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Study of electromyographic signal in stroke patients

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Abstract. With the rapid development of mathematical tools related to research on human behavior, more and more new discoveries are appeared in domestic and foreign. Surface EMG is a complex biological electrical signals and carrying a large body of information. In this paper, we found that the electromyographic signal is controlled by the brain signals and superposition of limb muscle action potential signal. The focus of this paper is to use mathematical analysis tools and MATLAB software to analyze the performance characteristics of EMG. Through the analysis of the electromyographic signal, we can quickly identify a breakdown of the patients with cerebral apoplexy， and it is cerebral infarction or cerebral hemorrhage, greatly improve the cure rate and reduce mortality. We have gathered upper limb muscle electrical signals of healthy people, patients with cerebral infarction and cerebral hemorrhage patients. By using Fourier transform and AR model to analyze electromyographic signal, we can easily find the difference between the patients with cerebral infarction and cerebral hemorrhage patients.

Keywords: surface EMG, Cerebral apoplexy, AR model, Fourier transform

1 Introduction

Electromyography (EMG) is produced in the complex process of bioelectricity generation during muscle excitation or activity, which has complex relationship with biochemical process, contraction process and neuromuscular control system of muscle tissue [1]. Surface EMG is widely used in clinical medicine, athletic medicine, ergonomics, restoration medicine, neurophysiology and electrophysiology. For example, Fougner (2013) used surface electromyography (SEMG) signal for the study of robust, coordinated and proportional myoelectric control of upper limb prostheses [2]. Many researchers and institutes have initiated studies involving joint movement recognition and successfully applied in smart artificial limb and control interface (De Luca 1978; Fougner et al. 2012; Lenzi etal. 2012) [3-5].

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SEMG signal is a specific, time-varying and non-linear weak electronic signal, its voltage ranges between 100-5000μV at 5-2000Hz. Surface neuromuscular signal recording is a simple, non-invasive process easily accepted by subjects, it is helpful not only in the reflection of muscle physiological and biochemical changes in movement but also in resting status; It is not only a meaningful diagnostic method for motion ability, but also a good technique for biological feedback treatment. For example, CaiQiFang etc used SEMG signal of upper limb in the study of Parkinson's disease patients [6], Dong etc used pelvic floor SEMG signal for clinical symptoms of functional constipation in elderly patients [7].

Stroke (cerebral apoplexy or cerebrovascular accident, CVA) is a non-infectious chronic disease which is difficult to cure and threats patient's life [8]. Stroke or CVA causes acute damage to brain tissue, which usually happens when the blood vessel responsible for oxygen and nutrition supply is ruptured, damaged or blocked by blood clot or other particulate matter. Neural cells die in a few minutes if deprived of oxygen, body functions controlled by these neural cells are lost as a consequence. As dead brain neurons are unable to be replaced, the impact of stroke is usually permanent[9].

If the human body is considered as a complete physiological system, it is fully automatic with high efficiency and stability when enough supply (energy, food, water) is supplied. The brain is the most important control unit of the whole system, providing countless signals controlling all physiological activities including basic breathing, heartbeat and muscle movement. From control engineering perspective, every nerve impulse generated by the brain is a group of control signal carrying ample information, including detailed instruction on muscle movements. The information rely on the nerve system to pass on to the muscle, which is the final controlling element in this case. We can view brain-nerve system-muscle as a complete closed control system (Figure 1):

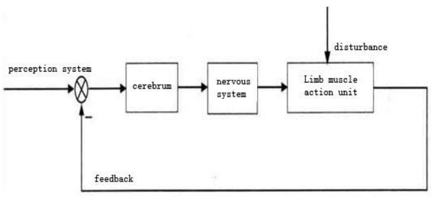

Fig. 1. Schematic structure of human control system

By recording changes of SEMG signals with various physiological indicators, and analyzing control and muscular motor signals using Matlab, we can deduce the pattern, further predict trend in muscle disorder, and build database by tracking SEMG signal in healthy population to analyze, predict and forecast diseases[10-11].

2 Problem formulation

Research subjects in this study are healthy volunteers (collage students) and stroke patients admitted in Second Affiliated Hospital of Heilongjiang University of Chinese Medicine, department of acupuncture and moxibusition, the latter divided as cerebral infraction group and cerebral hemorrhage group. Figure 2 shows original raw SEMG signal collected from upper limb, sampling frequency 25000Hz:

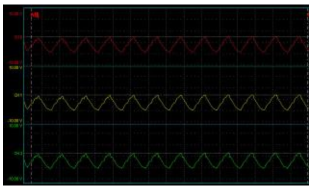

Fig. 2. Upper limb SEMG signal of healthy male

In this study, we focus on the application of Matlab in analysis of physiological implication of different upper limb SEMG signals between healthy population, cerebral infraction and cerebral hemorrhage patients.

