Detection and Analysis of the Designed Circuit for Ambulatory ECG Electrical Characteristic Points

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Abstract—**The heart is the motor of the human body, and the cessation of heartbeat signifies the end of life. Numerous cardiac pathologies such as arrhythmia, myocardial infarction, and cardiac hypertrophy occur. Electrocardiography (ECG) devices are typically required to examine the heart in hospitals. Physicians can use subtle differences in ECG signals to determine whether a patient has a heart disease. Thus, this study designed an ambulatory ECG circuit and applied software to determine the characteristic points of the QRS complex.**

I. INTRODUCTION

The QRS complex is the most distinct period among electrocardiogram (ECG) signals. A simple hardware device and improved ECG lead measurements were developed in this study. In addition, software was employed to detect the characteristic points of the QRS complex and record ambulatory ECG signals.

II. RESEARCH BACKGROUND

A. Electrocardiogram Waveform Composition

When the heart contracts, weak electrical signals can be detected on the body surface. The changes in potential of the heart and recorded, forming an ECG graph. A complete ECG cycle consists of the P,Q,R,S, and T waves, as shown in Fig. 1.
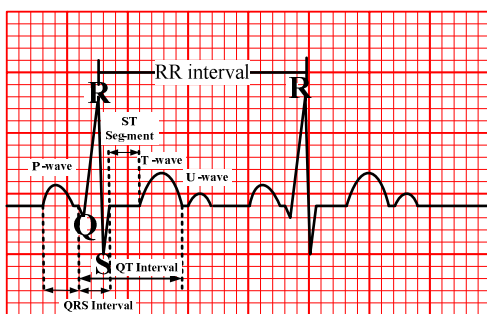

Fig. 1. PQRST waves in an ECG.

B. Standard Placement of Limb Leads

The standard placement of limb leads is shown in Fig. 2. This method places the leads on three axes, which form a triangle among the probe locations, with the heart in the middle of the triangle.
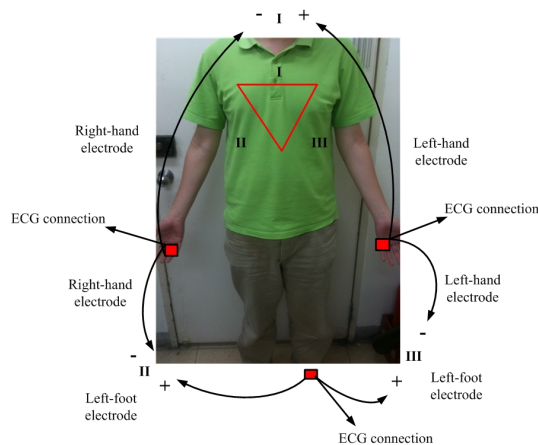
Fig. 2 Standard placement of limb leads

III. EXPERIMENTAL PROCEDURE

A. Wavelet Theory

Previously, nearly all standard tools for signal analysis applied Fourier transforms [1]–[2] to extract data from signals, as shown in (1).

$$F(\omega) = \int_{-\infty}^{\infty} f(t)e^{-jwt}dt \tag{1}$$

B. Determining the R Wave By Using the So and Chan Algorithm

To capture the QRS complex, the position of the R wave must first be obtained. The So and Chan algorithm was adopted in this study. The process is shown in Fig. 3.
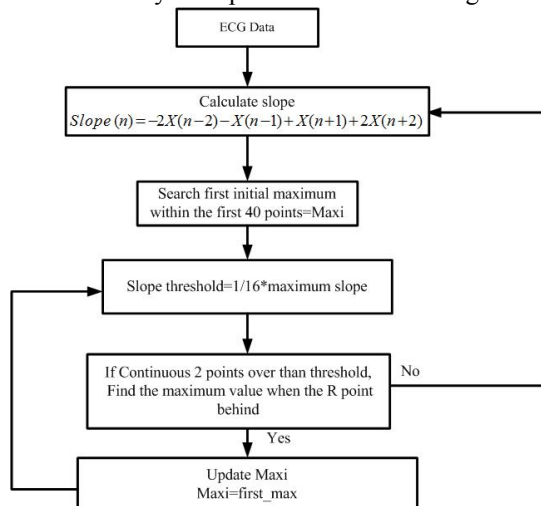

Fig. 3. Flowchart of the So and Chan algorithm.

