DIAGNOSIS AND ANALYSIS OF RESPIRATORY DISEASES USING DIFFERENT APPROACH FOR CRACKLES AND RIP

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Abstract- A neuro-fuzzy system is a fuzzy system that uses a learning algorithm derived from or inspired by neural network theory to determine its parameters (fuzzy sets and fuzzy rules) by processing data samples. Artificial intelligence and neuro-fuzzy is not only used in respiratory infection or lung cancer analysis but also tried to be used to diagnose thyroid disorder, diabetes, heart diseases, neuro diseases, asthma disease. In order to proper classification of respiratory diseases waveforms similar to the ones generated within the lungs must be recovered from the attenuated sounds. The equalization of crackle sounds recorded on the chest can be done for accurate classification of respiratory sounds. The paper discussed on different improvement of extraction of features from the crackle sound with modified equation for classifying disease and presents one innovative approach, which may assist researchers in the analysis of respiratory inductive plethysmography (RIP) data by calculating derived parameters from previously acquired physiological waveforms. The presented system is able to import RIP data stored in a dataset and plot the raw data traces for visualization of signal quality and phasing between the thoracic and abdominal signals.

Index Terms- Respiratory Sound, Auscultation, Plethysmography, Sound Analysis, Lung Sound, Thoracic and Abdominal.

I. INTRODUCTION

Respiratory sounds can be recorded with the help of devices having different technical specifications. The characterization of respiratory sound is not accurate [1]. The attenuation of the sounds traveling from the lungs to the thorax surface provides the crackles that can be best heard [2]. The lung sounds referred as crackles are useful for classifying cardiopulmonary diseases such as fibrosis, congestive heart failure, and pneumonia [3], [4]. The crackles are usually heard on the chest with a stethoscope during patient checkup. The importance of listening to and understanding respiratory sounds is evident from the iconic and symbolic usage of the stethoscope in modern medicine. Analysis of respiratory sounds using stethoscopes depends on the variable factors of the diagnosing physician’s experiences, hearing, and ability to recognize and differentiate patterns [6].

In addition, stethoscope data is not typically recordable, making long-term correlation of data difficult [7], [8]. All of these factors reduce the value stethoscopes bring to a world that increasingly demands quantitative measures of disease. A crackle is a discontinuous adventitious sound that is characterized by sharp bursts of energy [9]. Their duration is typically shorter than 20ms, and they are characterized by a wide distribution of frequencies. The high-frequency components of normal respiratory sounds are more attenuated by the transmission channel than the applied lower frequency tones. The wide bandwidth circuit (WBC) and the narrow bandwidth circuit (NBC) was used to measure sound from which attenuation curve was obtained. So the improvement in feature extraction is by using modified discrete time equation and improvement in mean root error and absolute mean root error is discussed in section II.

Respiratory inductance plethysmography (RIP) is a noninvasive monitoring modality [11]. Elastic bands embedded with insulated wires are placed around the thorax and abdomen. When charged with an electric current, the inductance of the bands varies as a function of thoracic and abdominal cross-sectional area. RIP is widely used in sleep studies to detect apnea and airway obstruction [12]. Limited applications for noninvasive assessment of ventilation and lung volumes in both ventilated intensive care unit patients and spontaneously breathing subjects have been described [11,13]. RIP as a postoperative apnea monitor in preterm infants was recently reported [7, 8]. The use of RIP under operating room conditions and general anesthesia is not well characterized. High-frequency jet ventilation (HFJV) [10] is a valuable ventilation strategy for patients undergoing surgical procedures involving the airway. The sub glottic technique produces limited interference with the operative field and minimal vocal cord movement, promotes expulsion of surgical debris, and improves safety by visual inspection of appropriate placement [10, 15]. RIP is under active study for use as a routine safety monitor during HFJV for interventional procedures under general anesthesia. Another goal of this paper is to analyze RIP data so it can be used as a detection monitor for different respiratory diseases.

II. RESEARCH METHODOLOGY

2.1 Improvement in crackle sound using modified equation

A discrete time equalizer can be used to recover sounds with characteristics closer to the ones generated by the lungs, after measuring the attenuation of the transmission channel. It can be assumed that the thorax and the thorax-microphone interface behave as a linear and time invariant system with the respective unit impulse responses $t[n]$ and $c[n]$, the output signal $x[n]$ acquired with the microphone on the chest is given by

$$x[n]=d[n]*t[n]*c[n]=d[n]*g[n] \quad (1)$$

where * is the convolution operator and $d[n]$ stands for the respiratory sound.

