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TCPD BASED PULSE MONITORING AND ANALYZING

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Abstract:

This article presents pulse monitoring and analysis approaches on Traditional Chinese Pulse Diagnosis (TCPD) by means of modern nonlinear signal processing technology. Pulse monitoring is significant for the research on cardiovascular and nervous system. But some interference, such as respiration, motion artifacts can be greatly brought into the long-term pulse acquisition. Thus, a cascaded adaptive wavelet filter is designed to solve this issue. Then analysis of long-term pulse waveform in TCPD is illustrated after being preprocessed. What's more, the chaos character of healthy Heart Rate Variability (HRV) is validated.

Keywords:

Traditional chinese pulse diagnosis; Pulse monitoring; Pulse waveform; Adaptive wavelet filter; Chaos

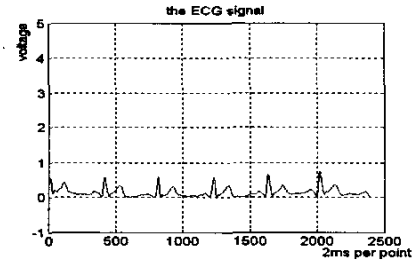
1 Introduction

Pulse Diagnosis, one of the four diagnostic methods of Traditional Chinese Medicine (TCM), has been proven to be worthwhile and clinically valid over 5000 years of the Chinese medicine history recorded.

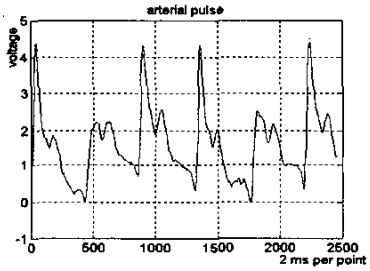
During the long period of medical practice, ancient Chinese physicians have accumulated rich experiences of diagnosis, which formed the comprehensive diagnostic system for TCM. By means of modern signal processing technologies, TCPD is developing in way of keeping the distinctive features and combining with modern sciences.

Medical informatics has expanded rapidly over the past few years [1]. Continuous electrocardiogram (ECG) monitoring in the patients has become a very common procedure during the last thirty years [2]. The MIT-BIH database also consists some of long-term ECG data [3].

Many western people may consider that pulse waveform is just the same as ECG and the patient's ECG analysis is enough. In fact, the signal of ECG acquired through several electrodes only reflects the bioelectrical information of body. By analyzing the pressure fluctuation signal of pulse, doctors can detect and predict more symptoms than by analyzing ECG. As shown in Figure 1(a), the patient's ECG signal cannot tell us the abnormal. On the contrary, his pulse, shown in Figure 1(b), indicates his disease information evidently. TCPD not only can deduce both positions and degree of pathological changes, but also is a convenient, inexpensive, painless, bloodless, noninvasive and non-side effect method promoteded by U.N.[4].



(a)



(b)

Fig.1. The same patient's ECG and Pulse

Compared with ECG, pulse has less complexity and can be easily acquired. Therefore we propose the pulse monitoring for studying the vascular and nervous system.

This paper is organized as following: In Section 2, long-term monitoring of pulse is stated firstly. Then an adaptive wavelet cascaded filter is described in Section 3. The analysis of long-term pulse waveform and their corresponding experimental results are presented in Section 4. Section 5 draws the conclusion.

2 Long-term Monitoring of Pulse

A pulse monitoring system should include the sensitive and stable sensor, amplifier, preprocess circuit, processing, analysis and interpretation.

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Employing a wrist-mounted optical sensor, Mikio Aritomo et al have developed an arterial pulse system for continuous data acquisition in studies of resting heart rate and circadian rhythms [5]. During the long-term acquisition of the pulse, the motion artifacts and baseline wander may be introduced greatly. This is the big challenge for long-term pulse research. Therefore, the removal of these interferences is a key issue for the further researches. But Mikio Aritomo et al did not notice this problem and did not analyze the pulse data further. Our pulse monitoring system comprises a set of pulse sensor, adapter, amplifier, and computer. The pulse sensor, named HMX-4, is a hyperbolic contact-terminal type of the strain cantilever beam transducer, which is more stable and sensitive than optical sensor.

