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Application of EMG fatigue detection algorithm in portable DSP system

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Abstract. Surface muscle fatigue detection is widely used in many fields, such as kinematics, rehabilitation medicine and muscle damage diagnosis. Muscle fatigue testing can provide reliable analysis data to determine the state of human muscle, so as to provide an effective analytical method for rehabilitation assessment, physical exercise and intelligent analysis. Surface electromyography has the advantage of being noninvasive, objective and convenient, so it has become a reliable tool for people to study surface electromyography. In the full understanding of the state of muscle fatigue, people can effectively avoid the damage caused by muscle fatigue. In this paper, the real time TMS320C6748 DSP was used instead of Matlab to collect and analyze the surface electromyography (SEMG), so as to realize the real-time detection of electromyogram (EMG) parameters. We use the frequency domain feature extraction method to analyze the muscle fatigue, and study the effectiveness of the EMG fatigue analysis. It is concluded that the TMS320C6748 floating point DSP can be used as a monitoring device, which can monitor the muscle fatigue status of the athletes and some patients who need to restore muscle strength.

Key words. Muscle fatigue testing, DSP, real-time detection.

1. Introduction

In recent years, with the deep research of electromyogram (EMG) acquisition and processing methods, the real-time requirement of EMG acquisition system is getting higher and higher. The real-time equipment can effectively capture the changes in EMG signals, so as to achieve real-time monitoring of the state of the human muscle, and to understand the state of their muscles. In the process of exercise, some muscle fatigue can be perceived from the body's own muscle discomfort, and some muscle fatigue cannot be perceived. In the absence of awareness, excessive exercise can lead to muscle strain or other body damage [1]. Therefore, it is necessary to monitor the EMG in real time. In addition, some of the hemiplegia patients such as stroke, they need to do the right body movement to promote muscle activity, and the normal movement of the upper limb for a person's rehabilitation is particularly important

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Therefore, the scientific development of rehabilitation programs and real-time monitoring of patients with muscle status can effectively promote its muscle recovery. And for some athletes, if they can plan a good training program, and real-time understanding of the state of their muscles, they can not only make each piece of muscle have been trained, but also can effectively avoid the excessive training caused by muscle strain and other conditions [3]. In this paper, we use the advantage of the floating point DSP processor TMS320C6748 which can do high-precision floating-point operation, and design the algorithm on DSP to process the data collected by EMG and compare with the MPF value obtained by Matlab. Take the place of Matlab to do algorithm processing in a certain range, and analyze the fatigue state of the electromyogram, which can make people understand their own muscle state, so as to make a scientific exercise program according to their own characteristics.

2. Acquisition and algorithm design of face trial EMUs

2.1. Surface EMG signal acquisition

Surface electromyrography (SEMG) signal is a kind of weak and non-stationary bioelectrical signal, and its effective range is concentrated at 20 Hz∼500 Hz [4], and it is collected by Ag-AgCl electrode. Before the experiment, use alcohol to clean the collection site, remove the surface dead skin and oil, and apply the conductive paste evenly to cover the contact surface.

The placement of the electromyor electrode is divided into two kinds of reference electrode placement and test electrode placement. The placement of the reference electrode is mainly to exclude the non-human self-generated voltage, and it can be placed in the body surface of the bony mark or placed in the test muscle that does not participate in muscle tendon. In the test, the reference electrode cannot collect the electric signal of autonomous motion. In this experiment, we use the wrist as the reference electrode. The test electrodes are placed parallel to the direction of the muscle fibers. In this experiment, we have to collect extensor communis digitorum, musculus biceps brachii and musculi extensor carpi radialis longus.

2.2. Feature extraction of surface electromyography

The method of surface electromyography is divided into time domain method, frequency domain method and time domain combined method [5]. The commonly used time domain analysis method includes measuring integral myoelectric value (iEMG), zero crossing point (zc), variance (VAR), etc. [6].

Time domain method is very simple to extract features of SEMG, but with the change of muscle contraction force, a lot of time domain parameters change greatly. However, after the Fourier transform in frequency domain, the change of the waveform is very small, so it has good stability in frequency domain. The commonly used frequency domain analysis method includes the mean power frequency (MPF) and

the median frequency (MF) of the SEMG power spectrum, which are defined as

$$\mathrm{MPF} = \frac{\int_0^{+\infty} f \cdot P(f)\,\mathrm{d}f}{\int_0^{+\infty} P(f)\,\mathrm{d}f}\,. \tag{1}$$

In this equation, $P(f)$ is the power spectral density function of the signal.
The median frequency can be solved by equation

$$\int_0^{\mathrm{MF}} P(f)\,\mathrm{d}f = \int_{\mathrm{MF}}^{+\infty} P(f)\,\mathrm{d}f = \frac{1}{2}\int_0^{+\infty} P(f)\,\mathrm{d}f\,. \tag{2}$$

The time frequency domain analysis method can combine the time domain and frequency domain analysis methods, and the time-frequency domain analysis method applied to SEMG mainly includes short-time Fourier transform, Wigner-Ville distribution, Choi-Williams distribution, wavelet transform and so on [7].

