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Research Article

A New Type of ECG Signal Acquisition and Storage Nonvolatile Chip Embedded in Mobile Devices for Sports Monitoring

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In the fast-paced development of life in today's society, the use of ECG signals is not only used in the medical direction to scan patients; portable ECG signal acquisition tools can collect and analyze the corresponding ECG signals in time and respond to the wearer in time, so that the user can make timely adjustments or seek medical treatment in time to avoid a malignant situation that occurs. For people in sports, the collection of ECG signals is more helpful to the arrangement and estimation of training conditions. Based on nonvolatile memory technology, data will not be lost when the computer is turned off or suddenly or unexpectedly shut down. This research puts forward the design of an antiexercise ECG monitoring system that collects ECG signals for a group that is in the process of exercise. Use mathematical calculation system to classify, and conduct in-depth analysis of the reasons for poor anti-interference ability, and use the original denoising algorithm calculation as the basis to adapt to the dynamic situation in the opposite situation to the normal ECG signal acquisition in the static state. The collection is modified from the original basis. This research proposes an improved scheme for multichannel acquisition. Chips of semiconductor memory devices based on nonvolatile memory are embedded in mobile devices for use. The experimental results in this paper show that the comparison experiment ratio of collecting ECG signals from the sixth, third, fourth, and fifth directions can effectively reduce the mean square error (MSE), and the error of channel 6 is directly from 0.1598. It is down to 0.00143. Several other items showed a significant decrease. It shows that the anti-interference ability of the ECG monitoring system can be further enhanced by increasing the number of collection terminals.

1. Introduction

1.1. Background. In today's society where speed is the main development, the fast-paced life and work have produced huge pressures, and people's physical conditions are basically in a subhealthy physiological state, which is one of the cases where there are no serious illnesses and many minor problems. Today's smart Internet is undergoing rapid development. With the widespread popularity of its applications, research in the direction of the medical industry has also begun to reform itself. This should be due to the pressure brought by digital networking. The worries about medical resources have now initially become an important influence plaguing its development. The masses now have the burden of "difficult and expensive" medical treatment for the medical industry. In addition, society has entered a serious aging trend. The continued development of the medical industry is the focus of global attention. For patients with heart disease, there is a medical gap that is difficult to bridge. According to medical statistics, more than 71% of heart disease cases occur outside the hospital, and three-fifths of them immediately die at home. Therefore, the existence of an ECG signal collector that can detect the time of a heart attack by a system with monitoring performance has an inevitable effect. When a disease occurs, it can feedback information in time, and the wearer who receives the prompt information in time can respond to it in the first time and make corresponding treatment in time. Therefore, the best treatment time will not be missed. So most patients can get timely diagnosis and treatment when they are sick and can be treated with the help of medical advice and can avoid death. Therefore, if they can wear portable health

appliances to monitor heart function and real-time monitoring and diagnosis, it will play an important role in alleviating diseases and implementing aid. For athletes, the ECG monitoring system can allow trainers to better understand the physical information of the athlete and avoid physical injury; it can also enable the athlete to maintain the exercise intensity and make the exercise effect better.

1.2. Significance. As far as the ECG signal acquisition and monitoring system is concerned, most of the current ECG monitors on the market require a static environment to collect ECG information, and the overall appearance is not too small. Even if there are portable ECG monitors on the market today, most of them are inefficient and relatively expensive. The test results are somewhat unreliable. Therefore, further research on the portable ECG monitoring system is also the focus of the development of the medical industry. The portable ECG signal monitoring system is in urgent need of further research and is also an important measure in the medical industry.

1.3. Related Work. Based on the current social population's emphasis on health, the ECG signal that can monitor the physical condition to a certain extent has been deeply researched. In the current research on the collection and storage of ECG signals, Son et al. first reported on their observations of these writing characteristics in the article: (1) log writing dominates storage writing. (2) Overwriting is frequently in mobile storage. And most importantly, (3) these overlays only change a small part of the data. Based on these observations, they recommend using a nonvolatile write buffer backed by small capacitors and using it to store small writes persistently without logging. This allows them to completely avoid those lowercase log writes, which helps to significantly reduce log-induced writes while still providing the same level of data consistency and durability [1]. The traditional PoP structure using FC-BGA (Flip Chip-BGA) has some problems in package warpage and thickness. To solve these problems, Tanaka et al. developed an embedded device package called MCeP (Molded Core Embedded Package) for the bottom package of the PoP structure. MCeP consists of a top substrate, a bottom substrate, and an embedded layer, and the IC device is encapsulated in the embedded layer by molding resin. This kind of package has the beneficial characteristics of reducing package warpage. The package warpage can be controlled by optimizing the thickness and material of each layer (top substrate, bottom substrate, and embedded layer) [2]. Lai and Shynk propose a two-stage continuous cancellation (SC) algorithm that sequentially separates the fetal and maternal heartbeats from the intrauterine electrocardiogram (IuECG) signal containing the fetal and maternal QRS complex. The ECG signal is modeled as a series of fetal, maternal, and noise events. Peak detection is first used to locate potential fetal and maternal QRS complexes, called candidate events. Each stage automatically generates source templates from candidate events in the initialization stage and then classifies the remaining candidate events according to template matching technology. Before the weaker signals are initialized and classified, the detected stronger signal events are subtracted from the composite ECG signal. Once the fetal and maternal complex is successfully detected and separated, the counting mechanism will be used to derive the corresponding heart rate [3]. Prove the capacitive effect and nonvolatile storage capability. A low-power passive filter is designed, which can be used in the design of reprogrammable analog circuits, paving the way for future multifunctional nanodevices [4]. As an active material for supercapacitor electrodes, biomass-derived carbon has attracted much attention due to its environmental friendliness, richness, and porosity. In this case, in Keppetipola et al., activated carbon prepared from coconut shell through a simple activation process (water or steam as the activator) is used as the active material in the electrode of the environmentally friendly supercapacitor. Studies have shown that the activated carbon produced by this method exhibits a graphite phase, high surface area, and large pore volume [5]. Xu et al. proposed a method for denoising and baseline drift correction of electrocardiogram (ECG) signals based on a complete set of adaptive noise into empirical mode decomposition (CEEMDAN) and wavelet threshold. Although CEEMDAN is based on empirical mode decomposition (EMD), it represents a significant improvement over the original EMD by overcoming the problem of mode mixing [6]. Abdullah et al. proposed a robust method for extracting fetal maternal heart rate from noninvasive composite abdominal electrocardiogram (aECG) signals. The proposed method is based on the fully integrated empirical mode decomposition (CEEMDAN) method with adaptive noise, in which the composite aECG signal is decomposed into its constituent frequency components, called intrinsic mode function (IMF) or simply "mode." The separated IMF is then manually selected according to the possible maternal-fetal heart rate information and further processed to quantify maternal-fetal heart rate and variability analysis [7]. The research expertise of the above scholars is extremely high and requires a deeper understanding of it and experience. During the verification process, the experimental samples are difficult to collect, and the operation technology requirements are high, and it is difficult to operate.

