Modern Researches on Pulse Waveform of TCPD

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Abstract: This article presents the modern researches on Traditional Chinese Pulse Diagnosis (TCPD) by means of some modern signal processing methods. In order to demystify TCPD and prove its efficiency, its significance is briefed firstly. Secondly, a survey of recent developments in TCPD is provided. Thirdly, some modern advanced signal processing methods are applied to the analysis of pulse waveform and some experiment results are also illustrated. Furthermore, our pulse acquisition diagnosis system is introduced. Finally, the emphases and future works are also pointed out.

Keywords : Traditional Chinese Pulse Diagnosis, Pulse waveform.

I. Introduction

TCPD has been proven to be worthwhile and clinically valid over 5000 years of the Chinese medicine history recorded. Now, TCPD is acknowledged and fascinates more and more people in the west countries. For example, Leon Hammer, a clinician, teacher and writer, has taught pulse diagnosis worldwide over the last decade; more and more forums on pulse diagnosis such as pulse diagnosis group in Yahoo mushroomed recently [1,2]. However, due to the difficulty to master it, many people still take it as a mystery. Thus, it is extremely necessary to introduce TCPD and let more and more people understand it. Many kinds of apparatus and systems that can automatically detect pulse in patients demonstrate that the researches of TCPD are significant and successful, but the modern research of TCPD slowed down recently due to pulse's complexity and variation [3]. Nevertheless, the development in medical sensor, pattern recognition, signal processing, database and other relative fields will promote the research of TCPD forward.

This paper aims to employ some modern signal processing technology in TCPD and point out its brighter future. In Section II, the background, significance and an overview of recent developments of TCPD is stated firstly. Then some of modern signal processing methods are employed for pulse waveform and their corresponding experimental results are presented in Section III. Section IV points out future tasks, emphases and restrictions of modern research on TCPD. For more clearly, some Chinese explanations corresponding to the English terms on TCPD are given in the round brackets together.

II. Recent Researches on TCPD

Pulse Diagnosis, one of the four diagnostic methods of TCM, is to judge disease by means of fingertips palpating patient' pulse image shown in the superficial arteries. Many western people may consider that pulse waveform is just the same as electrocardiogram (ECG) and the patient's ECG analysis is enough. 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 some symptoms that ECG cannot. TCPD can not only deduce the 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].

To reveal the scientific essence of pulse diagnosis, a lot of researches have been made in the fields of TCM, modern medicine, medical engineering and their related fields from 1950's. But some of them did not base on the

+ Supported by the Multidiscipline Scientific Research Foundation of Harbin Institute of Technology (HIT.MD2001.36)

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0-7803-7547-5/02/$17.00 ©2002 IEEE

theory of TCPD. Besides the researchers in China, some scholers in Japan [5], Korean [6,7], German [8], Canada and US got interested in this research of TCPD [9]. In order to objectify pulse, engineers have designed many kinds of pulse sensors for acquiring pulse. Of all these kinds of pulse sensors, the pressure sensors can reflect the information just as pulse feeling based on TCPD better. The HMX pulse sensor made by Shanghai Medical Instrument Company has better reproducibility in operation [10]. According to the theory of elastic cavity, McDonald [11], Liu Zhaorong studied the circulation system [12]. But the cardiovascular system is so complicated that it cannot be modeled accurately. It is meaningful but it still needs the further systematic research. What's more, new disease and new problems associated with our modern civilization have begun to show consistencies in TCPD. For example, the "ceiling dripping" scattered pulse of AIDS and a kind of knotted pulse related to cancer are among the few recently identified syndromes which seem to have characteristic pulse images [13]. At present, the parameters' extraction is mainly carried out by time-domain signal processing method such as computing the amplitude, slope, area and so on. Due to some limits of those methods, the researches on TCPD make less progress. As civilization accelerates the application of modern signal processing methods and technologies, some biometrics technologies such as speech recognition and signature recognition have made rapid progress. Thus, the research of TCPD should combine with the modern signal processing too.

III. Our Researches on TCPD

In this section, all the pulse data are acquired by our pulse diagnosis system, which comprises a set of pulse sensor, adapter, amplifier, and computer. The sensor, named HMX-4, was made by Shanghai Medical Instrument Company. It is a hyperbolic contact-terminal type of the strain cantilever beam transducer, which is not the same as the previous sensors for studying the western medicine. Our sensor's probe is a trapezoid whose area is 29.4 mm^2, that makes the probe's deviation influence its repeatability little. Thus the impersonal, stable, high-precision pulse waveform is ensured. The followings are the three points of our researches on the data from our pulse database.

