Bathroom Watching using a Breath Detection System

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***Abstract* — We have developed a watching system for bathrooms. The new feature of this system lies in its ability to detect a person's breathing by using an FG vision sensor. This support of breath detection is effective to reduce false alarms.**

I. Introduction

Recently, domestic accidents have been increasing in Japan [1]. These kinds of accident occur in private areas such as bedrooms, toilets and bathrooms, and tend to be found too late [2]. Accidents, particularly those occurring in the bathroom, can often result in the sufferer experiencing serious aftereffects, and can even result in death [3], [4].

In order to prevent these kinds of accidents, many systems have been proposed or implemented whereby people living together in the same place are alerted when danger is detected. Many of these systems sense the motion of the human body in the bathroom, and determine that a bather has taken ill when movement ceases [5]. However, the relaxed posture of a person bathing is actually very similar to that of a person who has passed out. It is therefore very difficult to differentiate between the two states.

We paid attention to the chest movements associated with breathing in order to make the distinction between the two postures. In this paper, we describe a new watching system supported by the breath detection using a fiber grating (FG) vision sensor.

II. Experimental system

A. Fiber Grating (FG) Vision Sensor

An FG vision sensor is composed of a semiconductor laser (wavelength 810nm, power 930mW), an FG element and a CCD camera. An FG vision element is a kind of diffraction grating. It is made from two optical fiber sheets put together at right angles [6], [7] and [8]. The laser beam incident on an FG element forms many bright spots on the plane which faces the FG elements. The CCD camera captures an image of the spots which are regularly located in a line in all directions (Fig. 1).

Each spot in the image moves in a fixed direction, with the corresponding distance due to the change in the height of the spots. The distance from the reference level plane to the spot on an object shown in Fig. 2 is calculated using equation (1).

$$Z = \frac{h^2\delta}{dl + h\delta} \qquad (1)$$

where h is the distance from the reference level to the center

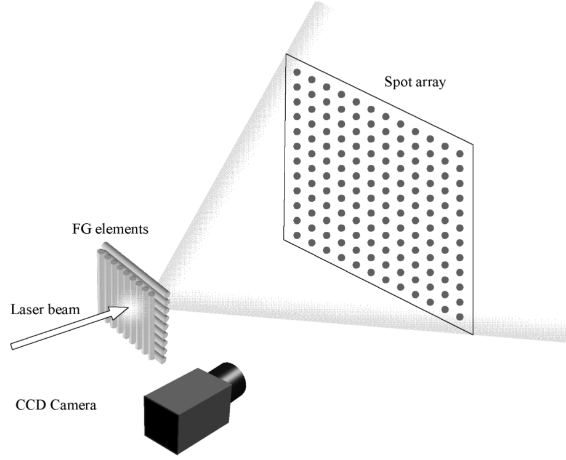


Fig.1. FG vision sensor.

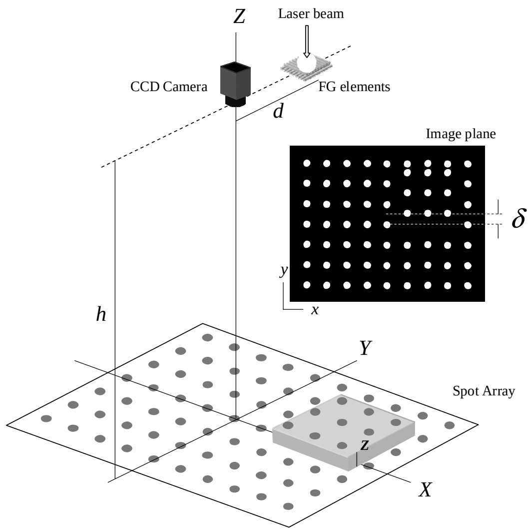


Fig.2. Projected bright spots and the movement of them due to the change in the height of the spots.

of the lens, d is the length of the baseline (the distance between the FG elements and the lens), l is the distance between the lens and the image plane, and δ is the amount of movement of the spot on the image plane.

B. System Configuration

Fig. 3 shows the experimental system. The bathroom is a normal prefabricated bath which is adopted to newly built or rebuilt apartment buildings.

