Pattern Recognition of Artificial Legs Based on WPT and LVQ

Lei Liu, Yinmao Song, Peng Yang and Zuo Jun Liu

1 Introduction

Multi-channel Surface Electromyographic (SEMG), is a complex of subcutaneous muscle activity on the Surface of the skin in time and space after the comprehensive physiological electricity phenomenon. It has been widely used in clinical diagnosis, rehabilitation medicine and sports medicine research [1]. In the disabled prosthesis control application of SEMG, it can achieve good effect of bionic, certain achievements has been made in the study of [2] in this aspect.

Artificial leg using SEMG signal needs good recognition rate, and the recognition rate with the method of feature extraction and classifier are closely related. The time domain analysis methods of SEMG are mainly, the average absolute value (MAV Mean Absolute Value), the number of passing zero, the root mean square (Root Mean Square) and electromyographic signal regression modeling analysis, electromyographic signal (Variance) and Willison amplitude histogram, Variance, etc., simple algorithm, feature extraction is easy, but the defect is poor universality and instability [3]. The main frequency domain analysis with Fourier spectrum analysis and power spectrum analysis, because of the need to assume the SEMG signal is a random signal, the lack of rigorous scientific evidence [4]. The experimental research showed that the SEMG is essentially a non-stationary characteristics of biological electrical signals. So some time - frequency analysis method in recent years, such as (Short-Time Fourier Transform), Short time Fourier Transform (STFT), Wavelet Transform (Wavelet Transform, WT) and Wavelet Packet Transform (Wavelet Packet Transform, WPT) have been considerable attention in the SEMG signal analysis [5]. The Wavelet Transform time-frequency local

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Transform multi-scale decomposition characteristics, To analysis the different scales of signals, has been widely used in filtering, but it was used for feature extraction, the fixed form of time-frequency decomposition is not optimal [6], such as low resolution, in some cases, the high frequency end is a disadvantage, so it needed to be improved. WPT because the multi-scale decomposition of signals with arbitrary form, contains rich wavelet BaoJi, different wavelet BaoJi have different nature, reflect different signal characteristics, so it can provide the important features of SEMG [6], thus in the feature extraction of SEMG, it has irreplaceable advantages.

Classifier design is closely related to the feature extraction, classifier for SEMG feature can choose statistical classifier, fuzzy classifier and neural network classifier. It is needed concrete analysis according to the feature extraction method. Neural network application in the electrical pattern classification is a hot topic in recent years, and obtained some significant research results. In the neural network classifier, learning vector quantization (Learning Vector Quantization, LVQ neural network compared with BP network, ART network in structure type choice application more simple network structure, learning rate faster and more reliable recognition and better fault tolerance [7]. based on SEMG signal characteristics and advantages of LVQ, This article attempts through the characteristics of the wavelet packet transform to extract the SEMG signal vector, then using LVQ classifier for pattern classification. Methods by two SEMG signals collection, complete four motion modes (upstairs, downstairs, uphill and downhill) recognition experiment. To illustrate the wavelet packet transform feature extraction method and the LVQ network classifier combination of advantages, this paper compared based on wavelet packet transform, wavelet transform, power spectrum analysis and the regression model (AutoregressiveModel, AR), the characteristics of the coefficient using the LVQ classifier classification outcomes. Compared with the characteristics of the wavelet packet transform to extract using the LVQ network, the BP network, RBF neural network and Elman network classifier recognition effect.

