

Detection of pulmonary abnormalities using Multi scale products and ARMA modelling

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Abstract -This paper present a contemporary method for separation of Heart sound (HS) from Lung sound. The detection of original signal of HS segment can be predicted using multiscale product of wavelet coefficient. After identification of HS segment, the wavelet coefficient at every level is removed and estimated by creating gaps by either an Autoregressive or moving average model. The features of lung sounds may be impure by heart sounds because lung and heart sounds overlap in terms of time domain and spectral content. This paper presents a method of lung sound (LS) analysis using the advanced signal processing tools of LabVIEW as it offers more flexibility and remove the heart sounds and predicts the gaps successfully. Auscultation has been proven to be highly subjective. To help bridging the gap between common respiratory diseases and modern computer technology, we propose a system to analyze lung sounds and separate the heart sounds and other noises from them using LabVIEW. The qualitative analysis and quantitative analysis is confirmed by listening to the reconstructed signal and spectral analysis respectively.

Index terms: Heart sound , Lung sound, LabVIEW ,ARMA.

I. INTRODUCTION

The pulmonary disease can be categorized into influenza, pneumonia and tuberculosis. Some lung diseases can lead to respiratory failure which also include lung cancer. Lung diseases can be differentiated and characterized on the basis of lung sound. Lung sounds are the sounds produced by the structures of the lungs during breathing. The lung sounds are best heard with a stethoscope. The computer assisted analysis of LS has become a routine clinical finding due to many diagnostic potential. Auscultation refers to the process of listening to the sounds inside the body, including the lungs, to diagnose problems. Normal lung sounds occur in all parts of the chest area, including above the collar bones and at the bottom of the rib cage. Since the frequency of LS is below 150 Hz, the main component of LS overlap the HS during the respiratory recording.

The LS detection from the respiratory records include different techniques such as Kalman filtering, adaptive filtering and wavelet denoising filtering[1,2].The new recent method which include adaptive thresholding and 2D interpolation of LS in the time frequency domain. We proposed a system to extract the lung sounds from heart sounds and digitally analyzed. This method is also used to

remove other noises from the lung sounds and estimate the gaps.

II. METHODOLOGY

A. Data Collection

Pre- recorded lung sounds are taken from the well known and authentic website www.rale.ca. The sounds are found to be containing both heart sounds and lung sounds components. The main components of Heart Sounds (HS) are in the range 20–100 Hz, in which the lung sound also has major components. HPF with a cut-off frequency between 70 and 100 Hz is not efficient in this case as the lung sounds have major components in that region particularly at low flow rates. So the wavelet method is preferred.

B. LabVIEW

LabVIEW is a graphical programming environment used by millions of engineers and scientists to develop sophisticated measurement, test, and control systems using intuitive icons and wires that resemble a flowchart.

LabVIEW offers unrivaled integration with thousand of hardware devices and provides hundreds of build-in libraries for advanced analysis and data visualization. The LabVIEW platform is scalable across multiple targets and operating systems. The graphical approach also allows non-programmers to build programs simply by dragging and droppings virtual representations of lab equipment. The LabVIEW programming environment makes it simple to create small applications. The most advanced LabVIEW development systems offer the possibility of building stand-alone applications.

C. Data Analysis

The process starts by applying the **Discrete Wavelet Transform (DWT)** to the original LS record . The removal of each level of the HS segment with wavelet coefficients is automatically and accurately using DWT. The segments are either removed by **Autoregressive (AR)** or **Moving Average (MA)** modelling of either previous or next data segments . Reconstruction of the data into the time domain is done by IDWT. Finally we designed a RBF

network to differentiate the commonly misdiagnosed respiratory diseases.

D. Multiscaling

Wavelets are mathematical functions that cut up data into different frequency components, and then each component with a resolution matched to its scale. Wavelets are functions that satisfy certain mathematical requirements and are used in representing data or other functions. Wavelet algorithms process data at different scales or resolutions. The wavelet analysis procedure is to adopt a wavelet prototype function, called an analyzing wavelet or mother wavelet. Temporal analysis is performed with a contracted, high-frequency version of the prototype wavelet, while frequency analysis is performed with a dilated, low-frequency version of the same wavelet.

The wavelet transform of a signal $f(x)$ is defined as

$$WS(x) = f(x) \otimes \psi_s(x) \dots\dots\dots(2.1)$$

where Ψ is an orthogonal wavelet, s is the scale of the wavelet function, and $\otimes$ denotes convolution.

