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A Low Cost, Home Care Smart Stethoscope for Diagnosis of Respiratory Diseases and Heart Rate Measurement

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ABSTRACT

Thedeveloped method presents a new concept for replacing the conventionally used stethoscope with a smart stethoscope. The real time acquisitions of heart and lung sound are initially discussed in the first phase. The second phase extends towards filtering and signal analyzing algorithm implementation. The last phase differentiates the heart rate and lung sound from the resulting waveform. The processed signalsmeasure heart rate and display the real time lung sound signal that can be visually compared with the sound samples of respiratory diseases for its diagnosis. This user-friendly,cost efficient device is thus developed to assist the doctors for arriving in accurate results and conclusions. Since less medical attendant is required, the device could be a home care appliance that can help all age groups in detection of heart and lung diseases.

Keywords: Hardware Design; Filter; LabVIEW; Heart rate;Lung sound; Diagnosis; Smart Stethoscope

1. INTRODUCTION

The 21st century has shown revolution in all areas of science and technology and one of the significant being the products turning smart. This innovation has spread in the medical area in the form of equipment going by the name Biomedical Instruments. The one and only instrument that has not changed since 1816, is the stethoscope invented by Rene Laennec. The Doctors have slung stethoscope since then around their neck, which have been playing a very important role in the department of cardiology until now. However there is huge demand now to remove or replace this decade old instrument from practice considering the advancement in technology.The young doctors mostly prefer the hi-tech medical instruments and this causing the patients to pay huge bill amounts in hospitals.Hence researchers are craving towards development of handy, low cost medical diagnostic devices. The design is verified analytically and then tends to include practical constraints before implementation. Many algorithms have been developed by scientists and academicians in this important arena of diagnosing diseases.

Researchers Arne Bilberg and team have proposed an analyzing tool using LabVIEW which included a complex hardware in acquiring and filtering the real time signal and then processing it to differentiate the systolic and diastolic parts of heart sound [1]. N Ruban, together with his co-authors, has presented an algorithm on separation of heart sound to interpret the heart disorders[3]. Ji Yun Shin and co-researchers have proposed a system to acquire real time heart bio signal to calculate the heart rate using a mobile application [2]. Kadam Patil D.D and Shastri R.K have introduced a wireless electronic stethoscope which performsamplification, filtering, processing using microcontroller and transmission using Zigbee module

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[4]. S.Tanaka and team have introduced a PCG based unconstrained and non-invasive measurement of heartbeat and respiration period using a phonocardiographic sensor [6]. T.Chen and co-authors had proposed an idea of using a cellphone based hands free kit for heart sound diagnosis [5]. Yu-Hsin and co-researchers have developed a heart rate measurement technique with phonocardiogram by online template extraction and matching method [7]. Automatic heart sound signal analysis by using multi scale wavelet transform is another method proposed by Ji Zhong and Fabien Scalzo [8]. In another analysis of heart signals, Shuping Sun and his colleagues have described an automatic moment segmentation and peak detection analysis of heart sound pattern via short time modified Hilbert transform [9].Sandra Reichert and partners have done a study in the art of analyzing respiratory sounds[10]. Todd R Reed, Nancy E Reed and Peter Fritzson have described and presented on heart sound analysis for symptom detection and computer-aided diagnosis [11]. M.Golabbakhsh and colleagues have developed respiratory flow estimation method from tracheal sound using adaptive filters [12].In another study of heart analysis, D.Janusek and colleges have presented a simulation of T-wave representation performed by changing the ventricular heart cells action potential duration [13]. Literatures have reported several methods to innovate the stethoscope in a more efficient manner and different analysis method of heart [14] and lung sounds have also been described.

A normal stethoscope can be used to hear heart and lung sounds mainly. Generally a stethoscope is used to recognize some lung diseases such as crackles, stridor, wheeze etc. In combination with a sphygmomanometer, it is commonly used for measuring the blood pressure.

The designed work can be divided into 2 parts mainly: the modification of diagnosticprocess used in the normal stethoscope and secondly, the development of analyzing algorithm in LabVIEW. The algorithm is designed to accurately filter out the real time sound signal for visual signal display and to find the necessary parameter related to the sound taken into account. Ultimately, the main objective is to measure the heart rate and to detectvarious respiratory diseases by onscreen comparisons between real time and sample sound signals.

The proposed device is a smart stethoscope.This provides a perfect alternative instead of removing all these instruments from use. The design of the smart stethoscope is simple and can be manufactured easily by modifying the conventional stethoscope. The product is designed to give better results with visual comparisons and make it cost efficient as well.