The purpose of the equalizer is to cancel the effect of $g[n]$ in order to recover $d[n]$, such that

$$y[n]\approx d[n] y[n]=d[n]*g[n]*h[n] \quad (2)$$

where $h[n]$ is the equalizer's unit impulse response. To cancel this effect, the convolution of the unit impulse responses of the equalizer and channel has to approximate to the unit sample

$$h[n]*g[n]\approx \delta[n] \quad \text{which gives } y[n]\approx d[n] \quad (3)$$

Thus, the input signal $d[n]$ can be recovered by a linear inverse filtering operation which is also referred as equalization, also called de convolution. MATLAB is used to sample the magnitude response of a FIR filter that imitates the measured attenuation curve ($G(ej\omega)$). The inverse of FIR filter ($H(ej\omega)$) contained poles outside the circle of unit radius. FIR least square inverse (FLSI) method [21] is an alternative approach to obtain a stable $h[n]$. The performance of the $h[n]$ obtained with the FLSI method depends on the choice of its number of coefficients (N). The effect of N on the equalizer response can be assessed by applying $h[n]$ of different sizes to crackles acquired from stable ambulatory fibrosis patients. In order to compare the equalized crackle to the applied one, they were normalized by their respective maximum amplitudes. The average attenuation values and its standard deviation are obtained from various respiratory sounds. The transmission channel acts as a LPF. Therefore, data on lung sounds with broad spectra will be distorted by the channel. Thus, the application of an equalizer may recover data from the lung sounds allowing the extraction of better quantitative diagnosis indices. In order to find out the most suitable filter length (N) for the proposed equalizer, crackle waveforms applied to the subjects' mouths were normalized by their respective maximum amplitudes; the same crackles were recorded on the chest, equalized by filters designed with different number of coefficients, and normalized by their respective maximum amplitudes. Afterward, the mean absolute error (MAE) and the root mean square error (RMSE) of the different equalized crackles were calculated

$$\text{MAE} = 1/\,M\ \Sigma\ Mi= \ |yi - y\bar{i}\,| \quad (4)$$

$$\text{RMSE} = 1/\,M\ \Sigma\ Mi = i\,(yi - y\bar{i}\,)\,2 \quad (5)$$

where yi is the normalized sample value of the crackle recorded at the mouth; $y\bar{i}$ is the normalized sample value of the equalized crackle recorded on the chest, and M is the number of crackle samples. The crackles recorded on the chest of each individual were reasonably corrupted by the channel.

2.2 Methodology for RIP data analysis

The developed system contains an easy to use layout, implementing a series of edit boxes, pushbuttons, and axes, each having its own individual function. In order for the program to function properly, the user must first import raw data to be analyzed; this can be accomplished by clicking the "Import Raw Data" pushbutton in the upper right hand corner, shown in figure 1. The callback for the import raw data button uses the get file command with an ".xls" Filter Spec to open a file browser window for the user to select an excel file to import. The file name is returned in the first edit box located at the top of the page labeled "File Path" using the set handles command. Once the raw data is imported, the user is then required to enter the thorax and abdomen data column numbers (the column numbers from the raw data spreadsheet) in two separate edit boxes.

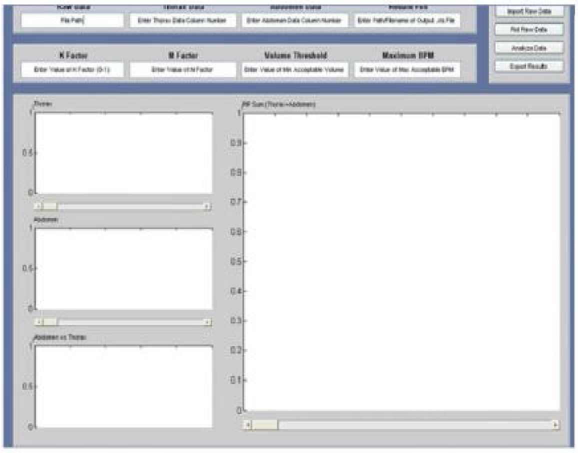

Figure 1: Designed System for RIP data

The thorax and abdomen column numbers are called using the get handles command. After the raw data is plotted, the user is then prompted to input the calibration coefficients K and M in first two edit boxes in the second row of boxes, labelled "K Factor" and "M Factor", respectively. Using an "If" statement, the program is designed to display a pop-up warning in the case that a K Factor not between 0 and 1 is entered. Once all of the inputs are entered by the user, the "Analyze Data" button can be pushed to simultaneously plot the calibrated volume, flow and raw RIP sum, as shown in figure 2 and figure3using the “hold on” command.