3 Adaptive Cascaded Wavelet Filter

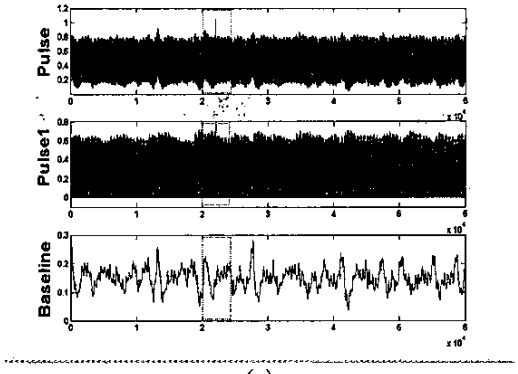
Pulse waveform in TCM is used extensively for the researches on diagnosis, pathology, physiology and psychology [6,7]. The bandwidth of the acquiring system is usually from the 0.05Hz to 100Hz with almost linear response, causing no distortion of the pulse waveform. However, distortion may arise from subject's movement, respiration and so on. The whole pulse goes down when exhaling and goes up when inhaling. Holding the breath may make pulse more stable. But these restricts not only make the patient uncomfortable and inconvenient, but also prevent us from acquiring the long-term stable pulse. However, this baseline wander introduced in the acquisition process will result in misdiagnosis. Therefore a wavelet based cascade adaptive filter to remove this wander is presented by us [8].

The proposed cascade adaptive filter consists of a first stage discrete Meyer wavelet filter, and a second stage cubic spline estimation. Compared with some traditional methods, such as cubic spline estimation and Linear-phase FIR least-squares error minimization digital filter, this proposed approach has better performance for removing the baseline wander of pulse waveform.

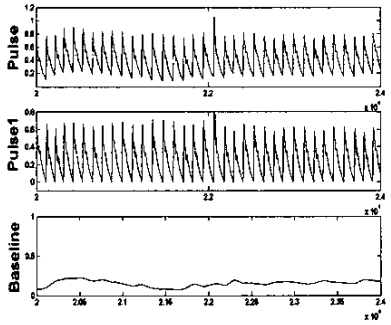
The discrete Meyer wavelet is applied in the first stage of the cascaded filter because it not only is linear-phase and orthogonal, but also has a better character in the frequency domain.

To remove the remaining contamination, we detect the 'reference points' of the pulse and apply the cubic spline to correct the baseline of pulse waveform. The researchers in Shanghai University of TCM apply the linear interpolation method without good result [9].

The traditional high-pass FIR filter has great oscillation at the stop band and transition band when the cut-off frequency is much smaller than the Nyquist sampling frequency. The proposed cascaded wavelet filter is adaptive and has better performance in both preserving the information and removing baseline wander. What's more, it is simple and easy to be implemented.



(a)



(b)

Fig. 2. The original pulse and its filtered results

The result of this filter is illustrated in Fig 2. Fig 2(b) is the local enlargement of Fig. 2(a). The Y-coordinate is the amplitude of the pulse and the X-coordinate is the sample point whose sampling rate is 100Hz. In Fig. 2, ***Pulse*** is the contaminated signal and ***Pulse1*** is the final filtered result. ***Baseline*** is the interference of respiration and others extracted from pulse. The pulse in Fig.2 is a waveform of ten minutes acquired from a health young graduate student during his sleep.

4 Analysis on Long-term Pulse Waveform

In Fig.2, the ***Pulse1*** signal still has some fluctuation. For the further analysis of the pulse, the pulse waveform should be normalized. Fig. 3 is the normalization of the pulse in Fig 2. The lower panel is the local enlargement of the upper one in Fig.3. The segmentation and feature extraction of pulse can be more precise due to normalization process.

