Analysis and Automatic Detection of Wheeze in Lung Sounds

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Abstract: Airway obstructive diseases like asthma, chronic obstructive pulmonary disease (COPD) and bronchitis produces wheeze pattern in lung sounds. Due to changing lifestyles, pulmonary diseases are increasing day by day. The current methods of detecting diseases for example asthma involves usage of spirometers and stethoscope. The results with these techniques are not efficient or depend upon doctors' experience. Accuracy of existing methods is depend on patient's health. It is troublesome for heart patients and children. In such cases, need for automatic tools that can detect presence of wheeze present in lung sound is emerged. This paper gives long-term solution to existing problems. This paper also explains details about wheeze pattern in lung sounds. This paper involves the system for lung sound acquisition and real time pre-processing and detection of wheeze in lung sounds using DSP processor. The aim of the paper is to design and develop portable device for acquisition and detection of wheeze in lung sounds.

***IndexTerms* - Lung diseases, Wheeze sound, DSP processor, FFT, Bluetooth**

I. INTRODUCTION

The method used for detection of asthma involves use of conventional stethoscope. Frequency response of stethoscope favors lower frequencies and attenuates higher frequencies. Therefore, it is insufficient for detection of pulmonary sounds. Also the physicians practice plays an important role. Currently spirometry is used in hospitals to diagnose various pulmonary diseases. The results depend on factors like age, height and previous records. Also it is troublesome for children, elderly persons and heart patients.

Sounds generated from breathing can be a good source of information on lungs health. Breath sounds have particular patterns. Breath sounds with abnormally high frequencies and intensity, and with a prolonged and loud expiratory phase are typical in many diseases with airway obstruction, like in asthma and in chronic bronchitis. These abnormal breath sounds have also been called bronchial sounds. They have frequency components up to 600–1,000 Hz recorded over the posterior chest wall.

Abnormal lung sounds are wheezes. Wheezes are continuous adventitious lung sounds, which are superimposed on the normal breath sounds. Wheeze sounds are characterized by a dominant frequency, usually over 100 Hz – 400 Hz, and duration of more than 100 ms, as in [6]. Wheeze contains a dominant frequency of 400 Hz or more, while rhonchi are characterized as low-pitched continuous sounds with a dominant frequency of about 200 Hz or less. Their presence is related to partial airway obstruction. Wheezes are found in diseases like asthma. Wheezes can be heard in several diseases, not only in asthma. They are common clinical signs in patients with obstructive airways diseases, and particularly during acute episodes of asthma.

In paper [1], Jyotibdha Acharya have described a low complexity T-F continuity based algorithm for feature extraction and wheeze detection with high accuracy. Two hardware friendly variants of the algorithm have also been proposed. The automatic wheeze detection algorithm discussed in [2] uses time-frequency analysis and the Short Time Fourier Transform to identify sections of wheezing in recorded lung sound files. This algorithm gave an accuracy of 86% for successfully detecting the presence of wheeze in a sound file. In paper [3], a novel method, namely Entropy-Based Wheeze Detection (EBWD), is introduced. The technical objective of the study is to develop a simple method that can detect and identify the possible target sound bearing health information (i.e. wheeze) automatically and continuously during long term. In [4] a portable FPGA based wheezing detection system is proposed. Spectrogram of the audio was processed by 2D bilateral filtering, image segmentation and image labeling to extract the wheezing features [CORSA standard]. Paper [5] have proposed a wearable wireless sensor implementing on-board respiratory sound acquisition and classification, to enable continuous monitoring of symptoms, such as asthmatic wheezing. Low-power consumption of such a sensor is required in order to achieve long autonomy.

II. WHEEZE SOUNDS

Wheeze is a high-pitched whistling sound produced by partially obstructed respiratory airways during breathing. Presence of wheezes has been used extensively as a diagnostic tool by medical professionals to detect lung and chronic pulmonary diseases such as asthma, COPD, bronchiolitis etc. Traditionally auscultation using stethoscopes has been used to detect and monitor wheezes. But this method suffers from two major drawbacks, namely availability of trained medical professionals and subjectivity in diagnosis due to disparate interpretation of wheeze sounds by diagnosticians. Moreover, for a better identification of the underlying medical condition, continuous monitoring and analysis of wheeze sounds is often preferred. The spectrograms of wheeze signals are characterized by continuous frequency contours which distinguishes them from normal breathing sounds. These frequency contours are 1) continuous in time 2) varying in shape for different patients and 3) present in different frequency bands for different patients. The spectrogram of normal and wheeze signal is shown in Fig 1.

