Surface Skin Blood Flow Dynamics during Muscle Contraction Using Filtered Camera

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***Abstract*—The purpose of this study is to elucidate the surface skin blood flow dynamics during muscle contraction using real images with filters that pass near-infrared wavelengths. It has been shown that the depth of transmission differs depending on the RGB color components. In the previous study, it was suggested that the blood flow state obtained from the R-B component value, which is the difference between the deepest R component value and the shallowest B component value, may be used as one of the evaluation indices of muscle activity. However, the use of the near-infrared light component, which has a deeper penetration depth into the subcutaneous region than the RGB light component, has not yet been examined in this method. The near-infrared light component has a possibility to measure the blood flow state inside the subcutaneous tissue with high accuracy, because the light penetrates deeper into the subcutaneous tissue than the RGB light component. Therefore, in addition to the RGB light components used in the conventional method, a visible light camera equipped with a filter that transmits wavelengths above the near-infrared light component is used. In the experiment, a load equivalent to 40% of Maximum Voluntary Contraction (MVC) was applied to the subject's upper arm. The subjects were kept in a resting state, and then the load was applied to their arms and they were kept in a resting state again. As a result, the R component values with the filter showed a larger change than the R-B component values without the filter when the load was applied. This result indicates that the R-B component with filter can capture the changes in blood flow more easily than the conventional method.**

Keywords- Real image, muscle, Filter, Blood Flow.

I. INTRODUCTION

Assessment and estimation of autonomic nervous activity, which changes in response to situations such as fatigue and concentration, can help humans to lead a comfortable life. It has been shown that autonomic nervous system activity affects blood flow. The methods to measure changes in subcutaneous blood flow include evaluation using thermal images of the face using an infrared thermography camera and evaluation using real images using a visible light camera such as a web camera. In particular, the real image method can be used for various applications because it does not require any special equipment for measurement.

Various studies have been conducted on the method using real images, and it has been clarified that the depth of transmission of each color component of visible light (RGB) to the skin differs depending on the color. Using this property, it has been suggested that by focusing on the R-B component values, it may be possible to obtain the state of peripheral blood flow and evaluate autonomic nervous system activity [1]. It was also suggested that the blood flow state obtained from the R-B component values could be used as one of the evaluation indices of muscle activity that enables the estimation of muscle fatigue. However, these methods have not yet investigated the use of the near-infrared light component, which has a deeper penetration depth into the subcutaneous region than the RGB light component.

In this study, we will examine whether a visible light camera equipped with a filter that transmits wavelengths near the wavelengths of near-infrared light that can be acquired can be used to measure subcutaneous blood flow in the biceps brachii muscle with high accuracy and to evaluate muscle activity.

II. PROPOSED METHOD

The near-infrared light component penetrates deeper into the subcutaneous tissue than the RGB light component, and thus has the potential to measure the state of blood flow inside the subcutaneous tissue with high accuracy. For this reason, in addition to the RGB light component used in the conventional method, a new visible light camera equipped with a filter that transmits wavelengths above the near-infrared light component is used. We will evaluate the possibility of highly accurate measurement from the RGB light component and the RGB light component of the camera equipped with the filter.

III. EXPERIMENT SUMMARY

Before the experiment, green tape was applied to the subject's upper arm so that it formed a rectangle, and the analysis area was limited to the green tape. During the experiment, two smart phones were placed in a position where the rectangle formed by the green tape and the entire area from the subject's wrist to the shoulder were captured by an external camera.

In order to obtain data during muscle contractions that cause significant changes in epidermal blood flow, isometric contraction experiments were conducted to minimize the effects of noise generated by body movements. First, the subject's Maximum Voluntary Contraction (MVC) was measured to identify the location of the platform; MVC was measured three times for 10 s. MVC was calculated by measuring muscle forces at 2, 5, and 8 s and averaging them.

Next, using the calculated MVC, four different wavelength transmission filters (560 nm, 600 nm, 640 nm, and 660 nm) were attached to one smartphone in turn, and the following procedure was performed a total of four times.

