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ELECTROCARDIOGRAM MEASUREMENT PLATFORM IMPLEMENTED THROUGH VIRTUAL INSTRUMENTS

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Abstract. *This paper proposes an electrocardiogram (also known as ECG) measurement platform implemented through virtual instruments of LabVIEW IDE. We use the electrode patches of the ECG sensor to attach in Lead II limb leading position and integrate the ECG sensor with Elvis II+ modular platform for capturing the ECG signals 500 sample points per second to computer in order to have further signal processing. When the ECG signals are captured, they initially contain lots of noises which are not conducive to the detection and identification of arrhythmia features. This ECG measurement platform implements some virtual instruments to remove baseline drifts of ECG signals and filter the edges of ECG signals. This platform uses "So and Chan" method to look for QRS complexes to identify the symptoms of arrhythmia, such as premature ventricular complex (PVC), atrial premature contractions (APC), bradycardia, and tachycardia. This platform also could display the status of heart rate variability (HRV) of human body. Moreover, we use MIT-BIH Arrhythmia Database to validate the correctness of the arrhythmia algorithm. From the verified result, we could see that this ECG measurement platform could provide a helpful reference for preliminary arrhythmia diagnosis to medical staff.*

Keywords: Arrhythmia, Electrocardiogram (ECG), Premature ventricular complex (PVC), Atrial premature contractions (APC), Heart rate variability (HRV)

1. **Introduction.** Recently, cardiovascular diseases have become one of the major causes of death in developed countries. After Taiwan was upgraded to developed country, cardiovascular diseases have also become one of the major causes of death in Taiwan. According to the newest statistics from the Ministry of Health and Welfare of Taiwan in the year 2013, among every five people there is usually one who died of cardiovascular disease. Because cardiovascular diseases have no significant symptoms in the beginning, it is easy to ignore. The prevention of cardiovascular diseases has become a very important issue.

The measurement and analysis of electrocardiogram (also known as ECG) [1] in the development of physiological signal have been used over hundreds of years. ECG measurement usually uses the noninvasive methods by electrode patches attached to fixed limb leading position to record electrical potential difference of myocytes produced by

little ECG electrical signal. We use this way to detect abnormal heart electrical conductions for acute and chronic heart related diseases in order to observe the patients' signs of life and regularities of heartbeat. By this way we could have some preliminary diagnosis of heart related diseases such as heart rhythm irregularities, hypertrophy, atrial enlargement, or myocardial infarction. However, we still need to depend on doctors' rich practical experiences and professional knowledge for the actual diagnosis of the disease cause.

The structure of this paper is organized as follows. Section 2 explains the system implementation. The experimental result is shown in Section 3. Section 4 details the validation with MIT-BIH Arrhythmia Database. Finally, the conclusion is presented in Section 5. This electrocardiogram measurement platform could capture ECG signals, detect the QRS complexes [2,3] in ECG signals, and get the status of heart rate variability (HRV) and preliminary arrhythmia analysis. We use MIT-BIH Arrhythmia Database to validate the correctness of the arrhythmia algorithm.

2. **System Implementation.** There are three parts in this work, the hardware part, the software part and the validation part. In the hardware part, we use Vernier's ECG sensor with electrodes to catch ECG signals. The NI's ELVIS II+ platform is integrated with Vernier's ECG sensor to transfer analog signals to digital signals and transmit ECG signals to computer for further processing.

In the software part of this work, we use NI LabVIEW IDE to implement Electrocardiogram Measurement Platform for ECG signal processing, ECG wave detection, heart rate variability (HRV) calculation and preliminary arrhythmia analysis. In the process of capturing ECG signals, some other noises would be mixed in ECG signals. We need to filter captured signals in order to detect the ECG signal waveforms and calculate heart rate variability (HRV) for preliminary arrhythmia analysis. We use MIT-BIH Arrhythmia Database to validate the correctness of arrhythmia algorithm used in this work. Figure 1 is the system structure graph, Figure 2 is the ECG actual measurements, and Figure 3 is the interface of ECG measurement platform realized by virtual instruments.