2. METHODOLOGY

The flowchart summarizing the method is shown in the Fig.1 given below.

The developed smart stethoscope is a no battery operational simple system incorporated with an audio-microphone interface supplying power and signal communication.

2.1. Hardware Design and Development

The device is designed with at most simplicity using least components: stethoscope, mobile earphones with electret microphones. The electret microphone of the earphones is inserted within the tube of stethoscope for acquiring the sound. The hose is blocked from all other ends except the reception area to cancel out the noise factor as shown in Fig. 2

The user (doctor) can listen to the heart sounds while the microphone acquires the signal. The microphone and audio jack is connected to a laptop or computer audio input, carrying the analyzing software.

2.2. Measurementof Heart Rate

The block diagram shown in Fig. 3 clarifies the methodology of heart sound acquisition and signal processing done by the smart stethoscope. The description of each block is as follows:

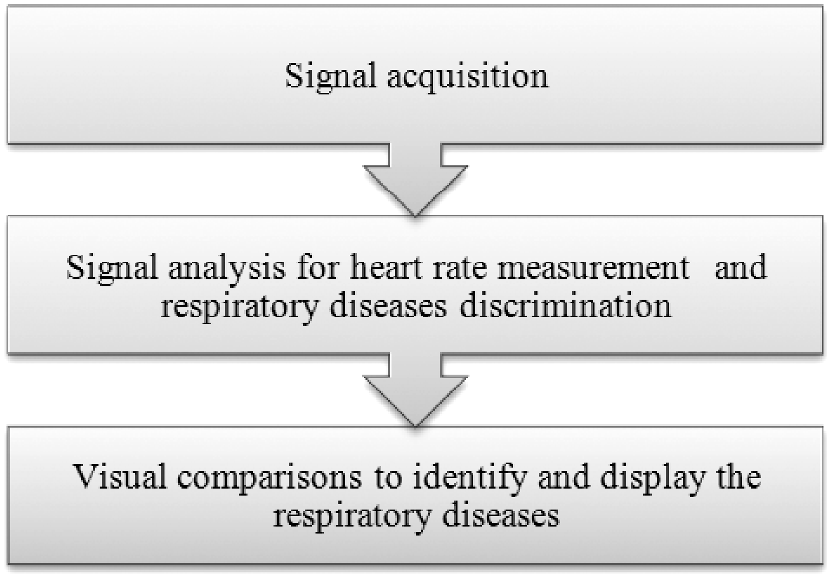

Figure 1: Flowchart showing summarized process

Figure 2: Smart stethoscope designed from conventional stethoscope

The procedure starts with the process of acquisition of heart sound using the electret microphone which is embedded within mobile earphones attached to the inner part of normal stethoscope tube protected against noises.

The stethoscope head is tobe placed where the heart sound can be heard properly towards the left of our body.The processing software tool undertakes the sound for 10s using voice recorder block function which is available in the LabVIEW library and a sample screenshot in included in Figure.4 This duration period of recording is variable and can be altered.The band pass and low pass filtersremoves the noise available within library. The frequency range is 20-200Hz for band pass filter [3].Low pass filter at a frequency 15Hz is applied to obtain the envelope of the signal [3].

The filtered signal is then amplified since amplitude of the signal would be in few microvolts, and would not help hearing the sound as well. The amplified signal is passed on to the final stage to a waveform

