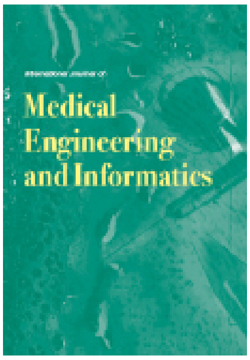

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Analysis of body constitutions discrimination based on radial pulse wave by SVM

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Abstract: In this work, a new method for distinguishing human's physical constitution based on pulse information is proposed. Firstly, pulse data were collected, processed and pulse cycles were segmented. Secondly, time domain features, features coefficients, power spectrums and energy values of pulse wave were extracted and analysed, respectively. Finally, pulse features were evaluated and classified to distinguish different body constitutions by SVM classifier. The experiment indicated that the features selected could be appropriately used to analyse the physical constitutions and can serve as the basis for research on constitution assessment based on traditional Chinese medicine pulse diagnosis.

Keywords: traditional Chinese medicine; TCM; pulse characteristics; body constitutions; support vector machine; SVM.

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1 Introduction

Traditional Chinese medicine (TCM) is a complete medical system that has widely application in disease diagnosis, treatment and prevention for over 30 centuries (Wu et al., 2017). In oriental as well as Western medicine, the pulse is considered as a fundamental signal of life, carrying essential information about a person's healthy status (Velik, 2015). Various pulse qualities have been described in TCM texts (Xiao et al., 2018). The Chinese medical doctors divide the terminal region of the radial artery into three adjacent intervals called Cun, Guan and Chi, and use the three fingers of index, middle and ring fingers simultaneously or individually to determine various characteristics of the pulse wave in pulse diagnosis (Huang et al., 2019a). It is generally believed that pulse can reflect people's different physical conditions, which is widely used in aid of diagnosing cardiovascular disease, such as hypertension, heart disease, thyroid function abnormality, diabetes, etc. (Zhang et al., 2018; Vallee et al., 2019).

From the point of view of TCM, pulse waves include objective information of human body. The researchers have found that time and frequency domain features can reflect some diseases. Therefore, a scientific way of studying the pulse should be to analyse its waves features, frequency spectrum distribution and correlate these features with physical conditions (Huang et al., 2019b). The spectrum of arterial pulse signals exposes discrepancies between healthy people, sub-healthy people and patients with certain diseases. Experienced doctors can determine the cause of disease and other information through the pulse of patients, and give reasonable treatment. Some diagnostic information can obtain by analysing the pressure fluctuation of the pulse. The TCM doctors could tell the pathological changes of the patients and further classify the patient into particular groups defined for particular treatment by perceiving the pressure of wrist pulse (Suguna and Veerabhadrappa, 2019). For example, the periodic and aperiodic components of the wrist pulse are used to analyse the health status by Wang et al. (2017). It found that four pulse features of the unhealthy subjects in the time series were highly correlated with the healthy pulse pattern.

Nine body constitutions are classified as gentleness, Qi-deficiency, Qi-depression, dampness-heat, phlegm-dampness, blood-stasis, special diathesis, Yang-deficiency and Yin-deficiency by TCM physician (Wang, 2005). TCM practitioner distinguishes everyone’s physical constitution according to the corresponding pulse characteristics.

Obviously, a better understanding of one’s constitution, the more conducive to health preservation. However, pulse assessment is a skill that requires long-term experience and is subject to subjective influence. Therefore, transformation of pulse feeling into quantified classification indices provides a new way to interpret the pulse waveform patterns objectively (Li et al., 2018).