In this system, the spots are projected on the floor of the bathroom by fixing the FG sensor to the ceiling and these

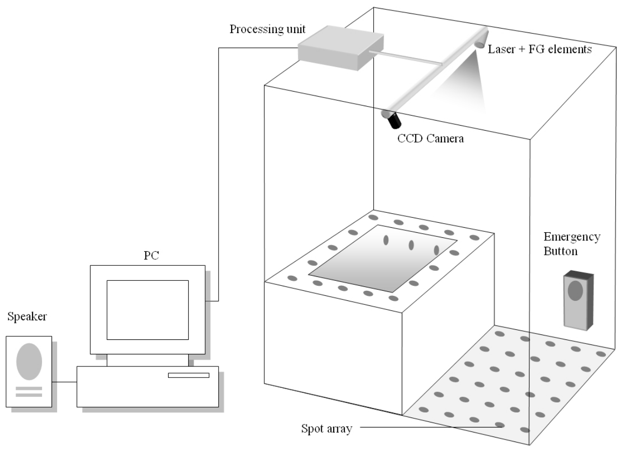


Fig.3. Experimental system.

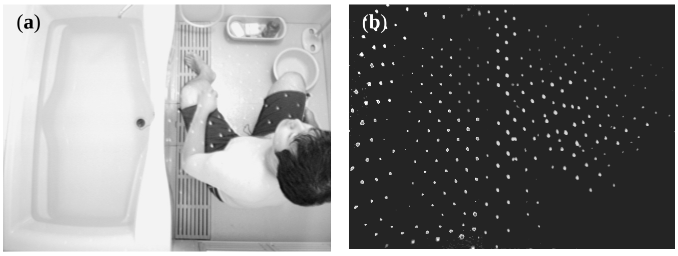


Fig.4. Obtained image. (b) is the bright spot image obtained through infrared-filter-covered lens.

Table 1. Optical parameters of this system.

h	1900mm
l	6.0mm
d	900mm

spots (approximately 330 spots) are captured with the CCD camera. Since the spots are infrared light, they are not visible to the human eye. The CCD camera incorporates an infrared filter (passing band is 760-900nm). Therefore only the spots come out in the obtained image (Fig. 4).

For the system, the optical parameters are chosen as shown in Table 1.

III. WATCHING ALGORITHMS

This bright spot image (640x480pixels) is obtained every 0.25 seconds while the system is running. As shown in equation (1), the amount of movement of a spot on the image is proportional to the change in the height of the spot. Therefore the coordinates of a spot vary in response to a person's breathing and body motion. This movement of the spots is used to watch the person's state. The image processing method is shown in Fig. 5.

A. Classification of the spots

Firstly, the coordinates of the center of gravity of each spot in the image are calculated. Next, the amount of movement

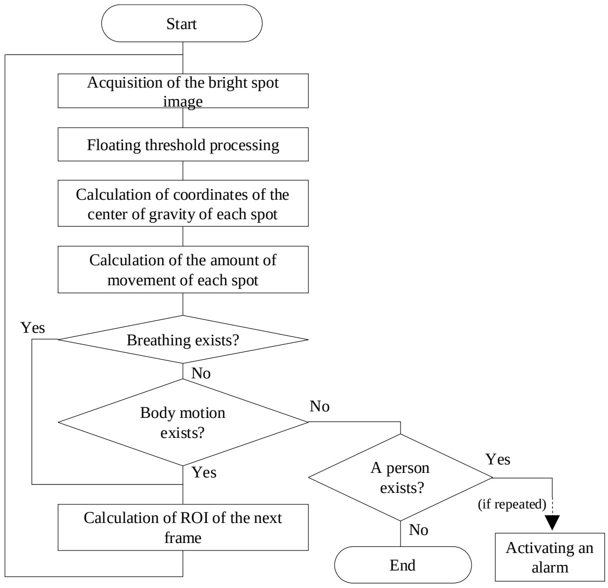


Fig.5. Flow of the processing.

of each spot is calculated from the comparison of the present and the previous frame. All of the spots are then classified into three groups: "Breathing", "Body motion", and "Immovable" (Fig. 6).