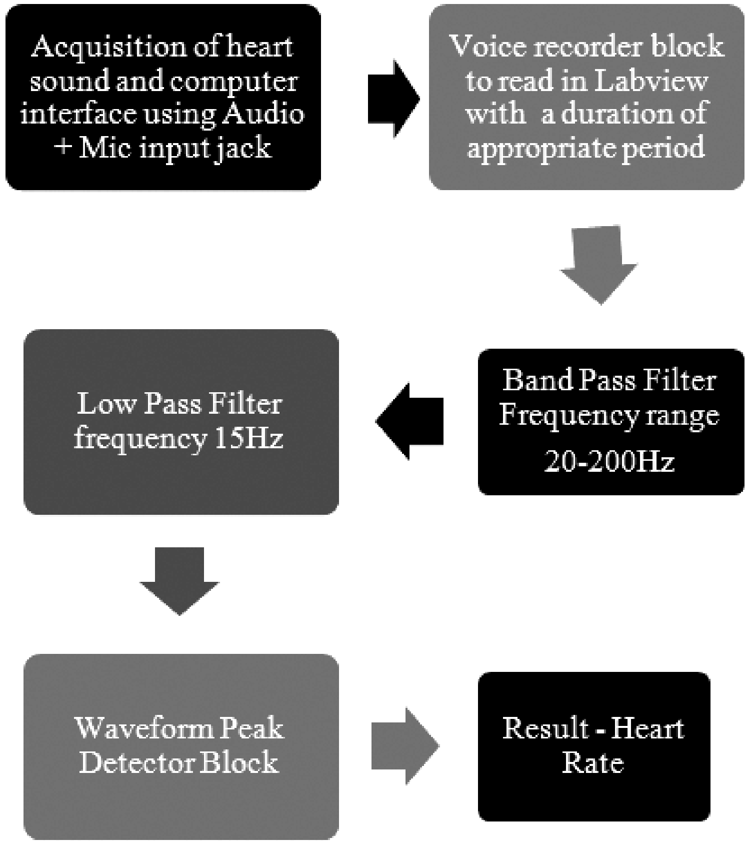

Figure 3: Heart sound analysis

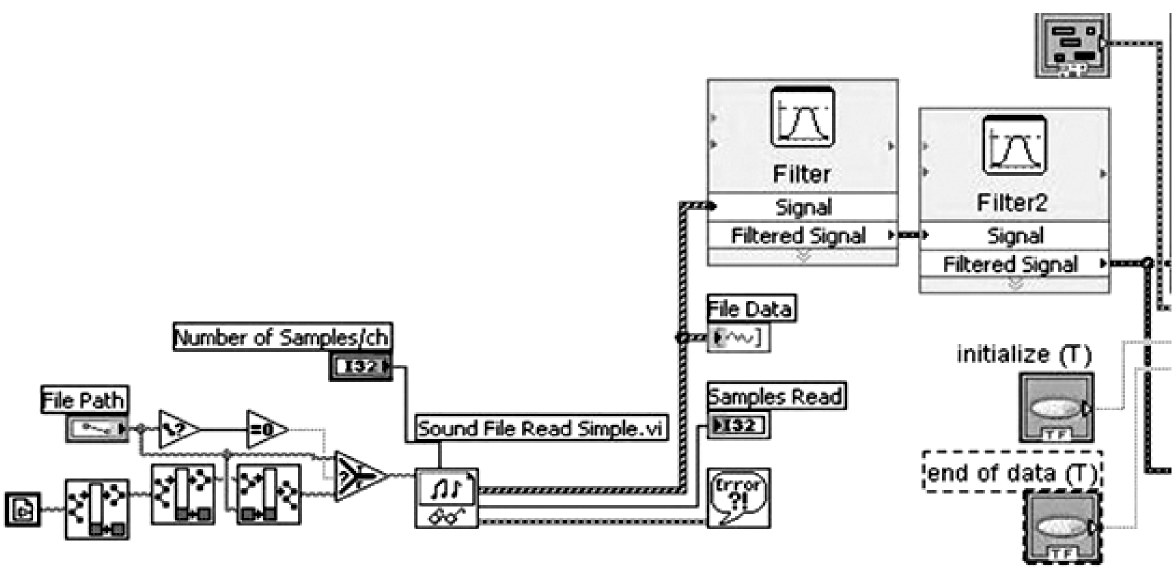

Figure 4: Sample Labview Screenshot

peak detector that finds the number of peaks present in that particular time duration and thereby obtains the heart rate.The heart rate and the waveform that shows the systolic phase/S1 and the diastolic phase/S2 that constitute a heart signal are displayed.

2.3. Diagnosis of Respiratory Diseases by Visual Comparisons

The block diagram implicating the methodology of lung sound analysis is shown in Fig. 5. The description along with the block diagram is as follows:

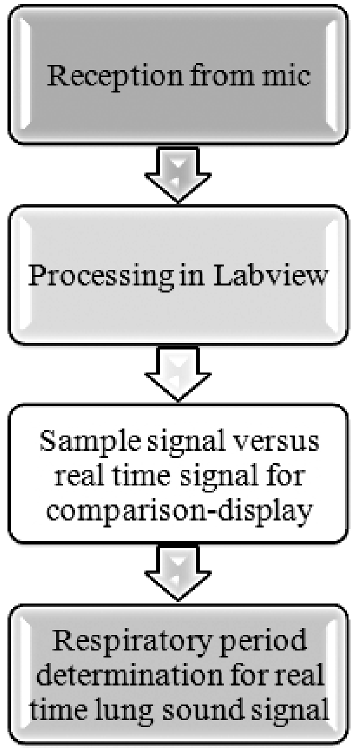

Figure 5: Lung Sound Analysis

- The placement of the stethoscope head is the only change when considering lung, as it should be placed more to the right to acquire the appropriate respiration sound. The acquisition process remains the same as the heart sound.
- The real time signal is filtered to remove noise using band pass filter in a frequency range of 50-200Hz.
- Sample sound signals of diseases such as stridor, crackles and wheezes are also processed along with real time sound signal processing for final diagnosis. The diseases taken are those that can be diagnosed using a conventional stethoscope.
- Waveform of the real time signal along with sample diseases plots are displayed for visual comparisons and diagnosis. The respiratory periods of all these are also displayed.

