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Control of external devices based on sEMG signals

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Abstract: *This topic studies how to use the sEMG signal portable external equipment to collect the surface EMG signal using the EMG instrument. In the signal data processing part, the causes of signal interference are analyzed from the hardware perspective, and the main frequency bands of its occurrence are recorded. In the code part, the data is processed through an analog filter. The communication mode uses TCP/IP protocol to achieve cross system interprocess communication. In the actual test process, there is unavoidable slight delay. At the same time, the voltage changes brought by the real-time adjustment mode of CPU and other computer hardware will also affect the accuracy of surface EMG signals. At the same time, the signal acquisition rate of the EMG is much higher than the transmission rate, so real-time transmission will lead to memory overflow. Therefore, this paper uses the fixed threshold algorithm as the control decision in the outgoing process, and tests the integral mean value of six different data sets and the grasping speed and reaction force of the gripper. It is finally found that when the data set has 20 elements, the delay is not large and the data is not easy to be blocked due to good real-time performance.*

Keywords: *sEMG, Intelligent workshop products, Moving target tracking*

1. Introduction

With the advent of Industry 4.0. All kinds of intelligent equipment are gradually stepping into production and manufacturing. There are more and more scenes of robot and human cooperation. Therefore, how to control external devices more conveniently has become a hot issue of the times. This topic will take the method of force control to control the external equipment. There are two main development paths of robot controlled by force. One is the force control strategy, and the other is the force feedback approach. This topic mainly explores the force control of surface EMG signal under the force feedback approach. [1] During muscle contraction, electrical signals will be generated actively. However, the torque model of EMG signal is relatively complex, which limits the force control performance of this method. This topic combines EMG signal with force control to complete the grasping control of EMG signal. This research is of great significance for improving the flexibility of intelligent manufacturing and expanding the application range of cooperative robots.

2. Manuscript Preparation

This part will describe the generation of sEMG signal, the selection of equipment before the experiment, and the methods used in the experiment

2.1. Generation of surface electromyography

Muscle is an important part of human tissue, and various forms of human movement are mainly completed by contracting some muscle cells. Each muscle is formed by the combination of many muscle cells (muscle fibers). These muscle cells are connected by connective tissue, and both ends are connected with tendons. In addition, the nerves, lymphatic vessels and blood vessels that supply them form together. Each muscle is attached to the bone tendons and other connective tissues to form a mechanical and effective system, which can perform certain motor functions under the random management of the nervous system. Excitation and contraction are the basic functions of skeletal muscle and the basis of electromyography. EMG is a very weak bioelectrical signal, which is closely related to neuromuscular activity and contains a lot of information related to limb movement. It can well show the force characteristics of muscles, and there is a corresponding relationship between them. The greater the muscle contraction force, the stronger the EMG signal. [4] The electrode can detect the voltage change

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when the muscle is moving, which belongs to the biochemical quantity sensor.

2.2. Introduction to experimental equipment

Introduce the manufacturer and relevant parameters of the experimental equipment

2.2.1. Selection of electromyograph

The number of channels of EMG directly determines the number of muscle blocks. The more channels, the more information will be obtained. The signal quality of sEMG will directly affect the recognition of grasping force. Therefore, in the process of signal acquisition, the selection of electrodes and the magnitude of signal interference will affect the quality of the signal. At present, the acquisition methods of surface EMG signal mainly include invasive and non-invasive ones. The invasive ones are divided into implanted electrodes or needle electrodes, which can obtain sEMG signals from the muscle fiber layer. The non-invasive ones directly collect the original sEMG signals from the human muscle epidermis. It is verified that the invasive electrode is not only inconvenient to wear, but also can not significantly improve the collection quality of EMG. [3] Inadequate disinfection may also lead to bacteria invading the human body. It is also the trend of future development to collect sEMG signals in a non-invasive way. There is also a relatively perfect non-invasive sEMG acquisition system on the market. This topic uses the gForcePro+ armband developed by OYMotion Company. Figure 1 shows what the gForecePro+ armband look like Just wear the armband on the arm to collect the EMG signals of multiple muscle groups. Compared with traditional sensors, the armband is convenient to carry, wear and interact naturally. It has a higher cost performance ratio. This topic is based on gForcePro+ armband and controls external equipment through ROS framework.

Figure 1: The gForcePro+ armband.

