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DELIVERING QUALITY SCIENCE TO THE WORLD

Design of sEMG Acquisition System Based on LabVIEW

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Abstract: Surface electromyography (sEMG) is an electrical signal produced by muscle movement. Although it is weak, it has strong regularity and is an important research content in modern rehabilitation medicine and human-computer interaction. A wireless sEMG acquisition system based on LabVIEW is designed, which consists of signal acquisition, transmission and sEMG data analysis platform designed by LabVIEW. The patch electrode, differential processing circuit and digital filtering algorithm are used to effectively reduce noise interference. LabVIEW upper computer can intuitively display the collected sEMG data in the form of waveforms. In the data analysis part, the data analysis algorithm of MATLAB is embedded in the LabVIEW interface by using the method of mixed programming of LabVIEW and MATLAB. Finally, weak sEMG data acquisition, data display and analysis can be achieved, the starting and ending time and intensity of each muscle contraction can be identified.
Keywords: sEMG; LabVIEW; Data analysis.

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1. INTRODUCTION

SEMG is the result of the action potential generated by multiple motor units of muscle on the skin surface. Surface EMG signal is weak to about 1 mV, and the useful signal frequency is between 20 and 500 Hz, so it is very difficult to detect. However, the amplitude of EMG signal is proportional to the strength of muscle contraction, and generally produces about 30-150 ms earlier than limb movement. sEMG has high research value in many fields. In medical field, sEMG can be used to make accurate judgments on patients'condition or to make rehabilitation medical plans; in sports science, it can be used to evaluate athletes' physical condition or muscle exertion mode; in artificial intelligence field, it can be used to achieve better human-computer interaction[1].

At present, the detection of EMG signal is still in its infancy, but through consulting the relevant literature and information, it is found that more and more people are studying how to accurately detect the EMG signal and how to effectively analyze the algorithm and extract the features of the detected EMG signal, whether at home or abroad. It is believed that with the continuous development of science and technology, there will be higher technological breakthroughs and wider application areas in the direction of surface EMG signal detection.

2. SEMG ACQUISITION SYSTEM

The hardware structure of the sEMG acquisition system is shown in Figure 1. It consists of four parts: electromyographic electrode, differential signal amplification circuit, Arduino development board and Bluetooth module. With this acquisition system, the weak 1 mV surface EMG signal can be amplified to 0-3.3V for easy detection, the useless spectrum components beyond 50Hz and 20-500Hz can be filtered out, the analog signal can be converted into digital signal, and then the data can be transmitted to the upper computer for processing and analysis[2].

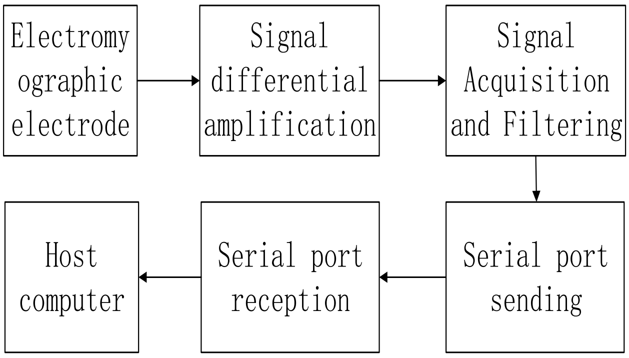

Figure 1 Hardware design of sEMG acquisition system

2.1 Electrode and Signal Differential Amplifier

Electrodes are the first and most important part of EMG signal detection. The performance of electrodes will directly affect the acquisition accuracy of the whole acquisition system. Different from traditional needle electrodes, patch electrodes are used on the surface of skin, which has the characteristics of less damage to skin and convenient wearing. Experiments show that stable EMG signals can be obtained by using Ag/AgCl as surface electrodes, and the electrodes made of this material are also used in medical instruments for measuring EEG and ECG. Therefore, Ag/AgCl is used as surface electrodes.

