Preliminary Detection of Respiratory Disorders for Rural Children using Modified Stethoscope

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ABSTRACT
This work embodies the development of simple and robust technique for preliminary detection of respiratory disorders like Bronchitis in the children living in the rural areas of resource poor countries like India by analysis of the lung sound recorded by Modified stethoscope without presence of medical practitioner. The method makes use of mel frequency cepstral coefficients of lung sound .Based on the statistical parameters of lung sound, neural network is trained. After proper training network is tested for 40 subjects out of which 20 were of normal and 20 of bronchitis. The method detects the disease with an accuracy of 90% and with specificity of 95%..The overall accuracy of this method is 92.5%. Future scope of the work is also discussed.

Keywords
MFCC, Modified Stethoscope, Lung Sound Analysis, Neural network.

1. INTRODUCTION
There is severe shortage of medical practitioners in developing and undeveloped countries. In rural areas of the India, there is only one doctor for every 17,230 people [1], while the United States of America (U.S.A.) has one doctor for every 500 Americans [2]. Most of the doctors prefer to practice in urban areas and so rural population have to face lot of hardships for getting medical treatment .The basic idea of this work is to alleviate some of health related problems of villagers specially children by developing a method which can be helpful in early detection of respiratory disorders such as bronchitis in children. There exists great potential to exploit cellular coverage to extend this work by transmitting the lung sounds using cell phone to healthcare server which will analyze and provide medical prescription based on symptoms and lung sound to rural population in remote areas. The reason for choosing children as subject of study is the greater challenge to identify the disease due to their inability to communicate effectively about their health problems and lack of research in this category.

Lung or breath sounds are produced during the process of breathing due to movement of air through abruptly branching respiratory passage. A change in the characteristic of normal lung sound or the emergence of adventitious (additional sounds overlapping the normal lung sounds) lung sounds is a reflection of diseased condition of the lungs. Various diseases of lung presents with different types of adventitious lung sounds that differ in their sound characteristics viz. pitch, amplitude, frequency, duration, etc. Wheeze is one of the types of adventitious breath sounds with shortest duration of ≥ 100 msec [3]. The objective of this work is to present a simple and robust technique for accurate detection and classification of wheeze episodes and harsh sounds from the lung sound recordings. The paper has been divided into four sections. The second section describes few major existing techniques for lung sound analysis. Section III describes the proposed method for lung sound analysis. Section IV shows the experimental results and conclusions.

2. PRIOR APPROACHES ON LUNG SOUND ANALYSIS
Several techniques are available for automatic analysis of lung sounds. These studies are aimed at detecting abnormal condition of the lungs in the individuals presenting with adventitious lung sounds such as wheezing.

Antoni et al. [4] have presented a technique to detect and analyze wheezes by means of a time-frequency algorithm and a grouping algorithm. The algorithm detects wheeze episode through analysis of frequency and amplitude peaks over time in the lung sound signal. The grouping algorithm evaluates the continuity of the wheezing episode with time. In this method the lung sound signals were acquired during forced exhalation and segmented into three parts corresponding to air flow levels of 1.2-0.4, 0.4-0.2 and 0.2- 1.0 L/sec.

Respiratory health screening using pulmonary function tests and lung sound analysis study by Gavriely et al. [5] shows an increase in the sensitivity of objective detection of lung diseases by combining lung sounds (Phonopneumography) analysis to conventional screening by spirometry (measurement of the volume and/or speed of airflow during inspiration and expiration).

The lung sounds analysis was done by Elphick et al. [6] to differentiate wheezes and rattles objectively. Most often rattles are wrongly identified as wheezes. In this study the lung sounds recorded from infants having wheezes and rattles was analyzed using waveform, power spectrum and the Sonogram (a plot of frequency as a function of time). The sonogram of wheezy infant was found to be characteristically different from the sonogram of the infant having rattles.

An efficient wheezing-episode detector based on breath sounds spectrogram analysis method by Taplidou et al. [7] identifies wheezes based on certain threshold applied to the peaks of the spectrogram of total breath cycle. The frequency range of the lung sound signal is divided into sub-bands and for each band the threshold is calculated based upon signal amplitude in that particular frequency band. This threshold when applied to the peaks of the particular frequency band discriminates wheezing from normal breath sound.

