A Study of Emotional Changes on Bionic Signal Evoked by Auditory Stimulus using Savitzky-Golay

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Abstract

The purpose of this study was to perform the evaluation of emotional change using bionic signal evoked by auditory stimulus, analyzing the HeartBeat signal data which were measured in stable and in auditory stimulus. Also, we accurately estimated the acceleration change of the R - R interval.
The experiments were performed to 8 people (6 normal males, 2 normal females in a group and mean 29±1 years). As evoked by auditory stimulus, the heart rate variability(HRV) was changed and the ratio of low frequency and high frequency.

Keywords:HRV, Savitzky-Golay Filter, Bionic Signal, Auditory Stimulus, Emotion

1. Introduction

While modern medicine develops, it is possible to judge the health condition or to distinguish the state of sensitivity from a plurality of signals measured by the human body.

The types of biosignals include electrocardiogram (ECG), electroencephalogram (EEG), electromyogram (EMG), galvanic skin response (GSR), skin temperature (SKT) , Pulse wave (photoplethysmography, PPG), and the like. Among these waveforms, an electrocardiogram(ECG) is a biological signal commonly used for measuring diseases and conditions of the heart, in a waveform showing electrical activity of the heart.

Electrocardiograms are defined in P, Q, R, S, T - wave and are made at intervals with these segments and are displayed on the axis of voltage (mV) and time (sec)[1]. All signals excluding the electromyogram from the biological signal are under the control of the autonomic nervous system and change of the biological signal occurs according to the change of the state of the emotion. The response of the autonomic nervous system is regulated by antagonism of the sympathetic and parasympathetic nervous

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systems, but it is activated mainly while maintaining homeostasis in the body. The cycle of muscles of the heart changes fluidly by the sympathetic and parasympathetic nervous systems of the autonomic nervous system. The rate of change in heart rate is quantified quantitatively in these cardiac heartbeat. It is possible to quantitatively analyze the actions of sympathetic and parasympathetic nerves through power spectrum analysis of this HRV[2].

In this paper, We analyze the electrocardiogram that changes according to the auditory stimulus and try to judge the extent of the change in sensitivity. Also, we accurately estimated the acceleration change of the R - R interval.

2.Materials and Methods

As the measuring device, an ECG circuit was used, Labview and Matlab were used as analysis software, and the sampling frequency of all physiological signals was set to 480 Hz.

2.1 Savitzky-Golay Filter

The noisy biomedical signal is x[n], n=0, 1,⋯, N-1, where N denotes the number of samples.
The Savitzky-Golay filter equation is expressed as Equation (1) [3].

$$p(x) = \sum_{r=0}^{n} a_r \cdot x^r = a_0x^0 + a_1x^1 + \cdots + a_nx^n \cdots (1)$$

a_r is the polynomial coefficient. the data section to which the Savitzky-Golay filter approximates is an area containing an index of -m from +m. That is, the data signal belonging to the window section is expressed by Expression (2).

$$X = [x[-m]\ x[-m+1] \cdots x[0]\ x[1]\ x[m]]^t, \text{t : transpose} \cdots (2)$$

In order to estimate the noise suppressed value, execute the pseudo-inverse operation as in the following equation (3) to obtain the Savitzky-Golay filter coefficient .

$$\hat{A} \approx (S^t \cdot S)^{-1} \cdot S^t \cdot X \quad \cdots (3)$$

Which is the result of applying the Savitzky-Golay filter is expressed as Expression (4).

$$\hat{X} = S \cdot \hat{A} = S \cdot (S^t \cdot S)^{-1} \cdot S^t \cdot X = P \cdot X \quad \cdots \quad (4)$$

In the projection matrix , the value of the row element is the polynomial coefficient of the Savitzky-Golay filter.
For example, when the size of the window area is 5, the obtained first derivative and second derivative coefficient are the same as Expressions (5) and (6) respectively.

$$\widehat{A_1} = [-2\ -1\ 0\ 1\ 2] \cdots (5)$$

$$\widehat{A_2} = [2\ -1\ -2\ -1\ 2] \cdots (6)$$

Perform a convolution operation to apply the data region to the whole signal.
In other words, the obtained electrocardiogram data is obtained by a convolution calculation like Expression (7) in which the Savitzky-Golay filter is applied to the data.

$$\hat{A} = (S^t \cdot S)^{-1} \cdot S^t \cdot G = [\widehat{a_{00}}\widehat{a_{10}}\widehat{a_{01}} \cdots \widehat{a_{ij}} \cdots \widehat{a_{n0}} \cdots \widehat{a_{0n}}]^t \cdots (7)$$

A differential signal obtained by applying the Savitzky-Golay filter can be acquired by using coefficients for the first order differentiation filter and coefficients for the second order differentiation filter.

