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Detecting Abnormalities in the Heart Valve

Ambika R[1]

Associate Professor, Department of ECE, BMS Institute of Technology and Management, Bengaluru, India[1]

Abstract: "Cardiac murmurs" are noise associated with deviation in blood flow dynamics and improper closure of valves. The whooshing sound is produced by blood flow across abnormal valves or due to abnormal connection between heart chambers. There are various equipment like ECG recording electrical activity of heart and echocardiography depicting structure of heart using Doppler waves. But these equipments require hospitalization and may be expensive to the patient. Clinical tool like stethoscope helps physician to know about heart murmurs, this require expert opinion and a trained ear of a doctor.

Keywords: Diastolic, Heart sounds, Murmurs, Stethoscope, Systolic.

I. INTRODUCTION

The heart sounds provide crucial diagnosis information for several heart diseases such as natural or prosthetic valve dysfunction and heart failure. Many pathological conditions of the cardiovascular system cause murmurs and aberrations in heart sounds. The advancement of intracardiac phonocardiography, combined with modern digital processing techniques, has strongly renewed researcher's interest in studying heart sounds and murmurs. Cardiac auscultation is widely used by physicians to evaluate cardiac functions in patients and detect the presence of abnormalities. Because phonocardiography (PCG) can provide valuable information concerning the function of heart valves and the hemodynamic of the heart, it has a high potential for detecting various heart diseases. But all the existing techniques require expertise opinion to help in diagnosing a condition. All of these require trained technicians, specialized equipment.

Clinical tool like stethoscope helps physician to know about heart murmurs without expertise help, yet disadvantages still persists. So there is a requirement of system that can effectively detect cardiac murmurs and can be implemented easily. Under normal conditions, the heart provides two major audible sounds (S1 and S2) for each cardiac cycle. Two other sounds (S3 and S4), with lower amplitudes than S1 or S2, appear occasionally in the cardiac cycle due to the effect of diseases or age .The first heart sound S1, corresponding to the beginning of ventricular systole, is due to the closure of atrioventricular valves. This sound is composed of two internal components: the mitral component (M1), associated with the closure of the mitral valve, and the tricuspid component (T1), associated with the closing of the tricuspid valve.
The second heart sound, marking the end of ventricular systole and signifying the beginning of the diastole, is made up of two components: the aortic component (A2), corresponding to the closure of the aortic valve, and the pulmonary component (P2), corresponding of the closure of the pulmonary valve. Valvular pathologies induce significant changes in the morphology of the phonocardiogram signal (PCG). On the other hand, systolic and diastolic murmurs of different shapes can be added to the PCG signal to build a track resulting from a given disease. The first step in this implementation is to obtain the real time signal. The system uses a sensor module using which the real time signal will be converted into electrical signals. Further these signals are given to the system via a PIC microcontroller. Then a MATLAB program is developed to perform simulations on the data to detect murmur.

II. LITERATURE REVIEW

An electronic stethoscope, which is based on embedded processors, is designed to fulfill the shortages from the auscultation [1]. It converts acoustic sound into electrical signal and this signal is amplified and heard on speakers, so there is no need of headphone for listening heart sounds. Heart Beats per Minute (HBM) is displayed on LCD. The cardiac sound waveform is displayed using MATLAB on a PC via UART interface of the microcontroller. It serves as a platform for potential Computer Aided Diagnosis (CAD) applications for the detection of cardiac murmurs which offers signal amplification and also added functionalities like storage, analysis and visual representation of sound signals

Paper [2] presents complete process and steps involved in FPGA based Computer Aided Diagnosis of cardiac abnormalities. Quality of the recorded heart beats is likely to be affected as the signal would be corrupted with noise. To overcome this problem Adaptive Line Enhancers (ALE) are used to eliminate the wide band noise and ALE, an adaptive noise cancellation technique is implemented with Least Mean Square (LMS) algorithm. The computation speed and noise rejection capability of DSPs do not serve the purpose. Since the FPGA is highly flexible, recursive algorithms are implemented in this device. The paper presents all the design steps involved in design of FPGA based phonocardiograph.

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Heart sounds give us information about the state of the heart [3]. Heart diseases can be detected at an earlier stage by analyzing the heart sounds. In this paper, detailed discussion of various methodologies that have been used earlier to analyze the heart sounds has been carried out. Comparison has been done on the basis of methodology used and the performance achieved.

A new robust approach for separation of murmur from heart sound has been suggested in this article [4]. Singular spectrum analysis (SSA) has been adapted to the changes in the statistical properties of the data and effectively used for detection of murmur from single-channel heart sound (HS) signals. Incorporating a cleverly selected a priori within the SSA reconstruction process, results in an accurate separation of normal HS from the murmur segment. Another contribution of this work is selection of the correct subspace of the desired signal component automatically. In addition, the sub space size can be identified iteratively. A number of HS signals with murmur have been processed using the proposed adaptive SSA (ASSA) technique and the results have been quantified both objectively and subjectively.