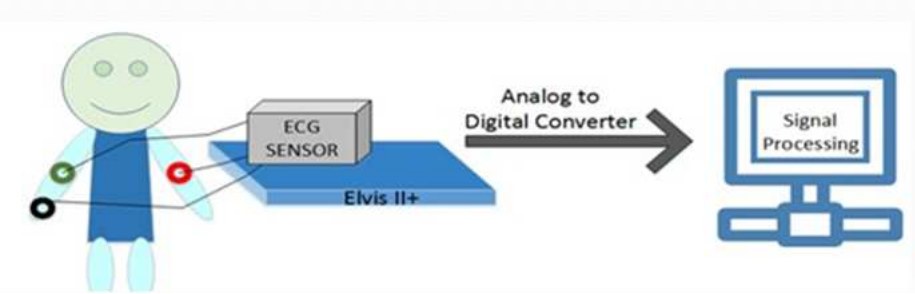


FIGURE 1. System structure graph

(1) ECG Signal Processing.

In the processing of ECG signals, we remove the baseline drifts in ECG signals and filter the edges of ECG signals. We use the Chazal's method [4] to remove baseline drift in ECG signal. The Chazal's method [4] uses two median filters: the first median filter of 200ms eliminates the QRS complexes and P waves and the second median filter of 600ms eliminates T waves of ECG signals. Then we get the baseline drifts without the QRS complexes, P waves, and T waves. By subtracting the result from the original ECG signals, we get the ECG signals without baseline drift. Figure 4 shows the comparison of ECG signals after removing baseline drift.

After taking away the baseline drifts from the ECG signals, we use NI LabVIEW's db08-wavelet filter component to filter the edges of ECG signals. Figure 5 shows the result of using db08-wavelet in ECG signals.

FIGURE 2. ECG actual measurements

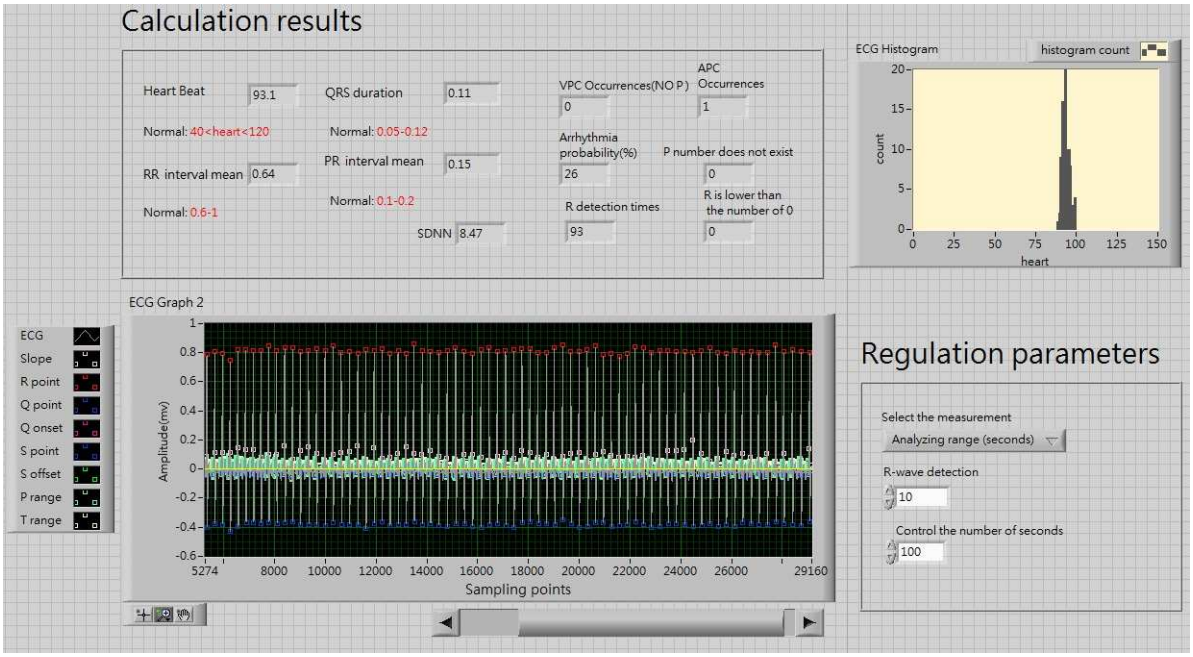


FIGURE 3. Interface of electrocardiogram measurement platform

(2) ECG Waves Detection

In order to get accurate detection of the QRS complex, the "So and Chan" method [2] is adopted in this work. The "So and Chan" method is based on the maximum slope detection with the QRS onset selected when two successive values of the slope exceed the threshold. First, let $X(n)$ represent the amplitude of the ECG data at a discrete time n. The slope of the ECG wave is calculated by Equation (1) [5].

