

Automatic Abnormal Sound Detection System for Diagnosis of Respiratory Diseases

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ABSTRACT: Respiratory sound generated by the lungs during inspiration and expiration is a good source of information about respiratory diseases. Environmental condition over the year's changes because of these peoples suffers the respiratory problem either from birth or develops over the years. Abnormal (adventitious) sounds are generated in certain pathological conditions of the airways or lungs which is the symptoms of respiratory diseases. Identification of the adventitious sound is the first step in controlling the various respiratory diseases. Using that easy to understand the disease progress, and how close research to developing new test and treatments and what still needs to be done. Although many studies have addressed the problem of adventitious sound detection, a limited number of scientific works has focused on real time detection of adventitious sound. The purpose of this study was to develop an automatic system that can monitor a health condition in real time using acoustical information and detect an abnormal symptom. In this paper we suggest the automatic adventitious sound identification method to efficiently discriminate the types of abnormal breath sounds, i.e., fine crackles, coarse crackles, and wheeze without physician depending upon the frequency components presents that help to treat the patient.

KEYWORDS: Respiratory Sound (RS), adventitious sound, computerized adventitious sound (CAS), crackles, wheeze and spectral power estimation.

I. INTRODUCTION

In Nineteen Century Laënnec noticed that respiratory sound generated by the lungs during inspiration and expiration contain information about respiratory diseases who also invented the relationship between human respiratory diseases and respiratory auscultation. He then invented stethoscope in 1921 which enabled physicians to listen to respiratory sounds of their patients and detect any symptomatic signs [1-6]. According to the computerized RS analysis (CORSA) guidelines respiratory Sound can be classified into two main categories, either normal or abnormal (adventitious) respiratory sound [5]. Normal respiratory sounds are generated during inspiration and expiration with louder inspiration phase with dominant frequency ranges below 1000 Hz. Adventitious sounds are generated in certain pathological conditions of the airways or lungs which is the symptoms of respiratory diseases. Adventitious sounds were characterized by a fundamental frequency, between 100 Hz to above 1000 Hz for wheezes and lower than 200 Hz for rhonchi; they both last from 80 – 250 ms [7-13]. In adventitious sounds also including crackles and squawks, showed a wide frequency band between 50 and 2,000 Hz and were of shorter duration [14]. For diagnosis of respiratory diseases physician normally used stethoscope as it is conventional method. But auscultation using stethoscope is subjective method and it is high possibility of false diagnosis because it need well trained physician to recognize abnormalities and ability to differentiate between the sound patterns [1-6]. As day to day increasing number of respiratory patients there is a need of automatic monitoring of the adventitious sound to assist the physicians in diagnosing and monitoring the patient.

According to literature survey to characterize the symptoms related time-frequency structure various CAS identification methods have been proposed based on linear time–frequency (TF) decomposition techniques such as

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wavelet transform (WT) [15-16] and short-time Fourier transform (STFT) [17-19]. In these survey the other information of adventitious respiratory sound such as amplitude and pitch variation, duration has been considered in addition to the spectral information [19-20] to enhance the identification of adventitious sound. As suggested in [21], the accuracy of adventitious sound identification based on time-frequency decomposition relies highly on the resolution and noise resistance of the obtained time-frequency representation. Clinically also several methods are used for detecting the adventitious sound such as spirometer and other pulmonary function test [22]. But these are very time consuming methods and patient need to put extra efforts. Adventitious sounds are continuous musical tones commonly heard at inspiration or expiration. This tonal quality is determined by the power spectrum in which most of the energy is contained in harmonically related frequencies [20]. Since the pitch, duration, and intensity information of adventitious sound associated to pathological conditions of the airways or lungs which is the symptoms of respiratory diseases associated to the origin of the pathology [20, 23] so it is very meaningful method to identify the frequencies present in adventitious sound.

The purpose of this study was to develop an automatic system based on classical method of spectral analysis for analysing and visualizing adventitious breath sounds, i.e., fine crackles, coarse crackles, and wheeze in respiratory sound which can monitor a health condition in real time using acoustical information and detect an abnormal symptom. In this paper we suggest the automatic adventitious sound identification method to efficiently discriminate the types of abnormal breath sounds, i.e., fine crackles, coarse crackles, and wheeze without physician depending upon the frequency components presents that help to treat the patient.

