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Detection of Ventricular Arrhythmia Based on ECG Using DWT

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Abstract--- *ECG is used to measure the regularity of the heart and it helps to detect any irregularity of the beat. Ventricular Arrhythmia is a type of irregularity of beat. Early detection of Arrhythmia is an important task for defibrillation therapy. Discrete wavelet transform (DWT) used to remove the baseline wander and power line interference in ECG signal. Uses morphological filtering for feature extraction and a naïve Bayesian algorithm for classification. Modelsim used as the simulation tool.*

Keywords---Discrete Wavelet Transform, classification, Electrocardiography, Ventricular Arrhythmia.

1. INTRODUCTION

Electrocardiogram has an important role in diagnosis, that measure and record the electrical activity of heart. ECG wave denoted with P-QRS-T, as shown in fig.1.1. Ventricular arrhythmia, a type of irregularity of heart beat. It include: Ventricular tachycardia (VT) and Ventricular fibrillation (VF).Normal heart beat rate is 72 beats/min, for VT beat rate is more than 100 beats/min, that is VT is a fast rhythm of more than 3 consecutive beats. Below 60 beats/min it is called VF.

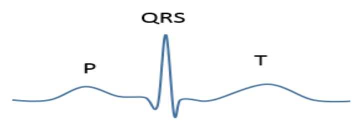

Fig. 1.1: ECG wave

Detection of arrhythmia is not an easy task. Many methods are developed for detecting arrhythmia based on morphological, spectral, and mathematical. Alsoto improve the detection efficiency machine learning techniques such as SVM (Support Vector Machine), and neural networks has been suggested. All those methods have their benefits and limitations, such as some are difficult to implement and compute and low specificity.

The main requirements of a defibrillator are low power consumption and low energy operation in order to get a longer battery life with a small area for wearability. Present systems are highly sensitive to noise such as muscle noise, power line interference, base line drift, etc. In [2], Shiu et al., implemented an electrocardiogram signal processor (ESP) to detect the heart diseases using a 90nm CMOS technology. The system consist of an instrumentation amplifier and a low pass filter to remove the noise in the ECG signal. In this system the feature extraction is carried

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out with a time domain morphological analysis and classification is done by evaluating the ST segment. One of the main disadvantage of the system was it uses fixed search window with predefined size to identify the S and T fiducial points so the system is not suitable for the real time scenarios. And LPF is only good for removing a small amount of high frequency noise. Also the time domain analysis doesn't have an efficient result because of its low sensitiveness due to the amplitude of signal has small change in time domain.

In [3], presents one recent system for cardiogram classification, and it provide a low power SOC for wireless ECG acquisition and classification system. This system have features such as low power consumption, wireless transmission and on time monitoring. It consists of 3 main blocks: a bio signal processor, on off keying transceiver, and a digital signal processing unit. Discrete wavelet transform (DWT) is used in DSP module, for ECG feature extraction and classification. The accuracy of the beat detection and classification is 99.44% and 97.25% respectively.

Chen et al., proposed a n ultralow power syringe implantable ECG system for arrhythmia classification with 65nm CMOS technology. Here the system can be injected under the skin near the heart using a syringe needle to avoid surgery. Device acquires the ECG signal, filtering it, amplifies it and then digitizes it through the analog front end module (AFE). The AFE consist of a low noise instrumentation amplifier, variable gain amplifier, and successive approximation register analog to digital converter. The proposed SoC consumes 64 nW power and the accuracy was not mentioned.

This paper proposes a low power arrhythmia detector, the detection of arrhythmia is critical due to the waveform doesn't follow a consistent patternas in fig.1. So to improve the quality of detector the system should alert the patient before such critical situations. Thus prediction along with classification is important.

