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Envelope Filtering Method for the SEMG Continuous Action

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In allusion to the defects of surface electromyography signals (SEMG) extraction currently caused by serious (electromyography signals) EMG distortion when we put the severe force to the SEMG extraction, this paper presents a envelope filtering method based on the shape of the SEMG contour curve and processes a frequency analysis to it. This method can not be influenced by the muscle contraction force and can restrain the distraction of power frequency electric and its overtone, then extracts the EMG effectively as well as decides the status of contraction and relaxation force of the corresponding muscles and the contraction force of the muscles by the variation trend of the EMG envelope curve, this method lay the root for the real-time processing of the follow-up EMG and the control of the artificial hand because of its simple algorithm and fast operation.

Key words: Surface electromyography signals (SEMG), Envelop filter, Spectrum analysis, Power frequency interference.

SEMG is a kind of biological electrical signals which are extracted by the surface electrode from the surface of human skeletal muscle concerned with muscle activities and action posture (Cram, 2003; Deluca,1979; Lorrain *et al*., 2011), it is made up of groups of MUAPT and it can response the fatigue degree, damage status and the contraction degree of the muscle. It has been used for diagnosis and research of the neuromuscular disease in the field of clinical muscle physiological, muscle metabolism, muscular fatigue, rehabilitation medicine, physical training and so on because of its simple operation, safety and non-invasively (Zhao, *et al*. 2011).

SEMG is a nonlinear, nonstationary and continuous signal that has a amplitude range from 500 μV to 5 mV and a frequency range from 5 to 500Hz. During the acquisition process, the signal will be very weak because of the serious distraction of all kinds of noises, such[1] as the noise of sensor itself and measuring system, power frequency electric distraction and so on, because the order of magnitude of the noise signal has a 1~2 greater than that of the SEMG, the detection of the SEMG should belong to the blind weak signal detection, and the key of gesture recognition based on the SEMG is how to extract the signal effectively. At present, the common methods for SEMG de-noising and extraction are hardware method and software method respectively. The hardware method can filter the signal mainly by setting the cut-off frequency of the filter through the analog filter, this method will remove a part of EMG in the basis of the removal of the noise, so it can not effectively remove the interference signal in essence (Geethanjali, *et al*.2011; Englehart *et al*., 2001). The software method is made up of digital filter trap method (Naoyuki, *et al*.,2009; Zhao *et al*., 2011; Jeffery, 2003), averaging method, wavelet threshold de-noising, independent component

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(Stulen, *et al.*, 1981; Nguang *et al.*, 2003), spectrum interpolation method, adaptive filtering(Zhang, *et al.*, 2010; Mewett *et al.*, 2004) and so on. Trap method can restrain power frequency electric interference effectively, but at one time it will remove the useful signal around 50Hz, so its application will be more or less limited. The other methods will obtain a bad filtering result because of the threshold that has to be set by human and complex algorithm, especially the increase of signal distortion degree during the severe force.

This paper proposes a method to extract the contour curve based on the envelope method by using the feature of the contour curve during its movement, at one time processes a frequency analysis to the effect of the envelope filtering method, this method can not be restrained by the force, it can remove the interference of power frequency electric and its overtone effectively during the acquisition process of EMG and it can extract the EMG effectively and in time, so it will lay the root for the real-time control online of the I-LIMB based on EMG.

System composition

We should do some processing to the hardware part because of the serious interference of the noises during SEMG collection processes, its system composition can be seen from the figure1. Because its amplitude of signal ranges from 500μV to 5 mV, we need magnify it. In this paper, we use a method of magnifying its two-stage and put a bridging circuit in the middle. The gain of prime amplifier should not be too high for fear that the direct-current composition mixes among the EMG would be amplified. Because of the frequency of SEMG ranges from 5 to 500Hz, we use a band-pass filter which has a low cutoff frequency of 5 Hz and a high cutoff frequency of 500Hz to remove the interference of low-frequency and high-frequency signals. This part is the former stage processing circuit of the signal. The rest part are the acquisition and processing of the signal, we use a DAQ card called PCI8622 and have a sampling frequency range from 1Hz to 250kHz. The number of analog channel is a single channel of 32 or a double channel of 16, the switching time is less than 10 us and it fits the requirements of EMG collection. In this paper, we use form of differential input to restrain the common-mode interference of the signal, namely dual input.