At present, more and more attention has been paid to the diagnose model of combining TCM with artificial intelligence (AI). As the core of AI, machine learning provides an effective way to solve the complex autonomous learning and data analysis problems, such as support vector machine (SVM) (Arji et al., 2019), convolutional neural network (Cui et al., 2019), etc. The SVM model based on statistical learning theory uses the least square method to solve the least square problem by a set of linear equations based on structural risk minimisation (Trinchero et al., 2018). It can avoid over fitting of the training data, does not require iterative tuning of model parameters, requires few kernel and has universal application and good performance (Amari et al., 2019; Verma and Sharan, 2017). Chui and Lytras (2019) proposed a novel multi-objective genetic algorithm-based support vector machine (MOGA-SVM) for the multinomial classification of the inflammations of appendix, pancreas and duodenum. Cho et al. applied SVM with GTWED kernel (GTWED-SVM) to evaluated on a dataset including 2,470 pulse waveforms of five distinct patterns, which achieves a lower average error rate than current pulse waveform classification methods (Jia et al., 2019). These literatures show that SVM could be used for TCM clinical diagnosis study with intelligent thought.

In this work, a new method of distinguishing participants’ constitutions based on pulse characteristics is proposed. Firstly, the pulse characteristics are extracted and spectrum distribution diagrams are drawn. Secondly, the energy distribution in different frequency ranges are calculated and given. Finally, the pulse characteristics are used to distinguish participants’ constitutions by SVM classifier. The experiment verifies the feasibility and effectiveness of the method.

The rest of paper is organised as follows. In Section 2, some related work will be present. In Section 3, a new method of body constitutions classification for populations based on pulse waves is proposed in detail. In Section 4, experiment results and discussion are given. Finally, some conclusions and suggestions for future work are given in Section 5.

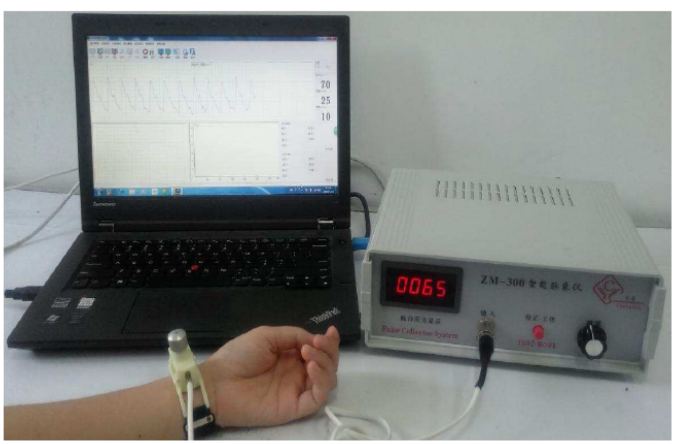
2 Methods

In this part, pulse data acquisition, data preprocessing and features selection were performed.

2.1 Data acquisition

The study protocol was approved by the Fifth Affiliated Hospital of Zhengzhou University. A total of 245 volunteers from Zhengzhou University have been recruited in this study, with a mean age of 24.2 ± 3.5. All volunteers agreed with the exposed terms by signing a written informed consent. Subjects were excluded from analysis if they lacked complete data or outcome variables or had significant disease. Each person collects six groups of data under six different pulse pressures, each group consists of 2,000 data points. The database contains 2,940 pulse signals that are unevenly distributed into nine constitutional types.

Figure 1 Pulse acquisition (see online version for colours)



2.2 Data preprocessing

Baseline wandering of original pulse wave was removed with a high-pass filter in the sampling device. A band-pass filter from 0.5 Hz to 30 Hz was used to eliminate the noise wave generated by tremor or respiration. The original pulse wave and filtered pulse wave are shown in Figure 2 and Figure 3, respectively. Pulse wave is the manifestation of various information carried by heart ejection activity and pulse wave propagating along all levels of arteries and vessels. Therefore, the rise, fall and isthmus of pulse wave have corresponding physiological significance. A typical cycle of measured pulse signal is illustrated including main parameters that are often used to characterise the waveform in Figure 4 and Figure 5. One of the advantages of these time domain parameters is that they are easy straightforward to understand, interpret and have some physiological significance. In this study, 32 pulse time domain features of both hands were chose for analysis including t_1, t_2, t_3, t_4, t_5, h_1, h_2, h_3, h_4, h_5, A_s, A_d, t, w_1, w_2 and A.