A. Baseline drift removal

Pulse waveform can easily be influenced by many factors such as respiration, body's movements 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 period of stable pulse. Thus, we developed an algorithm for baseline removal [14]. The pulse, with its baseline being adjusted, is signal3 in Figure 1, and its original pulse curve is signal1. Signal2 is the respiration and some other interference.

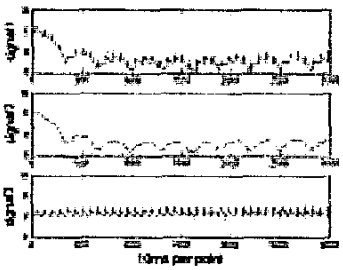


Fig. 1 Actual pulse and its results filtered by wavelet

B. Time-domain parameters feature extraction

About the extraction of pulse parameters, this article promotes two kinds of area grade analysis methods, namely X-axis area analysis and Y-axis area analysis. Applying the X-axis method, the systolic area and diastolic area and some related parameters are calculated. What's more, by means of the Y-axis area analysis method, the main peak's width and the variation of pulse waveform shape characters can be got. As Figure 2 illustrated, we gets the main peak's value P_m at first, then draw a line y=Pm. Then draw the equispaced lines parallel with the X-axis such as $y=0.99* P_m$, $y=0.98* P_m$,....., $y=0.02* P_m$ and $y=0.01* P_m$. Next, the pulse waveform intersects with these lines and the areas of these intersects can be calculated. According to the trends of areas, we can classify the various pulse images. If we combine these two kinds of area analysis method, the classification will be more satisfied.

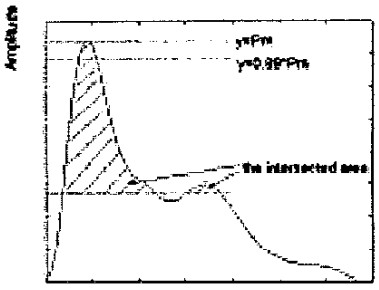
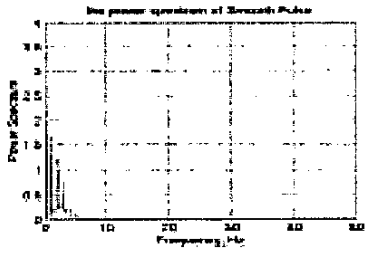


Fig. 2 Schematic figure of Y-area analysis method

C. Modern pulse waveform processing

Ling Y Wei found that the energy rate of pulse power spectrum did have some relation with the disease. This illustrates that the frequency analysis of pulse image is significant. Figure 3 shows our results of the pulses analyzed by frequency domain. From the power spectrum analysis, we can find that the ratio of the spectral envelope peaks are very important in analyzing people's physical condition. The smooth pulse contains three main peaks in power spectrum and the first three peaks are much higher than normal pulse; the taut pulse's power spectrum waveform has two main peaks and the other peaks are very small; normal pulse's harmonics decrease gradually. Applying method of power spectrum analysis, we can also analyze slow pulse ***(Man Mai)***, rapid pulse ***(Kuai Mai)***, moderate pulse ***(Huan Mai)***, scatter pulse ***(San Mai)***, knotted pulse ***(Jie Mai)***, running pulse ***(Cu Mai)***, intermittent pulse ***(Dai Mai)*** and so on [15-19]. At the same time, the distance between the adjacent spectral peaks is one of the criteria to judge the extent of the disease. The distances between the normal pulse's spectral envelope peaks are the same and every peak is more centralized.



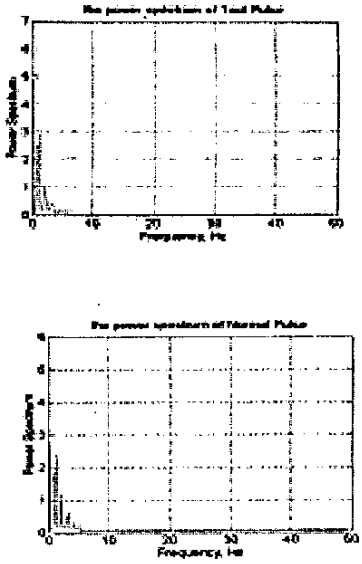


Fig. 3 Power spectrum compare of smooth, taut and normal pulses

There are some other frequency analysis methods too. The cesptrum analysis is one of useful methods in acquiring the pulse's period and intensity. In Figure 4, the first peak tells us the pulse's period is 1 second or so.