Compare the three kinds of analysis methods, the time-frequency joint analysis method has the unique advantages in the SEMG analysis, which can reflect the information of the time domain and the frequency domain [2]. However, for surface EMG analysis, MPF and MF in the frequency domain have been able to well reflect the difference between normal and fatigue in the muscle, and many studies have shown that the average power frequency is more sensitive in reflecting muscle activity and functional status. Therefore, this paper uses frequency domain analysis method to obtain MPF values and perform algorithm implementation.

3. Algorithm implementation

3.1. Algorithm implementation method

Algorithmic implementation usually has two methods: direct implementation and indirect implementation. The direct implementation methods usually need to consider the following questions:

1. DSP system processing capacity.
2. The support of the storage space and the corresponding library
3. Keyword matching and other issues.

And then through the DSP to program the algorithm needs to implement, so that it is consistent with the results before and after implementing the error within the allowable range. The specific steps of direct implementation are:

1. We have a more comprehensive understanding of the implemented algorithm, so as to ensure that its Matlab, VC platform or other platforms have been able to operate, and the results are accurate.

2. We have a comprehensive assessment of the degree of difficulty of the implemented algorithm and estimate the possible problems.

3. Compare the results of the program before and after implementation, so as to ensure that the results of the program before and after implementation error within the allowable range, and carry out program optimization for the parts that do not

meet the requirements.

4. In the premise of not affecting the accuracy of the program, we strive that it works in real time and is efficient.

The indirect implementation is a method that can be simplified by Matlab to simplify the programmer's algorithm,and it requires users to install the full version of Matlab or install components in the installation of Matlab Coder components. The specific steps are as follows: First, the algorithm needs to be implemented into function. Second, call it in the command window. After the test is successful, use the Matlab Coder component to write the M file into a C language source file that can be called by the DSP. Finally, open CCS, copy the Matlab build file to the CCS project directory, add the reference path to the header file, and write the calling program. This method can reduce the difficulty of programming, but not all of the function can be converted into the target source file through this method, because some functions do not correspond to the C language library, so it needs to be further improved.

Based on the two methods of implementation, the second method is simple, but there is no C language function library corresponding to this article. In this paper, the algorithm is implemented to Matlab to DSP hardware platform, and the purpose of this paper is to get rid of the upper computer and improve the real-time requirement of signal processing. The TMS320C6748 floating point DSP has the advantages of high processing accuracy and good real-time performance, and it has little effect on the results of the collected surface EMG signal processing, so it is more practical to choose direct implementation.

3.2. DSP algorithm implementation

For the surface of the EMG signal fatigue analysis, we need to carry on the frequency domain FFT processing to the EMG signal in DSP, and then calculate the MPF value after each experiment. It should be noted that, in Matlab, in order to meet the FFT transformation requirements, the system will not meet the 2 N-side data to take the automatic zero processing, making it meet the computing requirements, and the DSP also has this function. However, it requires the user to define a buffer area that is large enough to accommodate the collected data. The system will automatically zero the memory bits that are not defined by the user. The error in the processing result is relatively small, and it can ensure the integrity of data collection.As the collected EMG signal data is generally relatively large, so this article through the following methods to store the data in the definition of the data cache, and then processed by FFT.

3.3. Matlab to DSP algorithm implementation

From Matlab to DSP algorithm migration, there are usually two ways. One is the indirect generation of executable code through Matlab software for DSP reference, and the other is directly through the C language to program the function in the DSP. For the first method, we first program the algorithm that needs to implement

into a function, and through the Matlab command window call to verify whether the algorithm is executable. Then, through the Matlab Coder component, convert the M file into a c language source file that can be called by the DSP. At last, open the CCSV5.5, copy the Matlab generated file to the CCS project directory, and write the call code.This method can save programming time, but not all functions can be written as source files for CCS use. Because some functions do not have a corresponding C language library, so its use is limited obviously. The second method is to write the program directly in the DSP. It should be noted that in Matlab, some functions need to be replaced by the corresponding c language function, in order to achieve the same effect. Although this method looks more complex than the first method, for this experiment, the second method is more applicable.

4. Results and discussion

First, the MPF value of the EMG signal is calculated by Matlab, and then calculated by DSP. The calculation results are shown in Table 1 and Table 2, and they are expressed as double real numbers. (where M represents the MPF value obtained by Matlab processing, D represents the MPF value after DSP processing, QXL, LL is female, GJ, YY is male, the following table is not indicated and the units are Hz).