2.2.2. Selection of external devices

The external equipment to be controlled in this subject is Robotiq 2F-85 Gripper double finger adaptive gripper produced by Robotiq Company. The figure 2 shows what the gripper look like. The gripper has excellent force control capability while maintaining high load and high accuracy. The application of adaptive gripper can greatly improve the flexibility of production and manufacturing, and can complete various production tasks without introducing complex rigid fixtures. For small enterprises with high mixed small batch productivity, the gripper has higher flexibility.

Figure 2: The Robotiq 2F-85 Gripper

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2.3. Control system framework composition

The composition of the control system is mainly divided into three parts: electromyography, upper computer system, and external equipment to be controlled. The electromyography is gForcePro+, and the external equipment is Robotiq 2f-85 Gripper gripper. The clamping jaws are fully opened at a distance of 85 mm, and the hardware communicates with each other through the LAN. The following figure 3 shows the main working process of the control system.

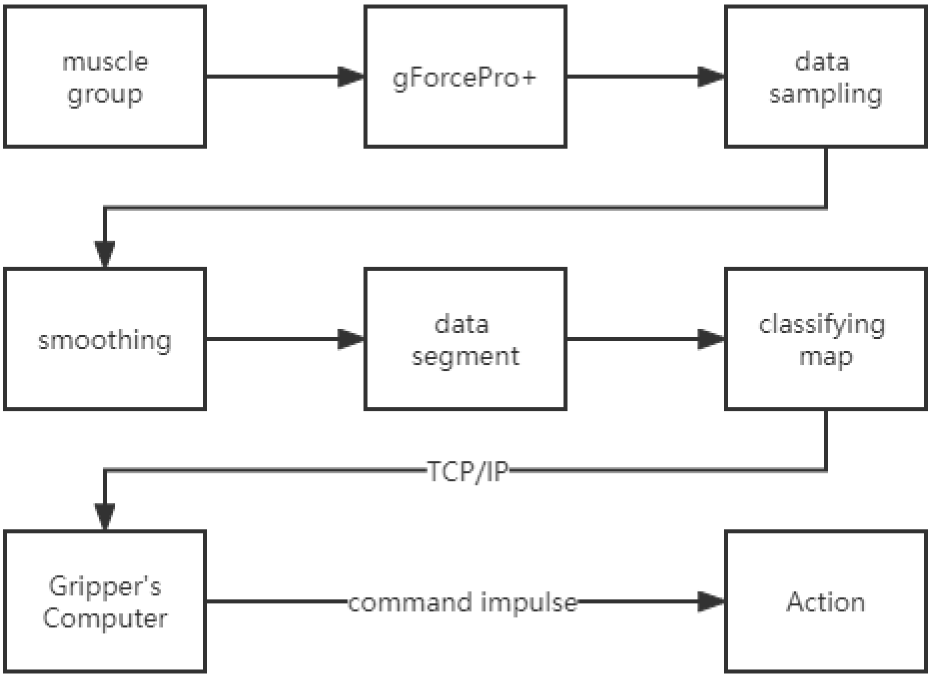

Figure 3: Flow chart of control system

Tables should be properly numbered, centered and should always have a caption positioned above it. Captions with one line should be centered and if it has more than one line should be set to justified. The font size to use is 9-point. Italic font style should be used. Spacing before and after should be 6 points, respectively.

2.4. Data acquisition

2.4.1. Surface EMG signal spectrum

When using surface electrodes, the energy of EMG signals is mainly concentrated below 1000Hz. The Neuromuscular Research Center of Boston University found that the EMG spectrum obtained by the bipolar model is between 20-500Hz, and most of the spectrum is concentrated between 50-150Hz.

2.4.2. Noise during data acquisition

Table 1: Interference source frequency and influence

Main source	**Major** frequency	**effect**
A/D converter, electrode and other hardware settings	0-30HZ	zero drift
Adjacent muscle movement during movement	0-15HZ	Lower frequency noise
EKG artifact	0-35Hz	The main noise
AC frequency	50Hz	The main noise

In the process of signal acquisition, the overlapping and mixing phenomenon between adjacent channels of gForcePro+armband and the interference between upper arm muscles have an unavoidable impact on sEMG, resulting in large interference of surface EMG signals acquired and poor signal quality,

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thus the signal characteristics cannot be clearly characterized. The main frequency spectrum of EMG is mainly concentrated between 50-150 Hz [5-6], but according to the regulations of the People's Republic of China on household voltage, if the signal is mixed with 50 Hz frequency spectrum, it is easy to generate power frequency interference, and the size of the power frequency interference signal is several times of the size of the normal sEMG signal. The following figure shows the main interference sources and frequency bands during the collection of sEMG signals. This is shown in Table 1.