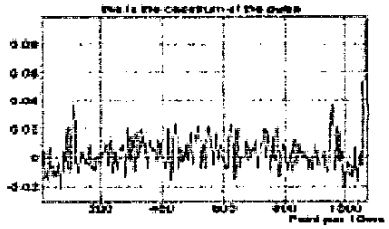
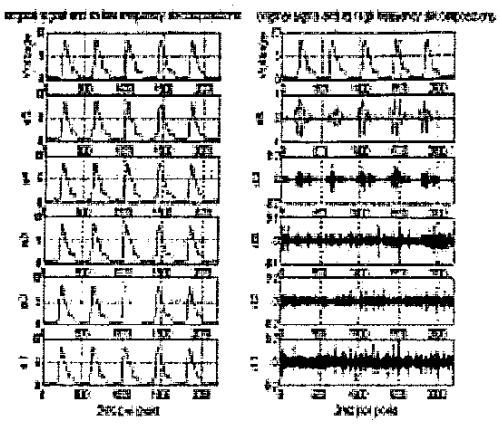


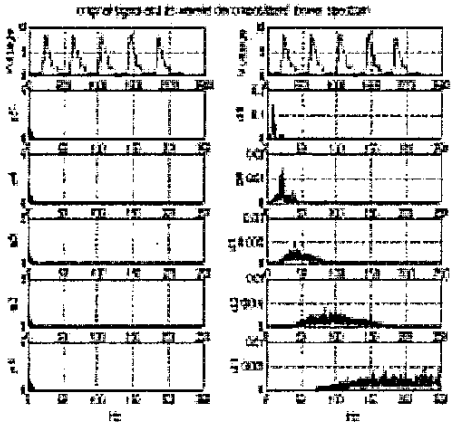
Fig. 4 Cepstrum of the pulse

Furthermore, many kinds of noise, such as the high-frequency noise and impulse noise are brought into the pulse signal. Applying the wavelet to denoise the dirty signal is satisfied, especially when the noise is impulse, but the FFT analysis cannot perform this work. The power spectrum of impulse is full of the whole spectrum domain and it cannot tell us the existence of the impulse; while the wavelet analysis method, the time-frequency domain analysis method, can perform this function. As Figure 5 shown, we can find a1, a2, a3, a4, a5, and the decompositions of signal S, become more and more smooth. The high frequency noise is extracted. The high frequency decompositions are very small and we can draw a conclusion that the pulse's frequency is very low too.

Having applied the wavelet in the analysis of 1-D physiological signal such as phyonocardiography, electrocardiography (ECG) and electroencephalography (EEG), great success has been achieved [20]. Those methods also can be employed for the research of TCPD.



(a)



(b)

Fig. 5(a) Original signal and its wavelet decompositions

Fig. 5(b) The frequency of the pulse's wavelet decompositions

After using Haar wavelet, Daubechies wavelets, Biorthogonal wavelets and so on, we found that the decomposition effect varies with the mother wavelets. So the best way is to construct the mother wavelets according to the characters of pulse. At the same time, some other time-frequency methods also have made some rapid progress for analyzing the medical signal [21]. Figure 6 illustrates the pulse and its short time Fourier transformation (STFT) result.

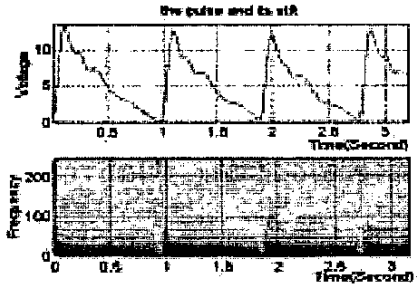


Fig. 6 Pulse and its STFT analysis

The choice on the method of the pulse's analysis is significant. Due to the variability of pulse mentioned above, some statistical approaches need to be used. Statistics alone do not help all the time, however. There is also a need for some signal processing algorithms, which are robust to the variability. Although several modern signal-processing algorithms have been developed for the research of pulse-taking, some technologies such as wavelet, STFT, Higher order spectrum, AR-spectrum array, neural network and so on were successfully applied in the research of heart's sound can be applied to study the TCPD too [22]. The methods of speech processing also can be used for reference. Based on our ever-growing database of pulse, our lab is on the way to improve the pulse image's efficiency of signal processing and recognition.

IV. Conclusions

For the purpose of probing the mechanism of manifestations of the pulse of Traditional Chinese Medicine (TCM), this article has made lots of researches on pulse wave by using signal processing methods. In time domain, a brand-new area analysis method is proposed. In frequency domain, Fast Fourier Transform and wavelet time-frequency methods are adapted to analyze waveforms. With these comments, we end our discussion of TCPD by stating some of its developing directions.

1. Putting more emphasis on the normalization of TCPD;
2. Unifying the instrument for acquiring pulse pressure, the analysis methods and the normalization of TCPD;
3. Combining the integral and dynamic research on TCPD with clinic;

4. Applying some modern signal processing & technology and looking for the new breakthrough of TCPD;
5. Combining with some other diagnosis methods such as tongue diagnosis, ECG, EEG and heart sound.

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