

Research Article

Design of Pulse Wave Feature Vigilance Detection System Based on Computer Software Technology

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In this paper, the pulse wave feature alertness detection system based on computer software technology is researched. First, the computer software technology designs the alertness detection system and then conducts the system alertness test experiment using a system that can not affect the subjects' alertness, a portable multichannel physiological signal acquisition system that measures the subjects' ECG signal, skin resistance, blood oxygen saturation, and other physiological signals in the case of a degree task experiment. The multichannel physiological signal acquisition system collects the signals during the vigilance task experiment. At the same time, before, during, and after the experiment, subjects are required to fill in the Stanford Sleepiness Scale (SSS) and evaluate the level of individual alertness through subjective self-evaluation. The relevant experimental data show that, 10 minutes before the experiment, the pulse amplitude increased rapidly, then slowly decreased at the beginning, reached a peak in about 25 minutes, and then began to rise.

1. Introduction

With the rapid development of computer technology, human beings have become supervisors of mechanical work [1, 2], and they will face situations such as reduced alertness, short-term distractions, and physical or mental fatigue and alertness within a certain period of time decreased [3, 4]. Decreased vigilance is likely to have serious consequences, such as decreased employee productivity or even work errors, especially in medical, aerospace, and other jobs that require precise operations. It is very important to maintain a high level of vigilance [5, 6]. Therefore, it is very important to study the changing laws of vigilance, establish an effective vigilance detection system, and then study effective countermeasures to maintain vigilance and even increase vigilance [7, 8]. Diseases may occur suddenly, with severe symptoms and rapid changes. Therefore, medical work is easy to fail. However, if the problem is found early, the condition may not deteriorate or even improve and alleviate. This moment is the "turning point" of the emergency. Vigilance is a necessary quality of a good doctor.

Aiming at the research on the alertness detection system, some researchers have proposed a wearable electrograph for the alertness detection system. The system is a wireless wearable brainwave acquisition instrument and uses fast Fourier transform to extract brainwave power; the spectral density is used to determine the degree of alertness [9]. In addition, the alertness of researchers is an important aspect of the aerospace and nuclear power industries. Because these industries have to design a large number of human-computer interactions, they have proposed a method of alertness monitoring based on biological and behavioral characteristics, using computer-computer interfaces [10]. There are also researchers who use vision, sensors, environment, and vehicle-based feature fusion and use deep learning architecture to analyze data to predict the level of alertness [11]. Some researchers have also proposed a real-time noninvasive driver alertness monitoring system, which analyzes and recognizes closed eyes in real time, detects drowsiness for more than 2 seconds, and detects fatigue by recognizing yawning actions [12]. Deep learning is the internal law and

representation level of learning sample data. The information obtained in the learning process is very helpful to the interpretation of data such as text, image, and sound. Its ultimate goal is to make the machine have the ability of analysis and learning like human beings and be able to recognize characters, images, sounds, and other data. Deep learning is a complex machine learning algorithm, which has achieved far more results in speech and image recognition than previous related technologies.

This paper studies the pulse wave feature alertness detection system based on computer software technology, has a general understanding of the pulse wave feature detection method based on relevant literature data, then designs the system based on alertness detection factors, and then designs the system tested in experiments, and relevant experimental conclusions are drawn. The pulse wave is formed by the pulse (vibration) of the heart propagating outward along the artery and blood flow. Therefore, its propagation speed depends on the physical and geometric properties of the propagation medium: the elasticity of the artery, the size of the lumen, and the density and viscosity of the blood, especially the elasticity, diameter, and thickness of the arterial wall.

