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RESEARCH ARTICLE

DETECTION OF CARDIAC MURMURS

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Abstract: The project describes a system for detecting cardiac murmurs so people are aware about their heart condition. The murmurs are the pathologic heart sounds that are produced because of turbulent blood flow that is enough to cause audible noise. Murmurs can be detected by a stethoscope but the accuracy level is not satisfactory. Different methods have been developed for detection and all are efficient enough but looking cost aspect a system should be designed that detect murmurs easily with maximum accuracy level. The designed system calculates the low energy rate (LER) from the recorded cardiac signals and then classifies the signals and either normal or murmur signal. The system is completely compatible with personal computer or a laptop for data visualization. Under the experiment a large number of people have been tested and results are consulted with a physician too. Results described for system designed to detect murmur classify signal either normal (LER >0.8) or murmur (LER <0.8)

Background

Many studies have worked towards designing system for many detection of cardiac murmur and improving systems accuracy to have better results. Cardiac murmurs can mostly be detected with the help of a simple stethoscope but the results are not satisfactory and the difference process requires special equipments and specialized trained physician. So there is a requirement of a system that can effectively detect cardiac murmurs and that is easy to be implemented.

A computer aided diagnosis algorithm has been designed and implemented on an ultra cyclone II FPGA to detect cardiac murmurs from recorded heart signals, but system is difficult to implement because of use of FPGA board and also it is difficult to interface with computer system. This intent to design a system that is easy to implement, simple to construct. Thus, this research is to develop an electronic stethoscope, that directly fed the cardiac signal to the sound card, amplify the sound and classifies them either normal cardiac signal or cardiac murmurs on the basis of analyzed signal parameters.

Thus, important goal is to achieve better accuracy and to design cost effective and simple system.

Introduction

Murmurs

The murmurs are the pathologic heart sounds that are produced because of turbulent blood flow that is enough to cause audible noise.

Mostly murmurs are normal and can be heard with the help of a stethoscope, during a physical exam and do not require any treatment. Cardiac murmurs, sometimes called as pathologic murmur as they are a result of some problems like narrowing of valves, leaking of valves or presence of abnormal passages from which blood flows in or near the heart [E. Etchell et al, 1997]. However, functional murmurs are heart murmurs due to physiologic conditions outside the heart, so they are also termed as physiologic murmur. Physiologic murmur also referred as innocent murmur as they are occurring under normal conditions causing no problem. But, pathologic murmurs, should be evaluated by an expert. Heart murmurs can also be caused if blood is flowing through any damaged or over worked heart valve [A.R. Freman et al and D. Mason]. The valvular problems may be by birth or may occur later because of ageing process or other related problems as heart attacks, rheumatic fever. Heart murmur can also be classified by using following parameters-frequency, pitch, quality, characteristics, location, shape and duration of murmur. Normal heart signal consists of two sound signal that corresponds to lub and dub phase and these are termed as S1 and S2. There are some other signal activities between S1 and S2 and these are the abnormal sound signals. If we are able to locate the S1 and S2, then individual heart signals can be identified.

Further on the basis of timing cardiac murmur can be –systolic and diastolic.

Intensity can be graded on 6 point scale, where intensity increases from grade 1 to grade 6 type of murmurs.

Different type of heart valve diseases are –

Mitral valve prolapse, in which mitral valve closes completely when left ventricle of the heart contracts, preventing blood from flowing back to left atrium. If any part of valve bulges out so that it does not close properly the mitral valve prolapse. This situation is not so serious but it can result into regurgitation (backward flow of blood). Mitral or Aortic Regurgitation – Backword blood flow occurs with mitral valve prolapse or mitral valve or aortic stenosis. For counter acting this back flow of blood, heart have to work harder to force the blood. But with passage of time, this weakens the heart and leads to heart failure. Mitral valve or Aortic stenosis - These occur as calcium get deposited on valves with age. Mitral or aortic valve both on the left side of heart, become narrowed because of infection (rheumatic fever), or may be narrowed by birth. In this condition heart to work harder to pump enough blood to satisfy the oxygen needs, this leads to heart failure. Aortic sclerosis –It is due to thickening, scarring or stiffening of the aortic valves. This situation is not so serious as the valve can function for years after it is detected. Congenital heart defects - Every year thousands of cases arises having heart defects by birth, these are congenital heart defects. Heart murmur can also be heard by using a stethoscope, then doctor prescribed further tests to check whether it is innocent or by congenital defect.

