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STUDY OF NON-CONTACT MEASUREMENT METHOD OF PULSE RATE AND RESPIRATORY RATE USING VIDEO IMAGING FOR SLEEP MONITORING

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ABSTRACT

We have been developing a heart rate measuring system using video imaging that is capable of precisely and sensitively measuring the heart rate of a human body without constraints. This study analyzes the efficacy of video imaging as a noncontact method to measure pulse rate and respiratory rate in order to evaluate sleep quality. To determine the effective light source wavelength, video images were recorded using a halogen light source and an optical filter in wavelengths of 810nm, 830nm and 950nm. During the recording of video images, participants were asked to breathe along with a metronome. Heart rates were also recorded continuously. For each frame, the average intensity values were calculated for each ROI to determine suitable ROIs. Subsequently, PR and RR were calculated using the proposed method. It was determined that a near-infrared image of 830nm of the cheek and lip area may be suitable for PR calculation. RR could be measured from the intensity value change due to respiratory motion.

1. INTRODUCTION

Evaluations of sleep quality have been carried out on a daily basis to diagnose sleep disorders such as Sleep Apnea. In this regard, it is important to note that sustaining or improving the quality of sleep is crucial for maintaining good health. Currently, the brain waves and eye movements of a subject are measured to accurately determine their sleep stage. However, these measurements using polysomnography are not feasible for evaluating sleep quality on a daily basis. Moreover, in clinical practice, it is difficult to attach electrodes or sensors to the body of a patient suffering from a mental illness or to that of a newborn.

Thus, a new method to evaluate the quality of sleep, which does not involve the use of electrodes or attachable sensors has been desired. The objective of this study is to develop a new method that does not involve the attachment of electrodes to the body of a subject to evaluate sleep rhythm.

Since it is known that there is a relationship between heart rate (HR) and sleep stage from past experiments [1], pulse rate (PR) is selected as a parameter to be measured. In addition, breathing information is also important for diagnosing diseases such as sleep apnea. Furthermore, since we think that body movements and facial expressions can also serve as an indicator of the quality of sleep, we propose using image measurement as a measuring method. In this paper we examine measuring pulse rate and respiration during sleep at the same time.

Methods to measure the PR and respiratory rate (RR) without contact are proposed for image measurements using visible light as well as methods using radar etc. [2][3][4][5]. High accuracy was obtained using these methods. In the measurement of a single wavelength, there was little information obtained compared with the measurement of visible light. However, visible light cannot be used in this study because the measurement is taken during sleep. Therefore, we examined which wavelength is suitable for measurement of pulse and respiration using near-infrared light from 800 nm to 950 nm. In the previous experiments, PR was measured using the average brightness value of the entire face [6]. However, it was possible that there are other more suitable sites for measurement of PR and respiration. Therefore other appropriate sites were also examined.

2. METHODS

2.1. Overview

Fig.1 shows a flowchart of the proposed method to calculate PR and RR using a video image. In the case of the proposed method; first, a video image of the head and the neck area of the subject was captured using a near-infrared light camera. Subsequently, the rectangular facial region is automatically detected from the acquired image sequence. It was then divided into smaller regions of interest (ROIs) followed by the calculation of the average luminance values of these ROIs. Then, a band-pass filter was applied to anti-alias and to eliminate the noise component from becoming a hindrance when calculating PR and RR. Discrete Fourier transform

(DFT) was applied to the obtained data. Finally, from the obtained frequency spectrum, the estimated PR and RR were calculated on the basis of the value of the frequency with the largest spectrum.

2.2. Facial Region Selection

First, a facial region was extracted from the first image using the Viola-Jones method implemented in matlab. Sleeping facial images of three subjects were used as learning classifiers by Adaboost. Since it takes time to extract the facial region for all frames, a KLT algorithm was used for tracking faces after the second frame. Feature points in the facial region used the standard "good features to track" advocated by Shi & Tomasi. If corresponding feature points could not be found in the subsequent frames, extraction of the facial region and selection of the feature points were performed again. The facial region was set to 400 × 400 pixels, which was further divided into smaller areas of 40 × 40 pixels.

