Covid-19 Detection model using Deep Learning

-Santhanam P

Feynn Labs services

31/01/2022

Problem Statement

Asymptomatic people who are infected with Covid-19 exhibit, by definition, no discernible physical symptoms of the disease. They are thus less likely to seek out testing for the virus, and could unknowingly spread the infection to others. But it seems those who are asymptomatic may not be entirely free of changes wrought by the virus. MIT researchers have now found that people who are asymptomatic may differ from healthy individuals in the way that they cough. These differences are not decipherable to the human ear. But it turns out that they can be picked up by artificial intelligence.

"*The effective implementation of this group diagnostic tool could diminish the spread of the pandemic if everyone uses it before going to a classroom, a factory, or a restaurant*," says co-author Brian Subirana, a research scientist in MIT's Auto-ID Laboratory.

So I hope to create an AI model using Deep learning concepts to predict Covid patients from their cough audio, which can be established in many useful places like schools, hospitals, or working places.

Needs of Market/Customer/Business Assessment

- Whenever each Covid-19 pandemic waves hit a place hard, its health centers are overflowing with people coming to test their Covid status. Due to this health workers are working tirelessly without any breaks and putting them under immense pressure, also people are going to have to wait a long time to get their results. If we could successfully install a model for detecting Covid-19 patients from their cough audio, this would be extremely helpful for healthcare workers and could create an enormous impact on medical community.
- The major places where covid virus is spreading are schools, working places, Cinema theatres and banks. The children/parents/elders who are around hundreds of people daily act as carriers of virus and bring them home. If we could install these models in such places, we can reduce the spread of viruses to a huge scale.

Target Specification

- The proposed model will provide medical centers with more accurate and faster results, so that the workers would not need to work continuously without taking any rest and people who came to test can return with their result faster.
- Model also provide schools safer atmosphere by identifying students with COVID-19 and reduce the spread of viruses.

External Search (information sources/references)

Dataset Used: Coswara-Data

Dataset can be found here: https://github.com/iiscleap/Coswara-Data

The COSWARA database is created by crowdsourcing sound samples. The metadata and sound files are publicly available in the COSWARA-DATA github repository.

What is the structure of the repository? Each folder contains metadata and audio recordings corresponding to contributors. The folder is compressed.

What are the different sound samples? Sound samples collected include breathing sounds (fast and slow), cough sounds (deep and shallow), phonation of sustained vowels (/a/ as in made, /i/,/o/), and counting numbers at slow and fast pace. Metadata information collected includes the participant's age, gender, location (country, state/ province), current health status (healthy/ exposed/ positive/recovered) and the presence of comorbidities (pre-existing medical conditions).

Metadata of Coswara-data:

In [ ]:

```
coswara_metadata = pd.read_csv(coswara_dir+'combined_data.csv')
coswara_metadata
```

Out[ ]:

	id	a	covid_status	ep	g	l_c	l_l	l_s	rU	asthma	cough	smoker	ht	cold	diabetes	um	ihc
0	DRBAZX64nuVtqBQf13gH7r36Mh52	26	healthy	y	female	United States	Madison	Wisconsin	n	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
1	Jw7YMfwGqMX22UbHh1TTgYMTYWs1	16	healthy	y	female	India	24 pargana	West Bengal	n	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
2	xa2v8z3Yzgb9dFrq2gEZz6oS7fh1	26	resp_illness_not_identified	y	male	India	Kolkata	West Bengal	n	True	NaN	NaN	NaN	NaN	NaN	NaN	NaN
3	xwHQrG0KwjTLJvBYVtVXfHp4JAd2	32	resp_illness_not_identified	y	male	Sri Lanka	Sri Jatawardanapura	Western Province	n	NaN	True	True	NaN	NaN	NaN	NaN	NaN
4	xKW2EpGmJcfigLecUTLVXEWQHPg2	22	healthy	y	male	India	Kolkata	West Bengal	n	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1498	Sy1VK1UgX0ZMcMJitgPal1sp8jj2	20	healthy	y	female	India	Bangalore	Karnataka	n	NaN	NaN	NaN	NaN	NaN	NaN	n	NaN
1499	4drDZUIQcteX5StIFT2CXEL0N0L2	57	healthy	y	male	India	bangalore	Karnataka	n	NaN	NaN	NaN	NaN	NaN	True	n	NaN
1500	qSDQMZj4iqhaRUz1SvwiUqyUzKH3	52	healthy	y	male	India	Bangalore	Karnataka	n	NaN	True	NaN	NaN	True	NaN	n	NaN
1501	vX3NZt9tyQUhXgS4dIz55VGEMdU2	55	healthy	y	male	India	NaN	Karnataka	n	NaN	NaN	NaN	NaN	NaN	True	n	NaN
1502	JQyIFoDDO1fwOuEH0GaOFskQ90q1	29	healthy	y	male	India	NaN	Karnataka	n	NaN	NaN	NaN	NaN	NaN	NaN	n	NaN

