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Complex System Based Automation Technology for Rehabilitation System Research

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Abstract. With the aging of the population in China in recent years, the number of stroke patients is increasing day by day. The sequelae of stroke-induced foot drop are expected to regain some mobility after timely rehabilitation, but if patients do not receive early intervention, they may miss the best rehabilitation period and lose the ability to walk and stand completely. The traditional means of rehabilitation treatment is manual rehabilitation by rehabilitation physicians, but with the increase in the number of patients with movement disorders, the number of rehabilitation physicians has become significantly insufficient. The use of rehabilitation robots to provide adjunctive therapy to patients has become a common and effective means of rehabilitation worldwide. The early rehabilitation robots could only drive the patient to do passive rehabilitation and could not reflect the patient's true motor intentions. Since EMG signals on the surface of the human body can advance the onset of human movement, they can be used to identify the intention of human movement. This paper validates and explores the experiment based on the underlying data.

1. Introduction

Traditional passive rehabilitation can provide effective rehabilitation in the early stages of rehabilitation for patients with minimal muscle activity. However, when the patient's muscles have a certain level of activity, simple passive rehabilitation cannot meet the patient's needs for more efficient rehabilitation treatment. When the patient's muscles are capable of generating EMG signals, the active rehabilitation treatment using them to train the patient according to his own motor intentions will be more effective and more motivating for the patient's rehabilitation training, making the rehabilitation effect twice as effective [1]. How to make the rehabilitation machine man follow the reciprocal activities according to the patient's own motor intention is an important issue [2].

2. sEMG Overview

The human surface electromyographic signal (sEMG) is an easily detectable bioelectric signal. It is generated by the following process: after the human brain detects the intention of movement, it causes the muscle to contract through the transmission of nerve mediators, generating an extracellular electric field around the muscle fibers and exhibiting a potential difference, which is amplified and converted by the acquisition equipment to form an electrical muscle signal that can be used for information analysis, as shown in Figure 1:

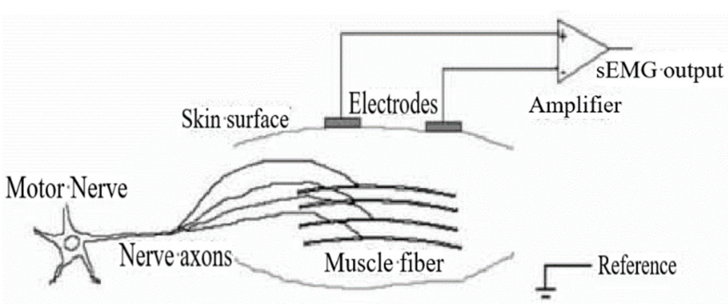

Figure 1. Principle of surface EMG signal generation

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The acquisition of EMG signals on the human surface is easy, does not injure the patient's epidermis, and is simple to perform during the acquisition, depending only on the degree of muscle activity. Human surface EMG signals can be generated in advance of limb movements, approximately 30-150 ms in advance, and as long as the response speed of the rehabilitation robot is sufficient, it can completely precede the patient's movements to determine the patient's movement and assist the patient to complete the movements [3].

3. sEMG acquisition and pre-processing

3.1 Acquisition method of sEMG

Internationally, the study of bioelectric signals has been a hot spot and a difficult area. The potentials generated specifically include resting potentials and action potentials, and representative ones include EEG and ECG, which are common in daily life and can be examined to determine the patient's condition based on the examination chart. In addition, there is the electrocardiogram, which is similar to the electrocardiogram, and the electroretinogram, which measures the function of the retina. The value of human surface electromyography (sEMG) as a bioelectrical signal with simple access has been widely recognized in the field of rehabilitation medicine [4]. Surface EMG signals are not only easy to acquire, but also contain a variety of human body information, and many advanced research results have been achieved in the field of human-computer interaction [5].

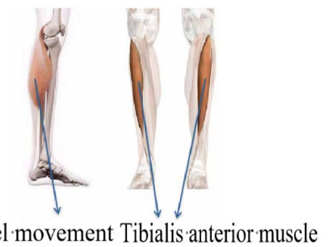

Figure 2. Location of the gastrocnemius and anterior tibialis muscles

The sEMG acquisition equipment uses wireless EMG acquisition equipment from the United States. Its equipment is highly accurate and its collection method is simple and easy to use. It is a wearable sensor that can accurately capture human movements by extracting electromyographic signals. The trig no surface EMG signal acquisition system is a mature technology, widely used in sports and medical fields worldwide, with special acquisition and processing software [6]. It can acquire simulation signals within plus or minus 5V, with Analog to digital conversion accuracy of up to 16 bits. The sampling frequency is 2000hz, and the paste type acquisition used is safe and easy [7].

