Scientific Journal Impact Factor (SJIF): 1.711

e-ISSN: 2349-9745
p-ISSN: 2393-8161

International Journal of Modern Trends in Engineering and Research
www.ijmter.com

Automatic RR Interval Measurement from Noisy Heart Sound Signal

Smart Stethoscope

Bharat Verma[1], Dr. Arun Kumar Wadhwani[2]
[1,2]*Electrical Engineering Dept., MITS, Gwalior*

Abstract— Heart sound is a physical property of heart which contains many information about the cardiovascular system and also do have relation with pulses. In Ayurveda theory the diagnosis depends on pulse duration and time difference between successive pulses. In the present work, heart sound is measure and analyzed for abnormalities detection. Heart sound recorded by using Electronic Stethoscope which contains capacitive transducer. The recorded Signal is then filtered firstly by hardware active filter and then by Wavelet transform in LabVIEW software environment. Also an algorithm is developed for finding optimum peaks present in recorded signal which in turn are the RR interval of ECG waveform. It is found that the proposed method of determining RR interval is parallel to existing methods using ECG signals.

Keywords- Heart Sound, Optimization, RR Interval, Bio-Medical, Instrumentation.

I. INTRODUCTION

Ancient Indian medical science depends upon the pulse measurement for diagnosing diseases of patients. In Ayurveda there are three type of pulses and time difference among those contains all information about body. In fact that pulses partially depended on heart sound. So the measurement of pulse duration and time difference could revel some interesting facts. ECG technique is growing over Heart sound since last few decades whereas heart sounds can give lots of information over ECG .We developed a hardware which record heart sound and an algorithm which automatically finds peaks in signal and hence measures the RR interval which measured by ECG. The algorithm is developed in LabVIEW environment Pattern of the sound depends upon the body structure. Algorithm developed always gives optimum results unlike other evolutionary technique which always gives some error and also algorithm can identify all available number of optima from the signal instead of best one.
Most Available instruments in medical field for primary detection focusing on the phonocardiogram. There are many instrumentation available in market which only displays the phonocardiograph without any audio profile of signal. Traditional way of initial screening of patient done by the stethoscope gives only audio profile of sound signal which does not provide an accurate information about the timing between pulses. There is also available dedicated sensors for physiological measurement [5]. Piezoelectric effect based sensors are widely used for the measurement of the low pressure signals [3]. These instruments just stores phonocardiogram.

This paper discuses, how to use capacitive transducer for measuring of heart sound. Paper also discusses de-noising of heart sound signal and the algorithm for measuring automatic RR interval and finding optimum peak of the signal. Other pulse measurement technique mostly use windowing of signal for measuring heart rate but windowing of signal also attenuate amplitude. The sound vibration is captured by the diaphragm in stethoscope which creates deflection in capacitor plate. Change in value of capacitance will be proportional to the input sound vibration. Wavelet de-noising technique [6] is used for extracting the sound of interest. The RR interval can be measured by the phonocardiograph

II. METHODS

2.1. Sensor Placement and Working

Phonocardiogram pattern depends upon the physical structure of body and may varies person to person. Heart contains four valves two upper and tow lower known is tricuspid and semilunar valve. The sounds Split1 (s1) and Split2 (s2) are generated in physically fit person with a uniform time difference. S1 is generated by the closing of the mitral and tricuspid valve there may be some lag between closing of these two valves. Similarly the second heart sound S2 generated due to the closing of the semilunar valve (i.e. the aortic and pulmonary valve) [2].

S1 and S2 amplitude depends upon the placement of the stethoscope. Near the semilunar valve S2 intensity will be higher than S1. Likewise Intensity of S1 will be higher stethoscope near the atrioventricular valve. We can record signal with equal amplitude if we place stethoscope just between the aortic and the tricuspid valve.

The current equation in a RC network, when the capacitance is variable and the voltage is constant is given by;

$$i = r * d(C * E) / dt \qquad (1)$$

But because the voltage is constant and the capacitance is variable then the equation will be like

$$i = r * E * d(C) / dt \qquad (2)$$

Where: i = Current [AMP]
r = Resistance [Ohm]
C= Capacitance [F]
E = Input DC Voltage [V]
t= Time (sec)

From the equation 2 it can be seen that the change in capacitance is proportional to the current. The current further converted into the voltage. We use the DC voltage source for measuring the capacitance.

