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Retraction

Retracted: Study on the Mechanism of Pathological Recognition Based on Bioelectrical Impedance Spectrum to the Elbow Joint

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] G. Gao, L. Pan, P. Zhang, K. Su, and J. Zhao, "Study on the Mechanism of Pathological Recognition Based on Bioelectrical Impedance Spectrum to the Elbow Joint," *BioMed Research International*, vol. 2023, Article ID 3158486, 8 pages, 2023.

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Research Article

Study on the Mechanism of Pathological Recognition Based on Bioelectrical Impedance Spectrum to the Elbow Joint

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The elbow joint is prone to stiffness and adhesion after trauma or surgery. High-energy trauma easily led to loss of mobility of the elbow joint. Mild trauma can also cause stiffness in the elbow joint. In order to investigate the pathogenesis of stiffness and adhesion in elbow joint, a feedback-type elbow joint control system based on network is proposed in this paper. The simulation results show that it has significant differences in elbow bioelectrical impedance in patients with elbow trauma, and this new method realizes the control strategy of converting the patient's elbow joint pathological information into elbow joint orthosis control information.

1. Introduction

Elbow orthosis is an auxiliary medical rehabilitation device that uses mechanical structure to fix the injured elbow and control its movement in a limited track and range. In recent years, more and more experts and scholars have studied and improved elbow orthosis. The improved orthopedic instrument can be angled according to the change of the patient's elbow extension barrier, so as to provide the best elongation for the patient under the best tensile load. Under the best tensile resistance, it also has the longest total tensile time, so the elbow fibrous tissue can restore the best plastic tensile. It also has the advantage of adjusting the action angle in real time according to the change of the degree of elbow dysfunction. In order to enable patients to carry out orthosis better, the weight of orthosis is often light. By adjusting the screw to make the joint move, the stiffness of the elbow joint after use can be improved, and can make patients feel comfortable. After nearly two years of clinical and clinical use, an orthotic device for elbow and knee joint is proposed. This orthotic device corrects the avoidable joint contraction through dynamic and continuous compression. The early rehabilitation of elbow deformity adopts the principle of progressive orthosis. The progressive elbow extension orthosis gradually stretches the elbow joint with low strength and lasts for a long time, which improves the stress relaxation and stress relaxation of creep soft tissue. In order to achieve good plastic deformation and reduce the risk of repeated damage, applying self-adjusting force to the injured elbow joint of the patients can promote the rehabilitation of the elbow joint without causing secondary injury to the elbow joint. The contraction disorder of elbow joint limits the range of motion of the joint, resulting in the loss of proteoglycan, water, and nutrients in the tissues around the joint, leading to the formation of fibers. Toughness and gradually the decrease of tissue toughness and even calcification will aggravate the obstacle of joint contraction and significantly limit the range of motion of the joint [1, 2].

The signal acquisition device in this paper adopts the acquisition hardware of Mr. Yang's research group of Hunan

Normal University, which can collect signals in real time. In this paper, the mechanical control parameters of elbow orthosis are obtained by improving Cole-Cole, VMD-HHT, and LSTM networks, so as to realize real-time change and better recovery of elbow joint. The experimental results show that it has significant differences in elbow bioelectrical impedance in patients with elbow trauma, and this new method realizes the control strategy of converting the patient's elbow joint pathological information into elbow joint orthosis control information.

The rest of this paper is organized as follows: Section 2 discusses related research of theoretical basis of elbow orthosis, followed by the excitation signal source in Section 3. The comparative analysis and signal processing based on deep learning are given in Section 4. Section 5 concludes the paper with future research and summary.