Figure 2 Original pulse wave (see online version for colours)

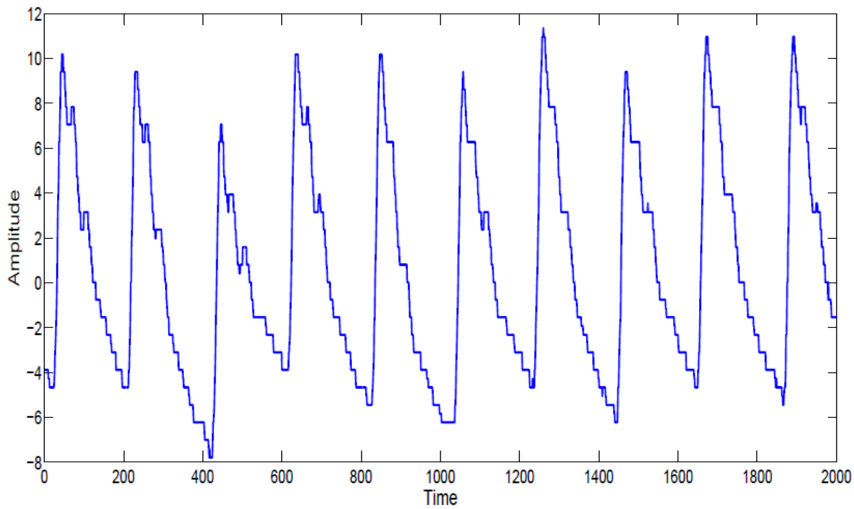


Figure 3 Filtered pulse wave (see online version for colours)

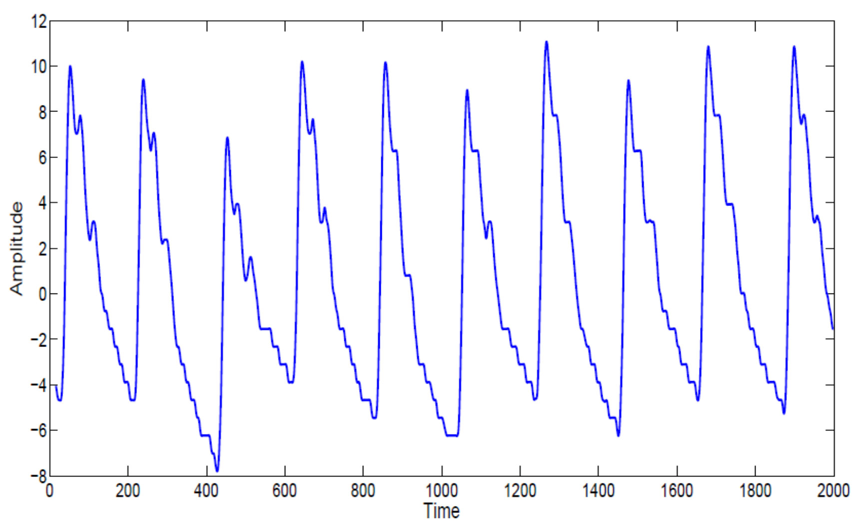


Figure 4 The time domain characteristics of pulse (see online version for colours)

