Cough Sound Disease Detection with Artificial Intelligence

Track: Artificial Intelligence and Machine Learning

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About me.

- Name: Sarah Jane Kho
- Education *(Swinburne University of Technology, Sarawak Campus)* :
  - 2021 – Present : Masters by Research.
  - 2017 – 2021 : Bachelor of Engineering (Honours) (Electrical and Electronic)
- Previous Accomplishments:
  - 2020 – Innovate Sarawak Open Design Challenge 2020.
    - Instant Detection and Identification Of Mycobacterium Tuberculosis.
    - Winner – AI & Data Analytics Category.
    - Innovate Sarawak Excellence Award.

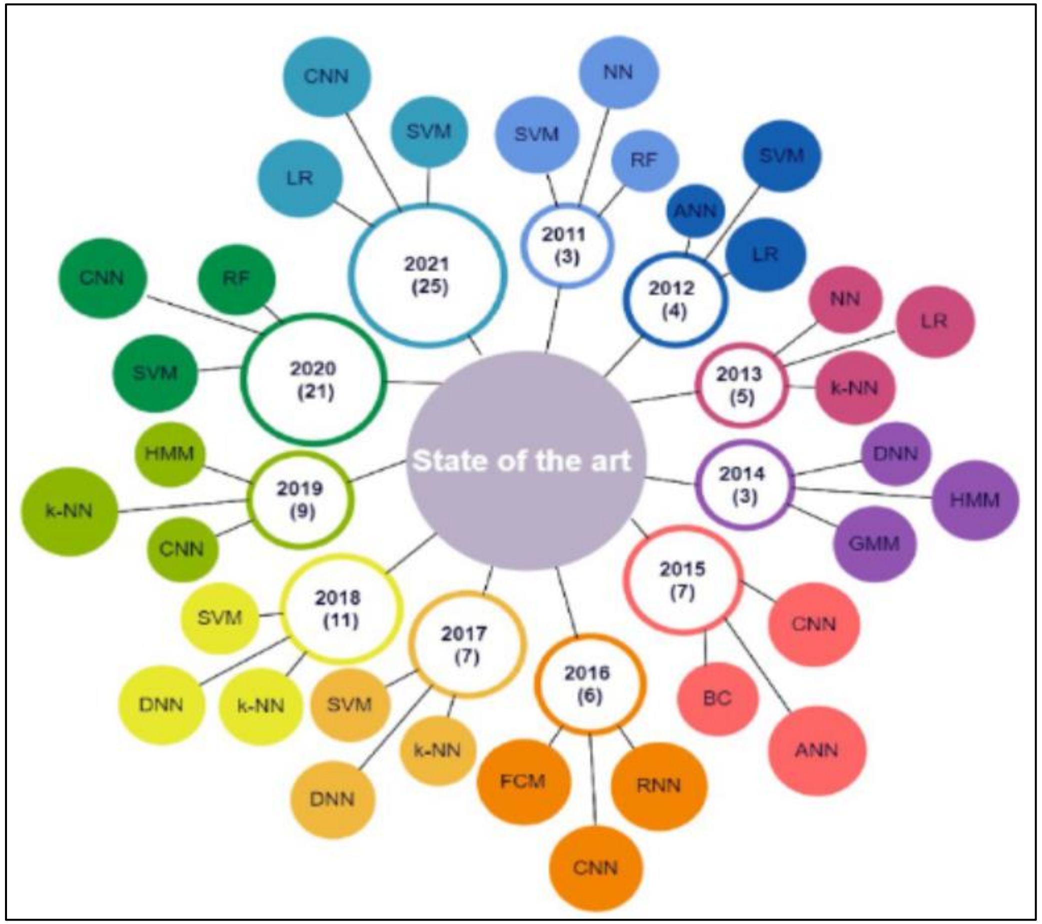
Presentation Outline.

1. Introduction.
2. Scope of Research.
3. Background.
4. Methodology.
5. Results
6. Discussion
7. Conclusion and Future Work.

COVID-19 and Cough.

- Among the common symptoms of COVID-19 is the presence of **cough** (Nitin et al., 2022).
- Cough sounds are essential to aid practitioners in identifying type of pulmonary diseases (Alqudaihi et al., 2021).
    - Feature based engineering and Artificial Intelligence (AI) can aid in the detection of pulmonary diseases using cough sounds.
    - This acts as groundwork for the detection of COVID-19 using cough sounds.
        - Quick and convenient way to pre-screen for the presence of the virus.
        - Promote early invention.

