Research on Upper Limb Motion Recognition Method Based on Support Vector Machine

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Abstract

The Electromyography (EMG) signal is the superposition of the action potential of the motional unit in many muscle fibers in time and space, while the Surface Electromyography (sEMG) signal is the comprehensive effect of the EMG of the superficial muscle and the electrical activity of the nerve stem on the skin Surface, which can reflect the activity of the neuromuscular to a certain extent.As a painless, non-traumatic and convenient sEMG detection method, sEMG signal has been widely used in gesture recognition, rehabilitation medicine, human-computer interaction control and other fields. In the human upper limb MYO armlets acquisition forearm muscle electrical signals, after extracting the average absolute value, the number of passing zero, the wave length of the three time domain features, through the Support Vector Machine (Support Vector Machine, SVM) classifier to classify the collected sEMG recognition, the experimental results show that the SVM classifier can better identify the 4 kinds of gestures, the average recognition rate is 97.3%.

Keywords

Surface Electromyography; time domain feature; Support Vector Machine.

1. Introduction

Human motion recognition technology is a kind of technology to identify human motion by collecting relevant information generated by human motion through sensors. SEMG can reflect the motion state of muscles and contains abundant information. Different types of motion have different sEMG[1], therefore, sEMG has good practical value in human-computer interaction, rehabilitation medicine, sports science and other fields.

With the continuous in-depth study of sEMG, some achievements have been made at home and abroad. Document [2] collects four sEMG from four forearm muscles, extracts five features, classifies and recognizes sEMG by BP neural network, and achieves high recognition accuracy. Document [3] combines five characteristic parameters of signals and classifies and recognizes them by LDA classifier, which verifies that good results can be achieved under different feature combinations and dimensions. Based on the EMG control of the exoskeleton of the assistant robot, the linear discriminant analysis method based on Bayesian decision-making is used to discriminate the types of motion, and the average online recognition rate of the five types of actions reaches more than 95%. However, researchers should not only consider the accuracy of recognition, but also consider the real-time, difference and other issues, and conduct more in-depth research.

In this paper, the EMG signals generated by upper limb movements are collected by MYO arm ring. Four kinds of gestures are recognized by SVM classifier, and good classification results are achieved.

2. Design of experimental system

After the signal data collected by MYO arm ring is transmitted from Bluetooth to the computer, the data are processed and identified. The design steps of the experimental system are shown in Figure 1, which mainly includes three parts: starting point detection, feature extraction and pattern recognition.

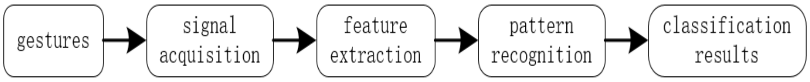

Figure 1 system design flow chart

2.1 Signal acquisition

In order to obtain the surface EMG signal, it is necessary to convert the bioelectric signal generated by the human body into the voltage signal in the circuit[5]. At present, a variety of myoelectric signal acquisition equipment has been developed at home and abroad to collect surface myoelectric signals. For example, the Trigno16 channel wireless myoelectric signal collection system developed by Delsys company can receive the signal of myoelectric signal sensor within 40 meters. MYO armband, developed by Thalmic Labs, Canada, is made up of 8 sensors arranged at equal distances by spring buckle, which enables the armband to be worn effectively on the arm. It is used to detect the electromyographic signals generated by body movements, and then transmit the collected signal data to the computer with bluetooth technology, as shown in figure 2.

Figure 2 MYO armband

The relevant principle is to detect the bioelectric changes caused by the muscle movement of the wearer's arm through the built-in biosensor on the ring belt. The bioelectric signals of these changes can be used to determine the wearer's idea. After the data is sent to the computer for processing, the results can be used to control various devices.The signal quality of the armband is good, the interference is small, and the equipment itself is cheap, so it is very suitable as a control source.

In consideration of the feasibility and convenience of experimental operation, this paper collected the surface electromyographic signals generated by the four gestures of open palm, open palm, closed fist and open hand through MYO armband as experimental data for experimental exploration, as shown in figure 3.It is stipulated that figure (a) is the state of relaxation and figure (b) - figure (e) is four gestures. In the process of data collection, it is stipulated that relaxation - action - relaxation is a complete action, and each action is repeated 48 times completely.

