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Automatic Wheeze Detection in Lung Sounds

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Abstract— Lung disease is mainly characterized by the variations that occur in breathing sound of human being. The variations are characterized as wheezes, crackles, etc. Wheezes are one of the most important adventitious sounds in pulmonary system. They are observed in asthma, chronic obstructive pulmonary disease (COPD) and bronchitis. The current method of detecting a lung disease for example asthma involves usage of spirometers and stethoscope. The results with these techniques are not efficient. A wheezing detection system may help physicians to monitor patients over the long-term. This technique involves on board capture and processing methodology. This paper involves the system for breath sound acquisition and real time pre-processing and detection of abnormality in lung sounds using DSP processor. The aim of the system is to design and develop portable device for acquisition and detection of abnormality in lung sounds.

Keywords— Lung Diseases, Stethoscope, DSP Processor, FFT, Wheeze, Android application

I. INTRODUCTION

A person when breathes a particular pattern is generated. When there are variations in breathing due to some sort of disease the pattern produced is different. Sounds generated from breathing can be a good source of information on lungs health.

Abnormal lung sounds may be classified according to two main categories: crackles and wheezes. Wheeze sounds are characterized by a dominant frequency, usually over 100 Hz, and duration of more than 100 ms, as in [6]. Their presence is related to partial airway obstruction. Therefore, its auscultation has been used for the detection and evaluation of diseases such as asthma. In contrast, crackles are short, explosive and discontinuous sounds, shorter than 100ms, usually occurring during inspiration. These adventitious sounds are classified as fine crackles and coarse crackles based on their duration. Thus, fine crackles are defined as those lasting less than 10 ms and coarse crackles are defined as those lasting more than 10 ms.

The method used for detection of asthama 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. In this method, patient has to blow air thrice and the results are obtained. The results depend on factors like age, height and previous records. Also it is troublesome for children, elderly persons and heart patients.

This paper focuses on limitations of existing methods. To overcome those limitation, work is proposed by author. Audio of lung sound is captured using stethoscope and this audio acts as input to the system after noise cancellation and amplification. The sound is converted to digital format and given to DSP for processing for further filtering. This is well explained in methodology section. DSP processor works on incoming digital lung sound and after classification it will give accurate results on android application using Bluetooth module. The results are mentioned in last section of this paper.

II. RELATED WORK

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.

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.

Table 1. Advantages and disadvantages of existing methods

Method	Advantage	Disadvantage
Auscultation	Simple yet longlife and proven method	Depends on doctors' skill and experience
Spirometry	Detection of abnormality	Accuracy depends on patiets' health, age and various factors
Chest CT scan	Accurate diagnosis by sight observation of lung and overall respiratory system	Requires high cost investment
Chest x ray	Accurate diagnosis by sight observation of lungs	Requires high cost investment

III. METHODOLOGY

Fig.1 shows the generalized block diagram of system. First stage of system is part of signal acquisition and analog front end. It consists of an acoustic sensor microphone. While conventional stethoscope auscultation is subjective and hardly sharable, this system provides an objective and early diagnostic help, with a better sensitivity and reproducibility of the results.

Stethoscope with microphone is the more frequently used method. The sensor is generally an electret microphone, the sampling frequency the most frequently used is the same as the one used for telephony codecs (8kHz), an analogue/digital conversion with a 16 bits resolution.[7] Heart sounds can introduce perturbations during the analysis of lung sounds. Most of the spectrum of heart sounds is located between 20 and 100 Hz. We can use band pass filter to attenuate heart sounds. The detailed blocks for signal Acquisition and analog front end are represented in fig.2.

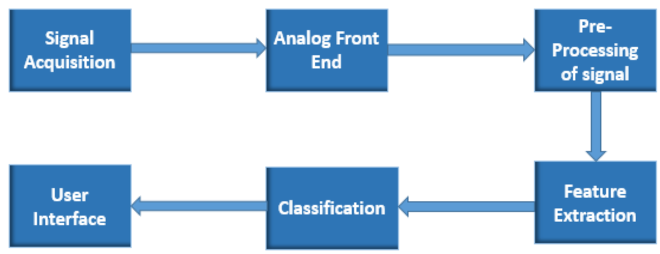

Figure 1. Generalised Block Diagram of System

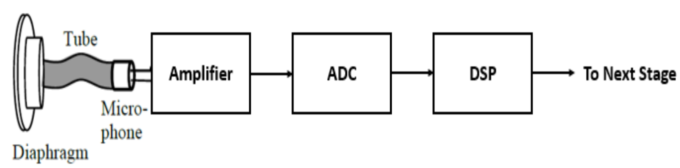

Figure 2. Signal Acquisition and Analog front end

To emphasize characteristics of lung sounds proper filtering methods should be used. The difference between normal sound and lung sound with wheeze is shown in fig. 1.1. The "cleaning" of respiratory sounds must also take care of the reduction of background sound. An analog bandpass filter is commonly used to isolate the respiratory sound signal band. An amplifier with a gain of 40–60 dB is required to adjust the dynamics of the microphone output (order of magnitude: 1–10 mV) to the input range of an analog to digital converter (ADC). Usually, the signal is digitized to 16-bit resolution, with a sampling frequency higher than 5,000 Hz.[5]