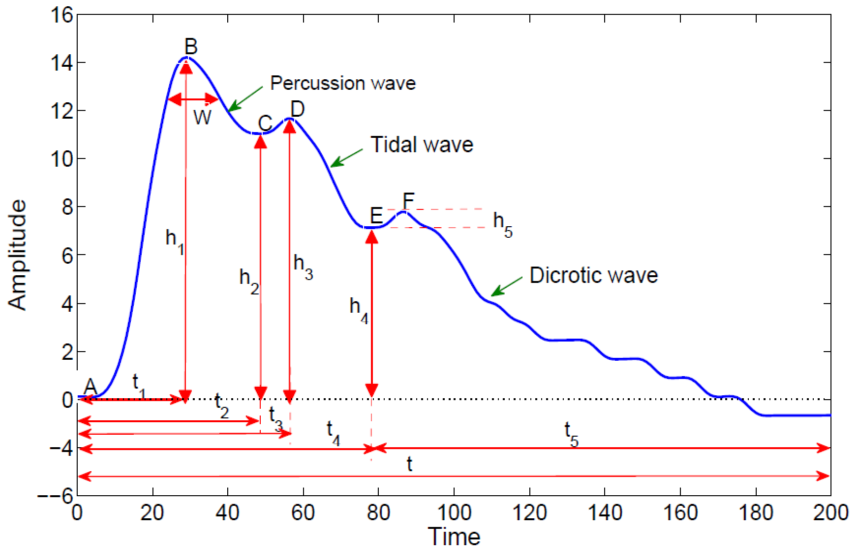
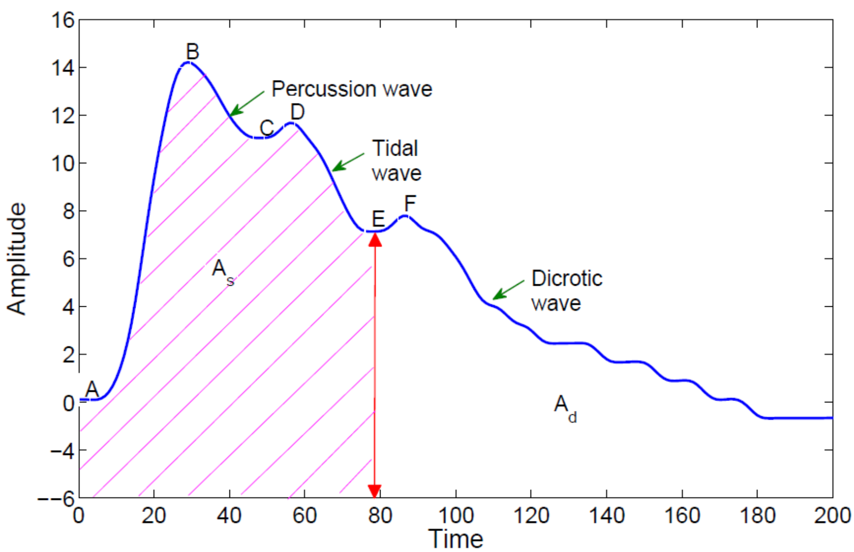


Figure 5 The systolic and diastolic area of pulse (see online version for colours)

