Plethysmography Using Skin Images Captured by RGB and Narrowband Filter Camera

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***Abstract*—Telecare has become of increasing importance during the COVID-19 pandemic, and the precise measurement of plethysmography has been shown to be highly effective. We propose a plethysmography measurement method using skin images captured by a combination of RGB and a narrowband filter (NBF) camera. For precise measurement, we introduce an independent component analysis score combined with the moving images. Our experimental results showed that the proposed method resulted in a better reproduction of plethysmography than that of individual images and also ICA scores only from RGB moving images.**

Keywords—noncontact plethysmography, moving images, telecare system, individual component analysis

I. Introduction

Because of the COVID-19 pandemic, online diagnosis and telecare systems have become increasingly important. In telecare systems, telemonitoring of vital data, such as blood pressure and heart rate, is useful and effective to diagnose health conditions and to detect acute disease [1]. Noncontact vital data measurement using moving image in particular is increasingly useful to assist with daily monitoring.

Heart rate monitoring using video has been studied previously [2][3]. Yoshizawa and colleagues proposed blood pressure measurement using pulse transit time from the image intensity changes of video [4]. The time variance interval from RR intervals from ECG can be used for the measurement of disturbance of autonomic nerves [5]. In this monitoring, precise measurements of plethysmography have proven to be highly effective. Pulse heart rates have usually been estimated using the moving images of green light using RGB cameras. For detecting more precise heart rates, independent component analysis (ICA) has been applied to each RGB image to decrease the effects of noises [6]. In this study, we propose a measurement method using moving images of the skin that are captured with an RGB camera and narrowband filter (NBF) camera, and these images are combined using ICA to achieve precise plethysmography.

II. Method

A. Capturing Skin Image data with RGB + Narrowband Filter Images

RGB moving images of the subjects' skin were captured with a normal RGB camera. Narrowband moving images were also captured using tunable narrowband filters and a grayscale camera, as shown in Fig. 1. The skin of the subject was illuminated using halogen light, which covered 400–1700 nm.

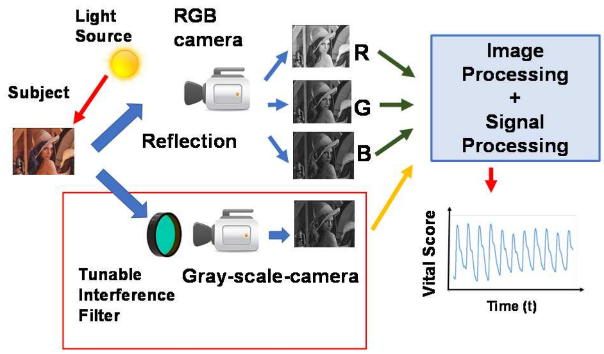

Fig. 1. Measurement with RGB + narrowband filter moving images

B. Processing the captured images

First, we selected a region of interest (ROI) for obtaining plethysmography. After preliminary studies in which we tried two parts of the skin, the forehead and palm, the palm was chosen since it showed better time-dependent changes. The ROI (100 x 100 pixels) was subjectively chosen such that the region that was highlighted included the vessel area. The average of reflectance intensity of the ROI image was assigned as the vital data for the corresponding plethysmography.

To obtain a stable area of the ROI in moving video to reduce signal disturbance caused by body movement, we tracked the selected ROI area by using pattern matching between the original ROI and the captured frames.

C. Signal Processing for precise plethysmography signal

The time sequences of the vital data were calculated based on the average intensity value in ROI pixels of moving images as original signals from each of the R, G, and B images and the narrowband filtered image. Each signal, filtered with a 0.7–3 Hz band-pass filter from the original signals using FFT, were used as the component signals. The plethysmography signal was calculated from the scores of multicomponent from individual component analysis (ICA) of those components.

D. Evaluation

We evaluated signal precision by obtaining the maximum value of a cross-correlation function (Rcc_max) between the calculated plethysmography from video and the control signals from photo-plethysmography.

III. Experiments

The size of each captured image was 960 x 600 pixels and the frame rate was 30 fps. We took three measurements, with 650 nm, 800 nm, and 900 nm narrowband filters, and selecting a 10 nm bandwidth from the tunable narrowband filter (Varispec™: CRI Inc.) (see Fig. 2).