2 The Wavelet Packet Transform

As a kind of multi-scale wavelet transform signal analysis method, it has good time-frequency localization features. It was used in high frequency short window. When low frequency signal is decomposed into a rough part of low frequency and high frequency detail part, and then only low frequency details were done the second decomposition. They were decomposed into low frequency part and high frequency part, without further decomposed high frequency part. The feature of wavelet transform is very suitable for non-stationary signal analysis of transient and time-varying characteristics. Compared with the wavelet transform, wavelet packet analysis can provide a more detailed analysis for signal method. It can according to the analysis of features of the signal, adaptively select band. It make it match the actual signal spectrum characteristics. It can improve the time-frequency resolution

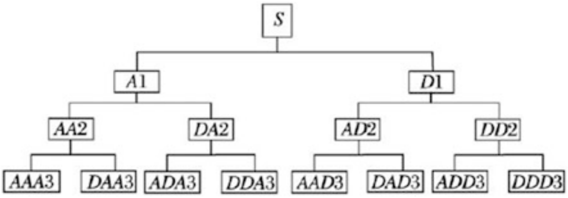

Fig. 1 Decomposition tree of WPT

[8]. The assumption for the analysis of the signal was the S, the three layer wavelet packet decomposition tree was shown in Fig. 1.

Signal S through wavelet transform, were expressed as high frequency and low frequency decomposition, such as AA2 + DA2 + D1, AA3 + DAA3 + DA2 + D1. And wavelet packet transform to allow signal S to a variety of combinations of low frequency and high frequency part, such as S = DAD3 AAD3 A1 + + + DD2. The relative wavelet transform, wavelet packet transform in the aspect of signal frequency resolution and feature extraction has a better adaptability [9].

3 The Optimal Wavelet BaoJi Decomposition

Step 1 normalized processing, for the sequence s sure to select the wavelet packet function and decomposition layers F, F layer wavelet packet decomposition, and calculate the entropy of each node.

Step 2 marked each node of the lowest layer, for other nodes in each layer does not make the mark.

Step 3 a total of 2 f each layer nodes, from left to right every two nodes constitute a group, from down to up to two adjacent layers the next layer of the sum of each group with a layer of the corresponding node entropy value comparison.

Step 4 if the two nodes of the next layer of entropy and greater than or equal to a layer of the corresponding entropy is marked on a layer of the node, and remove the next layer of the two nodes tag. Otherwise, the following a layer of the sum of the two nodes of entropy to replace a layer of the node of entropy, but not for processing of tag.

Step 5 from down to up to two adjacent layers according to the above process, step by step until all layers are processed and marked all the nodes of the wavelet packet function is to search the optimal wavelet BaoJi.

4 Feature Extraction Multi-channel Semg

Feature extraction is the key problem in pattern recognition or classification, it directly affects the design of classifier, and performance. The use of SEMG for intent recognition, with the increase of number of gesture recognition, recognition difficulty is becoming more and more big, so the effective extraction of intent recognition characteristic vector is crucial to the design of the classifier, and directly affect the accuracy of classification.

Although the intensity of the same action in different action under the SEMG in each wavelet packet decomposition energy will be different, but the relative changed little after normalization, but different actions on the same muscles of SEMG relative amplitude and energy have obvious difference, thus different modes of action of SEMG in various frequency bands after wavelet packet decomposition of the projection is different, completely can use this feature for feature extraction. Corresponding to the speed of hand gesture signal generated by the same action in each frequency band energy change is not obvious, so I can put the SEMG energy in each frequency band projection sequence was used as the characteristic of each type of motion vector, can avoid the strength of the action itself, the influence of the speed of characteristic value. Based on this idea, the steps of feature extraction.

Step1 Calculation of each frequency band energy. Signal after F layer wavelet packet decomposition, get the F layer 2^F from low frequency to high frequency band components coefficients of the characteristic signal of (j = 1, 2, …, 2^F), the corresponding frequency band characteristic signal energy.

$$E_F^j = \left| \int Q_F^j(t) \right|^2 dt = \sum_{k=1}^{M'} \left| d_{jn}^k \right|^2 \tag{1.1}$$

the first k to decompose signals; coefficients of discrete points, was to decompose the signal sequence by the number of discrete points.

