
4/4 [==============================] - 0s 31ms/step - loss: 0.5362 - accuracy: 0.8568 - val_
loss: 0.4051 - val_accuracy: 0.8967
Epoch 10/70
4/4 [==============================] - 0s 31ms/step - loss: 0.5291 - accuracy: 0.8568 - val_
loss: 0.3962 - val_accuracy: 0.8967
```

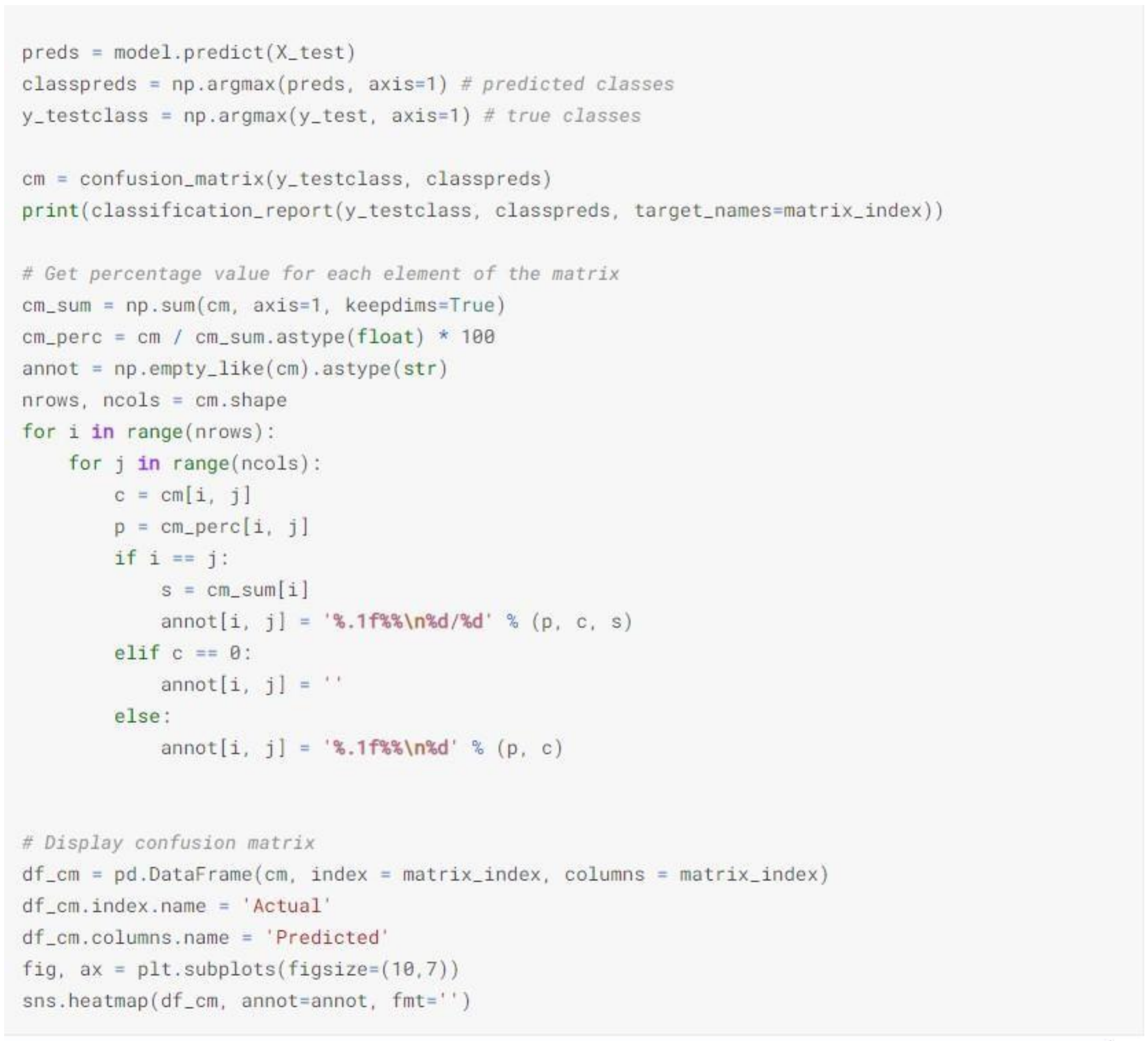
Shows accuracy at 89.67%



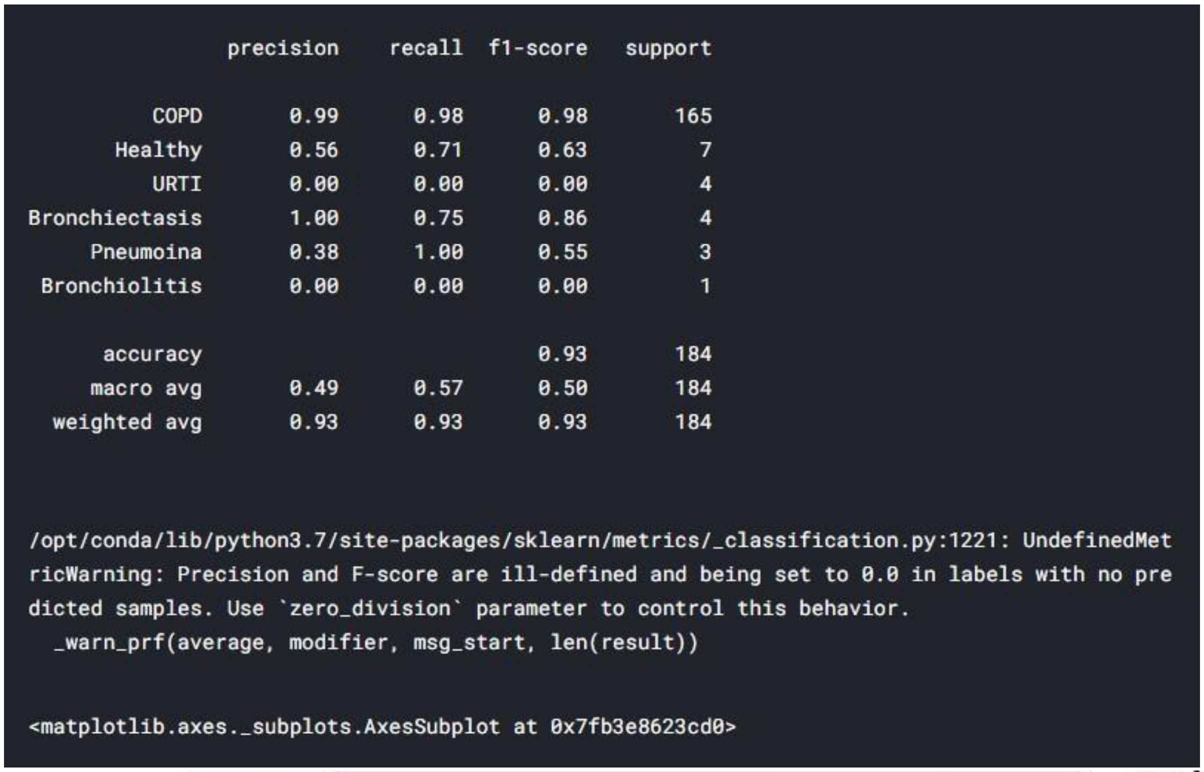
```
def visualize_training(history, lw = 3):
    plt.figure(figsize=(10,6))
    plt.plot(history.history['accuracy'], label = 'training', marker = '*', linewidth = l
w)
    plt.plot(history.history['val_accuracy'], label = 'validation', marker = 'o', linewidt
h = lw)
    plt.title('Training Accuracy vs Validation Accuracy')
    plt.xlabel('Epochs')
    plt.ylabel('Accuracy')
    plt.legend(fontsize = 'x-large')
    plt.show()

