IMAGE VISUALIZATION OF LUNG SOUND FOR ALTERNATIVE REFERENCE IN CHARACTERIZING ADVENTITIOUS BREATH SOUND

Kevin Lloyd D. Cocuaco, Diana Chiu, Christian D. Echavez, Joel P. Ilao, Eldridge Sherwin S. Tan
Department of Computer Technology, De La Salle University 2401 Taft Avenue, 1004 Manila, Philippines

Abstract: Pulmonary disease is the leading cause of death in the Philippines [1]. Normally pulmonary disease can be detected by conducting auscultation, which involves listening to sounds generated by breathing. Lung sound detected by auscultation can often be characterized as either normal or adventitious. On average, lung sounds gathered by a stethoscope is characterized by low amplitude and frequencies less than 2500Hz [2]. Often, doctors distinguish lung sound subjectively. Furthermore, due to the stethoscope's unsatisfactory volume and the presence of ambient noise in the area of auscultation, an obstruction arises in the correct classification of the lung sound. To create an impartial representation independent of the low volume and hindrance of ambient noise in the different lung sounds, this research presents the development of image visualization in representing the different lung sound.

Keywords: auscultation, lung sound, image visualization, image representation

1. INTRODUCTION

Since the arrival of the 21st century medical science has improved dramatically. Machines such as X-rays, Electrocardiography and Doctors co-exist to support and help determine accurate medical results. Although there are still various areas untouched by technology which could be supported and improved, one such area is auscultation which has stood strong as one of most common and simplest way of identifying pulmonary disease.

The process of auscultation revolves around listening in various areas of the lungs, lung sound are then identified base on its pitch and the lung sound classification of being continuous or discontinuous [3]. There are two classification of lung sound normal or adventitious. Adventitious sound which includes lung sounds such as wheeze, crackle or rhonchi is classified as abnormal movement of air in the bronchi or pulmonary tissue and typically associated with different types of disease [3]. Crackles which can be further classified as either coarse or fine crackles may either be low or high pitch depending on the explosive and transient discontinuous sound. A crackling sound also lasts for about 20 milliseconds or lower [3][4][5]. Wheeze are high pitched with a continuous sound lasting for a duration of 250 milliseconds or more [3][4]. Wheeze can normally be found in diseases such as Pneumonia and Asthma [3][4]. Lastly rhonchi which is interchangeably classified as a wheeze is low pitched and continuous sound [4][5].

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Auscultation which is based on the doctor's hearing [3] presents various limitation such as deficiencies present on the auscultation device like an acoustic stethoscope. A stethoscope is often vulnerable to ambient noise and presents low volume in captured lung sound. Recently various researches [3][5][7] have implemented a variety of lung sound image representation method in identifying a range of lung sounds. Techniques such as spatial representation [6] used in detecting the different types of thoracic sounds, a periodogram used in analyzing breath sound and a spectrogram [7] in differentiating a crackle, wheeze and a normal lung sound.

Image visualization technique may be used in identifying the different types of lung sounds, however, most technique are sensitive to interfering signal and may display an incorrect representation results given the presence of obstructive noise such as mechanical or ambient noise. For this research given a raw lung sound signal or lung sound signals having little or no processing, a visual representation categorizing the different lung sound will be presented. The presented visualization aims to produce images that would aid doctors in identifying various breath sounds.

2. METHODOLOGY

a. Data Summary

Data of normal lung signals is taken by manual auscultation using ThinkLabs Rhythm ds32a+ electronic stethoscope [8][9] directly connected to a desktop computer, recorded using the Thinklabs Phonocardiography software with sampling set to 8 kHz. For the adventitious breath sounds due to a failed data gathering, various adventitious sounds such as crackle and wheeze were taken from various online sources and resampled to 8 kHz. For the adventitious sound rhonchi only 2 of the 6 was gathered manually using the ds32a+ electronic stethoscope. To An assumption that either manually obtained lung sound and online sounds will be able to be used for this system. A total of 6 sounds for each category are used for a total of 24 lung sounds.

b. Spectrogram

Spectrogram which is a tool for the analysis of the frequency component of an audio signal is a visualization using the Short-Time Fourier Transform (STFT). It is a sequence of Fast Fourier Transforms of data which are sliced and divided. This is further explained using Equation 1.