2.2 Acceleration change estimation of RR interval

After detecting the R - R interval, the R - R interval data which is the boiling interval was converted at equally spaced intervals by using the cubic spline interpolation process at the sampling frequency of 4 Hz.
Finally, the results of the first and second differentiation by applying the Savitzky-Golay filter to this signal are shown in Figs. 1 and 2 respectively.

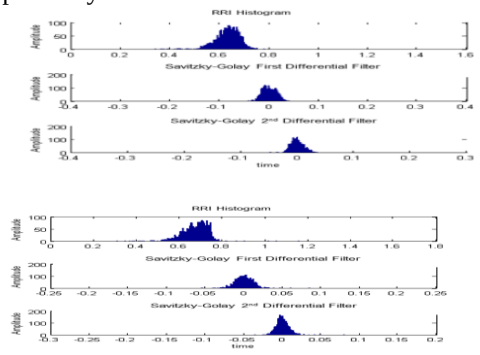

Fig. 1. Application result of SG Filter of the RR interval in normal state(Before Auditory Stimulus)

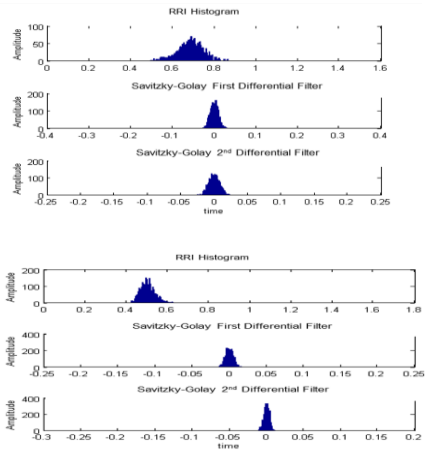

Fig. 2. Application result of SG filter of RR interval in stress state (After Auditory Stimulus)

3.Result

After showing the RR interval of the electro-cardiogram(ECG) from the data acquired from the subject and keeping this at the same interval as the value of bits / min as the heart rate variability (HRV), indicating this and the trend component in the time domain , Removing the trend component, re-sampling at 4 Hz, taking FFT, and showing HRV in the frequency domain. Then, the values of VLF, LF and HF in the HRV were extracted and the LF / HF ratio value was obtained. The values of LF / HF ratio that can determine the degree of stress received are as follows.

Table 1.LF/HF ratio parameters

LF/HF Raito-1st		
	Before Stress	After Stress
Mean	1.22101	1.3115

In the process of estimating the change of RR interval, if existing differential differential filter is used, since noise is amplified, it is difficult to estimate accurate change of acceleration. For these reasons, it was possible to confirm the fact that the noise was suppressed as a result of differentiating the RR interval by applying the Savitzky-Golay filter.

In other words, applying the Savitzky-Golay filter as compared with the conventional difference, first order and second order differential filter, it is possible to more accurately estimate the first and second derivative values while effectively suppressing noise .

Also, looking at the result of calculating the standard deviation of the result of applying the filter, it is found that the variance value is smaller in the case of a mental stress state than in both mental stable states of data of both subjects It could be confirmed.

4. Discussion

We can judge the state of emotion, wanting to know the health condition via multiple signals coming out of the human body. Among a plurality of signals, there are many methods of analyzing the ECG and judging the state of sensitivity. In this paper, based on ECG, it was confirmed that stress is generated with change in value of LF / HF ratio measured at auditory stimulation. However, since the factor that gives the change to the subject prior to the experiment is not the auditory stimulation but the voice signal, it is necessary to analyze the emotional state by recognizing and analyzing the voice signal, discriminating the relationship between the ECGs It can be said that it is a point to be improved in the future.

However, as described above, in the case of a patient or in a state of mental stress, since the complexity of heartbeat is reduced, it is expected to present a new parameter for judging the state of stress.

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