2.4. Algorithm Development

The signal is acquired for minimumtime duration of 10s and allowed on to filtering. Based on the change in time, the program self-adjusts in order to give accurate result. The filtered sound is amplified for at least a gain of 3000 since the maximum voltage peak of the signal would be in microvolts. The amplified signal is subjected to waveform peak detection block which finds the number of peaks available in the waveform for the same duration based on given threshold. The threshold changes with respect to age range. A range between 18-25yrs, threshold is 0.13. This value was chosen based on training set samples. The threshold value for a person other than this age range will differ only by a max of +/- 0.03. The value obtained is subsequently used to find the heart rate per minute using the formula given in eqn (1):

$$\text{Heart Rate} = \text{No. of peaks found} * (60/\text{duration of capturing the signal}) \quad (1)$$

The respiration period of the lung sounds acquired is calculated using similar method and formula (eqn.1) for the given samples. A case structure is used to toggle between the 2 function programs in LabVIEW and highlighted in Table 1.

Table 1
Case Structure

Case	*Organ*	*Status of Light*
TRUE	Heart Analysis	ON
FALSE	Lung Analysis	OFF

If "True" and the green light appear then heart analysis is done and if "False", the green light disappearsto show that the lung analysis is being done. This has to be chosen by doctor inside the software while consulting a patient.

3. DISCUSSIONS AND RESULTS

The smart stethoscope is a biomedical device that consists of hardware and software interfacing development that contributes to the world of medical arena in a positive manner [15]. The result presents the whole process of product innovation from an idea to a working prototype.

The LabVIEW front panel figures presented helps in understanding this product as a whole. The prototype was validated with the help of volunteers mostly in the age group of 18-25. The results shown are of a particular volunteer of age 21yrs.

Fig. 6 shows the heart sound analysis and Fig. 7 shows the lung sound analysis along with processed sample sound signal waveform display for visual comparisons.

The systolic and diastolic phases that constitute a heart sound can be differentiated easily in the waveform displayed of real time signal.