State of the Art Models – Cough sounds



- Based on a study done by Ijaz et. al. (2022), within the year of 2020 to 2021, state of the art models trained on cough sounds were evaluated.
- The trend in AI models that are trained on cough signals are support vector machines (SVM), convolutional neural networks (CNN), random forest (RF), and linear regression (LR).

Disease detection using Cough Sounds.

- Best feature set to represent cough sounds are:
  - Mel Spectrum features followed by Short Time Fourier Transform (STFT) features (Cai et al. 2021).
- Previous studies done on pulmonary disease detection using cough sound.

Authors	**Model**	**Pulmonary Disease**	**Results (ACC)**
Sharan et al. (2017)	SVM Model	Croup Cough	91.21%
Wang et al. (2015)	CNN	Pneumonia, Bronchial Asthma, and Chronic Pulmonary Obstructive Disease (COPD).	98.59%
Hamdi et al. (2022)	CNN-LSTM	COVID-19	91.13%

What do previous work show?

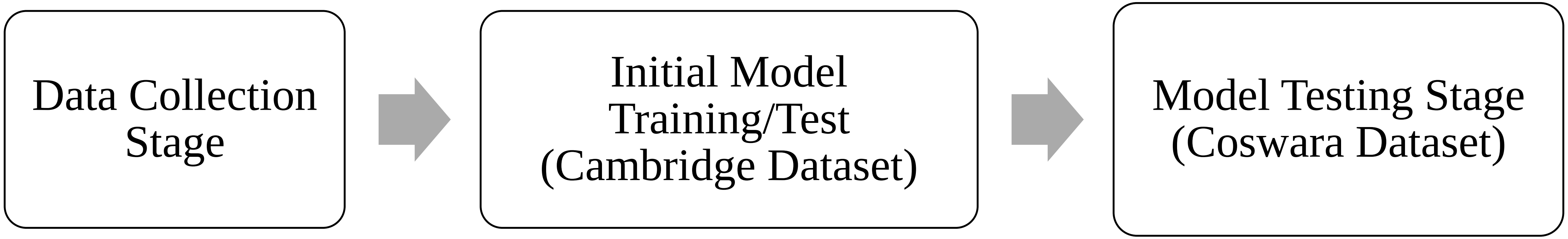
- Features from the Mel-Spectrum and STFT show potential to represent cough sound.
- Models such as SVM and CNN show high performance in the classification of pulmonary diseases through cough sounds.
- Current work by researchers have limitations such as:
    - Training and testing data only come from one source.
    - Data Pre-processing methods vary.

Scope of Research

- **Investigate the performance of the models' ability to generalise among datasets from different sources.**
- Models that are studied are:
  - Brown et. al. (2020) – SVM model.
  - Coppock et. al. (2021) – ResNet model.
  - Mahanta et. al. (2021) – CNN model.
- Data used in this study are:
  - Cambridge Dataset
  - COSWARA Dataset

Preliminary Findings (Methodology).

- Main package used for audio manangement and feature extraction (Python).
  - Librosa (McFee B. et. al. 2022).



Data Collection

- Data that were used in this study are from the University of Cambridge and Project Coswara.
- Differences in datasets:

Features	**Cambridge Dataset**	**Coswara Dataset**
Data Collection Application	Mobile Application & Web-based application	Web-based application
Type of respiratory audio	Cough, Breathing.	Cough Heavy
Total number of files	439 files	877 files
Original Sampling Frequency (Hz)	22050	48000

Data Preparation

- Data were separated into two separate classes.
  1. covid_positive - users who have declared **COVID-19 positive** and are from **both symptomatic and asymptomatic classes**.
  2. healthy_nosymp - users who are **COVID-19 negative**, have declared **no known comorbidities**, are **nonsmokers** and also show **no symptoms.**
- This was done for both the Cambridge dataset and the Coswara dataset.