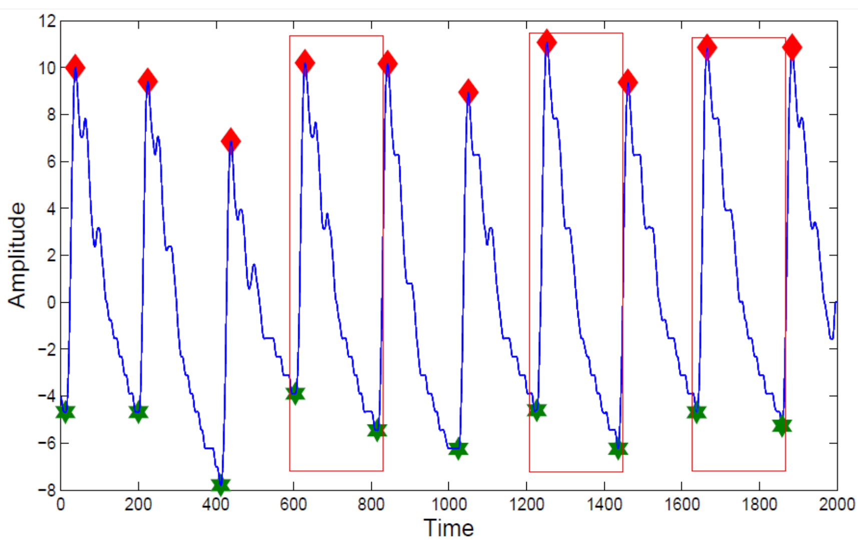


3 Constitutions analysis based on pulse characteristics

In this section, the constitutions analysis of 245 participants based on pulse characteristics were analysed in detail. From the perspective of TCM, everyone has their own physical characteristics, and the characteristics of the left hand and the right hand are not the same. The pulse datum collected from 245 volunteers are trained, studied and tested. The 32 pulse characteristics were used to classified by SVM. Concretely, the nonlinear pulse characteristics of input variables x is mapped into a Hilbert high-dimensional inner operator space H, the linear correlation characteristics was established with the target variables to form the SVM mode, so as to achieve the purpose of constitution classification.

In order to better distinguish the pulse difference in gender, the cepstrum and energy charts between male and female were drawn. The fundamental frequency of the pulse is the same as the beating frequency of the heart, which is related to the periodic pumping of blood by the heart. When human body is in a healthy state the pulse spectrum presents a complete and clear harmonic. If a part of the human body has pathological changes, then there will be a harmonic shift. Moreover, researchers have proved that there is a strong relationship between pulse features and gender. The relationship diagrams between pulse characteristics and gender, the power spectrum and time-frequency energy are used to analysis in this paper. Power spectrum is the power spectral density function in unit frequency band, which is the distribution of signal power in frequency domain. The energy spectrum refers to the signal energy of unit frequency. For the sake of generality, power spectrum of signal was obtained by autocorrelation function method. The power spectrums of healthy male and female were obtained in Figure 7 and Figure 8.

Figure 6 Periodic pulse waveform (see online version for colours)



The time-frequency domain can combine the time-domain and frequency-domain information, reflecting that the energy of signal varies with time in different frequencies. The pulse signal is transformed by wavelet transform, which can directly reflect the pulse energy under different frequencies. One-dimensional time function can be projected on the two-dimensional time-scale phase plane to obtain the time-frequency energy diagram by wavelet translation. The energy spectrums of male and female were shown in Figure 9 and Figure 10, respectively.

Figure 7 The power spectrum of healthy male (see online version for colours)