B. Determination of the region of the person

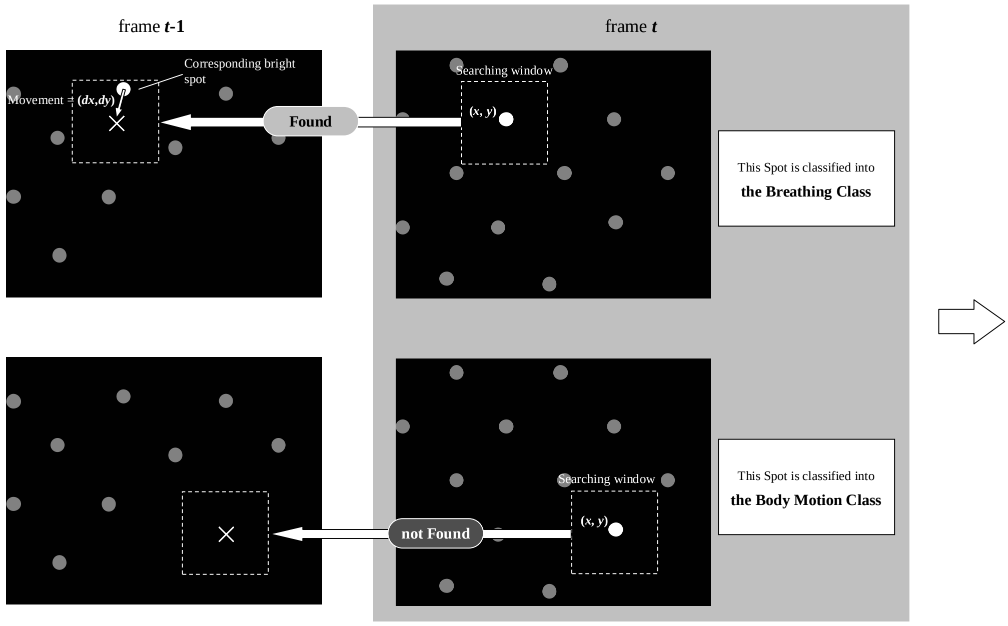
In this section, we describe the method for determining the region where a person seems to exist from the image using the classification information. The spots projected on the chest or abdomen of the person move up end down along with the person's breathing action. The direction and amount of movement of these spots resemble each other.

Firstly, this system tries to acquire breathing information using the spots classified into "Breathing". The coordinates of the center of gravity (x, y) and the amount of movement (dx, dy) of "Breathing" spots are mapped in a feature space. Spots which have a dominant feature are then extracted using a clustering method (Fig. 7).

If no subspace which has a prescribed number of spots is extracted, the system next tries to acquire the body motion information using the spots classified into "Body motion". The coordinates of the center of gravity (x, y) of "Body motion" spots are mapped in a feature space. Then, the spots which have a dominant feature are extracted, as is the case with "Breathing" spots. Conclusively, the region of respiratory information or body motion information acquired by the above method is determined as the region of the person.

C. Notification of emergency

When the region of the person isn't found in a prescribed time, the system activates an alarm to notify the bathing person and his/her family outside the bathroom. Fig. 8 shows the interface of the developed software.



Spot list (Example)

No.	Class	Center of Gravity (*x, y*)	Movement (*dx, dy*)
1	Immovable	---	---
2	Immovable	---	---
3	Immovable	---	---
4	Body Motion	(149.87, 14.16)	---
⋮			
52	Breathing	(153.55, 128.92)	(0.32, -1.57)
53	Breathing	(231.24, 131.40)	(0.41, -1.32)
54	Breathing	(138.74, 128.16)	(-2.61, 4.83)
55	Immovable	---	---
⋮			
148	Breathing	(169.85, 115.32)	(0.33, -1.08)
149	Immovable	---	---
150	Immovable	---	---
151	Body Motion	(263.11, 116.16)	---
⋮			
324	Immovable	---	---
325	Breathing	(49.80, 214.16)	(6.98, -4.34)
326	Body Motion	(63.21, 215.54)	---
327	Immovable	---	---

Fig.6. Searching for the corresponding spots and making up the spot list. This example represents a spot which is found in the searching window and a spot which is not found in the searching window. The above table is the classification of each spot. The coordinates for the center of gravity (*x*, *y*) and the amount of movement (*dx*, *dy*) are provided for "Breathing" class spots. For "Body Motion" class spots, only the center of gravity coordinates are provided.