Feature Extraction

- Audio data were loaded into using *librosa.load* with the uniform sampling frequency (Fs) of 22050Hz.
- Different features were extracted for each of the models.
- The features that were obtained for each model are:

Model	**Feature Set**
SVM Model (Brown et. al. 2020)	Transfer Learning (VGGish)
ResNet Model (Coppock et. al. 2021)	Log STFT spectrogram
CNN Model (Mahanta et. al. 2021)	15 MFCC coefficeints

Model Training Results – Cambridge

Model	**Training Dataset**	**Testing Dataset**	**Features**	**Results (AUC)**
SVM Model (Brown et. al. 2020)	Cambridge Dataset	Cambridge Dataset	Transfer Learning (VGGish)	0.671
ResNet Model (Coppock et. al. 2021)	Cambridge Dataset	Cambridge Dataset	Log-STFT spectrogram	0.738
CNN Model (Mahanta et. al. 2021)	Cambridge Dataset	Cambridge Dataset	15 MFCC coefficients	0.816

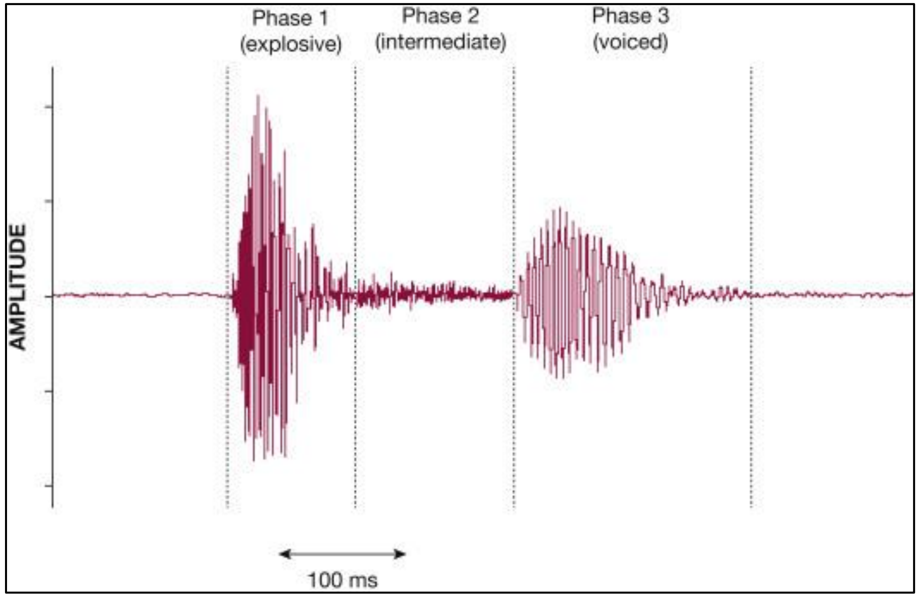
Model Testing Results – Coswara

Model	Training Dataset	Testing Dataset	Features	Results (AUC)
SVM Model (Brown et. al. 2020)	Cambridge Dataset	Cambridge Dataset	Transfer Learning (VGGish)	0.564
ResNet Model (Coppock et. al. 2021)	Cambridge Dataset	Cambridge Dataset	Log-STFT spectrogram	0.522
CNN Model (Mahanta et. al. 2021)	Cambridge Dataset	Cambridge Dataset	15 MFCC coefficients	0.443

Discussion.

- Results show that when models are tested on a different dataset, the model fails in detecting COVID-19 positive coughs from COVID-19 negative coughs.
- Features that were obtained from the audio samples are different.
- The methodology that was used by the authors differ from paper to paper.
  - Data Pre-processing technique that is different from paper to paper.

Cough Waveforms and Phases.



- Typically, a cough sound can be divided into 3 phases (Chang et al. 2016).
  1. Explosive phase
     - Typically identifiable by explosive sound/noisy like waveform.
  2. Intermediate phase
     - Decrease in airflow.
     - Decrease in sound amplitude.
  3. Voiced phase.
     - Produced by the vibration of partly closed glottis.
     - Produce a regular periodic noise.
- Patients effected by diseases tend to have multiple explosive cough after a signal breath or several breaths interspersed.
  - This is known as a cough “epoch”.