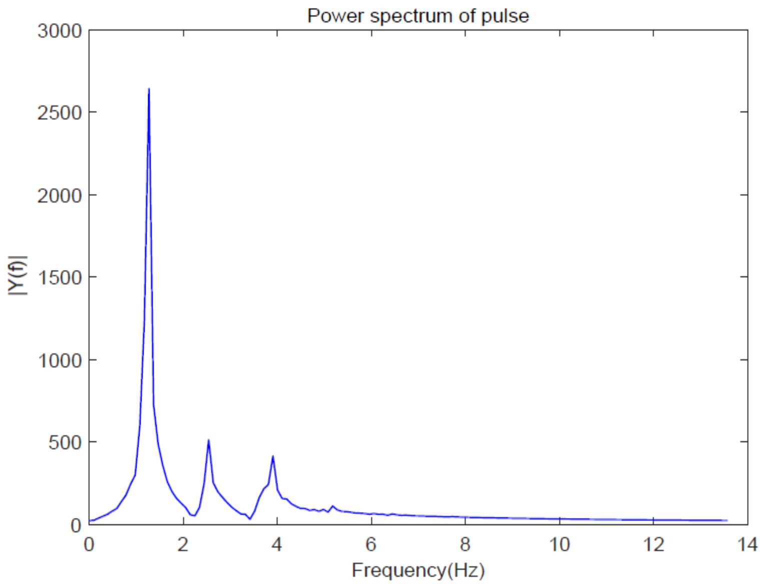
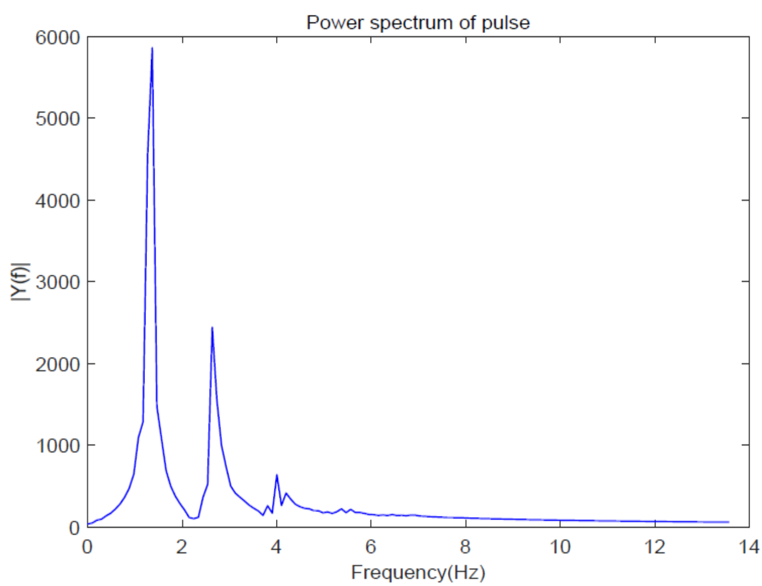


Figure 8 The power spectrum of healthy female (see online version for colours)



Remark 1: It is observed from Figure 9 and Figure 10 that the pulse power of human body is usually distributed in 0–20 Hz. Obviously, there are significant differences in pulse power and energy between male and female. The pulse power of men is generally lower than that of women in the 0–4 Hz frequency band. Compared Figure 9 with Figure 10, it is concluded that women's pulse power is nearly twice that of men.

Remark 2: Due to the periodicity of pulse, the time-frequency energy distribution of pulse is relatively concentrated in a certain frequency range, and basically concentrated in 0–4 Hz. For the convenience of research, the 0–4 Hz energy was divided into four sections, namely 0–1 Hz, 1–2 HZ, 2–3 Hz and 3–4 Hz, and the energy values calculated of each section in Table 1.

Figure 9 The energy spectrum of healthy male (see online version for colours)

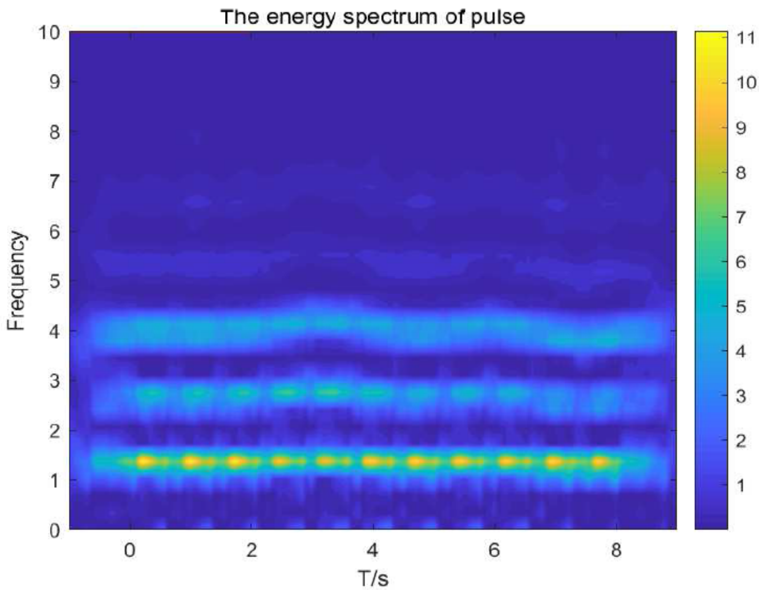


Figure 10 The energy spectrum of healthy female (see online version for colours)