2. Research on the Detection of Pulse Wave Feature Alertness

2.1. Method of Measuring Pulse Wave Characteristics. The measurement method of pulse wave characteristic parameters is based on the influence of physiological factors such as vascular resistance during pulse wave propagation. Through the analysis of some characteristic parameters in the pulse wave, the physiological information of the cardiovascular system can be reflected. Therefore, by studying the relationship between the characteristic parameters in the pulse wave and blood pressure, an equation is established to measure the blood pressure value. The characteristic pulse wave parameters used in the analysis are in addition to the T wave pulse cycle time of the pulse waveform output, the dominant wavelength H , and the decreasing average isthmus. In addition to the relative height of the main wave (h/H), there are also the relative height of the sweep wave and the main wave (g/H), the rising slope V of the main wave, the cycle time ratio occupied by the systolic $T1/T$, and the diastolic $T2$ cycle time ratio occupied by T , as well as parameters such as the characteristic quantity of the pulse wave K and the area of the pulse wave graph. Characteristic information refers to the process of people's dynamic reflection on objective existence (including material world and information world). The observation object itself can provide a large amount of rich information, and our observation is always carried out under certain goal constraints. In order to achieve this goal, we give up a lot of information about the object. The rest are essential, basic, and most reflective information in achieving our goals.

2.2. Related Factors of Alertness Detection

2.2.1. EEG Signal. Electroencephalogram is an overall reflection of the electrophysiological activities of brain nerve

cells on the cerebral cortex or scalp surface, directly reflecting brain activity, and is considered to be a reliable indicator for studying brain alertness and mental fatigue. Decreased alertness is the process from wakefulness to sleepiness during which the automatic electrical activity of the brain decreases, and its related characteristics can be used to characterize changes in alertness. For example, as alertness decreases, the relative intensity of Alpha and Theta low bands increases, and the relative intensity of Beta high bands decreases, and power ratios such as Theta/Beta and Alpha/Beta can enhance and better capture this change. As alertness increases, these characteristics will change accordingly. Brain waves originate from the postsynaptic potential of the apical dendrites of pyramidal cells. The formation of synchronous rhythm of EEG is also related to the activity of the nonspecific projection system of cortex and thalamus. EEG is the basic theoretical research of brain science. EEG monitoring is widely used in its clinical application.

In the study of ECG signals, it is mainly to study the change of RR interval, that is, the variability of heart rate. Heart rate variability is mainly controlled by the human autonomic nervous system (ANS), which in turn includes the sympathetic nervous system and the parasympathetic nervous system. Sympathetic nerves play an important role in individual stress and tension and can easily cause symptoms such as shortness of breath, high blood pressure, and increased heart rate. When the individual is calm and relaxed, the activity of the parasympathetic nerve increases the nervous system. Breathing becomes smoother, blood pressure drops, and heart rate slows down. It can be seen that heart rate variability can more accurately and sensitively reflect changes related to alertness. Heart rate variability is a small variation between RR intervals, reflecting the regulation of the cardiovascular system by the sympathetic and parasympathetic nerves in the nervous system. A decrease in heart rate variability will increase sympathetic nerve activity or decrease atrial nerve activity, while an increase in heart rate variability will be just the opposite, increase atrial nerve activity or decrease sympathetic nerve activity. Fluctuations and changes in alertness will affect the changes in the RR interval, so heart rate variability analysis may help to study alertness. The common method to measure brain lesions is to measure brain waves. The common method is EEG detection, that is, to observe the process of brain wave activity through electrodes placed on the scalp according to certain rules. EEG is the overall reflection of the electrophysiological activities of brain nerve cells on the surface of cerebral cortex or scalp. Clinical practice shows that EEG contains a lot of physiological and disease information, so we can provide basis for the identification of brain lesions through the processing of EEG.

2.2.2. Other Related Signals. In addition to brain electrical signals and ECG signals, other positive signals may also reflect changes in alertness to a certain extent, such as eye electrical signals, skin resistance signals, and pulse signals. For example, under normal circumstances, the movement of

human eyelids conforms to certain laws, but in the process of reducing alertness, the range of eye glare, the frequency of glare, the frequency of closing, the duration of closing time, and so on will change accordingly. Detecting the awake state by measuring the electrical signal of the eye is widely used in fatigue driving. Pulse signal, the heart continues to contract and expand, causes changes in the pressure, volume, and blood flow in the arterial tube. These changes propagate forward in the arteries, making people feel the reaction on the body surface. It has important clinical value in the diagnosis of Chinese and Western medicine.

Human eyes have different abilities to receive and analyze visual images, so as to form perception to identify the appearance and space (distance) of the object image, as well as the changes of the object in shape and space. The brain analyzes the object image information received by the eyes into four main types of data. It is about the space, color, shape, and dynamics of the object image. With these data, we can identify and respond to foreign objects in a timely and appropriate manner.