Automated breath sound analysis study by Mireille and Dooijes [8] comprise frequency analysis of breath sounds to show a relationship between lung sounds and airway obstruction. In this study FEV1 (Forced Expiratory Volume in one second) of the subject was measured during forced breathing followed by recording of lung sounds. FEV1 was used for labeling the sound recordings. The analysis is done using nearest neighbor classification where the power spectral vectors of the lung sounds are classified according to their corresponding rate of airway obstruction.

The lung sound analysis for continuous evaluation of airflow obstruction in asthma was carried out by Baughman and Loudon [9]. This study shows a correlation between the fraction of respiratory cycle occupied by wheeze and the degree of airway obstruction. The study reveals that the audible wheeze appeared between the frequency range of 150 – 1000 Hz. The wheeze was also associated with a peak in the signal and the peak amplitude was considered as a criterion for classifying the sound as wheeze Earlier study by Baughman and Loudon [10] showed that the degree of bronchospasm (abnormal contraction of the muscles in the wall of the bronchi causing airway obstruction) is related to wheeze duration and frequency of sound signal and not with the intensity of wheeze sound.

The lung sound recognition using model theory based feature selection and fusion method by Korona et al. [11] describes the recognition of lung sounds using automatic signal recognition method encompassing two main features. One of those features is the use of symbolic knowledge (extraction of features from different types of lung sounds and representing them in a structure that is used for recognition process) about signal sources (in addition to sensory inputs) and the other is the fusion of multi-sensor information. By using the knowledge of fused model a neural network based classifier is built and trained using the reference databases. The classifier was then used for lung sound recognition

3. PROPOSED METHOD

The proposed method for lung sound analysis is based on MFCC analysis of lung sounds and classification using feed forward neural network using Error back propagation algorithm.

Fig 1: Lung Sound Recording Set-up

In order to develop the set-up for extracting lung sounds, it was decided to modify the existing stethoscope which directly transmits sound from chest piece to ears. Two identical stethoscopes were purchased and rubber tubing of one was cut at the diversion point and microphone was inserted and sealed. The microphone output wires were brought out and connected to microphone input of Laptop. Figure 1 shows image of final set-up used for recording lung sounds. A sample recording was done to check the audio quality of received lung sound by comparing with sounds obtained from normal stethoscope model. After observing close resemblance, the database was generated by recording lung sounds of several child patients using modified stethoscope and a laptop at local pediatrician's hospital. The process involved the examination of child patient by the doctor using normal stethoscope and repeating the process by collecting lung sounds at sensitive locations using modified stethoscope. The file storing the recorded data was named based on name of patient, age, gender and disease diagnosis by the expert doctor.

Figure 2 shows the Block diagram of the proposed scheme. The lung sounds were sampled at 44100 Hz to extract maximum information from the lung sound. The sampled data were subjected to normalization to nullify the effect of different ambient conditions prevailing during recording and subject to subject variability. MFCC coefficients extraction for feature detection is quite popular technique in speech recognition and is described in detail in our earlier work [12-13]. The MFCC coefficients were extracted from the signal with different length of windows and frame size. The statistical parameters of MFCC were calculated and used as inputs to feed forward Neural Network. After successful completion of training using equal samples of lung sounds of normal and bronchitis suffering children, the system was tested for detection of disease for remaining samples.

MFCC calculation is carried out only for the frequency band of 100Hz to 800Hz (maximum energy of lung sound) to make the method more robust to environmental noise.To calculate MFCC, a 125 m sec Hamming Window with 50% overlap is used. The optimum value for number of Coefficients selected after experimentation is 18. It is observed that 18 rectangular windows are sufficient for the frequency range of 100-800Hz with 50% overlapping

Initially neural network was trained by 18 features of each data set. The results obtained by this approach were not accurate as shown in Table 1. So to increase the feature size MFCC coefficients were further divided in the group of 20 and for each group the statistical parameters like maximum, minimum, mean and Standard Deviation were calculated .Therefore the neural network has maximum training data representing the statistical characteristics.

Different combinations of frame length and frequency ranges were experimented and it was found that 100-800Hz is sufficient, so MFCC coefficients were only calculated for the frequency range of 100 to 800Hz.

