The 33rd Annual Conference of the Japanese Society for Artificial Intelligence, 2019

Waveform Processing of Electrocardiogram with Neural Network and Non-contact Measurement using Kinect for Driver Evaluation

Hao ZHANG [*1] Takashi IMAMURA [*2]

[*1]Graduat School of Science and Technology, Niigata University

[*2] Faculty of Engineering, Niigata University

In recent years, the measurement method of biological information using non-contact sensor have become popular. And, in-vehicle measurement systems for a driver evaluation are also needed in order to decrease the serious traffic accidents. In this research, improvement method of heart rate measurement with high accuracy by using the non-contact sensor “Kinect” is examined. As the reliable biological information, the Holter monitor of electrocardiograph is combination used for measurement experiment. Moreover, to extract high level features from electrocardiogram, a neural network based autoencoder has also constructed. In this paper, about the constructed neural network, the effectiveness of abnormal R wave detection through learning for waveform characteristics of electrocardiogram and the possibility of application for reconstruction of the heart rate signal from Kinect are discussed.

1. Introduction

According to a highway survey of 1000 drivers, the driver who experienced sleepiness during the operation was 78% of the total. In addition, "Front Carelessness" occupies about half of all accidents and about 40% in the death accident. It is thought that the factor which exists in this "front carelessness" is different by the driver, and there is insufficient attention and concentration as one of the big factors. Therefore, it is necessary to improve the attention to the operation, to operation of the quick handle, and the quick brake, the existence of the obstacle on the road, the sudden change of the curvature of the road, so maintenance and control of tension are necessary.

Recently, the driver's load is reduced by the various driving assistance, there is a possibility that attention is insufficient by lowering the tension. On the other hand, if the tension is too high, there may be a possibility that the physical strength and the mental state are exhausted early, and sleepiness may occur. It is thought that the extreme state of the tension seems to lead to the lowering of the accident avoidance capacity. It is said that the tension of the driver can be evaluated using electroencephalogram, blood pressure, electrocardiogram (ECG) [Deguchi 2006]. The purpose of this study is to develop a system to evaluate the feeling of tension by measuring the R-R interval variation of drivers during driving.

In this research, two kinds of technique to measure R-R interval variation are used. First one is acquisition for ECG with an electrocardiograph by using multifunctional wireless Holter monitor and recorder "CarPod" (Medilink inc.). It is an typical method of contact measurement, and it is also used in medical test for sleep apnea by its high accuracy. It can be used in daily life environment without disturbance for several behaviors or works. However, it is not suitable for the actual situation of vehicle driver monitor. Because, it is required to put the 3 or 5 electrodes on human skin directory.

Second one is sensing method using non-contact sensing such as Infrared sensors or cameras. "Kinect" (Microsoft Corp.) is typical example of such kinds of sensor which has already been put into practical use as a product of home game interface. And several researchers were tried to acquire the heart rate waveform by the changes of the luminance value (RGB) from the human face [Nakamura 2015].

On the other hand, although it is easy to acquire the electrocardiogram itself, there are still many unresolved parts about the analysis method and application method of information obtained from the detected waveform. Fundamental analysis is based on frequency analysis. For example, Yokoyama et al. Proposes a method to evaluate heart rate variability using the power spectrum which is frequency information of electrocardiogram and the amplitude spectrum extracted from the amplitude information [Kiyoko 1999]. In addition, recent developments in deep learning have been studied and applied to electrocardiograms. Takahashi et al. Has proposed the feature extraction from the electrocardiogram using stained convolutional extraction autoencoder (SCDAE) [Takahashi 2017]. Their research showed that robust feature extraction is possible for waveform changes due to observation objects and heart rate variability by using autoencoder.

In this paper, we propose a neural network (NN) - based autoencoder, which extracts high - level features from normal waveforms, and detects a location with abnormal electrocardiograms compared to required examination data. And, it is also possible to compare the electrocardiogram feature extracted by the autoencoder with the heartbeat waveform obtained from Kinect and to analyze the heartbeat characteristics from the RGB information.