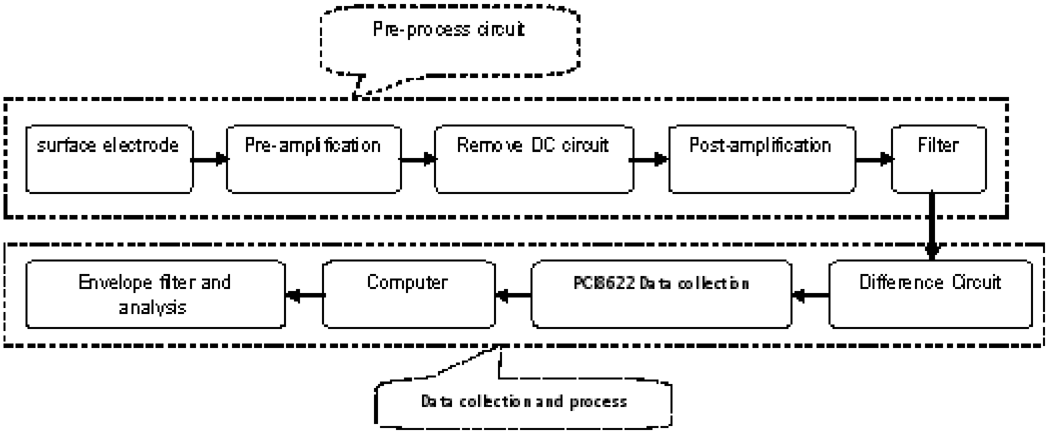


Fig. 1. Processing system of acquisition and analysis

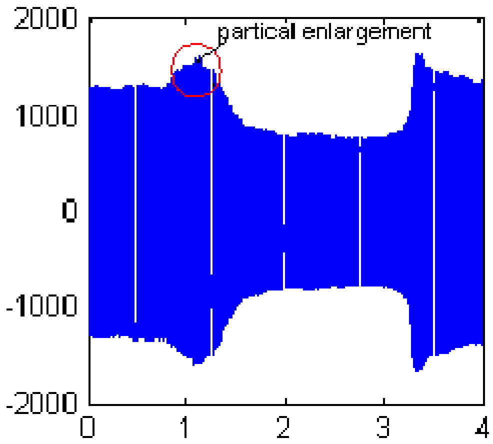
Principle and analysis of the envelop filter

The orignial data and analysis

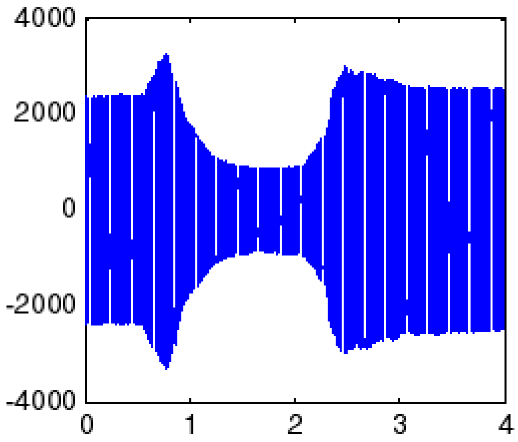
In this paper we will illustrate the principle of the envelope filter by the example of the hand action. The SEMG of the corresponding muscles of the forearm and its electromyography will change when kinds of hand actions are being done. We can find the electromyography of the continuous relax — fisting - relax actions from figure 2, the muscles of the sensor electrode detection of the SEMG is the radio carpus, and we can see that the curve contour of electromyography will change with this action. Here we name the curve contour for enveloping curve of EMG. And we can see the generating process of the action from the shape of the curve contour that amplitude of EMG is higher when we relax(the muscles relax), the amplitude of EMG is lower when we make a fist(the muscles make a fist), and the amplitude will increase with the enhancing of the hand force. During the process, enveloping curve of EMG will appear a peak, so we can decide the process of the action by extracting the enveloping curve of signal and observing the changes of the curve, that is the curve reports the change feature of the signal.