2. Theoretical Basis of Elbow Orthosis

The application of the stress law of Ilizarov in orthopedics is mainly limited to limb extension and extension and has achieved remarkable clinical results [3, 4]. However, there is no clinical report of elbow-related diseases. This design is based on the following three orthopedic design theories: firstly, tensile stress tissue regeneration theory is used in this paper. The patients with adjustable force on the elbow joint can promote the growth of elbow tissue by Ilizarov's biological theory. Secondly, tensile stress theory is used in this paper. Under the action of tensile stress, human tissues will slowly and continuously undergo metabolic changes, thereby promoting cell division and growth. This process is influenced by blood, frequency of stress stimulation, and weight bearing. In the clinic, tiny tensile stress is applied to human tissue to stimulate and maintain tissue regeneration. Finally, biomechanical three-point or four-point force correction law is used in this paper. According to the three-point or four-point correction law of biomechanics, the correction of joint function loss can be realized. Through theoretical analysis, it can be concluded that the designed elbow dysfunction orthosis has active orthopedic force and conforms to the principle of biomechanics by using the theory of tensile stress tissue regeneration, the theory of tensile stress, and the three-point or four-point force correction law of biomechanics [5]. Therefore, according to Ilizarov's law of tensile stress, the design and manufacture of orthosis for external fixation of elbow joint is based on theory. Shown in Figure 1 is the elbow mechanism platform used in this paper. After correction, the tension of soft tissue and bone will be stimulated by constant pressure. The mechanical stress external fixator is considered to be a physiological pressure stimulant against local tissue contraction [6]. Under continuous stress stimulation, atrophic tissue will regenerate and grow actively, and after correction, the systolic disorder will not recur.

Through the above analysis of the tissue mechanical properties and pathological changes caused by elbow joint deformity, provide a tensile and pressure load for the tissue with strength to adapt to the tissues around the joint, continuously apply continuous tensile stress to the tissues with contraction deformity, change the tissue stress state, alleviate and improve joint deformity, and form a healthy and stable joint tissue. The joint is fixed at the end of its range of motion, and the therapeutic tensile stress is applied to the connective tissue and the muscles around the shorter joint. After a period of corrective treatment, the muscle fibers can be changed, the connective tissue can be remolded, and the range of motion of the joint can be increased. Many studies in clinical medicine have also proved this conclusion. The control test showed that the observation group was assisted with prosthetic treatment while the control group was only treated with routine treatment. The treatment effect of the observation group and the control group was observed. It was found that the effect of routine treatment plus prosthetic treatment for patients with joint deformity was significantly better than that of only routine treatment. In the past, when carrying out auxiliary treatment for patients with elbow flexion and extension disorders, the auxiliary therapists carried out auxiliary treatment for elbow flexion and extension within the acceptable pain range according to the patient's muscle resistance. Although certain treatment effects were achieved, the patients had to change the treatment plan because they could not tolerate it for a long time, resulting in the fact that the clinical experience of doctors could not be directly used to control the auxiliary treatment of orthosis.

The above analysis explains the action principle of elbow external fixation orthosis and also provides a theoretical

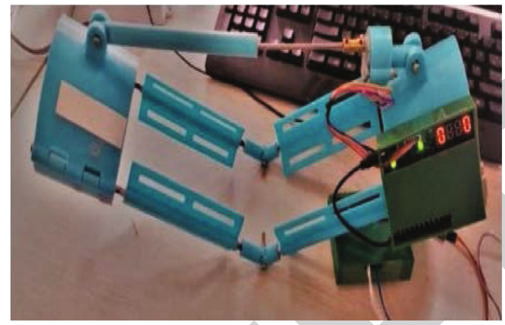

Figure 1: Elbow joint mechanical platform.

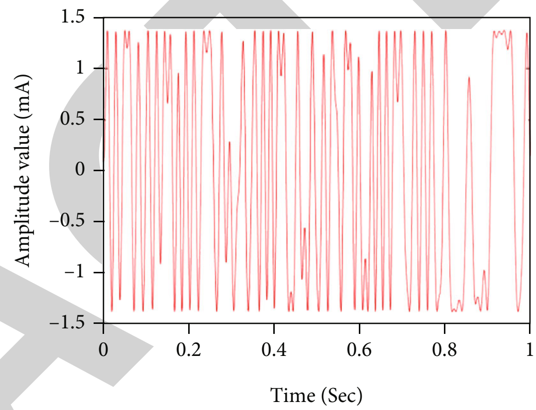

Figure 2: Multisine time domain signal.