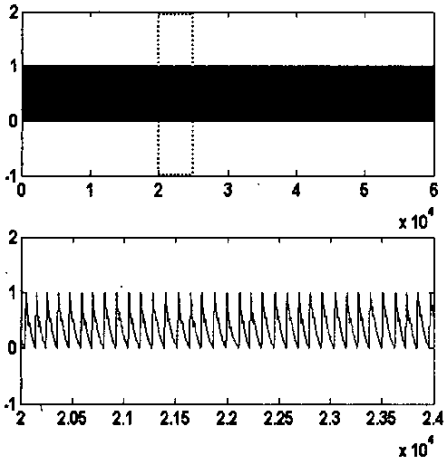


Fig.3. The normalization of the pulse

In this paper, all the pulse data are acquired by our pulse monitoring and diagnosis system [10]. After preprocessing above, the impersonal, stable, high-precision pulse monitoring is ensured and we can analyze the pulse waveform for medical application. Some well-known parameters in TCPD field are illustrates in Fig.4. ***Peak1*** and ***Peak2*** are the percussion wave and dicrotic wave of pulse respectively. ***W1*** and ***W2*** are their widths. ***H1***, ***H2*** and ***H3*** are the height of ***Peak1***, ***Valley*** and ***Peak2*** in pulse respectively. And ***t1***, ***t2*** and ***t3*** are their corresponding time. All of the parameters have the physiological, pathologic and psychological significance. The following are the analyses of long-term pulse parameters' variability.

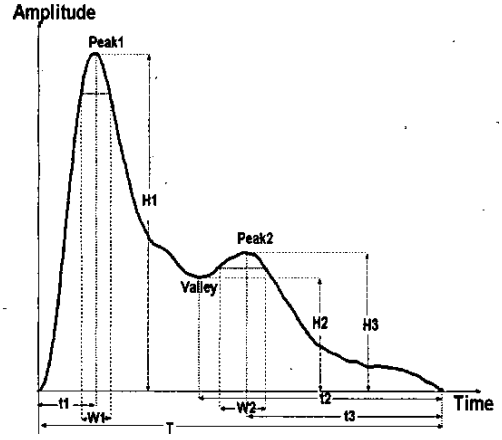


Fig. 4. Schematic figure of pulse's parameters

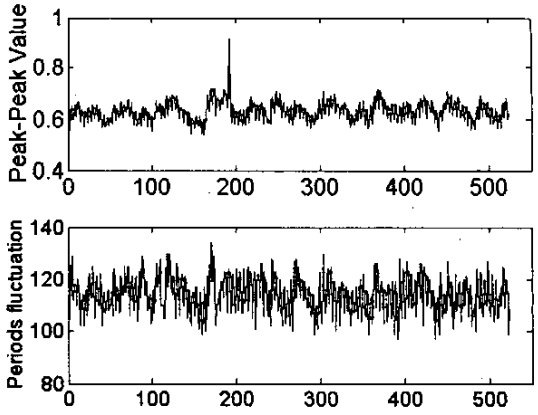


Fig. 5. The Peak-Peak values and periods variability

4.1 Peak-Peak Value and HRV

The variability of the peak to peak values of pulse waveform and the HRV signal in Fig.5 represent the information of the cardiovascular and nervous system [11]. The pulse in Fig. 5 is a 10 minutes long pulse which has 523 periods. The periods of this pulse fluctuate around 1150ms. The irregularity characteristic of the variability illustrates that the pulse is acquired from a healthy person. The wavelet analysis of the HRV also shows some Chaos characteristic in Fig. 6. We feel that this Chaos characteristic of HRV is related with health state of a person, which will be studied in our future work.