Frequency ayalysis of the orignal data

We will process a frequency analysis for the original signal to study the influence of the noises during the collection processing. Collection



(a) Mild force



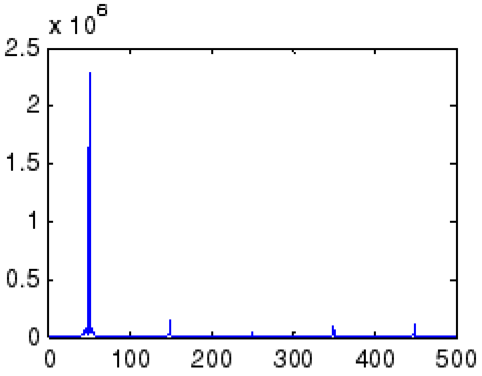
(b) Severe force

Fig. 2. Electromyography of the original data

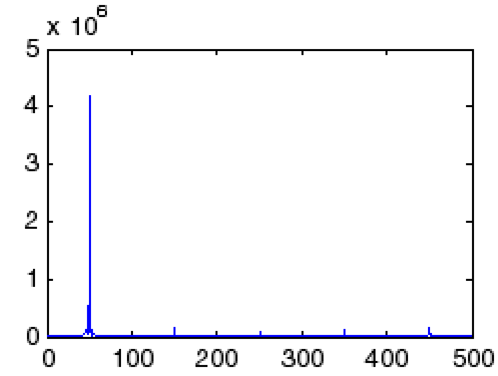
sequence is $x(n)$, the size is M, the DFT is

$$X(k) = DFT[x(n)]_N = \sum_{n=0}^{N-1} x(n) e^{-j\frac{2\pi}{N}kn}$$

$$k = 0,1,\cdots,N-1$$



(a) Mild force



(b) Severe force

Fig. 3. Frequency analysis of the original data electromyography

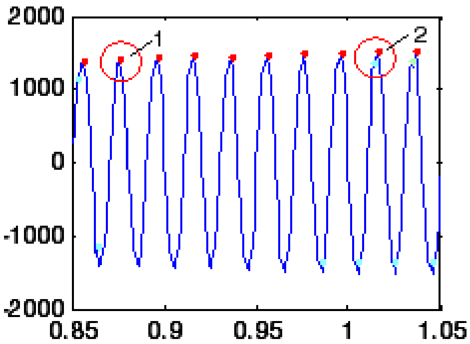


Fig. 4. Partial enlarged drawing

Where N is the burst length of the DFT, $N \geq M$.
Frequency spectrum is:

$$X(j\omega) = \sum_{n=0}^{N-1} x(n) e^{-j\frac{2\pi\omega}{N}n}$$

Amplitude Spectrum is:

$$|X(j\omega)| = \left| \sum_{n=0}^{N-1} x(n) e^{-j\frac{2\pi\omega}{N}n} \right|$$

We can see from the frequency spectrum in figure 3, most of the energy of original EMG concentrate around 50Hz,the rest focus on 150Hz, 250Hz, 350Hz, 450Hz. EMG is a non-periodic and constant signal, its frequency spectrum should be a continuous spectrum line, however the discrete spectrum lines in the figure under the frequency 150Hz, 250Hz, 350Hz, 450Hz illustrate that EMG contains a cycle composition and it has a frequency of 150Hz, 250Hz, 350Hz, 450Hz, it is seriously caused by interference of power frequency electric and its frequency overtone. We can find that distortion degree of the envelope carrier is different and the distortion degree when we relax or when we make a fist is also different as we have a partial enlarged amplification to its red circle part in figure 2, so the common de-noising methods are not very effective for the EMG. In this paper we extract the enveloping curve of EMG and decide the change of the action based on the shape of these curves.

