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Configuration of the Mckibben Muscles and Action Intention Detection for the Artificial Assistant Suit

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Abstract：The artificial assistant suit is a kind of assistant equipment, which is actuated by Mckibben muscles and can be put on the human upper body, to help the upper limb act. It can detect the action intention of human's upper limb automatically and output definite force complying with the intention. The configuration of the Mckibben muscles is introduced in detail. How to detect the action intention by the surface electromyography signal is discussed deeply. The related experiments and their results are given.

Keywords: artificial assistant suit, Mckibben muscle, action intention, SEMG, classifier.

1. Introduction

Recently, our lab has been developing an artificial assistant suit actuated by the Mckibben muscles, which can be put on the human's upper body to help the two arms act. It can detect the action intention of human's two arms automatically and output definite force complying with the action intention (mainly including the actions of the shoulders and the elbows). Therefore it is a kind of action assistant equipment for human arms. To the ordinary or the old people, it can be used as the action assistant equipment to make them act easier. To patients, it can be used as the recuperate equipment to help them train their arms. To part of the disables, it can be used as the motive force equipment to help them to recovery their arm functions. Based on the functions and its characteristics of the artificial assistant suit, it must refer to the following problems. One, how many pieces of the Mckibben muscles are needed? How to distribute them and connect them with the artificial assistant suit? Two, how to detect the action intention of the human arms automatically? It should detect the action intention correctly in real time. Then it can output the corresponding force complying with the action intention correctly. Three, how will each of the Mckibben muscles operate after the action intention is got? Of course, only all of the Mckibben muscles must operate coordinately, the artificial assistant suit can output the required force and human feels comfortable. This paper mainly aims at the first two problems.

2. Configuration of the Mckibben muscles

To help the human arms act correctly, the Mckibben muscle actuators must be configured reasonably。Only one piece of the Mckibben muscle can't complete all the actions [1], because that the structure of the human arm is complicated and its actions are many and varied. Therefore, many pieces of the Mckibben muscles are required and they need to operate coordinately to achieve the required force. Based on the above analysis, we resolve the arm actions into the following basic ones：

①Shoulder's rising up and down (including to the front, to the back, and to the side), shown in Fig.1(a) and Fig.1(b)；

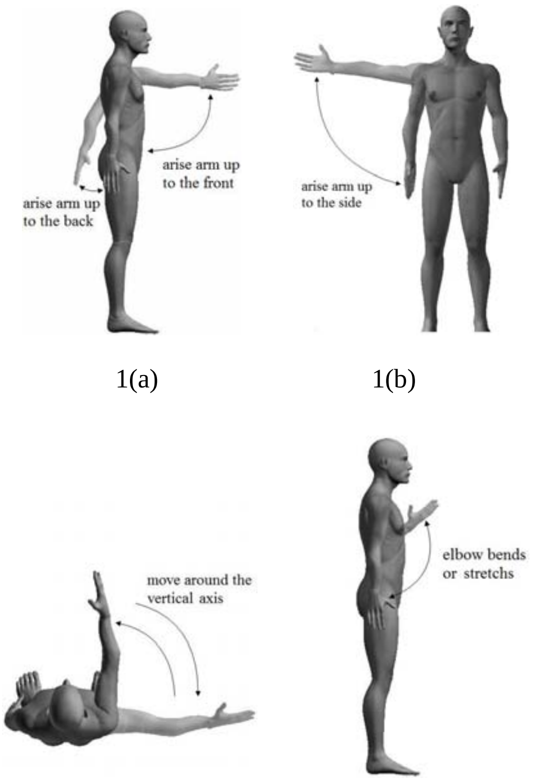
②Shoulder's swinging around the vertical axis, shown in Fig.1(c)；

③Elbow's bending and stretching, shown in Fig.1(d)；

④The forearm's rotating around the anatomic axis.

We think that all of the main arm actions can be realized based on the above four basic actions. The configuration of the Mckibben muscles can be done based on the requirement of the four basic actions. Let's analyze the anatomic structure of the human arm firstly. There are more than 20 pieces of muscles with the actions of both the shoulder joint and the elbow joint in the same arm[2]. All the actions of the shoulder and the elbow can be realized by these muscles' operating coordinately[3]. Based on both the analysis to the anatomic structure and the dynamic requirement for the artificial assistant suit, 8 pieces of the Mckibben muscles are selected for the configuration of one arm of the suit, shown in Fig.2. They are corresponding to the functions of the following 8 muscles:

① Triceps brachii
② Brachioradialis
③ Biceps brachii short head
④ Biceps brachii long head
⑤ Deltoid anterior part
⑥ Deltoid middle part 1
⑦ Deltoid posterior part
⑧ Deltoid middle part 2



1(a) 1(b)

1(c) 1(d)