2.5. Data acquisition and processing

2.5.1. SEMG data acquisition

In the process of data acquisition, first of all, we need to wear the gForcePro+ armband on the arm, and ensure that the relative position of the bracelet and muscle block will not change during the data acquisition process. The fixed sampling frequency of the gForcePro+ armband is 650Hz. During the acquisition process, we choose to collect the EMG signals of eight channels.

2.5.2. SEMG data preprocessing

In the method of processing data noise, the second order Butterworth filter is commonly used to filter data noise. In order to improve the accuracy of transient EMG pattern classification, Englehart K [10] et al. proposed a time-frequency representation set. The results show that the feature set based on short-time Fourier transform, wavelet transform and wavelet packet transform can provide an effective representation for classification under the condition of accepting proper form of dimension reduction. In this paper, we need to identify fewer categories of sEMG signals, and the armband itself has a corresponding time-frequency method to extract feature classification. Therefore, we also use the traditional second-order Butterworth filter to process.

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2.5.3. Power frequency interference processing

In the process of data acquisition, gForcePro+ needs to be connected to the municipal power grid, andthe standard voltage of China's municipal power grid is 220v 50Hz, which is generally difficult to eliminate [2], and filters the myoelectric signal at 50Hz by implementing a notch.Table *1: This caption has one line so it is centered.*

2.5.4. Band pass filtering processing

sEMG is a stable microelectric signal, its main frequency is concentrated in 20-150Hz, gForcePro+ armband in the process of data acquisition can process part of the data by itself, but the actual effect is limited, the filter can minimize the original interference signal, in order to get a higher quality signal This paper will use because the Butterworth filter has a good frequency response curve in the passband, so it is suitable for band-pass filters. In this project, a second-order Butterworth bandpass filter with a bandwidth set to 20-150Hz is used. [7] The amplitude squared function of the analog low-pass Butterworth filter system function is used to realize the filtering processing, and the function formula is shown in the figure below

$$|H(\omega)|^2 = \frac{1}{1+\left(\frac{\omega}{\omega_c}\right)^{2\pi}} + \frac{1}{1+\varepsilon^2\left(\frac{\omega}{\omega_P}\right)^{2\pi}}$$

n = filter order; ω_c cutoff frequency = frequency when the amplitude drops to -3 dB; ω_P =

The numeric value of the edge of the pass band.

The waveform before and after the sEMG filtering obtained from the eight channel acquisition based on gForcePro+armband is shown in the figure 4.

ISSN 2616-5775 Vol. 5, Issue 14: 126-132, DOI: 10.25236/AJCIS.2022.051418

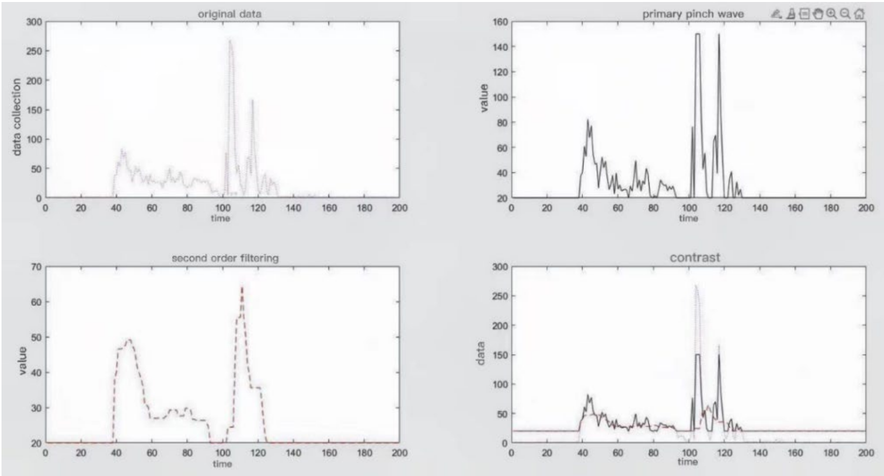

Figure 4: Waveform diagram before and after sEMG filtering

2.5.5. Fixed threshold algorithm

The microprocessor analyzes and judges the collected EMG signals, and outputs corresponding signals according to the results, so as to control the gripper to execute corresponding actions. The judgment of gripper action requires a standard signal, that is, the threshold value of electromyography. This threshold value is selected according to experience. In order to distinguish the single degree of freedom relaxation and tightening, the fixed threshold algorithm is used in this topic. The formula is shown in the following figure.

$$x_j = \frac{1}{n}\sum_{i=1}^{n} x\,(nj + \vec{i})$$

2.5.6. Perform environment configuration

The signals collected by sEMG in this topic are sent to the upper computer based on Windows system through Bluetooth connection for data processing_ Windows improves the operating environment under Windows, sends the processed data to Ros in real time using TCP protocol, and realizes the real-time control of gripper.

