International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)

ISSN: 0976-1353 Volume 8 Issue 1 –APRIL 2014.

FPGA BASED ECG QRS COMPLEX DETECTOR USING FIR FILTER DESIGN

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Abstract: **This paper is based on the very large scale integration for ECG QRS complex detector for body sensor networks. The main objective of this paper is to reduce the baseline wandering and background noises from the electrocardiogram (ECG) QRS complex detector. The proposed method is used to reduce the area and power consumption and also the low cost purpose. The proposed method is FIR filter based design producing lesser area and power reduction compared to mathematical morphological method. The ECG data can be taken from the MIT-BIH arrhythmia database and wearable exercise. The ECG data can be analyzed using FIR filter design and implemented in the FPGA. The commercial FPGA used for high detection rate and high speed demonstration with area reduction with the proposed method.**

Index Terms: **ECG QRS complex, FIR Filter, FPGA, MIT-BIH arrhythmia database.**

1. INTRODUCTION

The last decade has witnessed a rapid surge of interest in new sensing and monitoring devices for healthcare and the use of wearable/wireless devices and sensor networks for clinical applications. Especially, a new wave of technology, body sensor networks (BSNs), has played an increasingly important role in providing continuous diagnosis support and medical treatment. As one of the important physiological sensor nodes in BSN, wearable electrocardiogram (ECG) sensor is dedicated to measuring the rate and regularity of heartbeats as well as the size and position of the chambers, the presence of any damage to the heart and the effects of drugs or devices used to regulate the heart. In ECG signal processing, all the extensive analysis need the information of QRS positions as a basic QRS detectors have been regarded as a mature topic until the BSN is introduced, where; unfortunately, the ECG sensor requires real-time, miniature form factors and long lifetimes that push the limits of ultra low power circuit and system design.

The front end of an ECG sensor should be able to deal with extremely weak signals ranging

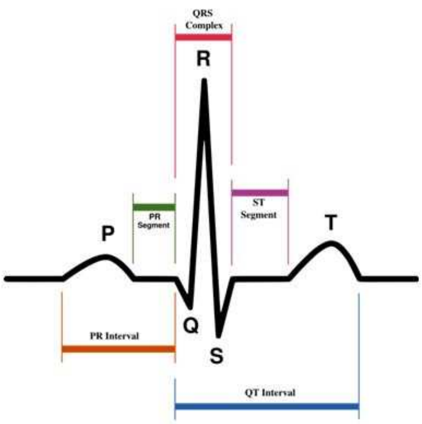

Fig 1: ECG Signal QRS Representation

from 0.5 to 5.0 mV, usually mixed with a dc component of up to mV and a common- mode component of up to 1.5 V resulting from the electrode- skin contact and the potential between the electrodes and ground, respectively. Depending on the specific application, the useful bandwidth of an ECG signal can range from 0.5 to 50 Hz for general healthcare purposes. A standard clinical ECG application utilizes a bandwidth of 0.05 to 100 Hz. While for a monitoring application in intensive care units, it could reach up to 1 kHz for late-potential measurements.

This project uses the MIT-BIH Database of ECG waveforms, forty seven subjects were studied by the BIH laboratory twenty three recording were picked at random from a set of 4000 and twenty five recording were collected from the same data to include abnormal ECG. 360 samples were digitized per second and each record was independently noted with an explanation, to include background information on the subjects, including their medications.

2. MATHEMATICAL MORPHOLOGY CONCEPT

Mathematical morphology is a set-theoretic method of image analysis providing a quantitative description of geometrical structures. And it provides an effective way to analyze signals using nonlinear signal processing operators incorporating shape information for extracting image components that are useful for representation and description. A morphological operation is actually the interaction of a set or function representing the object or shape of interest with another set or function of simpler shape called structure element. The geometry information of the signal is extracted by using the structure element to operate on the signal. The shape of the structure element determines the shape information of the signal that is extracted under such an operation. Such operators serve two purposes, i.e., extracting the useful signal and removing the artifacts.