III.IMPLEMENTATION

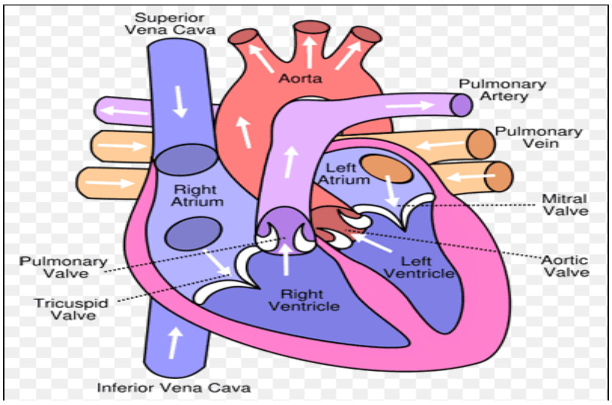

Fig.1. Cardiac Structure

The heart has four chambers, two upper atria which are the right atrium and the left atrium, the receiving chambers, and two lower ventricles which are the right ventricle and the left ventricle, the discharging chambers. It also has four main valves namely: Tricuspid valve, Mitral valve, Pulmonary valve and Aortic valve. The valves ensure blood flows in the correct direction through the heart and prevents backflow.

Tricuspid Valve: Between the right atrium and the right ventricle is the tricuspid valve, this prevents the back flow of blood into the atrium when the ventricle contracts. The tricuspid valve prevents back flow of blood from the right ventricle into the right atrium during ventricular systole when it closes and allows blood to flow from right atrium into right ventricle during ventricular diastole when it opens. The back flow of blood is also known as regression or tricuspid regurgitation.

Mitral Valve: Between the left atrium and left ventricle is the mitral valve, this valve also prevents the back flow of blood into the atrium. During diastole, a normally-functioning mitral valve opens as a result of increased pressure from the left atrium as it fills with blood. As atrial pressure increases above that of the left ventricle, the mitral valve opens. Opening facilitates the passive flow of blood into the left ventricle. Diastole ends with atrial contraction, which ejects the final 20% of blood that is transferred from the left atrium to the left ventricle. This amount of blood is known as end-diastolic volume, and the mitral valve closes at the end of atrial contraction to prevent a reversal of blood flow.

Pulmonic Valve: The **pulmonic valve** allows blood to leave the heart via the arteries. It is a one-way valve, meaning that blood cannot flow back into the heart through it. The valve is opened by the increased blood pressure of the ventricular systole (contraction of the muscular tissue), pushing blood out of the heart and into the artery. It closes when the pressure drops inside the heart. It is located in the right ventricle of the heart. The pulmonic valve opens into the pulmonary artery. The frequency of this cycle depends upon the heart rate. **Pulmonary stenosis** is a condition where the blood flow out of the heart is obstructed at the pulmonic valve. The most common cause of this is congenital heart disease, although rheumatic heart disease and a malignant carcinoid tumor can also initiate the problem. The condition is treated by surgical repair or replacement of the pulmonic valve.

Aortic Valve: When the pressure in the left ventricle rises above the pressure in the aorta, the aortic valve opens, allowing blood to exit. It closes off the lower left chamber that holds the oxygen-rich blood before it is pumped out to the body. Opens to allow blood to leave the heart (from the left ventricle to the aorta and on to the body). The aortic valve functions to prevent the regurgitation of blood from the aorta into the left ventricle during ventricular diastole and to allow the appropriate flow of blood—the cardiac output —from the left ventricle into the aorta during ventricular systole.

Blood Flow:

The heart works as a pump in the circulatory system to provide a continuous circulation of blood throughout the body. This circulation consists of the systemic circulation to and from the body and the pulmonary circulation to and from the lungs. Blood in the pulmonary circulation exchanges carbon dioxide for oxygen in the lungs through the process of respiration. The systemic circulation then transports oxygen to the body and returns carbon dioxide and relatively deoxygenated blood to the heart for transfer to the lungs.

The right heart collects deoxygenated blood from two large veins, the superior and inferiorvena cava. The blood collects in the right atrium and is pumped through the tricuspid valve into the right ventricle, where it is pumped

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into the pulmonary artery through the pulmonary valve. Here the blood enters the pulmonary circulation where carbon dioxide can be exchanged for oxygen in the lungs. This happens through the passive process of diffusion.
In the left heart, oxygenated blood is returned to the left atrium via the pulmonary veins. It is then pumped into the left ventricle through the mitral valve and into the aorta through the aortic valve for systemic circulation. The aorta is a large artery that branches into many smaller arteries, arterioles, and ultimately capillaries. In the capillaries, oxygen and nutrients from blood are supplied to body cells for metabolism, and exchanged for carbon dioxide and waste products.