The object, the front of the palm of the hand, was recorded for a time period exceeding one minute to obtain stable images. Simultaneously, photo-plethysmography was measured as control signals. In these experiments, the palms of 2 subjects were investigated.

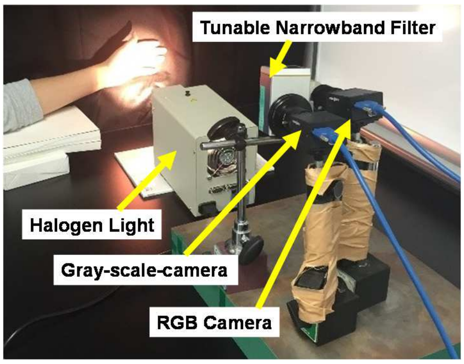

Fig. 2. Depiction of Experimental Setup

IV. Results

Table I shows the results of the cross-correlation values between the calculated signals from the single-band images, the combined ICA images, and the vital plethysmography for each subject.

TABLE I. Cross-Correlation Values

Sub1/Sub2	(1) NBF=650 nm	(2) NBF=800 nm	(3) NBF=900 nm	Ave.
only R	0.745/ 0.618	0.852/ 0.789	0.782/ 0.784	0.793/ 0.730
only G	0.873/ 0.554	0.898/ 0.815	0.890/ 0.850	0.887/ 0.740
only B	0.845/ 0.516	0.890/ 0.807	0.887/ 0.836	0.874/ 0.719
only NBF	0.673/ 0.598	0.830/ 0.829	0.622/ 0.344	0.708/ 0.590
RGB(ICA)	0.904/ 0.812	0.904/ 0.799	0.900/ 0.842	0.903/ 0.818
RGB+NBF(ICA)	0.906/ 0.811	0.895/ 0.905	0.903/ 0.761	0.902/ 0.826

The results show that the evaluation values using ICA scores were higher than using only component signals including only G images. Concerning the NBF wavelength, the evaluation score differed depending on the subject. In the case of subject A, there was no difference between the ICA score with RGB images and RGB+NBF. On the other hand, the evaluation value of ICA score of RGB+NBF was better than using only RGB signals.

V. Discussion

Fig. 3 shows the changes in cross-correlation values between the ICA scores of multi-band images and the vital signals of each of the 100 frames for subject 2. The red line shows the cross-correlation values using ICA scores of 4-band images with 650 nm NBF, and the blue line shows the scores of only the RGB images. Comparing the two signals, the 4-band scores covered more precise patterns than the RGB scores.

Concerning the individual differences in the evaluation values, Fig. 4 shows the result of signals to compare the measurements, in which the red line shows the calculated ICA score signals using 4-band images and the blue line shows the photo-plethysmography signals. The photo-plethysmography signals of subject 1 had lower second-peak components, related to angiosclerosis, than subject 2, which might have caused individual differences in the evaluation values.

VI. Conclusion

Plethysmography measurement using RGB+NBF filter moving images was proposed for precise plethysmography. Our experimental results showed that using the ICA of combination signals of RGB images and NBF moving images resulted in a better reproduction of plethysmography than both the vital signals from individual images and also ICA scores only from RGB moving images. However, the precision depended on the individual characteristics of the subjects.

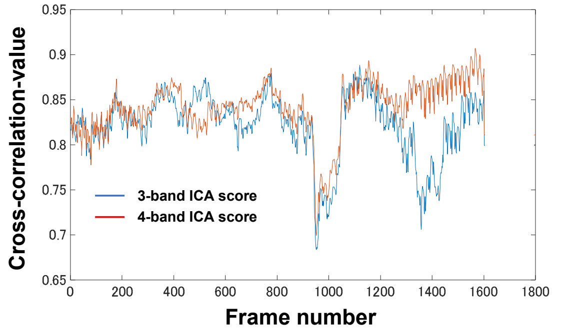

Fig. 3. Changes in cross correlation values for short time divisions

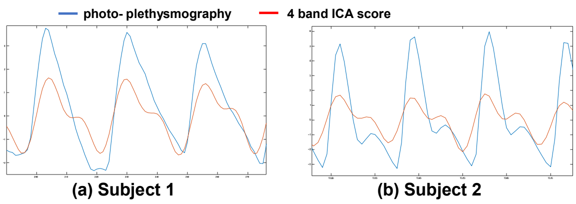

Fig. 4. Individual differences in plethysmography

Acknowledgment

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