1503 rows × 27 columns

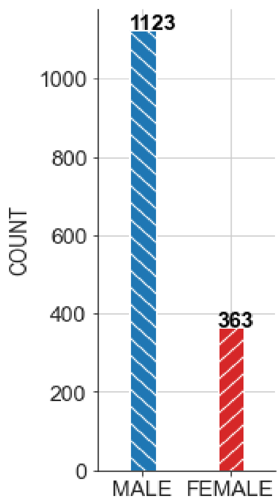
In [ ]:

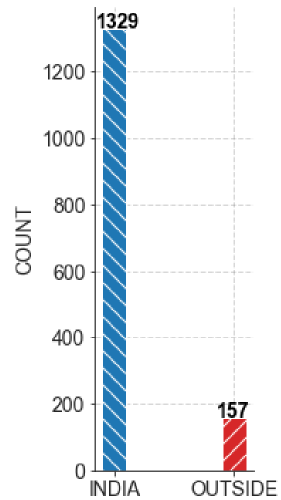
```
set(coswara_metadata['covid_status'])
```

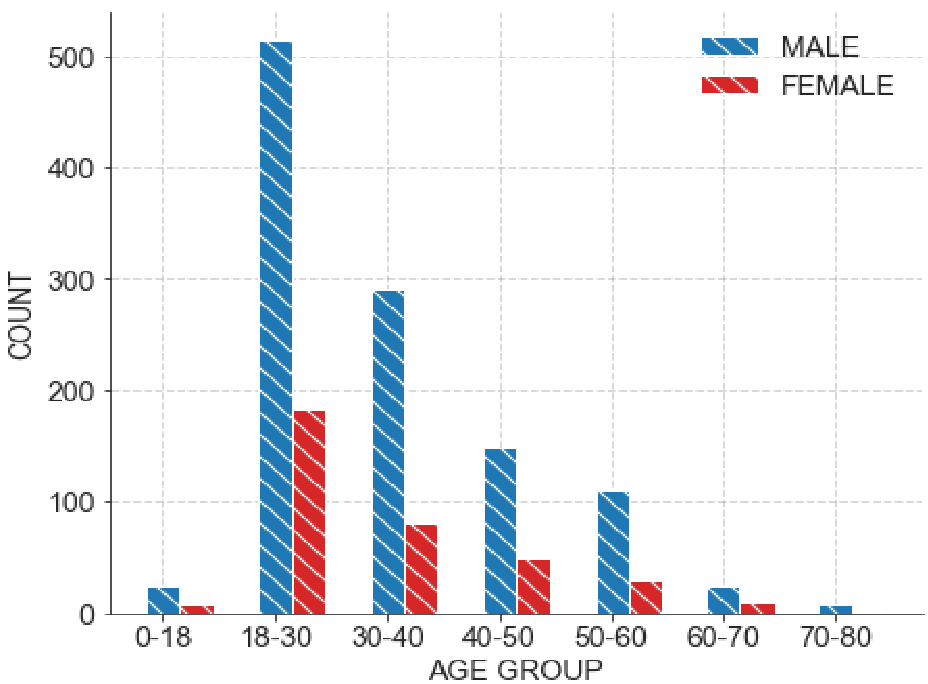
Out[ ]:

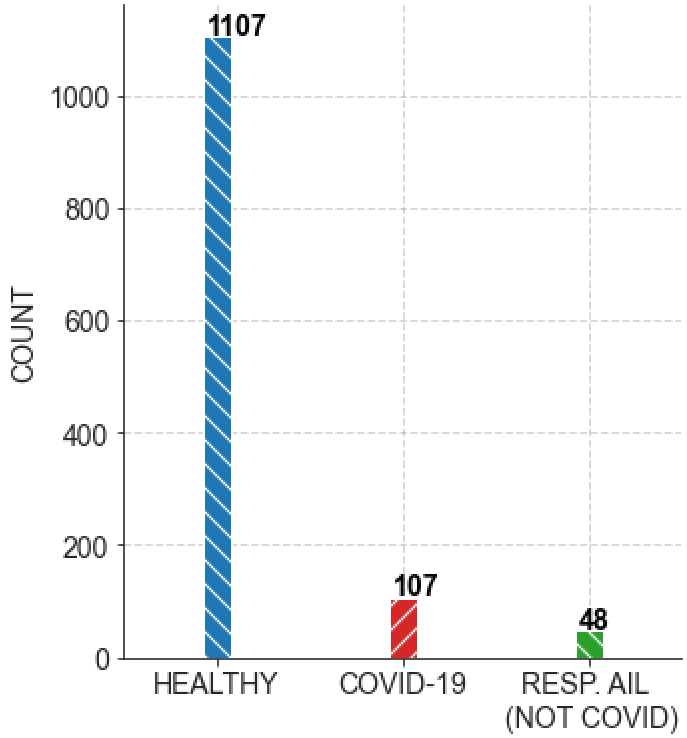
```
{'healthy',
 'no_resp_illness_exposed',
 'positive_asymp',
 'positive_mild',
 'positive_moderate',
 'recovered_full',
 'resp_illness_not_identified'}
```

Benchmarking


1123
363
COUNT
0
200
400
600
800
1000
MALE
FEMALE


1329
157
COUNT
0
200
400
600
800
1000
1200
INDIA
OUTSIDE


MALE
FEMALE
COUNT
0
100
200
300
400
500
0-18
18-30
30-40
40-50
50-60
60-70
70-80
AGE GROUP



Applicable patents

- Application number: US13/571,876 Filing date: 2012-08-10, Cough detector, this invention relates to detection of signals from the body of a person or an animal and more specifically to the detection of cough.
- INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY. Publication No: WO 2004/091503 A2, Issue: 28.04.2004. Title: SYSTEMS AND METHODS FOR RESPIRATORY EVENT DETECTION.

Applicable constraints

- Data collection from patients
- Confidential cough audio data to be obtained to train the model.
- verification of the results must be performed by the pathologist from the machine learning model to provide a great health prescription and service to the user.
- Lack of technical knowledge for the user

Applicable Regulations

The patents mentioned above might claim the technology used if the algorithms are not developed and optimized individually and for our requirements. Using a pre-existing model is off the table if it incurs a patent claim.

- Data protection and privacy regulations of patients
- Medical-legal complication
- Likewise, the Customs Act – 1962
- Protection/ownership regulations
- Patents on ML algorithms developed

Business Opportunity

Service has become an important field for research in AI/ML, as technology revolutionizes the way services are delivered. Many services hereby not only play a key role for societal advancements, but become necessary for a well-functioning society. AI/ML enables new forms of cooperation and communication in services as well as automation, standardization, and new concepts for customer integration. In the health sector, which is of utmost importance for all societies, this is the case as well.

While the business model landscape is continuously evolving an AI-driven health care startups can be useful to future entrepreneurs and managers.

