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A Comprehensive Analysis of Cough Sounds Using Representation Learning

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ABSTRACT

Coughing is a typical sign of several respiratory conditions. The type and sound of a cough can be essential aspects to consider while diagnosing an illness. Respiratory illnesses throw human health at risk all throughout the world, but they also have a huge economic impact, especially in countries with limited medical resources. In this study, we examined the most recent technologies that were being considered for use in minimizing the effects of respiratory diseases. We explained how representation learning may be used to accurately detect and diagnose a variety of known diseases, such as pneumonia, pulmonary edema, asthma, tuberculosis (TB), COVID-19, pertussis, and other respiratory diseases. We look into how coughing works and how coughing is hidden in different breathing patterns. Representation learning involves the combination of multiple models to achieve superior predictive performance compared to any individual model. This approach encompasses the collection of cough sounds from both infected and healthy individuals, the refinement of these sounds through noise elimination, and the integration of multiple models for thorough analysis.

Keywords: Cough Analysis, Covid-19 detection, Representation learning, Classification, Healthcare.

INTRODUCTION:

The technology used in the health sector has evolved significantly in recent years. In the field of health care, new and evolving technologies are presented. AI has a lot to offer the healthcare industry in terms of advancement. The cough is a typical symptom of many disorders. Various diseases also have various cough patterns. While there are other respiratory sounds such as wheeze and crackles, cough stands out as having distinct characteristics. For instance, covid-19 causes a dry cough. Cough therefore presents with a variety of symptoms depending on the condition. Thus, cough sounds can be used to identify various disorders. For instance, both the positive and negative COVID-19 cough sounds are dry cough noises. One noteworthy finding, however, is that the waveform and spectrogram of the negative COVID-19 cough sounds are clear and sparse and positive covid-19 cough sounds are dense and noisy. There are many features like this that can distinguish between the positive and negative covid-19. It will save time because some diseases diagnosis tests take more time to detect the diseases. Audio analysis is used to extract some features like MFCCs, Zero crossing rate, Spectral roll off etc from the collected cough sounds. The features can be extracted by the python libraries like Librosa, saafe etc. After feature extraction we can use the ML algorithms like SVM etc and DL algorithms like CNN, LSTM, and Attention etc to diagnosis the disease. It has been demonstrated that deep learning models can accurately diagnose and prognosticate common lung disorders like cancer. A branch of machine learning called representative learning is concerned with training models and obtaining features from data. In order for computers to use the data, deep learning is a process that teaches them how to represent the data in a meaningful and practical way. It employs neural networks to transform high-dimensional data into low-dimensional data, making it simpler to identify trends and anomalies and improving our comprehension of the overall behaviour of the data. Another name for it is feature learning. Since cough sounds are a non-contact method of illness diagnosis, they can also be used to stop the spread of diseases that are capable of spreading quickly from one person to another person. Using ML and DL models, it is possible to diagnose diseases from cough noises and give a mobile application that can be swiftly implemented in any scenario.

RELATED WORKS:

Hamdi, S. et al.,[1] A unique framework that can distinguish between a positive and negative COVID-19 was developed using a hybrid deep learning attention-based CNN-LSTM architecture. There is one positive limitation. The combination of the COVID-19 and Symptomatic classes into a single class may help lower the false negative rate. Pitch shifting strategies aid in the model's capacity to accommodate fluctuations in cough, and SpecAugment was utilized to lessen the data's imbalance. Model has an accuracy of 91.13% and F1 score: 90.71%. The error rate was 9.07% i.e. 9.07% positive cases were incorrectly classified as negative. Because misclassified patients won't be isolated there is a chance of spread of disease, it results in type-II error, which needs to be fixed.

Ijaz, A. et al., [2], It included an in-depth examination of the amount of research on the use of cough sounds and AI-based models for the early detection and diagnosis of respiratory disorders. The information is gathered through a mobile application, and users provide disease-related data that must be processed safely and shielded from unauthorized access. Additionally, it examined the research in the broad areas of cough acoustic detection and diagnosis followed by similar sound analysis (breathing, snoring, auscultations, and lung sounds). The complex nature of various respiratory disorders added to the variety of cough acoustics within and between people should be captured by hardware and software.