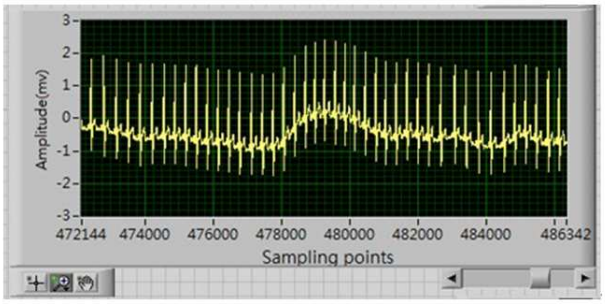
$$Slope(n) = -2X(n-2) - X(n-1) + X(n+1) + 2X(n+2) \tag{1}$$

The *Slope_threshold* is computed using Equation (2).

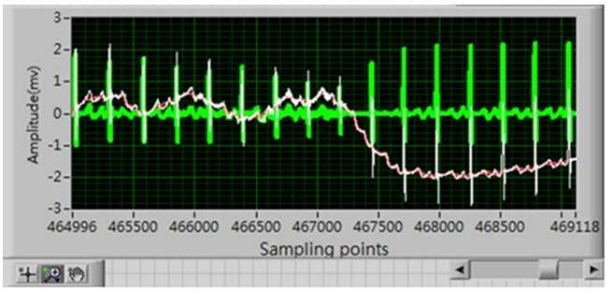
$$Slope\_threshold = (Threshold\_param/16) * \max i \tag{2}$$

When two consecutive ECG data satisfy the condition that $Slope(n) > Slope\_threshold$, the onset of the QRS complex is detected. According to the suggestion given in [2,5], the parameter *Threshold_param* could be set as 2, 4, 8 or 16 and the *Filter_param* could be set as 2, 4, 8 or 16. After the detection of the onset of QRS complex, we shift the appropriate samples to detect the maximum point ($\max i$) and take as the R point. The $\max i$ is then updated by Equation (3) [5].

$$\max i = ((First\_\max i - \max i)/Filter\_param) + \max i \tag{3}$$

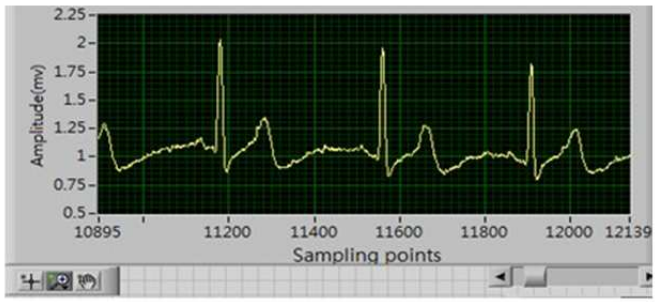


(a)

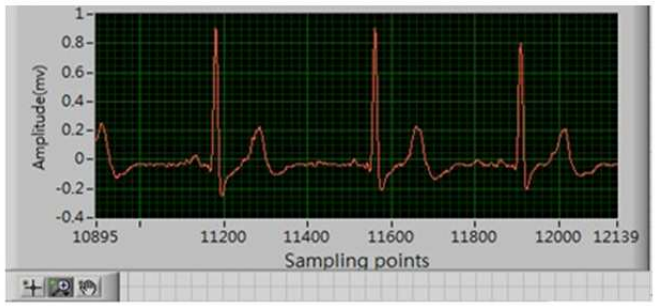


(b)

FIGURE 4. (a) Original ECG signal, (b) after baseline drift elimination



(a)



(b)

FIGURE 5. (a) Original ECG signal, (b) after the usage of db08-wavelet

The $First\_\max i$ is defined by Equation (4).

$$First\_\max i = height\ of\ QRS\ onset - height\ of\ R\ point \tag{4}$$

The initial $\max i$ is the maximum slope of first 250 points. The appropriate *Threshold_param* is 8 and the *Filter_param* is 16 in [2,5].