II. METHODS

DATA ACQUISITION:

The real time respiratory sound recordings were carried out in a laboratory with the subjects in sitting position. Single electrets condenser microphone (ECM-77B, Sony, Inc., Japan) was inserted into a hemispherical rubber chamber of stethoscope, and placed over a trachea. The respiratory amplifier is ultrahigh-gain preamplifier, which is fed by electrets microphone is actually an extremely sensitive audio preamplifier that exploits the fact that moving air close to a microphone causes an overload in the audio output.

RECORDING SOFTWARE:

Agilent Technologies 1.8.5.0 (Model No. U2352A, serial No. TW50471004) was used and the RS recordings were saved in a mono channel at sampling frequency (F_s) of 10000 Hz.

DATA PROCESSING:

For removing the heart sounds in respiratory sound is obtained by using a Kaiser Window FIR band-pass filter [50 Hz, 2500 Hz]. Nevertheless, a high-pass filter at 100Hz is not a good solution in so far as the main components of respiratory sounds are also located in this frequency range. Kaiserord uses empirically derived formulas for estimating the orders of low pass filters, as well as differentiators and Hilbert transformers. Estimates for multiband filters (such as band pass filters) are derived from the low pass design formulas [24].

The design formulas that underlie the Kaiser window and its application to FIR filter design are as given under

$$\beta = \begin{cases} 0.1102(\alpha - 8.7), & \alpha > 50 \\ 0.5842(\alpha - 21)^{0.4} + 0.07886(\alpha - 21), & 50 \geq \alpha \geq 21 \\ 0, & \alpha < 21 \end{cases}$$

Where $\alpha = -20\log_{10}\delta$ is the stop band attenuation expressed in decibels (recall that $\delta_p = \delta_s$ is required).

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The design formula is

$$n = \frac{\alpha - 7.95}{2.285(\Delta\omega)}$$

Where n is the filter order and $\Delta\omega$ is the width of the smallest transition region.

The frequency response of a digital filter can be interpreted as the transfer function evaluated at $z = e^{j\omega}$. You can always write a rational transfer function in the following form.

$$H(e^{j\omega}) = \frac{\sum_{k=0}^{M-1} b(k)e^{-j\omega k}}{\sum_{l=0}^{N-1} a(l)e^{-j\omega l}}$$

The spectral power is computed for each of the selected samples in the frequency range 50 to 2500Hz. A straight forward method which mostly used is discrete Fourier transform (DFT) to calculate the power with high resolution. It does not require setting the further parameters but it is computationally expensive. The resulting spectral vectors are not constant for all respiratory signal samples and impractically high dimension (a few thousands). Frequency resolution as well as dimension depends upon the length of original respiration signal. The respiration duration vary depend on natural variation. Averaging techniques reduces the dimension of the spectral vector over a preset number of spectral samples.

For calculating spectral power with less computational cost is possible by using the Welch method of spectral estimation [25]. In this method we have a choice to select the type of window, width of the window and amount of overlap of window. We select and applied Kaiser Window with 50% overlap and window width is chosen such that the frequency resolution of the Welch spectrum equal to the averaged bin width of the DFT spectrum.

The sound power depends on the flow of air during inhale and exhale. The flow respiration sound tends to vary due to irregularities in pathological condition of the respiratory system, such as variations in respiration detect using depth and respiration frequency.

The variance of the power spectral density estimate ($\overset{w}{P}$) without segmentation at frequency f_b is equal to the square of its contents [9].

$$\text{var}\{\overset{w}{P}(f_b)\} = P^2(f_b)$$

Where $P(f_b)$ is the expectation value of $\overset{w}{P}(f_b)$. In case of 50% overlap between successive data segments considerable reduction of the variance ²⁴

$$\text{var}\{\overset{w}{P}(f_b)\} \approx \frac{11}{18} \frac{P^2(f_b)}{K}$$

Where $K=N/L$ with N is length of the signal and L the window width.