3.2 Eigenvalue extraction of sEMG

Since the EMG signal is relatively weak, the acquisition process is susceptible to interference and noise, so the EMG signal should be filtered first. The EMG signal characteristics mentioned above mention that the energy of EMG signal is mostly within 20-150hz, so Butterworth filter is used to retain the EMG signal from 20-150hz of the patient, and since the power system can interfere with the signal near 50hz, the filtering process to eliminate the industrial frequency interference is performed to obtain more pure and effective information about the patient [8].

3.3 Motion Intent Recognition Classification

3.3.1 Classification *model construction*

Before the recognition and classification of EMG signals, a model is trained for each patient. For normal individuals and patients with some mobility in the gastrocnemius and tibialis anterior muscles, the EMG signal is very clearly differentiable, whereas for patients in the early stages of rehabilitation, the degree of mobility is very limited and the leg muscles cannot be controlled to perform dorsiflexion or plantarflexion movements for a long period of time. T In this case, the mean absolute value is used as the input data for the support vector machine classification model; the mean absolute value, root mean square, and magnitude are collectively used as the model input data for continuous motion angle estimation [9]. The model training process is shown in Figure 3:

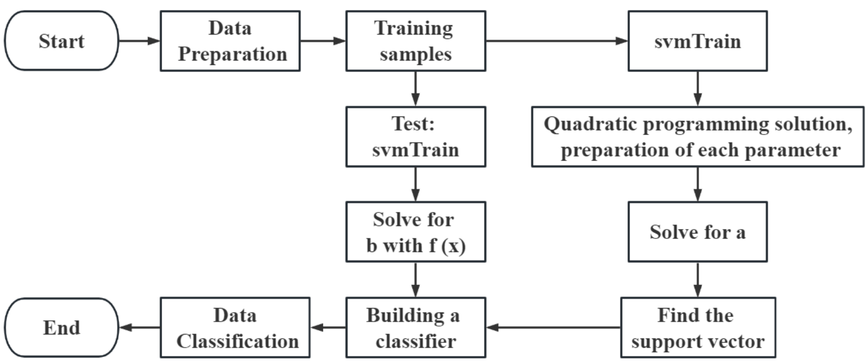

Figure 3. svm training flow chart

The most important problem when classifying support vector machines is the optimal solution of the hyperplane. That is, in the sample data set $W = \{(x_1, y_1), (x_2, y_2), \cdots, (x_n, y_n)\}$ that needs to be classified, the hyperplane with the largest and most suitable support vector interval between the two classes of data is searched for, which can be expressed as $W = \{(x_1, y_1), (x_2, y_2), \cdots, (x_n, y_n)\}$, where w represents the direction of the hyperplane and b represents the amount of displacement, and these two items can determine a hyperplane whose distance from the support vector of any class is $1/w$. As shown in Figure 4:

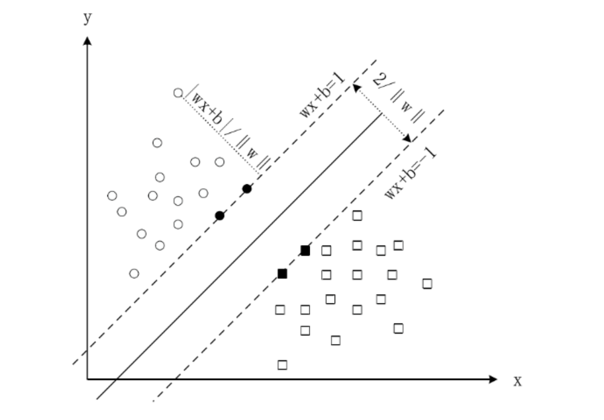

Figure 4. Diagram of svm decision boundary

The two types of samples are marked with y_i as positive and negative, where i is the i-th sample, and a positive sample when y is +1 and a negative sample when y is -1, expressed as shown in equation 1:

$$\begin{cases} w^T x_i + b \geq +1, y_i = +1 \\ w^T x_i + b \geq -1, y_i = -1 \end{cases} \quad (1)$$

As mentioned above, the mathematical essence of the branch vector machine is to solve the extremum problem of the interval, so the objective function of this problem is set as the distance M from the sample point X to the hyperplane, and then M is shown in Eq. 2:

$$M = \frac{|w^T x + b|}{\|w\|} \quad (2)$$

To maximize the interval is also to maximize M. Since the value of y is ±1, the maximum value of the numerator in the expression of M is 2. The maximum value of M is the minimum value of w, which is the minimum value of $w^T w$. And the parameters w and b should satisfy the requirements of Eq. 2 at the same time. For the convenience of subsequent derivative calculations, the equivalent minimal value objective function is obtained by multiplying $w^T w$ by 1/2 in front, Eq. 3:

$$\max M = \frac{2}{\|w\|} \Rightarrow \min \frac{1}{2} w^T w \quad (3)$$

After using Eq. 3 as the objective function and Eq. 2 as the constraint, the original support vector machine basic type, the ordinary support vector machine classifier and the support vector machine classifier with soft interval are able to provide binary classification decisions when they are able to split the samples linearly or mostly. And for nonlinear problems where the samples are not completely separable, the idea of mapping can be used to project the samples from a one-dimensional space or a two-dimensional space into a higher-dimensional space and do the classification in the higher-dimensional space as shown in Figure 5:

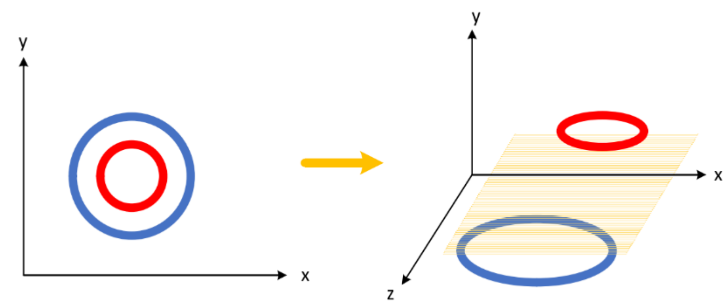

Figure 5. Diagram of mapping relationship

However, the dimensionality of the mapping will be greatly increased, and if each sample point is calculated one by one, its computation is very large and will also occupy a lot of memory, and the classification speed will be affected. In order to obtain the inner product of the sample after mapping, the kernel function can be used instead of the inner product of the sample, which has the same effect but does not increase the true dimension of the sample and minimizes the computational effort.

3.3.2Analysis of experimental results

After the motor intention recognition model is constructed, the patient is trained on the model before rehabilitation treatment. Rehabilitation therapy is performed after the model is trained. The EMG acquisition recognition process is as follows:

(1). First, the patient sat relaxed in a chair and did dorsiflexion and plantarflexion respectively to feel the muscle groups of their legs, and selected the best position for attaching the EMG acquisition module;

(2). Disinfection of the site to be collected and elimination of skin hair interference as far as possible;

(3). Select the EMG acquisition module and confirm whether the acquisition module is in normal working condition in the trig no software of the host computer, and paste it in the corresponding position after confirming normal;

(4). as far as possible to move the tibialis anterior and gastrocnemius muscles, do a set of dorsiflexion, and hold for more than three seconds, then relax, do not let the muscle force, hold for three seconds and then do a set of plantarflexion action, also hold for more than three seconds;

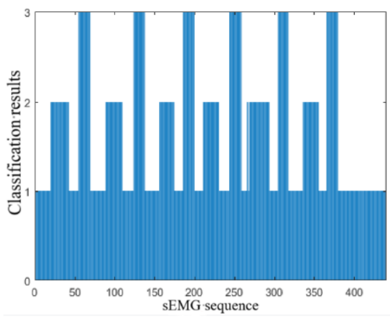

Figure 6. Classification results chart

The overall comparison results are shown in Table 1:

Table 1. Comparison table of classification results

Number of samples	svm	knn	Neural Networks
150	99%	96%	94%
75	99%	92%	93%
15	97%	90%	83%
6	97%	47%	75%

In summary, it can be concluded that support vector machines are not only highly accurate in triple classification, but also require fewer training samples, and the classification accuracy is very stable, and can complete the classification work even when the training samples plummet, which is suitable for the recognition of patients' motion intention; the accuracy of the neural network in classification fluctuates very significantly [10], and it is very easy to have a significant decrease in accuracy when the sample is reduced, and if the patient's muscle activity is not high, the effect of motion intention recognition will be unsatisfactory; the classification accuracy of knn is more stable when the sample is sufficient, but when the number of samples is reduced to a certain level, it will completely fail to perform the classification, which is not suitable for patients in the early stage of rehabilitation and those with low muscle mobility[11].

4. Conclusion

This paper provides a detailed description of the classification of EMG signal recognition in rehabilitation strategies. The electromyographic signals of the gastrocnemius and tibialis anterior muscles were identified using a combination of support vector machines and voting methods to discriminate the three movement patterns of dorsiflexion, plantarflexion, and relaxation of the patient, and then the results of the intention identification were used as input for the next step of model training for continuous motion angle estimation.

Before patients undergo online rehabilitation, they are first trained in a targeted motor intention recognition model, i.e., the sEMG of the target movement is collected and the classification model is trained by mentioning the feature value. After recognition and classification, the three types of results obtained, dorsiflexion, plantarflexion, and relaxation, are represented by 1, 2, and 3 in the vertical coordinates of the classification chart, respectively, and the classification result figures are used together with the above three feature values as input data for the next step of the motion angle estimation model for continuous motion angle estimation.

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