A Detection and Analysis System of ECG Signals Based on Wavelet Entropy

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***Abstract* — In order to remove the noise of ECG signals and extract their characteristics, a new detection and analysis system based on wavelet entropy is proposed. We outline the theory of wavelet transform, the method of ECG feature extraction based on wavelet entropy application, and using Matlab programming, we design an automatic extraction system of ECG signal features with MATLAB GUI interface, including ECG signal detection, amplification, denoising and feature extraction. Test results show the system can complete the detection of ECG signal, amplification, denoising, feature extraction, and achieve automatic extraction of ECG signal feature points. The clinical ECG has an excellent practical value.**

Key words — ECG signal; wavelet entropy; feature detection; disease analysis mixed programming

I INTRODUCTION

ECG signal is a bioelectricity signal generated by the excitation of cardiac muscle. The characteristics of ECG signal reflect the health status of the heart [1]. In recent years, the incidence of heart disease continues to rise, seriously affecting the quality of life and family happiness [2]. In order to detect and treat heart disease, it is very important to study the feature extraction method based on wavelet entropy.

ECG signal preprocessing, mainly divided into three directions, namely the classic digital filter, adaptive filter and the latest wavelet transform filtering method. In the filtering of baseline drift noise, the most commonly used method is reasonable with curve fitting correction method, namely using spline interpolation, polynomial fitting to estimate noise, and then subtracted estimation noise from the original signal[3]; Xue Q et al add neural network into nonlinear adaptive filter, the removal effect of this.

Filter is good for baseline drift noise and artifacts are, but once QRS wave changes, filtering effect of the filter will be greatly influenced by[4] Kunt M and Rey et al. Divided digital filter into remove the baseline drift noise and enhance the characteristic waveform two layers, received a good denoising effect[5].

In the filtering of frequency interference noise, the first method is smoothing filtering method, this method is simple, operation speed and good effect is acceptable, but the drawback is the key of ECG QRS wave will be affected, the overall signal attenuation; Warrior designed a FIR filter of the integral coefficient, the filter requirements in rank is strict[6]; In order to filter out the noise of power frequency, Levkov dealed ECG signal with the linear and nonlinear processing, but this method affects the QRS wave group[7]; In 2002, Shen Qian designed the equal ripple FIR filter and zero phase IIR filter by using the Chebyshev theory, which is simple and practical8; Li G et al aim at the frequency of ECG signal in noise, a template matching method for the design of adaptive filter, the filtering method with frequency noise by the noise signals of the template, followed by a noisy signal minus the template[8].

In the aspect of EMG noise removal, due to the serious overlap of the EMG noise frequency and the QRS wave group, the traditional filtering method is difficult to achieve satisfactory results. Donoho handle ECG signal with wavelet transform, set the threshold to filter the EMG noise[9]. Ji Hu et al. In order to overcome the pseudo Gibbs phenomenon of the traditional discrete orthogonal wavelet to produce noise in the ECG signal, puts forward the discrete stationary wavelet of removing the noise in ECG, this method can not only retain the key waveforms of ECG signal, and can be very good to remove noise[10];Zhao Li et al proposed a de-noising algorithm based on improved wavelet threshold method which does not change the ECG signal, this algorithm can not only overcome the traditional threshold algorithm will appear oscillation in the ECG, but also improve the signal-to-noise ratio, reduces the mean square error[11]; Li Nan et al. By regulating the Q wavelet transform de-noising of ECG signals, this method can have the frequency spectrum and the different oscillation form signals effective separation, has achieved good effect in de-noising of ECG signals, but does not avoid the problem of selecting wavelet function in wavelet transform[12].

Aiming at the advantages and disadvantages of the existing ECG signal preprocessing and feature detection methods, study a GUI interface of ECG automatic analysis

based on the reasonable detection and analysis of ECG signals. According to the results of ECG GUI interface analysis to determine the health status of the heart, assist doctors to provide a reference for doctors[13].