2.3. Application of Computer Software Technology in the Pulse Wave Characteristic Alertness Monitoring System

2.3.1. Development Mode. The system adopts B/S architecture for design and development. The B/S (browser/server) structure is called the browser/server structure, which is based on a three-tier structure, namely, the browser, the web server, and the database server. The browser is the interface between the system and the user and is responsible for transmitting user requests and displaying the content that the user wants. The web server is responsible for retrieving the data that the user wants from the database and accepting the data returned by the database for sorting. The database server provides data for the application.

The third layer is the database server which plays an important role because it stores a large amount of data. When the database server receives the request from the web server, it will process the SQL statement and send the returned results to the web server. Next, the web server will convert the received data results into HTML text and send them to the browser, that is, the interface we see when we open the browser.

2.3.2. Development Tools. Java is well suited to the Internet or enterprise network environment and thus becomes one of the most popular and important programming languages on the Internet. Compared with C++, Java removes many unused features, including those such as simplicity, object-oriented, distributed, structure neutral, portability, high performance, interpretability, reliability, security, multi-threaded, and dynamics. It allows any client of the processor to run and stream transmission on the Internet.

Java's storage allocation model is one of its main methods to defend against malicious code. Java has no pointers, so programmers cannot get hidden secrets and fake pointers to point to memory. More importantly, the Java compiler does not handle storage scheduling decisions, so

programmers cannot guess the actual storage scheduling of classes by looking at the declarations. The actual storage address of the storage reference in the compiled Java code is determined by the Java interpreter at run time.

2.4. Correlation Calculation of Pulse Wave Characteristics

2.4.1. Elasticity of Blood Vessel Wall. When ignoring the influence of vascular viscosity, vascular wall viscoelastic properties, and surrounding tissues, the propagation velocity of pulse wave can be calculated by the following formula:

$$PWV = \sqrt{\frac{Eh}{\rho d}} \quad (1)$$

In the formula, E represents the elastic modulus of the blood vessel wall, the larger the E , the worse the elasticity of the blood vessel wall; h is the thickness of the blood vessel wall; ρ is the blood density; and d is the diameter of the blood vessel.

If the thickness of the blood vessel wall is considered and Poisson's ratio σ is assumed to be 0.5, the corresponding wave velocity of the pulse wave is as follows:

$$PWV = \sqrt{\frac{E(R_a^2 - R_b^2)}{3\rho R_a^2}} \quad (2)$$

In the formula, R_a and R_b are the inner radius and outer radius of the blood vessel wall, respectively.

3. Design of Pulse Wave Feature Alertness Detection System

3.1. Signal Acquisition. This article is based on the design of the alertness detection system of pulse wave characteristics, so the pulse characteristic parameters are collected, but in order to monitor the results more accurately, other signal acquisitions are added in this article, such as ECG signal, skin resistance, and blood oxygen saturation portable multichannel physiological signal acquisition such as physiological signals, so that the detection results can be more accurate.

3.2. Signal Processing. For the relevant data collected above, the data need to be processed. This paper uses FIR filters to filter the collected original signals to remove noise signals and then uses time domain, frequency domain, wavelet transform, and other means to analyze and process the signal. Key signs of physiological signals such as pulse characteristic parameters, blood pressure, heart rate, heart rate variability, blood oxygen, amplitude of skin resistance, and first-order differential of skin resistance amplitude are obtained. In addition, finite length unit impulse response filter, also known as non recursive filter, is the most basic element in the digital signal processing system. It can ensure arbitrary amplitude frequency characteristics and strict

linear phase frequency characteristics. At the same time, its unit sampling response is finite, so the filter is a stable system. Therefore, FIR filter is widely used in communication, image processing, pattern recognition, and other fields.

3.3. Signal Analysis. The processed data are analyzed to get the result of alertness. This article uses principal component analysis, polynomial regression algorithm, and support vector machine. Algorithms such as k -means clustering find the most suitable combination of physiological signal characteristics to reflect changes in alertness.