For classification purpose feed forward neural network with single hidden layer is used. The numbers of neurons in the hidden layer are determined by conducting trials and observing results and it is found that 18 neurons are sufficient for the proper training and good classification results. The Frame length of FFT window is varied and accordingly tested by neural network, after experimentation it is found that frame length greater than 100ms is necessary for proper training of the neural network, So 125 ms frame length is sufficient complying with the definition of wheezing as continuous sound of >100ms.

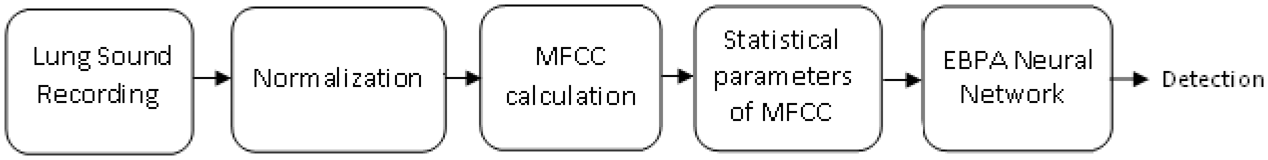

Fig 2: Block diagram of proposed system

4. EXPERIMENTAL RESULTS

The lung sounds samples analyzed by the proposed method include nnormal lung sound and lung sound of children having bronchitis. Both normal and abnormal sounds were recorded at different chest locations of pathological significance.

Table 1. Experimental Results for 18 features

No of MFCC coefficients	Success for normal detection	Success for Bronchitis detection	Overall Success
10	50%	70%	60%
12	60%	60%	60%
16	40%	85%	62.5
18	60%	65%	62.5
20	75%	80%	77.5
22	35%	75%	55
24	55%	65%	60

To establish the robustness of the algorithm for ruling out false positives, noisy lung sound (e.g. crying of child) are also analyzed by the same algorithm. The results of the proposed algorithm are shown in Table 2. The results are obtained by testing neural network with 40 subjects out of which 20 are normal and 20 are of bronchitis. The hidden layer neurons are selected as 18 and analysis is done for different combination of MFCC coefficients with 18 rectangular windows for MFCC calculation.

Table 2. Experimental Results for 72 features

No of MFCC coefficients	Success for normal detection	Success for Bronchitis detection	Overall Success
10	50%	80%	65%
12	100%	55%	77.5%
16	66.66%	80%	75
18	**95%**	**90%**	**92.5%**
20	75%	85%	80%
22	65%	85%	75
24	55%	75%	65
26	85%	70%	77.5
28	70%	75%	72.5

5. CONCLUSION AND FUTURE SCOPE

Early detection of harsh breath sounds and wheezes in lung sound recordings gives an important clue about the extent of underlying lung disease and its severity, especially if detected early in children the disease can be cured completely and further penetration of disease can be prevented. We proposed a method that integrates various parameters of lung sound for early detection of bronchitis in children in accordance with the literature.

The proposed algorithm is simple, robust, and independent of flow information like FEV etc. The frequency range (100-800 Hz) and duration of wheeze ($\geq$ 100ms) used for automatic wheeze detection was adopted based on the CORSA (Computerized Respiratory Sound Analysis) definition of wheeze [3] and the prior approaches on lung sound analysis. The proposed method detects the disease with an accuracy of 90% and excludes normal lung sounds from being classified as wheeze/pathological with a specificity of 95%. The overall accuracy of the method is 92.5%.

The encouraging results obtained from work have tremendous implications in affirming feasibility of providing low cost remote rural health care by exploiting the cellular network coverage. Our work relating cell phone application in home automation can be extended to fulfill this requirement [14]. A suitable cell phone model can be chosen for recording lung sounds using modified stethoscope from child patient and this audio file can be transmitted with other useful supplementary information like case history, symptoms, etc. to health care servers located in urban area which can analyze the received information and provide guidance to the patient through prescription and instructions. For complicated cases, services of medical experts at urban region can be undertaken and emergency health care can be instantaneously taken resulting in greater protection against loss of lives of this deprived population.

6. ACKNOWLEDGMENTS

We express our deep gratitude to Dr Sanjay Bhangde (Practicing Pediatrician, Pusad) for providing guidance and diagnosis of patients during lung sound recording in spite of his busy schedule .We also thank the Principal Babasaheb Naik College of Engineering, Dr. K. Ravi for providing necessary facilities for carrying out this work.

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