1.4. Innovation. Most ECG signal monitoring systems on the market today have a common defect; that is, only when the test subject with testing needs is in a certain static situation, a qualified ECG signal sample can be extracted. That is to say, the ECG signal receiving system of the existing portable ECG monitoring system on the market has poor antiexercise interference ability [8], because the human body will have a larger breathing pattern after exercise, which is more intense. The respiration of the ECG signal will cause the collected ECG signal to be mixed with larger amplitude noise, which will distort the sample recorded in the ECG signal, and excessive noise will cause the waveform of the ECG signal to be distorted. Therefore, in this case, it is very necessary to study and explore the experimental design of antiexercise portable ECG monitor to improve the performance of ECG anti-interference.

2. Collect Nonvolatile Memory Based on ECG Signal

2.1. The Basic Principle of Nonvolatile Storage Based on ECG Signal Acquisition. Nonvolatile memory is a computer memory whose stored data does not disappear when the current is turned off. The main classification of current nonvolatile memory is shown in Figure 1. The storage is divided according to the different ways of data processing, and the nonvolatile semiconductor memory is divided into two types [9]. Random access memory allows reading and writing of stored data, but when the power is turned off and power is lost, it will cause the stored data source to lose its storage content [10]; read-only memory operates normally without external interference. In the case that only the data content in the storage unit is allowed to be read, the stored data content cannot be modified [11]. Its advantage lies in the stored data even when the power is lost. The samples can also be kept intact [12].

The modern system chip design of the IP core based on the nonvolatile storage circuit allows system designers to explore different system architectures. The application of the IP core makes the system architecture unnecessary to study each module in-depth [13]. This method effectively reduces the complexity of the problems encountered in the design process [14]. This can shorten the design cycle and speed up the product speed. You can use existing process solutions more effectively and reduce costs [15]. Embedded nonvolatile memory is used as part of many current system solutions. Not only can it provide the ability to change the execution data on each software production line or on-site software. Communication applications include mobile phones, mobile phone communication devices and smart cards, and in-vehicle electronic devices. This design can extend the life of the entire system, reduce the chip area [16], and save costs.

2.2. Nonvolatile Memory Programming Mechanism Based on ECG Signal. Nonvolatile storage [17] can be freely written and modified by the user, such as programmable, erasable programmable, electrically erasable, flash memory, and storage. Among them, the programmable ROM is manufactured with fuses, and the interconnection between memory cells is realized by blowing the fuses [18]. ROM is an abbreviation for read-only memory that can only read and cannot write information. Erasable programmable ROM uses ultraviolet rays to inject and remove hot electrons from the floating gate of the memory cell to achieve memory programming and erasing operations [19]. Both electrically erasable PROM and flash memory belong to electrically erasable nonvolatile memory; PROM is short for programmable read-only memory. Their working mechanism is to inject electrons into floating gate devices through electrical means [20]. Below, we mainly discuss the two types of programming and erasing. The main methods are FN tunnel effect and channel hot electron injection.

The threshold voltage VT of the floating gate transistor can be changed by programming. A high voltage is connected to the source grounding gate terminal and the drain terminal. The high potential difference will generate a strong electric field, and then, the strong electric field will cause electron avalanche injection. When the electrons get enough energy, they will pass through the first insulating oxide layer and be trapped by the floating gate. Therefore, floating gate transistors are also called floating gate avalanche injection.