$$(\quad) \int [( ) ( )]$$

Equation 1

From Equation 1, given the time domain signal represented by x(t) or the input signal, w(t) or the window function and τ as the time localization of the STFT [3]. The resulting spectrogram image is represented through the different color intensity of the image. A spectrogram may display a two-dimensional or three dimensional plots. In the work of [7] a spectrogram is used in the automatic classification of a wheeze breath sound displaying the

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fundamental frequency. As seen on the left side of Figure 1, the fundamental frequency of the wheeze pointed by the black arrow.
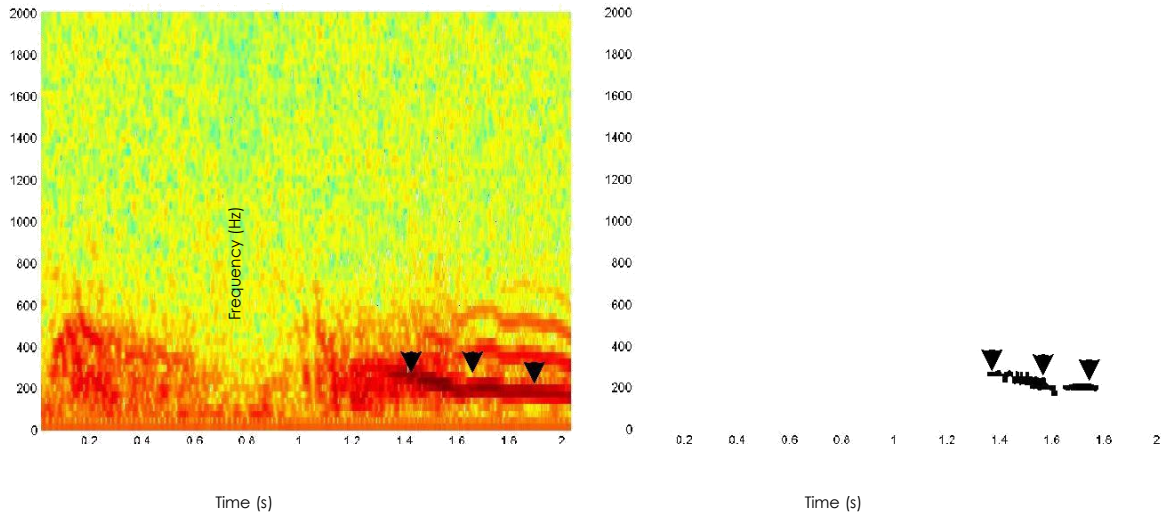

Figure 1. (L) Wheeze lung sound represented using a spectrogram (R) Wheeze lung sound in a binary spectrogram

To isolate the fundamental frequency of the wheeze breath sound, further processing is done. Processing involves the conversion of the spectrogram to its binary representation. The processing involves applying a Gaussian filter, generating the gray scale image and finally converting to the binary representation. As seen on the right of Figure 1 the binary representation with a threshold level set to 0.2 leaves the fundamental frequency of a wheeze.
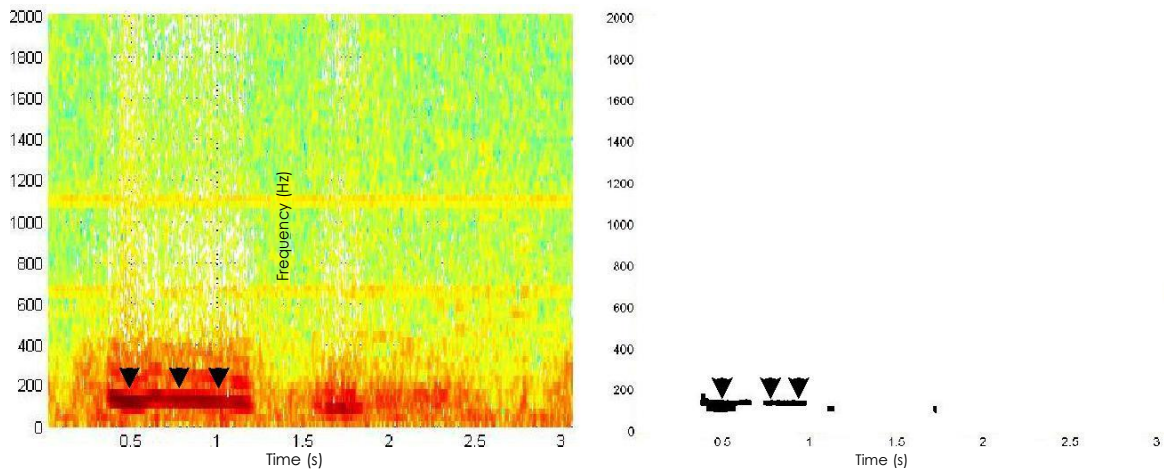