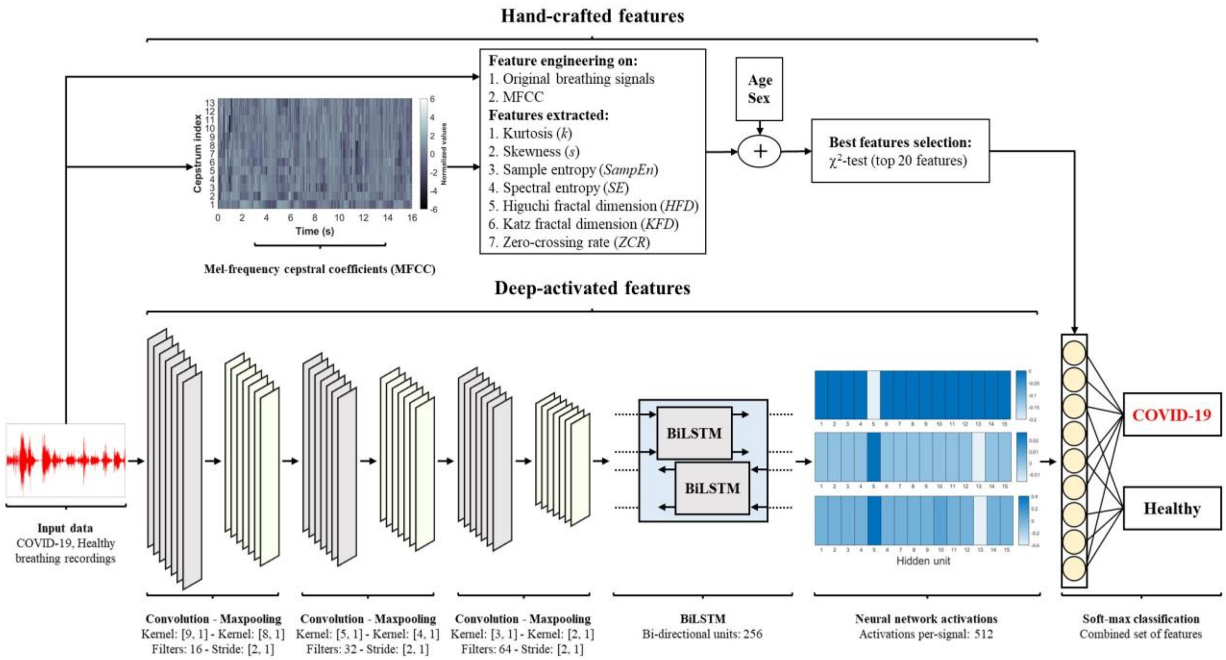
Value Areas Provided by Data-Driven Solutions in Healthcare:

- Patient Healthcare Accessibility, Disease Predisposition, and Lifestyle Management
- Clinical Effectiveness and Patient Outcomes/Satisfaction
- Patient Safety
- Operational Effectiveness and Efficiency
- Financial and Administrative Performance

Audio-based cough detection systems are now increasingly applied in clinical research. They are becoming more important to study cough. Automated cough algorithms are being developed in quality and processing speed so that audio-based cough monitors will change the assessment of patient's responses to treatments and enter many families in the near future.

Concept Generation

A computer vision and deep learning (with transfer learning) framework for detection of COVID-19 from cough audio files. Log Mel spectrogram and Wavelet transform images were obtained for sound data samples. A Convolutional Neural Networks based model was trained on this audio dataset to detect COVID cough sounds with high test accuracy.