(1) FN tunneling effect: for nonvolatile memory, the tunneling effect is an important injection method [21]. Macroscopic quantum tunneling is one of the fundamental quantum phenomena; that is, when the total energy of a microscopic particle is less than the height of the potential barrier, the particle can still pass through the potential barrier [22]. Electrically programmable read-only memory (EPROM) uses channel hot electron injection for programming, but hot electron injection cannot be used for erasing. EPROM erasing is achieved by irradiating ultraviolet rays (UV) onto the unit through a closed transparent window. When EPROM is programmed and read, it is addressed in the unit of byte, and each byte can be addressed separately [23]. However, when erasing with ultraviolet light, the entire memory area will be affected. At the same time, UV erasing has problems such as time-consuming, poor durability, and low reliability. EPROM uses UV erasing, so a quartz window needs to be provided in the package, which leads to higher costs for EPROM packaging. On the other hand, EPROM has a simple structure and high density, so it can produce large-capacity memory at a lower cost, so there is still a certain market in some applications that do not require frequent erasure and reprogramming [24]. But due to price and reliability reasons, EPROM was replaced by flash memory. The electron passes through the tunnel, and its current density is expressed as

$$G = \delta V_{\text{ing}}^2 \exp\left\{-\frac{\beta}{V\text{ing}}\right\}, \tag{1}$$

$$\delta = \frac{Q^3}{8\pi H \Phi r}\frac{n}{n^*}, \tag{2}$$

$$\beta = 4\sqrt{2n^*}\,\frac{\varphi_n^{3/2}}{3HQ}. \tag{3}$$

In the equation, H represents the Planck constant, Φr is the barrier height when injected at the interface, Q represents the charge of a single electron, and n represents the free electron. Among them, $H = h/2\pi$

(2) Thermal injection of carriers: the process of electron injection is to inject electrons into the floating gate through the discharge of the memory cell area [25]. The electric field receives the electric field from it. If there is a positive voltage and when the electrons pass through the substrate and the gate, the barrier

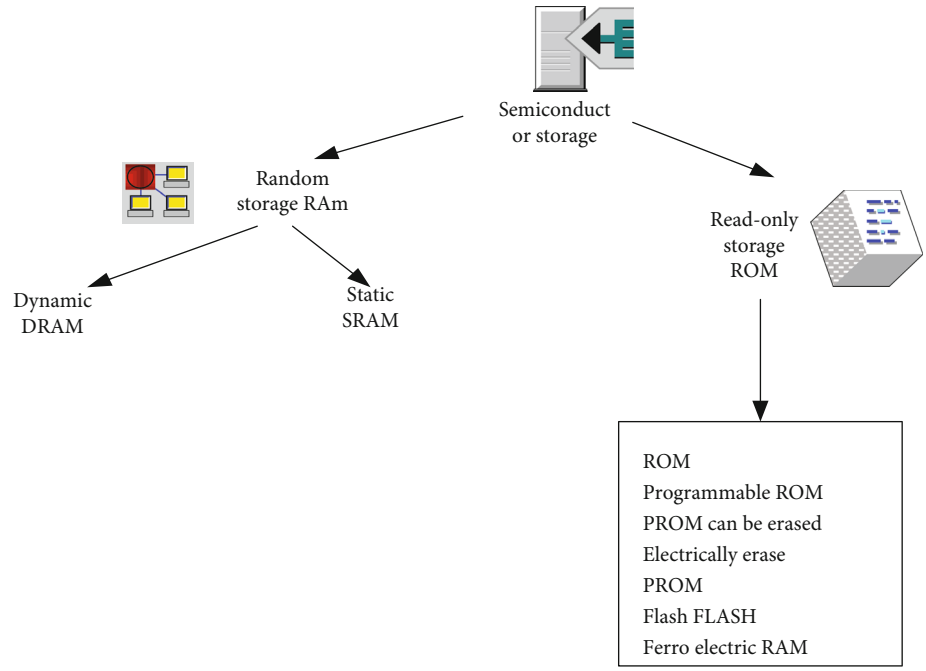

Figure 1: Storage classification.

between the oxides rises 3.3 eV with the negative voltage of VDS. The control gate VCG absorbs electric heat to the floating gate. Since the floating gate is surrounded by silicon dioxide and has no contact with other things, and silicon dioxide is an excellent insulator, the negative charges captured by the floating gate are not easily lost and can stay in the floating gate for a long time. For a long time, even if there is no power supply voltage, it will not be affected at all. This is the reason why the memory with floating gate transistor as the core component is called nonvolatile memory [26]

In fact, almost all current nonvolatile memories are based on floating gate transistors [27], and the different types of nonvolatile memories are mainly due to their different erasing mechanisms. This EPROM cell structure is shown in Figure 2. Figure 2(a) is a diagram of the corresponding basic structure of the storage unit; Figure 2(b) is a cross-sectional view from the perspective of the installation direction of the structural diagram on the left, and Figure 2(c) shows the schematic diagram of the circuit structure of its operation. But the improvement of EEPROM function comes at the expense of area. Because EEPROM performs various operations in bytes, its memory cell is composed of two transistors, one is a memory transistor [28], and the other is a selection transistor. Compared with a tube of EPROM, EEPROM has two transistors.

Table 1 shows the voltage value of each port of the EEPROM cell under different operating conditions.

Flash memory (FLASH) is combined with electronic processing and removal to realize your EPROM tube. It can be deleted completely, or the function can be deleted in one operation.

Currently, there are two types of flash memory systems: NOR-based flash memory (FLASH) memory used for program and data storage and NAND-based flash memory (FLASH) storage tools required for large-capacity data storage, such as memory cards and state disk devices. Flash, Flash EEPROM, was proposed in 1984 and soon developed into the most widely used nonvolatile memory structure. Flash memory is equivalent to a technical combination of EPROM and EEPROM. It is based on a floating gate structure and uses avalanche hot electron injection programming and electrical signal erasing. However, unlike EEPROM, the erasing of Flash is not done in bytes. Block erase is performed on a subpart of the memory. Although it is not as flexible as EEPROM in this respect, its advantages are also obvious. The cell structure eliminates the access transistor, so that the cell area is significantly reduced, the density is higher, the integration level is improved, and the production cost is reduced.