II ECG SIGNAL ACQUISITION SYSTEM

The ECG signal acquisition system is mainly composed of ECG lead, ECG signal conditioning circuit, ECG signal conversion circuit, microprocessor and memory. ECG signal is obtained by ECG lead. The signal conditioning circuit is used to preprocess the ECG signal. It comprises three parts of an amplifier, a filter, a level lifting and the like, and the processed signal is converted into a digital ECG signal by the signal conversion circuit of the ECG signal, and send it to the microprocessor.

The microprocessor sends the data into the memorizer, and using bluetooth sends the digital signal to the host computer for further processing. In the upper computer, using MATLAB for signal processing and analyzing achieve waveform display, data identification and feature extraction, diagnostic alarm, storage and other functions, the structure of ECG acquisition system shown in figure 1.

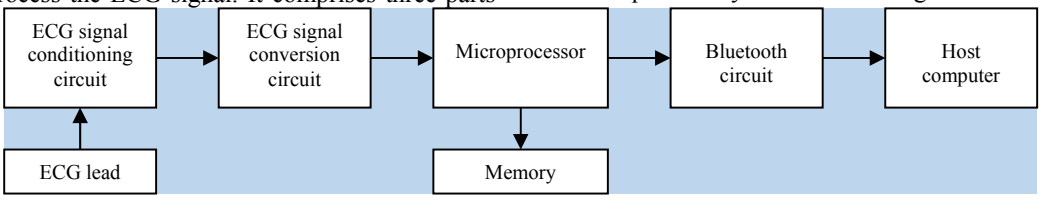


Figure 1. Structure of ECG acquisition system

A. ECG Signal Conditioning Circuit

The ECG signal is a low frequency weak signal under the condition of high intensity noise, which requires that the preamplifier has the characteristics of high input impedance, high common mode rejection ratio, low noise, low drift and high voltage amplification. The ECG signal is a weak signal, the frequency distribution is in the range of 0-100Hz, and the signal noise is low, Therefore, in the process of signal acquisition will be affected by a variety of interference,

These noises generally include power frequency interference, electrode contact interference, EMG interference, baseline drift and so on, among which the 50Hz power frequency interference caused by the human distributed capacitance is the most serious, In order to eliminate the interference, the 50Hz double T notch filter and the low pass filter are designed. It can be seen that the ECG signal conditioning circuit includes: pre amplifier circuit, filter circuit, notch circuit three parts, the specific circuit shown in figure 2.

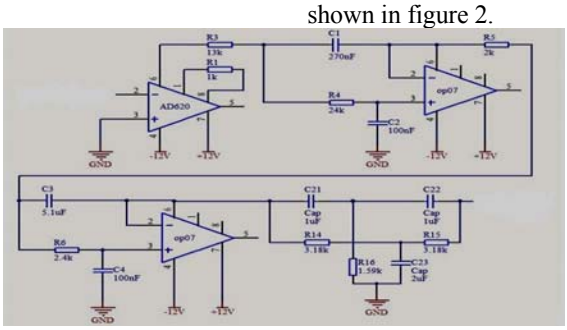


Figure 2. ECG signal conditioning circuit

B. Microprocessor and Bluetooth Interface Circuit

After the microprocessor gets the digital ECG signal, the result is sent to the host computer through Bluetooth, and the ECG signal feature extraction and diagnosis alarm function is realized by the host computer. The microprocessor and Bluetooth interface circuit is shown in figure 3, Microprocessor and Bluetooth chip through the serial port to achieve information exchange, so as to complete the ECG data transmission, Bluetooth broadcast control tasks.