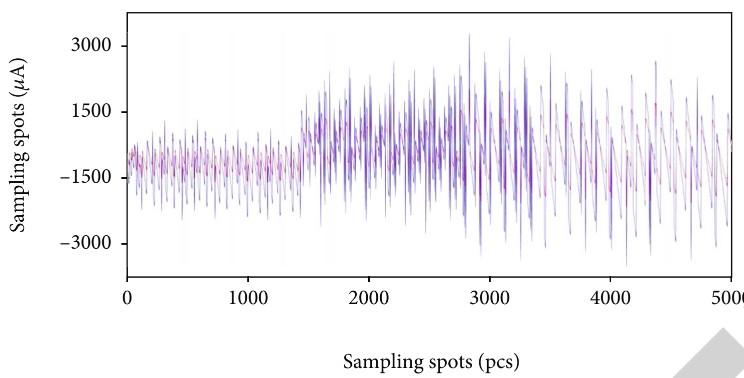

Figure 3: Comparison of common resistance transmitting and receiving signals.

basis for orthosis design. The elbow joint mechanical platform is shown in Figure 1. After the patient wears the orthosis, the orthosis can provide instrument stress for the soft tissue and bone of the patient's knee joint. Under the action of continuous mechanical stress, it can stimulate the regrowth of atrophic tissue and correct the deformed tissue. And because the corrective treatment has improved the bone and tissue structure of the patient's joints, there is basically no risk of recurrence of the joint contraction disorder after corrective treatment.

3. Excitation Signal Source

The time domain spectrum and frequency domain spectrum of multisine signal used in this paper are shown in Figure 2. It is formed by mixing multiple equal amplitude sinusoidal signals with different frequencies and phases. Among them, the frequency of each sinusoidal signal is twice that of the previous sinusoidal signal, which provides the feasibility of whole period sampling [7].

Bioelectrical impedance spectroscopy (BIS) is a technique for measuring and monitoring the impedance of biological tissues in the frequency domain; the collected signals can be used for early disease diagnosis, biological tissue fluid monitoring, and physiological status assessment. The Bioelectrical impedance acquisition system includes the interface circuit diagram of constant current source, OSC, Flash, voltage conversion module, Spartan-6, and RS485. The excitation signal is transmitted and the destination signal is received by this platform. The electrical properties of biological tissues can be divided into active and passive categories according to the source of electrical signals. Active response means that the current of biological tissue is generated by ions inside cells such as ECG and EEG signals. Passive response means that the current of biological tissue is generated by external electrical stimulation (such as current or voltage generator). Bioelectrical impedance analysis is a noninvasive technique that is used to measure body composition and assess clinical conditions. It is a new diagnostic and treatment method that uses the electrical conductivity of biological intracellular fluid and extracellular fluid to detect changes in human tissue or organ function.

As shown in Figure 3, the received signal can be clearly obtained in hardware, and different return signals can be obtained under different detection objects, which provides a hardware basis for the analysis of subsequent signals. In Figure 3, the red signal represents the waveform of the excitation source signal, and the blue signal represents the waveform of the received signal.

Table 1: Common resistance transceiver signal.

Serial number	Transmit signal	Receive signal
01	0.6493	0.5121
02	0.7121	0.6060
03	0.8047	0.6700
04	0.8881	0.7405
05	0.9995	0.8329
06	1.0999	0.9165
07	1.1662	0.9718
08	1.2146	1.0121
09	1.2602	1.0500

Table 2: Signals transmitted and received by human body.

Serial number	Transmit signal	Receive signal
01	1.3031	1.0639
02	1.3778	1.0772
03	1.2973	1.1433
04	1.3546	1.2510
05	1.3447	1.0496
06	1.3135	1.0107
07	1.3083	1.0733
08	1.3630	1.0508
09	1.2883	1.0847

Table 1 is the human body signal collected by collecting the equivalent resistance, and Table 2 is the human body signal collected. Through comparison, the following conclusions can be drawn: the system can clearly obtain the impedance characteristics of human body.

4. Comparative Analysis and Signal Processing Based on Deep Learning

4.1. Traditional Cole-Cole Model. The traditional Cole-Cole model bioimpedance characteristic equation is used to

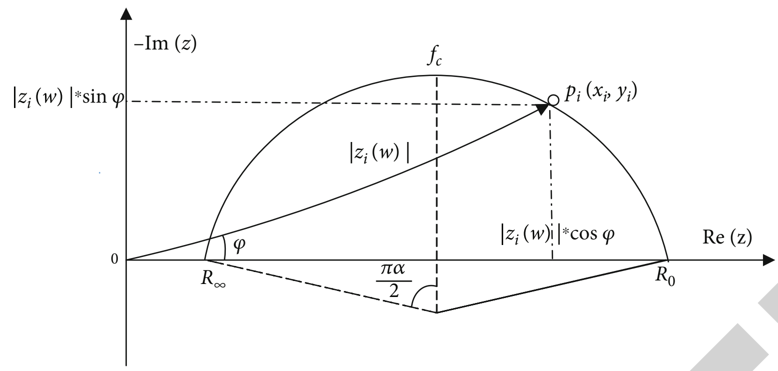

Figure 4: Complex impedance trajectory of biological tissue.