Fig.1 The basic actions

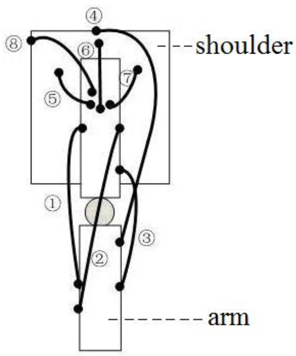


Fig.2 Configuration of the Mckibben muscles

3. The detection of the action intention of the human arm

To assist the actions of the human arm correctly, the artificial assistant suit should know the action intention of the person who is putting on it firstly. Then it calculates the quantity and the direction of the force. To the analysis of the motion intention of the human, the traditional way is getting it by analyzing the unbiological signals such as the angle, acceleration, force, or vision and hearing. All these unbiological signals are not direct to the motion intention. But the surface electromyography signal (SEMG) is generated directly by the muscles. Therefore, SEMG signals can express the motion intention more directly and more precisely [4], which is more suitable to be the control signal of the artificial assistant suit. This paper is right just to discuss how to detect the motion intention of both the human shoulder joint and the elbow joint by collecting the SEMG signals of the human.

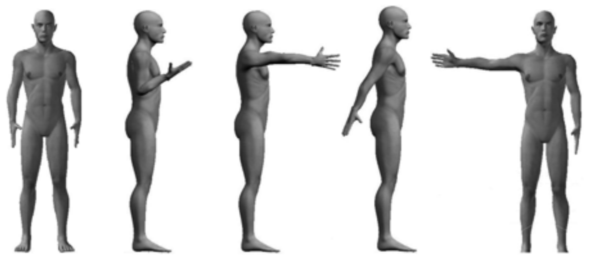
On whole, we collect the data about the SEMG signal related with the given basic action. Then we establish the relationship between the motion intention and the SEMG signal by the classifier or BP neural network. We select the classifier in our research.

3.1 Design of the experiments

The motions of the human arm are very complicated. Here only the motions of both the shoulder and the elbow are considered. The experiments only referring to the four basic actions and their combination are done。Actually the first three actions are selected for the experiments. And they are divided into different degrees of freedom, which are degree 1 of freedom - shoulder's rising up and down, degree 2 of freedom – shoulder's swing around the vertical axis, degree 3 of freedom – elbow's bending and stretching.

The five motion states of the arm when human standing freely on the ground needs to be defined before experiment, shown in Fig.3. State 0 corresponds to when the arm is relaxing. State 1 corresponds to when the elbow is bending to almost its largest angle. State 2 corresponds to when the arm is rising up frontward to almost the same level with the shoulder and the elbow doesn't bend. State 3 is when the arm is rising up backward to the largest angle of the shoulder joint and the elbow doesn't bend. State 4 is when the arm rises up sideward to almost the same level with the shoulder.

Three healthy male master students took part in the experiments. The electroencephalogram apparatus, EEG1100 made by a Japan company is used, which's sampling frequency is set as 100Hz，sensitivity as 100μV, passband as 0.1~200Hz. A pair of electrodes, which locates 3cm apart from each other, are used and the distribution is consistent with the muscle fiber. The referential voltage is the average of the voltages of the two earlobes. To get the motion intention of human arm on every degree of freedom, the SEMG signals of Biceps brachii, Triceps brachii, Deltoid anterior part, Deltoid middle part, Deltoid posterior part and pectoralis major are detected.



3(a 3(b) 3(c) 3(d) 3(e)

Fig.3 The different states of the upper limb

The experiments are divided into two stages which are training stage and test stage. In the training stage, the data of the SEMG signals of the four basic actions are sampled to establish and train the classifier. In the test stages, the classifier is tested to prove whether or not it can forecast the action intention correctly.

In the training stages, the experimenter's arm acts circularly as the following sequence（seeing Fig.3）: 0, 1, 0, 2, 0, 3, 0, 4, 2, 4, 0. The training is divided into two groups. Every group circulates this way ten times.

In the test stages, two complex actions are designed, shown in Fig.4. The classifier is used to forecast the action intention. The motions are recorded by a video camera so that it can be compared with the result calculated by the classifier.

4(a) 4(b)

Fig.4 The complex actions

3.2 Data process

In the training stages, the action between state 0 and state 1 is actually the motion on the degree 3 of freedom. The actions between state 0 and 2, state 0 and 3, state 0 and 4 actually are the motions on the degree 1 of freedom. The action between state 2 and 4 is actually the motion of the degree 2 of freedom. The task of the training stage is to train the three classifiers by the data of the SEMG signals to judge the motion intention on the three degrees of freedom. In the test stages, the experimenter does the complex actions. The complex action 1 includes the motions on all the three degrees of freedom, and the complex action 2 includes the motions of both degree1 of freedom and degree 3 of freedom.