The voltage is transferred to the computer via 4711a DAQ hardware. Data can be processed with the help of LabVIEW.

2.2. Signal Processing in LabVIEW

An indigenous capacitive sensor based Sound recording system in LabVIEW software is used for the data analysis and acquisition. LabVIEW software is used for the data analysis and acquisition. Signals have been filtered by the third order low pass filter with inverse chebyshev topology. The cutoff frequency is of 200 Hz. Because the heart sounds frequency lies in the range of 40Hz to 60Hz (Ansourian's research [3]). After filtering the signal, that can be stored or can be processed further which is user defined. In further processing the signal passed to the Wavelet de-noised block in LabVIEW [6].

There are three performing VIs and one main VI for initial interfacing. Acquire signal contains a code for interfacing of LabVIEW to the Hardware. Data Entry is for saving the information about patients and Analysis VI perform algorithm for finding interval and other time domain analysis.

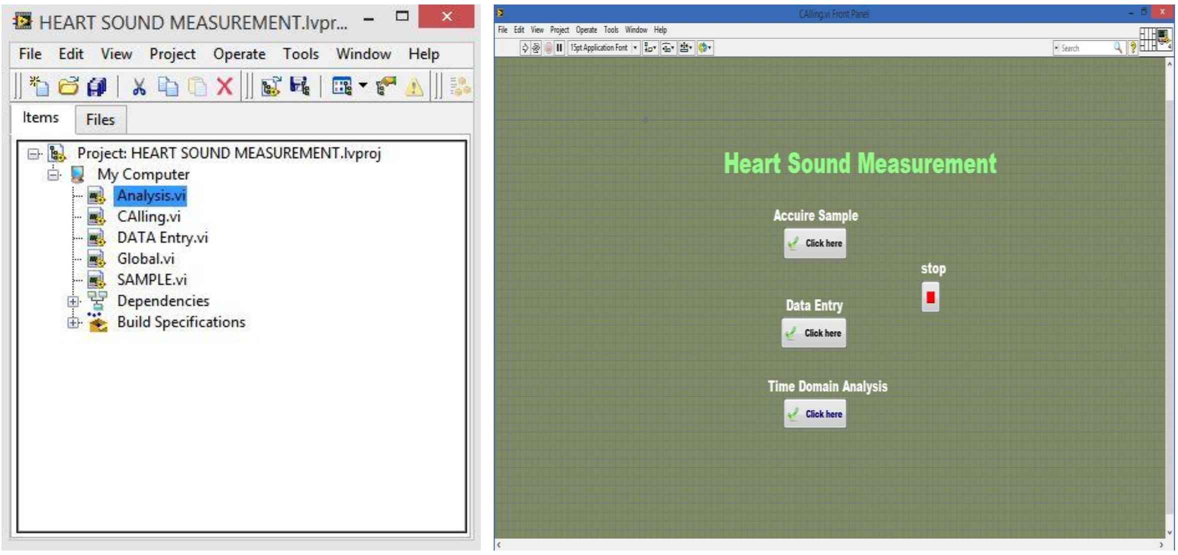

Figure 1: LabVIEW project window on left and the main 'CALLING' VI running on right.

2.3. LabVIEW Code and Algorithm

This algorithm identifies optimum peaks and measures difference between the first and third peak. Algorithm is spatially designed for the Heart sound signal for measurement of the RR interval. RR interval is the difference between the first 'Lub' or S1 sound and second 'Lub' S1 sound. As we know that a cardiac cycle is a series of 'Lub-Dub' sound technically S1-S2 sounds.