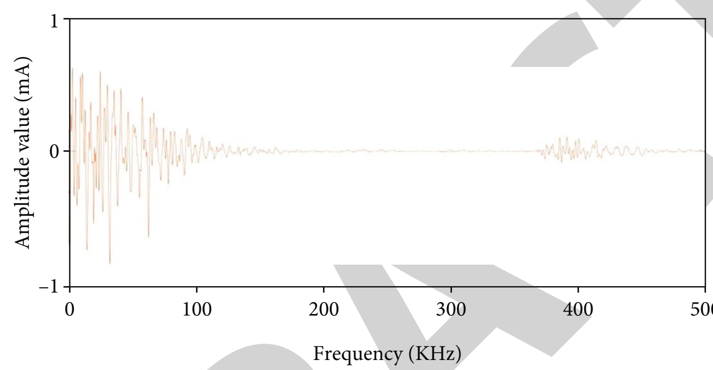

Figure 5: Transmit frequency domain signal.

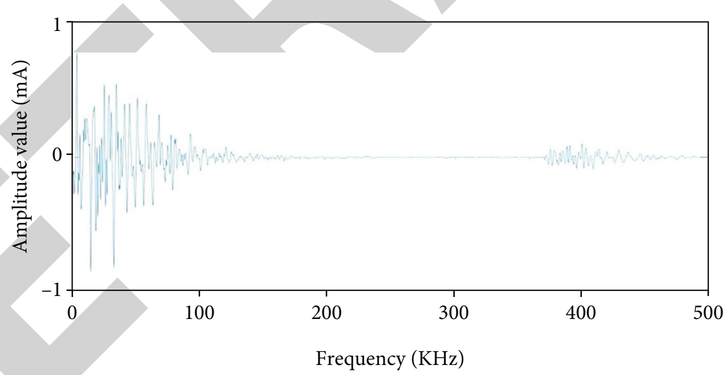

Figure 6: Frequency domain signal detection.

describe biological tissue in Figure 4. We can see that the abscissa and ordinate of the bioimpedance are at R_0 when the frequency is zero. When the frequency is infinite, the abscissa and ordinate of bioimpedance are at R_∞ [8, 9].

$$Z = R_\infty + \frac{R_0 - R_\infty}{1 + (jw\tau)^\alpha}, \tag{1}$$

in which $\tau = (R_i + R_e)C_m$, $R_0 = R_e$, and $R_\infty = R_i R_e/(R_i + R_e)$. Eigenfrequency f_c is the frequency point when the imaginary part of the bioimpedance is maximum.

$$f_c = \frac{1}{2\pi\tau} = \frac{1}{2\pi(R_e + R_i)C_m}. \tag{2}$$

Let Equation (2) into Equation (1) to get

$$Z = R_\infty + \frac{R_0 - R_\infty}{1 + (j(f/f_c))^\alpha}. \tag{3}$$

4.2. Improved Cole-Cole. The improved Cole-Cole experimental steps are as follows:

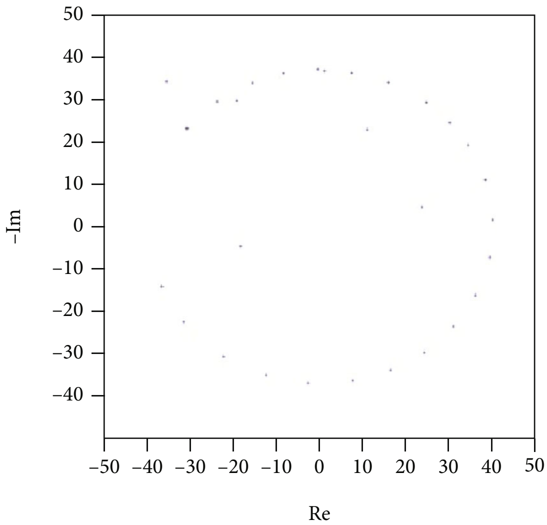

Figure 7: Initial Cole-Cole model diagram.