Step2 to normalization processing get energy relative value:

$$\overline{E_F^j} = E_F^j \Big/ \sum_{j=1}^{2^F} E_F^j \tag{1.2}$$

Step3 tectonic feature vector

$$T = \left(\overline{E_F^1}, \overline{E_F^2}, \ldots, \overline{E_F^{2^F}} \right) \tag{1.3}$$

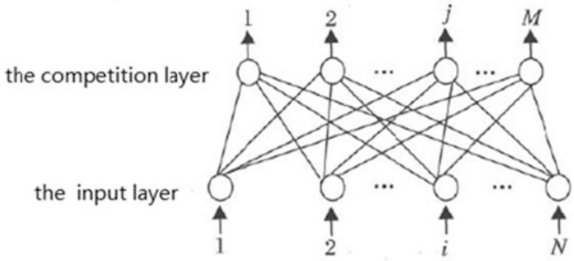

Fig. 2 Neural network structure of LVQ

5 Learning Vector Quantization Neural Network Classifier

Study of classifier based on SEMG hand motions, in previous research work, try a variety of types of neural networks, such as, the BP network, Elman network, the self-organizing competitive network, etc., are good recognition effect, but there are still certain deterrent rate. Here, try using LVQ neural network to design the classifier.

LVQ network is made up of Kohonen, and been successfully applied in many identify problems [10], LVQ network belongs to the basic competitive neural network, is composed of input layer and competition, have N input neurons, the input vector for the Competition layer M neurons, the basic structure is shown in Fig. 2. The network connection for {wij}, i = 1, 2, …, N.j = 1, 2, …, m. constraints of Cj category, j for the output neuron represents different output neurons can output the same mode.

6 The Experimental Results and Analysis

Based on WPT feature and the LVQ classifier combination mode, it including signal filtering and the selection of effective signals load-point and length, etc., then the feature extraction by wavelet packet transform. In the training phase, set the basic parameters of the classifier as the number of neurons in hidden layer, learning rate, etc.

Experiment was designed to study and verify the above structure based on WPT and the movement of SEMG and VQ neural network pattern recognition classifier. The subjects for health students, experimental muscle group for the long strands of rectus muscle and adductor, identify actions to go upstairs, downstairs, uphill and downhill four categories. Before the trial, the electromyographic signal collecting electrode paste in the subjects of rectus muscle and long adductor corresponding on the surface of the skin, at the same time also selected a place without muscle activity of skin surface as a reference point grounding, common mode signal to eliminate the body surface. Through Labview and the building of the data

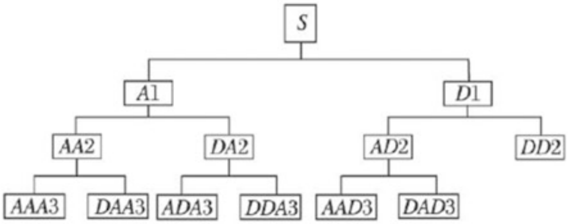

Fig. 3 Best wavelet packet decomposition tree

acquisition card signal acquisition system, set up the sampling frequency of 2.5 kHz, when the hand and wrist, wrist flexion, exhibition boxing and four kinds of action, at the same time gathering foot side wrist flexor and two road side wrist extensor muscle signals. Each action done 100 times, choose the most out of every action category specification of 30 times, a total of 120 groups of data.

In view of the SEMG movements, using Sym5 wavelet function, according to the method of optimal wavelet BaoJi fast algorithm, the preprocessing of two way electromyographic signal level 3 wavelet packet decomposition, to seek the optimal basis under the optimal wavelet packet tree consistent results as shown in Fig. 3.

According to the selection of optimal wavelet packet tree (3, 1), (3, 2), (3, 3), (3, 4), (3, 5), (3, 6), (2, 4) as a vector of the node structure characteristics, corresponding to the frequency of each node were 5–67 Hz, 67–129 Hz, 129–191 Hz, 191–253 Hz, 253–315 Hz, 315–377 Hz, 377–500 Hz. 7 per road signal is the signal frequency band energy feature, the normalized processing, characteristic vector of signal form 14 dimension.