Flow chart of algorithm is shown in 'figure 3'. Signal is first save using 'Acquire Sample' VI which capture signal from the hardware. After acquiring input which will be in sampled form, DAQ 4711a support 150k sample. The data is stored for 2 sec that means there will be 300k sample available for processing. LabVIEW load signal and store in array of 300k x 2 dimension first row will contain the amplitude and second row will be of sample numbers. N is the max number or peaks which we want to store in output array. 'th' is the threshold value of time required for discriminate two peaks. We use an inbuilt VI 'PeakDetector' in LabVIEW which find out all available peaks in signal. There is two output from peak detector one is the index of corresponding peaks and second is the 1D array of identified peaks. Then we sort the array of peaks in descending order and kept only top 10 value because heart sound signal is of 2 second. And hence we create a new 2D array which contains peaks and corresponding index. According to the threshold value we identifies first S1 and Third S1 sound, which difference gives the RR interval (Code is written in MathScript Node).Value of 'th' here we consider 0.3sec.

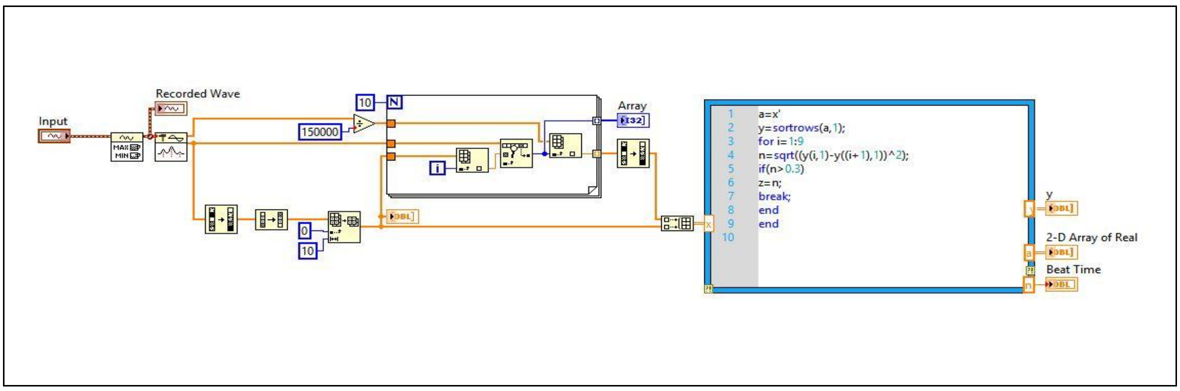

Figure 2: LabVIEW implementation of Algorithm

The LabVIEW VI code for algorithm is shown in figure 2. This is only a sub-VI which is used in main VI code for measuring in the 'Time Domain Analysis' window.