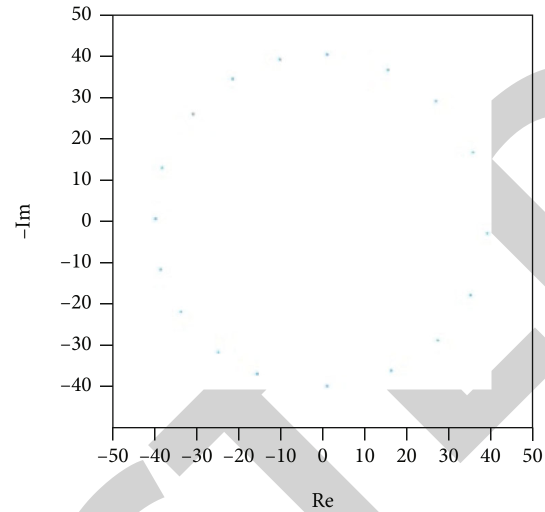

Figure 8: Cole-Cole model diagram after filtering.

Step 1: denote the transmitted and received signals as $u(n)$ and $e(n)$, and perform Fourier transform operations on them to obtain $U(k)$ and $E(k)$

Step 2: accurately calculate the amplitudes of $U(k)$ and $E(k)$ shown as follows:

$$U(k) = U_{RE}(k) + jU_{\mathrm{Im}}(k) \tag{4}$$

Step 3: combine the relational expressions of $U(k)$ and $E(k)$, and analyze the mechanism relationship between the excitation signal and the equivalent electrical impedance of the elbow joint, as shown in Equation (5). The target signal can be solved by it.

$$Y(k) = E(k) - U(k). \tag{5}$$

Then, perform threshold filtering on Equation (6), and the filtered frequency domain signal is denoted as $Y'(k)$, and the relationship is shown as follows:

$$Y'(k) = Y'_{\mathrm{re}}(k) + jY'_{\mathrm{im}}(k) \tag{6}$$

Step 4: $y''(k)$ is shown in Equation (7), $Y''_{RE}(k_1)$ is the X-axis, and $-Y''_{\mathrm{Im}}(k_1)$ is the Y-axis. The image of Cole-Cole can be drawn.

$$Y''(k_1) = Y'_{re}(k_1) + jY''_{\imath m}(k_1) \tag{7}$$

Step 5: use the least square method to perform circle fitting on the result

The improved Cole-Cole used in this paper is a mixture of traditional Cole-Cole and error judgment algorithm. The results of the initial Cole-Cole model are greatly affected by the random error and gross error in the data, so it is impossible to obtain more accurate results of variables. Filter the Cole-Cole model using the Leyte criterion [10, 11].

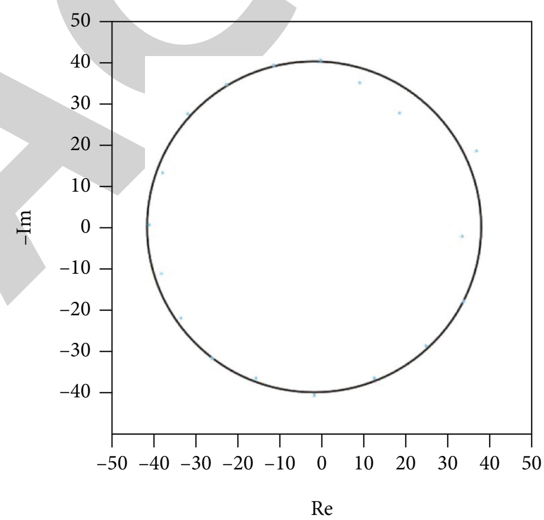

Figure 9: The fitting diagram of traditional Cole-Cole model.

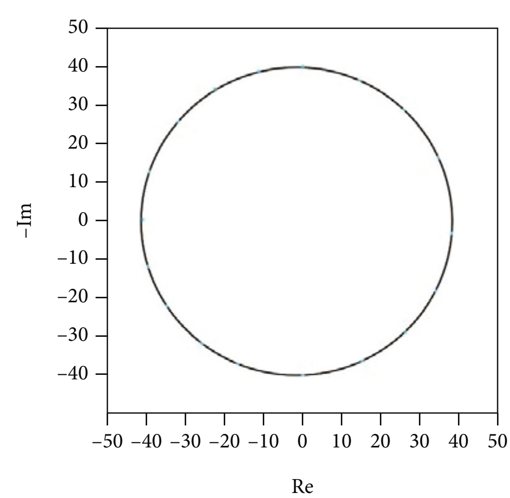

Figure 10: Cole-Cole model fitting diagram after filtering.