Figure a Relax

Figure b wrist extension

Figure c wrist flexion

Figure d his fist

Figure e open hand

Figure 3 Schematic diagram of four gestures

2.2 Feature extraction

Feature selection is the key to action pattern recognition.sEMG carries information of different gestures [6].The purpose of feature extraction is to distinguish different gestures as far as possible and represent them through a certain feature data of sEMG.At present, the main feature extraction methods in EMG signal classification include time-domain feature, frequency-domain feature and time-frequency feature.Because time-domain features can also obtain better classification characteristics, and have the advantages of less computation and rapid acquisition, this paper selected time-domain features as the classification criteria, which are the average absolute value (MAV), the number of zero crossing (ZC), and the waveform length (WL).

The average absolute value is shown in formula (1):

$$MAV = \frac{1}{N}\sum_{i=1}^{N}|x(i)| \quad (1)$$

The number of zero crossing is shown in formula (2) :

$$\begin{cases} \mathrm{ZC} = \frac{1}{N}\sum_{K=1}^{N-1} f_k \\ f_k = \begin{cases} 1 & x_k x_{k+1} < 0, |x_k - x_{k+1}| > \varepsilon \\ 0 & else \end{cases} \end{cases} \quad (2)$$

The waveform length is shown in formula (3) :

$$WL = \sum_{i=1}^{N-1}|x(i+1) - x(i)| \quad (3)$$

During the experiment, 24-dimensional feature sample data of one action was extracted for the experiment (namely, three time-domain features were extracted from each channel of MYO armband).

2.3 SVM classifier

Pattern classification refers to the process of classifying input eigenvectors through a classifier, which is a mathematical model that identifies input eigenvectors according to certain mathematical algorithms and outputs the types to which these eigenvectors belong.The classifier selected in this paper is support vector machine (SVM).SVM is put forward by Vapnik in 1995 a supervised machine learning method, is used to solve the small sample, nonlinear and high dimensional feature classification problem, its basic principle is: the binary classification problems of non-linear feature mapped to high-dimensional space, makes the nonlinear characteristics in the high-dimensional space linear separable, and then build in high dimensional space classification hyperplane to sample [7], its essence is through optimizing algorithm, seek geometry in the feature space interval biggest hyperplane.As shown in FIG. 3.1, how to effectively separate the two types of samples with two different types of samples? As shown in FIG. 3.1, multiple lines exist to separate the two types of coordinates. The following rules are defined: if a segmented line is too close to the coordinate point, it will be affected by noise, and it is not optimal.Therefore, the goal is to find a dividing line as far from all sample points as possible, as shown in figure 3.2.

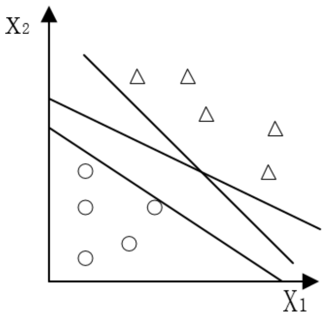

Figure 3.1 Schematic diagram of SVM principle

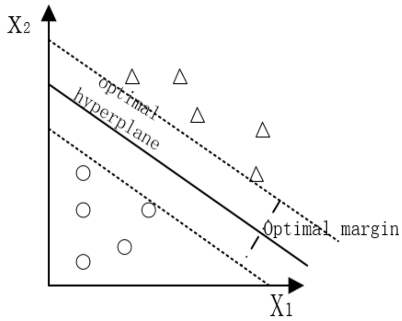

Figure 3.2 Schematic diagram of SVM principle

Suppose the hyperplane is $f(x)$, and its expression is shown in formula (4) :

$$f(x) = w * x + b \tag{4}$$

δ_i is defined as the geometric distance from the eigenvector x_i to the hyperplane, as shown in equation (5) :

$$\delta_i = \frac{1}{\|w\|}|f(x_i)| \tag{5}$$

in this expression $\|w\|$ is the 2-norm of w.

In order to obtain the maximum geometric interval, $\|w\|$ is required to be the minimum. The minimum $\|w\|$ is defined as $min\frac{1}{2}\|w\|^2$, and an optimization function with constraints is obtained due to the existence of constraint conditions:

$$\begin{cases} min\frac{1}{2}\|w\|^2 \\ subject\ to\ y_i(w * x + b) - 1 \geq 0 \end{cases} \tag{6}$$

The above problems can be transformed into unconstrained functions by introducing Lagrangian operators:

$$\mathrm{L}(w, b, a) = \frac{1}{2}\|w\|^2 - \sum_{i=1}^{m} \alpha_i (y_i(w * x_i + b) - 1) \tag{7}$$

in the expression, m is the number of training samples.