Contact: ZHANG Hao, Niigata University,8050 Ikarashi-2nocho Nishiku-Niigata-JAPAN,950-2181,025-262-7475, ima@eng.niigata-u.ac.jp

2. The Proposed Method

2.1 Summary of Techniques

The fixed length data divided by the sliding window method in the electrocardiogram waveform does not consider labels for heartbeat interval or arrhythmia, so it is easy to use the acquired data [Noriyasu 2018]. Autoencoder (Ae) is a dimension compression algorithm using neural network. the weight of the AE is trained through neural network layer used to reconstruct the input data, which is of high dimensionality. As a result of the training, we can obtain a higher-level representation of the input data [Takahashi 2017].

The proposed method consists of three steps: Generate Partial Time-series, Autoencoder Pre-learning, Abnormal Inspection and R Wave Detection.

- Generate partial time-series of fixed length data from normal and abnormal data
- Autoencoder pre-learning and extracting normal data features
- Inspecting data abnormally with the trained autoencoder
- Constructing the R wave detector using discrete wavelet transform (MODWT)

(1) Generate Partial Time-series

ECG data X divided into fixed length D by slide window method

$$X=(X_1, \ldots, X_R)$$

Here, X_r is the r-th section, and R is the total number of spaces. The fixed length D and shift of the sizes of stride S are given as parameters.

(2) Autoencoder Pre-learning

Input $X=(X_1, \ldots, X_R)$,We use NN based deep autoencoder in MATLAB 2017A. As shown in Fig. 2, it is possible to obtain a low dimensional feature which holds information representing data.

The encoder section of the autoencoder is represented by encoder (・), and the decoder section is represented by decoder(・). The feature of the r-th section is expressed by

$$Z_r=\mathrm{encoder}(X_r)$$

As a result of applying the decoder to the encoder result Z_r which is the low dimensional feature quantity,

$$Y_r=\mathrm{decoder}(Z_r)$$

is similar to the original signal X_r.

The loss function for calculating how much the neural network matches the original data is the mean square error (mase sparse) between the original signal X_r and the decoded result Y_r,

$$E=\frac{1}{2R}\sum_{r=1}^{R}(X_r-Y_r)^2$$

Which is an indicator of poor performance of the neural network.

(3) Abnormal Inspection

An autoencoder has the function of bringing an abnormal waveform closer to a normal waveform. Using this function, it is possible to check waveform abnormality.

(4) R Wave Detector

The R-wave detector was constructed using the discrete wavelet transform (MODWT) to emphasize the R peak of the ECG waveform.

'Sym4' wavelet is similar to 'QRS' complex, so it is suitable for 'QRS' detection. For comparison, the results of extracted 'QRS' complex and the results with 'sym4' wavelet are shown in Fig.1.

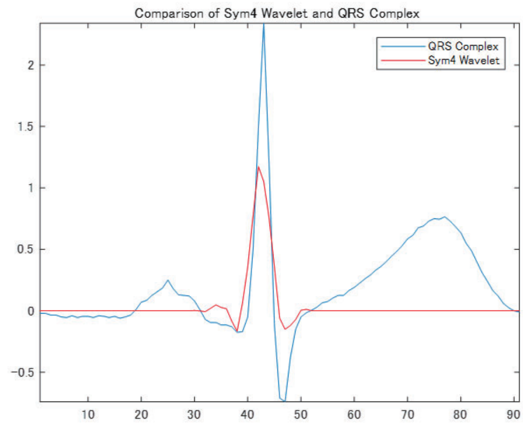

Fig.1 Comparison of 'QRS' and 'sym4' wavelets

3. Experiments

3.1 Measurement Experiment

Measurement experiments were made of electrocardiogram and Kinect. The resting state was maintained for more than 1 hour before starting the measurement. In the measurement at rest, the subject was chosen to be the most comfortable sitting position. The measurement time of the electrocardiograph and Kinect is half hour and one minute. The subjects were healthy 25 years old men without arrhythmia, heart disease, and autonomic neuropathy.

3.2 Numerical Experiment

In this experiment, we rely on MATLAB 2017A, fixed length D = 100 Samples, S =1 Samples in the sliding window system, hidden layer set 160, and an autoencoder was constructed as shown in Fig. 2.