3.4. Choice of Hardware

3.4.1. Amplifying Circuit. Since the collected signal may be very weak, it is necessary to add an amplifying circuit to amplify the collected signal. According to the commonly used amplifying circuit on the market, this article chooses the AD620 chip.

Amplifiers can be sized according to their input and output properties. They show the nature of the gain, that is, the proportional coefficient between the amplitude of the output signal and the input signal. According to the type of gain, it can be divided into voltage gain, current gain, and power gain. In addition, the mutual resistance amplifier, which responds to changing input current, provides a related changing output voltage. Other names of the device are transimpedance amplifier and current voltage converter.

3.4.2. Main Control Processor. The main control processor adopts the most common M2 microcontroller processor on the market. The M2 microcontroller integrates a high-performance RISC 32 bit MIPSX2 core, built-in memory, and ample peripherals and I/O ports. In addition, the M2 microcontroller processor also provides standard communication interfaces (SPI and UART), 16 bit ADC, 4 timers, and LCD driver. M2 chip has built-in 1M-bit on-chip flash, $2k \times 32$ bit RAM, UART, SPI, timer, and other peripheral hardware resources. The microcontroller can meet the design requirements of this system. In the acquisition system, the communication between AD sampling and the host is carried out through the M2 microcontroller.

3.4.3. Converter. The signal converter is completed by the 16 bit ADC of the main control processor, and the ADC sampling clock frequency can be controlled by adjusting the special operation register of the AD module. When the pulse wave signal processed by the signal intermediary circuit is input to the main control processor, the M2 microcontroller converts the analog signal into a digital signal through the built-in 16 bit ADC and transmits the sampled data to the upper PC for subsequent processing of the pulse signal.

Parallel data acquisition means that there are multiple data acquisition devices or channels in the system, which work at the same time to complete the data acquisition task

of the whole system. Using parallel data acquisition can not only meet the design requirements of a specific system but also improve the system acquisition efficiency so as to improve the system performance.

4. Testing of the Alertness Detection System

4.1. Subject. The subjects of this article are the students and teachers who collected resources to participate in the alertness test in universities in this city. Finally, a total of 14 students and teachers who voluntarily participated in the alertness test were recruited. All of them are in good health and have no history of neurological disease or attention deficit disorder. Participants are required to work and rest regularly and do not use caffeine and alcohol-containing products within one week before the experiment. The basic information of the experimental subjects is shown in Table 1.

It can be seen from Figure 1 that the number of boys is equal to that of girls, and the influence of gender on the results of the experiment can be excluded.

4.2. Experimental Process. First, an alertness task experiment that combines the standard PVT experiment design and the on-duty process for the experimenters is performed. Before, during, and after the experiment, the participants are required to fill in the Stanford Sleepiness Scale (SSS) and pass the subjective self the evaluation method that evaluates the level of individual alertness, the experimenter's pulse characteristic parameters, blood pressure, heart rate, heart rate variability, blood oxygen, and the amplitude of skin resistance. The first-order derivative of the skin resistance the signal is collected by sensors and analyzed by the system designed in this article.

4.3. Stanford Sleepiness Scale (SSS) Analysis. Before, during, and after the experiment, the subjects were asked to fill in the Stanford Sleepiness Scale (SSS) and assess the level of individual alertness through subjective self-evaluation. Five subjects' scores were selected. The relevant experimental data are shown in Table 2.

It can be seen from Figure 2 that the scores of the Stanford Sleepiness Scale (SSS) before, during, and after the experiment are not much different, so it can be seen that the fatigue state of the subjects has changed before, during, and after the experiment, but the change is not significant. The experiment controlled the overall fatigue and mental fatigue of the subjects in a relatively stable range, which also made the experiment's research on alertness more purified.

4.4. Pulse Signal Analysis. For the pulse wave characteristics, the main wave peak value of the pulse wave signal and the time value from the beginning of the pulse wave to the main wave peak value, that is, the peak latency period, is mainly selected for analysis. The relevant data results are shown in Table 3.

It is seen from Figure 3 that during the course of duty, the pulse rose about 10 minutes ago, then the area is stable,

TABLE 1: Basic information of experimenter.

