Electromyography (EMG) Signal Compression using Sinusoidal Segmental Model

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Abstract—**Muscle signal called electromyography signal have a positive-negative signal generated by MUAP. The number of MUAP is depends on the muscle activity. On the stressed muscle, the characteristics is like periodic signal. Based on its characteristic, we can be modeled this by sinusoidal model. On the sinusoidal model, there are many kinds for representing the signal. One of model is Segmental Sinusoidal model. EMG signal can be represented as a combination of sinusoidal signal which was generated by muscle system with infinite combination of amplitude, frequency and phase. On quantization based on peak to peak, EMG signal was detected its peaks, both of positive and negative. Then time distance between peak to peak would be quantized. In this paper, we proposed a new method to quantize and reconstruct ECG signal which segmented by peak to peak based on sinusoidal model. The part of signal between positive peak and following negative peak or vice versa was estimated as a half period of the sinusoid signal. Magnitude between peaks was the double of the estimated sine amplitude. The information which taken from quantization process were period and gain. The experiment result show that synthesis signal quality was reduced on the high frequency component.**

Index Terms—**sinusoidal, quantization, electromyography, internet, gain, peak to peak, synthesis**

I. Introduction

Telemedicine system is important for county with limited health facility but have large territory like Indonesia. Advance on telecommunication technology has endorsed all aspect of human life to get the better condition. Telecommunications infrastructure with advances in the ability to capture, store, transmit, and display electronic representations of medical information, allow doctors to do many things remotely that they have traditionally done. This human body signal may be compressed, so that we get smaller bytes of signal files. Telemedicine that using communication channel needs simple form coding method. The number of transmission channel for communication become limited due to increase of the communication channel usage. EMG signal data rate can be developed by using encoder to obtain the simpler information. The research aim is obtained the low rate of the muscle signal encoder with high quality.

Signal that has quasi-periodic component could be modeled as linear combination of sinusoidal component with varying amplitude, frequency and phase. So that, signal could be composed into k sinusoidal signals called as sinusoidal model. Quality of signal using sinusoidal modeling would be decrease when there were finite of sinusoidal components. In this paper, we describe the segmental sinusoidal method to approach EMG signal form.

EMG signal is composed by voltage of the MUAP. The number of muscle fiber is correlated with number of the signal fluctuation. Strength of that signal is representing the muscle signal stress. On the maximum muscle contraction, we obtain the high magnitude signal.

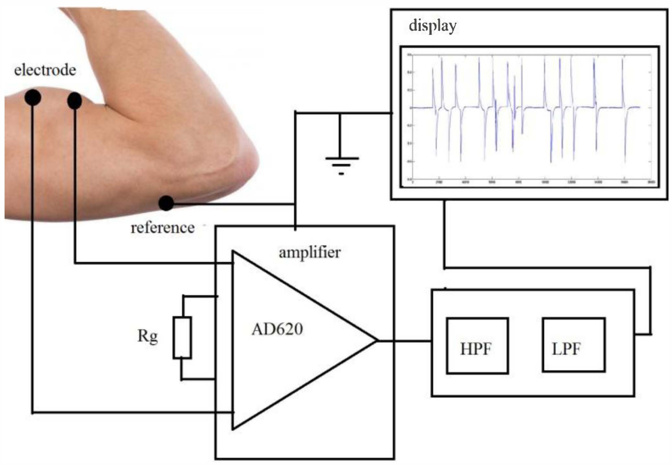


Fig 1. Electromyography Signal Acquisition and display

The research aim is obtaining method for compressing electromyography signal using sinusoidal model. The main research consists of encoder and decoder development at muscle frequency signal between 0.01 Hz and 5000 Hz. Diagram of the research is shown on Fig 1. For The simulation is developed by using the Scilab open source software. Software simulation consists of muscle signal acquisition, signal encoder, signal reconstruction, and signal reproduction as results of the signal reconstruction and performance tests. Error of period quantization is including on the transcoder performance test.

On the sinusoidal model, there are many variation for representing the signal including muscle signal. The segmental sinusoidal model is an approximation method based on sinusoidal model for speech signal, especially for periodic detection. Muscle signal have the identical characteristic with the speech signal, especially on voiced signal. The periodic signal can be decomposed by infinite sinusoidal signal with combination of amplitude, frequency and phase. Some parameters of muscle signal are detected. The useful parameters are peaks and period between consecutive peaks. Period and peak information obtained from this quantization tends to different than the original. The useful information of the muscle signal are peak and period. Peaks are representing the magnitude of muscle contraction and periods are representing the frequency of muscle signal. Muscle signal can be obtained by using muscle amplifier with electrode mounting shown in Fig 2.

