Proposal of Leaving the Bed Motion Detection Method Corresponded at Night using Obrid-Sensor

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Abstract

Recently, due to the aging of population⁽¹⁾, the increasing of dementia patients has become social problem. The dementia patients are feared to go wander, and some of them may be gone missing after going out and have a risk to encounter accident⁽²⁾. However, watching over them all the time is difficult. Especially watching over at midnight or after sleeping is mental burden for helpers. In order to solve the problem, watching by camera is given, but it is difficult to use cameras in daily life from the viewpoint of privacy violation.

As the solution for this problem, we have developed one-dimensional brightness distribution sensor (Obrid-Sensor) that can detect the subject's position, motion and condition without violating their privacy. In this paper, the method of leaving the bed detection that detect the leaving the bed motion day and night by installing the sensor in the edge of in the bed and irradiating infrared light is proposed.

Keywords: Obrid-Sensor, Privacy protection, Leaving the bed motion detection.

1. Introduction

As the recent aging of the population progresses, the increase in patients with dementia has become a serious problem. Some dementia patients wander alone. Thereby they have risks of going missing or having an accident. In order to prevent their wandering, watching by helpers is needed. However, watching all the time is a burden to the helpers. Therefore, it is expected to develop the system that detects wandering and reduces the stress of helpers.

In order to solve the problem of wandering, surveillance

camera was proposed⁽³⁾. However, from the viewpoint of privacy, it is difficult to introduce cameras in daily life. As the method not encroaching on their privacy, there are leaving the bed detection systems that detect by using clip sensor⁽⁴⁾, mat sensor⁽⁵⁾ and ultrasonic radar^(6,7). Nevertheless, because they are touched by users, there is a possibility that are broken, and the sensor is visible, so there is the problem the subject avoids it intentionally. In order to solve this problem, we proposed the leaving the bed detection system that detects leaving the bed motion by installing the Obrid-Sensor on the floor and detecting the subject's legs⁽⁸⁾. However, the system was conducted only in the environment where the fluorescent light was lit, so there was a problem not corresponding to the watching over at night. Therefore, in this paper, we will propose the leaving the bed detection method that can detect the subject's condition day and night by installing the Obrid-Sensor in the position that can detect the condition of the subject on the bed and irradiating infrared light.

2. One-dimensional Brightness Distribution Sensor

2.1 Theoretical Structure

The Obrid-Sensor consists of line sensor and cylindrical lens. Line sensor is a sensor set light receiving elements in a row. Hence, it is generally used as the products like scanner or barcode reader. Cylindrical lens is a plano-convex lens, so it collects incident lights. The theoretical structure of the Obrid-Sensor is shown in Fig. 1(a). The top view of Fig. 1(a) is shown in Fig. 1(b) and the side view of Fig. 1(a) is shown in Fig. 1(c). The horizontal lights irradiated from each points R , C , L of the subject space enter each corresponding points

Fig. 1. Theoretical structure of Obrid-Sensor

S^R , S^C , S^L on the line sensor through the center of the cylindrical lens. As shown in Fig. 1(c), the cylindrical lens does not have the effect of lens because it is the shape of flat glass. Thus, the vertical lights from each points C^+ to C^- of the subject space enter one point S^C on the line sensor. Therefore, the vertical lights irradiated from the subject space are integrated and the brightness that corresponds to the integral value is obtained. The system will detect the subject condition without infringing privacy by using distribution of the brightness.

2.2 Subject Detection Method

In order to detect the subject, the proposed system uses the background subtraction method. The background subtraction method is the image processing method to extract the object that did not exist in the previous image by comparing both the current image and the previous image⁽⁹⁾. In this paper, the Obrid-Sensor is installed with the line sensor horizontal and obtain the brightness distribution waveform of the subject by applying this extraction method.

Next, the method to obtain the brightness distribution waveform of the subject applied the background subtraction method to the Obrid-Sensor will be explained. The image captured by camera for the confirmation in the detection range of the Obrid-Sensor is shown in Fig. 2(a). The brightness distribution waveform obtained by the Obrid-Sensor is shown in Fig. 2(b). Firstly, the Obrid-Sensor obtains the brightness distribution waveform (i) in the state where no subject exists. Secondly, the Obrid-Sensor obtains the brightness distribution waveform (ii) in the state where the subject exists. By taking a difference between the two waveforms, the method can obtain the brightness distribution

(a) Camera image

(b) Brightness distribution

Fig. 2. Background subtraction method

waveform (iii) of the subject.