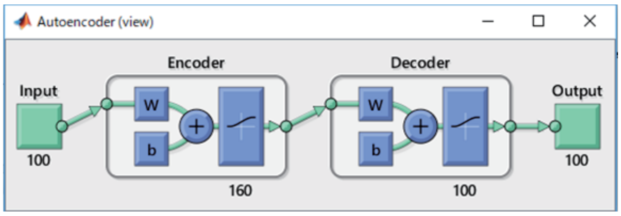

Fig. 2 Block diagram of Autoencoder

The normal part of the measured ECG waveform was chosen, and 10000 samples were trained as training data and 5000 samples were tested.

Fig. 3 shows the learning curve of Ae. The mean square error (mase sparse) between the decoded result Y_r and the original signal X_r is only 3.5195e-05 when the number of calculations is 3000, which shows that high accuracy learning has been performed.

This is because the amount of information can be greatly lost by reducing the dimension of the autoencoder. Fig.4 shows the following. We calculate the square error (MSE) of the restored signal Y_r and the original data X_r by selecting a random one waveform feature. Error division of individual data is shown. It seems to have succeeded in maintaining the waveform characteristic and restoring it.

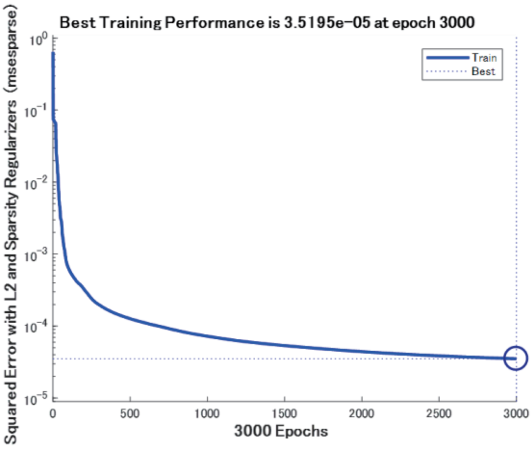

Fig. 3 Learning Curve of Ae

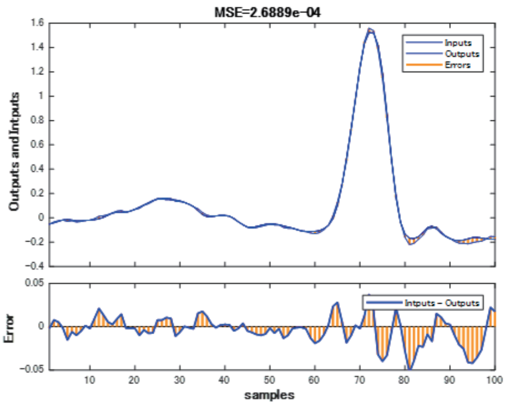

Fig. 4 Waveform Feature

And, the threshold of the error is set to 0.55 (the minimum value exceeding the maximum value of the training data error), and through the test data experiment, the error becomes 0 in the normal case of the electrocardiogram. In addition, two R-wave anomalies were found by the pre-learning Autoencoder from 5-minute data.

Finally, we measured the total heart rate 330 and average heart rate 66 for 5 minutes using MODWT.

4. Heart Rate Measurement Using Kinect in Driving Situation

In order to examine the characteristics of heart rate signal in driving situation, experimental setup using several measurement method as shown in previous section and driving simulator is constructed. In this section, several measurement problem not only signal processing issue but also installation of measurement devices are described through the experimental setups.

4.1 Driving Heart Rate Measurement Using Kinect

As the human heart contracts, the volume of the blood vessel changes. The amount of reflection of light also changes according to the changes. It is able to obtain the reflected light from the capillary of the face with Kinect. Then, it becomes possible to acquire a heartbeat waveform.

However, environmental light conditions will be always change in actual driving situation. And the driver also has driving behavior such as maneuvering the steering wheel on the curve or at the intersection. According to them, drastically changes of the light condition and driving behavior have possibility of making disturbance for visual sensing. Therefore, position of installation for Kinect is also important to consider in order to acquire the driver's face in stable.

4.2 Fixture Design with DS-6000

In order to measure the driver to a better angle with Kinect, the fixture points and its device is designed considering with several structures and dimensions of cockpit of the typical vehicle. In this research, driving simulator "DS-6000" (Mitsubishi Precision Inc.) is used for driving environment. It is simulated for the driving cockpit of typical type of car and their component such as driver's sheet, steering wheel, shift lever and pedals. Especially, driving instruments such as speed and gas meter are also set in the back of steering wheel.