II. PROPOSED SYSTEM

The proposed system contains 3 stages: ECG preprocessing, feature extraction, and classification as in fig.2. Base line elimination and noise removal of raw ECG is carried out in the first stage called preprocessing. In the 2nd stage different features where extracted from ECG signal such as RR, PQ, QP, RT, TR, PS and SP intervals. In the last stage classification a Naïve Bayes algorithm is used to identify the given raw of signal is susceptible to ventricular arrhythmia or not.

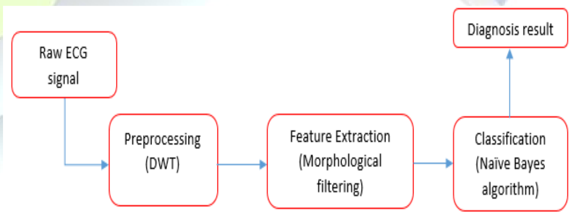

Fig.2: Block diagram of proposed Ventricular Arrhythmia detector

A. ECG Preprocessing Stage

Different ECG analysis based on classical digital signal processing such as linear filtering, Fourier

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transform etc. Now a days many new promising approaches are emerged for the analysis of ECG signal, among them WT (wavelet transform) is important. Fourier transform permits the determination of frequency contained in a given signal, WT can overcome this problem [6].

Most of the time desired ECG signal is mixed up with noises, and to detect the abnormalities of heart we have to accurately analyze the ECG signal inorder to accurately extract the features of ECG signal. So wavelet based analysis is used for signal processing applications. WT is used for the analysis of non-stationary signals.

In this paper Discrete wavelet transform is used for the preprocessing stage. In discrete domain, we can save a fair amount of work and also get an accurate result by choosing carefully of the scales and positions based on powers of two. DWT is also called as decomposition by wavelet filter banks, because it uses 2 filters, a LPF and a HPF to decompose the signals. By using DWT implicitly frequency domain filtering is performed, and making the system robust and allows a different application over the ECG signals [5]. Here we used spline wavelets for our analysis, which is more similar to an ECG signal. Four levels of DWT decomposition is done a sample ECG using spline wavelets. High frequency component on the signal decreases as lower details are removed, thus the signal becomes smoother and the noises on the T and P waves disappears. Fig 2 shows the preprocessed output of ECG signal by DWT analysis.

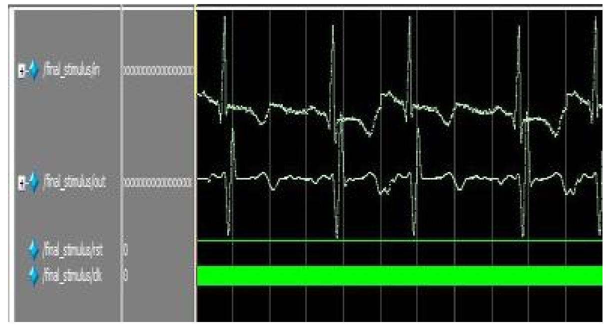

Fig. 3. Preprocessed output of ECG signal

B. Feature Extraction Stage

Automatic ECG signal detection is a very important topic, performance of such systems relies heavily on accuracy and reliability of QRS complex detection. Detection of R-peak value is the main step of feature extraction. Here morphological filtering is used for detection of feature extraction. The QRS width is also detected for further analysis process of ECG signal. The basic morphological operations: erosion, dilation, opening and closing. Opening and closing operations are simple and is the good way for peak or valley detection. [4] proposed a system in which OWT extracts wavelet features which give a good separation of different patterns. Moreover the proposed algorithm uses morphological operators for effective segmentation. From the qualitative and quantitative results, it is concluded that our proposed method has improved segmentation quality and it is reliable, fast and can be used with reduced computational complexity than direct applications of Histogram Clustering. The main advantage of this method is the use of single parameter and also very faster. While comparing with five color spaces, segmentation scheme produces results noticeably

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better in RGB color space compared to all other color spaces.

Opening expressed as an erosion followed by a dilation of the eroded output and the opening can be expressed as a dilation followed by an erosion of the dilated output. The dual operation of opening is same as of closing operation. Dilation, sets the maximum value over all the values and erosion, sets the minimum value over all the values. Opening followed by closing is done on the digitized data and reverse operation is also done. Taking the average of two and subtracting it.