After the Lagrangian multiplier is introduced, the optimization function is transformed into:

$$min(w, b)max(a_i \geq 0)L(w, b, a) \tag{8}$$

This optimization function satisfies the KKT (Karush Kuhn Tucher) condition, and the optimization problem is transformed into an equivalent dual problem by Lagrangian duality.According to the dual complementarity in KKT condition:

$$a_i\big(y_i(w * x + b)\big) = 0 \tag{9}$$

If $a_i > 0$,then $y_i(w * x + b)$=1, the point is on the support vector, otherwise if $a_i = 0$,then $y_i(w * x + b)$ ≥1, the sample has been correctly classified or on the support vector.

Due to the advantages of SVM classifier such as strong adaptability and generalization ability, effective solution of non-linearity and small sample size, this paper selects SVM classifier for pattern recognition of EMG signals.

3. Analysis of experimental results

3.1 Collect data

Experiment acquisition a healthy person's gestures of sEMG, first of all let the arms in the process of signal acquisition is in a state of relaxation, and keep arms try to maintain a stable state in the experimental process, reduce the influence of the external factors on the experiment, and muscle by muscle relaxation began to do the action, to return to the relaxed, each action do 48, the experimental data collected in 4 different actions.Figure 5 is the waveform of myoelectric signals collected by the MYO armband. The eight waveforms in the figure correspond to the myoelectric signals of the eight muscles collected by the armband. Figure 6 is part of the data collected.

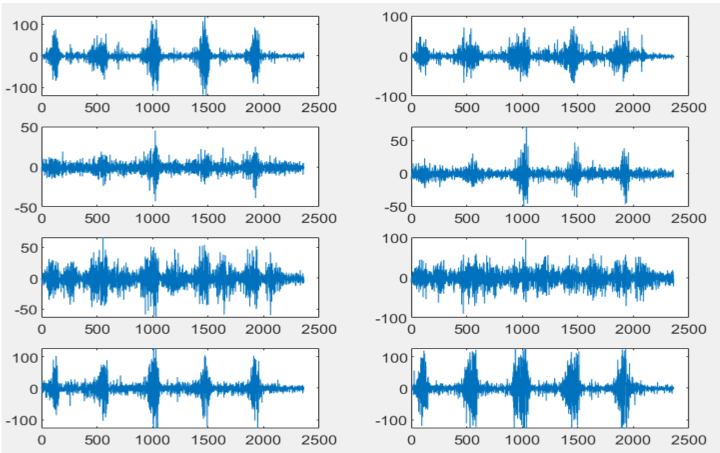

Figure 5 Eight channel raw data waveforms

emg1	emg2	emg3	emg4	emg5	emg6	emg7	emg8
-1	-2	-2	2	-1	-2	3	0
-4	-2	-1	0	-3	-2	-2	2
-1	1	-2	-4	-3	-6	-1	-3
0	0	-3	-5	-2	-4	-4	-3
1	1	0	-7	-1	5	-4	-4
1	1	3	-3	-5	-6	-1	3
-3	-2	-1	0	5	8	-1	-2
1	2	2	5	12	4	6	0
-2	-2	-5	-8	-17	-11	-4	-3
-2	-1	-1	-2	7	0	0	-4
1	-2	-2	1	-5	8	-1	-1
0	1	5	3	2	5	1	0
1	1	4	3	7	3	3	-1
-2	-3	-4	-3	-5	-5	-8	-3
-1	-3	0	-1	3	-4	4	-1
-4	-4	-7	-1	-1	4	14	0
-1	-3	-3	-2	-2	10	-1	1
2	-8	1	1	1	0	0	-1
1	5	1	-2	-1	-7	-1	0
1	-3	-2	-5	-6	-7	-8	-2
-4	0	0	0	0	-9	-4	0

Figure 6 Original data

3.2 Feature extraction

For example, in section 1.2, the absolute mean value, the number of zero crossings and the waveform length of each channel data are extracted, and then there are 24 channels of data in total, as shown in Figure7.