1.Download the Data

We are going to download the COSWARA-DATA from the github repository:

https://github.com/iiscleap/Coswara-Data

```
!git clone https://github.com/iiscleap/Coswara-Data.git

Cloning into 'Coswara-Data'...
remote: Enumerating objects: 775, done.
remote: Counting objects: 100% (13/13), done.
remote: Compressing objects: 100% (12/12), done.
remote: Total 775 (delta 1), reused 10 (delta 1), pack-reused 762
Receiving objects: 100% (775/775), 14.63 GiB | 43.34 MiB/s, done.
Resolving deltas: 100% (303/303), done.
Checking out files: 100% (186/186), done.
```

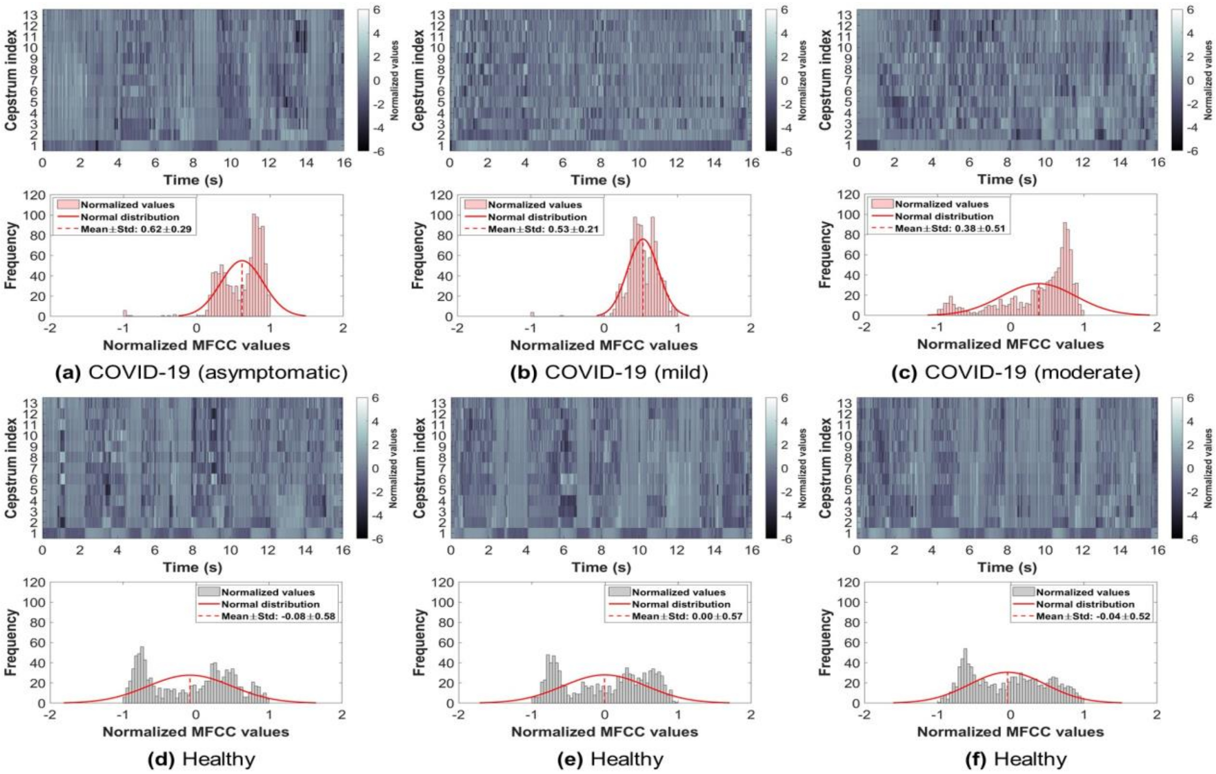
2.Prepare the dataset

```
[ ] coughvid  = '/content/public_dataset/'
    custpath  = '/content/custom_dataset/' #Where mel spec images will be stored

    VidData   = pd.read_csv(os.path.join(coughvid,'metadata_compiled.csv'),header=0)
    VidData   = VidData.loc[VidData['cough_detected'] >= 0.9][['uuid','fever_muscle_pain','respiratory_condition','status']]
    VidData.dropna(inplace=True)

    extradata = VidData.loc[VidData['status']=='COVID-19']
    notradata = VidData.loc[VidData['status']!='COVID-19'][0:1000]

    TotData   = pd.concat([extradata,notradata],ignore_index= True)
    TotData['DIR'] = coughvid + TotData['uuid'] + '.webm'
    TotData['DataSet'] = 'coughvid'
    TotData['fever_muscle_pain']    = TotData['fever_muscle_pain'].apply(int)
    TotData['respiratory_condition']= TotData['respiratory_condition'].apply(int)
    TotData   = pd.concat([CosData,TotData.rename(columns={'uuid':'ID','status':'STATUS','fever_muscle_pain':'Fever/MP','respiratory_condition'
    TotData   = TotData.sample(frac=1).reset_index(drop=True)
    TotData.head()
```