Because the original signal or function can be represented in terms of a wavelet expansion (using coefficients in a linear combination of the wavelet functions), data operations can be performed using just the corresponding wavelet coefficients. The data is sparsely represented by choosing the best wavelets adapted to data, or truncate the coefficients below a threshold. This sparse coding makes wavelets an excellent tool in the field of data compression.

E. Filtering Of LS

The sound signal was high-pass filtered at 7.5 Hz to remove DC offset (1st order Butterworth filter) and low-pass filtered at 2.5 kHz to avoid aliasing (8th order Butterworth filter). The original sampling rate was 10 kHz (some files were up sampled from 5 kHz). Analog-to-digital conversion was performed with 16-bit **quantization** (AT-MIO-16x, National Instruments), using a notebook PC and R.A.L.E.® software.

F. Extraction of lung sound

The extraction of LS from HS is depicted as flow chart, shown in figure 1

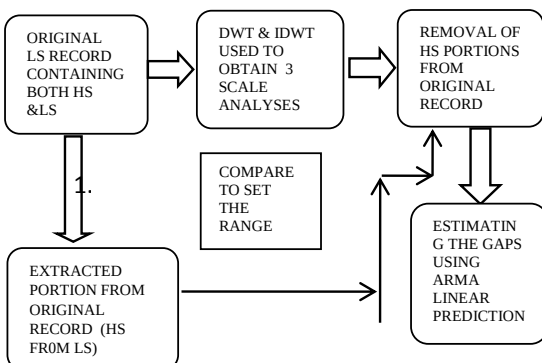


Fig.1: Flowchart for the Extraction Of LS

From figure 1, the flow chart elucidate that the extraction of the original signal containing both HS and LS. The overlapping of HS and LS takes place in time domain and spectral content. The multi scale analysis of the wavelet

approximation coefficients of the original signal is to detect HS included segment. The removal of HS from the wavelet coefficients takes place. The estimated gap are filled by using ARMA. A normal range is set and used to compare to find the abnormalities.

Figure 2 shown below illustrates the extracted signal which contains combination of both HS and LS. Advanced signal processing toolkit of LabVIEW 8.6 is used for processing the original LS including HS. The wavelet analysis tools are used for detection, localization and cancellation of HS included segments. This method is well suited for approximating the data with sharp discontinuities. When the acquisition takes place in real time or physical situation it may contain some spikes. The wavelet can be processed in both time and frequency domain which is also suitable for non-stationary signal. The multi scale product is obtained by calculating the **Discrete Wavelet Transform (DWT)** and **Inverse Discrete Wavelet Transform (IDWT)**.

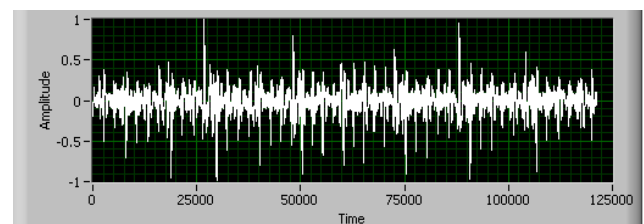


Figure 2: Original Signal containing both LS And HS

Figure 3 explains the unsheathed portion of LS free from HS. Signal and noise have totally different behaviour in the wavelet domain. The magnitude of the singularities i.e. the portions of the signal that is singular in nature such as the HS within a LS record and not the noise samples, increase along the scales. On the other hand, the DWT magnitude from signals with negative regularity i.e. Gaussian noise decreases as the scale increases. Thus, the multiplication of the DWT coefficients between the decomposition levels can lead to identification of singularities. Here we used the fifth order Symlet wavelet as the mother wavelet, which is a compactly supported wavelet with least asymmetry and decomposing the signal into 3 levels.

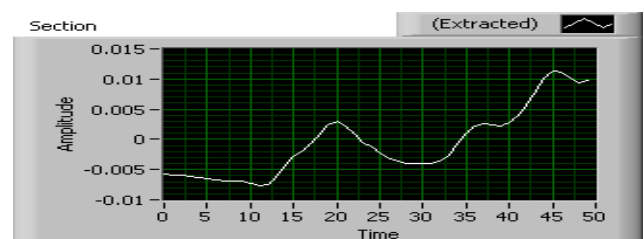


Figure 3: Extracted Portion of Respiratory records

During the first stage, the wavelet analysis tools are used for detection, localization and cancellation of HS included segments. The multiscale product is obtained by calculating

$$P_j(n) = \prod_{i=1}^j W_i\{f_{LS}(n)\},$$

where $W_i\{.\}$ is the DWT, a level i , $f_{LS}(n)$ is the LS signal, j is the desired number of levels to be multiplied, and P is the multiscale product of order j which was 3 in this study.