There are two most basic morphological set transformation operators: dilation and erosion, which all other mathematical morphology operations are based on. The operators for 1-D signal f(n) and structure element g(n) are listed below for easy reference, i.e.,

Dilation: $f \oplus g(n) = \max_i [f(n-i) + g(i)$ (1)

Erosion: $f \ominus g(n) = \max_i [f(n+i) - g(i)]$ (2)

Opening and closing are two extended morphological operators based on dilation and erosion. In mathematical morphology, opening is the dilation of the erosion of a set by a structuring element; the closing of a set by a structuring element is the erosion of the dilation of that set. Opening and closing operations could also work as morphology filters with clipping effects, i.e., cutting down peaks and filling up valleys

Opening: $f \circ g(n) = (f \ominus g) \oplus g(n)$ (3)

Closing: $f * g(n) = (f \oplus g) \ominus g(n)$ (4)

Another two common operators, top-hat and bottom-hat, encompass the opening and closing operators with two different order, defined as,

Top- Hat: $T_{hat}(f(n)) = f(n) - f \circ g(n)$ (5)

Bottom- Hat: $B_{hat}(f(n)) = f(n) - f * g(n)$ (6)

This morphology based method can effectively detect the components of interest from contaminated signal without any prior knowledge about frequency spectrum which embarrasses the utilization of frequency based filters.

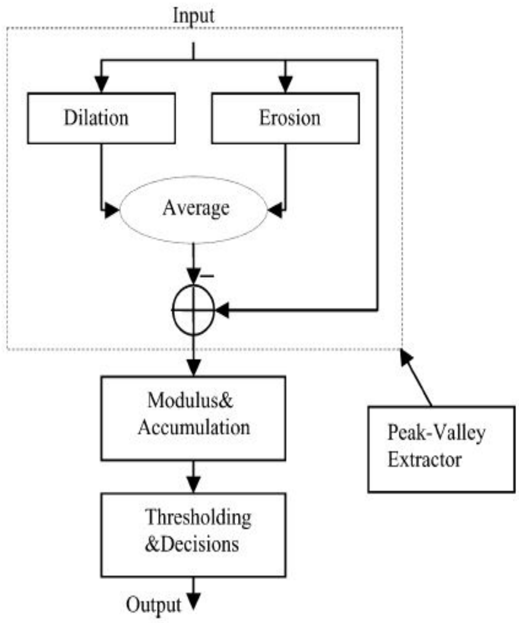

Fig 2: Mathematical Morphological Method

Algorithm Concept

Detection of QRS complexes equals to the distinguishing of a group of consecutive positive and negative peaks. As mentioned above, originating from 2-D image processing, mathematical morphological technology extracts the effective information based on shapes in the image, not pixel intensities like conventional methods.

A fundamental advantage of mathematical morphology applied to signal processing is that it is intuitive since it works directly on the spatial domain: the structuring elements considered as the "basic bricks" play the same role as frequencies do in the analysis of the frequently used frequency filters.

Dilation and Erosion

Dilation expands an image object and erosion shrinks it. The opening smoothens a contour in an image, breaking narrow isthmuses and eliminating thin protrusions. Closing tends to narrow smooth sections of contours, fusing narrow breaks and long thin gulfs, eliminating small holes, and filling gaps in contours. In most applications, opening is used to suppress peaks while closing is used to suppress pits. Here, in order to detect QRS complex accurately and quickly, a peak extractor is defined only based on basic dilation and erosion morphological operators, instead of a series of advanced openings and closings as in existing literature.

3. PROPOSED FIR FILTER DESIGN

The purpose of filtering an ECG signal is to remove background noise and other interference to emphasize signal of interest. E.g. QRS complex.A band pass filter removes the upper and lower frequencies of an ECG signal. The typical low cut-off frequency ranges from 5 to 10Hz. Note that a filter is not able to give a sharp cut-off of one frequency. e.g. 10Hz. A high cut-off frequency should be in the region of 20-40Hz.