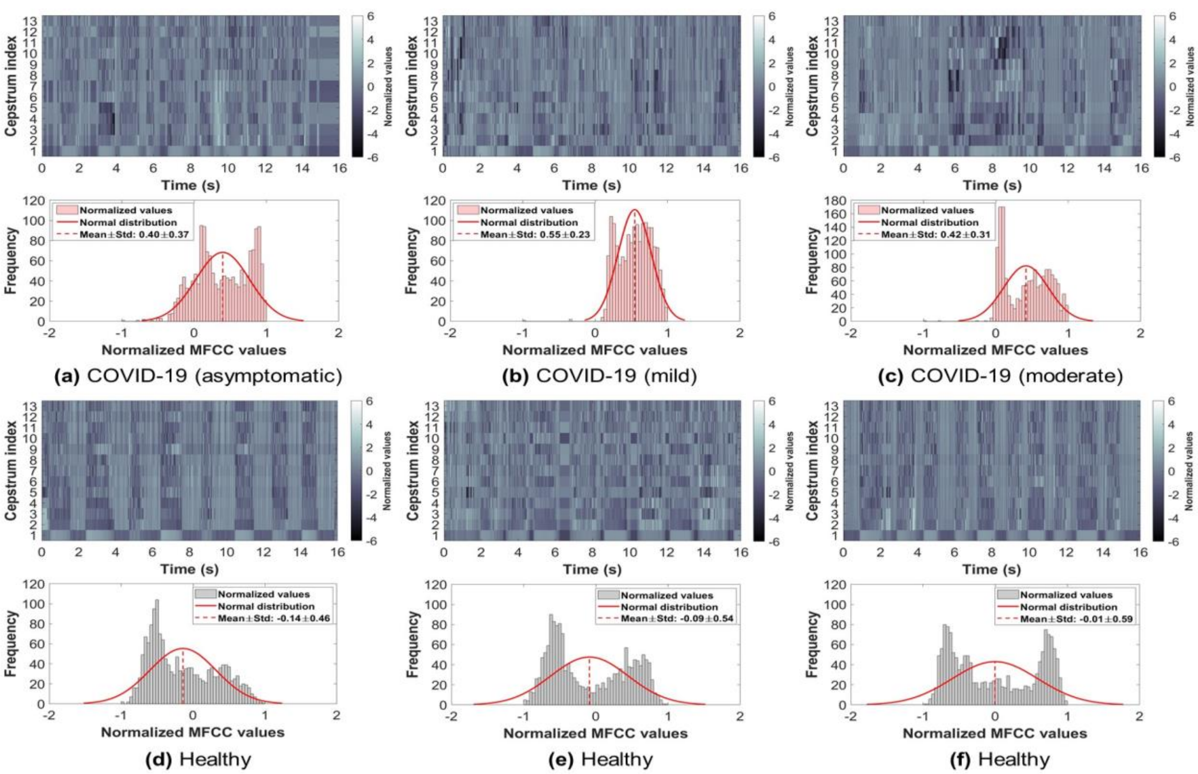
	ID	STATUS	DIR	Fever/MP	ORC	DataSet
0	6FftFI1jWlQHb0N37KW4ajs9dqH3	healthy	/content/Coswara-Data/20200416/6FftFI1jWlQHb0N...	0	0	coswara
1	fnNx5YGGVbZ4H8HtWucxTmQlt7y1	positive_mild	/content/Coswara-Data/20210714/fnNx5YGGVbZ4H8H...	0	0	coswara
2	cfbda12e-fdc6-4749-a7ec-3a81c3106317	COVID-19	/content/public_dataset/cfbda12e-fdc6-4749-a7e...	0	1	coughvid
3	3BUB0leQxthtm7CndU3zJdUktrK2	healthy	/content/Coswara-Data/20210507/3BUB0leQxthtm7C...	0	0	coswara
4	1a07cc8b-a7f5-4cea-b1df-43bf3b2b1414	healthy	/content/public_dataset/1a07cc8b-a7f5-4cea-b1d...	0	0	coughvid