Generally, the electrodes of EMG signal are composed of three pieces. In order to minimize the interference of skin surface noise signal, the differential amplification circuit shown in Figure 2 is adopted. The difference between electrode 1 and electrode 2 is processed, and electrode 3 is used as reference electrode. Thus, a relatively pure sEMG signal can be obtained. After testing, the values of resistor R1 and capacitor C1 are set to 100_and 100 UF respectively. AD8220 can amplify EMG signal about 1000 times, just within the reasonable range of AD acquisition.

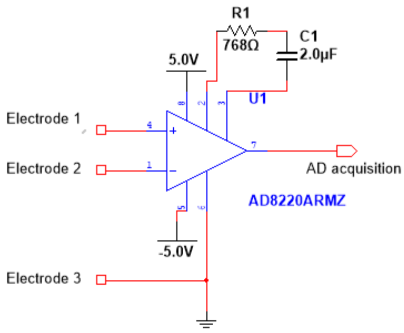

Figure 2 Differential Amplifier Circuit

2.2 Signal Acquisition and Filtering

Converting analog signal to digital signal is a necessary part of each acquisition system. Arduino development board is used as the signal acquisition card. Arduino is a convenient and fast open source electronic platform, using Arduino IDE software as the development platform. Compared with the traditional STM32 series MCU, Arduino is cheap, easy to program and easy to use. The number of interfaces of Arduino and the 10-bit precision A/D converter provided by Arduino fully meet the needs of the system[3].

The surface EMG signal obtained by differential amplification at the front end is not directly available. It also needs to be filtered to remove 50 Hz power frequency interference and 20-500 Hz useless signal. It is filtered by analog circuit, but the effect is not particularly ideal, especially 50 Hz power frequency interference. It is difficult to achieve fundamental filtering. Combining with digital filtering, it is found that the amplitude change of EMG signal is in good agreement with the law of muscle movement, and the useless spectrum components are successfully filtered out.

3. LABVIEW HOST COMPUTER DESIGN

LabVIEW is a program development platform developed by National Instruments Corporation of the United States. Unlike other software development platforms, LabVIEW is mainly composed of the front panel display interface and the back panel program block diagram[4]. The back panel uses graphical programming method. The front panel is mainly used for data input and display. The function block diagram of the host computer of this system is shown in Figure 3.

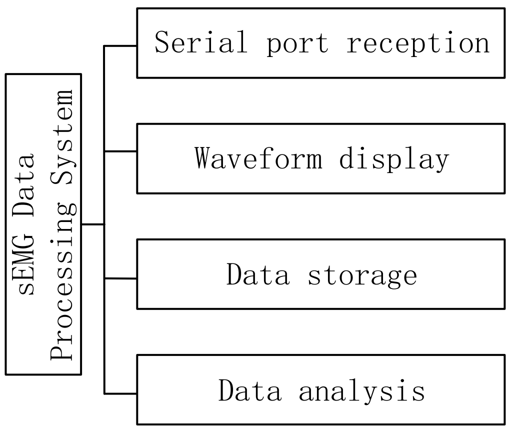

Figure 3 Functional block diagram of upper computer

3.1 Receiving, displaying and storing data

The serial port receiving part is mainly written by calling the VISA function of LabVIEW. The VISA function can parse the communication data of RS232 serial port protocol and convert it into the corresponding string. Configuring the parameters of serial port, baud rate, parity bit and stop bit required by the serial port protocol in VISA function, the serial port communication can be realized with the lower computer, as shown in Figure 4.

After converting the ASCII code received by serial port into decimal digits, the data can be displayed in the form of waveform by waveform display control. As shown in Figure 5, the motion state of muscle can be visualized by waveform chart. The upper left corner of Figure 5 is the serial port parameter configuration section, and the lower left corner is the four function keys. After the lower computer and serial port are configured, click the first button to "start acquisition", the system begins to collect sEMG signals and display them in real time through waveforms. Clicking on the "save data" system will create an Excel file and save the collected data in the form of arrays to the Excel file. The third key is to analyze the data in Excel file, and the next key is to finish the program. Figure 6 is a program diagram of LabVIEW waveform and data preservation. The left-most side is a comparison function. When the number of bytes is greater than zero, the output of the function is 1, that is to say, the program in the condition block diagram begins to run. The string-to-numeric function in the graph can convert the string in the serial port into decimal numeric value, so that the real-time display of data waveform can be realized by connecting a waveform control later. Array insertion part is to insert each decimal value received into the array in the form of array elements, so that all data will form a large one-bit array, convenient for subsequent storage and processing. The right-most part of Figure 6 is the data preservation section, which is used to save data to spreadsheet functions. From the figure, you can see that the data is saved to a spreadsheet named sEMG on computer D disk[5].

