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Development of privacy-preserving sensor for person detection

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Abstract

A privacy-preserving sensor for person detection has been developed. In theory, the sensor can be constructed with a line sensor and cylindrical lens because only a one-dimensional brightness distribution is needed. The proposed sensor obtains enough information to detect person's position and movement status from a one-dimensional horizontal brightness distribution that is approximately equal to the integration value of each vertical pixel line of the two-dimensional image. Thus the privacy is protected. Moreover, the appearance of the proposed sensor is very different from the conventional video camera, so the psychological resistance of having a picture taken is reduced. The verified results of practically developed sensors showed that it can correctly detect a present person's state without violating privacy.

Keywords: Privacy-preserving; line sensor; rod lens; person detection; security

1. Introduction

In a home rest room and bathroom, serious accidents and falls of senior citizens often happen. Surveillance cameras are convenient but cannot be installed in restrooms and bathrooms because of privacy. Many people feel uncomfortable about video images being recording by cameras even in public places, and in recent years, preservation of privacy has been requested. Therefore, such a video image is deteriorated by a lot of processing methods for the preservation of privacy (Kitahara et al., 2004; Koshimizu et al., 2005; Yabuta et al., 2005). However, the image may be restored as far as it where it was obtained with a camera even if the image is blurred or encrypted. Moreover, it is not easy to notice the difference between privacy-preserving cameras and normal cameras from external sources. That is why a system for the detection of a person's state and position without taking pictures is needed. For instance, pyroelectric type temperature sensors are generally used to detect a person's presence by infrared rays, but it cannot distinguish the person's state and/or position indoors (Takenouchi et al., 2004). In order to solve this problem, we proposed a privacy-preserving sensor for person detection in a previous work (Mitsutoshi et al., 2008), and by using the integration value of each vertical pixel line of the two-dimensional image instead of the one-dimensional brightness distribution obtained by combining the line sensor and the cylindrical lens, because these two are thought to be approximately the same in theory. Simulation results showed that it can confirm a

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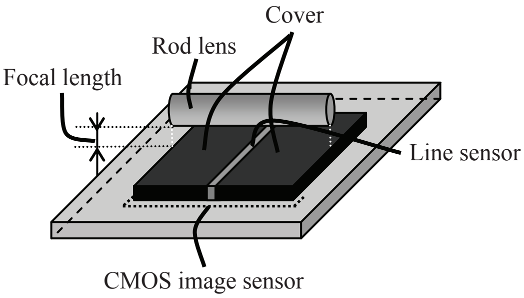

Figure 1. Model of the proposed sensor.

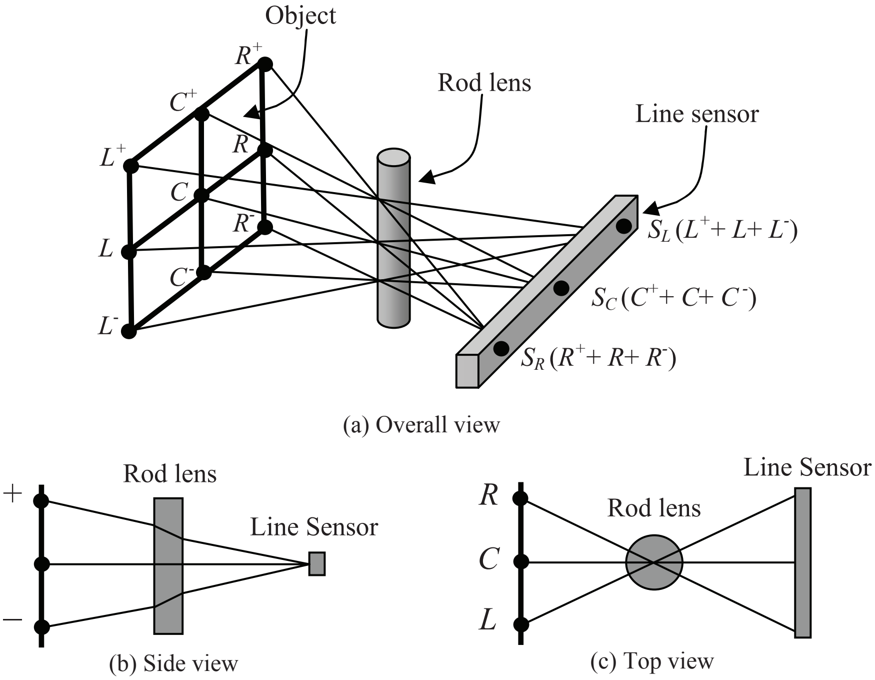

Figure 2. Mechanism of the proposed sensor.