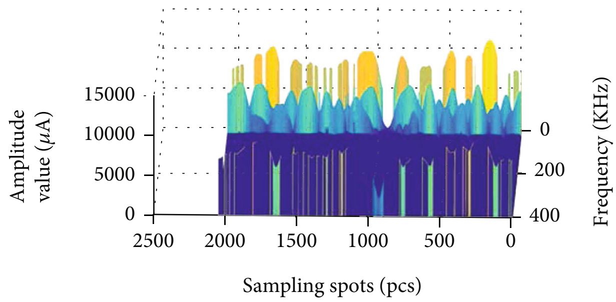

Figure 11: Three-dimensional diagram of original VMD-HHT effect of excitation signal.

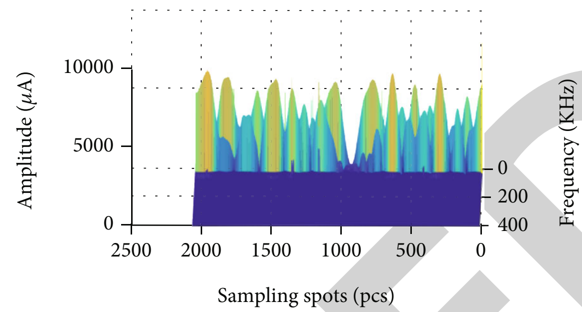

Figure 12: Three-dimensional diagram of VMD-HHT effect improved by excitation signal.

Figure 5 shows the transmission frequency domain signal diagram.

Figure 6 shows the detection frequency domain signal diagram. It can be seen in Figure 6 that the amplitude changes of signals with different frequencies are different under the same conditions.

The initial Cole-Cole model diagram is shown in Figure 7; it is the result of the initial Cole-Cole model, which will be greatly affected by random and gross errors. Therefore, it is difficult to effectively and accurately obtain the equivariant results.

The model after the initial Cole-Cole model is treated with Leiter criteria is shown in Figure 8. From the results, the data error is significantly reduced.

The fitting diagram of the traditional Cole-Cole model is shown in Figure 9. The traditional Cole-Cole model, filtering, and Cole-Cole model are fitted by least square method.

Figure 10 shows the fitting diagram of the filtered Cole-Cole model. It is found that the filtered Cole-Cole model is closer to the circular trajectory, and the accuracy is greatly improved [12].

4.3. Improved VMD-HHT Experimental Steps. VMD-HHT is used to decompose the signal and select the appropriate filter to select the target waveform. Figure 11 shows the original VMD-HHT effect of the excitation signal.

The improved VMD-HHT effect of the excitation signal is shown in Figure 12. After comparison, it can be found that the edge effect of the improved VMD-HHT is greatly weakened, making the result of signal analysis closer to the real value.

4.4. Experiment and Analysis. Frequency domain amplitude diagram of multiple measured signals is shown in Figure 13. In Figure 13, "*" is the frequency domain amplitude curve of measured signals shortly after multiperson operation, and "." is the frequency domain amplitude diagram of the measured signal after recovering for a period of time.

Destination frequency domain signal after multiple measurement filtering is shown in Figure 14. In Figure 14, "*" is the frequency domain amplitude curve of measured signals shortly after multiperson operation, and "." is the frequency domain amplitude diagram of the measured signal after recovering for a period of time.

Amplitude diagram of target frequency domain signal after multiple measurement filtering is shown in Figure 15.

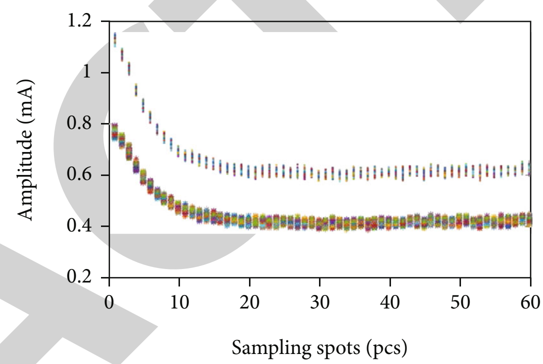

Figure 13: Frequency domain amplitude diagram of multiple measured signals.