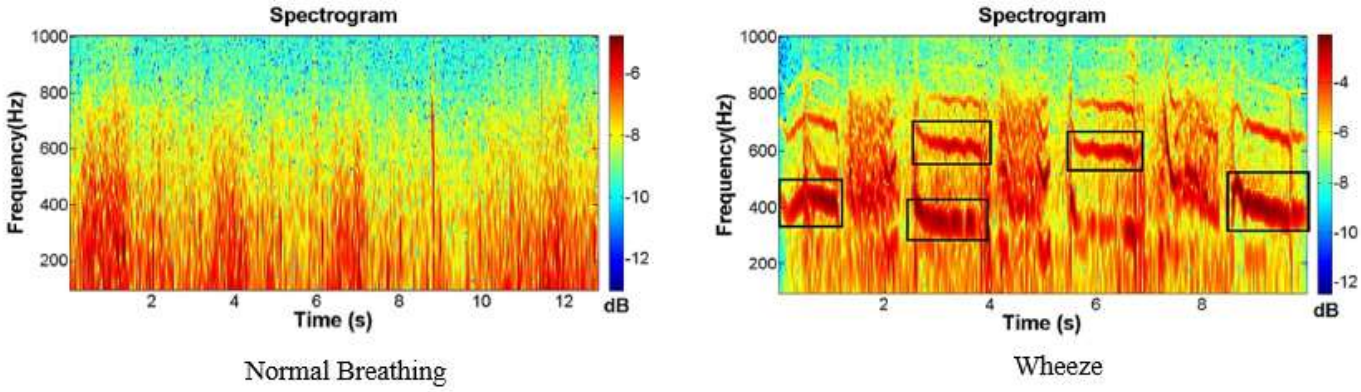

Fig.1. Spectrogram of Breathing Sounds of Wheeze Patient and Normal person: frequency contours corresponding to wheeze are marked

III. Comparison of Existing Models

Table 1. Comparison of existing systems

Methodology	Advantages	Limitations
A novel low complexity wheeze detection method based on frequency contour tracking for automatic wheeze detection.	Achieved very high classification accuracy (>99%) at low computational complexity.	Commercially available audio recording device is not available. Software based approach.
Time frequency analysis and STFT to identify sections of wheezing in lung sounds	Best wheeze detection algorithm has accuracy of 86%.	Detection is on PC (MATLAB compiler). Lack of real time detection.
Wearable monitoring system to detect and identify wheeze from lung sound. Entropy based method is used.	Identifies 85% wheezy samples with SNR 6 dB.	Only microphone alone is used as sensor node. Use of LABVIEW.
FPGA architecture to detect wheeze rapidly. Image processing, pattern recognition and SVM is used to detect wheeze patterns.	Rapidly performs wheezing detection. Low power consumption.	Hardware is not optimized. Noise disturbances are not adequately managed.
A respiratory sound analysis algorithm performing real-time detection of wheezing is executed on the DSP on-board sensor node. Low powered wearable is designed.	Accuracy of 92% is achieved while occupying 2.6% of DSP's processing time.	Optimization of architectural requirements of DSP is future work.

IV. Research Methodology

The lung sound is the sound arising from breathing excluding adventitious sounds, heard or recorded over the chest wall, the trachea or at the mouth. The generation of breath sounds is related to airflow in the respiratory tract. Acoustically, they are characterized by broad spectrum noise with a frequency range depending on the pick-up location. Figure 2 shows block diagram of system. The stethoscope is used as sensor to capture pulmonary sound. To enhance quality of sound we can use electret microphone. The signal captured by the sensor is sent to the signal conditioning circuits for amplification, filtering and then converted to digital signal. The analog to digital convertor from DSP processor is used for digital conversion of signal. We can use DSPIC33FJ710 for signal processing. 10 bit ADC Channel 1 is used from DSP processor. Preprocessing of this digital signal enhances the properties of lung sound signal. Fast Fourier Transform (FFT) is applied on this digital signal to convert it into frequency domain signal. The frequency is analyzed and dominant frequency is used as distinguishing feature. The sound is then classified into normal, wheeze. This result is sent over Bluetooth module HC-05 to smartphone application. Bluetooth Module HC-05 can be used as RF module. This module is an easy way to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. The result will be easy to analyze for users/doctors/patients on smartphone and the overall system will become portable and user friendly.