3.Feature Extraction

We'll be using librosa for analyzing and extracting features of an audio signal. We willl be using one of the popular audio feature extraction method that is the Mel-frequency cepstral coefficients (MFCC) which have **39 features**. The feature count is small enough to force us to learn the information of the audio.



Examples of MFCC extracted from the shallow breathing sounds recorded and illustrated as a normal distribution of summed coefficients.



Examples of MFCC extracted from the deep breathing sounds recorded and illustrated as a normal distribution of summed coefficients.

```python
def feature_extractor(row):

  name     = row[0]
  try:
    audio,sr = librosa.load(row[-4])
    #For MFCCS
    mfccs    = librosa.feature.mfcc(y=audio,sr=sr, n_mfcc=39)
    mfccsscaled = np.mean(mfccs.T,axis=0)

    #Mel Spectogram
    pylab.axis('off') # no axis
    pylab.axes([0., 0., 1., 1.], frameon=False, xticks=[], yticks=[])
    melspec  = librosa.feature.melspectrogram(y=audio,sr=sr)
    s_db     = librosa.power_to_db(melspec, ref=np.max)
    librosa.display.specshow(s_db)

    savepath = os.path.join(custpath,name+'.png')
    pylab.savefig(savepath, bbox_inches=None, pad_inches=0)
    pylab.close()
  except:
    print('File cannot open')
    return None,None
  return mfccsscaled,savepath

features = []
diagnoses= []
imgpaths = []
```

```python
for row in tqdm(TotData.values):
  mfccs,savepath  = feature_extractor(row)
  features.append(mfccs)
  imgpaths.append(savepath)
  diagnoses.append([row[3],row[4]])
```

```
  0%|          | 2/3814 [00:03<1:38:52,  1.56s/it]/usr/local/lib/python3.7/dist-packages/librosa/core/audio.py:165: UserWarning: PySoundFil
  warnings.warn("PySoundFile failed. Trying audioread instead.")
  0%|          | 4/3814 [00:06<1:22:40,  1.30s/it]/usr/local/lib/python3.7/dist-packages/librosa/core/audio.py:165: UserWarning: PySoundFil
  warnings.warn("PySoundFile failed. Trying audioread instead.")
  0%|          | 7/3814 [00:07<50:26,  1.26it/s]/usr/local/lib/python3.7/dist-packages/librosa/core/audio.py:165: UserWarning: PySoundFile
  warnings.warn("PySoundFile failed. Trying audioread instead.")
  0%|          | 8/3814 [00:08<53:55,  1.18it/s]/usr/local/lib/python3.7/dist-packages/librosa/core/audio.py:165: UserWarning: PySoundFile
  warnings.warn("PySoundFile failed. Trying audioread instead.")
File cannot open
  0%|          | 13/3814 [00:11<39:00,  1.62it/s]/usr/local/lib/python3.7/dist-packages/librosa/core/audio.py:165: UserWarning: PySoundFile
  warnings.warn("PySoundFile failed. Trying audioread instead.")
  0%|          | 14/3814 [00:12<45:15,  1.40it/s]/usr/local/lib/python3.7/dist-packages/librosa/core/audio.py:165: UserWarning: PySoundFile
  warnings.warn("PySoundFile failed. Trying audioread instead.")
  0%|          | 15/3814 [00:12<35:03,  1.81it/s]File cannot open
```

4. Data Sampling

We will first clean the data, remove the Nan values. After cleaning the data, we then will prepare the data splits.