Signal of human being stress can be acquisited on several muscle. One of the kind of muscle tension that indicating human stress is the Neck Extensors muscle and the Rectus Abdominis muscle. Neck Extensors acquisition signal using disposable electrode is depicted in Fig 2.

Fig 2. Electrode Mounting Location

II. SINUSOIDAL MODEL ON MUSCLE SIGNAL

There are many part of muscle signal would be represented into k sinusoidal signals that vary in amplitude, frequency, and phase. Muscle signal was reproduced by electrical activity of human muscle. For modeling signal, muscle signal could be quantized into infinite sinusoidal components. Muscle signal may have variation like the human speech signal that can be decomposed into many components [2-6]. The muscle signal also have characteristics like speech signals that could be represented into amplitude modulation and frequency modulation. [7-10]. Electromyography that representing of muscle signal can be depicted on Fig 3.

When the muscle on relax state, the signal tend to small. But the muscle signal can raise into higher voltage when the muscle contracted. Signal contracted will have voltage measured in some microvolt until millivolt depends on the muscle mass and tension. The gain of amplifier is 1000x, so that the multimeter will display the muscle peak around hundred millivolt until 2 volt.

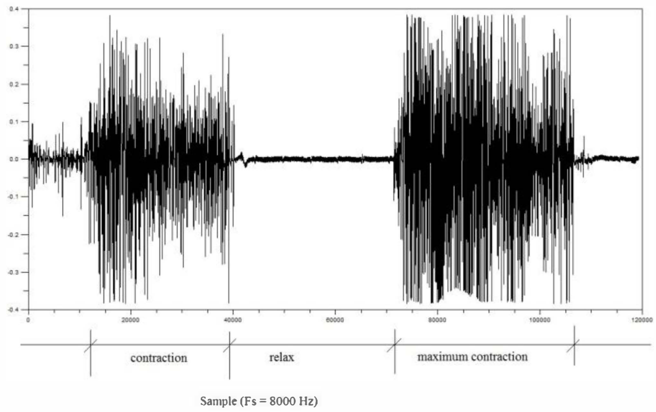


Fig 3. Electromyopgraphy signal on variaton of muscle state

Muscle signal is composed by activity of muscle fibre (MUAP) have the near periodic characteristic. The quasi-periodic signal sampled at sampling frequency *Fs* would generate *N* discrete signal *s(n)* from n=0 until n=N-1. The discrete signal *s(n)* could be represented into Fourier series. The n represents signal sampling, , a_0 represents 0-th Fourier series coefficient, a_k and b_k are k-th Fourier series coefficients , then k represents the number of sinusoidal components, we would formulate the discrete signal as[5] :

$$s(n) = a_0 + \sum_{k=1}^{\infty} a_k \cos k\omega + \sum_{k=1}^{\infty} b_k \sin k\omega \quad (1)$$

EMG signal could be modeled as linear combination of sinusoidal component with varying amplitude, frequency and phase. This signal could be represented as k sinusoidal signals. If the signal would be quantized in sinusoidal components, k was infinite. Infinite number of k could be reduced by representation the significant part of spectra. Quality of signal would be decrease when there were finite of sinusoidal components.

Fluctuation of the muscle voltage would result peaks that contain of maximum and minimum value on certain time interval. Signal characteristic with peak and valley (minimum peak) could be use as a model to approach electromyography signal form. Part of signal which contain interval between one peak to the consecutive peak could be represented by one sinusoidal signal segment. Peak to peak pattern was significant to represent the level of signal periodicity. Fig 4. Shown that muscle signal can be decomposed into amplitude, period and DC-offset.