Table 1. QXL experimental data Matlab processing results

Collection site	M first time	M second time	M third time	M fourth time	M fifth time	M sixth time
extensor communis digitorum	0.220374	0.229343	0.219162	0.211829	0.208613	0.198264
musculus biceps brachii	0.243682	0.244132	0.241766	0.240734	0.220412	0.202575
musculi extensor carpi radialis longus	0.243537	0.243614	0.242489	0.240247	0.228134	0.207103

It has been proved through the analysis of experimental data that the error of Matlab processing result and DSP processing result is 0 0.000002 Hz, and the error is within the allowable range. Therefore, the use of frequency domain calculation MPF value is suitable for implement to the DSP. After finishing the four subjects' EMG signal MPF values, their line charts are shown in Figs. 1–4.

As shown in Figs. 1–4, the MPF values of the four subjects show a significant downward trend after treatment. The spectral values are shift to the low frequency region, and the slope MPF is negative, which is consistent with the results of other researchers. And the absolute value of the slope increases, especially after the fourth and fifth times, the absolute value of the slope value is significantly increased. For different individuals, the beginning of the MPF value corresponding to the slope is

relatively flat.

Table 2. QXL experimental data DSP processing results

Collection site	M first time	M second time	M third time	M fourth time	M fifth time	M sixth time
extensor communis digitorum	0.220178	0.219383	0.219183	0.211579	0.208815	0.198604
musculus biceps brachii	0.244559	0.244146	0.241462	0.242354	0.222615	0.200739
musculi extensor carpi radialis longus	0.243443	0.253466	0.242269	0.240244	0.228333	0.205131

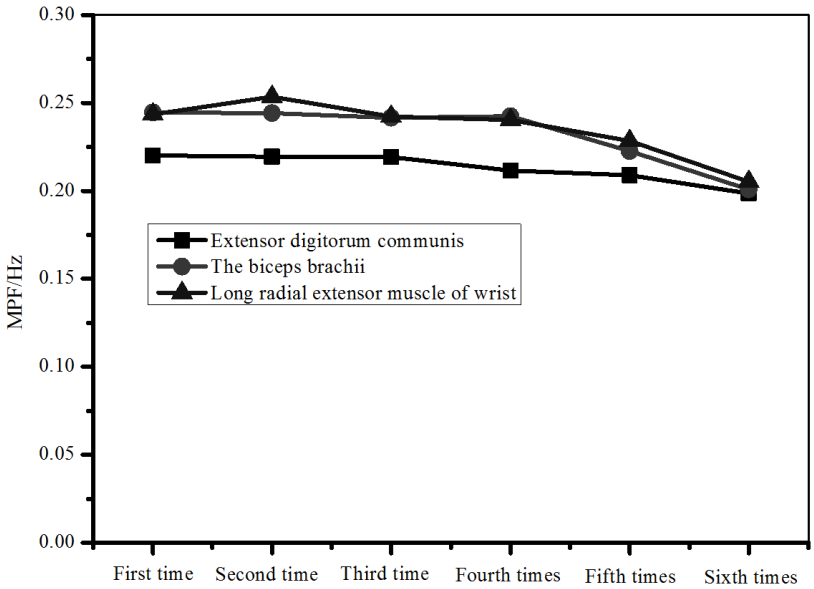

Fig. 1. Subjects QXL surface EMG signal processing MPF value line chart

After a period of exercise, subjects YY, LL after the third experiment, they have appeared the situation of the slope increased,and the other two subjects have also appeared this situation after the fourth time, which indicates that the four subjects have shown a muscle fatigue state at this time. The time of occurrence is different due to individual differences in muscle fatigue, and it is related to the fat content of each individual, people who exercise regularly have relatively low levels of fat, so the EMG signal conduction velocity is significantly faster than that of the subjects with relatively little exercise. And for the placement of the electrode, we