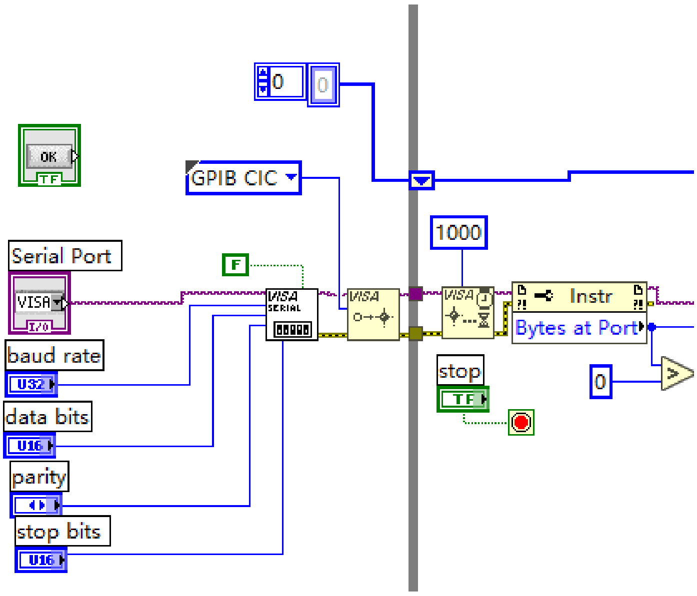

Figure 4 Serial Port Part Program Diagram

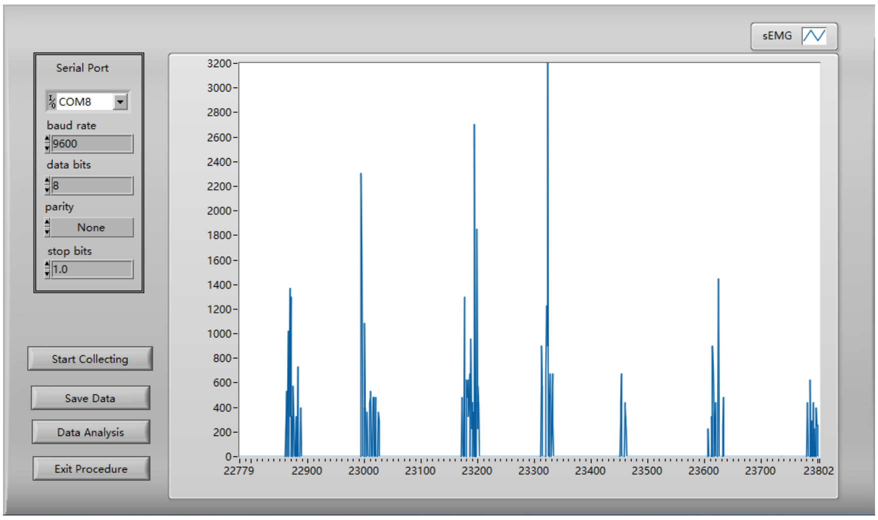

Figure 5 The upper computer interface

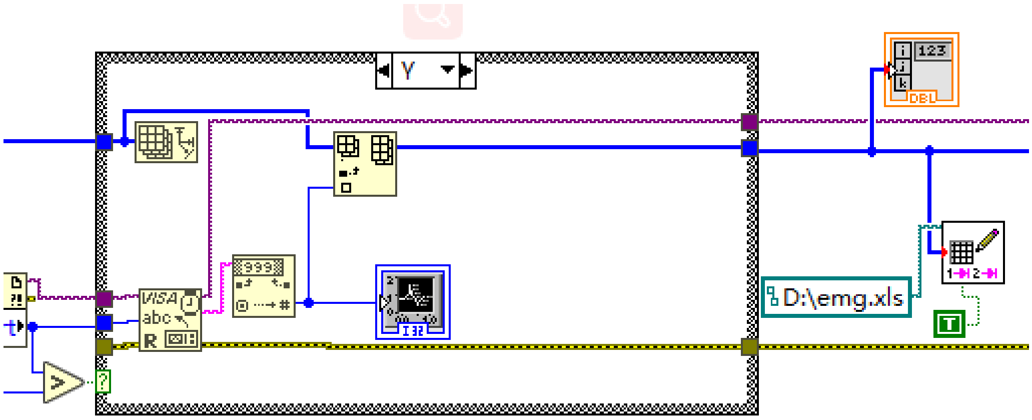

Figure 6 Waveform and Data Preservation Section

3.2 Data Analysis

Arduino's AD sampling frequency is 500 Hz, which means that the lower computer uploads 500 data in one second. Faced with thousands of data, it is difficult to use LabVIEW for effective data analysis. But LabVIEW has built-in MATLAB Script node. After the data analysis program written in MATLAB runs correctly, the program code is copied to the MATLAB Script node of LabVIEW. It can realize the mixed programming of LabVIEW and MATLAB, which is convenient and efficient. Figure 7 is the program diagram of the MATLAB Script node. When the mouse clicks the data analysis button of the front panel, the program in the MATLAB Script node will be executed.

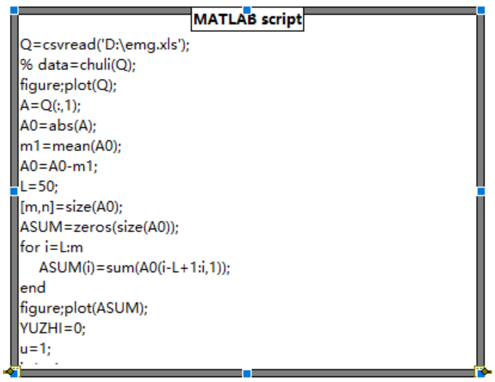

Figure 7 MATLAB Script Node Program Diagram

The collected sEMG always contains some noise components in the circuit. In order to accurately identify the starting and ending points of each action, the moving average method and the threshold method are combined to detect the starting and ending points of the action, so as to obtain the effective data segment of the action. Firstly, the sliding sum of the original sEMG signal is made, and the sliding length N = 50. The calculation formula is as follows:

$$\mathrm{sEMG}_S = \sum_n^{n+49} sEMG_n \tag{1}$$

$$\mathrm{sEMG}_{an} = \frac{sEMGs}{50} \tag{2}$$

Formula 1 sEMG_n is the original signal, sEMG_s is the sum of each original signal and 49 subsequent data. Formula 2, sEMG_an is the average value of 50 data, set 10 as the threshold. If sEMG_an is greater than 10, then the n+24 (taking the intermediate value) data is determined to be the data generated by muscle contraction. This method neglects the first 24 and the last 50 data, because the sampling frequency of the system is very high, the impact can be neglected.

Figure 8 is an image of the original data collected. Figure 9 is a data image drawn after the starting and ending points of each muscle movement are obtained through algorithm analysis, which is more intuitive and clear than the original data.