2.3. ECG Signal Noise. The ECG signal not only contains a variety of noise interference, but its own waveform also has unpredictable volatility, which is an unstable nonlinear signal. When analyzing and detecting ECG signals, it is often necessary to decompose and analyze the local information. Therefore, the classic Fourier transform technology obviously cannot be satisfied. The short-time Fourier transform developed on the basis of the Fourier transform to some extent made up for the shortcomings of the former localization analysis. The phase of the Fourier transform is very sensitive to noise. Even if a small segment of the data is wrong, the phase obtained by the Fourier transform will be much different from the real phase [29]. But because it still uses a continuous periodic sine function as the transform base function, it leads to its time domain. Analyzing ability and

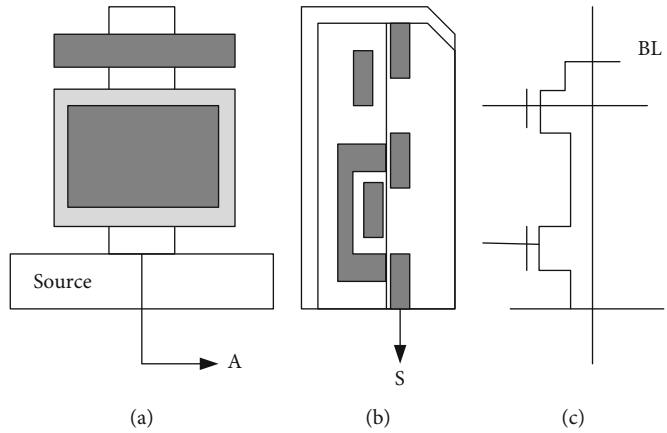

Figure 2: Schematic diagram of structure, storage unit, and cross-section.

Table 1: Port voltage under different operations.

	EEPROM		
Port	Erase	Program	Read
VCG	15.5	GND	2.4
VSG	15.5	15.5	3.3
VD	GND	15.5	1.5
VS	GND	FLOAT	GND
VB	GND	GND	GND

frequency domain analysis ability often constrain each other and cannot adapt to signals with changeable time-frequency characteristics at the same time. In recent years, wavelet transform has developed rapidly, and the technical level has become more mature. Because of its excellent time-frequency analysis and localized analysis characteristics, wavelet transform has been applied to many fields such as earthquake prediction, petroleum exploration, image processing, and speech recognition.

The ECG signal is the physiological signal of the human body, and it is a weak signal. In the process of collection and transmission, it will be interfered with by the electrical characteristics, the environment, and the activities of the human body itself, and it will be doped with many noises and interferences.

(1) Power frequency noise: power frequency interference comes from the electromagnetic field emitted by the power frequency power supply and the transmission line near the equipment. Line frequency noise is generally related to the measurement and use environment. However, the source of interference in the environment still exists, so further processing is still needed in the monitoring center

(2) Baseline drift noise: the basic noise comes from the human body. The body and tissues in the thoracic cavity will change to different degrees when a person breathes. The small change in the electrode's skin interface impedance becomes the influence of the amplitude. In addition, the amplitude of the ECG waveform is recorded on the body surface, affecting the image. This type of noise rarely has signal interference, and the frequency is usually less than 1 Hz. When such a curve is superimposed on the ECG waveform, the waveform changes, making it difficult to analyze and analyze the ECG waveform, especially the segments that affect the ECG waveform

(3) EMG noise: EMG noise interference is a very large interference, which can change up to 30 mV inside and outside the human epidermis. The ECG signal is input through the electrodes on the body surface, causing noise interference

(4) Motion artifact noise: since the ECG monitoring terminal is movable, the movement of the user in daily life will inevitably cause slight movement or jitter in the contact part of the electrode, which will cause the difference between the electrode and the skin. The impedance changes, causing contact noise. This interference generally lasts for a long time, and the amplitude can exceed the amplitude of the ECG signal and even lead to the full output of the amplifier, resulting in jump interference

3. System Design of Multichannel ECG Monitoring against Exercise Interference

The frequency response curve of the filter is not a perfect step curve, but a straight line with a slope. Therefore, even after the filter is used to denoise, the noise near the ECG signal frequency still exists. Noise seems to affect the ECG signal, so improve the signal to get a good ECG signal.

3.1. ECG Signal Measurement Based on Exercise Monitoring. The electrocardiogram is an important indicator to measure the bioelectricity produced by the human body. The reason for the electrocardiogram is that the energy cycle of the heart involves changes in its volume. Since the human body can be regarded as a very valuable conductor, the exchange capacity of the heart can be quickly transferred to the surface of the human body. Therefore, by attaching electrodes to the surface of the body, the capacitance during the heartbeat can

Table 2: Main noise of ECG signal.

Noise	Power frequency interference	EMG interference	Baseline drift
Frequency	50 Hz and high frequency harmonics	0-1000 Hz	0.05-2 Hz
Amplitude	Less than 50% of the ECG signal wave value	5 mV	ECG signal peak 15%
Manifestations	There are regular small ripples	Irregular small ripples	Up and down shift of heart waves

be separated, and the heartbeat can completely collect electrical signals to obtain the corresponding electrocardiogram [30].