Following tests are ordered by the doctor to see whether heart murmur is innocent or caused by acquired valve disease or congenital defect.

ECG (Electrocardiogram)- Which measures the electrical activity of the heart.

Chest X-Rays to see if the heart is enlarged due to heart or valve disease.

Echocardiography which uses sound waves to map the heart structure.

Most murmurs can be heard with the help of stethoscope but the results with a normal stethoscope are doubtful. A system based on segmentation techniques and artificial neural network has been implemented as a detector and classifier. The system allows the user to design and create a heart sound classifier to enable the user to select any audio file to be used as input to ANN system [S. L. Strunic]. To show systems ability testing performed to classify type of heart sounds-normal aortic stenosis and aortic regurgitation. An automated cardiac auscultation system implemented for detection of pathologic heart murmurs. The cardiac sound signals were low pass filtered at 1000 Hz and converted to time scale domain using continuous wavelet transform method. The derived energy values, expressed in decibels are relative. Data were analyzed using one – tailed, two sample unequal variance student's t-test, with $p< 0.005$ [W. R. Thompson et al, 1993]. A computer-aided diagnosis (CAD) algorithm has been designed and implemented on an Altera Cyclone II FPGA to detect cardiac murmurs from recorded heart signals.The FPGA system interfaces with a commercial digital stethoscope to acquire real time data as well as a VGA(video graphics array)-compatible monitor for visualization and metric reporting[Michael Yenting,2010]. Signal processing approach has also been used to isolate systolic heart murmurs based on wavelet transform and an energy index[B. Tovar-Corona et al,1999].This approach demonstrates the isolation of the systole interval and the detection of systolic murmur onset and duration[Nikolay Atanasov and Taikang Ning,2008].one of the methods uses artificial neural network , the method include the major steps as study subjects, recording of the signal, signal analysis and ANN prediction. Using an electronic stethoscope, heart sounds are recorded from 69 patients (37 pathological and 32 innocent murmurs). Sound samples are processed using digital signal analysis and fed into a custom ANN. With optimal settings, sensitivities and specificities of 100% were obtained on the data collected with the ANN classification system developed. in the process to Study Subjects Digital heart sound recordings are obtained from various pediatric patients who were referred to a cardiology clinic for evaluation (aged 1 week to 15 years; mean age, 2 years). in the process of recording signal :using an electronic stethoscope and a personal computer ,heart sounds were recorded at the left of midsternal border in the supine position in a standard examination room. For each patient, 2 separate heart sound recordings were acquired. 2 heart sound recording are equivalent to 8 heart cycles in length. one sound sample of three representative heart cycles is chosen form these two recordings. One recording location was chosen with the expectation that murmurs generally not heard from this location (using standard stethoscopic methods) would be detected by the electronic microphone used due to its sensitivity. during Signal Analysis process in Artificial Neural Network customized ANN software developed in the laboratory. ANNs were trained to discriminate between normal and pathological examples. for Statistical Analysis Standard equations for sensitivity and specificity are used ANN Predictions to differentiate between murmur and normal cardiac murmur. this method had certain limitation because The process of selecting the optimal 3 consecutive heart cycles required an intelligent selection process. In developing a screening device, automating this selection process will need to be investigated. The performance of the ANN with the addition of noise processes (eg. from an uncooperative patient) to the input signal will need to be investigated.

In order to detect sound, recordings of diastolic heart sound segments are analyzed by using four signal process-ing techniques; the Fast Fourier Transform (FIT), the Autoregressive (AR), the Autoregressive Moving Average (ARMA), and the Minimum-Norm (Eigenvector) methods. To further enhance the diastolic heart sounds and reduce background noise, an Adaptive filter is used as a pre-processor [Yasemin M. Akay,2013]. The power ratios of the FFT method and the poles of the AR, ARMA, and Eigenvector methods are used to diagnose patients as diseased or normal arteries using a blind protocol without prior knowledge of the actual disease states of the patients to guard against human bias. Results showed that normal and abnormal records are correctly distinguished in 56 of 80 cases using the Fast Fourier Transform (FFT), in 63 of 80 cases using the AR, in 62 of 80 cases using the ARMA method, and in 67 of 80 cases using the Eigenvector method. Among all four methods, the Eigenvector methods showed the best diagnostic performance when compared with the FFT, AR, and ARM A methods. These results confirm that high frequency acoustic energy between 300 and 800 Hz is associated with coronary stenosis .