192x24 double

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	21.1305	10.8703	4.2619	8.5528	14.4527	14.5559	16.0910	26.3735	53.9832	26.1429	12.0756	20.4748	35.7899	41.1639	47.9916	64.3403	0.6371	0.6245	0.5401	0.5696	0.6456	0.6287	0.5570	0.6034
2	17.1397	7.5583	2.8253	3.9943	6.9292	7.3306	15.5935	28.2657	44.6215	20.5198	10.4548	13.5367	22.2853	27.2910	46.9350	67.7514	0.5836	0.5722	0.5609	0.5779	0.6062	0.5552	0.5581	0.5666
3	19.5895	7.8434	2.5618	5.2766	9.6140	8.7619	16.2424	27.4900	49.5374	19.7213	9.4511	15.6408	27.6092	30.0345	47.9598	62.2213	0.6023	0.5360	0.4986	0.5965	0.6225	0.5418	0.5504	0.5303
4	13.3597	7.4895	2.7207	5.2529	9.7054	3.5139	12.6488	25.8856	38.1774	20.1070	9.5229	15.1957	27.7920	21.6972	44.1804	64.4862	0.5890	0.6043	0.4785	0.5153	0.5859	0.5890	0.5675	0.5951
5	14.8265	7.0624	2.7203	4.3927	9.0037	9.3298	15.0322	22.9111	39.4388	19.3138	10.0765	13.7628	26.7526	31.4847	45.8087	59.7347	0.5729	0.5448	0.5550	0.5396	0.6215	0.6087	0.5703	0.5499
6	17.2508	10.9819	3.5890	6.3765	9.2332	1.8413	19.4373	30.8499	44.5487	27.3755	11.1733	16.9711	26.7906	18.5307	53.2166	75.7220	0.5942	0.6196	0.5326	0.5435	0.6377	0.5688	0.6341	0.6703
7	15.6516	8.4971	2.9367	5.3587	9.3242	11.3254	12.7869	20.9157	40.7690	21.7255	9.5190	15.2527	26.2255	34.1957	42.5734	55.2745	0.5531	0.5640	0.4550	0.5286	0.5886	0.6131	0.5940	0.5450
8	17.5929	8.4145	4.1146	6.8595	8.4685	3.7858	23.3258	29.5072	44.0992	22.4008	12.0794	17.9365	24.9881	22.1746	58.5278	69.6468	0.5817	0.5817	0.5179	0.5657	0.5857	0.5976	0.5657	0.6135
9	17.0449	7.2103	3.0544	4.9967	7.0369	1.5333	18.2555	27.9470	45.5099	20.3543	9.9570	14.2417	22.2550	18.6623	52.0066	70.0828	0.5847	0.5880	0.5415	0.5183	0.5648	0.5947	0.5714	0.6113
10	19.9566	9.9417	3.0929	4.3620	6.3457	5.5247	16.7892	22.4387	48.2485	24.9320	10.5000	14.1420	21.9408	24.6805	49.4704	59.3698	0.5727	0.5905	0.5223	0.5460	0.5816	0.5964	0.5994	0.5816
11	20.6516	7.0250	2.5865	3.5536	4.7467	2.0630	18.5056	22.4584	51.6931	19.3448	9.4103	12.6345	18.3931	19.0690	52.9103	60.2655	0.6090	0.5398	0.4810	0.5087	0.5813	0.5675	0.5709	0.5709
12	16.9899	6.5475	2.3373	3.4040	5.4089	2.7744	18.6147	21.3304	46.2388	18.9170	8.7301	12.2145	19.9204	20.3806	50.9343	57.7232	0.5799	0.5590	0.5035	0.5243	0.5903	0.5938	0.5486	0.6111
13	13.8633	5.7067	2.2709	3.5422	5.1022	1.3670	12.8696	24.5565	41.1354	17.9199	9.1906	12.7182	19.2403	17.9448	43.6657	67.1436	0.6122	0.5845	0.4903	0.5152	0.5596	0.5651	0.5706	0.6371
14	14.1764	5.5668	1.9270	4.0932	4.7654	-0.2655	11.5568	17.6047	39.3023	16.8503	8.5254	13.3927	18.1525	14.9124	40.1695	52.6695	0.5609	0.5212	0.4958	0.4929	0.5354	0.5496	0.5666	0.5836
15	11.6539	6.6325	1.8973	2.5526	4.4973	0.9342	11.1280	22.1611	35.9522	18.1502	8.3413	11.1024	17.9420	17.2150	40.2389	60.5085	0.5616	0.5342	0.4555	0.5548	0.5342	0.5685	0.5890	0.5890
16	22.2678	9.7354	3.3315	2.7987	4.1233	3.9997	20.0491	29.7666	53.5159	24.2650	10.7138	11.7597	18.6714	23.4664	52.3887	68.2120	0.5816	0.5745	0.5426	0.5709	0.6312	0.6489	0.5674	0.5745
17	13.7013	6.7350	2.6604	3.5980	5.2760	2.6002	17.4842	27.9531	39.5994	19.5673	9.7749	12.4152	18.9854	20.1842	48.2164	69.0117	0.6041	0.5894	0.5279	0.5836	0.5689	0.5513	0.5308	0.5543
18	13.7143	5.2988	2.0166	3.8310	4.5660	2.2856	13.4228	20.6780	39.8845	16.7954	8.1287	12.8383	18.6436	20.8086	44.3795	60.5941	0.6258	0.5894	0.4934	0.5331	0.6093	0.6258	0.5795	0.6258
19	14.3534	5.9573	1.9908	2.7852	5.5801	4.0066	13.7678	25.0993	39.0848	17.6023	8.6579	11.2778	20.8304	21.9795	44.1287	63.4591	0.5748	0.5513	0.5220	0.5689	0.6100	0.6041	0.5718	0.6012
20	10.9694	5.7940	2.0957	3.3120	4.6417	1.4384	16.2063	23.4508	35.6677	18.2695	8.4910	11.5269	18.9671	17.8054	46.7455	60.7814	0.6126	0.5916	0.4865	0.4985	0.5766	0.5856	0.5616	0.5856
21	18.1376	6.0082	1.8757	2.1840	3.8745	2.5843	14.3299	19.4239	47.9832	17.2685	8.2047	10.0570	16.6779	20.3658	46.1376	55.1980	0.6094	0.5253	0.4781	0.4747	0.5152	0.5892	0.5892	0.5926
22	19.5451	7.8016	2.1306	2.8106	4.8362	4.4128	13.2258	19.1189	51.1750	21.4950	8.8050	11.1125	19.4150	23.7325	42.1975	55.5500	0.6040	0.6216	0.5038	0.5013	0.6140	0.6516	0.5388	0.6065
23	13.9570	6.0402	2.7705	3.9293	4.3924	-0.7353	15.3920	24.2454	40.3829	18.1190	9.5911	13.3755	17.8476	14.1673	46.1190	64.8736	0.6269	0.5709	0.5336	0.5970	0.5410	0.5261	0.5373	0.6194
24	13.1259	6.1749	1.9940	3.4381	5.4679	3.8236	14.0274	20.1839	37.4800	17.2067	8.0900	12.0067	20.0933	21.8667	41.6167	57.6567	0.5853	0.5452	0.4548	0.5251	0.6020	0.5853	0.5585	0.6054