IV. HARDWARE DESIGN

A. Improved Hardware Architecture

This study focused on ambulatory ECG. The primary problem to be resolved in ambulatory ECG is signal noise processing. During exercise, the body produces noise, including electromechanical signals. To reduce costs and to detect the true characteristic points of the QRS complex, two leads, instead of three leads, were used for detection. This circuit diagram is shown in Fig. 4. All of the detected signals were exported to MATLAB [3]–[4], and the characteristic points of the QRS complex were processed using an algorithm in the software.
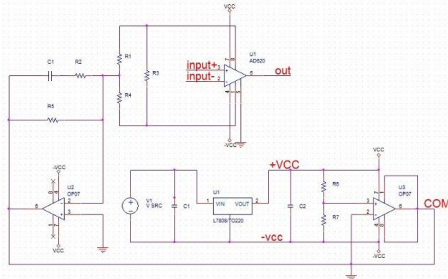

Fig. 4. The dual lead ECG circuit diagram.

In this circuit, AD620 [5] was used as the instrumentation amplifier. Because only two leads, namely input+ and input-, were used, the voltage was unstable, causing the ECG baseline to drift and exhibit fluctuating levels. Thus, an OP07 amplifier was added to regulate the signals. The result is shown in Fig. 5.

B. The final product for dual lead measurement

Fig. 5 The final product for dual lead measurement

V. COMPARISON OF SIMULATED RESULTS

A. Simulated ECG Using So and Chan Processing

Fig. 6 shows the R wave obtained using a third order transform and So and Chan algorithm processing of the wavelet. Each calculated R wave is labelled.
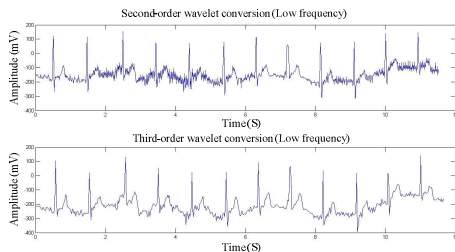

Fig. 6. Diagram of the R points.

B. Analyzing Effectiveness By Using the Physionet Database

The Physionet [6] Web site combines the MIT-BIH Arrhythmia Database developed by the Massachusetts Institute of Technology and other databases developed by schools such as Boston Medical Center of Boston University. Physionet consists of abundant reference data, including ECG signal data, ECG waveforms, and composite data. Table 1 shows that the average margin of error in the calculations in this study was approximately 3.478 ms. According to the CSE , the standard margin of error is 6.6 ms for QRS-on and 9.2 ms for QRS-off. The largest margin of error is approximately 15.8 ms. Thus, the effectiveness of the results of this study is acceptable.

TABLE I
COMPARISON OF MARGINS OF ERROR

Record No.	QRS Interval (ms) (QT Database)	QRS Interval (ms) (Present study)	Average Margin of Error (ms)
sel102	108.6	114	-5.4
sel103	67.4432	67.2	0.2432
sel104	116.52	119.2	-2.68
sel114	54.8	69.2	-14.4
sel116	60.4	58	2.4
sel117	89.2	92.4	-3.2
sel14046	70.8	61.6	9.2
sel15814	127.72	125.2	2.52
sel16265	67.2	56	11.2
sel16272	47.8	32.8	15
	QRS Interval (ms) (QT Database)	QRS Interval (ms) (present study)	Average Margin of Error (ms)
Average	70.68707556	67.20888889	3.478186667

VI. CONCLUSION

The Physionet database was used in this study to verify that the proposed algorithm can detect the QRS complex and ambulatory ECG signals. The article entitled "Delineation of QRS-complex, P and T-wave in 12-lead ECG," published in the IJCSNS, reported an average margin of error of 8.4 ms. In comparison, the margin of error was 3.478 ms in the current study, implying that the proposed device is more effective.

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