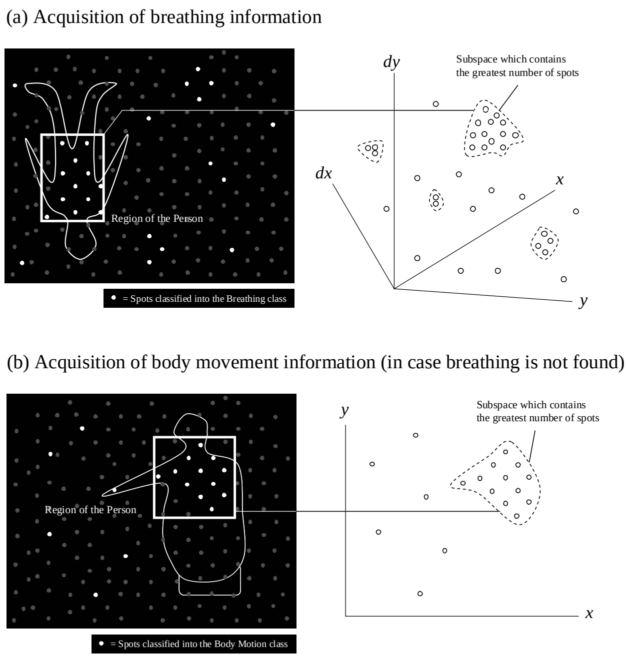


Fig.7. Determination of the region of the person

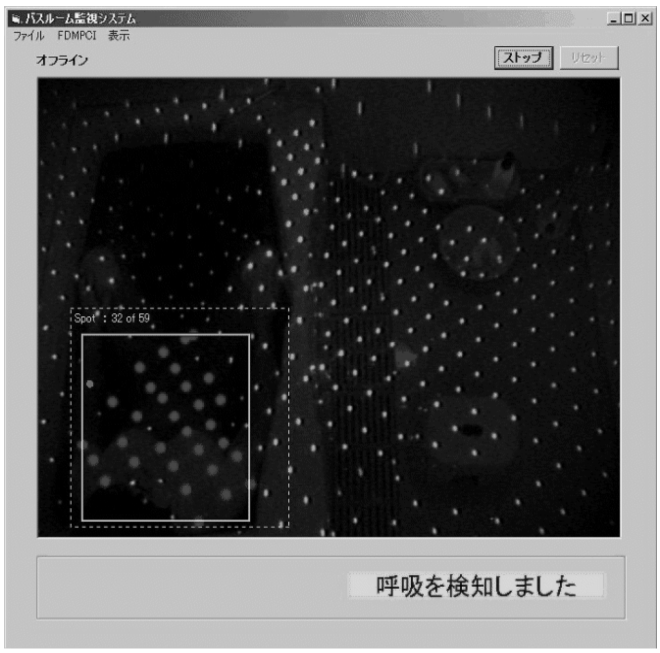


Fig.8. Interface of the watching program. In this scene, a message of "Breathing is detected" is displayed.

IV. Experiment and Discussion

In order to verify the effectiveness of this method, we applied the developed system to the generally used prefabricated bathroom. We asked some volunteers to play out two situations —— one in which they were bathing safely, and one where breathing was perceived to have stopped.

Fig. 9 represents the rate of false alarms and oversights to the number of contiguous dangerous frames (NCF) for sending out an alarm.

From the experiment, it was found that false alarm rate is expected to reach less than 0.0001% when NCF is set to 147 (36.8 seconds) as shown in Table 2. Furthermore, oversights were found to be evadable by means of ignoring the isolated frames.