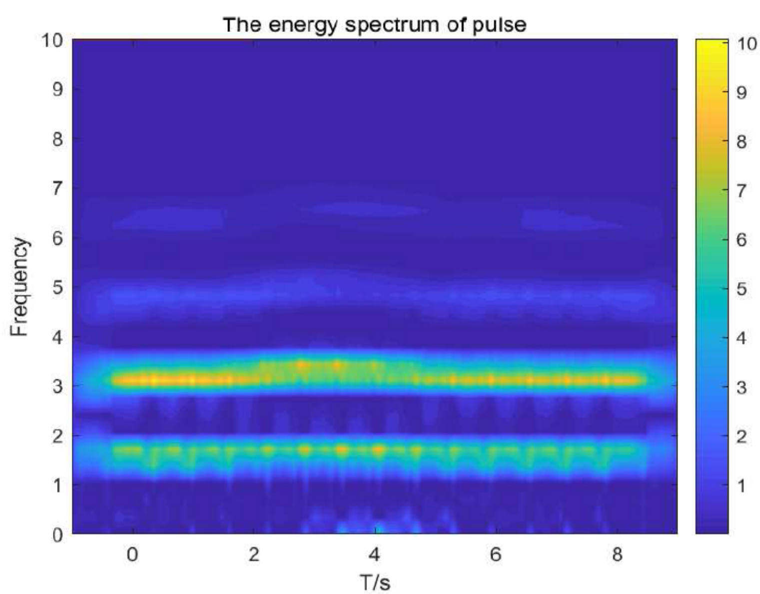


Table 1 Energy values of pulse

Frequency band/Hz	0–1	1–2	2–3	3–4
Male's energy value/dB	0.4493	3.7454	2.2335	1.4062
Female's energy value/dB	0.3658	3.3200	1.2164	4.1389

4 Experiment results and discussion

The support vector machine (SVM) with Gaussian RBF kernel was used, which has a good generalisation on small database in the experiments. Our experiments were done under the MATLAB environment by using the SVM-KM toolbox. The volunteers' constitutions are discriminated based on the 32 pulse features collected by right hand and left hand, and 16 pulse features collected by right hand and left hand, respectively. Furthermore, the following abbreviations are given for nine kinds of constitution, which is:

a gentleness

b Qi-deficiency

c Qi-depression

d dampness-heat

e phlegm-dampness

f blood-stasis

g special diathesis

h Yang-deficiency

i Yin-deficiency.

80% of the pulse data were selected as training and the remaining 20% as testing. The average classification accuracy was obtained by ten cross-validation. The SVW classification results are as shown in Tables 2 and 3.

Table 2 Classification accuracy of left and right hands

Parameter	*Accuracy rate (%)*
Left and right hands	76.50 ± 5.58
Right hand only	77.67 ± 8.22
Left hand only	72.10 ± 7.26

Table 3 Classification accuracy of nine physical constitutions

Constitution type	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
Accuracy (%)	85	78	80	82	78	84	82	81	84

There are some related attributes between human pulse and constitution, then we can distinguish physiological phenomena according to the characteristics of pulse. Thirty-two pulse features were extracted and the absolute value of correlation coefficient was used to evaluate the body contribution in this paper. The greater the absolute value of the correlation coefficient, the greater the influence on the constitution. The correlation coefficients between the pulse characteristics and the targets tag were shown in Figure 11.

