Breath Monitoring by Thermal Vision

Sonomi NAGATA
Graduate School of Information Science and Technology
Aichi Prefectural University
Nagakute, Aichi, 480-1198 Japan
im182008@cis.aichi-pu.ac.jp

Atsuya ISHIDA
Graduate School of Information Science and Technology
Aichi Prefectural University
Nagakute, Aichi, 480-1198 Japan
im162003@cis.aichi-pu.ac.jp

Kazuhito MURAKAMI
Graduate School of Information Science and Technology
Aichi Prefectural University
Nagakute, Aichi, 480-1198 Japan
murakami@ist.aichi-pu.ac.jp

***Abstract*—In this paper, we propose a method to monitor breathing rate using two features, temporal feature and spatial feature. Temporal feature is obtained by the periodical change of temperature of the nostrils, and spatial feature is obtained between wing of the nose and around it. The effectiveness of the proposed method was confirmed by testees breathing with a metronome. As a result, the difference between the frequency of the metronome and the frequency obtained by the proposed method is less than 0.01 Hz, and it was confirmed that the breathing rate can be estimated from the temperature image without contact with testees.**

Keywords—thermal change of nostril, thermal vision, nostril detection, breath monitoring

I. Introduction

This paper proposes a method to monitor breathing rate using two features, temporal feature and spatial feature. In inhalation, air passes through the nose and the temperature around the nostrils becomes lower. On the other hand, in exhalation, it becomes higher, and this temperature change is periodically repeated.

The key point in our prototype system is the correctness of the nostril regions extraction and the accuracy of breathing rate. We have confirmed experimentally the appearance of the nostrils regions with change in observation position (angle)[1].

This paper describes basic features of the prototype system that is used to extract nostril regions from thermal image sequences in Section 2, and explains steps to extract nostrils and obtain breathing rate in Section 3. Section 4 concludes our research and explains our future works.

II. Thermal Features in Nostril Regions

This paper defines the nostrils and wings of the nose as follows. The image is shown in Fig. 1.

- [Nostril] one of the two holes at the end of the nose, through which breathing and smelling things are taken place.
- [Wing of the nose] the lateral surface of the external nose, and which flares out to form a rounded eminence around the nostril.

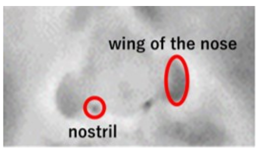

Fig. 1. An example of nostril and wing of the nose.

This research is sponsored by the Juten-Kenkyu-Project (R1) of Knowledge Hub Aichi.

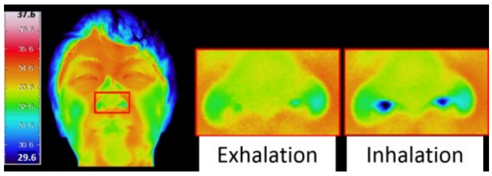

Fig. 2. Temperature change of nostril regions

The basic features to measure breathing rate from thermal image sequences are as follows:

- Spatial temperature difference between wing of the nose and around it is high.
- In inhalation, the temperature around the nostril becomes lower.
- The temperature around the nostril regions will change periodically and is influenced by exhalation and inhalation as shown in Fig. 2.

III. Steps to Extract Nostrils and Obtain Breathing Rate

The flowchart to extract nostrils and obtain breathing rate is shown in Fig. 3. The results of each step are shown in Fig. 4.

Step0. Input thermal images

The thermal image T of size W x H is taken from thermal vision camera facing straight to the camera, here W is the width and H is the height of the image, and let the upper left corner of the image be the origin.

Step1. Extract face region

The background is subtracted from the face region. The thermal image T is binarized with a threshold t_1 and let the binary image be I_1. Since the neck is assumed to be the thinnest part in the face region, the projection $n(j)$ in each row j in the image I_1 is calculated by

$$n(j) = \sum_{i=1}^{H} I_1(i, j) \tag{1}$$

, and let j which minimizes $n(j)$ be the neck position j_{neck}. Among the connected components with $I_1(i,j) = 1$, let the minimum i in row j be $i_1(j)$ and let the maximum i in row j be $i_2(j)$. Obtain the center of face region R as follows:

$$R = \{(i,j) | i_1(j) + \frac{i_2(j) - i_1(j)}{3} \le i \le i_2(j) - \frac{i_2(j) - i_1(j)}{3}, \; j_1 + \frac{j_{neck} - j_1}{3} \le j \le j_{neck}\} \tag{2}$$

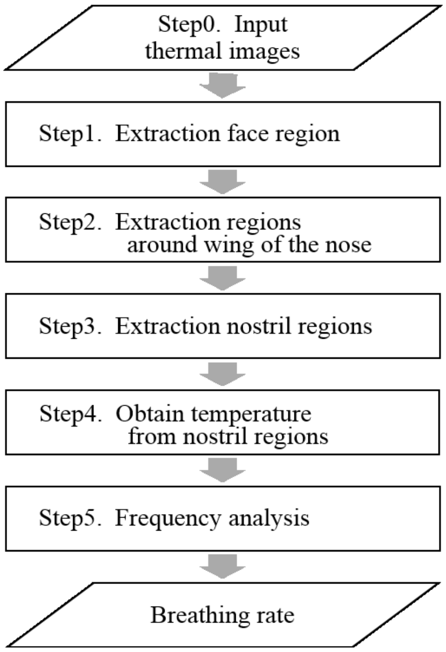

Fig. 3. Flowchart of the proposed method.