Method

The procedural steps include real time signal acquisition and filtering of the signal, display of the signal waveform, classification of the signal as normal heart signal or a cardiac murmur and the performance metrics calculation.

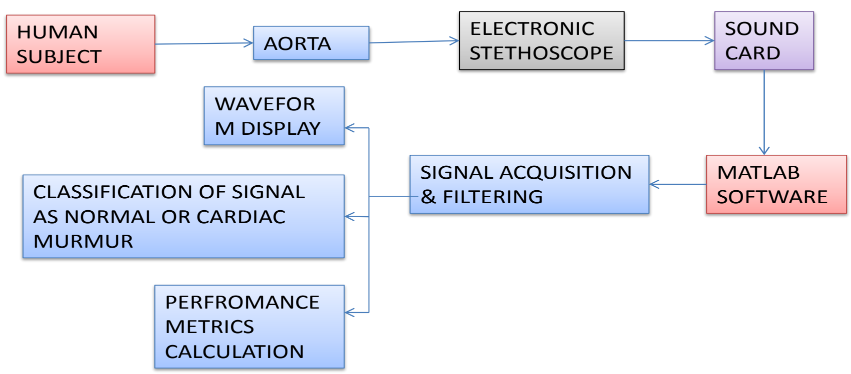


Fig: System design

For the signal acquisition purpose a digital stethoscope is used. The stethoscope is a medical device used for listening heart sounds of human body and for measurement of blood pressure. An electronic stethoscope amplifies body sounds by electronically amplifying the signal. Electronic stethoscope converts sound waves to electric signals which can be amplified and processed. The signals can be interfaced with a computer to analyse the signal waveforms. The signal processing approach is used to perform the cardiac signal analysis and acquisition. An electronic stethoscope is designed to acquire cardiac signals in real time. Signals transferred to the sound port from where they are transferred to the sound card. The MATLAB software used is compatible with sound port and the signals are acquired directly from the sound port to the software. The cardiac signal from the human aorta is acquired in real time using the digital stethoscope. Aorta is the major artery of human body that carry oxygenated blood to all the organs of body else to lungs. The cardiac signals are directly fed to the sound card. No external interfacing circuitry is required for interfacing hence it reduces the system cost. From the sound card, the signals are transferred to MATLAB software. The software has the provision to acquire signals from sound card .after the signal acquisition in the software; the noise is removed that is the process of filtering is applied on the acquired signal. The raw cardiac signal before filtering and the filtered signals are displayed on the software. After analysis of signal parameters the cardiac signal is classified as either normal or a cardiac murmur. The performance metrics such as accuracy, specificity, and sensitivity of the algorithm are calculated in order to be sure about the results of the algorithm.

Parameters:

RMS: root mean square value. The root of mean of square of all the values of a signal is termed as root mean square value of the signal.

$$\mathrm{rms} = \sqrt{\frac{1}{n}}(x_1{}^2 + x_2{}^2 + x_3{}^2 + \cdots \ldots \ldots \ldots . x_n{}^2)$$

Where x_i is thei_{th} sample of signal x.
n is the total no of samples in the signal.

Low energy rate

if P is the no of signals below RMS and Q is the total no of signals then the fraction of these two is called the low energy rate.

$$\text{rms} = \sqrt{\frac{1}{b}\left(x_1{}^2 + x_2{}^2 + x_3{}^2 + \cdots \ldots \ldots \ldots . x_b{}^2\right)}$$

Where x_i is thei_{th} sample of signal x.

The Low Energy Rate for a signal is between 0 and 1.

$$\text{LER} = \frac{P}{Q}$$

Where P is the no. of signals which are below the root mean square value and Q is the total no. of signals.

Performance Metric:

Three metrics can be used to evaluate the performance of the algorithm: (1) Accuracy, (2) Sensitivity, and (3) Specificity. These measures are defined as follows:

Accuracy

$$\text{accuracy} = \frac{PT' + NT'}{PT' + NT' + PF' + NF'}$$

Sensitivity

$$\text{sensitivity} = \frac{PT'}{PT' + NF'}$$

Specificity

$$\text{specificity} = \frac{NT'}{NT' + PF'}$$

T' refers to true and F' refers to false classified signal. a positive identification indicates a murmur and a negative identification indicates a normal signal. The accuracy describes the measurement perfection of the algorithm that how well the algorithm discriminates between a murmur and normal signal.