Normal respiratory sounds are cyclostationary, exhibiting the repetition of respiratory cycles. Each respiratory cycle can be divided into the inspiratory phase, the expiratory phase and the inter-respiratory pause. Normal respiratory sounds' frequency spectrum is similar to a bandlimited colored noise. The majority of the energy of the respiratory sounds acquired over lungs is typically grouped into the 100 to 250 Hz band, while tracheal sounds have a wider frequency band, with components extending to about 1,000 Hz. Asthmatic wheezing is a time-continuous, tonal adventitious sound occurring during a fraction of the respiratory phase. It can last from tens of milliseconds to several seconds. Wheezing can be modeled as a single- or multi-component harmonic signal superimposed on the frequency spectrum of a normal respiratory sound. The harmonic components originating from wheezing typically appear in the frequency range between 100 and 1,500 Hz. Both the amplitudes and instantaneous frequencies of the harmonic components of wheezing gradually change throughout its duration. The peaks of wheezing are localized along the frequency axis and spread in the direction of time axis. [5]

The stethoscope is used as sensor to capture lung sound. To enhance quality of sound we can use 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. Pre processing 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 analysed and dominant frequency is used as distinguishing feature. The sound is then classified into normal, wheeze and crackle sound. This classification result is sent over bluetooth module to smartphone application. Bluetooth Module HC-05 can be used as RF module. HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module,designed for transparent wireless serial connection setup. The result will be easy to analyse for users/doctors/patients on smartphone and the overall system will become portable and user friendly.

IV. Results and Discussion

The calculated result and filtered digital data is sent on Android application for user / patient / doctors. The incoming breath 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 3, 4, 5, 6 depicts same.

Dominant frequency considered here is around 400 Hz. If dominant frequency on incoming sound signal is around 400 Hz the severity is low. If dominant frequency value exceeds frequency of around 800 Hz then severity level considered as high and in between frequencies are considered as medium severe.

Result window will have name of patient, age, and value of dominant frequency, severity level and a plot of filtered data. Using sliding bar option we can modify the time axis of waveform. User / doctor / physician can save this result into phone.

The system is tested using clinically approved sound signals and data is plotted on to bar chart.

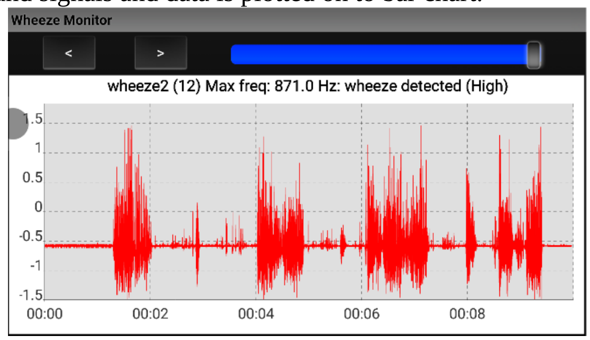

Figure 3. Wheeze detected (High)

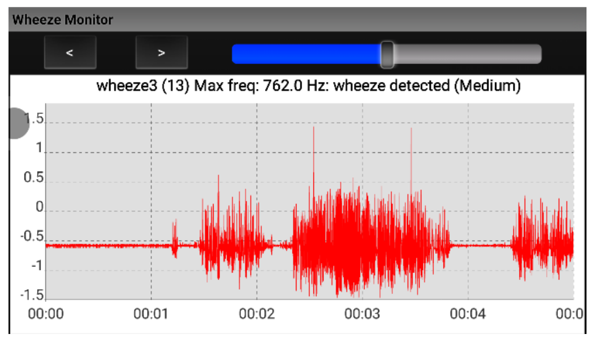

Figure 4. Wheeze detected (Medium)

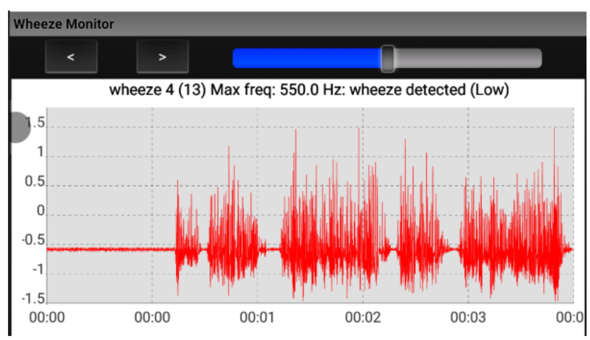

Figure 5. Wheeze detected (Low)

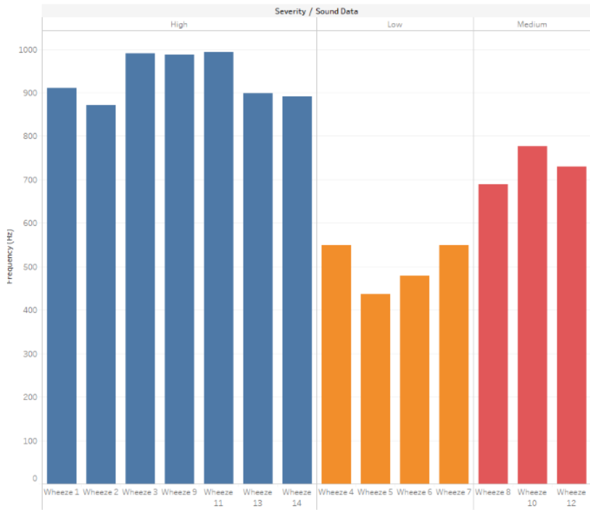

Figure 6. Horizontal bar chart analysis

V. CONCLUSION and Future Scope

The main aim in development of system is to design portable device to record and accurately detect the abnormality in lung sounds. Noise free signal acquisition is the main task. The acquisition and processing hardware is portable and user friendly. To achieve this, we have used DSP processor. The systems used till date are focused mostly on processing of sound using software. This makes that system bulky and less user friendly. Using this system, we can minimize use of software implementation and can use hardware system for maximum filtering and classification process. Hence, we are replacing most of the processes with DSP processor. On chip capture and filtering method can be implemented and hence this increases portability of system. The accurate classification can be achieved and results are displayed on android application to users/patients/doctors.

In future, crackle sound can also be detected in the same way.

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