Figure 11 Correlation coefficient between pulse characteristics and target tags (see online version for colours)

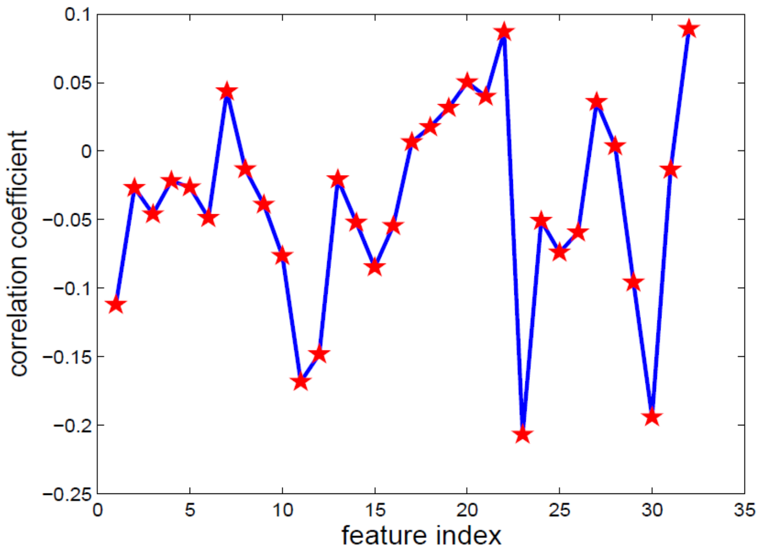
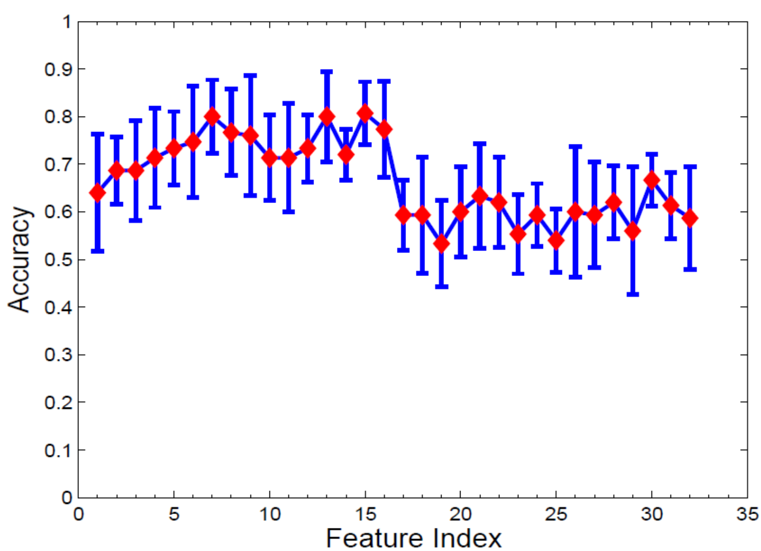


Figure 12 Accuracy rate of features index (see online version for colours)



The correlation between 32 features and accuracy was analysed in Figure 12. It clearly shows that the classification results generally show a general upward trend and a downward trend. The first seven pulse features can make the recognition accuracy more than 85%, so multi-features have advantages in body constitution classification. However, the feature redundancy will occur as the number of features increases. Therefore, the increase of features will affect the accuracy of classification.

5 Conclusions and recommendations for the future

TCM doctors believe that human wrist pulse wave contains a lot of important information, which can reflect pathologic changes of the human body condition.

In this paper, the characteristics of wrist pulse signal are introduced. Furthermore, a new method of distinguishing body constitution based on pulse features is proposed. We processed the pulse data collected and extracted the characteristics of the pulse wave. Power spectrums and energy spectrums are used to analyse the differences between different genders, and SVM classifier is used to evaluate and classify the nine constitutions. It is demonstrated that gender differences in many physical indices obtained from wrist pulse waves are significant in healthy adults. The experimental results show that the accuracy rate of this method is about 80% in classifying the healthy person's constitutions. In the future, we will extract more pulse features, use feature dimension reduction to eliminate feature interference caused by feature increase. In addition, new classifiers will be implemented to improve the classification accuracy, and further verify the new pulse diagnosis method.

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