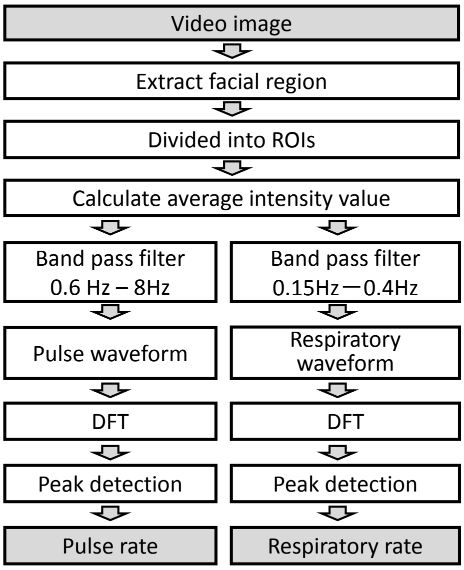


Fig.1 The flowchart for PR and RR calculation

3. EXPERIMENTAL EVALUATION

3.1. Relationship between PR and Sleep Stage

In order to investigate the relationship between PR change through image measurement during sleep, measured HR, and the relationship between PR and sleep stage, electrocardiograms (ECG) and electroencephalograms (EEG) video images were recorded simultaneously. MyBeat was used for HR measurement. Also, a camera sensitive to near-infrared light and a near-infrared light source of 940 nm was used for this experiment. The acquired video images were analyzed using the method described above, and the PR and RR were calculated. In this experiment, the average intensity values were calculated using all facial regions. The sleep stage was judged by 6 steps (Awake, REM, stage 1 to 4) every 30 seconds by analyzing the electroencephalogram.

3.2. Investigation of measurement conditions

A video image and an ECG were simultaneously recorded in order to investigate the light source wavelength and measurement region suitable for PR and RR measurement. Participants were asked to keep still and to breathe along with a metronome in 12, 15 and 20 breaths per minute intervals. Video images were recorded at a frame rate of 20 fps for 2 minutes. The sampling frequency of the ECG was 128Hz using MyBeat. The acquired video images were then analyzed using the method described above, and the PR and RR were calculated. An accurate HR was calculated using the RR interval obtained by detecting the peak value of the R-wave from the ECG.

The above experiments were conducted with the approval of the ethics committee of Saitama Medical University, Faculty of Health and Medical Care.

4. RESULTS

4.1. Relationship between PR and Sleep Stage

Fig. 2 shows the PR obtained by this method and the change of HR in first 2 hours. Except for the section where the facial region could not be traced, the PR and HR changed in a similar way in general. Fig.3 shows a comparison between the PR obtained using the proposed method and the sleep stage estimated from the brain waves of the subject. There is a relationship between the estimated pulse rate and sleep stage; PR decreases in deeper sleep. This is consistent with previous studies.

4.2. Pulse Rate

Fig. 4 shows the results of the comparison between the calculated PR and measured HR. In Fig.4 (a), the average error rate of each ROI's for six trials on the same subject is shown. Fig. 4 (b) shows the average of (a) for 10 people. Blue indicates that the error is small (0%), and red indicates that the error is large (30%). As shown in this figure, cheeks and lips are ROIs where PR errors are relatively small. Fig. 5 shows average error rate for all regions and for all subjects. The error was the smallest at the wavelength of 830 nm.

4.3. Respiratory Rate

Fig.6 shows the comparison between the calculated RR and instructed RR. This is the average value for 10 people. In the RR measurement, errors in the ROI of the