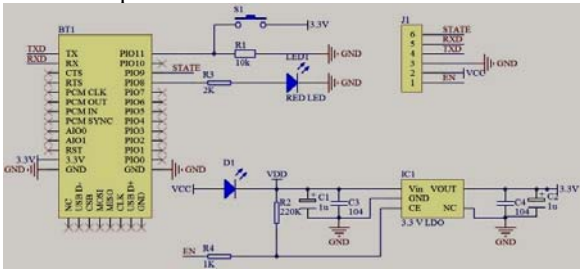


Figure 3. Microprocessor and Bluetooth interface circuit

III RESEARCH ON ECG SIGNAL FEATURE EXTRACTION

A. Research on Wavelet Transform Theory

Wavelet transform is a new signal time-frequency analysis theory, which is based on Fu Liye analysis. The essence of Fourier analysis is to decompose the signal into a series of sine waves with different frequencies, the same wavelet analysis is to decompose the signal into a series of wavelet functions[14].

If the function f (T) can be expressed as a linear decomposition:

$$f(t)=\sum_{l} a_l \varphi_l(t) \tag{1}$$

In the formula:

l—Integer index of Finite and infinite sum;

a_l —Real valued coefficients;

$\varphi_l(t)$ —A collection of real valued function of T.

If the expansion is unique, the set is called a set of functions that can be expanded. If the base is orthogonal, so the coefficient can be used for inner product computation, i.e.:

$$a_k=\left\langle f(t),\varphi_k(t)\right\rangle=\int f(t)\varphi_k(t)dt \tag{2}$$

In the formula:

a_k —expansion coefficient;

$\varphi_k(t)$ —A collection of real valued function of T.

Wavelet transform on the basis of 1, constructed a two parameter system available:

$$f(t)=\sum_{j} a_{jk}\sum_{l}\varphi_{jk}(t) \tag{3}$$

In the formula:

j, k—Integer index;

$\varphi_{jk}(t)$ —Wavelet expansion.

B . Wavelet Entropy Denoising Algorithm

In information theory, entropy for each symbol represents the average the average amount of information and the source of the uncertainty of signal entropy reflects the size of uniform probability distribution[15].

Calculated by the coefficient matrix of the wavelet transform entropy reflects the sparse degree of the coefficient matrix, which is the probability distribution of the order degree of signal, The probability distribution of the signal is close to random distribution, the greater its entropy, the entropy is called wavelet entropy[16].

The ECG signal is decomposed by wavelet transform, which is decomposed into m scales, and the wavelet coefficients on the scale J are set as:

$$w_j=(\overline{w_{j1}},\overline{w_{j2}},\ldots,\overline{w_{jn}}) \tag{4}$$

The energy on the scale J is:

$$E_j=\left\|w_j\right\|^2=\sum_{j=1}^{n}\left|\overline{w_{jl}}\right|^2=(\overline{w_{j1}},\overline{w_{j2}},\ldots,\overline{w_{jn}}) \tag{5}$$

The total energy of the signal is:

$$E=\sum_{j=1}^{m}E_j \tag{6}$$

In the formula:

E_1 —Wavelet energy spectrum of signal f (T) on a scale;

E_2 —Wavelet energy spectrum of signal f (T) on tow scale;

$\vdots$

E_m —Wavelet energy spectrum of signal f (T) on m scale;

According to the characteristics of orthogonal wavelet, the total power of E in a certain time window is equal to the sum of the power components E_j of each component found:

$$\sum p_j=1(p=E_j/E,j=1,2,3,\ldots,n) \tag{7}$$

Therefore, the wavelet entropy is defined as:

$$w=-\sum p_j \ln p_j \tag{8}$$

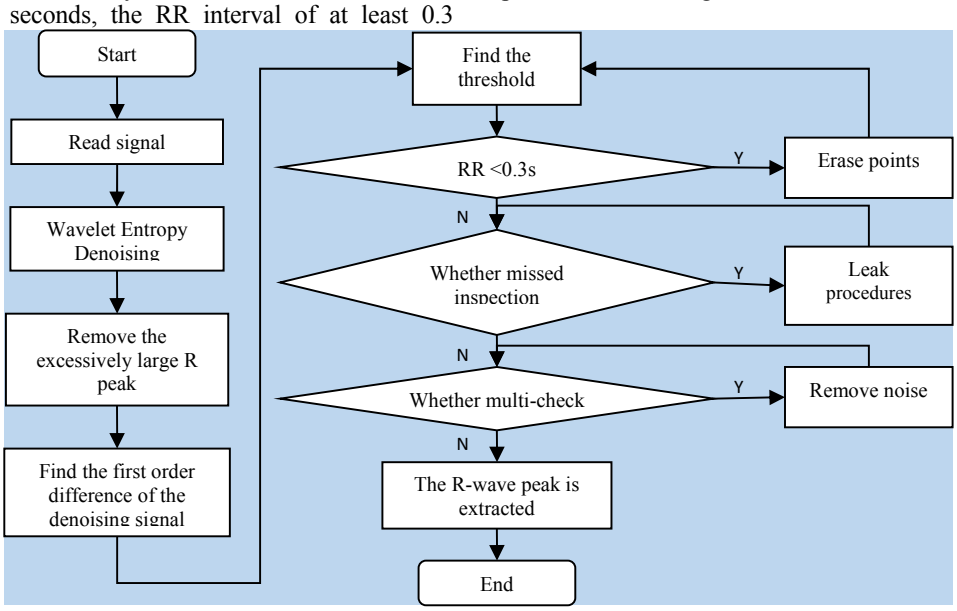
The wavelet entropy is used to detect the noise signal and filter the noise signal, And then extract the characteristic signal. By using different wavelet entropy on different wavelet decomposition scales, the threshold of high frequency coefficients can be adaptively determined, So it can detect the weak signal in the strong noise environment and realize the strong noise removal. Algorithm steps: 1)By using the method of multi-resolution decomposition, the wavelet function is selected to decompose the ECG signal to a certain scale, Selecting reasonable wavelet decomposition level, the wavelet decomposition coefficients of the noise signal and the wavelet decomposition coefficients of the ECG signal are obtained; 2)The calculation of wavelet threshold J scales; 3)Threshold quantization is performed on the high frequency component of the J scale; 4)Increase the decomposition scale, so that the wavelet coefficients of the noise signal is getting smaller and smaller; 5)The two wavelet transform is performed for single branch reconstruction of high frequency decomposition signal, then the wavelet entropy threshold quantization is used to deal with the high frequency coefficients of the two wavelet decomposition, get the high frequency wavelet coefficients of the approximate two transform; 6)By means of the wavelet coefficients of the wavelet decomposition of the highest level and the different frequency scales of the two wavelet coefficients, finish the components of signal reconstruction are reconstructed and reconstructed.

IV RESEARCH ON ECG SIGNAL FEATURE EXTRACTION AND DIAGNOSIS

A. R Wave Feature Extraction

The R wave is the largest amplitude wave in all the waveforms of ECG signal, the feature change is relatively

obvious. In addition, the Q wave and S wave are respectively adjacent to the R wave, according to the position of the R wave to determine the position of Q wave and S wave, which is simple and reliable. On the basis of the traditional differential threshold method, two improvements are made. First of all, the R peak is eliminated to avoid the influence of threshold selection. Secondly, a R wave duration of 0.08 seconds to 0.11 seconds, the RR interval of at least 0.3 seconds, so the RR interval of less than 0.3 seconds to remove the R wave point, re positioning of the wave crest position. The improved differential threshold method not only makes use of the advantages of the differential threshold method, but also avoids the disadvantages. The improved differential threshold method of R wave detection process shown in figure 4.



Figiure 4. Flow chart of R wave detection with improved differential threshold method

B. Feature Extraction of Q Wave and S Wave

The peak value of Q wave is adjacent to the R wave before the peak of R wave, and the peak value of S wave is adjacent to the R wave after the peak of R wave. Therefore, according to the peak of R wave, Q wave and S wave are extracted. The specific method is that the R wave peak is extended to a certain time window, and then the Q wave and S wave valley point are obtained.