Having calculated the multiscale product at level 3, it was then thresholded such that

$$A_i^{Th}(n) = \begin{cases} A_i(n) & P_j(n) < Th \\ 0 & \text{Otherwise} \end{cases},$$

where $A_i(n)$ and $A_i^{Th}(n)$ are the original and thresholded wavelet approximation coefficients at level k , respectively; and Th is the threshold value. The standard deviation ($\mu \pm 5\sigma$) of the portions of original LS free of HS. The HS locations were detected accurately and removed from the DWT coefficients of the original LS record.

G. Prediction of gaps

Once the HS segments were localized and removed from the set of wavelet coefficients, the next step is to estimate the removed data. Estimating the removed data is done by linear prediction, using Autoregressive or Moving Average (ARMA) model. Shown in Fig.4. Given a time series of data X_t , the ARMA model helps to understand and predicting the past and future values in this series. ARMA model is a type of random process used to model and predict various types of natural phenomena and is one of a group of linear prediction formulas that attempt to predict an output of a system based on the previous outputs.

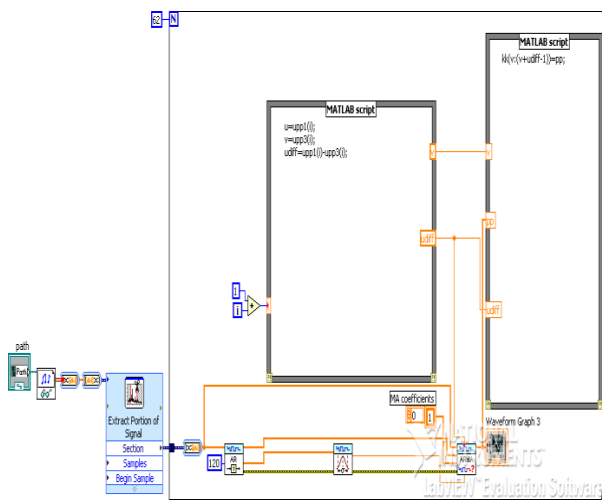


Fig.4 Block diagram of ARMA modelling and prediction

The estimation of removed data is done by linear predicted using either AR or MA model. The selection of order and type is essential for prediction of gaps. It is considered that upper 40% of the target is stationary. At this condition the selection between AR or MA model does not concern. But when HS occur in the respiratory phase, the breath sound is not stationary.

The selection between two model is very essential. AR model is done when the onset of HS is very close to the beginning of respiratory phase. MA model is used to predict the gap with future values. The prediction process is performed until the last sample is sensed by ARMA model.

III. RESULTS AND DISCUSSION

The separation of heart sounds from lung sounds was performed and a RBF network was used to differentiate between the commonly misdiagnosed respiratory diseases. The HS locations were detected and removed from the DWT coefficients of the original LS record.

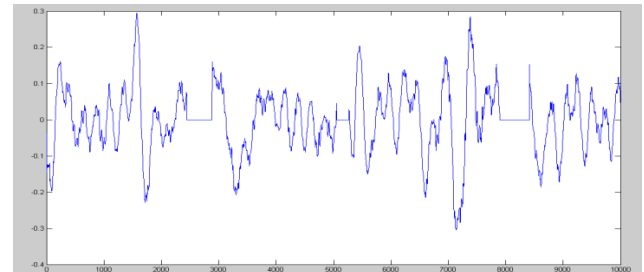


Fig. 5: HS portion approximated to zero

The created gap was then estimated by the method described in the previous section. As it can be seen, all HS segments were removed successfully and the main lung sound components were left intact. This procedure has been performed for few more recorded lung sounds and was thus proved to be successful in removing the lung sounds and predicting the gaps and the result is shown in Fig.6.