	Men	Women
20-22	2	3
22-24	3	2
24-26	1	1
26-28	1	1

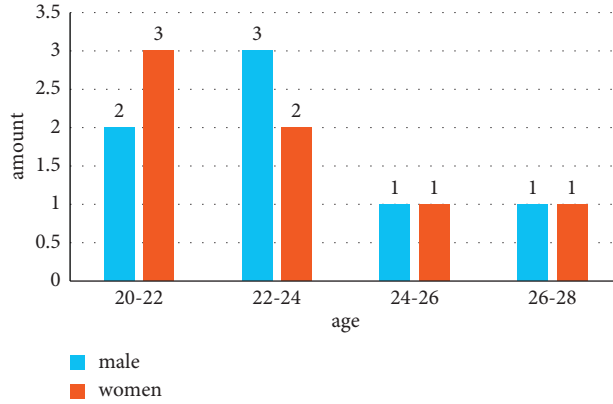


FIGURE 1: Basic information of experimenter.

TABLE 2: Stanford Sleepiness Scale (SSS) analysis.

	Before the experiment	In experiment	After the experiment
1	0.4	0.6	0.58
2	0.41	0.62	0.59
3	0.5	0.7	0.6
4	0.38	0.58	0.55
5	0.39	0.59	0.56

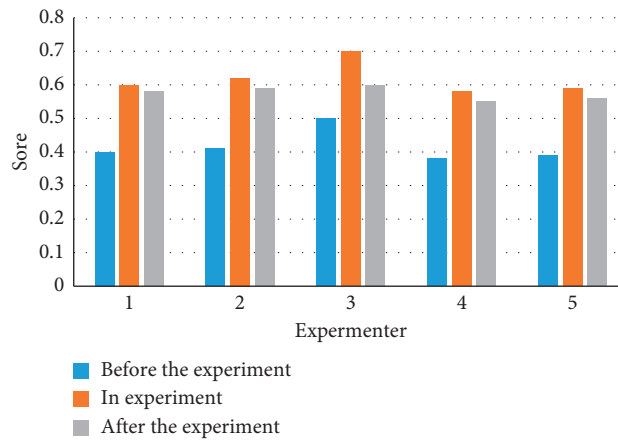


FIGURE 2: Stanford Sleepiness Scale (SSS) analysis.

after about 25 minutes, the pulse dropped, which is not very high, relatively gentle, and when reaching a peak, it began to rise after about 45 minutes.

4.5. *Skin Resistance Signal Analysis.* For the skin resistance signal, two time-domain characteristics of the electrical skin signal are mainly selected: the amplitude and the first-order

difference of the amplitude, and the signal is analyzed. The relevant data results are shown in Table 4.

It can be seen from Figure 4 that the skin resistance has been on the rise during duty, while the first-order differential value of the skin is fluctuating and falling. It can be seen from the figure that the fluctuation range of the skin resistance is relatively small, while the first-order differential value of the skin fluctuates. The first-order

TABLE 3: Pulse signal analysis.

	Peak value of main wave	Crest latency
5	0.71	241
10	0.90	243
20	0.92	245
30	0.88	250
40	0.85	251
50	0.83	245
60	0.89	258

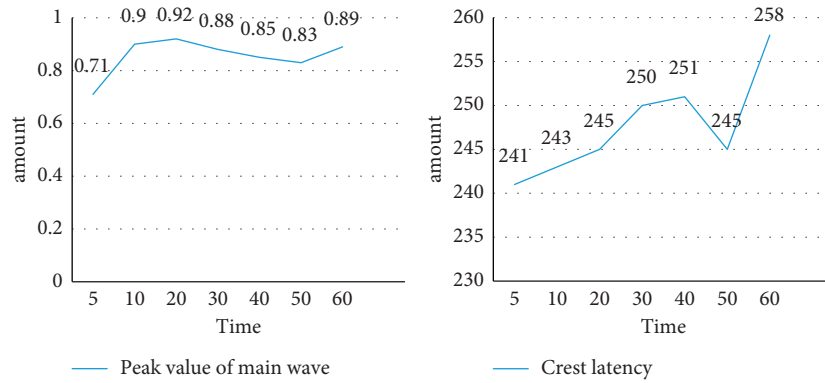


FIGURE 3: Pulse signal analysis.