Figure 7 Data with extracted features

3.3 Action classification experiment results

In SVM classifier, the extracted feature data is called. The data contains 192 samples, each sample contains three features. The first 15 of the four actions are used as test sets, and the remaining 33 data are used as test sets. The classification result of test sets reaches 97.73%, as shown in Figure 8, among category labels 1,2,3,4 correspond to four movements: wrist extension, wrist flexion, his fist and open hand. It can be seen that SVM classifier has better classification effect and can be applied to the recognition of upper limb movements.

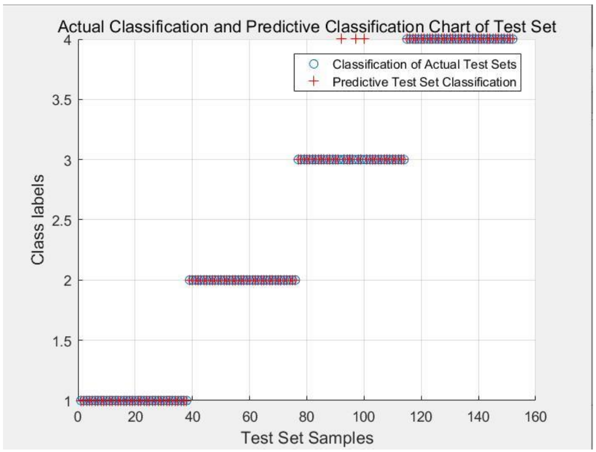

Figure 8 classification results with 15 test sets

4. Summary and prospect

In this paper, three time-domain features are extracted: average absolute value, number of zero crossings and waveform length. The signal data are classified and identified by SVM classifier, and the accuracy rate is up to 97.73%. However, there are many shortcomings. This paper does not take into account the specificity among individuals, the diversity of actions and the real-time processing, which need to be addressed in the later work.

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