person's presence, position, and movement state, and it also can judge whether person is standing upright or has fallen based on a one-dimensional brightness distribution that does not violate privacy. Images which violate privacy are not restorable in theory because the proposed sensor obtains only a one-dimensional brightness distribution. However, a sensor designed for this purpose had not been previously developed.

In this paper, the privacy-preserving sensor for person detection was actually made, and whether or not a person's position could be determined with it was verified. As a result, a person's correct position was detected from the one-dimensional brightness distribution without acquiring the two-dimensional image data with this sensor. A real privacy-preserving sensor was developed.

2. Privacy-preventive sensor

The proposal of a sensor that detects a person's state without invasion of privacy was introduced in our previous work (Mitsutoshi et al., 2008). In the study, we proposed a privacy-preserving sensor that differentiates between the standing and tumbled states of a person by a one-dimensional brightness distribution of a two-dimensional image. In theory, the sensor can obtain a one-dimensional brightness distribution by combining the line sensor and the rod lens (see *Sect*.2.2 for details). The one-dimensional brightness distribution contained the human state and we used the LVQ as the algorithm for estimating the human state. Furthermore, in order to obtain the optimum parameters of the

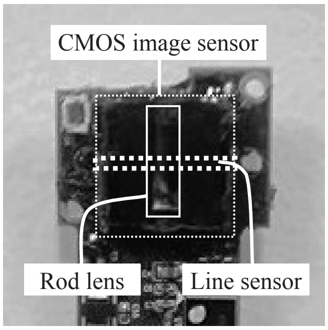

Figure 3. Appearance of the proposed sensor.

LVQ, we used the S-System, which is one of the extended models of GA and GP. Thus, a privacy-preserving sensor that differentiates between a person who is upright and one who has fallen was made possible without using cameras and other equipment. In addition, use of the S-System provided good parameters despite a lack of experience and familiarity, and a discrimination circuit was created using LVQ.

However, because the device configuration was incomplete at that time, we simulated the brightness distribution from a camera captured image to verify our thinking. Naturally, it is necessary to confirm the effectiveness by using the true proposed sensor. Thus, this time we actually developed a privacy-preserving sensor for the use of person detection in indoors.

2.1. Basic structure of the sensor

The appearance of the proposed sensor is shown in Figure 1. This sensor is constructed with a CMOS sensor and a rod lens. Compared to expensive line sensors, CMOS area sensors are low cost and increasing in sensitivity according to recent rapid advancement in the technology. Therefore, a CMOS image sensor was covered by a black cover that had a line shaped window over the center row, so that it behaved as a line sensor. The rod lens has the same properties as the cylindrical lens which is written in Ref. (Mitsutoshi et al., 2008).

2.2. Acquisition model of brightness distribution

The proposed sensor detects a person's state while preserving their privacy. The structure is shown in Figure 2. Figure 2 (a), Figure 2 (b) and Figure 2 (c) show its overall view, side view and top view respectively. As can be seen in Figure 2 (b), when viewed from the side, the rod lens is the shape of a flat panel, and the light radiation from a physical object is input into the sensor even if a vertical position is different. In other words, the distribution of vertical light is integrated. In addition, as can be seen in Figure 2 (c), the rod lens is a convex lens when it is viewed from the top. Therefore, when the physical object's horizontal position is different, the position projected on the sensor will also be different. Summarizing the abovementioned data, as shown in Figure 2 (a), the light radiated from the physical object's R^+, R, R^- enters the S_R point of the line sensor that radiated from C^+, C, C^-, enters the S_C point, and L^+, L, L^- enters the S_L point. In other words, the output from the line sensor indicates how the vertical integration of the light from the object distributes in the horizontal direction. Thus, a privacy-preserving sensor can be achieved without using cameras or a large scale device.