Kapoor, T. et al., [3] The Deep Learning Neural Networks were used for the initial diagnosis of COVID-19 with cough samples and it was built as a pre-screening tool for detection of COVID-19 which is low cost and ease of access to everyone. Four machine-learning models—Multilayer Perceptron, Convolutional Neural Networks, Recurrent Neural Networks with Long Short-Term Memory, and VGG-19 with Support Vector Machines—were competitively analysed in this study. The Audio samples with noises were not classified properly by the proposed framework that results in misclassification and also female cough samples, senior citizen cough samples were not classified accurately. Cough after augmentation with higher speed were not able to classify properly. Multilayer perceptron achieved highest accuracy of 96%.

K. S. Alqudaihi et al., [4] It provided the most recent opportunities, problems, and solutions in the identification and diagnosis of respiratory diseases, enabling researchers and practitioners to create more advanced methods It detected or diagnosed diseases like pneumonia, tuberculosis, Asthma, covid-19, pulmonary diseases, bronchitis etc.. The training dataset's sample quality for Covid-19 detection and diagnosis is impacted by background noise. Using RNN and LSTM, Covid-19 detection achieved 97% accuracy, 97.9% F1-score, precision 99.3%, recall 96.4%, and AUC 97.4%.

Ulukaya. S. et al., [5] the suggested multi-branch model, also known as MSCCov19Net, was utilized to diagnose COVID-19 because it accepts M el Frequency Cepstral Coefficients (MFCC), Spectrogram, and Chromagram as inputs. The model performance was negatively affected when the noisy data which is collected from different mobile phones are given to the model. A deep neural network based model was built that was capable of detecting corona virus from cough sounds that was remotely operable and has no side effects.They used the smart phones for the collection of cough sounds from the people so no need for patients to come to hospital and wait long and have a fear of virus spread. Accuracy of 61.5 % in Virufy and 90.4 % in NoCoCoDa for unseen test datasets.

Hemdan, E.ED. et al., [6] A CR19 framework was built that can detect covid-19 from cough sounds that are recorded using IoT based mobile phones that is cheaper for detection for COVID-19 when compared with the other techniques. It used machine learning algorithms in a hybrid with GA algorithm for building a framework that can detect COVID-19 from cough audio analysis. The results they produced proved that the hybrid (GA-ML) technique provides the best results based on different evaluation metrics as compared with different machine learning approaches.GA-KNN shows more than 97% accuracy in the diagnosis of COVID-19 from cough audio signals. They used the cloud based analytics system for the storage of the data that is collected from the IoT based mobile phones and this data need to be protected and not misused.

Erdoğan, Y. E. et al., [7] It used the traditional feature extraction methods like empirical mode decomposition (EMD) and discrete wavelet transform (DWT) to extract the features from cough for COVID-19 detection. Pre-trained models like ResNet50 and MobileNet models were used to obtaining the deep features. It has been determined that the features which were extracted from the traditional methods show better and higher performance compared to the features extracted from the deep features. Usage of the limited data results the deep features to have less accuracy. The accuracy of covid detection using deep features can be increased by using the large amounts of data.As they are using 2D scalogram images so the clean and noise free data is needed.Accuracy of 98.4% was produced by the model using EMD and DWT to extract features.

Tena, A. et al., [8] A pre-screening method for the automatic detection of COVID-19 in raw audio files based on the extraction of time-frequency cough features was proposed. YAMNet a deep neuronal network was used for the automatic identification of the cough sounds from the raw audio files. Misclassification happened as the negative samples are not correctly classified. An accuracy close to 90% in diagnosing COVID-19 using the proposed methodology, indicating its effectiveness in distinguishing COVID-19 cough patterns. Further analyses was needed for comparing COVID-19 cough patterns with cough patterns from other conditions, such as asthma or bronchitis, are needed.

A. Hassan. et al., [9] It has made possible an innovative and cutting-edge method for COVID-19 early diagnosis. It also shows how the suggested COVID-19 detection system works. It was not able to demonstrate good accuracy with patient sounds. The various acoustic characteristics of voice, breathing, and cough sounds were assessed as part of the analysis process. Cough noises were accurate at 97%, breathing sounds at 98%, and voice at 88%. Time constraints and the relatively modest amount of data collected are the reasons why voice samples produced erroneous conclusions.