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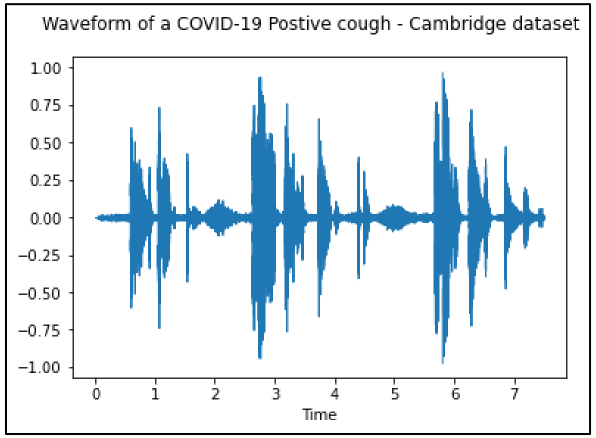
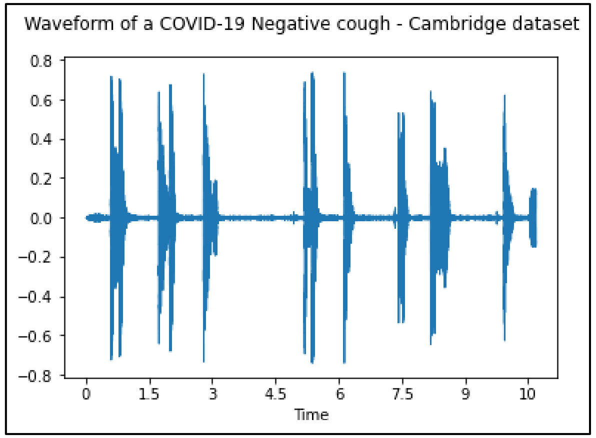
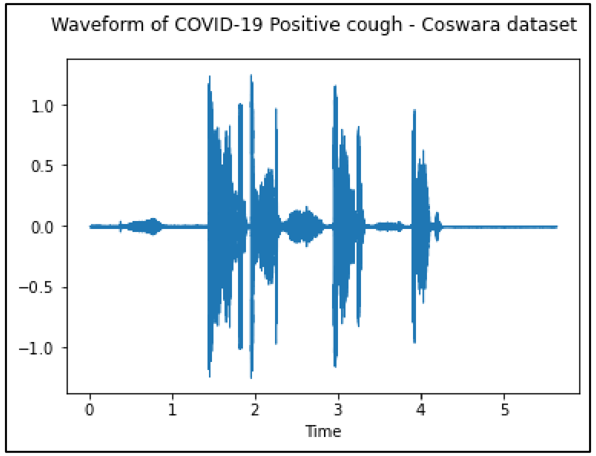
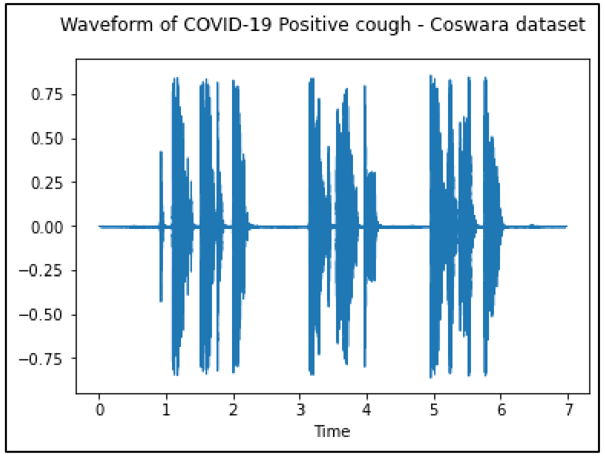
Coughing Patterns – Compared

- Data exploration shows that dataset obtained from sources show an inconsistency in patterns exhibited.
- Previous work show the usage of the cough recordings as a whole with multiple cough “epochs” present.
- This may lead to an inconsistency in the features that are extracted.

