A Method for Estimating Blood Flow Condition from Skin Tone Information in Real Face Images

Miku Shimizu, Naoaki Itakura, Kazuyuki Mito, Kaito Hino, Kohei Okura, Tota Mizuno
The University of Electro-Communications
1-5-1, Chofugaoka, Chofu, Tokyo, Japan
e-mails: m.shimizu.0320@gmail.com itakura@uec.ac.jp k.mito@uec.ac.jp kai.vas.1023@gmail.com
xzjb2957@gmail.com mizuno@uec.ac.jp

Abstract**—In this study, we investigate a method to obtain detailed blood flow changes from nasal images. We have previously estimated autonomic nervous activity as an indicator of stress by focusing on the R-B component values (Difference value between R and B component values, the three primary colors of color) of the nasal region in real face images. In fact, changes in R-B component values were found to correspond to large stress fluctuations. However, the effect of noise due to light reflection and shadows could not be taken into account. If the effects of light intensity can be removed, the accuracy of the assessment of autonomic nervous activity can be improved, which would greatly contribute to the development of emotion estimation methods. As a method for this purpose, we propose the introduction of the R+G+B value (Total value of the three primary colors of light: R-component value, G-component value, and B-component value) index, which is black when the R+G+B value is close to 0 and white when the R+G+B value is close to 765. This study will clarify the usefulness of this index by using a heat map that reflects the number of pixels present, with R+G+B values on the x-axis and R-B component values on the y-axis. When this method was applied to an experiment in which changes in blood flow were intentionally induced, characteristic changes in distribution were observed at locations where changes in blood flow occurred. This suggests that by focusing on the locations in the heat map where changes corresponding to changes in blood flow rate are observed, it will be possible to remove the effects of light intensity regardless of differences in people or environments. By applying the proposed method, it is possible to construct a stress estimation system that can be easily used by anyone and contribute to the development of the interface field.**

Keywords - Real face image; Blood flow; Heat map; Stress.

I. INTRODUCTION

In recent years, the need for emotion estimation has increased for humans to lead more comfortable lives, for example by measuring fatigue and concentration levels in the workplace and improving the workplace environment by introducing appropriate rest systems. Methods for emotion estimation using various biological information, such as heartbeat pulse waves, electroencephalography (EEG) and thermal images have been investigated. Unlike other methods, the method using thermal imaging does not cause stress to the subject. It does not restrict the subject's behavior, as it uses a non-contact infrared thermography camera. This makes it a useful method for emotion estimation. In addition to thermal images, methods using real images have also been studied in recent years as a more cost-effective and easy-to-use method of emotion estimation for everyone. We have been studying methods for estimating autonomic nervous activity, which is an indicator of stress, from real face images taken with a webcam. However, the effects of light exposure caused by differences in the shooting environment and by facial irregularities have reduced the accuracy of the evaluation. There have been no studies that have examined the effects of light intensity. However, considering that this stress estimation system is to be operated in a real environment, it is considered to be a problem that needs to be solved as soon as possible, since there are no restrictions on how the system is to be used to take pictures, and the pictures are not always taken under the same conditions. Therefore, this study attempts to solve this problem.

The rest of the paper is structured as follows. Section 2 introduces previous studies on stress estimation, Section 3 describes the proposed method, and Section 4 examines the results of the actual implementation of the proposed method and its effectiveness. Section 5 concludes our work.

II. PREVIOUS STUDY

Many emotion estimation methods have been studied using facial thermal images. Previous emotion estimation using facial thermal images has been based on the differential temperature between the nasal area, which is a sympathetic index of autonomic nervous activity, and the forehead area, which is less affected by autonomic nervous activity [1]. Skin temperature is the antagonistic temperature between the conducted heat of deep body temperature, changes in blood flow under the skin and environmental temperature. Therefore, the differential temperature between the nasal and forehead areas is an index that captures changes in peripheral blood flow under the skin in the nasal area due to the low influence of environmental temperature changes and deep body temperature [1]. Furthermore, a method that utilizes temperature changes not only in the nasal area but also in the entire face is also being considered. Since evaluation in combination with multiple facial regions is now possible, it is

 ISBN: 978-1-68558-163-3

possible to estimate autonomic nervous activity with higher precision than with conventional methods [2]. However, these previous methods require the use of an infrared thermography camera, which is costly.