First, determine the item of the original item listed. Key indicators include ECG signal and noise. These usually include the influence of power frequency, route drift, and EMG interference, as shown in Table 2. Power frequency interference is generally 50 Hz power line interference and a small amount of interference resolution. Due to the distribution of the human body surface, the human body has an antenna effect. In addition, under normal circumstances, whenever the ECG receives a signal, a long time reading occurs, which affects the frequency response. The skin volume of the outer and inner layers of the human body is 30 millivolts. If the skin stretches slightly, it will drop to 25 mV. Therefore, a skin capacitance of up to 5 mV should be superimposed on the ECG signal. This is the noise that people see due to myoelectric contraction. When users are stressed and affected by certain diseases, EMG frequencies may occur. Briefly summarize the main noises into a table:

3.2. Improvement Direction of Acquisition Circuit Based on Motion Monitoring. Simply put, the amplifier circuit is to amplify the weak signal provided by the signal source to drive the load to work normally. The failure of the amplifier operating circuit is random, and this random error causes the initial phase of the multisignal receiving system to be different, and the phase difference is not constant. In this experiment, the six purchased terminals passed a signal processing circuit. Each signal processing circuit has two operational amplifiers on the chip, but each amplifier in the amplifying circuit and filter circuit corresponds to the operational amplifier chip. In fact, only one of them is used, and the other op amps in the chip are in idle state. The advantage of this design is that it is easy to debug the circuit at each stage. There are two disadvantages. One is the high cost, and the other is the increase in errors caused by subtle differences in the circuit. Between each amplifier is not neutral. Therefore, if allowed, high-performance machines should be purchased. The difference between twins is not limited to cousins, because the difference between two amplifiers packaged on the same chip is much smaller than the difference in appearance and appearance of the amplifiers packaged on two chips. Therefore, you can choose a chip with greater internal noise to reduce errors. The best scenario for this test is to buy a chip with internal noise and send the signal to the amplifier on the chip. Reduce the random error reported by the amplifier circuit parameters. The loop created in this experiment has no obvious effect on efficiency, so you do not have to spend time rebuilding the loop based on the above improvements, but as the number of receiving channels increases, the error will be random. There is no doubt that the circuit will affect the experiment, so if you encounter this problem in future experiments, please install electrical equipment according to the above procedures.

3.3. Hybrid Algorithm Design. Based on the sum of wavelet coefficients of wavelet transform, the collected ECG signals are classified. The analysis method of wavelet transform inherits and develops the idea of localization of short-time Fourier transform and at the same time overcomes the shortcomings of window size that does not change with frequency. It is an ideal tool for signal time-frequency analysis and processing. After classifying the interference factors, analyze them one by one and divide them into 6 branches.

As shown in Figure 3, even if the original signal is processed by the filter circuit, there is still residual noise, resulting in distortion of the ECG signal.

4. Hybrid Algorithm Denoising Algorithm and Experimental Results

4.1. Wavelet and Independent Component Analysis. The ECG signal is located in the low frequency region of 0.03-45 Hz, which is relatively stable, and the noise signal usually appears as a high signal. Therefore, as shown in Figure 4, it is best to use the wavelet transform method to decompose the noisy original signal. Noise is usually in high-frequency wavelet coefficients, which is characterized by large amplitude and small size in the ECG signal. When the wavelet coefficient is similar to the noise, it is characterized by small amplitude and large value. Based on the above characteristics, an initialization method can be used to process the wavelet coefficients. The algorithm block diagram is shown as in Figure 5.

As shown in Figure 6, it can be seen that the baseline drift of the six ECG signals caused by respiration has been basically eliminated, and other interference components have also been greatly weakened.

However, the ECG signal in Figure 6 still contains residual power frequency interference and other intermediate frequency noise components. The reason for this is that the frequency of the noise is similar or even the same as the frequency of the ECG signal. Therefore, the threshold method cannot separate the ECG signal and noise. In order to finely filter the noise, independent component analysis methods must be used. The independent component analysis method is based on the mutual statistical independence between the sources. Compared with traditional filtering methods and accumulative averaging methods, independent component analysis does not destroy the details of other signals while