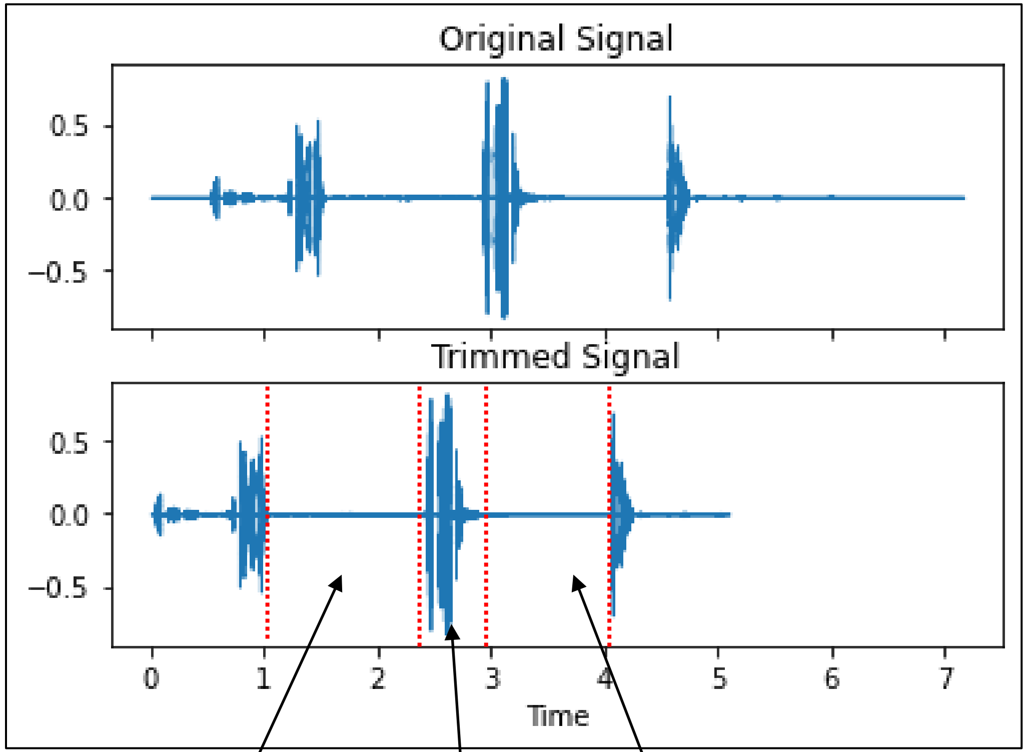








Data Pre-processing – silence removal



Silent Region

Silent Region

Coughing Region

- Current readings on COVID-19 models include the removal of silences from the **leading and trailing silences.**
- This is done with utilizing *librosa.trim*
- This leads to silent regions to still exist within the audio sample.
- This may lead to an inconsistent representation of coughing patterns.

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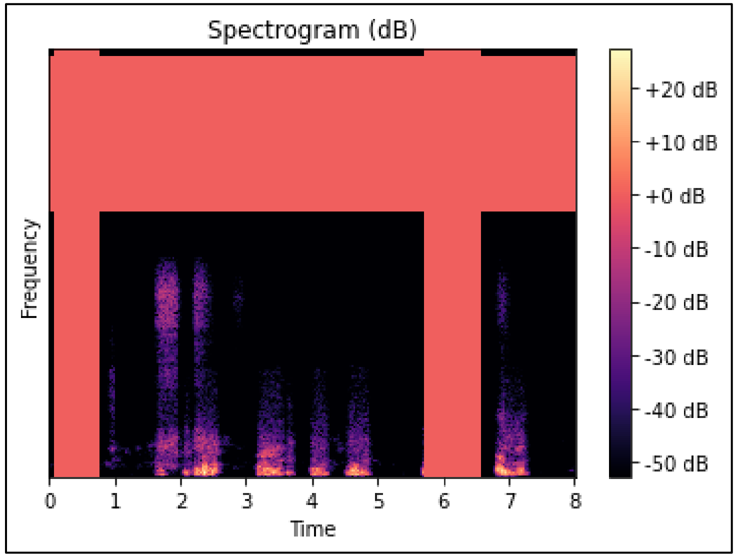
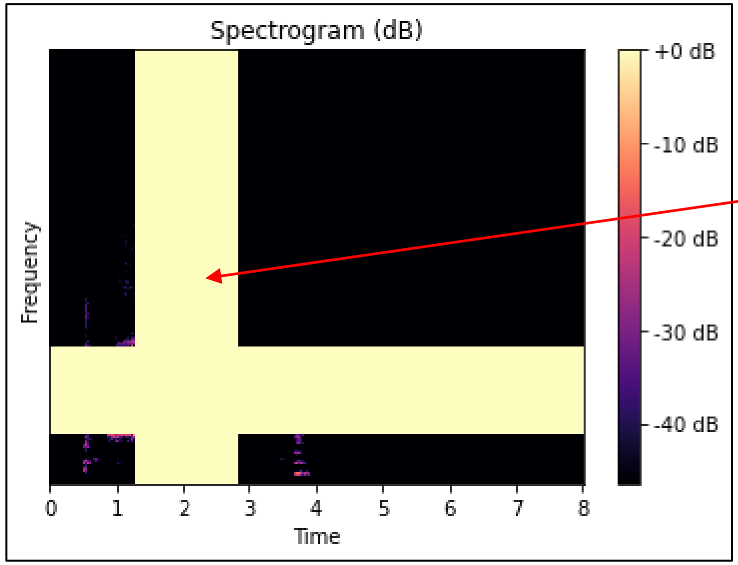
Data Pre-processing – SpecAugment.