The impulse response of a digital filter is the output arising from the unit impulse input sequence defined as

$$\delta(n) = \begin{cases} 1, & n = 0 \\ 0, & n = 0 \end{cases} \qquad (7)$$

There are two types of impulse response Finite Impulse Response (FIR) and Infinite Impulse Response (IIR).

An FIR filter is non-recursive. I.e. no feedback this means the current output depends on:

- current input
- previous input

FIR Filter block can be introduces with the modulus and accumulation and then threshold and decision block is performing. The FIR filter can be act as a peak valley extractor over the advancement of the dilation, erosion and average. The FIR system is more reliable over the mathematical morphological method.

The Filter Block can be used here for quicker computation and for more accuracy than the dilation and erosion concepts. The FIR filter conceived with more types of designs like windowing and linear phase filter and multiband design. So that the FIR filter basic block can be varying according to the accuracy results getting while test with the signal from the database.

FIR filter Implementation

To implement filter banks which are nothing but sets of FIR filter which are able to

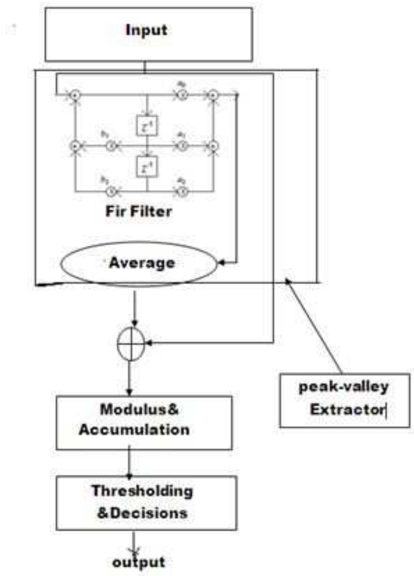

FIG 3: FIR based Proposed method

construct wavelet. Typical FIR filters are associated with a particular wavelet and to implement filter bank filters are depends on types of wavelet.

QRS detection

We have marker array, that show to us points with bigger + & - deference (>1.2*dev.) which is determine by using standard deviation. Using the array MINMAX, we go to the next step of our simplified algorithm, these minima and maxima points indicates QRS peaks.

Enhancing ECG by Modulus and Combination

The absolute value of the above output is then combined by multiple-frame accumulation, which is much alike energy transformation. The energy accumulation process is expressed as

$$\mathbf{S\ (n)} = \sum_{i=n-\frac{g}{2}}^{n+\frac{g}{2}} |v\ (i)|. \qquad \mathbf{(8)}$$

The value of should correspond to the possible maximum duration of normal QRS complex.

Threshold and Decisions

An adaptive threshold is used as the decision function in connection with the proposed transformation for QRS detection. Usually, the threshold levels are computed signal dependent such that an adaption to changing signal characteristics is possible. For the signal produced by (8), it is proposed that the required adaptive threshold is a function of the maximum of the transformed ECG waveform S (n). The guideline in selecting the threshold, **T**, is given by

$$\mathbf{T} = \begin{cases} 0.1\,Max, & Max < 3 \\ 0.3\,Max, & 3 \leq Max \geq 7 \\ 0.13\,Max\,, & Max > 7 \end{cases} \qquad \mathbf{(9)}$$

Where Max is determined from the current signal segment which is within the range of millivolts. The upper and lower bounds of Max will be subject to the selection of structure elements.

4. CONCUSION

This paper is based on the 2-D image processing in FIR filter design which is performing a technique that would extracts the effective information based on a shapes in the image file, not the pixel intensities like conventional methods. The input signal for making an ASCII code is applied to the VHDL programming to perform noise reduction and baseline drift. The simulation is done through MATLAB and ModelSim.

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