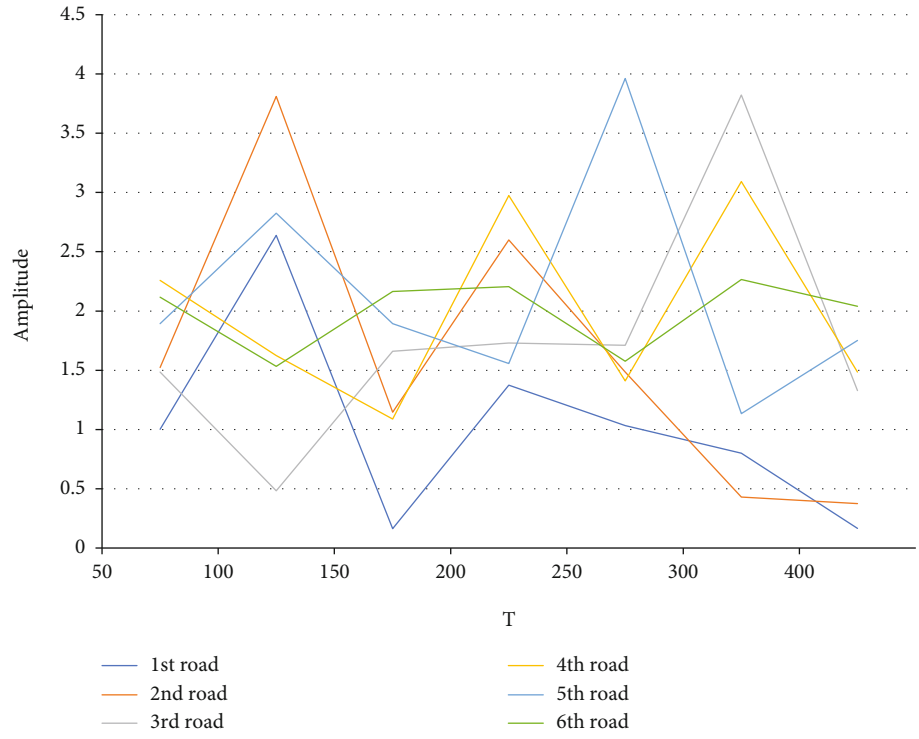

Figure 3: Timing diagram of the original electrical signal.

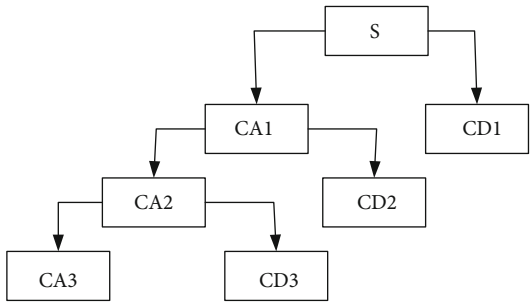

Figure 4: Schematic diagram of the decomposition process.

eliminating noise, and the denoising performance is often much better than traditional filtering methods. This experiment has 6 signal acquisition channels, which are sufficient to estimate the residual power frequency interference and EMG interference. The six signal channels are analyzed independently to obtain separated ECG signal and noise, as shown in Figure 7.

It can be seen that the residual noise of the ECG signal is suppressed, and the waveform is closer to the standard ECG signal.

If you compare the advantages and disadvantages of the four methods, it is far from enough to make qualitative statements based on observation methods. However, when conditions permit, mathematical evaluation indicators should be used to make quantitative statements. For quantitative analysis, two indicators, signal-to-noise ratio (SNr) and root mean square error (MSe), are used. The signal-to-noise ratio refers to the ratio of the power of the propagated signal to the power of the noise involved in the process of signal propagation. That is to say, the larger the signal-to-noise ratio, the stronger the noise suppression capability. Root mean square error (MSe) is the arithmetic square root of variance, which is used to measure the degree of dispersion of a set of numbers itself, which can better reflect the actual situation of the predicted value error, as shown in Equations (4) and (5). Among them, Y_i represents the amplitude corresponding to time i, while X_i represents the estimated amplitude after processing.

$$\mathrm{SNr} = 10 \times \log 10 \left[\sum_{I=1}^{t} \frac{X_{\mathrm{i}}^2}{\left(X_i^2 - Y_i^2\right)} \right], \tag{4}$$

$$\mathrm{MSe} = \frac{1}{t} \sum_{I=1}^{t} (Yi - Xi)^2. \tag{5}$$

The experimental results are shown in Figure 8. It can be seen that when compared with each other, the line graph does not show monotonous characteristics, and it seems that the results are contrary to expectations.

4.2. Problems Encountered Based on Motion Signal Acquisition. The results of this experiment do show that the quality of the six-channel acquisition and the five-, four-, and three-channel acquisition signal quality is not regular at all. If you do not carefully analyze it, it is too sloppy to conclude from the results. This section will focus on the analysis process and point out the difference between the actual

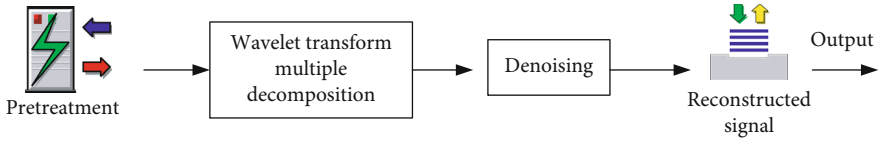

Figure 5: Schematic diagram of denoising process.

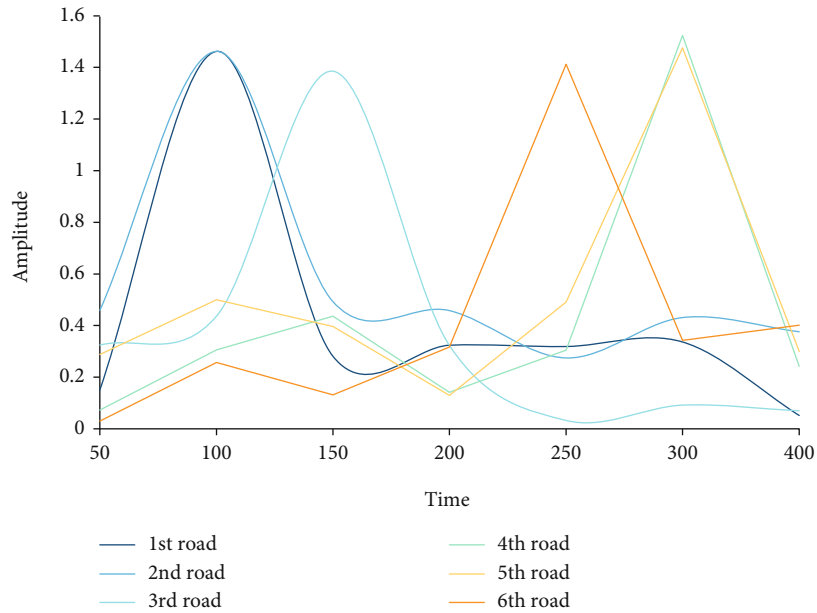

Figure 6: ECG with baseline drift removed.