5. Data Generator

We split the data into training and testing datasets.

6. Model Evaluation

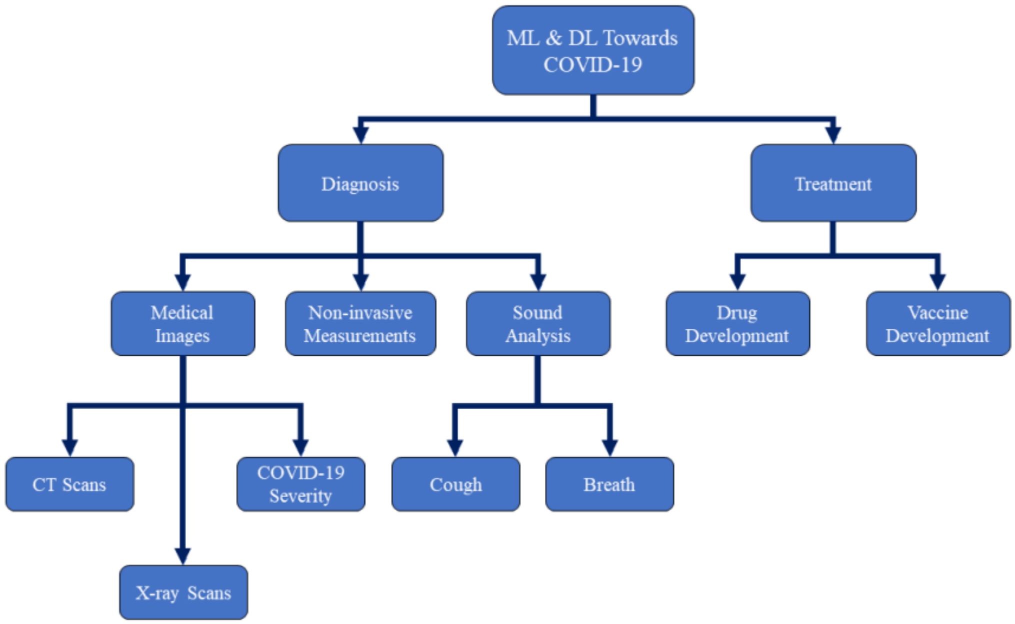
We build a neural network model with Convolution layer, Dense layer, Dropout and Pooling layers. Convolution and Dense layers with Relu activation functions. And an Output Dense layer with Sigmoid activation function since we are gonna predict a Yes/No output. With the provided dataset the predicted maximum accuracy attained from the model is 80.55%

7. Model visualization

We will calculate ROC curves for each run and visualize it.

Final Prototype

The final prototype provides a faster connection between COVID-19 subjects and medical practitioners or health authorities to ensure continues monitoring for such cases and at the same time maintain successful contact tracing and social distancing. By embedding such approach within a smartphone applications or cloud-based networks, monitoring subjects, including those who are healthy or suspected to be carrying the virus, does not require the presence at clinics or testing points. Instead, it can be performed real-time through a direct connectivity with a medical practitioners. In addition, it can be completely done by the subject himself to self-test his condition prior to taking further steps towards the RT-PCR assay.



Therefore, such approach could set an early alert to people, especially those who interacted with COVID-19 subjects or are asymptomatic, to go and further diagnose their case. Considering such mechanism in detecting COVID-19 could provide a better and well-organized approach that results in less demand for clinics and medical tests, and thus, enhances back the healthcare and economic sectors in various countries worldwide.

Conclusion

This study suggests breathing sounds as a promising indicator for COVID-19 cases. It further recommends the utilization of deep learning as a pre-screening tool for such cases prior to the gold standard RT-PCR tests. The overall performance found in this study (accuracy 80.55%) in discriminating between COVID-19 and healthy subjects shows the potential of such approach. This study paves the way towards implementing deep learning in COVID-19 diagnostics by suggesting it as a rapid, time-efficient, and no-cost technique that does not violate social distancing restrictions during pandemics such as COVID-19.