Frequency analysis of the orignal data

We will process a frequency analysis for the original signal to study the influence of the noises during the collection processing. Collection sequence is x(n), the size is M, the DFT is

$$X(k) = DFT[x(n)]_N = \sum_{n=0}^{N-1} x(n) e^{-j\frac{2\pi}{N}kn}$$

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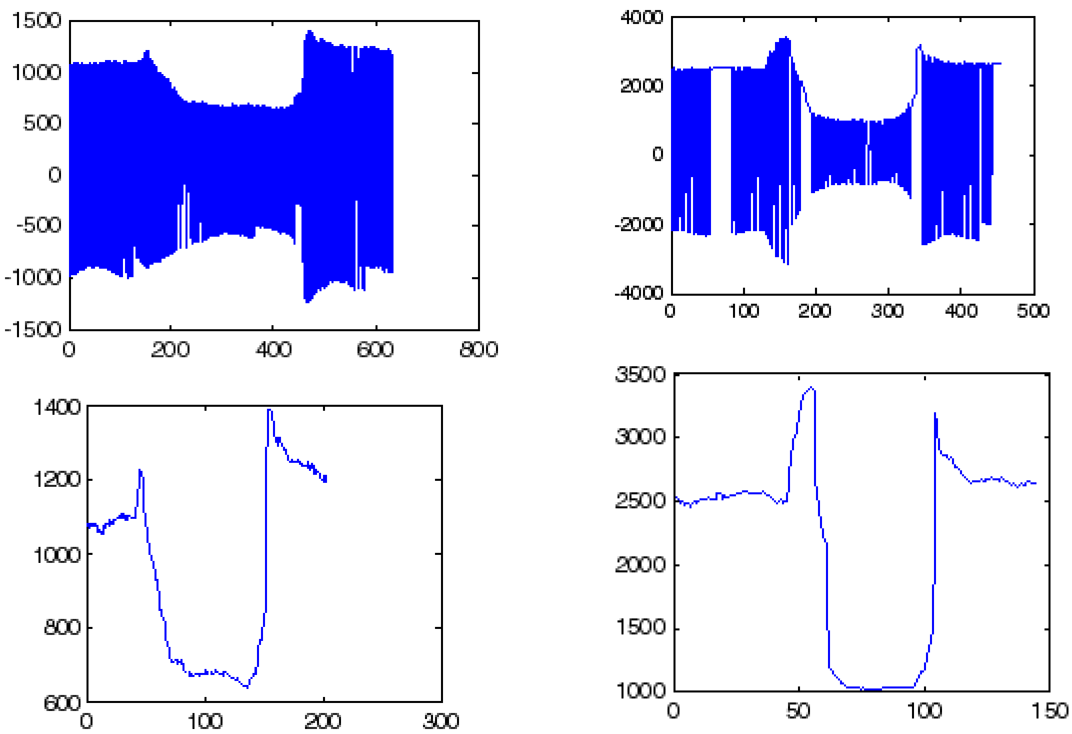

(a) Mild force (b) Severe force

Fig. 5. Envelope diagram of EMG

$$\left|X(j\omega)\right| = \left|\sum_{n=0}^{N-1} x(n) e^{-j\frac{2\pi\omega}{N}n}\right|$$

We can see from the frequency spectrum in figure 3, most of the energy of original EMG concentrate around 50Hz,the rest focus on 150Hz, 250Hz, 350Hz, 450Hz. EMG is a non-periodic and constant signal, its frequency spectrum should be a continuous spectrum line, however the discrete spectrum lines in the figure under the frequency 150Hz, 250Hz, 350Hz, 450Hz illustrate that EMG contains a cycle composition and it has a frequency of 150Hz, 250Hz, 350Hz, 450Hz, it is seriously caused by interference of power frequency electric and its frequency overtone. We can find that distortion degree of the envelope carrier is different and the distortion degree when we relax or when we make a fist is also different as we have a partial enlarged amplification to its red circle part in figure 2, so the common de-noising methods are not very effective for the EMG. In this paper we extract the enveloping curve of EMG and decide the change of the action based on the shape of these curves.