III. RESULTS & ANALYSIS

Test subjects were asked to the breath deep and recording was saved for each subjects. In this study, dataset consists of respiratory sound recorded over trachea from 100 healthy and 50 pathological subjects with different degrees of airway obstruction. The test subjects have the age range from young to elder, and were having a wide range of pulmonary dysfunction such as asthma, COPD. Analysis of RS for the identification and extraction of various conditions, the variety in the associated pathology was considered

The recorded respiratory sound signals were first filtering with band pass filter into individual inspiratory/expiratory segments, and manual classification results for these segments were obtained, respectively, from doctors in Amravati, by listening to each individual RS segment. The sound power depends on the flow of air during inspiration and expiration. The maximum flow level of a respiration cycle tends to vary due to abnormalities in breathing pattern, such as variations in respiration depth and respiration frequency.

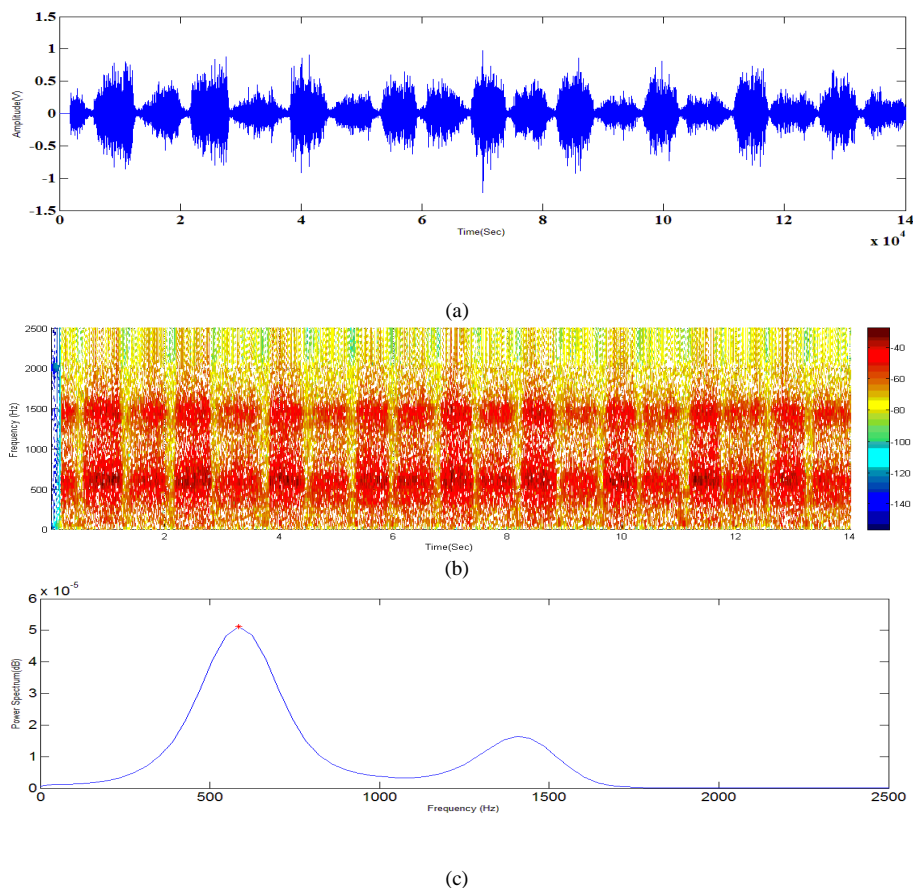


Fig. 1 Normal Respiratory sound presented in (a) time domain,(b) Time-Frequency domain (Spectrogram) (c) Spectral Power estimation by Welch method.

Fig. 1 shows that normal RS signal. Fig. 1 (a), (b) represent the normal respiratory sound (Bronchi Sound) in time domain and time-frequency domain in which inspiration much louder than expiration. Fig. 1 (c) shows that the power spectrum estimation having most of the peak frequencies present in normal RS sound having 600 Hz.