Lella, K. K et al., [10] A multi-channelled Deep Convolutional Neural Network (DCNN) has been suggested and put into practise for the automatic detection of COVID-19 disease from human respiratory sounds, such as breath, voice, and dry cough. Rather than using the conventional MFCC as an input, they created deep sound characteristics that function as 1D CNN using a method called DDAE (Data De-noising Auto Encoder). The method by which the model is able to gather records from regular people is not explained. assigned a classification of either positive or negative for COVID-19, positive or negative for COVID-19 with cough, positive or negative for COVID-19 with cough, or positive for COVID-19 with cough but not non-COVID asthma cough.

V. Bansal et al., [11] they employed two different strategies: the first relies on the MFCC as an input to the CNN algorithm, while the second uses the spectrogram as an input. They also don't employ tiny datasets with proper labelling. They made use of features like spectral roll-off, spectral centroid, and MFCC. The MFCC method yielded an F1 score of 69.71%, 70.58% test accuracy with 81% sensitivity, and 60.71% precision. They can employ larger, more detailed datasets and improve accuracy as well.

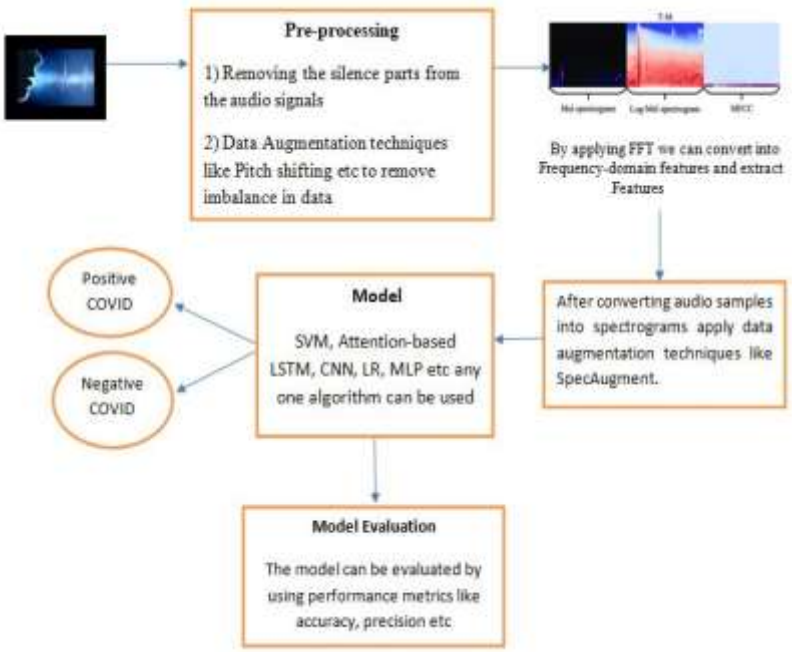
Nguyen, L. H. et al., [12] A two-stage-vision-based framework which is named as Fruit-CoV is proposed in which the first stage takes the Log-Mel spectrograms as an input and the second stage takes the Wavegram-log-Mel spectrograms as an input. A pretrained Audio neural networks (PANNs) was used. They used the audio samples with 3 sampling rates i.e. 4 kHz, 8 kHz and 48 kHz. The framework can be easily integrated into existing applications and systems. There was a drawback that each device has a different type of sensor that leads to different sampling rates.

Rumana Islam et al., [13] The acoustic features used in this work can be broadly classified into two major classes: time-domain and frequency-domain features. The dataset is collected from the Virufy database. To solve the over fitting problem in DNN algorithm, we employ a dropout algorithm. Research has demonstrated that some acoustic characteristics are distinct in COVID-19 patients' cough sound recordings, and as a result, a classifier such as DNN can effectively distinguish them from healthy cough sound samples.