(3) Heart Rate Variability (HRV) Calculation

Heart rate variability (HRV) is the physiological phenomenon of variation in the time interval between successive R points (the peak of the QRS complex of the ECG waves). The beat-to-beat intervals are analyzed to give SDNN variables [6,7] in time-domain method.

(4) Arrhythmia Analysis

In this work, we use the electrocardiogram waveforms to detect four kinds of arrhythmias: premature ventricular complex (PVC), atrial premature contractions (APC), bradycardia, and tachycardia. When arrhythmia occurs, there will be some certain features in the electrocardiogram waveforms. We classify some features of electrocardiogram waveform changes to define the preliminary diagnosis of cardiovascular diseases. Table 1 shows the related diseases of abnormal electrocardiogram waveforms. Figure 6 shows the flow chart of detection methods of cardiac arrhythmias.

Table 1. Related disease of abnormal electrocardiogram waveform table

Wave Forms	Features	Related Diseases
P wave	hidden	atrial fibrillation
	Too early	APC (Atrial Premature Contractions)
PR Interval	Prolonged PR: > 0.20s	Slowed conduction in AV node
RR Interval	a resting heart rate of below 60 bpm	bradycardia
	a resting heart rate of above 90 bpm	tachycardia
QRS Complex	wide QRS	ventricular tachycardia
	tall R-waves in LV leads	Left Ventricular Hypertrophy (LVH)
	opposite direction of T wave (R Wave Inversion)	Premature Ventricular Complexes (PVC)
T wave	ST Segment Elevation and T Wave Inversion	Myocardial infarction, myocardial ischemia

3. **Experimental Results.** From our practical measured analysis results, we could find that both sympathetic and parasympathetic nervous system will affect the balance of autonomic nerve system. In order to prevent from chronic diseases caused by dysfunction of autonomic nerve system, we evaluate their statuses of heart rate variability (HRV). After all, we discover the best way to prevent from chronic diseases is to get relaxed in the daily life, trying not to stay up late and have pressures, and maintain some exercise habits.

4. **Validation.** We use six records from MIT-BIH Arrhythmia Database, each one five minutes, to validate the arrhythmia algorithm. The results of the arrhythmia algorithm compared to the records in MIT-BIH database are recorded in Table 2. We could see the R wave detection algorithm really has high correctness in detection rate. However, some conditions would cause our R wave detection algorithm to have misjudgments. The followings are some known conditions that would lead to misjudgments of the R wave detection algorithm.

- Too many noises (Over-filtering will cause signal loss)
- R wave upside-down (opposite with T wave)
- Successive premature ventricular complex (bigeminy coupled rhythm)

The work of detecting the occurrences of cardiac arrhythmias is organized in Table 2. The meanings of all significances are as below:

- TP: Symptom(s) detected, also found in MIT-BIH Arrhythmia Database.