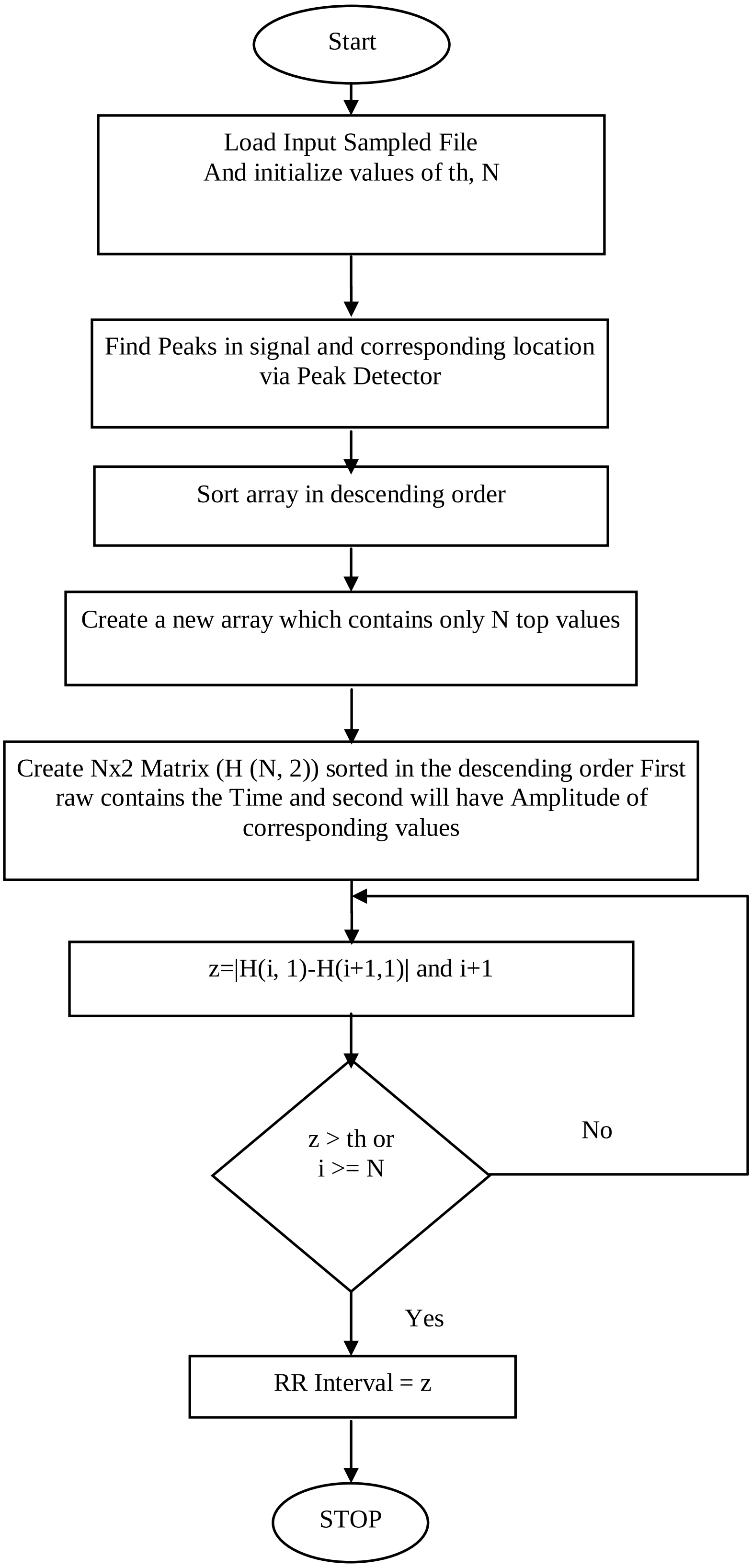

Figure 3: Flow Chart of Automatic RR interval Measurement

III. RESULTS

The proposed methodology is tested on twenty different subjects of different age groups. Figure 4 show the recording of one subjects. First signal is directly captured from the hardware in figure 4(a) and second figure 4(b) which is filtered via software. Algorithm give accurate results for the filtered signal instead of the raw signal. Signal from the hardware contains noise and sometimes peak detector also consider low voltage level as a peak. This happened with only one person till now whose sound signal was very weak due to the fat around the heart(max peak was about 0.5 V). Apart from that case the algorithm gives accurate results for both type of signal noisy or filtered.

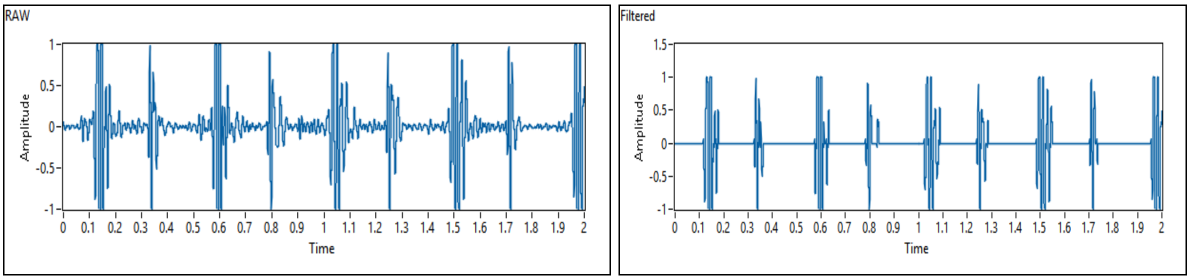

Figure 4: a) Raw DATA), b) Signal after LabVIEW filtering (Filtered)

Control panel output window is given below in which we can see that there is automatic measurement which automatic measure RR interval as you load the signal and second is the manual measurement in which we can measure via cursor operation on the waveform window.