For in-vehicle measurement, it is also important to keep enough fields of view for driver. On the other hand, to make better acquisition of driver's face, it is expected to put the non-contact sensors in front of the face. To satisfy these constraints, the upper side of the front windows is selected and the fixture of Kinect sensor was designed as shown in Fig. 5.

Fig. 5 Experimental setup of Kinect on Driving simulator

4.3 Measurement Result

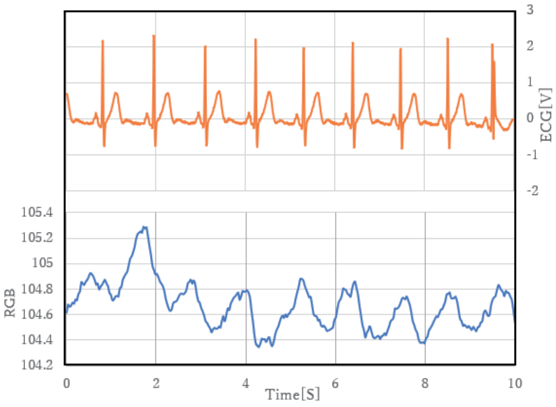

Fig. 6 Comparison of RGB heartrate waveforms and ECG waveforms

The experiment in driving situation with a subject driver has been conducted using constructed experimental setup as shown in previously. The measurement results in this experiment as shown in Fig.6. In this figure, red line shows heart rate waveform obtained by the electrocardiograph, and blue one shows the heart beat waveform measured by Kinect.

Through the simple comparison, heart beat have weakness of overall waveform for typical heart rate signal while heart rate signal has stability. However, it has possibility that the peak points of heart beat can be indicate the R wave characteristic based on the waveform reconstruction techniques.

5. Conclusion

In this paper, we propose a new method of analysis of electrocardiogram waveform data using an NN based autoencoder. At first, the waveform feature of a high level was extracted after the longtime waveform of the electrocardiogram was cut into the fixed length by the slide window system, and the high accuracy automatic encoder was prepared by adjusting various parameters. In addition, abnormal electrocardiogram was passed through a trained autoencoder, and abnormal R wave was accurately detected. Finally, more accurate heart rate information was obtained using MODWT.

As a future problem, the heart rate data of the RGB acquired from the face by Kinect has some correspondence with the electrocardiogram waveform, but it is not easy to detect heartrate. Therefore, it is expected that Kinect's heartbeat data will be processed with an autoencoder that extracts high level waveform features, and concrete connection with electrocardiogram will be examined. With that continuation, we will experiment a plurality of subjects and measure the R-R interval to achieve the final purpose of evaluating the driver's tension.

References

[Deguchi 2006] Mitsuo Deguchi, Junichi Wakasugi, Tatsuya Ikegami, Shinji Nanba, Masaki Yamaguchi, Evaluation of Driver Stress Using Motor-vehicle Driving Simulator, IEEJ Trans, SM,Vol.126,No.8, 2006.

[Nakamura 2015] Koru Nakamura, Tsukasa Sugiura, Takata Tomohiro, Tomoaki Ueda, KINECT for Windows SDK Programming, syuuwa System, 2015.

[Kiyoko 1999] Kiyoko Yokoyama, Junichirou Ushida, Takayoshi Yoshioka, Osamu Ozeki, Yosaku Watanabe, Kazuyuki Takata, Proposal of the Evaluation Method of the Heart Rate Variability using the Frequency Information of the Electrocardiogram, T.IEE Japan, Vol.199-C, 1999.

[Takahashi 2017] Thu Takahashi, Keiichi Ochiai, Yusuke Fukazawa, Feature extraction and arrhythmia classification from 2-lead ECG using stacked convolutional denoising autoencoders, 2017 Information Processing Society of Japan, IPSJ SIG Technical Report, 2017.

[Noriyasu 2018] Noriyasu Omata, Yoshihiro Nakanura, Susumu Shirayama, Extracting Long-term Patterns from Electrocardiogram Waveform using Deep Learning, The 32nd Annual Conference of the Japanese Society for Artificial Intelligence, 2018