First, the subject sat in a resting position for 60 seconds. Next, the elbow joint angle was maintained at 90° and the subject held a weight with 40% load by hand for 45 seconds, then the weight was removed and the subject again sat in a resting position for 60 seconds.

IV. RESULTS ANALYSIS AND CONCLUSION

A. Comparison of B-component values for each filter

Time series data of the wavelength of the B component acquired from cameras with filters on the entire upper arm were compared among four types of filters. The wavelength of the B component is generally between 460 and 500nm. There is a large difference in the B-component values between filters with wavelengths below 600 nm and above 640 nm, and a large change in the B-component values between filters with wavelengths of 640 nm and 660 nm. In natural environments, the sensitivity of the camera itself also changes due to changes in light intensity. When using such a filter, it is necessary to keep the light level constant. In this study, we used a filter that transmits light from wavelengths below 600 nm, which is sufficient for the filter to function even under fluorescent light, where the light intensity does not change to some extent. The higher the cutoff frequency of the filter, the lower the visible light component that can be acquired, and the lower the amount of light that can be acquired, the more the sensitivity of the camera is automatically increased. Therefore, the B-component values at 560nm to 640nm are higher than those at 640nm due to the increase in the sensitivity of the camera. On the other hand, the B-component values are lower at 660nm than at 640nm. It is considered that the pass-cut function of the filter works more strongly than the sensitivity adjustment to reduce the B-component values.

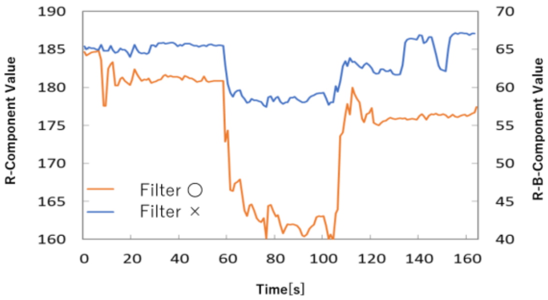
B. Comparison of data with and without filter

The time series data of the variation of the R-B component values obtained from the camera without the filter and the R component values obtained from the camera with the filter for the entire upper arm of subject 1 are shown in Figure 1 for the 560-nm filter and the 660-nm filter. Figure 1 shows that both component values decrease between 60 and 110 seconds when the camera is loaded by the weighted camera, regardless of the presence or absence of the filter.

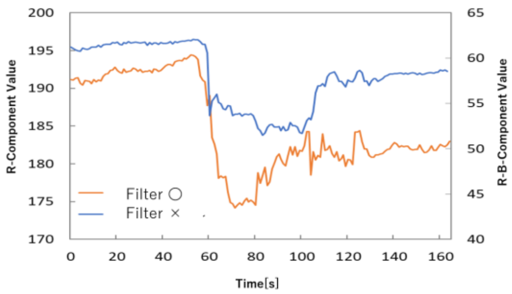
In Figure 1-(a), during the period of 60-110 seconds, the R component with the filter shows a larger change than that of the R-B component without the filter. Therefore, the proposed method can capture changes in blood flow more easily than the conventional method. On the other hand, fluctuations are observed in the unfiltered R-B component values between 120 and 160 seconds, but not in the filtered R component values. Whether these fluctuations are noise or not is not clear, and is a subject for future study.

In Figure 1-(b), we can see that the R component with filter contains higher frequency fluctuations than the R-B component without filter in the period from 80 to 120 seconds. It is considered that the difference between the R- and B-component values cancels out the fluctuations caused by the subject's movements and other factors.

From the above, it can be concluded that this method can easily capture the amount of change and can be applied to the measurement of minute changes in blood flow, such as in medical applications. On the other hand, the R-B component value of the conventional method that takes the difference value may be utilized for general applications where the shooting environment changes.



(a) 560 Filter



(b) 600 Filter

Figure 1. Change in R component value with filter and R-B component value without filter

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