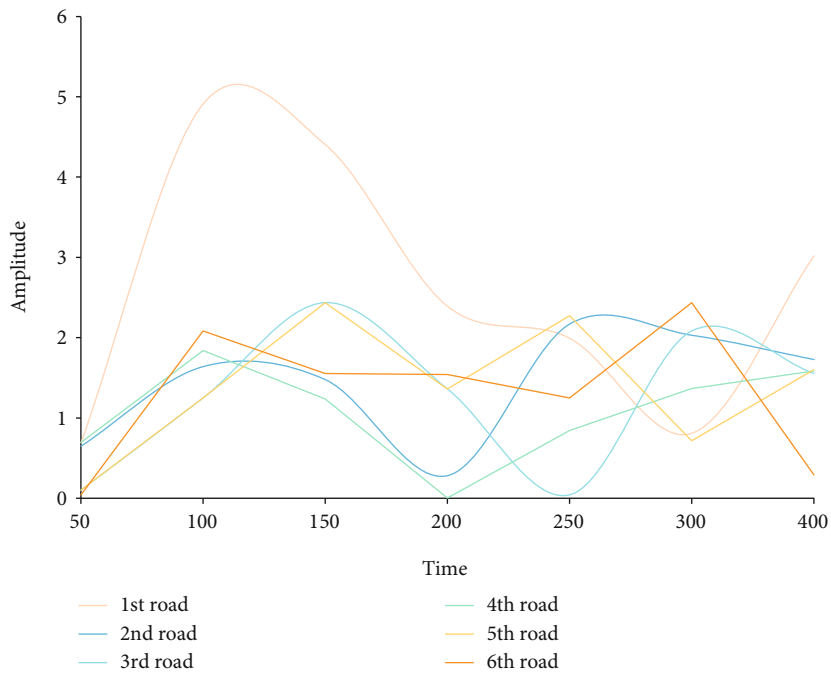

Figure 7: Acquisition signal after unmixing.

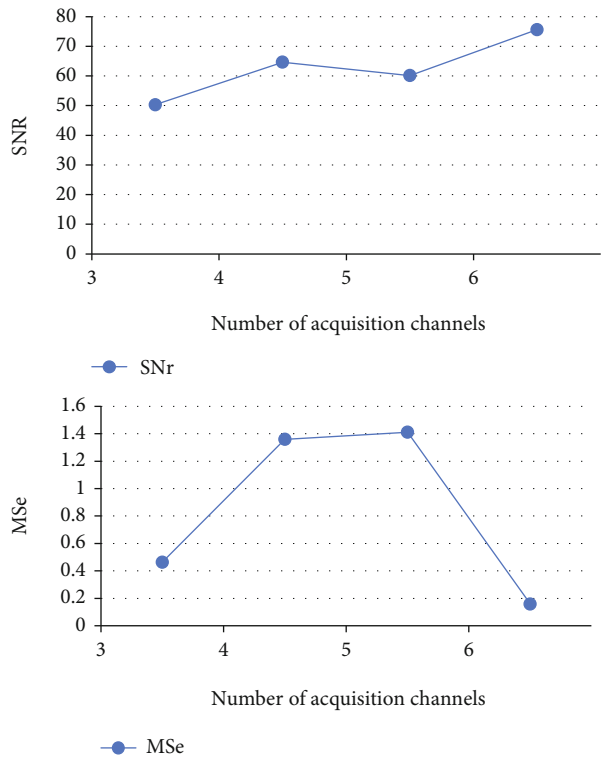

Figure 8: Line chart after comparison experiment.

situation and the ideal situation described in theory. Review the expression of independent component analysis again:

$$\begin{bmatrix} x1 \\ x2 \\ \vdots \\ xn \end{bmatrix} = \begin{bmatrix} a11, a12 \cdots a1n \\ a12, a22 \cdots a2m \\ \vdots \\ \text{an1, an2} \cdots anm \end{bmatrix} \begin{bmatrix} s1 \\ s2 \\ \vdots \\ sm \end{bmatrix}, \tag{6}$$

which is

$$X = Bh. \tag{7}$$

Using evaluation indicators, three, four, five, and six of the six acquisition signals are registered, and then, independent component analysis is performed in turn to investigate whether the acquisition signal registration will affect the quality of the estimated source signal, and it is also semiqualitative. Analyze the influence of signal synchronization on the quality of the estimated source signal. The comparison between the evaluation SNr and MSe after registration and the comparison before registration is shown in Figure 9:

It can be seen that the synchronization of the signal has a great influence on the results of the independent component analysis.

4.3. Improvement of ECG Signal Registration Method Based on Exercise Monitoring. The meaning of the convex peak of the function $M(x)$ is as follows:

$$\int \begin{matrix} M'(x) = 0, \\ M''(x) < 0. \end{matrix} \tag{8}$$

Or

$$\begin{cases} M'(x + \Delta x) < 0, \\ M'(x - \Delta x) > 0, \\ \mathrm{M}'(x) = 0. \end{cases} \tag{9}$$

Based on the second derivative of the signal, Equation (8) and Equation (9) are two ways of expressing the logical relationship.