The real time cardiac signals are contaminated with external noise, so the signal will required to be filtered before analysis. Different signal parameters like low energy rate, root mean square value, energy index are calculated for the evaluation process of the signals. Based on these parameters, the cardiac signals are classified as either normal heart sound or the cardiac murmur. Once the algorithm is designed different analysis metrics are calculated including accuracy, sensitivity, specificity that tells whether the system is capable to detect the cardiac murmurs or not. The performance metrics determines if the system can perform well in real time scenario. if the calculated LER value is less than the specified limits then the signals are considered to be normal otherwise the signal is considered to be cardiac murmur.

Low energy rate is defined as the fraction of no of signals whose value is below the root mean square value of the signal.

If LER < 0.8, the signal is classified as cardiac murmur.

LER > 0.8 the signal is considered to be normal signal and not suffering from any abnormal heart diseases.

Results and Analysis

The signal waveforms are plotted having amplitude versus number of samples. Depending on parameters signals are classify as normal (if LER value >0.8) or cardiac murmur (if LER <0.8).

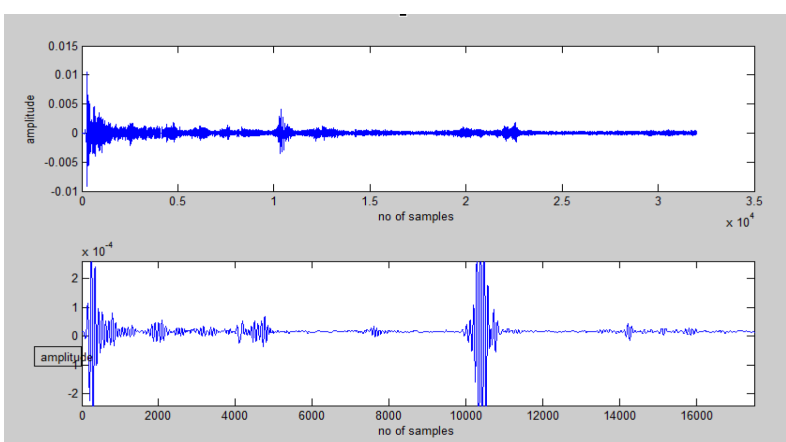
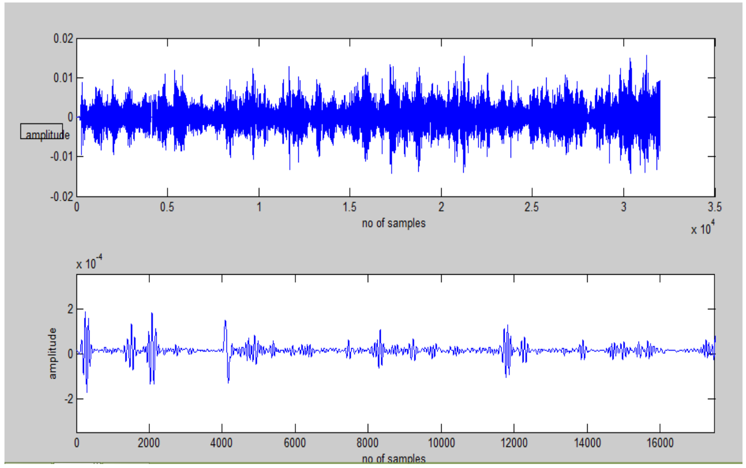


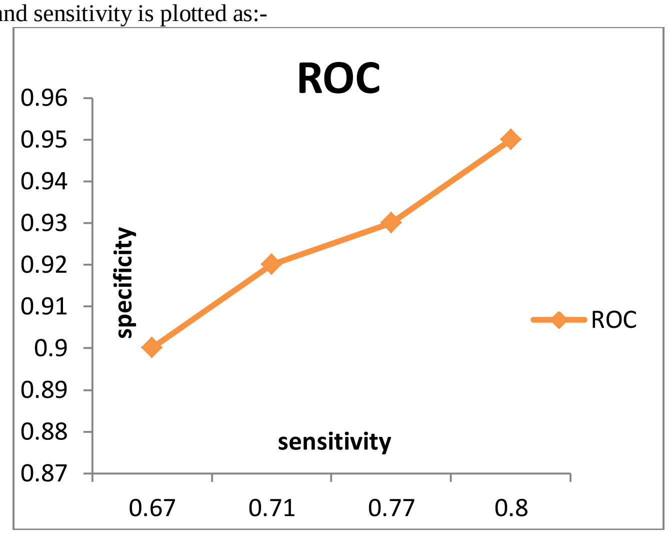
Fig: input signal.