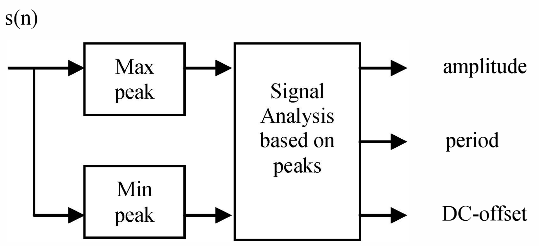
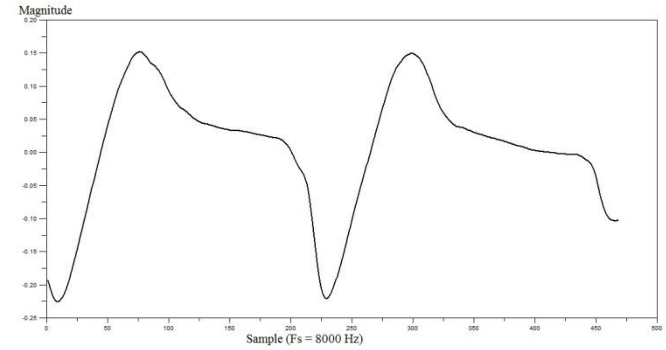
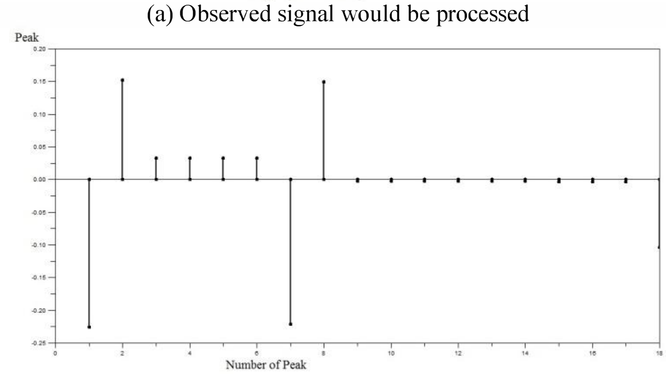


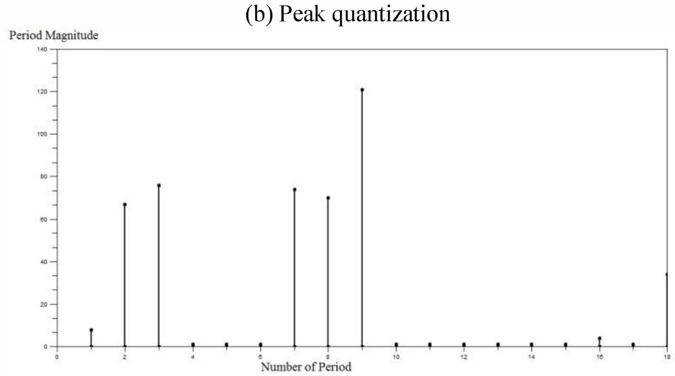
Fig 4. EMG Peak Signal Quantization



(a) Observed signal would be processed



(b) Peak quantization



(c) Distance between peaks

Fig 5. Observed signal and its analysis result

Muscle signal could be analyzed by segmental peak to peak with sinusoidal model approach. On sinusoidal transformation method, signal was modeled by harmonic over certain frame. Some of highest peak over spectra from Fourier Transform were taken to represent the estimated signal. New method on this paper is approaching process in the time domain. Process will start by marking the maximum and minimum peak. If in a certain time interval (frame), there are consist of i maximum peak and i minimum peak, denoted as p(i) and v(i). Fig. 5 shown the signal would processed and its quantization result.

In that equation, the number of Fourier coefficients is infinite. By similar way with sinusoidal transform method to get estimated signal, we can take some Fourier coefficient to represent the whole of sinusoidal components for time interval between p(i) and v(i). In this paper, only coefficients a_0 and a_1 are used to get the estimated signal for one peak to following peak. So that, for i-th time interval of signal can be represented by the following equation [5]:

$$s(i) = a_0 + a_1 \cos \omega_i \quad (2)$$

Each value of a_0 and a_1 represent average amplitude (DC offset) and the first Fourier coefficients. For the part of signal in time interval between v(i) and p(i+1) can be repersented by the following equation :

$$s(i) = a_0 - a_1 \cos \omega_i \quad (3)$$

Based on this model, a part of signal between minimum and the following maximum peaks could be approached by cosine signal from π to 2 π. In the other hand, a part of signal between maximum and the following minimum peaks could be approached by cosine signal from 0 to π. Each of cosine signal have to be corrected by adding DC offset to get the same maximum or minimum peak for original signal and synthesized signal. Signal could be reconstructed based on maximum and minimum peaks value on the observed interval (frame). If p(i) represents the i-th maximum peak value, and v(i) is the i-th minimum peak value, so that the estimating signal could represent as following explanation. For the part of signal between maximum peak to the following minimum peak, there was represented by equation (2).