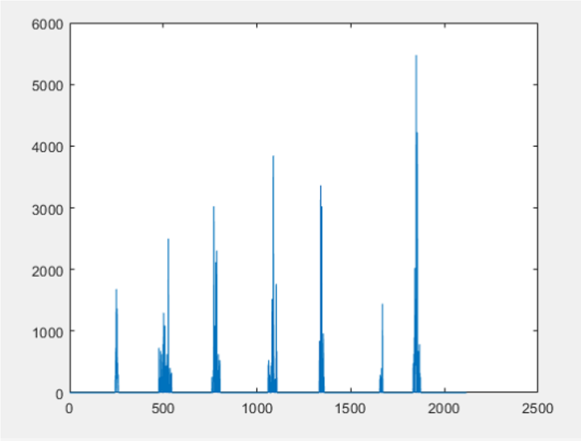

Figure 8 Original data image

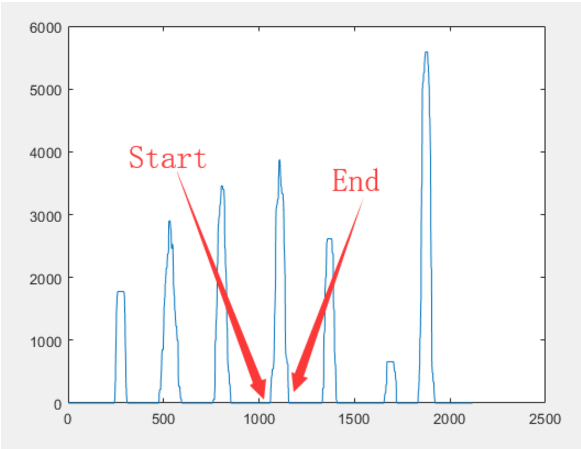

Figure 9 Data image processed

Table 1 lists the starting and ending points, total energy and average energy information of each muscle contraction exercise. The information of muscle strength, muscle health and fatigue can be analyzed. The calculation method is as follows:

$$sEMG_{sumi} = \sum_{si}^{ei} sEMG_n \quad i = 1,2, \dots 7 \tag{3}$$

$$\mathrm{sEMG}_{ai} = \frac{sEMG_{sumi}}{sEMG_{ei} - sEMG_{si}} \tag{4}$$

In formula 3, si and ei represent the starting and ending points of each muscle action, $sEMG_{sumi}$ represents the total energy of each action, and sEMG_{ai} in formula 4 represents the average energy information of each action.

In time domain analysis, the root mean square of sEMG can reflect a distribution of limb movement between muscles and the muscle strength of each muscle group during limb movement. The calculation formula is as follows:

$$sEMG_{RMS} = \sqrt{\frac{\sum_{n=1}^{N} sEMG_n{}^2}{N}} \tag{5}$$

Among them, N is the sampling point and $sEMG_n$ represents the information of the nth sampling point.

Table 1 Analysis of each action data

Number	Start	End	Sum	Average
1	244	309	8340	128.31
2	477	594	15860	135.56
3	760	852	16247	176.60
4	1060	1155	18197	191.55
5	1332	1047	12289	163.85
6	1655	1720	3095	47.62
7	1833	1921	26271	298.53

4. SYSTEM TESTING

The hardware design of the sEMG acquisition system and the programming process of the host computer software are mainly introduced in the above section. Some testing work has been done in this section. Firstly, data calibration is carried out, and the patch electrodes are placed on the muscle to relax the muscle. Then a group of EMG signal data with little change in amplitude can be detected. By modifying the internal program of Arduino development board, this group of data can be changed to zero, that is to say, the output data of muscle in relaxation state can be adjusted to zero, so the subsequent detected data is the electrical signal change of muscle during exercise.

The patch electrodes are placed on the side masseter muscle of the arm and face respectively. After a lot of tests, it is found that the EMG signal on the arm will have different amplitudes when different strength is used in clenching the fist. The occlusal force of the teeth is different, and different amplitudes will be collected, and both of them are proportional[6].

5. CONCLUSION

The acquisition system successfully detected the amplitude change of weak AC signals on the skin surface, and realized the modeling and analysis of muscle strength and signal intensity through LabVIEW host computer. But the application of EMG signal is not only that, because of the limited time and energy, only one sEMG data analysis is mentioned in this paper. A multi-channel sEMG acquisition system will be designed to be placed on the arm, and gesture recognition will be made according to the changes of the multi-channel sEMG of the arm. Placing multiple sensors in the muscle lesions of patients can accurately detect the muscle lesions of patients. These are important research contents in the future.

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