Abnormalities

There are many valvular disorders and other cardiac diseases which occur due to the different hemoglobin activities and the abnormal activities due to the different cardiac structures.

Cardiac Murmers

Heart murmurs are heart sounds produced when blood flows across one of the heart valves that is loud enough to be heard with a stethoscope. There are two types of murmurs. A functional murmur or "physiologic murmur" is a heart murmur that is primarily due to physiologic conditions outside the heart.

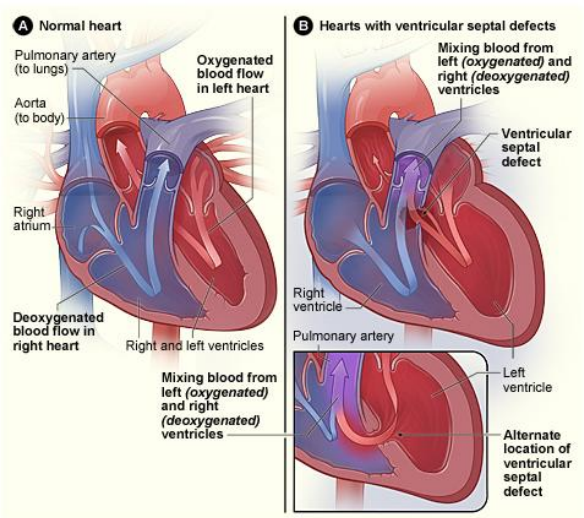

Fig. 2. Heart Defects: Ventricular Septal Defect

The first step in this implementation is to obtain the real time signal. The system uses acoustic sensor to obtain the real time signals and a transducer using which the real time signal will be converted into electrical signals. Further these signals are processed using MATLAB. Then the MATLAB program is developed to preform simulations on the data to distinguish between innocent and abnormal murmur. The heart beat frequency lies in the range of 25-250 Hz, whereas the heart murmur frequency lies in the range of 700-1200 Hz. Hence the program must be able to differentiate these frequency ranges and give result whether it is innocent or abnormal murmur.

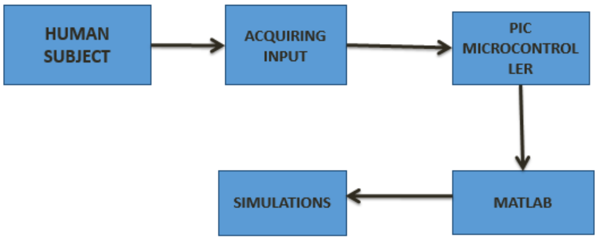

Fig.3. Block Diagram

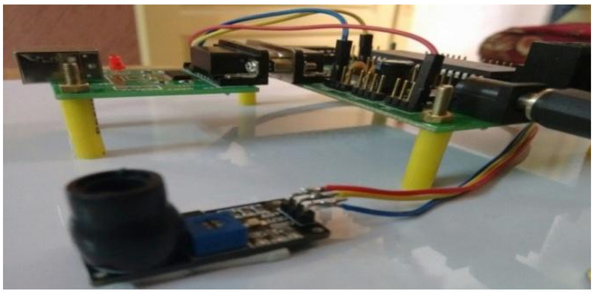

Fig. 4. Module Developed

IV. RESULTS

The captured output from microcontroller for normal and murmur patients is as follows in fig.5 and Fig.6 respectively.

