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Arrhythmia Denoising and Detection using DWT Technique: A Review

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Abstract: ***Electrocardiogram (ECG) signal has been widely used for heart diagnosis. This paper presents a VLSI based design of high speed and area efficient distributive arithmetic discrete wavelet transform (DA-DWT) for Arrhythmia Detection and its FPGA implementation. The main focus of the work is to filter and detect the QRS complex in the ECG signal and to identify the time and frequency variations. By comparing these variations with that of the variations in the normal ECG waveform one may reach to a conclusion if the patient is suffering from Arrhythmia or not. The DA-DWT is also used to filter the ECG signal so as to detect the ECG signal for Arrhythmia Detection***

Keywords: DA-DWT, ECG, FPGA, QRS Complex

1. Introduction

Major causes of threat to life are the diseases associated with heart. Arrhythmia is one such heart disorder which is an irregularity in heart beat. In cases of Arrhythmia the heart may beat either too fast or slow. Heart Arrhythmias occur when the electrical impulses in heart that coordinates your heartbeats don't work properly, causing your heart to beat too fast, too slow or irregularly. Arrhythmias can take place in a healthy heart and be of minimal consequence but they may also indicate a serious problem that may lead to stroke or sudden cardiac death. Heart Arrhythmia treatment can often control or eliminate irregular heartbeats. Electrocardiogram (ECG) is a diagnosis tool that reports the electrical activity of heart recorded by skin electrode. Any disorder of heart rate change in the morphological pattern is a reading of cardiac Arrhythmia, after measure could be detected by analysis of ECG waveform. It is very difficult to identify the symptoms of Arrhythmia from the lengthy ECG record. Information regarding this disorder can be obtained from the variations in the length and width of the QRS complex. Some of the common symptoms of Arrhythmia are dizziness, fainting and on the worst it may turn out to be deadly causing ventricular fibrillation.

The aim of the paper is to implement an ECG analysis system basically an Arrhythmia detection approach .For such system it is first of all necessary to remove the noise in the ECG signal that is caused due to the disturbances caused during the ECG measurement using the electrodes. Some sort of noise in ECG signal are electrode contact noise, baseline drift, motion artefacts, EMG from the chest wall, instrumentation noise and electrosurgical noise .These also can be because of the power supply variation or any other reason such as interference of RF signals. So the initial process involved in processing the ECG signal is to remove such variations using appropriate filtering methods. Once the signal is devoid of such variations it is subjected to a 4 level decomposition using the distributive arithmetic DWT that is responsible for extracting the details in the ECG signal. After extracting such information embedded in the signal, i.e. the timing and frequency details of the waveforms it is compared with the actual signal to identify if there are conditions of Arrhythmia. My focus is to reduce the time taken for the DWT process as it involves many multiplication and other complex operations. I am trying to incorporate a distributive arithmetic DWT which reduces the time by incorporating a design that contains the bandstop filter and the down-sampler into a single module.

2. DA-DWT (Distributive Architecture Discrete Wavelet Transform)

In DA-DWT the ECG signal is passed through a series of low pass and high pass filters. It is used for decomposing the ECG signal so that relevant features necessary can be extracted. One of the advantages of using DWT is multi-resolution analysis capability (MRA). MRA provides good time and poor frequency resolution at high frequencies and good frequency, poor time resolutions at lower frequencies. DWT analyzes the signal at different frequency bands with different resolutions by decomposing the signal into approximation and detailed information. Using successive high pass and low pass filtering the ECG signal can be decomposed into different frequency bands. The QRS complex feature can be extracted by performing decomposition up to 4 levels. After the signal has been passed to successive low pass and high pass filters they are subjected to down sampling. When the signal is passed through low pass and high pass filters they split the frequency content of the signal into half. Therefore it seems logically for performing a down sampling with a factor of two to avoid redundancy.

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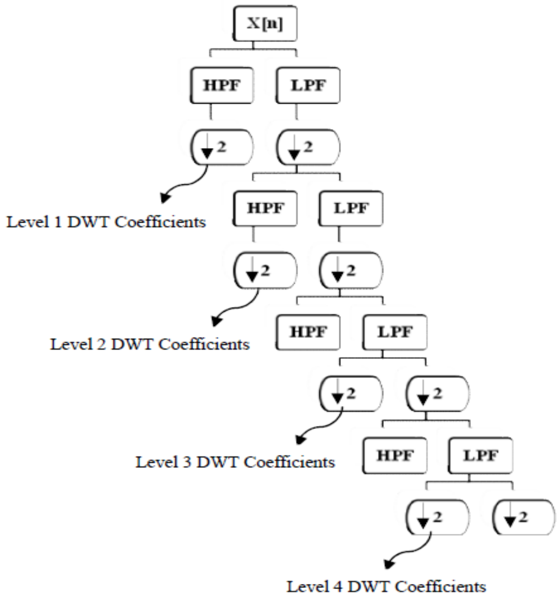

Figure 1: DWT Architecture

3. QRS Detection

The QRS complex is the largest deflection voltage of about 10-20 mV but may vary in size depending on age and sex of the human. The amplitude of the voltage of the QRS complex may also give information on heart disease. Duration of the QRS complex indicates the time for the ventricles to depolarize and can provide information on problems conduction in the ventricles as the bundle branch block.