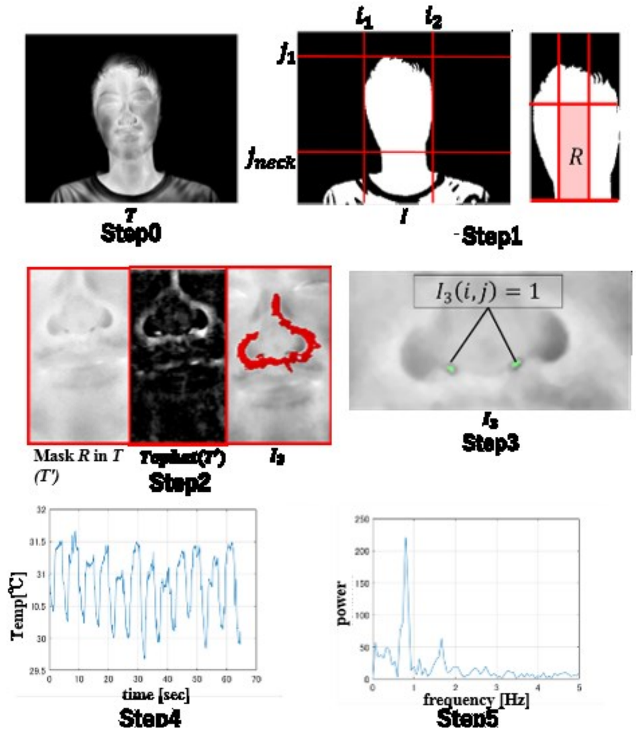

Fig. 4. Result of processing in each step.

Step2. Extract regions around wings of the nose

Since the thermal difference is not so large, the contrast in the face region R is enhanced by Top-hat transformation. Then, the image is binarized with a threshold value t_2 that is determined by the discriminant analysis method. Next, apply labeling processing to the binarized image and extract largest two connected components. Let the binarized image which includes only these two connected components be I_2. Then, mask T by I_2 and obtain thermal image T_2.

Step3. Extract nostril regions

Calculate the temperature histogram of T_2 and obtain threshold t_3 by p-tile method. Then, binarize T_2 with t_3, and let the result image be I_3. Let these areas be the nostril regions.

Step4. Obtain temperature from nostril regions

Mask I_3 in the thermal image T, and calculate the average temperature $c(n)$ (n = 1, ..., the number of frames) in the region where $T(i,j) > 0$ ($i = 1, ..., H, j = 1, ..., W$).

Step5. Frequency analysis

Fourier transformation is performed on the temperature sequence $c(n)$ ($n = 1, 2, ...$) of the nostril region in each frame, and let the frequency having the highest frequency power from 0.1 Hz or more be the breathing frequency.

IV. Experiment and Future Works

The effectiveness of the proposed method was confirmed by testees breathing with a metronome. As a result, the difference between the frequency of the metronome and the frequency obtained by the proposed method is less than 0.01 Hz as shown in Table 1. We also confirmed experimentally

TABLE I. Comparison of Frequency Breathing with Metronome

Frequency	Value 1	Value 2	Value 3
Metronome [Hz]	0.250	0.333	0.416
Testee 1 [Hz]	0.250	0.333	0.416
Testee 2 [Hz]	0.250	0.333	0.416
Testee 3 [Hz]	0.260	0.333	0.420
Testee 4 [Hz]	0.249	0.333	0.416
Testee 5 [Hz]	0.249	0.333	0.416
Testee 6 [Hz]	0.249	0.333	0.416
Testee 7 [Hz]	0.249	0.333	0.416
Testee 8 [Hz]	0.149	0.333	0.116

with a radar Doppler sensor that the breathing rate can be estimated from the temperature image sequence without contact with testees. Although our system works well, it is necessary to improve the algorithm to be calculated in short time range.

References

[1] A. Ishida and K. Murakami, “Extraction of Nostril Regions using Periodical Thermal Change for Breath Monitoring,” Proc. of International Workshop on Advanced Image Technology 2018 (IWAIT2018), paper number 117, 5pages, Chiang Mai (Thailand), Jan. 2018.