3 Analysis of upper limb SEMG signal using Matlab

Some possible characteristics of SEMG signals recorded are observable with bare eyes. In order to obtain more accurate results, assist diagnosis and treatment, muscle SEMG signals need to be processed with mathematical functions in Matlab. After importing the data into Matlab, raw data of three different groups are presented

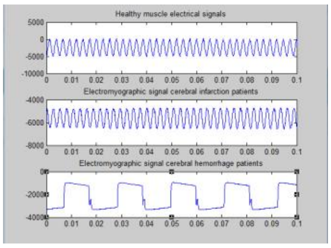

Fig. 3. Raw SEMG signal comparison

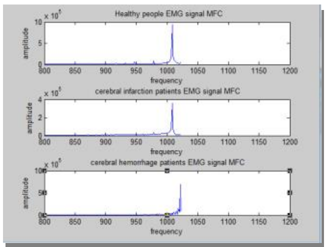

Fig. 4. The comparison of MFC(high frequency part)

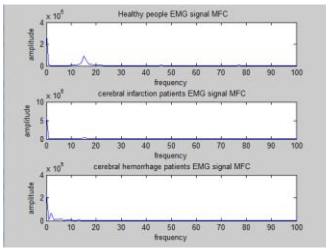

Fig. 5. The comparison of MFC (low frequency part)

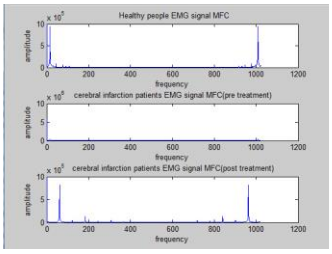

Fig. 6. The comparison of MFC (pre and post treatment)

As shown in figure 3,SEMG signal amplitude from healthy population ranges between 0-5v (x axis represents data collected in 0.1s). Cerebral infraction patients lost action potential from part of the control signal stimulation, their signal amplitude is significantly reduced as a result. Cerebral hemorrhage patients almost lost all muscle control by the brain. A quantitative analysis will be used in upper limb SEMG signals in different population groups.

As shown in figure 4, 5 (MFC is magnitude-frequency characteristics) .After Fourier transformation, SEMG signal of healthy population is mainly concentrated between 10 Hz and 1000 Hz. In high frequency band around 1000Hz, the amplitude of healthy population is twice the value of stroke patients. It is more complex to treat cerebral hemorrhage patients. Around 1000 Hz where normal SEMG signals function, almost no SEMG signals are detectable in hemorrhage patients, however, some signals are present in frequency band much higher than 1000 Hz. Further studies are needed to understand the implication of these signals. Similar conclusions can be made in lower frequencies.

As shown in figure 6.After acupuncture and moxibusition treatment, the magnitude-frequency characteristics of infraction patient tend to move to that of healthy population. The rise in amplitude of SEMG signal is an indicator of muscular function recovery.

Human body SEMG signal is a smooth signal, which makes it possible to analyze with AR process modelling.

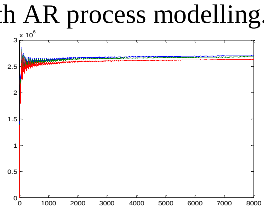

Fig. 7. Healthy people Correlation function

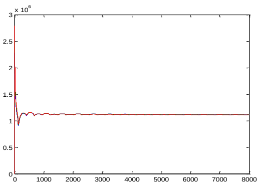

Fig. 8. Cerebral hemorrhage patient

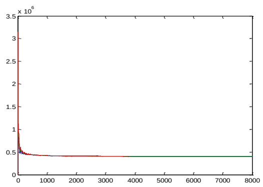

Fig. 9. cerebral infraction patient

From the figure 7 we can see rich information in AR modelling of healthy population SEMG signal. Third order correlation function is close and shows stable characteristic.

Different correlation function can be obtained using AR model to process the SEMG signals of cerebral infraction and hemorrhage patients, as shown in figure 8,9:

It is further concluded that AR modelling correlation function analysis of patient upper limb SEMG can quickly determine cerebral infraction or hemorrhage in the event of stroke, which has important clinical usage.

4 Conclusions

In this study, we used multiple Matlab tools to analyze upper limb SEMG signals of collected from healthy population and stroke patients. By intuitive analysis of raw data of upper limb SEMG signal, it is easy to distinguish between two types of stroke, i.e. cerebral infraction and cerebral hemorrhage. By further processing raw data with Fourier transformation, amplitude-frequency frequencies can be obtained. Combining with Fourier transformation and AR modelling of SEMG signals, we can further observe the different characteristics in different population groups and distinguish between different types of stroke.

In conclusion, multiple Matlab analysis of upper limb SEMG signals of stroke patients can quickly distinguish cerebral infraction and cerebral hemorrhage patients, providing mathematical basis of stroke treatment where every second counts.

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