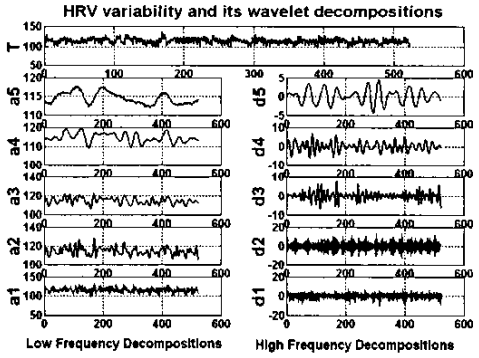


Fig. 6. The Chaos of HRV

4.2 Variability analysis of *t1*, *t2* and *t3*

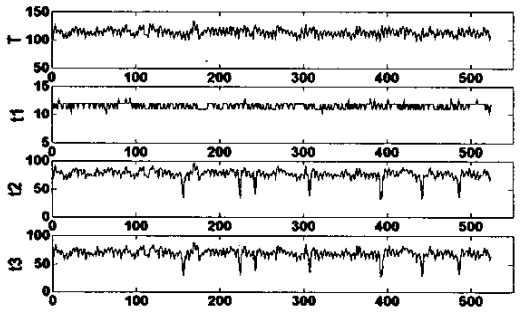


Fig.7. The fluctuations of *T*, *t1*, *t2* and *t3*

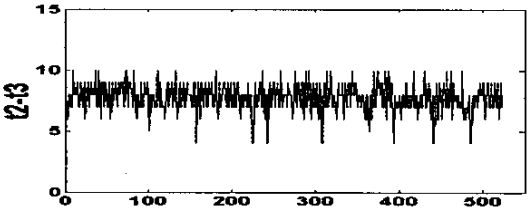


Fig. 8. The variability of *t2-t3*

The variability of *t1*, *t2* and *t3* illustrates in Fig.7 and 8. From the figure, we can see that the parameter *t1* varies little. Ordinary, its value is 11 to 12 sample intervals and it only fluctuates between 10 and 13 sample intervals. On the contrary, the parameters of *t2* and *t3* fluctuate greatly. The fluctuation of *t2* and *t3* also has the same trend. When the parameters of *t2* and *t3* vary greatly, the remaining of *t2* minus *t3* also has the same fluctuation. As sampling rate is 100 Hz, we can only discriminate the interval of 10ms. Therefore this sample rate is too low for more accurate variability analysis. However, with the increase of sampling rate, the long-term acquisition of pulse will consume much disk space. Therefore a compressing algorithm based on wavelet was employed in our pulse monitoring system for saving disk space.

4.3 Variability analysis of W1, W2, H2 and H3

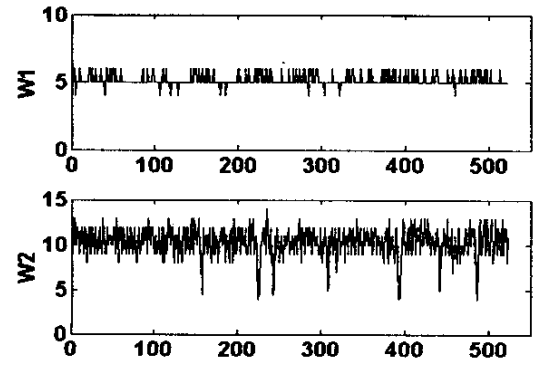


Fig.9. The variability of *W1* and *W2*

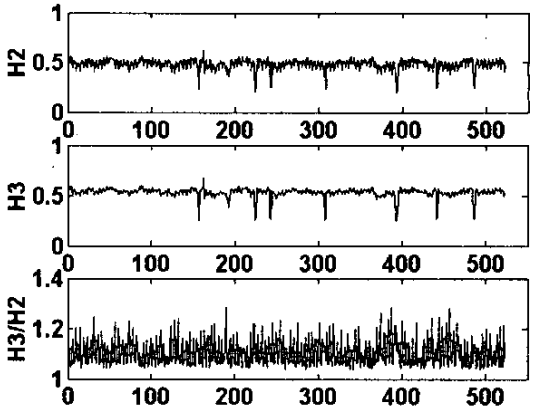


Fig. 10. The variability of *H2* and *H3*

From Fig.9, we can find that the **W1** fluctuate less than **W2**. Fig. 10 shows that the parameters **H2** and **H3** have some relation. But **H3** and **H2** have a little difference too.

From the researches on the above parameters' variability, we find that the parameters of health person's pulse also have some irregularly fluctuation. The peak1 parameters such as **t1** and **W1** vary little. The parameters of **t2**, **t3**, **W2**, **H2** and **H3** also have some relation. The medical significance of these parameters needs further researches. It needs hard work of both medical experts and computer scholars.

5 Conclusions

For the purpose of investigating the mechanism of manifestations of the pulse of TCM, this article has made lots of researches on pulse long-term monitoring and analysis. The baseline wander is a crucial issue for long-term monitoring and therefore a cascaded filter is designed. The features extracted from the long-term pulse waveform are analyzed. The chaos characteristic of HRV variability of healthy person is validated.

Thomas Martin et al have realized the wearable ECG Monitoring device [12]. Therefore, wearable pulse monitoring system will be developed in our future work for further research of long-term pulse. Due to dynamically changing of subjects and their environments, the complexity and non-linearity of the signal such as HRV and pulse features provide big challenges.

Acknowledgements

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