Therefore, as a solution to the cost problem, we have studied a method to evaluate autonomic nerve activity with the same accuracy as facial thermal images by acquiring changes in peripheral blood flow using real facial images, which can be easily acquired by anyone [3]. The real facial image captured by a visible light camera, such as a web camera, is the reflected light on the skin surface that is not absorbed by capillaries and subcutaneous tissues among the light transmitted into the skin. As shown in Figure 1, the R component has the deepest depth of transmission, followed by the G and B components, in that order. Based on these facts, we considered that the R-B component value, which is the difference between the R component with the deepest penetration depth into the subcutaneous region and the B component with the shallowest penetration depth, could be used to capture changes in the peripheral blood flow rate through the subcutaneous region. In our previous study, we obtained the variation of R-B component values in the nasal region during a 10-minute mental arithmetic task, suggesting the possibility of evaluating stress variation in response to switching events, such as the timing of calculation errors during a mental arithmetic task or at the end of a mental arithmetic task [3]. However, in the methods of previous studies [3], all pixels acquired as the nose were used for analysis. Therefore, the R-B component values are calculated including information that does not include changes in blood flow, such as blown-out highlights and blocked-up shadows caused by changes in light intensity and nostrils in the nasal area, which may reduce the accuracy of obtaining changes in blood flow. So, it is necessary to identify whether the pixels used represent the effect of light intensity or blood flow conditions.

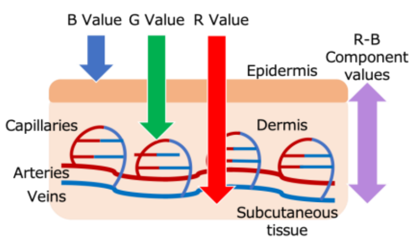


Figure 1. Transmission depth by wavelength of RGB light.

In this study, we propose to observe the distribution of color information of pixels corresponding to the nasal area in each frame by creating a heat map with R-B component values on the vertical axis and R+G+B values on the horizontal axis. Using the proposed method, we believe it is possible to observe how the characteristics of pixels that do not contain information on changes in blood flow, such as white highlights and blocked shadows due to changes in light intensity, differ from pixels that represent changes in blood flow. By clarifying this difference, it will be possible to remove the effect of light intensity from the nasal image and capture only changes in blood flow, using the nature of the data, thus enabling a more accurate estimation of autonomic nervous activity.

III. PROPOSED METHOD

The purpose of this study is to clarify the distribution and characteristics of pixels corresponding to the nose by creating heat maps, and to devise a method to quantitatively remove the effect of light intensity and acquire only blood flow changes. The heat map should be created as shown in Figure 2, with R-B component values on the vertical axis and R+G+B values on the horizontal axis. The reason for adopting R+G+B values on the horizontal axis is that R+G+B values close to 0 indicate black color and those close to 765 indicate white color, and we thought it would be possible to distinguish pixels that correspond to white skips or shadows by using R+G+B values to limit pixels of interest.

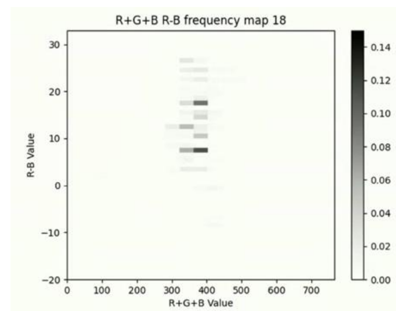


Figure 2. Heat Map Example.

The proposed method was implemented in a video of an upstream vascular compression experiment in which changes in blood flow can be intentionally induced. By creating this heat map for each frame, it is possible to reveal how the distribution changes when changes in blood flow occur, such as during vascular compression or release, and how the effect of light intensity is distributed over time.

IV. RESULTS

Figure 3 shows the time-series data of R-B component values in the nasal area when the proposed method is applied to an experiment in which blood flow changes are intentionally induced, and Figure 4 shows the results of the heat map. Figure 4 (a) shows the heat map before the blood flow change at the 20-second point in Figure 3, (b) shows the after the blood flow change at the 30-second point in Figure 3, and (c) shows the 50-second point in Figure 3 when the blood flow change occurred again and the condition returned to the same as in (a).