TABLE 4: Skin resistance signal analysis.

	Skin resistance	Skin resistance first-order difference $\times 10^{-4}$
5	8	1.7
10	7.7	0
20	7.8	-0.1
30	8.4	-0.2
40	9.3	-0.5
50	9.5	0.4
60	9	0

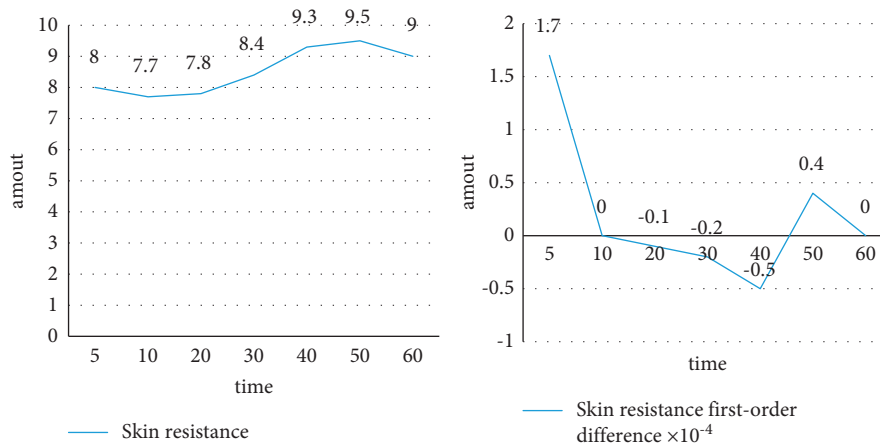


FIGURE 4: Skin resistance signal analysis.

TABLE 5: Establishment of alertness characteristics.

	R^2
1	0.1
2	0.3
3	0.35
4	0.39
5	0.43
6	0.59
7	0.71
8	0.82
9	0.82

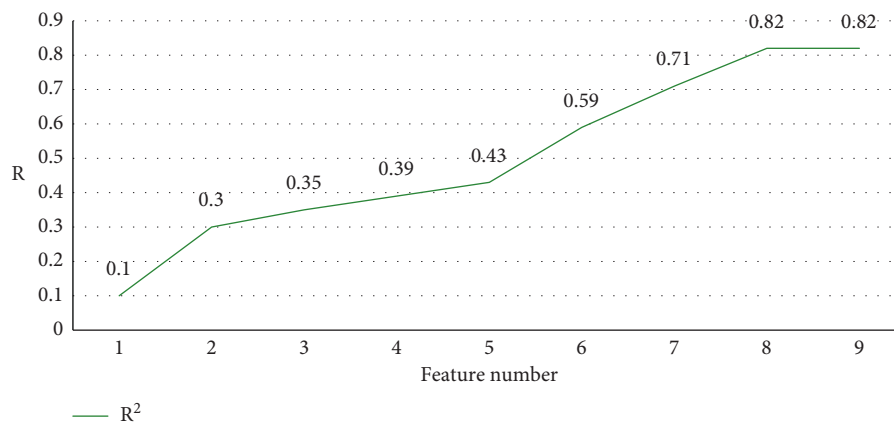


FIGURE 5: Establishment of alertness characteristics.

differential fluctuates greatly because the experimenter's sympathetic nerve activity is weakening, and the experimenter is in a low alert state.

4.6. Establishment of Alertness Characteristics. In this paper, the optimal combination is selected from the 19 signal feature groups based on the goodness of fit test R^2 in the regression analysis. The relevant data results are shown in Table 5.

It can be seen from Figure 5 that as the number of features increases, the goodness of fit of the model rises, and it does not increase after more than 8 features. Therefore, it is more reasonable to select 8 data features than to perform regression model analysis.

5. Conclusions

This paper studies the pulse wave characteristic alertness detection system based on computer software technology. By designing the system and conducting the experiment of the designed system, the pulse wave amplitude fluctuates with the time, while the resistance skin value increases with time but with less fluctuation. In the course of this paper, the depth can be insufficient due to the lack of the relevant literature.

Data Availability

The data underlying the results presented in the study are included within the manuscript.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

The authors have seen the manuscript and approved to submit to your journal.

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