It is listed as shown in Table 1, upstairs, downstairs, uphill and downhill four gait each type of five categories, a total of 20 typical samples by feature extraction

Table 1 Characteristic energy of 4 intent kinds based on best wavelet packet decomposition

Intent recognition		E_3^1	E_3^2	E_3^3	E_3^4	E_3^5	E_3^6	E_2^4
Upstairs	Vastus rectus	−15.7426	−502.138	16.5047	−462.387	0.5709	5.1963	355.874
	Vastus lateralis	8.5377	21.9184	8.2753	22.9371	0.2582	0.4267	32.7208
Downstairs	Vastus rectus	15.5140	30.9163	11.1703	27.3487	0.2805	0.5184	42.3289
	Vastus lateralis	−1179.62	−13,575.3	−541.80	−5630.68	−0.7254	16.0291	−5745.27
Uphill	Vastus rectus	−47.8772	−490.16	22.5125	−160.77	0.2038	2.4150	−77.6421
	Vastus lateralis	−160.823	−981.56	23.7462	−179.72	0.3012	3.0129	−78.3192
Downhill	Vastus rectus	19.3871	−200.17	26.1612	−99.017	0.2415	2.0825	−11.7548
	Vastus lateralis	−25.7054	−532.19	18.6515	−105.64	0.3315	1.8096	−70.0461

Table 2 Identification results of intent recognition using LVQ method

Intent recognition	Upstairs	Downstairs	Uphill	Downhill	Error recognition rate
Upstairs	30	0	0	0	0
Downstairs	0	30	0	0	0
Uphill	0	3	27	0	3
Downhill	0	3	0	27	3

calculated the optimal wavelet packet decomposition characteristics of each sub-band energy averages.

LVQ neural network classification recognition, each action corresponding to the two lines of SEMG 14 is a band of normalized energy as input vector of LVQ neural network, output vector [1 0 0 0] = y1, y2 = [1 0 0 0], y3 = [1 0 0 0], y4 = [0 0 0 1] respectively upstairs, downstairs, uphill and downhill four state. For each type of action samples randomly selected five times each, a total of 20 sets of data as learning samples for training. The remaining 25 each, a total of 100 groups of test samples as a signal is input into the LVQ neural network has been trained in complete identification, and the output results comparing with actual sample category, get the results in Table 2.

As can be seen from Table 2, using the LVQ classifier to go upstairs and downstairs two action recognition rate is 100%, the uphill and the downhill recognition rate is 92%, the average recognition rate reached 96%. The uphill and downhill respectively 2 times is deterrent to go upstairs, possible reason is that (1) the action of the experimenter normative enough data deviation, (2) the building of characteristic vector and remains to be perfect.

Also, with the characteristics of the wavelet packet transform to obtain and use a variety of classifiers are compared, and identifying respectively to investigate LVQ network, the BP network and RBF neural network and Elman network classifier, four kinds of gait recognition rate are shown in Table 3. We can find that, according to the characteristics of the wavelet packet transform, extract method, LVQ classifier can more accurately identify the different gait.

Table 3 recognition rate comparison among 5 recognition methods

Different classifiers	Upstairs	Downstairs	Uphill	Downhill	The average recognition rate
WPT + LVQ	100	100	93	93	96.5
WPT + BP	95	100	85	86	91.5
WPT + RBF	95	100	77	90	77.4
WPT + SVM	94	100	84	87	90.25
WPT + KNN	95	100	88	91	92.6

7 Conclusion

With long strands of rectus muscle and adductor two SEMG signals as a has four actions: upstairs, downstairs, uphill and downhill prosthetic control signal source using optimal wavelet BaoJi subband of wavelet packet transform each frequency band energy as the feature vector of each movement mode is fully display of SEMG signal under different wavelet BaoJi nature, has the characteristics of good presentation skills. When taken characteristics applied to LVQ network classifier for training and classification, obtains the excellent classification performance, shows that feature extraction method of wavelet packet transform and LVQ network classifier combination is very suitable for SEMG signal processing, targeted. The experimental results show that using this method can well identify four hands movement pattern classification, recognition rate of 96%, has a certain practical value.

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