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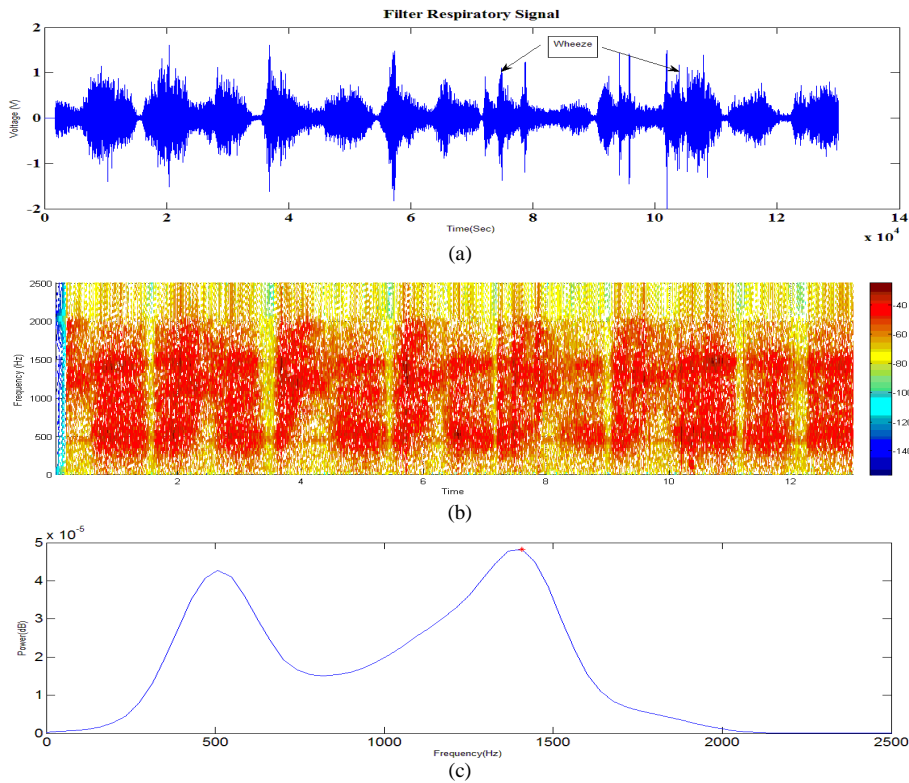
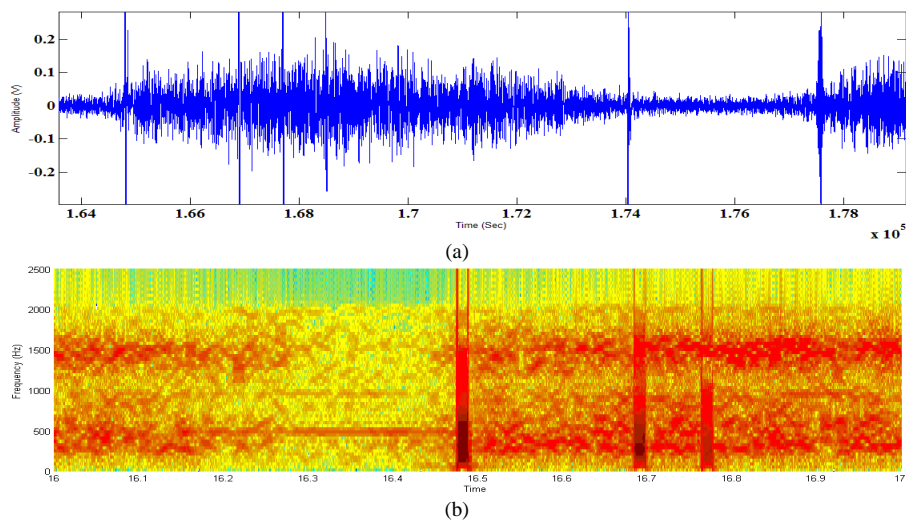


Fig. 2 Wheeze presented in (a) time domain, (b) Time-Frequency domain (Spectrogram) (c) Spectral Power estimation by Welch method.

Fig. 2 shows that RS signal contain wheeze, fig. 2 (a), (b) represent the wheeze present in RS signal in time domain and time-frequency domain. Fig. 2 (c) shows that the power spectrum estimation having most of the peak frequencies present in asthmatic RS signal having 1410 Hz because of change in pathological condition such as airway obstruction and flow limitation.