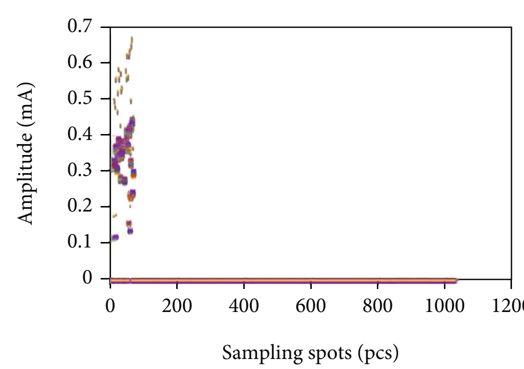

Figure 14: Destination frequency domain signal after multiple measurement filtering.

In Figure 15, "*" is the frequency domain amplitude curve of measured signals shortly after multiperson operation, and "." is the frequency domain amplitude diagram of the measured signal after recovering for a period of time.

It is clearly evident from Figure 15 that the impedance of the patient's elbow joint has changed greatly during recovery. The experimental data are substituted into the neural network. Let the center x position, the center y position, and the radius of the circle be the input of the network and the force exerted by the orthosis be the output of the network. The following results can be obtained. Take the training results of the improved Cole-Cole neural network

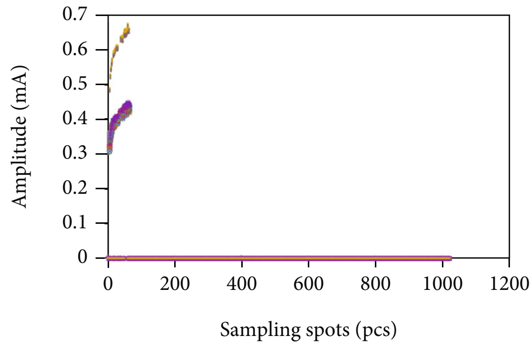

FIGURE 15: Amplitude diagram of target frequency domain signal after multiple measurement filtering.

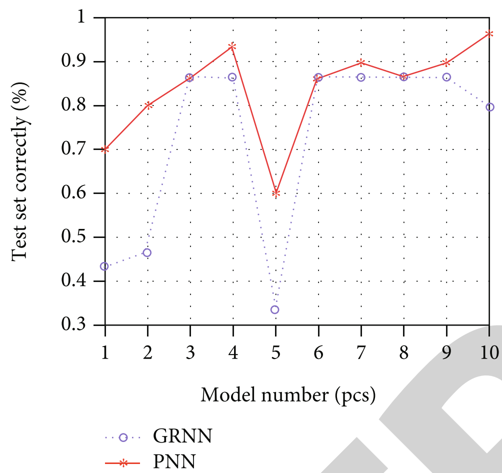

FIGURE 16: Comparison of correct prediction rate between GRNN and PNN.

as an example, and output the training results of the improved Cole-Cole neural network. Figure 16 is the comparison of correct prediction rate between GRNN and PNN.

PNN network and GRNN network are used to a comparative experiment in Figure 16. Through the above experimental results, it can be observed that the prediction accuracy of GRNN network in each test set is greater than that of PNN network.

5. Conclusions

Posttraumatic elbow stiffness is a posttraumatic complication of the elbow joint, with high morbidity, strong disability, and concurrent functional limitations of the hand and wrist, which seriously endangers human health. Data shows that 15 percent of elbow dislocations, 21 percent of dislocations with radial head fractures, and 25 percent of humerus fractures result in elbow stiffness. This paper first introduces the working principle of orthosis and the effectiveness of clinical adjustment rules, then introduces the design theoretical basis of orthosis and its structural composition, then introduces the principle and acquisition hardware circuit of electrical impedance signal of elbow orthosis, and finally introduces the signal decomposition and useful part extraction of the improved Cole-Cole model and VMD-HHT model. Finally, the learning process of GRNN network and the feedback of elbow orthosis control are introduced.

Data Availability

The simulation experimental data used to support the findings of this study are available from the corresponding authors upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

Guodong Gao and Li Pan contributed equally to this work and should be considered as equal first coauthors.

Acknowledgments

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