Real time swallowing measurement system by using photometric stereo

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***Index Terms*— Photometric stereo, near-IR light, Real-time swallowing measuring system,**

I. Introduction

In this paper, we propose a measurement system to estimate the movement of the thyroid cartilage by the camera sensor. Several analyses methods of swallowing have been proposed. However, these methods require to put on contact sensors on the subject's throat, then subjects cannot drink naturally. Therefore these system cannot measure the natural swallowing process correctly.

We developed a measurement system based on the vision sensor in order to achieve the non-contact and non-invasive sensor. The movement of the subject's thyroid cartilage is tracked by the three dimensional information of the surface of the skin measured by the photometric stereo [1]. To solve a problem of the photometric stereo, we constructed a camera system that used near-IR light sources and three near-IR camera sensors.

We confirmed the effectiveness of proposed system by experiments.

II. Real time photometric stereo

The photometric stereo requires three images that the images be captured under at least three light sources. Three non-visible near-IR light sources 780nm, 850nm and 880nm are introduced to the proposed camera system, and these are irradiated to the object at the same time. These three wavelength lights are separated using band-pass filters in the camera. By this framework, proposed system can measure surface normal vectors in real time. Fig.1 shows the proposed system. Band-pass filters are used to limit the wavelength of the light to each sensor corresponding light source. The wavelengths of the band-pass filters are 780nm, 850nm, and 880nm wavelength in the near-IR spectrum not influenced by fluorescent light sources. Normal vectors of the subject's thyroid cartilage are measured by this system.Fig.2 is a result of measuring the subject's throat.

The subject's thyroid cartilage is tracked by the template matching by using the normal vectors measured by the photometric stereo. The similarity of the template is calculated by ZNCC.

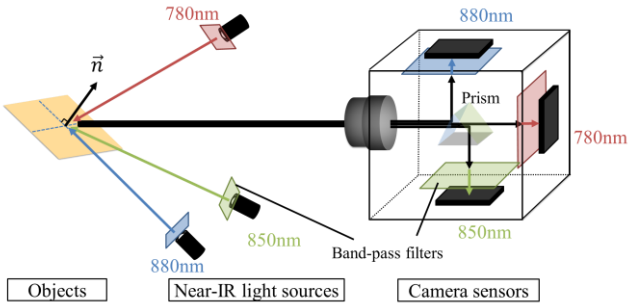

Fig.1 Proposed camera system

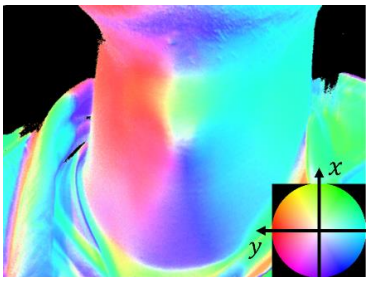

Fig.2 Estimated surface normal vectors of the subject's throat

III. Experiments

We performed evaluation experiments of the measurement accuracy of the movement of the thyroid cartilage. We measured the swallowing process of five subjects. The ideal values were selected the location of the thyroid cartilage manually from the movie of the swallowing process. The measurement accuracy was calculated the distance between the ideal values and the measured location of the thyroid cartilage. Fig.3 shows a result of one experiment. This shows that the movement of the thyroid cartilage could be measured with high precision. Table.1 shows the measurement accuracy of the all subjects.

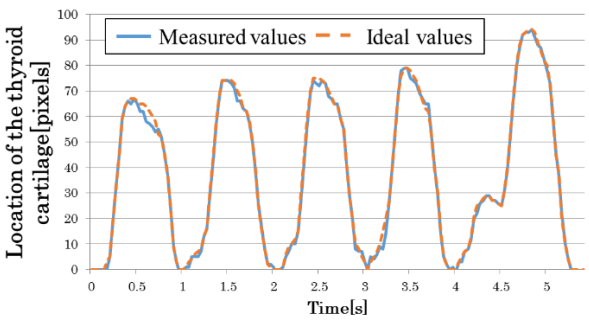

Fig.3 The tracking result

Table.1 Measurement accuracy of the all subjects

	No.1	No.2	No.3	No.4	No.5	Ave.

Differences [pixel]	0.872	1.367	1.193	1.097	0.778	1.061

REFERENCES

[1] WOODHAM R.J, "Photometric method for determining surface orientation from multiple images", Optical Engineering, vol. 19(4), pp. 139-144, February 1980