USING TIME-VARYING AUTOREGRESSIVE FILTER TO IMPROVE EMG AMPLITUDE ESTIMATOR

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ABSTRACT

An electromyography (EMG) amplitude estimator can be the proportional control input of power prostheses or functional electrical stimulation system. In this paper, an improved temporal whitening process through a time-varying autoregressive (AR) filter is evaluated in experiment. The results of our experiment demonstrated time-varying whitening filter can improve the SNR of the amplitude estimators. It implies the influence of non-stationary characteristics of tissue filtering.

Keyword: EMG, time-varying autoregressive filter

INTRODUCTION

Previous studies showed that EMG signals can be modeled as a white noise of which amplitude modulated by muscle force in isometric contraction[1][2]. Therefore, amplitude estimation is useful for muscle force estimation. Whitening is an important technique to improve the SNR of the classical moving-windows-root-mean-square method (MWRMS)[2]. Although all investigators assumed EMG as a wide-sense stationary (WSS) signal, non-stationary characteristic of tissue filtering may influence on amplitude estimation.

In 1989, Moser and Graupe developed a nonstationary model to identify EMG signals as the input commands of a functional electrical stimulation system[3]. We use this time-varying AR filter as a whitening filter to improve SNR of EMG amplitude estimator.

METHODS

A pair of electrodes was placed on the subjects' muscle belly of right biceps brachii. EMG signals were amplified 1000 times through preamplifier (Gould model 20-4615-58). Torque signal was measured from Cybex 6000 System. All the data were digitized from a 12-bit A/D card (Metrabyte DAS-16) and stored in a 486PC. Subjects were asked for a

maximum voluntary contraction (MVC) before test beginning for calibration. In each trial, subjects maintain 50% or 25% MVC elbow flexion for 3 seconds at the position of elbow flexion of 60 degrees. The time-varying AR model is described by the following equations[3][4]:

$$y(n) = \sum_{i=1}^k a_i(n)y(n-i) + w(n)$$

where $y(n)$ denote the EMG signal at time n and $a_i(n)$ is the i th order AR coefficient that evolves under the constraint:

$$a_y(n) = \sum_{j=1}^l b_{ij}a_i(n-j) + v_i(n)$$

where $w(n)$ and $v_i(n)$ are mutually orthogonal, zero mean, second moment ergodic white noise processes. We should notice $w(n)$ is the residual of time-varying AR filter which can be the input of MWRMS estimator. The flowchart of signal processing is shown in Fig 1.

Fig 1 Flowchart of Signal Processing

RESULTS

The EMG amplitude from MWRMS without whitening, with linear whitening (modified from [2]), and with time-varying AR filter whitening are compared. Figure 2 shows a typical EMG data, MWRMS amplitude estimator without whitening, with linear whitening, and time-varying AR filter whitening. Table 1 is the mean and variance of SNR.

Table 1 SNR of EMG Amplitude Estimator

SNR		without whitening	with linear whitening	with time-varying AR whitening
50% MVC	mean	10.5009	10.9323	13.4592
	variance	3.3703	4.2510	4.3585
25% MVC	mean	10.2030	10.4837	11.5953
	variance	5.1686	5.9848	15.7385

DISCUSSION

Initial comparisons among MWRMS EMG amplitude estimators with linear whitening, time-varying AR whitening, and without whitening, the results show that time-varying AR filter can get a better estimation of EMG amplitude. This filter can combine with the estimation of time-vary AR coefficient for power prosthesis control[3]. Time-varying AR filter can eliminate the effect of non-stationary phenomena from muscle to electrode and let residual signal be a white signal, but it may not the inverse of tissue filtering function.

In this experiment, $k=4$ and $l=1$ were choiced for convenience. It can be justified by AIC [4].

CONCLUSION

The time-varying AR filter technique described herein promises to be a whitening filter that can improve the performance of EMG amplitude estimator. Our result provides an evidence that the influence of non-stationary phenomenon may be an important reason to get a low SNR for non-stationary EMG amplitude estimation.

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Fig2 Typical MWRMS EMG amplitude estimator. From top to down: original EMG signal, amplitude estimator without whitening (SNR=13.21), amplitude estimator with linear whitening (SNR=13.79), and amplitude estimator with time-varying AR filter whitening (SNR=17.5194)