In this paper, the maximum value of the brightness in the whole of the brightness distribution waveform (iii) of the subject is the peak value and let the pixel position of the peak value be the peak position. By measuring the size of the peak value of the brightness distribution waveform, the presence or absence of the subject can be detected. Nevertheless, the system has the fear to detect the state of subject by mistake because of the dark current noise occurred in photodiodes of the line sensor and the foot movements of the subject. Hence, the threshold Th is set to the size of the peak value of the brightness distribution waveform in order to prevent the misdetections. Because the brightness distribution waveform of the subject appears more largely than the brightness distribution waveform of the noise, the subject is distinguished from the noise and the subject is detected by setting the threshold Th . Furthermore, the position of the subject who exists in the detection range can be estimated.

2.3 Leaving the Bed Motion Detection Method

In this paper, the threshold of Th_{min} and Th_{max} is set on the positions of both ends of the bed edge in order to judge whether the subject wakes up, move to the end of the bed or leave the bed. Thereby, the system estimates the condition of

(a) Camera image

(b) Brightness distribution

Fig. 3. Getting up

(a) Camera image

(b) Brightness distribution

Fig. 5. Leaving the bed

(a) Camera image

(b) Brightness distribution

Fig. 4. Moving to the end of the bed

leaving the bed of the subject from the peak position. The camera images for the confirmation in the detection range of the Obrid-Sensor are shown in Fig. 3(a), Fig. 4(a) and Fig. 5(a). The brightness distribution waveforms obtained by the Obrid-Sensor are shown in Fig. 3(b), Fig. 4(b) and Fig. 5(b). The subject is estimated to be waking up if the peak position is between the maximum pixel and the threshold Tb_{max} like Fig. 3. As shown in Fig. 4, the subject is estimated to be moving to the bed edge if the peak position is between the threshold Tb_{min} and Tb_{max} . The subject is estimated to be leaving the bed if the peak position is between Tb_{min} and the minimum pixel position like Fig. 5.

In addition, the current method was conducted only under the environment where the fluorescent light was lit. Thus, the current method does not correspond to the environment the fluorescent light is not lit because the Obrid-Sensor cannot obtain enough brightness. As the solution of this problem, infrared light is irradiated both when the fluorescent light is lit and when the fluorescent light is not lit in order to watch over day and night. Hence, the infrared-pass filter is attached to the light receiving part of the Obrid-Sensor because the proposed method watches over by using only the brightness obtained by infrared light. It is said that

Fig. 6. Side view of theoretical structure of Obrid-Sensor

Fig. 7. Position relationship between subject and Obrid-Sensor

the wavelength of human visible light is generally 380 to 760 nm⁽¹⁰⁾. On the other hand, the wavelength of infrared light is 760 to 10000 nm⁽¹¹⁾. Therefore, the proposed method can watch over the subject without preventing the subject from sleeping by irradiating infrared light satisfying the wavelength sensitivity of the line sensor.

The proposed method fixes that the sitting height is within the detection range when the subject gets up by narrowing the full length of the cylindrical lens. The side view of the theoretical structure of the Obrid-Sensor is shown in Fig. 6. The position relationship between the subject and the Obrid-Sensor is shown in Fig. 7. When the distance between the subject and the Obrid-Sensor is a [cm], the focal distance between the line sensor and the cylindrical lens is b [cm], the height of the bed is c [cm], the sitting height of the subject is h [cm] and the vertical detection angle is θ_v , the following equation holds.

$$\tan \theta_v = \frac{h}{a+b} \quad (1)$$

When the full length of the cylindrical lens is L [cm], the following equation holds.

Fig. 8. The appearance of Obrid-Sensor

Table 1. The specification of the Obrid-Sensor

Structure	Infrared-pass filter	Wavelength sensitivity	790 ~ 1100 nm
	Cylindrical lens	Full length	8.25 mm
		Focal length	12.5 mm
	Line sensor TSL1402R	The number of pixels	256 × 1 pixel
Detection range		Wavelength sensitivity	400 ~ 1000 nm
		Horizontal detection angle	72.4 deg
		Vertical detection angle	33.4 deg

$$\tan \theta_v = \frac{L}{2b} \quad (2)$$

From equation (2), L can be expressed as the following equation.

$$L = 2b \tan \theta_v \quad (3)$$

Therefore, the full length of the cylindrical lens can be determined from equation (1) and (3). In this paper, the installed height of the Obrid-Sensor is adjusted to the height of the head when the subject gets up. Therefore, the proposed method sets the detection range below the height of the subject when the subject gets up. Hence, the full length of the cylindrical lens in this paper is set the half length of L .