R wave have the highest peak, two R peaks are located in 0.25 second. RR interval detection helps to calculate the beat rate. Heart beat rate in beats per minute (bpm) is calculated as: 60/RR interval.

C. Classification Stage

Now we have to classify the waveform belongs to arrhythmia or not. So that here uses a statistical classifier called Naïve bayes classifier. It have high accuracy and speed when applied to a large database also it is easy to build. It uses Bayes theorem. Bayes theorem for a set of features d and class c_i, is defined as:

$$P(\mathrm{ci}|\mathrm{d}) = \frac{P(d|\mathrm{ci})P(\mathrm{ci})}{P(d)}$$

The class that have the maximum conditional probability, data is assign to that class. It can be defined by:

$$c = argmax\ P(ci|d)$$

$$c = argmax\ P(ci)\ \prod P(ci|d)$$

During calculation of probabilities, which leads to float point underflow, so the product operation is converted to summation with log. So choose the class with highest log score instead of highest probability. And it can be defined by,

$$c = argmax\ [\log P(ci) + \sum_{x} \log P(x|ci)]$$

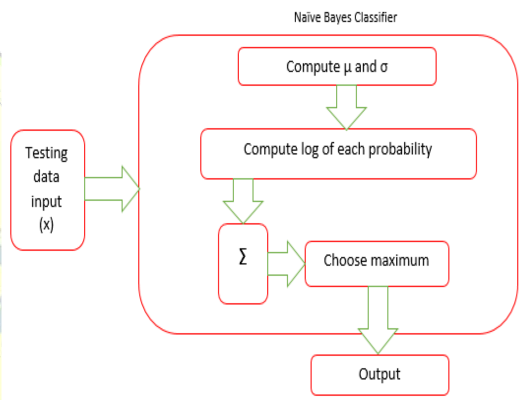

Fig.4. Architecture of Naïve Bayes classifier

Conditional probability for a value *v*from a feature vector *x* given a class $c_i$is P(x=v|ci), is given by,

$$P(x = v|ci) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(v-\mu)^2/2\sigma^2}$$

$$\mu = \sum_{i=1}^{N} xi$$

$$\sigma^2 = \frac{1}{N}\sum_{i=1}^{N}(xi - \mu)^2$$

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Algorithm 1 Training Gaussian Naive Bayes Classifier

procedure TRAINNAIVEBAYES
    $X \leftarrow$ Extract Feature
    N $\leftarrow$ Count Values
    for each c $\in$ Class
    do $N_c \leftarrow$ Count Values in c
    prior [c] $\leftarrow \frac{N_c}{N}$
    do $\mu \leftarrow \sum_{i=1}^{N_c} (X_i)$
    do $\sigma^2 \leftarrow \frac{1}{N_c} \sum_{i=1}^{N_c} (X_i - \mu)^2$
    for each V $\in$ X
    do condprob [v][c] $\leftarrow$ *LUT*
    return *prior, condprob*

Algorithm 2 Testing Gaussian Naive Bayes Classifier

procedure TESTNAIVEBAYES (PRIOR, CONDPROB)
    Z $\leftarrow$ Extract Feature
    for each c $\in$ Class
    do c = condprob [c][Z] $\leftarrow$ *LUT*
    return *argmax c*

III. CONCLUSION

The system was implemented in Verilog-HDL, modelsim is used as the simulation and verification tool. ECG recordings from the PhysioNet databases were used to constructthe study data sets of this paper. Proposed a low power arrhythmia detector that combines DWT for preprocessing, morphological filtering for feature extraction and naïve bayes classifier. Naive Bayes classifier, which classifies heart beat as normal or abnormal.

In order to improve the area and speed replace multipliers in each stage by distributed arithmetic (DA) with look up table. We can make a system to predict arrhythmia before it occur.

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