Murmur detected cardiac signal

System has been designed and tested sensitivity and specificity. Sensitivity is a measure of the percentage of patient with unhealthy hearts that are recognized as such. Specificity is the percentage of healthy cases that are classified as healthy. So there is always a tradeoff between specificity and sensitivity.

The plot between specificity and sensitivity is plotted as:-



Receiver operating characteristics

Discussion

Ausculation of pericardium with a stethoscope will disclose an perceptible S_1 andS_2. The normal heart sounds are produced by valve closures. Closure of mitral and tricuspid valve produces S_1, which is perceived best at the top of the heart. Abnormal S_1 sounds arrive when there is infection of the mitral valve. S_2 associates with the closure of aortic and pulmonic valves and is perceived best at the base of the heart. Fixed splitting of S_2 can arrive in patients atrial septal defect, in pulmonic stenosis and right bundle branch block, there is a wide split S_2Systolic murmurs appear between the first (S_1) and the second (S_2) heart sound; diastolic murmurs are perceived after S_2 and before the arrival next S_1 sound [2].The present works acquire heart signal directly in the sound port, there is no need of additional ADC and amplifier, so the system is cost effective. The signal parameters to be calculated do not require any complex matrix operation so the algorithm is simple to implement. In the wavelet transform methods the data analysis is relative so efficiency of the algorithm reduces due to relativity. There is no relative analysis in this work, so the efficiency is higher. A computer-aided diagnosis (CAD) algorithm has been designed and implemented on an Altera Cyclone II FPGA to detect cardiac murmurs from recorded heart signals, but the system is difficult to implement because of use of FPGA board and its interfacing with computer system. The digital stethoscope used in the proposed method is simple to construct and cost effective and the cardiac signal acquired is directly fed to sound card so no external ADC or amplifier is required this too makes the system attractive in terms of cost. As shown in figure 4 amplitude of the pulse on Y axis is plotted with no of samples on the X axis, the waveform indicates the RAW signal that is being acquired in MATLAB software with the help of digital stethoscope. The signal is then filtered to remove extra noise. There is a software code designed to perform the filtering action. After filtering the filtered signal is displayed with amplitude plotted on Y axis and no of samples on X axis. After performing the filtering operation, a noise free cardiac signal is obtained for further analysis. We can get the data values on any corresponding point of the waveform by simply scrolling the data cursor or the data values corresponding to X and Y axis can be acquired by designing a software code. Cardiac murmur of high intensity can be classified by visual analysis as well after getting the filtered waveform. Or to differentiate between a normal cardiac signal and a cardiac murmur we need to analyse some signal parameters such as RMS and LER value of the signal. On the basis of the analysed signal parameters, the signal is binary classified as either a normal cardiac signal or a cardiac murmur.

Conclusion

A computer aided system has been designed for detection of cardiac murmurs. The signal are acquired from the artery AORTA, and then fed to sound port of the computer. Since the signals are directly fed to the sound port so no external ADC or amplifier is required so the system is cost effective. The system is efficient to acquire real time data using digital stethoscope and classify the signal as normal or a cardiac murmur depending on signal parameters like RMS value and LER of the signal. The calculation of RMS and signal LER does not require any complex matrix operation. The system can be used to assist physician to detect cardiac murmur in an efficient way as ordinary stethoscope can sometime fail to detect a murmur with low intensity. The work efficiency of the designed algorithm is calculated using the performance metrics. The performance metrics include accuracy, sensitivity, and specificity. Depending on the performance metrics it can be concluded that the system is efficient to differentiate between a normal heart sound and a cardiac murmur. The designed system is cost effective and efficient.

Future Scope

The electronic stethoscope used in the designed system amplifies the cardiac sounds so it can be used in the case when the sound level is low. It can be used not only for doctors, but home mechanics, exterminators, etc. The designed system can be used to record and see the cardiac signal for a second opinion. The designed system is capable of differentiating between a normal heart sounds a cardiac murmur so it can be used in various medical applications. The designed system is user friendly and hence can be used for individual patients at their home so that they do not need to consult the physician every time. In future, ordinary stethoscope can be replaced by such system as the system is highly efficient and the results are trustworthy. The system can be used for detailed study of the cardiac signals since the signals are stored and the waveforms can be analysed at anytime.

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