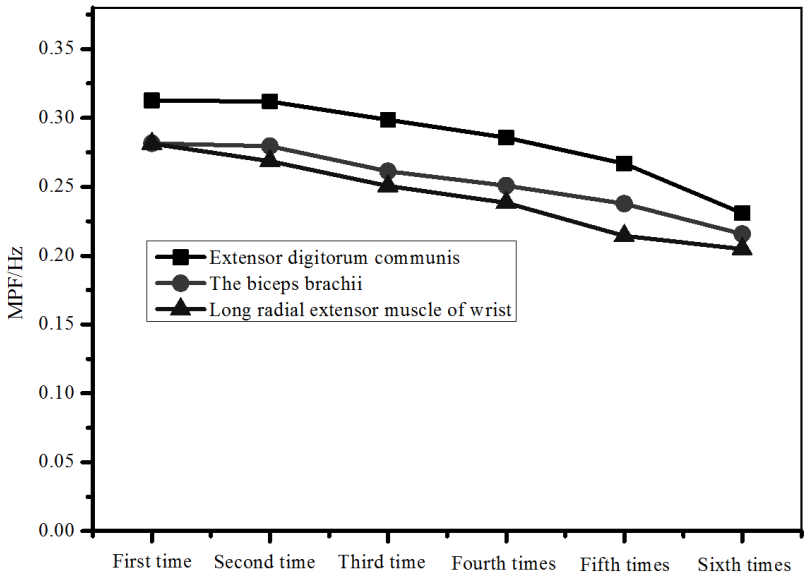

Fig. 2. Subjects LL surface EMG signal processing MPF value line chart

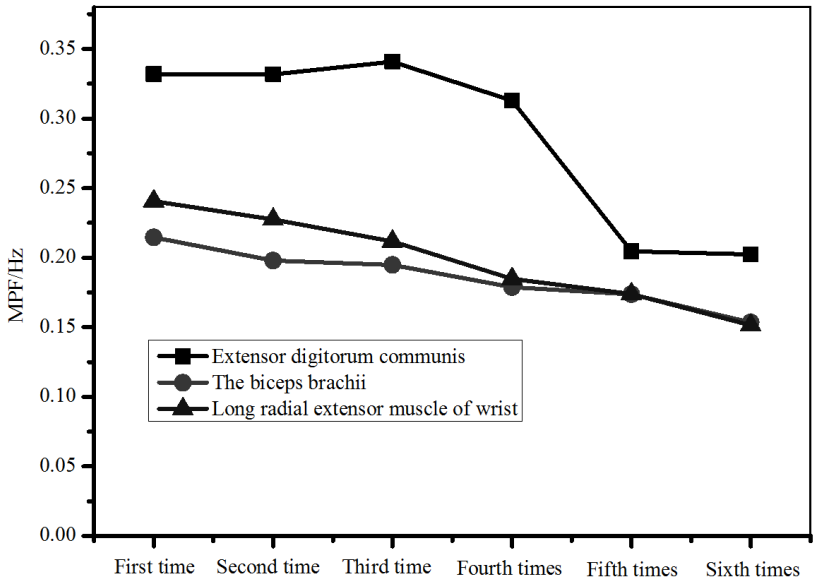

Fig. 3. Subjects GJ surface EMG signal processing MPF value line chart

cannot guarantee absolute accuracy, and only to determine the approximate location of the region where the muscles are, so it will also have a certain impact on the experiment. The size of the specific MPF value is caused by individual movement

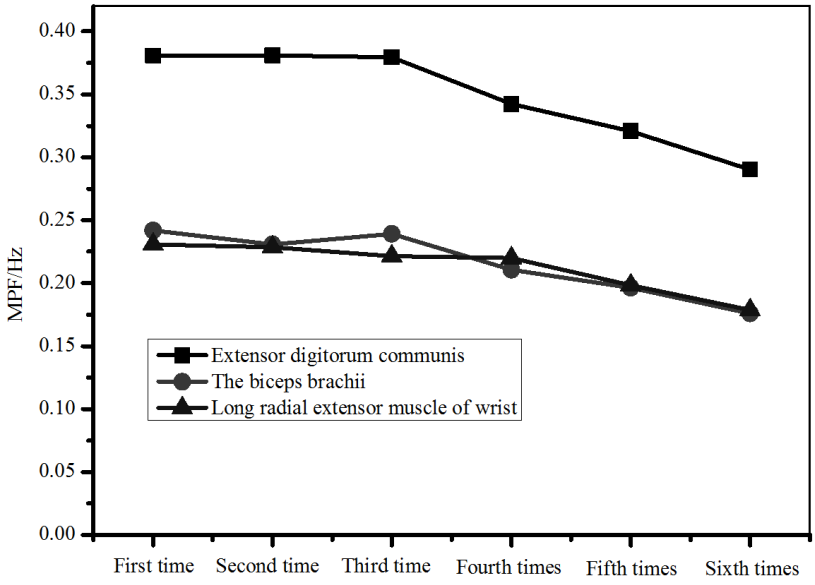

Fig. 4. Subjects YY surface EMG signal processing MPF value line chart

force. For different subjects, some people exercise force frequency is faster, so the experimental collection is relatively fast, which will have a certain impact on the experiment.

5. Conclusion

In this paper, through comparing the line charts and MPF values which are obtained by TMS320C6748 and Matlab processing EMG data, we can see that the use of TMS320C6748 can effectively deal with EMG signals. Through the analysis of the surface EMG data, it can be seen that the slope of the electromyogram MPF increased significantly after a certain period of motion, which indicates that the fatigue state of the muscle is further deepened. In the future, we can use DSP visualization to further analyze the EMG fatigue, and supplement and improve the research.

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