Figure 2. (L) Rhonchi lung sound using a spectrogram (R) Rhonchi lung sound in a binary spectrogram

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As discussed earlier, the fundamental frequency of a wheeze lung sound can be seen with the use of a spectrogram. Rhonchi as discussed in [3] are classified as a low-pitched wheeze. Using this information, the analysis of the 2-dimensional spectrogram suggests a similar spectrogram output containing a fundamental frequency. The resulting spectrogram seen in the Figure 2 displays the fundamental frequency of a rhonchi breath sound in a normal and binary spectrogram present in the area below 250Hz.

On the other hand crackles as opposed to a rhonchi and a wheeze has little or no indication of its fundamental frequency, but only presents an imbalance of frequencies in the inhale and exhale phases of signal is seen in its spectrogram representation on Figure 3. Enclosed in the box are a number of sharp spikes peaking at 2 kHz with its other half only containing frequency in areas below 400 Hz. The right side of Figure 3 shows the binary representation of the crackle spectrogram which yields a more clear representation of the imbalance present in a crackle lung sound.
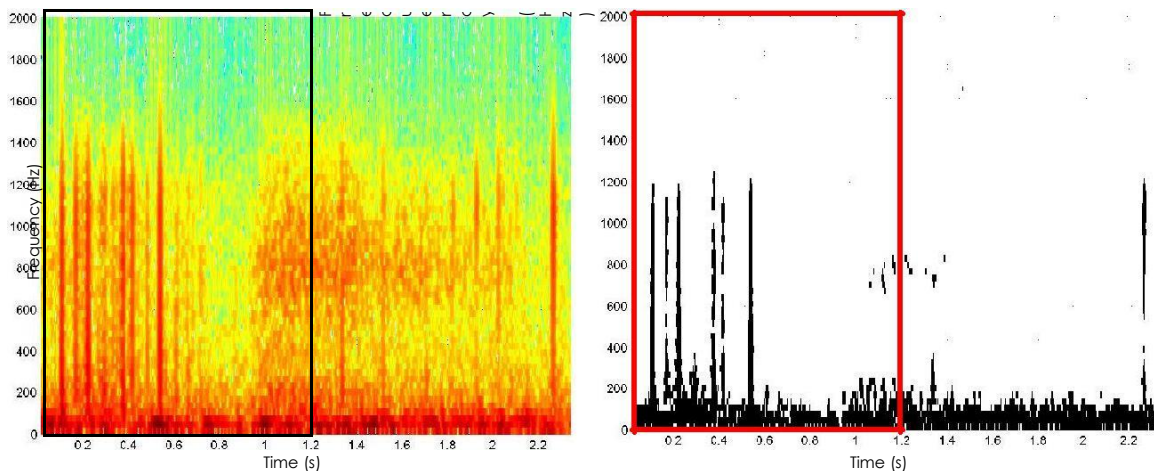

Figure 3. (L) Crackle lung sound using a spectrogram (R) Crackle lung sound represented using a binary spectrogram

Lastly for a normal lung sound signal no distinction can be made given the spectrogram of the signals. However due to the crackle, wheeze and rhonchi having a clear distinct spectrogram compared with a normal lung sound. The classification of a normal spectrogram may conclude to having little or no fundamental frequency and a balanced inhale and exhale phase as seen in Figure 4.
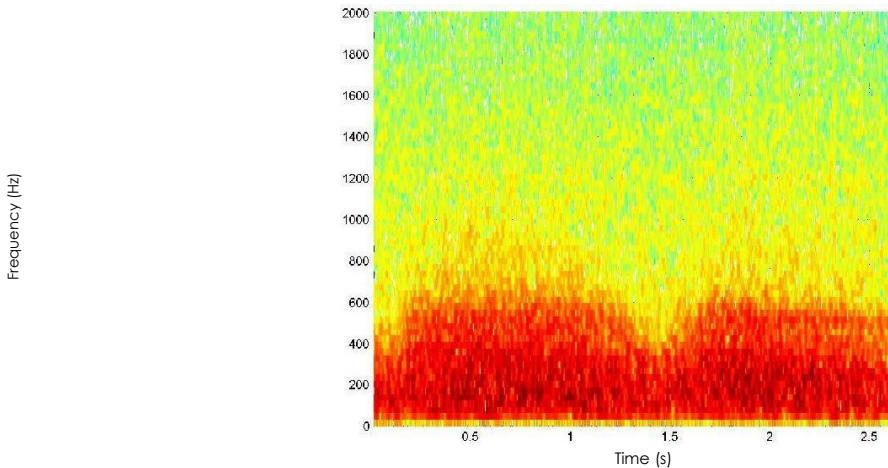
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Figure 4. Normal lung sound represented in a spectrogram