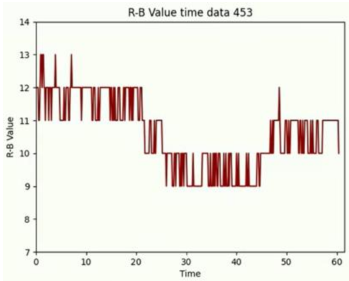
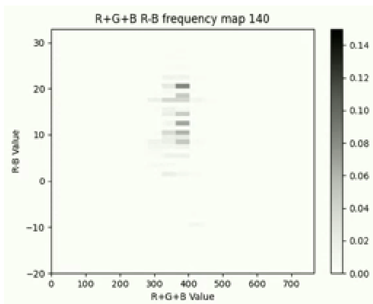
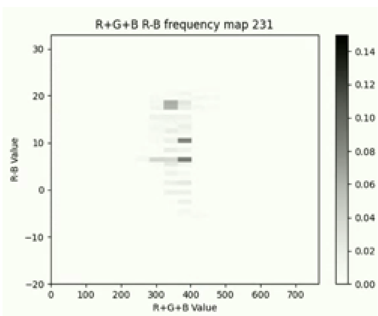


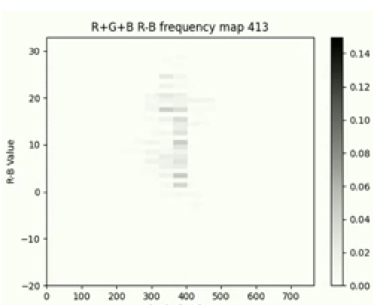
Figure 3. Time series data of R-B component values of the nasal area.



(a) Before the blood flow change at the 20-second point



(b) After the blood flow change at the 30-second point



(c) the blood flow change occurred again and the condition returned to the same as in (a)

Figure 4. Heat map results.

As can be seen from the results of (a) and (b), when a blood flow change occurs and blood flow slows down, the distribution of pixels in the nasal area does not move horizontally, but tends to drop vertically overall. This is thought to be because the R component of arterial blood decreased and the B component of venous blood increased due to the slowing of blood flow, resulting in a decrease in only the R-B component value without much change in the total R+G+B value. When the blood flow improved and returned to the initial state again, there was an overall tendency for the distribution to be pulled up vertically, as in (b) to (c), with (c) returning to a distribution similar to that in (a). However, the shape of the distribution does not completely return to the same state, but is slightly elongated vertically, leaving remnants of the distribution in (b), suggesting that when blood flow is impaired, the effect appears instantaneously, but when blood flow is improved from a bad state, it does not return instantaneously but slowly.

V. CONCLUSION

The purpose of this study was to examine the relationship between changes in blood flow and changes in pixel distribution by creating a heat map with two axes: the R-B component values, which allow us to see changes in blood flow, and the R+G+B values, which are pixel coloration. The results showed that, using the proposed method, heat maps tend to show characteristic changes in the time at which changes in blood flow occur. In the present experiment, the characteristics of the heat maps were more pronounced because we used an experiment in which changes in blood flow were intentionally induced. However, in an actual environment in which a stress estimation system is used, changes in blood flow are not likely to occur as frequently as in this experiment. Therefore, there is a need to examine whether the proposed method is still useful under actual operational conditions.

In addition, changes in the features of the heat map were visually confirmed this time, which is not sufficient to reflect them in the system. Therefore, it is considered necessary to quantitatively discriminate between this change in blood flow rate and the corresponding heat map features. If quantification of discrimination becomes possible, it will be possible to obtain only the changes in blood flow rate from skin color information without regard to individual differences in skin color, such as suntan, or light intensity in the shooting environment, eliminating the effects of light intensity, and this will improve the development of this system.

REFERENCES

[1] H. Zenju, A. Nozawa, H. Tanaka, and H. Ide, “Estimation of Unpleasant and Pleasant States by Nasal Thermogram”, Transactions on Electronics, Information and Systems, vol. 124, no. 1, pp. 213-214, 2004.

[2] S. Matsuno, T. Mizuno, H. Asano, K. Mito, and N. Itakura, “Estimating Autonomic Nerve Activity Using Variance of Thermal Face Images”, Artificial Life and Robotics, vol. 23, no. 3, pp. 367-372, 2018.

[3] M. Shimizu, Y. Matsumoto, N. Itakura, K. Mito, and T. Mizuno, “Evaluation of Methods for Estimating Autonomic Nervous Activity Using a Web Camera”, Artificial Life and Robotics, vol. 28, pp. 718-725, 2023.