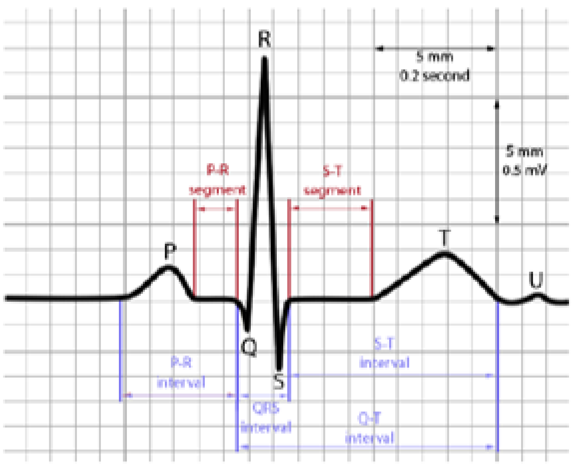

Figure 2: QRS Waveform

4. Overview Of ECG Analysis Sysyem

In order to extract the information hidden in the ECG signal many types of transformations can be adopted and because of the quasi periodic nature of the non stationary ECG signals transformation is done using the DWT. The ECG signal that is non stationary has P, QRS complex and T waves. The duration of each of the waves signifies the electrical activity of the heart. P wave indicates the atrial contraction or depolarization. PR interval indicates the time duration for the travel of the depolarization wave from the atria to the ventricles. QRS complex indicates ventricular depolarization.ST segment shows the time between ventricular depolarization and the starting of repolarisation. And the T wave shows the ventricular repolarisation. For detecting the heart rate QRS complex detection is necessary. Among all the waves in the signal the QRS complex has higher amplitude. Here the ECG signal is captured from the MIT-BIH database. Once the signal has been captured, filtering can be done in order to remove any unwanted noise in the captured signal. Basic principle behind the ECG signal analysis system is to find the QRS complex. Easier method for detecting the QRS complex is to find out the R peak.

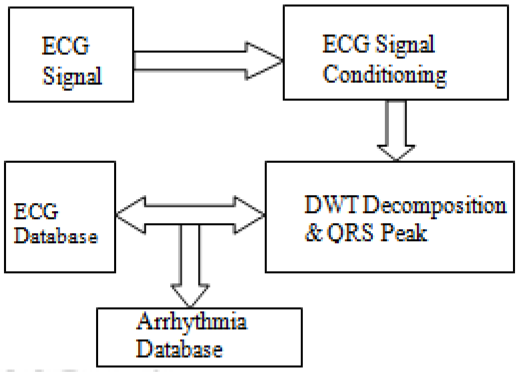

Figure 3: ECG Signal Analysis System

5. Proposed Work

The wavelet transformation is based on a set of analyzing wavelets allowing the decomposition of ECG signal in a set of coefficients. Each analyzing wavelet has its own time duration, time location and frequency band. The Wavelet coefficient resulting from the wavelet transformation corresponds to a measurement of the ECG components in this time segment and frequency band. Discrete Wavelet Transform (DWT) has been used in the last few years in applications of signal processing like denoising, compression and coding. Methods for both offline and online mode have been proposed. At first, the information is processed frame-by-frame; and then, it is processed sample-by-sample. The algorithm presented gives a rapid decomposition of the discrete wavelet transform. Previously all works carried out under the method are software based but the intention of this paper is to propose a hardware design for the QRS detector.

6. Methodology

6.1 Hamming Filter

Recently, I have designed a filter based HDL design for de-noising the ECG data. I used FIR window technique namely, Hamming window for this filter. The response of the Hamming window has been studied and is found to be better as compared to others due to the Zero Side Lobes present in its structure. In this complete work, two filters namely, BSF (Band Stop Filter) and LPF (Low Pass Filter) are used with different cut off frequencies.

The general equation for FIR Filter is

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$$y(n) = \sum_{k=0}^{N-1} (h(k)x(n-k))$$

6.2 DWT Based Filter

Next, I will implement the Wavelet Transform based filtering technique. Transforms are used to obtain further information from the signal which may not be available from the raw signal. In DWT, the ECG signal is passed through a series of low pass and high pass filters and hence used for decomposing the ECG signal so that relevant features necessary can be extracted.

7. Conclusion

This work intends to design an Arrhythmia detection system for ECG signals using Discrete Wavelet Transform. By using the concept of wavelet transform, significant amount of noise in ECG can be filtered by performing suitable operations. The input ECG signal corrupted by noises can be transformed using suitable mathematical operations and properly removed using suitable filter banks to obtain conditioned ECG signal devoid of noises. After filtering is done, DA-DWT technique is further implemented for the denoising of the QRS complex. This system is very efficient in terms of reducing the calculation time and area.

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