3. Experiments

3.1 Environment and Method

The specification of the Obrid-Sensor used in this experiment is shown in Table 1. The Obrid-Sensor used in this experiment is shown in Fig. 8.

The image of the experimental environment is shown in

Fig. 9. Experimental environment

Fig. 10. The appearance of infrared emitter unit

Table 2. The specification of the infrared emitter unit

	Irradiation range	Wavelength	Equipped LED
Infrared emitter unit	55 deg	940 nm	56 pieces

Fig. 9. In this experiment, the proposed method detected the leaving the bed motion under two environments. One is the case the fluorescent light is lit. It is assumed daytime. The other is the case the fluorescent light is not lit. It is assumed nighttime. In order to confirm that the proposed method can detect the leaving the bed motion day and night, infrared light was irradiated in both environments by using infrared emitter unit. The proposed method installed the Obrid-Sensor and three infrared emitter units on the subject's head side. The infrared emitter unit used in this experiment is shown in Fig. 10. The specification of the infrared emitter is shown in Table 2. The installed height of the Obrid-Sensor was 120 cm from the floor. It is the sum of the average sitting height of the elderly people 80 cm⁽¹²⁾ and the height of the bed 40 cm. Infrared light was also irradiated with satisfying the detection range of the Obrid-Sensor. In both experiments, the subject performed the serial leaving the bed motion. If the serial leaving the motion correctly can be detected, it is

Fig. 11. How to install infrared emitter units

Table 3. Leaving the bed motion detection experimental results

Test subjects			Experimental results	
Person	Clothes		Daytime	Night
	Tops	Bottoms		
A	red	dark blue	10/10	10/10
B	black	dark blue	9/10	9/10
C	white	black	10/10	10/10
D	gray	brown	8/10	9/10
E	gray	black	9/10	10/10
Recognition rate			92 %	96 %

defined as success. If the serial leaving the bed motion cannot be detected correctly, it is defined as failure. The experiment was performed ten times with five test subjects who are different height and clothes. The illuminance of the experimental environment used a lit fluorescent light was 277 lx. The test subjects were same in the case the fluorescent light is lit and the case the fluorescent light is not lit. Furthermore, in this paper, the threshold Th that distinguish the subject from the noises was 40, the thresholds Tb_{min} and Tb_{max} set on the positions of both ends of the bed edge were 80 and 160.

3.2 Results & Discussion

The result of the detection experiment of leaving the bed is shown in Table 3. In terms of the results of both the experiment the fluorescent light is lit and the experiment the fluorescent light is not lit, the proposed method could detect

the leaving the bed motion with the high recognition rate, but there were cases that detected the leaving the bed motion in the case of subjects B, D and E by mistake. As the cause of the erroneous detections, two causes are given. One is that the subject moved widely before the subject gets up because the serial leaving the bed motions of all subjects are not same. The proposed method fixed that the sitting height is within the detection range when the subject gets up. Thus, it is thought that the motion of sleeping subject was detected, which resulted in erroneous detection. Therefore, considering more appropriate detection range is given as the solution. The shadow of the subject that was made on the wall by irradiating infrared light is also considered as the cause of the erroneous detections. Therefore, as the future task, there is the necessity to consider the influence of the shadow.

4. Conclusions

Due to an aging society, the increasing wanderings or accidents of dementia patients have become social problem. Thus, watching over by helpers is needed, but it is hard for helpers to watch over. Watching over at night is especially difficult and it is a burden for helpers.

In order to solve this problem, the detection systems of leaving the bed used clip sensor, mat sensor and ultrasonic radar have been proposed. However, these systems may break down by touching and there is a problem that they are purposely avoided because they can be visually observed.

In this paper, as the detection method of leaving the bed motions used the Obrid-Sensor, the method that can detect the leaving the bed motions by setting thresholds on the positions of the ends of the bed edge and irradiating infrared light was proposed. Thus, the detection of the leaving the bed motions day and night is confirmed.

As the future issues, the problem of the shadow is needed to consider as it may be the cause of false detection. Thereby, it is expected that it is possible to detect the leaving the bed motion of the subject with higher recognition rate.

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