3. RESULTS AND ANALYSIS

In order to evaluate the effect of the proposed image visualization technique, three types of informal subjective tests were performed, namely: (1) image test, (2) listening test and (3) image with audio test.

The first survey aims to utilize the image representation of the lung sound. The second survey uses the traditional way of lung sound analysis using recorded lung sound signals. Finally, the third and final survey uses both the image and the recorded sound. Each survey consists of two parts, the instruction set and the questions. For the instruction set, the subject is given four different categories. Each category contains 3 similar items that may consists of images for the first survey, sounds for the second survey or both images and sounds for the final survey. After the subject has confirmed and understood each sample sets he/she may proceed to answer the survey. Each survey consists of 12 lung samples, randomly arranged. The subject is tasked to categorize the sample under the category it is suited for. Whenever the subject would like to compare, or clarify the sound or image in that certain set, the subject may take a peek at the instructions to review each set.

Participants comprised of students aging from 18 – 26 years old, with the majority of the participant being male. A total of thirty four participants were able to answer the three tests with the image test being the first test followed by the listening test and lastly the image and audio test being the final test.

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TABLE 1. AVERAGE SCORE OF SUBJECTIVE TEST

Image Test	Listening Test	Image with audio Test
7.7941	8.2059	8.0882

All of the tests consist of four sets of image/audio or image and audio namely normal, crackle, wheeze and rhonchi renamed as set A, B, C and D. For each sets three sample files were present. For the image and image with audio test three representations were present for each file the (1) spectrogram (2) binary representation of spectrogram using a threshold of 0.2 and (3) binary representation of spectrogram using a threshold of 0.5. For each tests, three test files for each lung sound is renamed and randomly ordered for a total of twelve test sound for every tests. Participants were instructed to correlate each of the twelve files into one of the four sets. The correct answer of each participants test was then tallied by counting the number of correct answers with the highest score being 12 making no mistakes for the particular test. The score of all the participants in each test is then averaged with the average score seen in TABLE 1. Results shows the listening test having the highest average score of 8.2059 followed by the image with audio test with a score of 8.0882, lastly the image test giving the worst average score with 7.7941. As seen in the results, using images as the basis of auscultation is not recommended and using images together, the lung sound decreases the result of correct classification by 0.1177.

TABLE 2. IMAGE CONFUSION MATRIX

	Normal	Wheeze	Rhonchi	Crackle
Normal	72	9	18	3
Wheeze	19	57	18	8
Rhonchi	15	13	70	4
Crackle	13	11	12	66

As shown in TABLE 2 majority of the participant have correctly predicted the correct set for the lung sound. In the case of Wheeze there is a possibility for people to get confused since the inhale part of the Wheeze spectrogram looks like a Normal lung sound spectrogram, and in some paper such as [10] explains that there are low pitch Wheeze that are being considered as Rhonchi or vice versa.

Most of the people that were surveyed complained about the length of the survey, since a total of 3 surveys is conducted, with each survey having 12 samples of lung sounds to identified.

Each survey takes approximately 10 minutes to finish, resulting to a total of 30 minutes to complete the whole survey. Person taking survey has little or no background regarding the subject.

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4. CONCLUSION

The image visualization using a spectrogram implemented in this research concludes the presence of a fundamental frequency present below 250 Hz on a rhonchi lung sound. The image representation presented in this study might be flawed and lacks reliability resulting in a below average score. One possible flaw might be with the use of gathered online lung sound data, which is often processed and filtered. This lung sound may have changed the results of the listening test. Changing the adventitious lung sounds used by only utilizing data gathered from a single source or only from the electronic stethoscope may be done to improve the reliability of the comparisons in three subjective tests. Also an implementation of another type of image visualization technique in order to help in the classification of the wheeze lung sound should be done due to having the lowest image score results.

The proposed visualization technique might be of used as another reference in the identification of the lung sound signal, although with little or no guarantee of improvement.

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