The control object of the sEMG in this paper is the gripper. Although the gripper does not require high real-time processing capability, the gripper can be configured on the mechanical arm with corresponding interface when it is actually put into production and manufacturing. In the actual production process, the robot arm needs to configure a real-time kernel to meet the real-time requirements. Therefore, this paper uses Robotiq 2f-85 Gripper gripper to run in the real-time kernel environment.

2.6. Comprehensive test

2.6.1 Upper computer debugging

The upper computer installs the real-time kernel Full Preemptible Kernel (Real Time) and the required drivers such as the USB FTDI Single Drive driver of the gripper in the Ubuntu 16.04LTS operating system, [9] verifies the integrity of the environment, installs relevant patches, and finally compiles. During the compilation process, USB devices are not recognized and the network is not connected, which is mainly due to the compatibility problems of products from different manufacturers, The Github open source files that the underlying files depend on may have DNS pollution. During the experiment, the dynamic adjustment of the CPU's energy-saving mode will also lead to the decline of the operating accuracy, so the energy-saving mode of the computer CPU needs to be turned off during the experiment. The signals collected in the actual transmission process need to be transmitted to the gripper in real time, so there is a high demand for bandwidth. The success rate can be controlled above 99% by using the industrial gigabit switch.

2.6.2 Communication

The official source code of the EMG armband is mainly written for the Windows operating system. The channel selection and signal processing of the EMG armband are also written under Windows. The processed EMG signal needs to be sent to the Ros frame of the upper computer of the gripper, and Ros releases the topic to realize the control of the gripper by the EMG signal. Before signal acquisition, it is necessary to ensure that the EMG armband is correctly worn, that is, it is close to the skin, and the position of the armband worn on the arm does not change during the collection process.

In order to complete the real-time control in this paper, it is necessary to transmit the collected sEMG signals in real time, use the LAN to transmit, query the IP addresses of two upper computers, and use Roserial_ Windows establishes TCP-IP communication. Put roserial_ The files generated by Windows are added to the EMG armband project package. Start a server on the side of the ROS master to establish a connection_ Windows can communicate with ROS master. The wearer determines whether the communication is successful by exerting force and relaxing and observing the data changes received in Ros.

2.6.3 Experimental steps

In the process of comprehensive debugging, this paper fixed the relative position of the clamping claw and the object to be clamped. During the experiment, the tester wore the armband tightly to avoid other signal interference caused by the displacement of the EMG armband during the test. Initialize the engineering file of the EMG armband code. After confirming the position of the target and the gripper, replace gesture recognition with the strength of the tester's arm by the threshold segmentation method. [8] The tester's arm continues to exert force, making the gripper continue to tighten, relax the arm, and slowly release the gripper, indicating that the test is successful.

3. Conclusion

In the experiment, the initial effect is not ideal. First of all, the deformation of the gripper on the target under several different grasping forces was tested with the empty mineral water bottle as the target. The experimental results show that even under the conditions of 1N and 80N, which are 80 times different from each other, there is no obvious difference in the degree of bottle deformation to the naked eye. Therefore, the variable is changed from grasping force to position information, and the subscribed topic is transmitted to the fingertip movement position, so that the travel between the grippers of the mechanical arm can be adjusted in real time according to the EMG signal. Since the collection frequency of the EMG bracelet is 650Hz, it is necessary to integrate the average value of the collected data and then fix the threshold value for discrimination. The grasping speed and reaction force of the manipulator after the integration mean value of 6 different number data sets were tested. It is finally found that when the data set is 20, the time delay is not great and the data is not easy to block. The gripper can make a better real-time response according to the EMG signal. When the muscle is forced, the gripper contracts and clamps the object; When the muscle is relaxed, the gripper gradient opens to release the object.

Acknowledgements

University of Electronic Science and Technology of China.

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