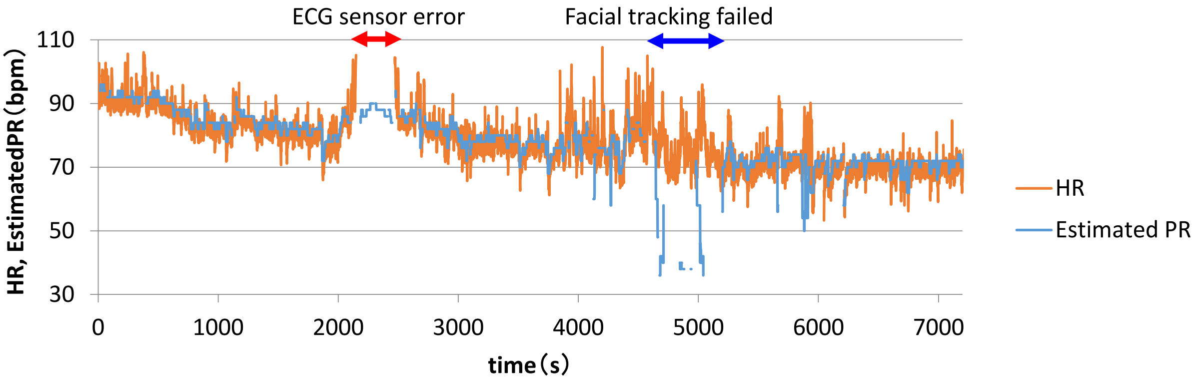


Fig.2 Estimated PR and HR during sleep

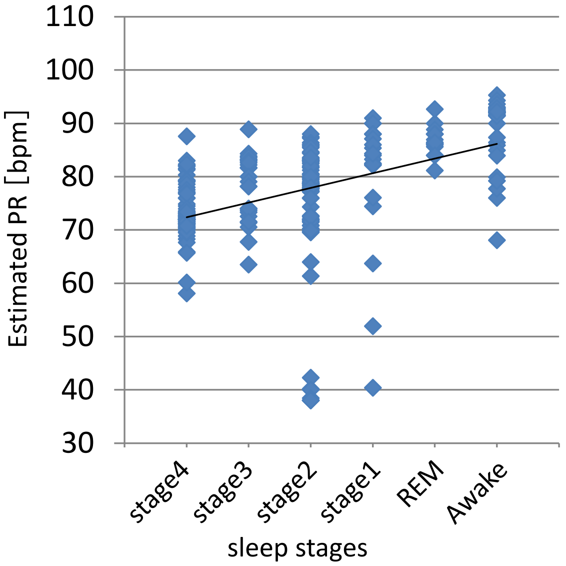
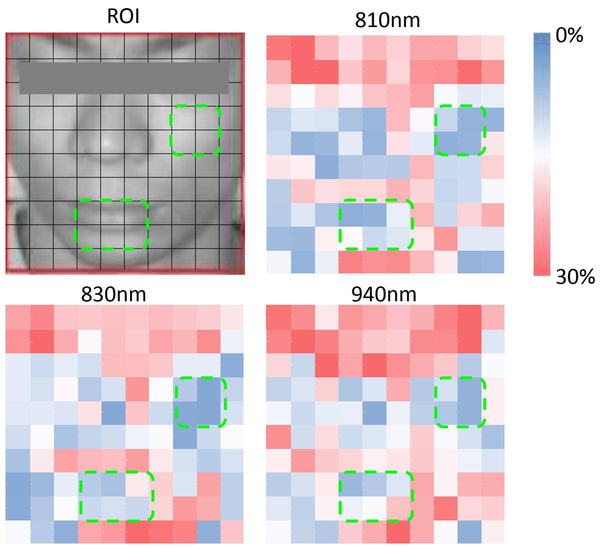


Fig.3 Calculated PR and Sleep Stage

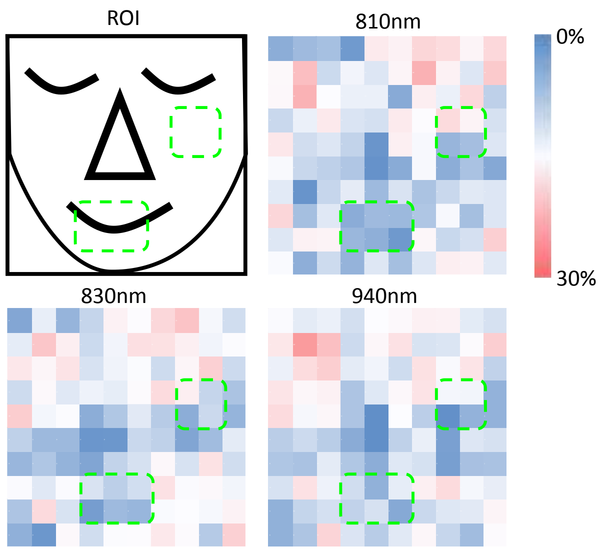
shoulder and nose are relatively small. Fig.7 shows the average error rate of the ROI enclosed by the green frame. The higher the RR, the lower the calculation accuracy. It was considered that a low RR produces deep breathing, and deep breathing movements create a large luminance value change.