3. Experiment

Detection of a person's position was tested for verification of the sensor's accuracy. In the experiment, the brightness distribution of the sensor was measured when a person moved from the right to the left. First, the brightness distribution of the background where the person was not present was acquired. Next, the brightness distribution of the area where the person was present was acquired. Then the difference between the backgrounds in presence and absence of object was calculated. Because the difference of the brightness distribution changed according to the person's movement, it is thought that the person's position information was included in the

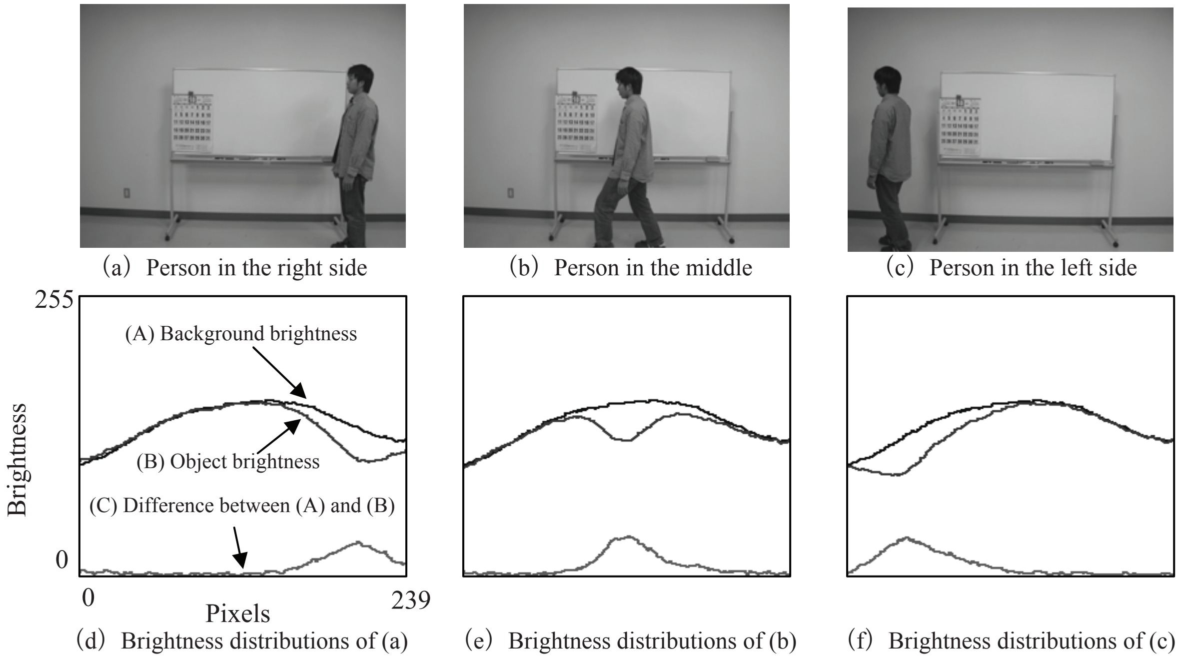

Figure 4. Relation between positions of a person and one-dimensional brightness distributions.

difference value. The patterns of the experiment were person on the right side, in the middle and on the left side. The sensor was constructed by a rod lens (SAKAI-G rod lens $\phi 3 \times l10$) and a CMOS image sensor (Logicool Qcam Pro 9000) as shown in Figure 3.

The situations of the experiment are shown in Figure 4 (a) ~ (c) and the brightness distributions of that are shown in Figure 4 (d) ~ (f). Simulation results showed that the position where the highest difference value appeared corresponded to the person's position. Therefore, the position that gives the greatest difference value is judged as the person's position. By using our proposed sensor, we are able to find a person's position without detecting personal detailed features.

4. Conclusion

In this paper, a privacy-preserving sensor for person detection was developed and an operational verification was done. The proposed sensor was able to find a person's position from a one-dimensional brightness distribution without getting two-dimensional image data. This brightness distribution did not include detailed information about the person, although it contained enough information to distinguish the person's position. As a result, it can be said that the position of a person can be detected correctly without detecting personal detailed features such as facial information. In this work, the sensor was set horizontally for person position detection, and it can detect whether a person has fallen or is standing if the sensor is set vertically. Moreover, if two sensors are installed on the ceiling in orthogonal way, it is thought that two or more people's states can be detected.

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