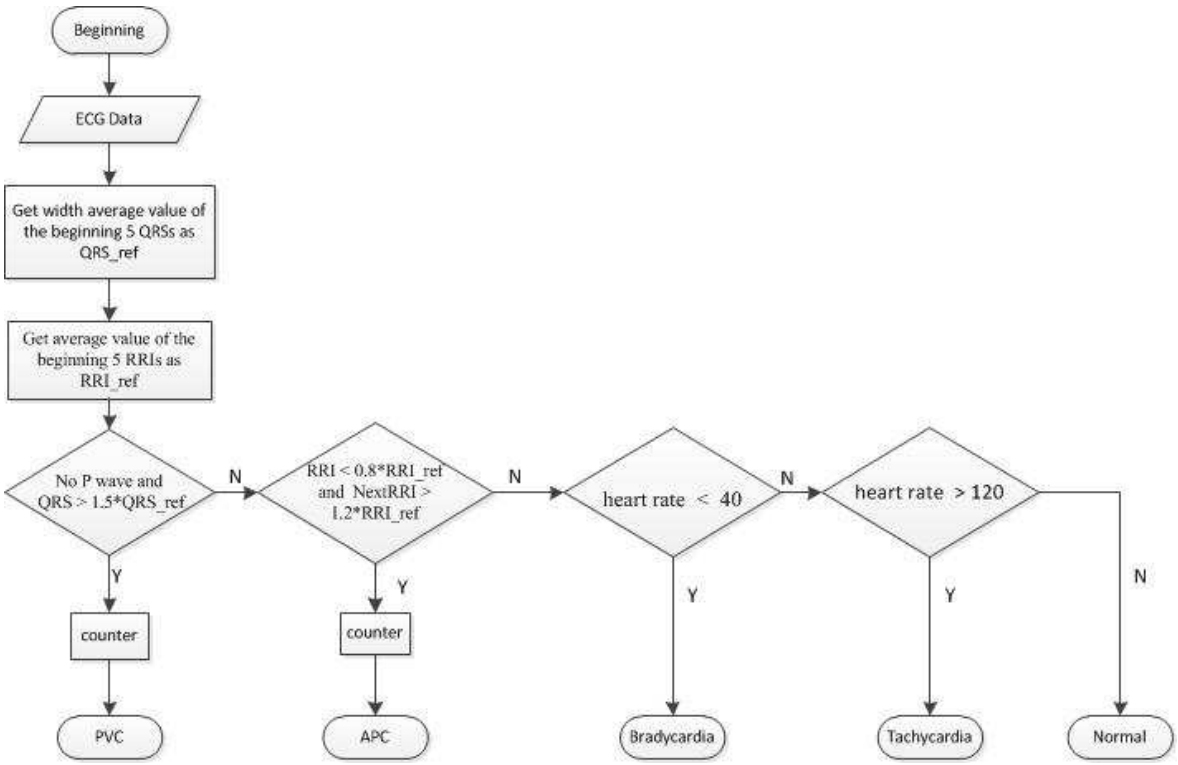


FIGURE 6. Flow chart of detection methods of cardiac arrhythmias

TABLE 2. The sensitivity rate of cardiac arrhythmia table

MIT-BIH Record					
Record	**FP**	**TP**	**FN**	**Sensitivity (%)**	**Symptom**
100	0	4	0	100%	APC
103	0	0	0	N/A	Normal
105	13	12	0	100%	PVC
114	16	13	0	100%	PVC
209	7	10	1	90.91%	APC
210	37	21	11	65.62%	APC/PVC
Mean				**91.3%**	

- FP: Symptom(s) detected, but not found in MIT-BIH Arrhythmia Database.
- FN: Symptom(s) not detected, but found in MIT-BIH Arrhythmia Database.
- Sensitivity (%) = TP/TP + FN
- Symptom: The types of cardiac arrhythmia happened within 5 minutes.
- Mean: The average value of Sensitivity (%)

We could see the sensitivity of record no.100; no.105 and no.114 are all 100%. The sensitivity rate of record no.209 is 90.91%. Although this record had misjudgments caused by detection errors, we still have all detail conditions detected. However, record no.209 lost one occurrence of premature atrial contractions (PAC). We first use official online electrocardiogram to look for the time of cardiac arrhythmia occurrence. Then we compare the lookup results with our experiments. Because the algorithm in our experiment did not count this premature atrial contraction, one occurrence of premature atrial contractions (PAC) was lost.

The sensitivity rate of record no.210 is only 65.62%. The reason was due to noises in ECG signals and successive premature ventricular complex (PVC). The noises often

cause the detection errors in the beginning of R wave by making the successive waveforms undetectable. Therefore, this sensitivity rate is so low.

5. **Conclusions.** In this paper we include the conditions of user's autonomic nerve system (ANS) to prevent from chronic diseases in HRV analysis. We also use MIT-BIH arrhythmia database to validate the correctness of the arrhythmia algorithm in cardiac arrhythmia detections. The result of arrhythmia algorithm shows that the average sensitivity rate is 91.3%. This really could prove that this ECG measurement platform could help medical staffs in preliminary diagnosis.

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