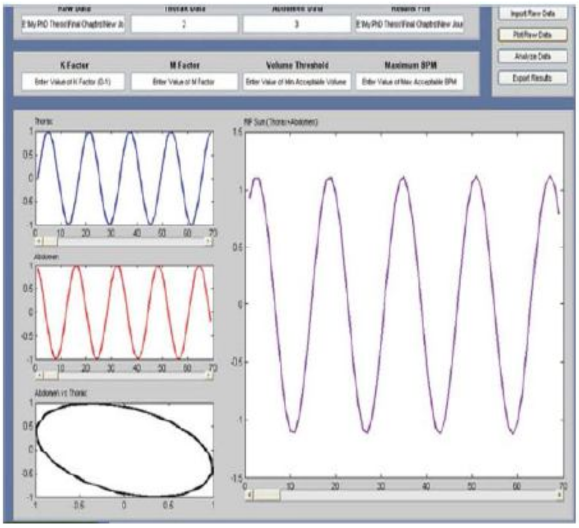

Figure 2: Depicts plotting raw data

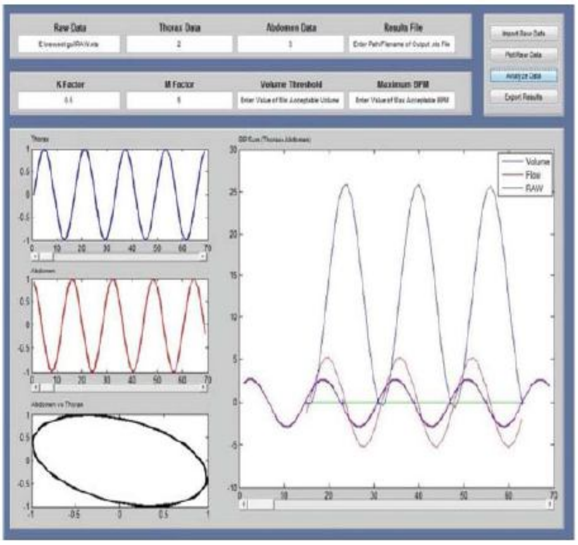

Figure3: Depicts Analyzing RIP data

III. EXPERIMENTAL RESULTS

3.1 Results for MAE and RMSE

Table 1: MAE and RMSE values calculated between the crackle waveforms sampled in the mouth and on the chest

Classification	MAE_{BE}	$RMSE_{BE}$	MAE_{AE}	$RMSE_{BE}$
Corrupted crackle	0.18	0.23	0.12	0.15
Very Corrupted crackle	0.28	0.34	0.13	0.18

Table 1 depicts the MAE and RMSE calculated before and after the equalization by filters of different sizes applied to the crackles acquired on the chest.

3.2 Analyzed results for RIP data

As the development of this system progressed, many shortcomings in the original layout of the program were identified. First and foremost, structures should have been used to organize the data. The use of structures would have helped keep the data much more organized, which in turn, would have made the program code much simpler to write, understand, and later, modify. Secondly, it was discovered that zero crossing logic was flawed. To identify the start and stop of each breath, every other raw signal zero crossing was used by only including the even numbered zero crossings. Inclusion of the slope of the raw signal at the zero crossing would have mitigated any errors that original method may have incurred. Lastly, storing the data from each breath in a single matrix would result in error if the breaths were of different lengths (of time). This is due to a dimension mismatch. Again, the use of structures would have alleviated many of these issues. The following Table 2 shows the exported values from the analyzed RIP data.

Table 2: Analyzed result from the RIP data

Breaths /Minutes	Minute Volume	Tidal Volume
0	0	207.1128
37.5	7681.851	204.8494
37.5	7582.648	202.2039

The other interface that has been designed for the analysis of sound files is shown in figure 4. User can input a sound file and view a plot of the sound wave. User can use menu to perform functions such as increasing speed at which sound is played, selecting for certain frequencies and wavelengths, and outputting file.

User can provide respiratory or lung sound files as an input to this interface. These file can be represented or can be exported to excel spreadsheet.

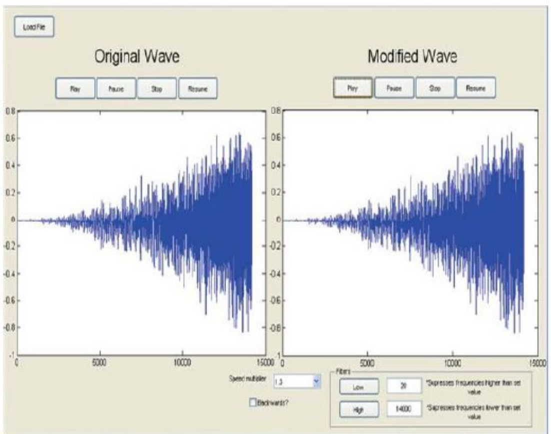

Figure 4: Interface for Analyzing respiratory sounds with original and modified wave

CONCLUSION AND DISCUSSION

This paper presented the discrete equalization method to compensate sound attenuation enforced by the thorax and thorax-microphone interface with a system based on the CORSA guidelines. The diseases are classified after analyzing the recorded respiratory sounds. The disease classification is improved after respiratory sound equalization. The disease classification results can be further improved by using neuro fuzzy systems. The disease classification results can be further improved by using neuro fuzzy systems. The designed system is useful for the analysis of the RIP data. Future work to further develop this system will involve the refinement of the exclusion criteria (noise filters), and the addition of newly developed derived parameters.

The user will set a maximum expected breathing frequency, and any breaths detected which are of a higher frequency than that of the expected frequency, will be considered noise and excluded from the analysis. The development of additional specialized parameters which will be utilized in phase angle (phase angle measured between the thoracic and abdominal signals), cough, and sneeze analysis will be developed to further assist researchers interested in acquiring and analyzing RIP data.

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