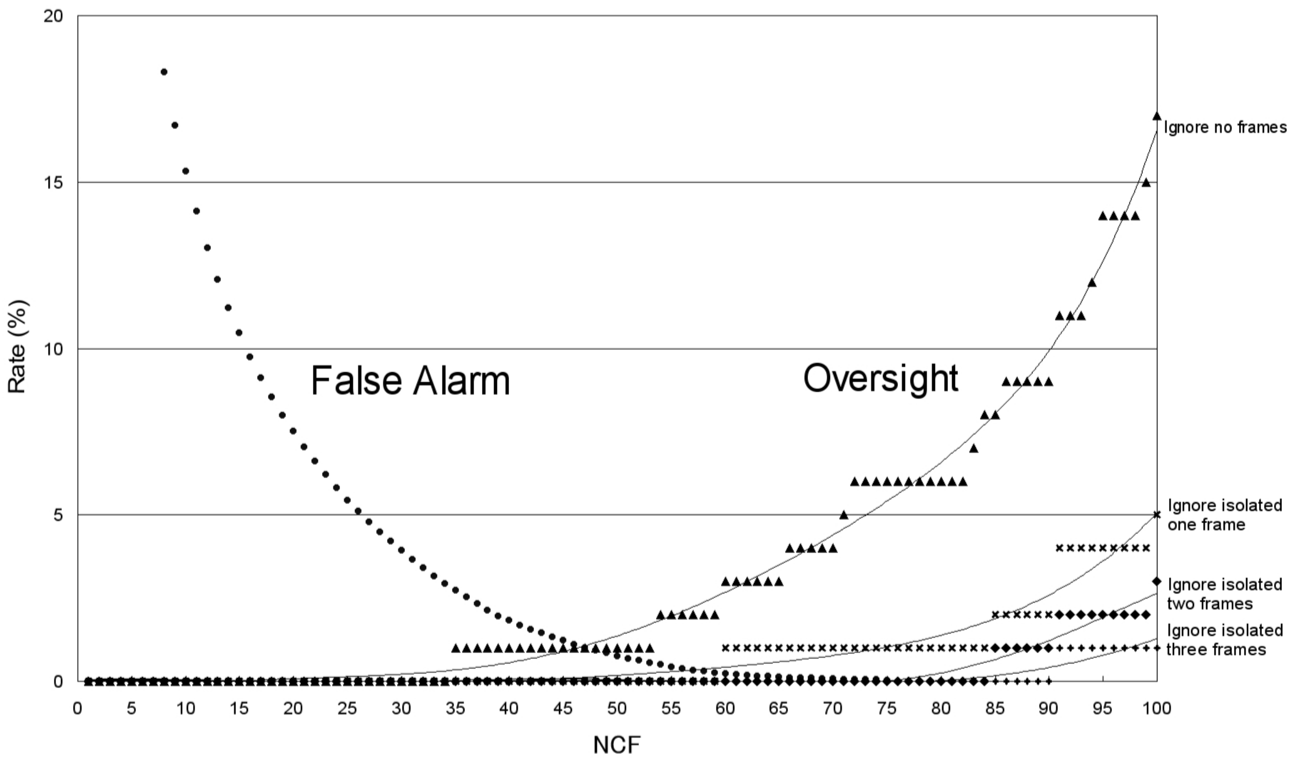


Fig.9. Relationship between NCF / false alarms and oversights.

Table 2. Required NCF for each false alarm rate.

False alarm rate	Required NCF (sec.)
Less than 1.0%	44 (11.0)
Less than 0.1%	70 (17.5)
Less than 0.01%	96 (24.0)
Less than 0.001%	122 (30.5)
Less than 0.0001%	147 (36.8)

V. CONCLUSION

A bathroom watching system supported by breath detection is proposed. This system is able to avoid confusing a state of relaxation with one of unconsciousness by using an FG vision sensor, and is useful for watching those bathing. From the experiment, it is found that false alarm rate is expected to reach less than 0.0001% when the waiting time is set to 36.8 seconds. This result suggests that this system will extremely useful in the early discovery of bathroom accidents.

ACKNOWLEDGEMENTS

This work is supported in part by a Grant in Aid for the 21st century Center of Excellence for Optical and Electronic Device Technology for Access Network from the Ministry of Education, Culture, Sport, Science and Technology in Japan. And also we would like to thank Yasuhiro Takemura and Kazuhiro Mimura (Sumitomo Osaka Cement Co., Ltd.) for their valuable advice.

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