The principle of envelope filtering

Even through the signal is interfered seriously by the power frequency electric and its frequency overtone, we still can find from the figure of original data that the contour shape of the enveloping curve is changing with the change of the action, the upper part and under part of enveloping curve of the electromyography is symmetric on the whole, so we can decide the change of the hand action by extracting a part of the envelope curve diagram, here we just extract the upper part of the envelope curve, namely the maximum point of the envelope curve of EMG. Because the data of data card collection is the discrete data, we calculate the maximum point by the difference equation.

Time sequence of EMG collected is x(n), its maximum point should content that:

$$\begin{cases} x(n) > x(n-1) \\ x(n) > x(n+1) \end{cases}$$

We can see from the partial enlarged drawing in the figure 4 that because the distortion degree of carrier signal of the EMG is different with the change of the force, we will get a blue and red point in the figure through each difference, and enveloping curve is made up of the red maximum point of EMG in fact, so we can not extract the whole envelope curve of EMG by first difference, we need process second difference to get the whole envelope curve of EMG through a lot of experiments, we can see the envelope curve from Fig. 3.

Data analysis after filtering

We have a frequency analysis to the secondary envelope curve in figure 5, we can see from figure 6 that no matter how hard we put to our muscles, the power frequency electric interference

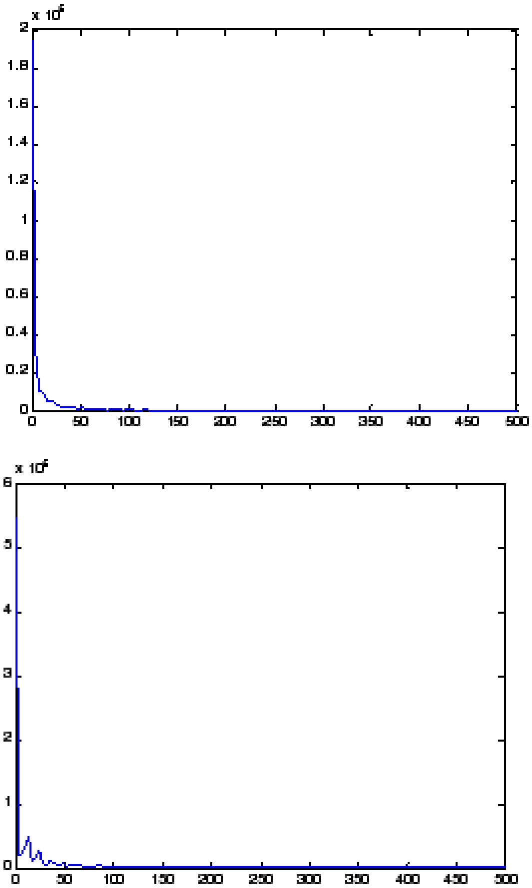

Fig. 6. Frequency analysis after filtering

which has a frequency of 50Hz and its frequency overtone would all be removed effectively and only leave continuous spectrum of EMG in the frequency spectrum of EMG after the envelope filter, so we can find that envelope filter can restrain the interference of power frequency electric and its frequency overtone totally

CONCLUSION

The extraction of the EMG effectively lays the root for analysis and processing based on EMG. This paper proposes the envelope filtering method for the EMG preprocessing. This method can extract the signal effectively without the influence of muscle contraction force, and can decide contraction and relaxation of the corresponding muscles and the contraction force of the muscles by the variation trend of enveloping curve of EMG, namely amplitude of EMG is higher when we relax and the amplitude of EMG is lower when we contract. However the amplitude difference during the relaxation and extraction reflects the contraction force, namely the contraction of muscle force would increase with the increase of the amplitude difference. This pre-processing method of EMG is simple and fast, and makes the real-time control of I-LIMB based on EMG possible.

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