Stethoscope is used as acoustic sensor for the system. Electret microphone is inserted into the earphone of stethoscope to increase the level of incoming lung sound. This pulmonary sound is then amplified using microphone amplifier and followed by power amplifier and filtering circuit. This sound is rich sound with heart beats data as well as sound data and noise added by environmental conditions. Filter is used to remove the noise added by environmental factors. The filtered sound or signal is given to DSP processor. One cycle of inhale and exhale is enough for the analysis. So there is no need to take sounds / air for three times unlike spirometry test. Approximately 8 sec – 10 sec signal is enough for the detection.

The nominal breath sounds recorded over the lungs have their main frequency band up to 200–250 Hz. Unfortunately, this frequency band also contains components from respiratory muscles and the heart. The range of heartbeats is between 60 Hz to 100 Hz. To eliminate heart sounds from lung sounds band pass filter is implemented in DSP filter with range 100 Hz to 2 KHz. The filtered signal is then digitized using in built ADC and then FFT is applied on the filtered digitized data.

From FFT we get list of all frequencies for the sound. The dominant frequency and its amplitude will give us the severity level of wheeze present. This result and signal is send to Android application over Bluetooth. The sound waveform, patient name, age, dominant frequency and severity of wheeze detected is displayed on mobile screen. If normal sound is detected same is mentioned on screen.

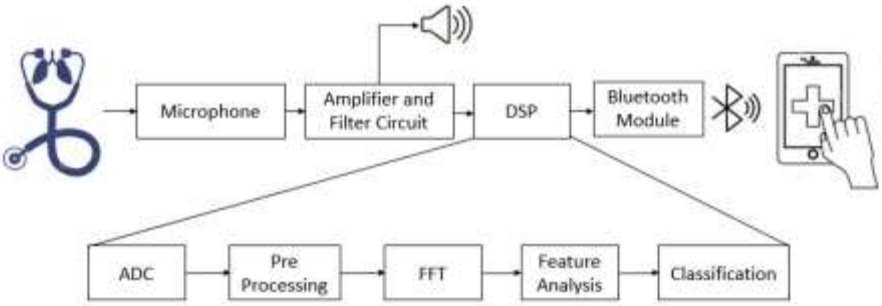

Fig. 2. Block Diagram of System

V. Results and Discussion

The result is calculated on clinical pulmonary sound signals. Table 2 shows the result set for same. This calculated result and filtered digital data is sent on Android application for user / patient / doctors. User can add patient's name and age before starting the detection. After getting the results, user can save result into their mobile phones. User can afterword load the saved data for further analysis. The incoming lung sound can be classified into four different sections and result can be displayed as: 1) Wheeze Detected (High), 2) Wheeze Detected (Low), 3) Wheeze Detected (Medium), 4) Normal sound. Figure 1 shows the landing page for application. Figure 4 and figure 5 depicts result for wheeze detected high and low respectively. Figure 6 depicts analysis of wheeze sounds selected for testing of system.

The main aim in development of system is to design on chip detection device to detect wheeze pattern in lung sounds. Noise free signal acquisition is the main task. The acquisition and processing hardware using DSP processor is portable, low powered and user friendly. There is no need of any machine / laptop to analyze detected data. This decreases the dependency of system on any other machinery. This system uses maximum hardware modules for filtering and classification process. On chip capture and filtering method is implemented and hence this increases portability of system. Hence, accurate detection is achieved.

Table 2. Wheeze Data with Results

Sound Data	Frequency (Hz)	Severity
Wheeze 1	910	High
Wheeze 2	871	High
Wheeze 14	891	High
Wheeze 9	987	High
Wheeze 11	993	High
Wheeze 13	898	High
Wheeze 3	990	High
Wheeze 4	550	Low
Wheeze 5	437	Low
Wheeze 6	479	Low
Wheeze 7	549	Low
Wheeze 8	690	Medium
Wheeze 10	777	Medium
Wheeze 12	730	Medium