Mouawad, P. et al., [14] The use of MFCC characteristics together with symbolic recurrence quantification measures for the automated identification of COVID-19 in cough sounds from both ill and healthy individuals is examined. By employing prolonged vowel utterances, the suggested model demonstrated robustness in disease diagnosis. It shows great potential in assessing and automatically identifying COVID-19 from web-based audio recordings of people's vocalizations and coughs. The data gathered by the Corona Voice Detect project-collaboration between Carnegie Mellon University and Voca.ai—is used to train the machine learning models. Together with vowels like "ah," it uses these sounds to identify specific cough characteristics.

J. Vrindavanam et al., [15] its main objective is the contactless identification of COVID-19 cases through the analysis of individual cough audio recordings. It presents three machine learning classification models, including logistic regression, random forest, and SVM, and establishes which of these three the superior classifier is. The University of Cambridge's "Covid-19 Sounds app" was used to record the audio files on web-based and android platforms. The audio recordings include both forced and spontaneous coughs. Librosa is a Python package that is used to extract 65 features in total. The model will need to be trained in the future so that it can differentiate between a forced cough and a natural cough. Hardware should be developed to implement the suggested algorithm so that it can be utilized in practical applications.

METHODOLOGY:



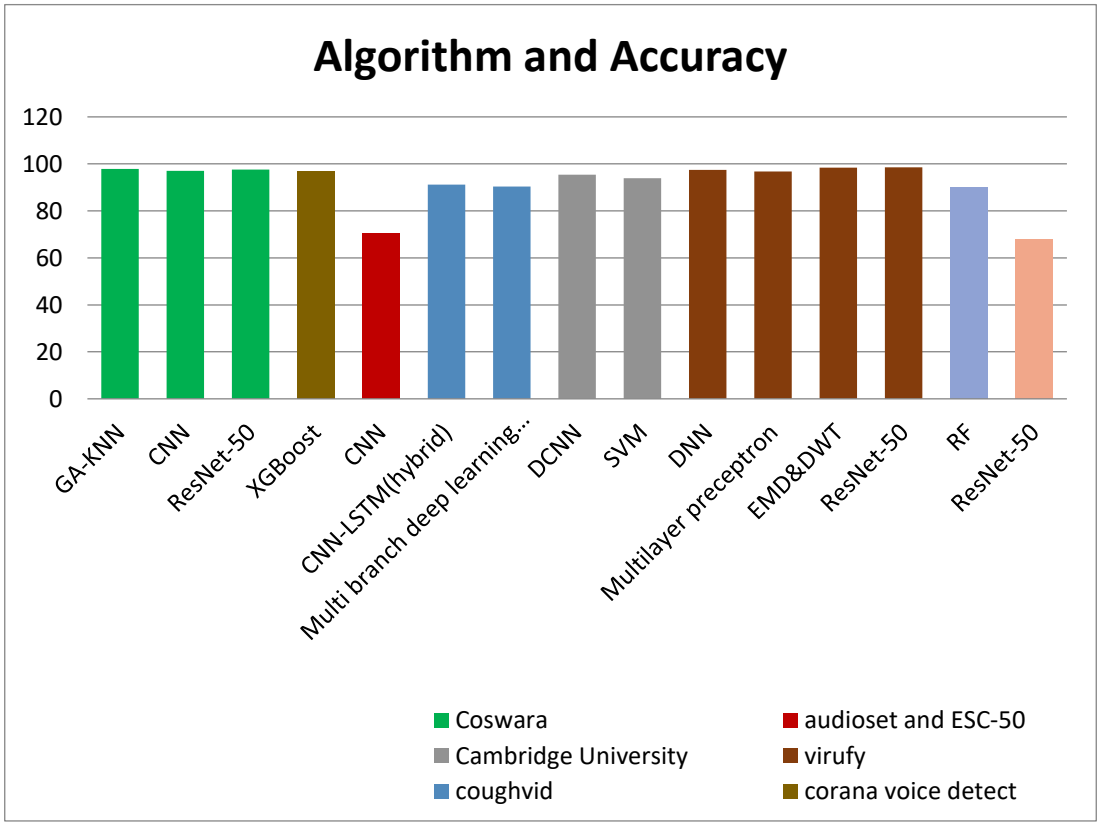
The input is in the form of the audio signals i.e. the cough sounds are recorded by the mobile phones. And after recording the cough sounds they were asked to fill a questionnaire about the name, age, gender, covid status etc. After input the cough sounds may include the silence parts and they can be removed by using the python library known as Unsilence. As the different mobile phones have the different sensors and the sampling rate of different audio signal is varies we need to first know its sampling rate and then we can perform further. The audio signals must be brought into a constant sampling rate.