    plt.figure(figsize=(10,6))
    plt.plot(history.history['loss'], label = 'training', marker = '*', linewidth = lw)
    plt.plot(history.history['val_loss'], label = 'validation', marker = 'o', linewidth =
lw)
    plt.title('Training Loss vs Validation Loss')
    plt.xlabel('Epochs')
    plt.ylabel('Loss')
    plt.legend(fontsize = 'x-large')
    plt.show()
visualize_training(history)
```


Training Accuracy vs Validation Accuracy
training
validation
Accuracy
Epochs
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0
10
20
30
40
50
60
70

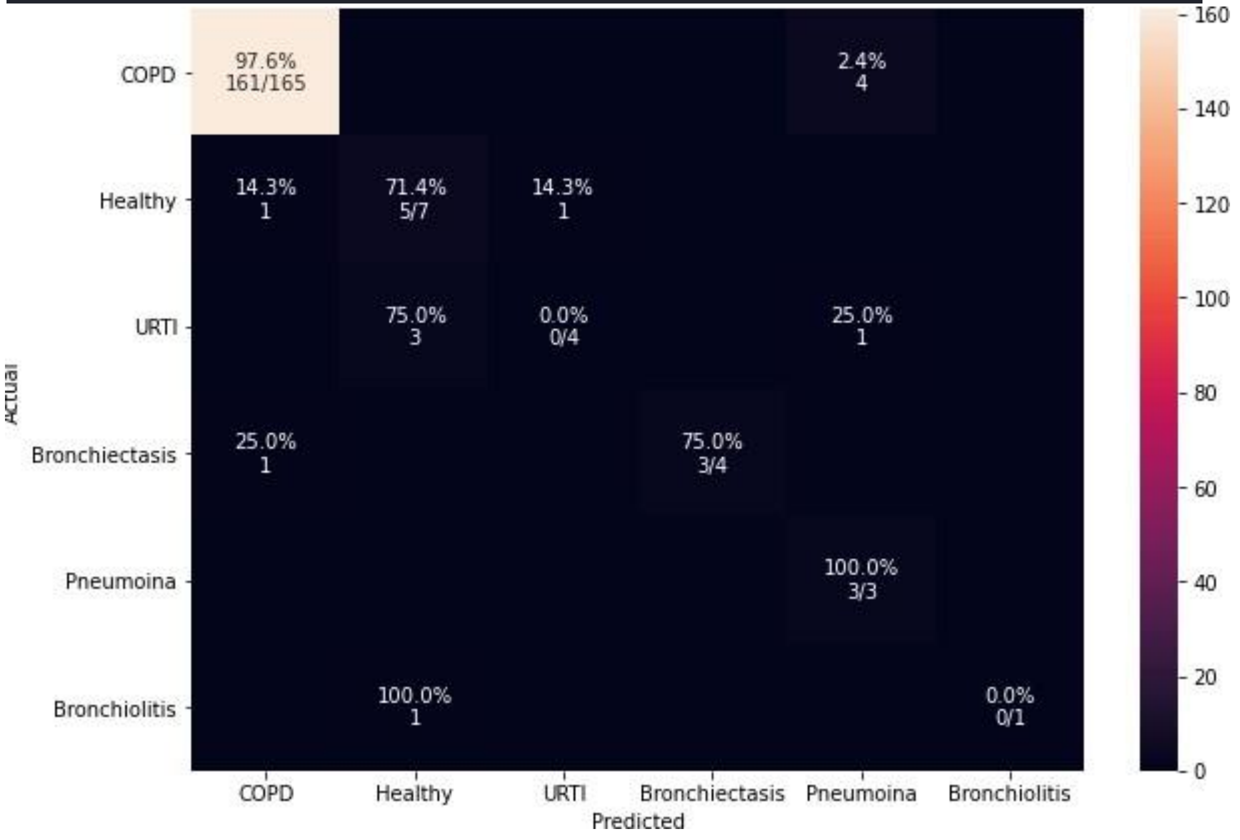

Training Loss vs Validation Loss
training
validation
Loss
Epochs
1.2
1.0
0.8
0.6
0.4
0.2
0
10
20
30
40
50
60
70