Based on equation (2) and coefficient value from equations (4) and (5), we get estimated signal for segment form i-th maximum peak to i-th minimum peak as follow:

$$s_{pv}(n) = \sum_{i=1}^{k} \left[\left[a_0 + a_1 \cos\left(\frac{(n - n_{p(i)})\pi}{n_{v(i)} - n_{p(i)}} \right) \right] \right] \quad (4)$$

We get estimated signal for the segment between i-th minimum peak to i-th maximum peak as follow :

$$s_{vp}(n) = \sum_{i=1}^{k} \left[\left[a_0 - a_1 \cos\left(\frac{(n - n_{v(i)})\pi}{n_{p(i+1)} - n_{v(i)}} \right) \right] \right] \quad (5)$$

The procedure to get signal gain and signal period of estimated signal is like the following process. The first step is defining one block of signal with certain length. Then, peaks of signal are marked both of positive peaks and negative peaks. Signal between the positive peaks to the following negative peak is mentioned as a half period of sinusoid. Difference between the first peak magnitude and the following peak is mentioned as estimated signal amplitude. Time distance between the first peak and the following peak is a half period of estimated signal. This process is applied to the following peaks.

By using this procedure, we get a train of the gain signal and a train of period signal for one frame. Dynamic range of two information values, that were gain and period, are smaller than the dynamic range of the original signal. So, size of bit which have to prepare to send gain and period information are smaller than sending information without compression. The original muscle signal compared with estimated signal is shown in Fig.6.

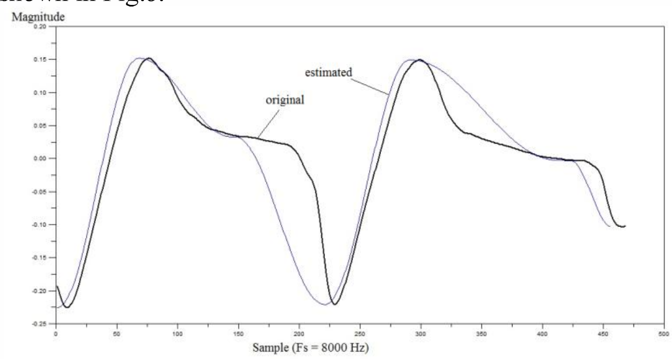


Fig 6. Sinusoidal Segmental Model

III. Experimental results

There is a electromyography signal segment that modeled by sinusoidal approach for each interval between maximum peak to minimum peak and vice versa. This model would result a train of periods which change for every segment with changed amplitude. If amplitude was kept constant on normality number, the result was the signal in frequency modulated. Period and gain value for every segment could be used as information which sent to decoder in order to save the transmission channel. In the decoder, signal would be reconstructed to get the original signal estimation by sinusoidal model. Gain and period information had less dynamic range than the original signal. So, It is feasible to compress the muscle signal based on this model.

Part of signal between minimum to maximum was approached by negative cosine at half period. When the other part of signal between maximum to minimum would be approach by a half period of cosine signal.

The number of sinusoidal signals which resulted would vary respect to the number of peaks on the signal frame. The more peak would decrease compression factor. Result of signal reconstruction by sinusoidal approach seems smoother than the original that had arbitrary form between one peak to the consecutive peak. Nevertheless, roughness of original signal means containing high frequency component. So that there was leaked the high frequency component.

In this experiments, original signal was compressed with proposed method. Then, peaks and periods was transmitted on internet network by email. On the receiver, this information would decompressed by decoder in order to get the synthetic signal.

IV. Discussion

Signal electro-myography have large variation depends on muscle type and muscle activity. Muscle with bigger mass tends to have the higher signal on full contraction than the lower mass signal. Frequency shifting will not make different perception the human visual system. The reconstructed signal will be different from the original. When the period information is compressed with code book, there will much error on decoder.

V. Conclusion

Electro-myography signal can be decomposed into peak and period component using Segmental Sinusoidal Signals like speech signal and cardiac signal. For compressing EMG signals, Segmental sinusoidal signal model needs these parameter to obtain simplest form of encoded signal. The most important parameters are peak information and period information. High compression ratio is obtained when the muscle on the full contracted condition. When the muscle on relaxed condition, the compression ratio will be reduced.

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