Since the ECG signal needs to be converted by A/D, the ECG signal changes from a continuous signal to a discrete signal, and a differential operation is required:

$$\mathrm{diff}M(xn) = \frac{M(xn) - M(xn-1)}{n - (n-1)} = M(xn+1) - M(xn). \tag{10}$$

Among them, $M(xn)$ represents the standard amplitude change time n, and $M(xn)$ represents the previous standard value. The advantage of determining the ECG signal is that you can see the highest point xn of the value point, which shows the uniqueness of this point:

$$\begin{cases} M(xn) - M(xn-1) > 0, \\ M(xn+1) - M(xn) < 0. \end{cases} \tag{11}$$

Based on improving the efficiency of the code, the symbolic function is used in combination with the maximum value. The meaning of the symbolic function is

$$\mathrm{sign}\ (x) = \begin{cases} 1, x \le 0, \\ \text{-1}, x > 0. \end{cases} \tag{12}$$

Therefore, the maximum candidate points satisfy

$$\mathrm{diff}\{\mathrm{sign}\ [\mathrm{diff}M(xn)]\} = -2. \tag{13}$$

By extracting the sample points that meet the conditions in the ECG signal, the maximum preselection $x1 \cdots xn$ can be obtained:

Since there are many sample points in the ECG signal that meet the conditions of maximum value discrimination, it is necessary to judge by the amplitude relationship of the maximum value belonging to the wave crest. Therefore, the conditions that need to be filtered by the threshold are

$$M(xn) \ge \mathrm{thresh}. \tag{14}$$

Filter the remaining extreme points based on nonpeak

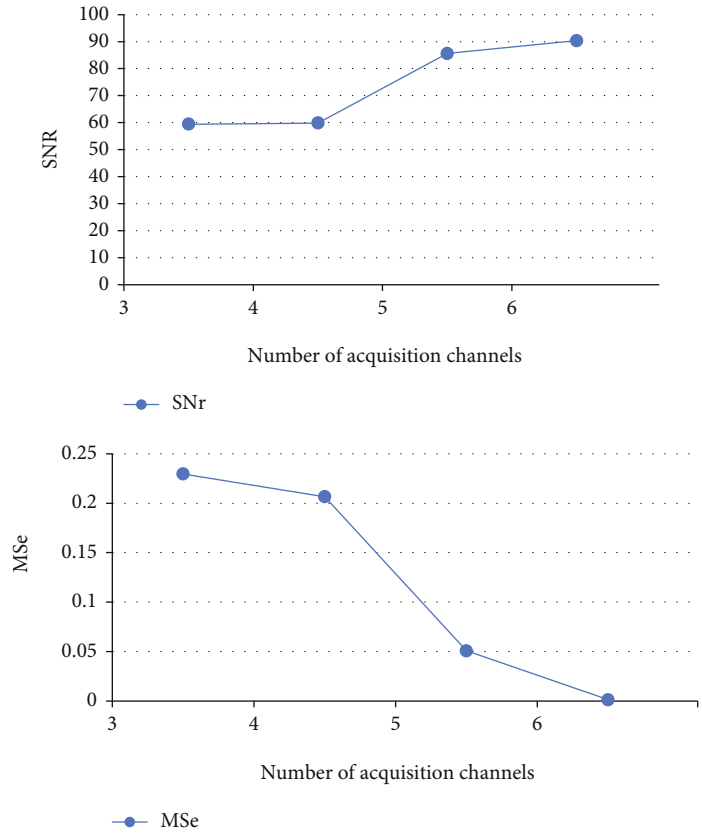

Figure 9: Polyline comparison after matching.

extreme points. Use time relationship to separate major and minor peaks. The selection conditions based on the ECG cycle are

$$Mn + 1\text{-}M \le \frac{t}{2}. \tag{15}$$

Among them, T is the period of an ECG waveform, and the main peak and the secondary peak belonging to an ECG cycle can be separated by this filtering condition.

$$\bar{x} = \sum_{I=1}^{6} xi. \tag{16}$$

Then, pass the time compensation amount of the signal:

$$\Delta xi = xi - \bar{x}. \tag{17}$$

Generally, the advantage of using the average value as the registration position instead of taking a signal as the reference is that it reduces the influence of circuit delay on the signal and can compensate for the delay caused by each processing circuit. The principle is similar to that of multiple experiments. The average value improves the accuracy of the collected signal in terms of time.

5. Conclusions

In this article, we use wavelet transform to decompose the original signal in multiple layers, and each layer will get an approximate signal. The more decomposed layers, the stronger the integrity of the approximated signal, but it will also increase the amount of calculation. We use wavelet transform and independent component analysis algorithms to process the collected ECG signals and analyze the unrecorded signal processing results in detail. It can be seen that the transient ICA model and the signal quality evaluation parameters are sensitive to the signal. Synchronize this feature to make the results meet expectations. In addition, by comparing the 6-channel acquisition method after signal registration with 5-channel, 4-channel, and 3-channel, it is proved for the first time that the quality of the ECG signal collected by the system can be improved by increasing the number. When the experiment is running stably, the ECG monitoring system increases the number of collection terminals by collecting ECG signals in 6 directions, 5 directions, 4 directions, and 3 directions. In addition, this paper refines the registration method, so that the registration algorithm has the effect of suppressing spikes. In terms of time accuracy, the average registration method is used to create the reconstructed ECG signal after registration, which makes it better than the original signal.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The author declares no conflicts of interest.

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