```python
preds = model.predict(X_test)
classpreds = np.argmax(preds, axis=1) # predicted classes
y_testclass = np.argmax(y_test, axis=1) # true classes

cm = confusion_matrix(y_testclass, classpreds)
print(classification_report(y_testclass, classpreds, target_names=matrix_index))

# Get percentage value for each element of the matrix
cm_sum = np.sum(cm, axis=1, keepdims=True)
cm_perc = cm / cm_sum.astype(float) * 100
annot = np.empty_like(cm).astype(str)
nrows, ncols = cm.shape
for i in range(nrows):
    for j in range(ncols):
        c = cm[i, j]
        p = cm_perc[i, j]
        if i == j:
            s = cm_sum[i]
            annot[i, j] = '%.1f%%\n%d/%d' % (p, c, s)
        elif c == 0:
            annot[i, j] = ''
        else:
            annot[i, j] = '%.1f%%\n%d' % (p, c)


# Display confusion matrix
df_cm = pd.DataFrame(cm, index = matrix_index, columns = matrix_index)
df_cm.index.name = 'Actual'
df_cm.columns.name = 'Predicted'
fig, ax = plt.subplots(figsize=(10,7))
sns.heatmap(df_cm, annot=annot, fmt='')
```



```
                precision    recall  f1-score   support

         COPD       0.99      0.98      0.98       165
      Healthy       0.56      0.71      0.63         7
         URTI       0.00      0.00      0.00         4
Bronchiectasis       1.00      0.75      0.86         4
    Pneumoina       0.38      1.00      0.55         3
 Bronchiolitis       0.00      0.00      0.00         1

     accuracy                           0.93       184
    macro avg       0.49      0.57      0.50       184
 weighted avg       0.93      0.93      0.93       184


/opt/conda/lib/python3.7/site-packages/sklearn/metrics/_classification.py:1221: UndefinedMet
ricWarning: Precision and F-score are ill-defined and being set to 0.0 in labels with no pre
dicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))

<matplotlib.axes._subplots.AxesSubplot at 0x7fb3e8623cd0>
```



References

Pramono RXA, I. S.-V. (2016). A Cough-Based Algorithm for Automatic Diagnosis of Pertussis. *PLoS ONE*, 11(9).

Reichert, S. &. (2008). Analysis of Respiratory Sounds: State of the Art. *Clinical Medicine : Circulatory, Respiratory and Pulmonary Medicine.*, 2. 10.4137/CCRPM.S530.

Database of audio https://www.kaggle.com/vbookshelf/respiratory-sound-database