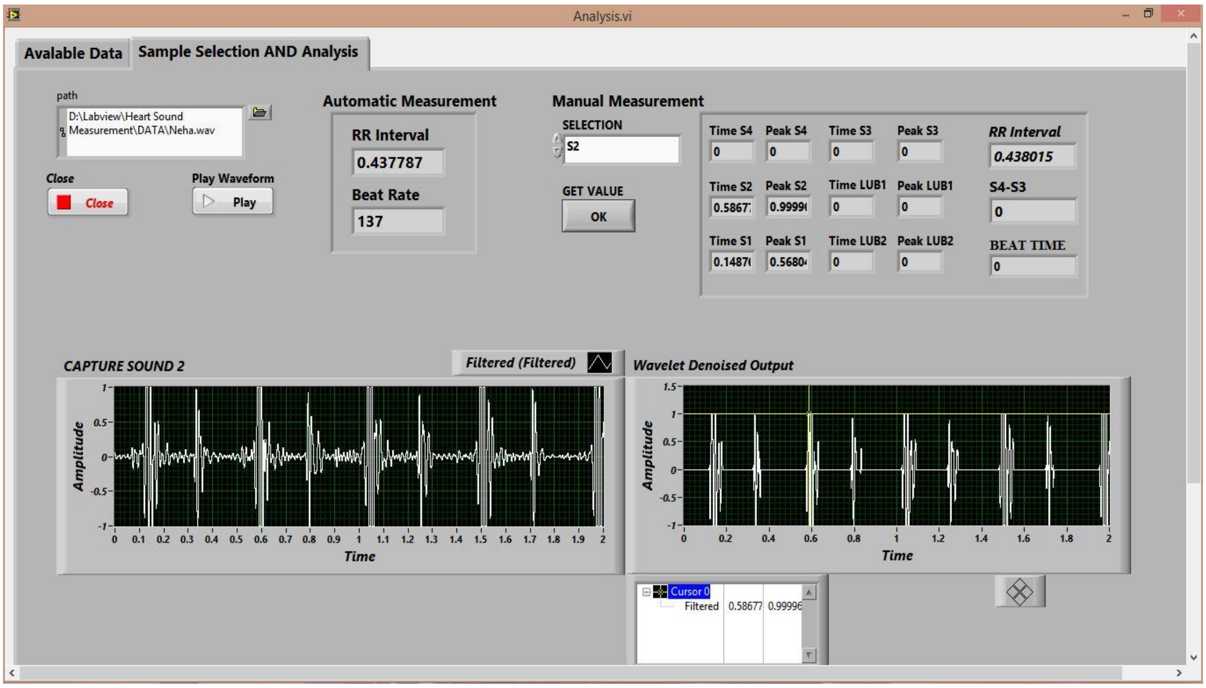

Figure 5: Project's main output Control panel window

Table 1 is showing results for five subjects whose RR interval is also measures with the ECG machine.

Table 1: RR interval measured from our Device and algorithm and from ECG machine

Subjects	RR Interval from Device (sec)	RR interval from ECG machine (sec)
s1	0.886133	0.887
s2	0.766513	0.766
s3	0.437787	0.437
s4	0.860317	0.860
s5	0.691923	0.700

III. CONCLUSION

In this paper we discussed about the use of the capacitive transducer as a heart sound measuring sensor. We also discussed how to place a sensor on chest for recording heart sound, by placing the stethoscope just between the aortic and the tricuspid valve we can record S1 and S2 sound of the almost equal amplitude. Signal is recorded in computer with the help of Advantech 6711a DAQ device. We applied software low pass filter with inverse chebyshev topology and wavelet de-noising technique for removing noise. The algorithm we develop identifies the available numbers of peaks and hence finds difference between the first S1 and second S1 peaks which will gives the RR interval.

The device is not costly almost made with the generic components. Size of instrument will be very small (equal to a mobile phone charger) if we use SMD component also there will be less noise and low power consumption. We designed algorithm especially for the heart sound signal but the algorithm can be used on any signal where we want amplitude and difference between the two peaks. Algorithm can be able to modify easily by changing the value of N and 'th' so it can also be useful for other type of signals like Pulse Oximetry. In future one can also use the instrument for comparing the pulse theory to the heart sound interval.

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