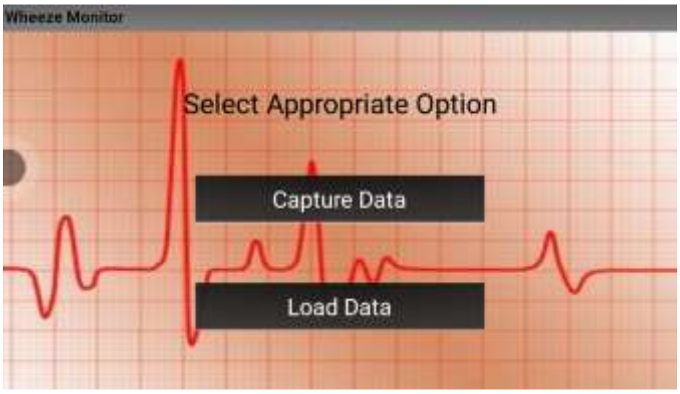

Fig. 3. Landing Page of Android App

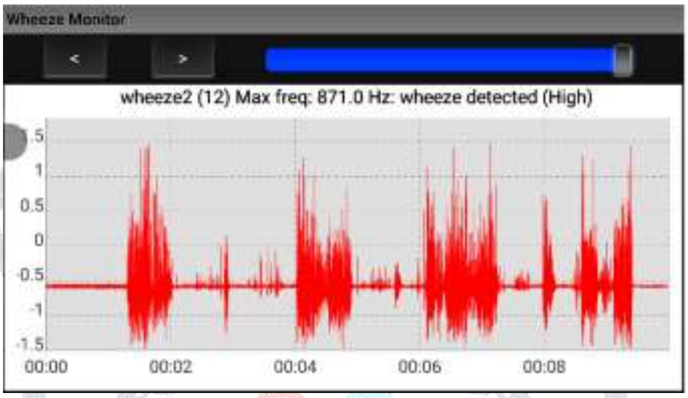

Fig. 4. Wheeze Detected (High)

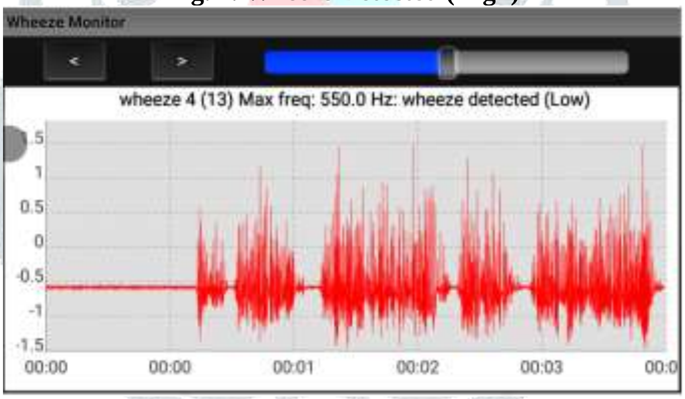

Fig. 5. Wheeze Detected (Low)

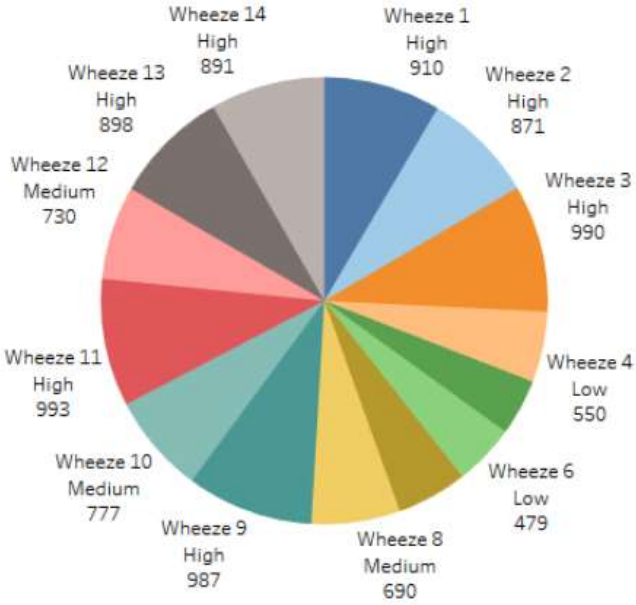

Fig. 6. Analysis of result

VI. Acknowledgment

This paper cannot be considered complete without mentioning Prof. Dr. S.S.Chorage, Department of Electronics and Telecommunication, BVCOEW, Pune. I wish to express true sense of gratitude towards her valuable constant encouragement and guidance in the fulfilment of this activity.

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