C. Feature Extraction of P Wave and T Wave

On the basis of the time window detection method, the method of ECG signal de-noising based on wavelet entropy is used to create a clean, low noise environment. Secondly, the ECG signal in the time window is transformed, to enhance the energy characteristics of P wave and T wave. The improved time window detection method for detecting P wave and T wave is shown in figure 5.

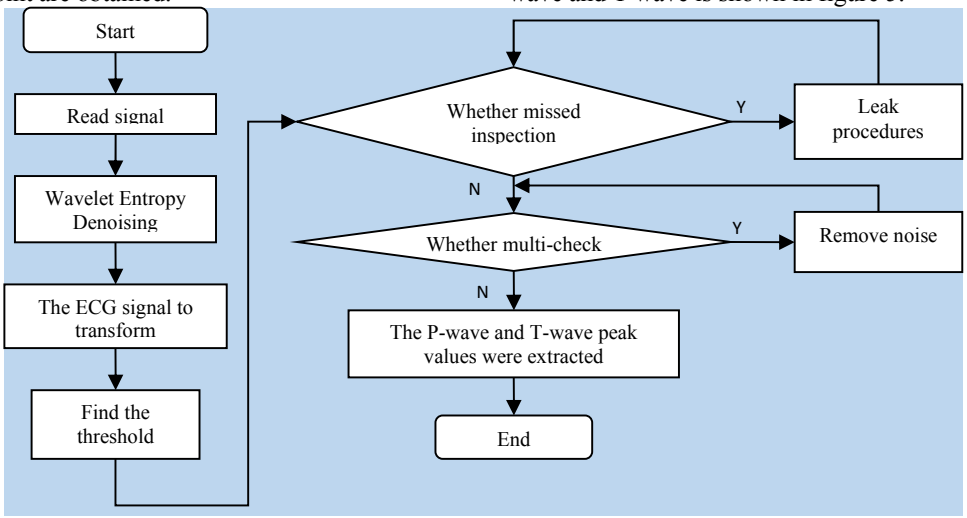


Figure 5. Improved time window method to detect P wave, T wave flow chart

V SYSTEM TEST

A. Denoising partial test

using wavelet entropy threshold de-noising method on De-noising of ECG signal using Matlab programming, ECG denoising effect diagram shown in figure 6.

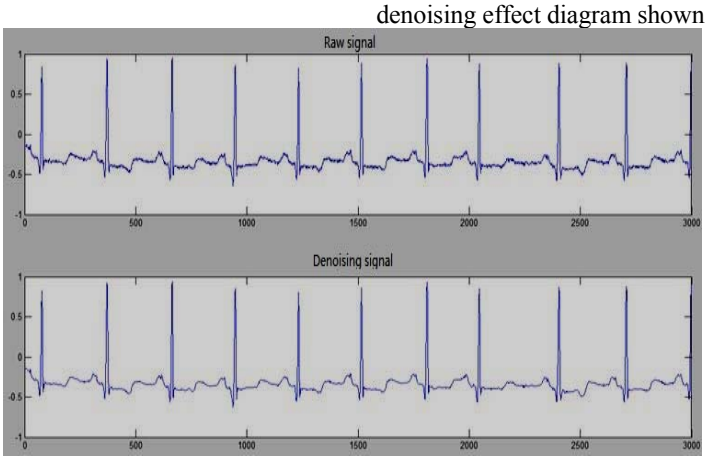


Figure 6. Effect of ECG signal de-noising

B. Feature extraction part test

ECG feature extraction effect diagram shown in figure 7. Among them, P wave by green dots, Q wave by the yellow dots indicate, R wave by the red dot, S wave by the red dots indicate, T wave by a blue dot said.