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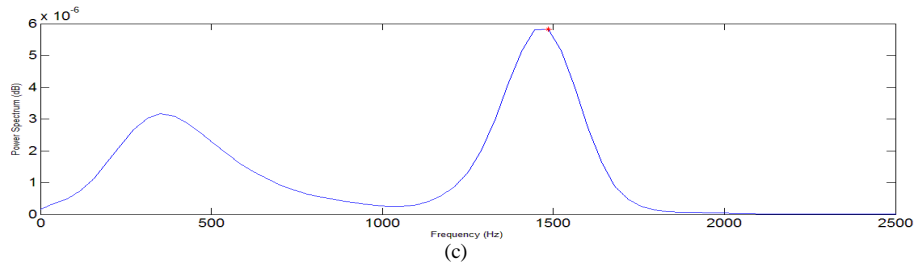


Fig. 3 Fine Crackles presented in a) time domain, b) Time-Frequency domain (Spectrogram) c) Spectral Power estimation by Welch method .

Fig. 3 shows that RS signal contain crackles, it is sign of diseases. Fig. 3 (a),(b) represent the crackles present in RS signal in time domain and time-frequency domain. Fig. 3 (c) shows that the power spectrum estimation having most of the peak frequencies present in asthmatic RS signal having 1490 Hz because of change in pathological condition such as airway obstruction and flow limitation.

Table 1: Classification performance of the proposed spectral power estimation method from Datasets

Case	Sex	Age	BMI	Type of Adventitious Sound	Peak Frequency (F_p) Hz
1	M	21	19.6	Normal	600
2	M	22	19.5	Normal	430
3	M	40	19.7	Normal	430
4	M	34	19.5	Normal	470
5	F	22	19.2	Normal	470
6	F	22	19.3	Normal	590
7	F	21	19.2	Normal	510
8	M	22	19.7	wheeze	1370
9	F	22	19.4	wheeze	1370
10	F	21	19.3	wheeze	1375
11	M	22	19.9	wheeze	1372
12	F	21	19.3	wheeze	1405
13	M	40	19.8	wheeze	1400
14	M	20	19.7	wheeze	1410
15	F	23	19.1	wheeze	1405
16	M	22	20	wheeze	1410
17	M	32	20.1	Fine crackles	1450
18	M	30	19.8	Fine crackles	1485

Notes: Abbreviations: BMI, Body Mass Index

Table 1 shows the peak frequencies, as measured from successive power spectrum. Wheezing, crackles were detected during breathing as a result of pulmonary obstruction was declared by the physician. As table 1 shows that the normal subject peak frequency presents in their RS signal ranging from 470 Hz to 600 Hz and in case of wheezing peak frequency components present in RS signal ranging from 1370 to 1410. In case of crackles peak frequencies are much higher ranging from 1450 Hz to 1490 Hz.

Automatic Abnormal Sound Detection System

The automatic abnormal sound detection system based on real-time processing and divided into hardware and software parts. The hardware part includes a microphone with amplifier, a digital acquisition (DAQ) board, and a computer. Microphone and amplifier have wide frequency ranging from 50 Hz up to 10 kHz. Sixteen-bit DAQ board for

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converting analog signal into suitable digital signal with sampling rate of 10000 Hz is applied. The specification of the used computer as follows: Intel(R) Core(TM) i3 CPU 2.40 GHz with 3 GB RAM was employed. The algorithm for real-time detection of a wheeze sound coded with MATLAB having data acquisition and signal toolboxes.

IV. CONCLUSION

An algorithm to detect abnormal (adventitious) sound in the time-frequency domain and spectral power estimation, with high sensitivity, developed and validated from doctors by listening to each individual RS segment. In RS signal contain adventitious sound carry enough information about pathological condition of the airways and lungs presents in RS signal are higher frequencies which easily identified in power spectrum. The analysis of spectral data by applying a spectral power estimation to detect the adventitious sound prove to be beneficial reliable, fast and accurate adventitious sound detection method which is essential for automatic diagnosis and treatment of respiratory disorder.

The results indicate very significant differences between RS signal of the normal healthy person and patient having respiratory diseases. For frequency and other analysed parameters, differences were also significant the peak frequency components present in normal respiratory sound range below 600 Hz and adventitious sound contains wheeze these peak frequencies are much higher range from 1370 to 1400 Hz. In crackles these frequencies are much higher range from 1450 to 1490 Hz.

The purpose of this study was to develop an automatic system that can monitor a health condition in real time using acoustical information and detect an abnormal symptom. In this paper we suggest the automatic adventitious sound identification method to efficiently discriminate the types of abnormal breath sounds, i.e., fine crackles, coarse crackles, and wheeze without physician depending upon the frequency components presents that help to treat the patient.

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