The audio samples without any covid status are ignored. The data contains the imbalance to avoid this imbalance we perform the data augmentation techniques. By using these techniques the imbalance in the data will be reduced. SpecAugment is one of the mostly used data augmentation method for audio samples. The features can be extracted from the audio signals. The features like MFCC, Mel-spectrograms etc can be obtained. For obtaining the frequency-domain features a FFT has to be applied on the audio. SpecAugment can be applied on the Mel-spectrograms. After pre-processing of the data completed the data has to be split into training data and testing data. Then the training data is given to the model to train the model. The different algorithms can be used for training the model like CNN, SVM, Attention-based LSTM and CNN, CNN, MLP, LR etc.

The output is a binary classification i.e. positive covid-19 or negative covid-19. After the model training we have to check its performance by using the evaluation metrics like accuracy, precision, recall, F1-score etc. We can also use a k-fold cross verification method.

RESULTS:

S no	Author	Dataset	Sensitivity	Accuracy	Precision	Recall	F1-score	AUC
1	Hamdi, S et al	Coughvid	90.93	91.13	90.47	----	90.71	----
2	Ulukaya, S. et al	Trained on Coswara and Coughvid & tested on Virufy dataset	----	61.5	----	----	----	73.2
3	Hemdan et al	Coswara	----	97	----	----	----	----
4	Lella et al	Cowsara, Virufy, university of Cambridge audio samples	98.91	94.81	----	----	97.00	----
5	Erdoğan et al	Virufy	----	98.4	97.3	99.5	98.6	----
6	A. Hassan et al	Cough sounds recorded from persons in United Arab Emirates hospitals	----	97	99.3	96.4	97.9	----
7	V. Bansal et al	Audioset and ESC-50	80.95	70.58	60.71	----	69.59	----
8	Rumana Islam et al	Virufy	----	97.5	100	----	97.4	----



DISCUSSION:

The disease diagnosis using cough sounds is a less expensive and easily accessible for everyone because the results are obtained without the need for a person to be physically present, the sickness cannot spread. Cough sounds have been used in numerous recent studies to diagnose diseases. The most recent attempts to diagnose diseases using cough noises were all mobile applications, making them accessible to anyone. One disadvantage was that the various types of sensors used in each device resulted in varying sampling speeds. Therefore, the models ought to be trained so that they can identify the illness using cough sounds at various sampling rates. The information gathered must be protected because, in addition to cough sounds, the health status of the patients was also gathered. We are unable to guarantee that results from trained models will be as accurate. For instance, when considering a disease like COVID-19, certain trained models for COVID detection incorrectly identified the positive findings as negative, which leads to the disease spreading because the person who tested positive for COVID-19 is not isolated and the disease spreads. More research must be done in order to use a person's speech to detect illness. Additional research is required to identify the different diseases that have cough as a common symptom.

CONCLUSION:

There are numerous methods for identifying diseases. Certain methods for diagnosing diseases take longer to complete, while others are less precise and cost more money. Cough sounds can be used to diagnose disorders in which coughing is a common symptom. Different coughs are produced by different diseases, and the patterns of cough vary from one disease to the next and from healthy individuals to those who are affected. The recent works for disease diagnosis using cough sounds trained the models that can detect the diseases not accurately but the models are developed with accuracy greater than 90%. Many frameworks that can be utilized as mobile applications and swiftly deployed have been developed. Everybody can readily access this. CNN, LSTM, SVM, LR, RF, and other machine learning and deep learning algorithms can be used to diagnose diseases. The applications need to be integrated with the hardware so they are available to everyone. Those people without the funds for expensive testing may find these built-in frameworks helpful. It is also beneficial for those residing in areas lacking enough medical infrastructures to ascertain if they were infected with the illness.

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