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Implementation of ECG QRS Complex Detector for Body Sensor Networks By using nano-FPGA

Priyanka Mundhe, Harsha Bodhey, Prof. Anuja Diggikar

Abstract*— *An electrocardiogram (ECG) is a low-cost, noninvasive measure of cardiac electrical activity. An ECG is obtained by placing an electrode on chest; arm or legs.ECG analysis has become a standard diagnostic tool for cardiac arrhythmia. Ambulatory ECG recording effectively detects cardiac arrhythmia and circadian cardiac rhythms. QRS detection is an important part of many ECG signal processing systems. There are many algorithm for QRS detection. Here a QRS detection algorithm which is based on VLSI architecture is given. Baseline wandering and background noise are removed from original ECG signal by a mathematical morphological method. Then the multipixel modulus accumulation is employed to act as a low-pass filter to enhance the QRS complex and improve the signal-to-noise ratio. Corresponding VLSI architecture is implemented by nano PFGA having less power and area. This algorithm has high detection rate and high speed.

***Index Terms*—Electrocardiogram (ECG), body sensor networks (BSNs), QRS complex detection, baseline wondering, modulus and combination, VLSI architecture, nano FPGA**

I. INTRODUCTION

Electrocardiogram (ECG) is formed by continuous tracings of the electrophysiological activity emitted from cardiac muscle, it reflects the instantaneous status of patient's heart. It has been widely used by physicians for a variety of diagnostic purposes. 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. Among the noises plaguing the ECG are the power-line interference: 50/60 Hz pickup and harmonics from the power cord; electrode contact noise: baseline drift due to variable contact between the electrode and the Skin; motion artifacts: shifts in the baseline caused by changes in the electrode-skin impedance; muscle contraction: electromyogram type signals (EMG); respiration causing drift in the baseline and electromagnetic interference and noise coupled from other electronic devices. For meaningful and accurate detection, steps have to be taken to filter out or discard all these noise sources. Hence, a reliable on-the-fly QRS detection method with low hardware cost, high sensitivity, and good noise susceptibility is of urgent need. The front end of an ECG sensor should be able to deal extremely weak signals ranging from 0.5 to 5.0 mV, usually mixed with a dc component of up to plus or minus of 300mv. 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.

II. QRS COMPLEX DETECTION

Among all ECG components, QRS complex is the most significant feature. For example, QRS detection provides an important basis for instantaneous *heart rate* (HR) computation since the accuracy of instantaneous heart period estimation relies on the performance of QRS detection. On the other hand, it is acknowledged that QRS complex is varying with the physical variations and also affected by noise as time evolves. Therefore, seeking for a reliable QRS detection algorithm is essential to the realization of automatic ECG diagnosis.QRS is the dominant complex in the Electrocardiogram (ECG). Its accurate detection is of fundamental importance to reliable ECG interpretation and hence, to all systems analyzing the ECG signals (e.g. Heart-monitoring).Syntacticmethods is a very powerful tool for QRS detection, since they can easily describe complex patterns, but their high computational cost prevents the implementation for real time applications. In this paper, we present VLSI architecture for ECG signal processing. The corresponding VLSI architecture is designed and implemented on a commercial nano-FPGA.The good performance of computerized ECG processing systems relies heavily upon the accurate detection of the QRS complex. Three different classes of algorithms for the automatic detection of this complex can be found in the literature. Non-syntactic, syntactic and hybrid.

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The main advantage of the syntactic methods is focused on their ability to use the structural information of the ECG signal and describe more complex relations than the common non-syntactic methods. However the computational cost of these methods is in general high. The average complexity is equal to the time complexity of a context free grammar (CFG).Among these, some algorithms were developed based on digital filters in order to extract the feature components due to the QRS complex , some were based on non-linear transforms. In addition, some existing QRS detection algorithms employ a specific QRS template which might be considered the best way to prevent the QRS detection performance from being degraded by the undesired noise sources contributed from: (1) baseline drifts, (2) artifacts due to electrode motion or power-line interference, and (3) other ECG components with similar morphologies to the QRS complex, such as P and T Waves. However, since the template-match technique involves intensive cross correlation-based similarity measurement between the QRS template and a number of windowed ECG segments, such a heavy computational burden might somehow undesirably restrict its use to only a limited number of aspects. Fortunately, there still exist a number of different possible techniques for noise reduction,

and one of the most effective approaches is given below.