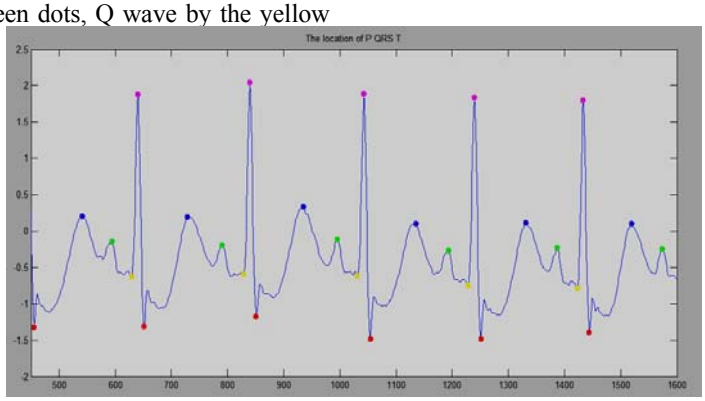


Figure 7. Effect of ECG feature extraction

C. Application Software IntegrationTest

Edit the front panel analysis of automatic functional design using MATLAB powerful graphics, including ECG signal input module, spectrum analysis module, ECG signal amplification module, ECG signal de-noising module and display module and feature extraction module and ECG images. Among them, according to the introduction of ECG data drawn to detect ECG, analysis spectrum analysis and feature extraction by introducing signal; according to clinical experience, further to determine the suspected heart disease; to determine the health status of the heart rate according to the size and time of each band. As shown in Figure 8 for the design of the MATLAB GUI interface.

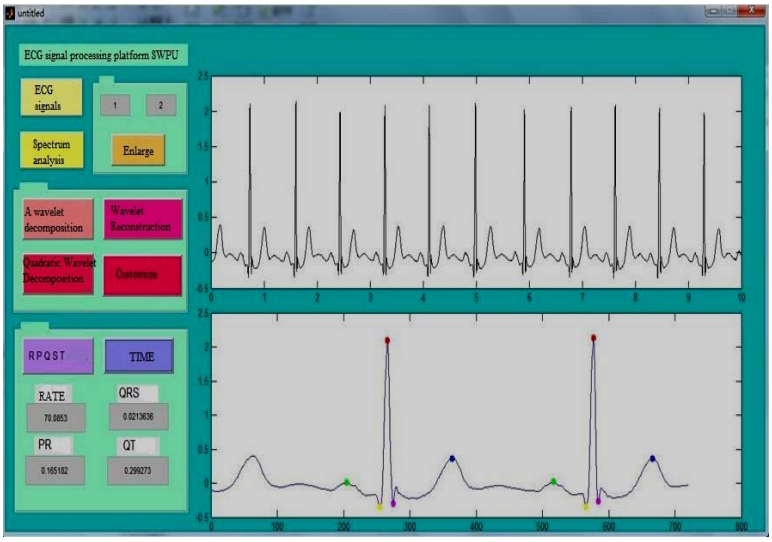


Figure 8. Feature extraction of ECG signal GUI

Through the verification, the interface can be used to extract more accurate feature points, and finish the ECG signal spectrum analysis and de-noising, then provide the basis for pathological diagnosis for hospital staff.

VI CONCLUSION

Studied the wavelet transform theory, and denoise the ECG signal with the wavelet entropy algorithm. At the same time, through the MATLAB programming, an efficient, convenient and intuitive ECG signal feature analysis system is realized. The following conclusions can be drawn:

(1)During studying and improving the feature extraction method of the ECG signal based on Wavelet Transform, a feature extraction method of ECG signal based on wavelet entropy is presented. during studying and improving the feature extraction method of the ECG signal based on Wavelet Transform, a feature extraction method of ECG signal based on wavelet entropy is presented.

(2)A GUI interface of feature extraction based on wavelet entropy is designed, and elaborates the design details of the GUI.

(3)Through the simulation test, the result of feature extraction of ECG signal is obtained. The test results show that the software has the advantages of better de-noising effect, more accurate feature extraction and so on, can be applied to the clinical examination industry.

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