To realize the judgment to the real-time motion intention of the human arm on the three degrees of freedom, the six pairs of SEMG signals are divided into three groups, shown in Table 1. Every group corresponds to one degree of freedom, which is used to judge the motion intention. The group 1, consisting of the SEMG signals of Deltoid anterior part, the middle part and the posterior part, is to judge the motion intention on degree 1 of freedom. Group 2, consisting of the SEMG signals of Pectorals Major, is to judge the motion intention of the degree 2 of freedom. The group 3, consisting of the SEMG signals of both Biceps brachia and Triceps brachia, is to judge the motion intention on degree 3 of freedom. The data processing of the three groups of SEMG signals are independent. For example of the group 1, affected by the weight on the vertical direction，the motion intention of the experimenter is to arise up when both the arm keeps the state 2, 3, 4 and it really rises up.

Like Fig.5, the three classifiers are designed and trained. Like Fig.6, the data in the test stage are used to check whether or not the classifiers work correctly. The output of the classifiers will be compared with the videos taken by video camera.

3.3 Experiment results

Fig.7 shows that the experimenter does the complex action 1. The former six figures show the relative SEMG signals, the later three figures show the analysis result of the motion intention which is clearly consistent with the real motion intention. Fig.8 is something with the complex action 2, and it shows the same situation with Fig.7

Table 1 Three signal groups and the corresponding degrees of freedom

Signal group	Related SEMG signals	Related degree of freedom	Motion intention
Group 1	SEMG of Deltoid anterior part, the middle part and the posterior part	Degree 1 of freedom	Rise up, put down
Group 2	SEMG of Pectorals major	Degree 2 of freedom	Swing forward, relaxed
Group 3	SEMG of Biceps brachia and Triceps brachia	Degree 3 of freedom	Bend forward, relaxed, stretch backward

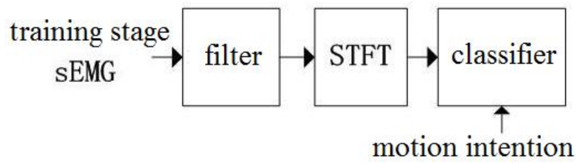


Fig. 5 data processing in the training stage

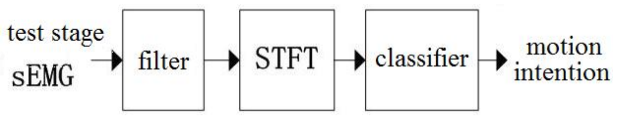


Fig. 6 data processing in the testing stage

4. Conclusion

Based on the requirement of the artificial assistant suit, the configuration of the Mckibben muscles is investigated. The detailed detecting methods of the action intention by SEMG signals are introduced. The experiment results show that the action intention detection is efficient and accurate. Of course, the research hasn't been completed. The third problem still hasn't been resolved. This is right just we are going to do in the next step.

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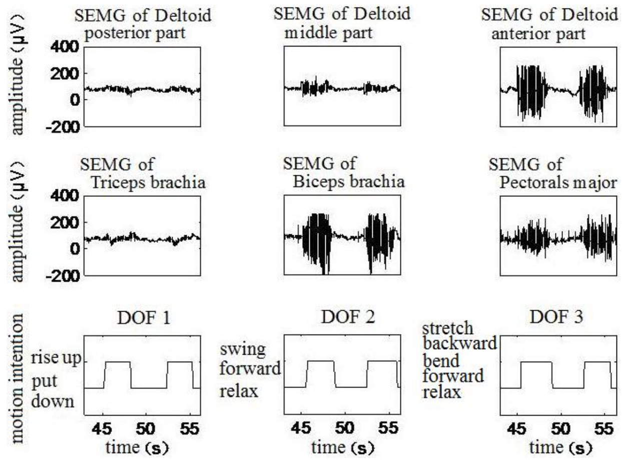

Fig. 7 Analysis of the complex action 1

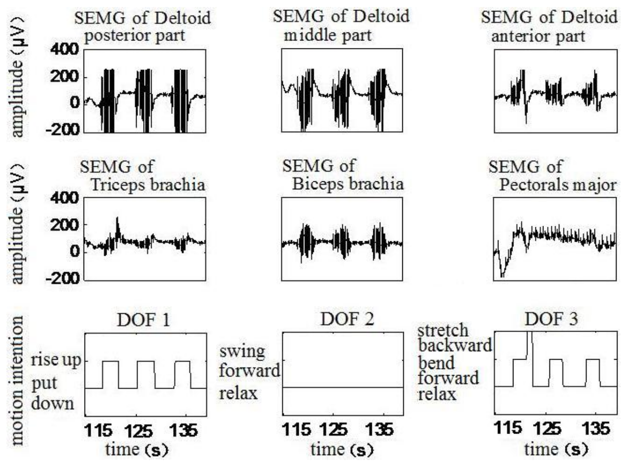

Fig. 8 Analysis of the complex action 2

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