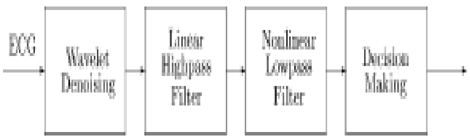

Fig. 1 – A Block Diagram of the QRS Detection System

III. PROPOSED ALGORITHM FOR QRS COMPLEX DETECTION

In this technique the QRS complex is detected by background wondering and noise reduction. The background wondering and noise reduction is done with the help of mathematical morphology. Morphological operators have been widely used in the signal and image processing fields because of their robust and adaptive performance in extracting the shape information in addition to their simple and quick set computation. In this technique the combined opening and closing operators for baseline correction of ECG signals are used and good filtering performance is obtained. Mathematical morphology, based on sets operations, provides an approach to the development of non-linear signal processing methods, in which the shape information of a signal is incorporated 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.,

$$\text{Dilation}: \; f \oplus g(n) = \max_{(i)}[(f(n-i)+g(i)] \qquad (1)$$

$$\text{Erosion}: \; f \Theta g(n) = \min_{(i)}[(f(n+i)-g(i)] \qquad (2)$$

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.

$$\text{Opening}: \; f \circ g(n) = (f \Theta g) \oplus g(n) \qquad (3)$$

$$\text{Closing}: \; f * g(n) = (f \oplus g) \Theta g(n). \qquad (4)$$

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. Another advantage is that it leads to better reproducible results because of the strong mathematical foundation. The simplicity in terms of computation and hardware implementation is also one of its main advantages. The last point that is worth noting lies in its capability in allowing easy customization of the program for the choice of every parameter according to physical measurements if necessary.

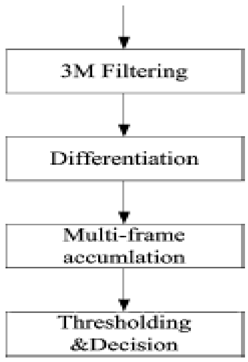

Fig. 2. Block Diagram of Proposed QRS Detection Algorithm

IV. 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 follows.

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$$s(n) = \sum_{i=n-\lfloor \frac{q}{2} \rfloor}^{n+\lfloor \frac{q}{2} \rfloor} v(i)|.$$

.

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 (9), 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, , is given by

$$T = \begin{cases} 0.1\mathrm{Max}, & \mathrm{Max} < 3 \\ 0.3\mathrm{Max}, & 3 \leq \mathrm{Max} \leq 7 \\ 0.13\mathrm{Max}, & \mathrm{Max} > 7 \end{cases}$$

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

V. VLSI ARCHITECTURE AND IMPLEMENTATION

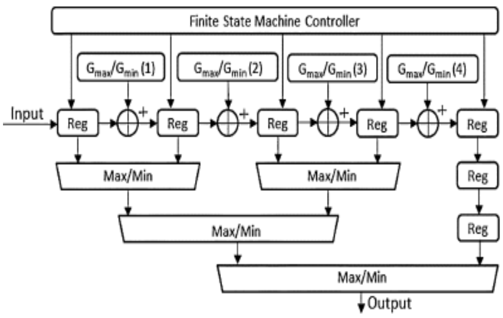

Fig 3.[1] Circuit Diagram Of The Dilation/Erosion Module For A Five-Point Operation

The ultra-low power consumption is essential for ECG sensor application in BSN. The straightforward format of erosion, dilation facilitates the VLSI friendly implementation of the proposed method. The similarity between dilation and erosion operation further permits sharing the same architecture of computation core. The design strategy of the hardware implementation is to reduce as much computation load as possible. As shown in Fig. 3, the proposed VLSI architecture consists of shift registers, Rom, adder, comparator, and a finite state machine (FSM)-based controller.In above diagram, an example of five point length structure element is given Here, the "Reg"means the shift registers, storing the intermediate values, and "Max/Min" represents the comparators for dilation and erosion. The components for the "Adder," i.e.G_{max}/G_{min}(i) mean the differences between two values in the structure element, which are stored in the Rom. The overall implementation of this algorithm is verified using the Actel nano-FPGA starter kit. The FPGA operating under 3 kHz and 1.8 V supply voltage can successfully detect the QRS complex as expected.

VI. CONCLUSION

This paper has presented a FPGA based morphology algorithm for both resting and wearable exercise ECG QRS detection in BSNs. The method can also work in case of the bandwidth overlaps between QRS complex and other components. The algorithm is implemented in FPGA. that the proposed detector compares very favorably with published results of other QRS detection algorithms

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