5. DISCUSSION

Conditions to measure PR and RR from images are examined. For PR, it was thought that the lip and cheek region is suitable for measurement ROI. Since the measurement of pulse rate is derived from the change in luminance intensity value due to increase and decrease of absorption of hemoglobin in the capillaries, it is thought that the skin, where the epidermis is thin, and the plane, which is not easily influenced by body motion, were good. In addition, the shoulder and nose region was suitable for RR measurement. Because the



(a) Subject A



(b) Average error for all subjects

Fig.4 PR error for each region; Blue represents less error and Red represents larger error

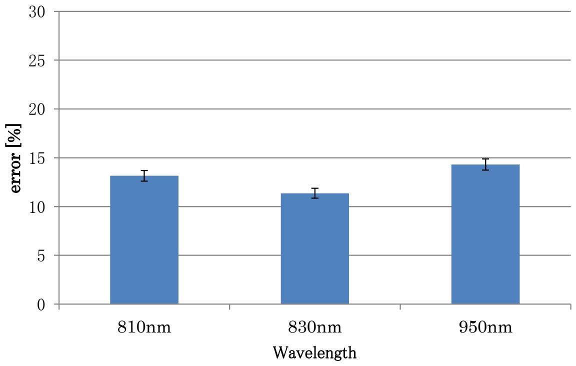


Fig.5 Average error rate of calculated PR of the ROI enclosed by the green frame

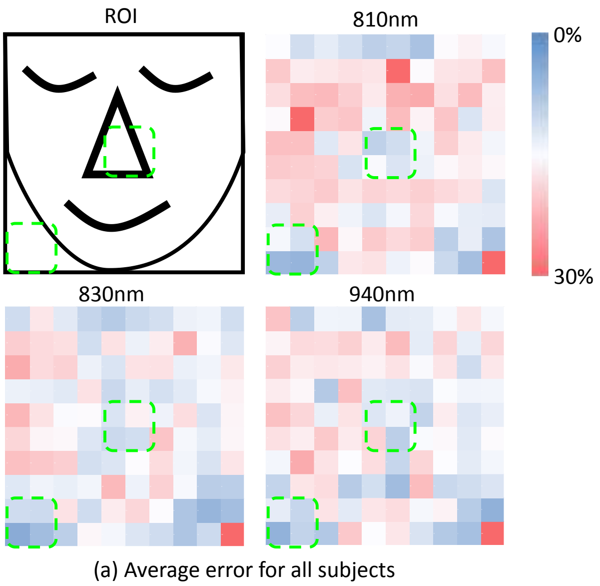


Fig.6 RR error for each region; Blue represents less error and Red represents larger error

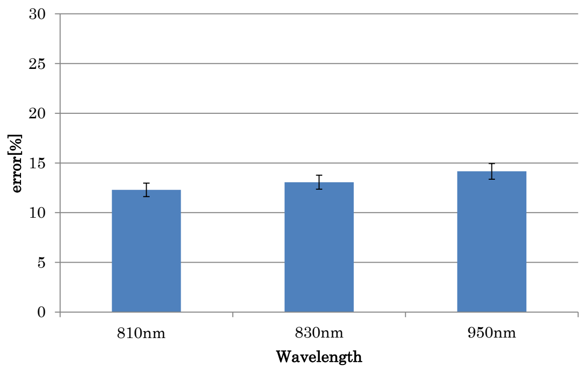


Fig.7 Average error rate of calculated RR of the ROI enclosed by the green frame

measurement of RR is derived from the change in luminance intensity value caused by movement of the thorax in respiratory motion, it is considered that the shoulder region was more suitable than the facial region.

The accuracy of the PR and RR were not very high. We believe that improvement of accuracy can be achieved by improving signal processing with reference to other research. However, since the relationship between the PR and the sleep stage can be seen in the present method, in the future, it is thought that sleep evaluation by near infrared image measurement is possible by composing information such as pulse rate, respiration rate, body motion, etc., which improved accuracy.

4. CONCLUSIONS

This study aims to propose a non-contact measurement method for evaluating sleep quality. In this paper, an effective light source wavelength and suitable ROIs were examined. In the future, we intend to integrate information obtained from video imaging such as for PR, RR and other information to develop a more efficient algorithm for evaluating sleep quality.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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