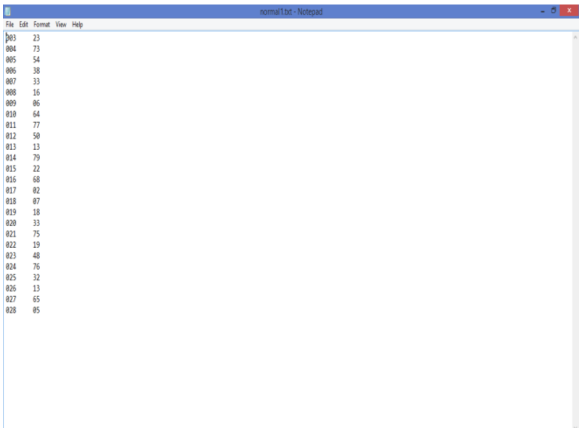

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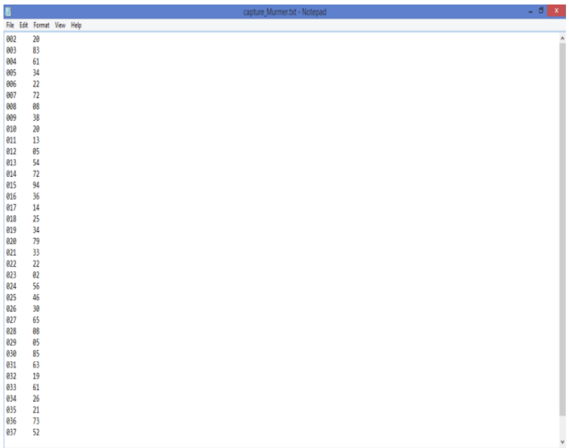
Fig.5. Captured Output for a Normal Person



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025	46
026	30
027	65
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030	85
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032	19
033	61
034	26
035	21
036	73
037	52

Fig. 6. Captured Output for a Murmur Person

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These are the values of obtained on the RA4 pin of PIC microcontroller. These values depict the intensity of the sound that was detected at the sensor module, and hence are in decibels (dB). These values are used later in the MATLAB programming by reading the text file in order to obtain the simulation.

From the values obtained, it is evident few higher notes are observed for the captured sounds of a heart suffering from murmur. These peaks in sound intensity is also very significant in the MATLAB simulation results shown in the below figures. The final result we obtained to distinguish between normal heart beat sound and murmur is in the below two graphs fig. 7 and fig. 8. Fig. 7 showing the heart wave for a normal patient is steady between a range of frequencies. The peaks lie between the frequency that has been researched and found as the frequency range for normal beating heart in a human body, which is up to 250Hz.

The second graph shown in Fig. 8 is the heart wave captured for the heart of a patient suffering from cardiac murmur. The whooshing or rasping sound that is produced due to abnormalities of the heart such as regurgitation or stenosis, cause sudden peaks that are abnormal.

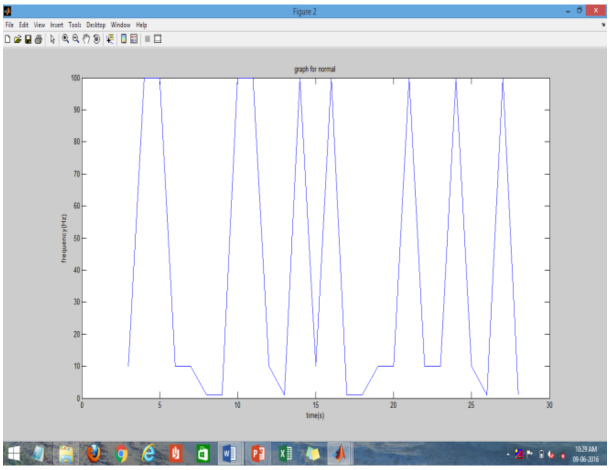

Fig. 7 Graphical representation of Normal Heart

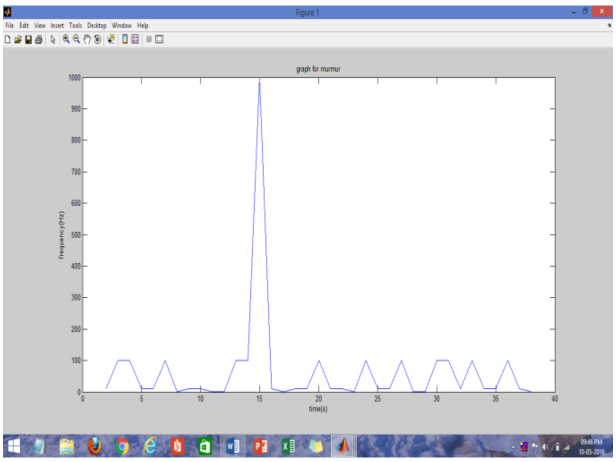

Fig. 8 Graphical representation of Cardiac Murmur Patient

The cardiac sounds produced by a heart for a person suffering from cardiac murmur lie in the frequency range that is higher than normal, and is found to be above 750Hz.

V. CONCLUSION

The heart is one of the vital organs of the body. The heart sounds provide crucial diagnosis information for several heart diseases such as natural or prosthetic valve dysfunction and heart failure. Advantages of the implemented method are Economical, easy debugging and simple design. In order to enhance the uses of the system, this can also be combined with other small scale modules that detect and check other parameters of the human body. For instance, a glucose checking module along with body temperature sensor can be integrated. These future enhancements can make the uses such that there is health checkup available to people, even the poor, at the convenience of their time and comfort of their homes. This system can be equipped with alarm system to alert selected relatives or personal doctor.

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