- SpecAugment:
  - The methods that are used for data pre-processing are not always suitable for large variation of data.
- For example, SpecAugment on COSWARA dataset.





Data completely masked

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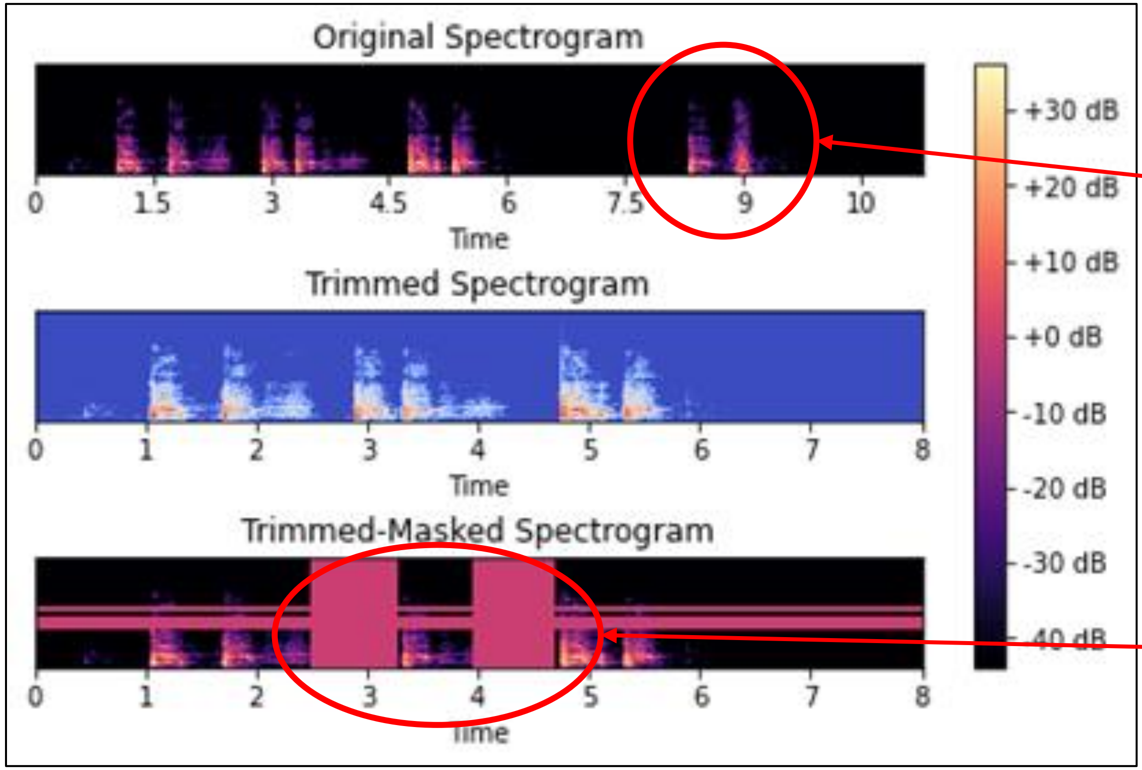
Data Pre-processing – SpecAugment (cont)

- Further data pre-processing techniques include normalizing the duration of audio.
  - Duration longer than the threshold value, the audio will be trimmed.
  - Duration shorter than the threshold value, audio will be zero padded.
- This cause an alteration in the patterns of the cough.

Data Pre-processing – SpecAugment (cont)



- Original Duration = 11.28 seconds
- Duration is standardized to 8 seconds.
- Causes loss of last cough "epoch"

- SpecAugment which involves the masking of the time and frequency axis causes loss of information.
- Masking in this case causing the loss of information in the coughing regions.

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Conclusion.

- Current models have limitations:
  - Inability to generalize with different datasets.
- Model testing show that the models tested with the Cambridge dataset performed poorly when classifying COVID-19 positive and negative classes.
- Data Pre-processing might be a contributing factor to the models' performance.
  - Current methods show little impact in standardizing the coughing patterns within the audio data.
  - SpecAugment causes an alteration in the patterns of cough which leads to loss of information.

Future Work

- Improving the data pre-processing methods.
  - Obtain features that represent coughing phases.
  - Segment cough recordings to smaller windows.
  - In efforts to standardise the cough recordings among datasets.

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Thank you!

Questions?