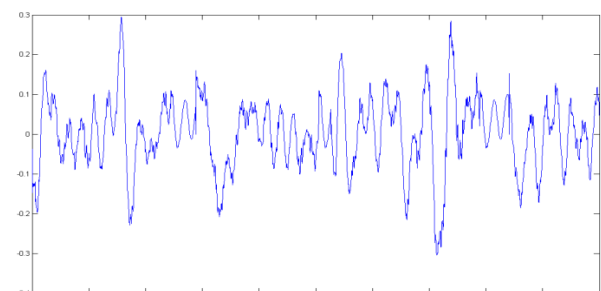


Fig. 6: Reconstructed signal of ARMA modelling

Comparing this method with HS removal based on the use of the STFT of the LS record, the presented method in this paper has the advantage of having higher accuracy for HS segment detection. The RBF network proves to be very efficient in differentiating the normal and abnormal lung sounds based on the frequency components. It was used to differentiate the commonly misdiagnosed respiratory sounds such as asthma and pneumonia. This network thus provides good clinical significance.

The fig.7 shows the waveform of the original signal used for this study. It represents a bronchiovesicular sound obtained from the website www.rale.ca. The waveform of the extracted portion of the original signal which is taken as heart sound free lung sounds for comparison, shown in Fig.8

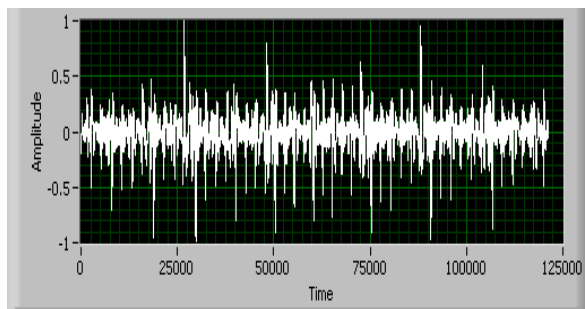


Fig.7. Original Signal

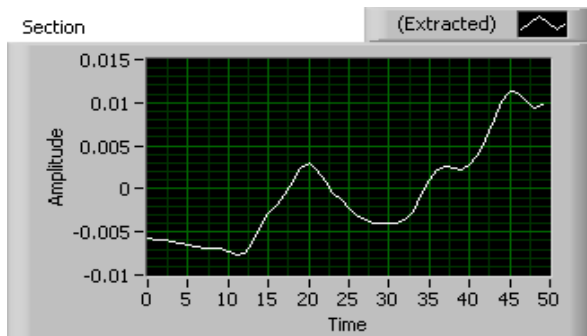


Fig.8. Extracted Heart sound free Lung sound

The wavelet transformation at third scale of resolution are shown below in Fig.9:

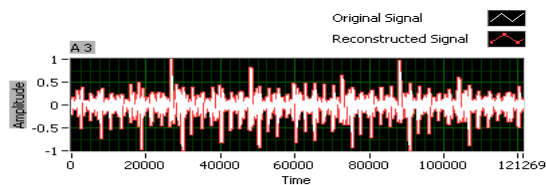


Fig.9. Wavelet transformed LS at third scale resolution

Fig.10 represents the output where the heart sound portions in the original signal are approximated to zero and thus removed.

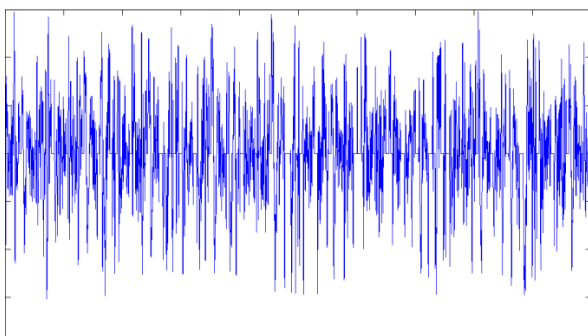


Fig.10. HS Cancelled LS

IV.CONCLUSION

The primary objective of respiratory sound research is to bring about improvements to monitoring and diagnosis of respiratory disease, the potential usefulness of any method for filtering heart sounds from lung sounds rests on its ability to perform in a clinical setting.

The proposed method for HS removal based on a single recording has shown promising results mainly in terms of lung sound characteristic preservation. This method did not add any noticeable clicks or artifacts in the reconstructed signal. Manual inspection by visual means of the reconstructed signals confirmed that lung sounds were the dominant sounds with no perceptible HS in the background.

Furthermore, the proposed technique is far more efficient than other techniques for HS cancellation in terms of computational load and speed. This paper presents a novel method for heart sound cancellation from lung sound records using LabVIEW. The method uses the multiscale product of the wavelet coefficients of the original signal to detect HS segments. Once the HS segments are identified, the method removes them from the wavelet coefficients at every level and estimates the created gaps by ARMA model. The results were promising in HS removal from LS without hampering the main components of LS.

Once the results are confirmed, the presented method may be used as a part of LS analysis in lung sound assessment in clinical environment.

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