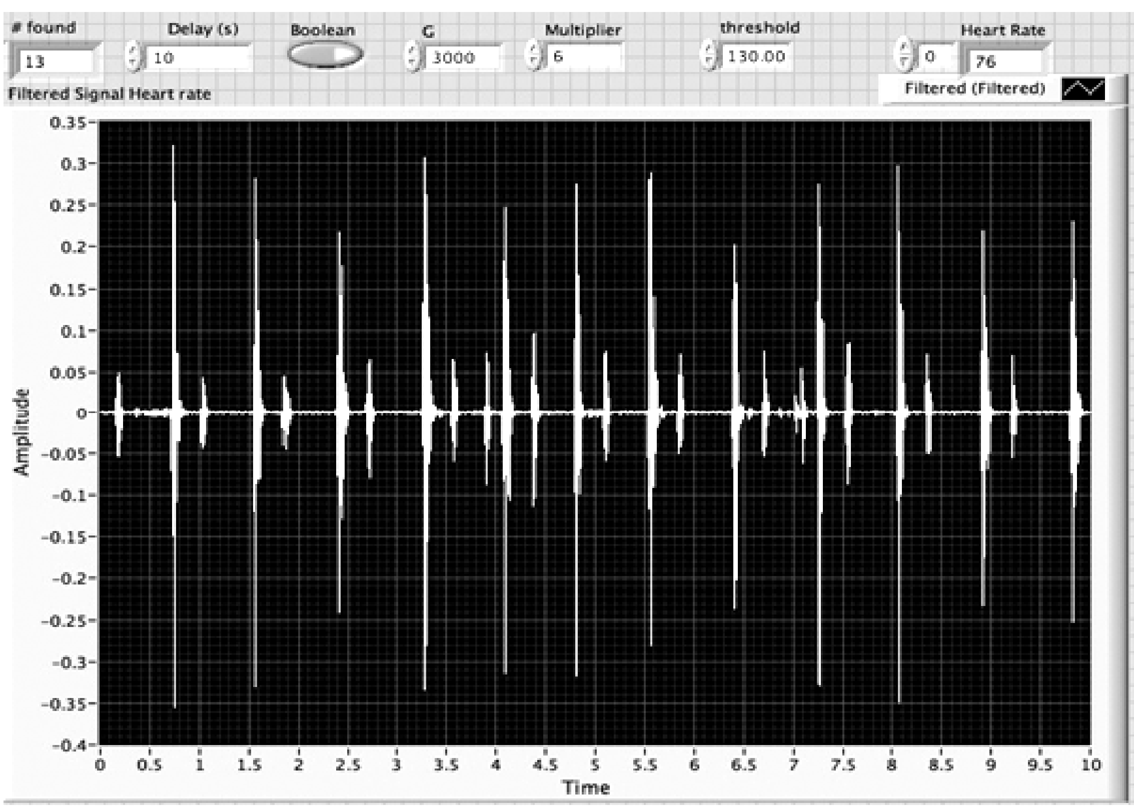

Figure 6: Heart sound Analysis

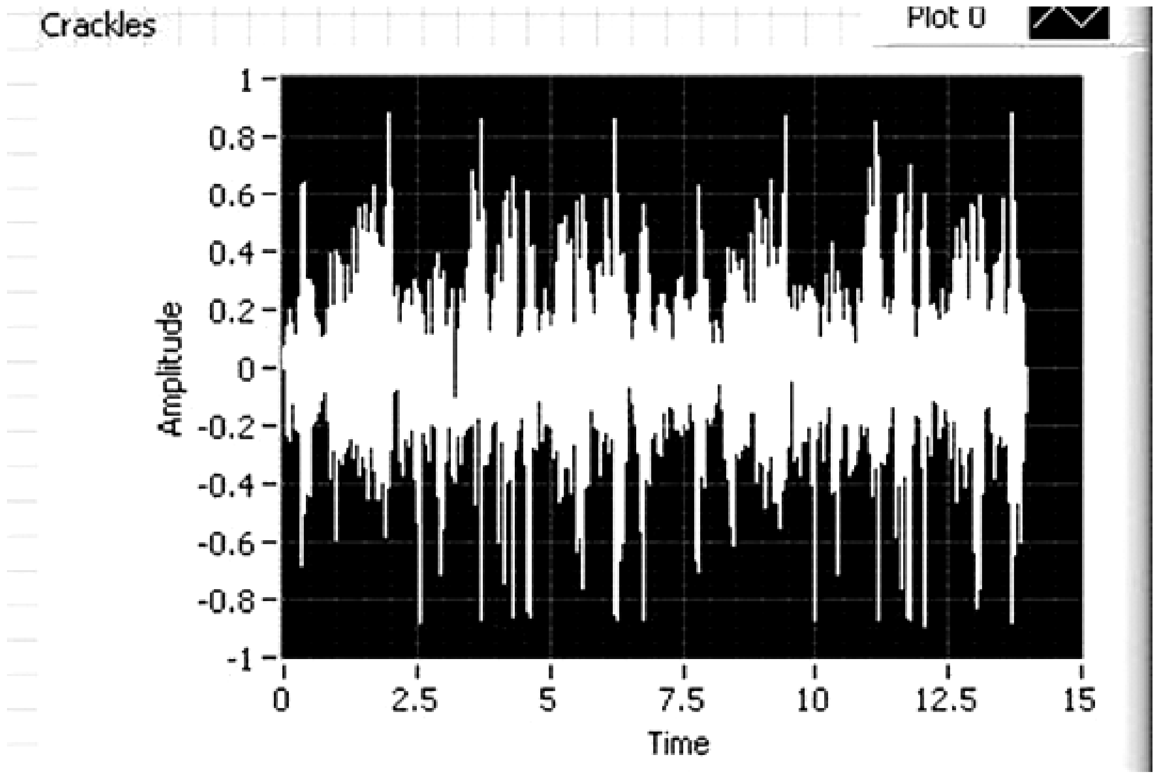

Figure 7: Lung sound analysis – Screen shot showing the waveform display for the disease, crackles

4. CONCLUSIONS

The smart stethoscope is cost efficient and user-friendlyequipment to help physicians to arrive at accurate results and conclusions. It offers a new homecare medical device, a useful doctors' assistant, and a new way to use the conventional stethoscope by giving a very small at the same time a simple innovative design. The algorithm behind the analysis software is found to be effective as well as simple. It helps in diagnosis of respiratory diseases and disorders based on heart rate. The equipment features a plug and play method making it like a toy for doctors and would always keep them interested in using this age's old medical equipment.

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