35th Annual International Conference of the IEEE EMBS
Osaka, Japan, 3 - 7 July, 2013

Development of an image processing support system based on fluorescent dye to prevent elderly people with dementia from wandering

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***Abstract*—The wandering of elderly people with dementia is a significant behavioral problem and is a heavy burden on caregivers in residential and nursing homes. Thus, warning systems have been developed to prevent elderly people with dementia from leaving the premises. Some of these systems use radio waves. However, systems based on radio waves present several practical problems. For instance, the transmitter must be carried and may become lost; in addition, the battery of the transmitter must be changed. To solve these problems, we developed a support system that prevents elderly people with dementia from wandering. The system employs image processing technology based on fluorescent dye. The composition of the support system can be described as follows: fluorescent dye is painted in a simple shape on the clothes of an elderly person. The fluorescent color becomes visible by irradiation with a long wavelength of ultraviolet light. In the present paper, the relationship between the color of the dye and the cloth was investigated. A 3D video camera was used to acquire a 3D image and detect the simple shape. As a preliminary experiment, 3 colors (red, green and blue) of fluorescent dye were applied to cloths of 9 different colors. All fluorescent colors were detected on 6 of the cloths, but red and blue dye could not be detected on the other 3 cloths. In contrast, green dye was detectable on all 9 of the cloths. Additionally, we determined whether green dye could be detected in an actual environment. A rectangular shaped patch of green fluorescent dye was painted on the shoulder area of a subject, from the scapula to the clavicle. As a result, the green dye was detected on all 9 different colored cloths.**

I. Introduction

The number of elderly people with dementia in Japan has increased due to an increase in the number of elderly people, and it is expected that both the number of elderly people and those with dementia will continue to increase [1, 2]. Elderly people with dementia present behavioral problems. For instance, wandering is a heavy burden on caregivers in nursing and residential homes. When caregivers do not pay attention to patients, the patient may leave the residence and not be able to find their way home due to their dementia. A wandering patient may cause a traffic accident, become seriously injured or risk dehydration in the summertime. The caregiver must always pay attention to the patient's behavior. Thus, support systems that prevent the wandering of elderly people with dementia have been developed [3], and some systems are commercially available [4-6]. These systems use a radio system that includes a portable transmitter and receiver. However, radio systems present several practical problems. For instance, the transmitter must be carried and can be lost; in addition, the battery of the transmitter must be changed. Therefore, a support system is required to prevent these problems. The present study aimed to develop a novel support system based on image processing technology using fluorescent dye to prevent the wandering of elderly people with dementia.

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II. Basic Concept

We propose to paint a mark on clothes with fluorescent dye that is invisible under visible light. The luminescence reaction is weak under visible light such as sunlight or fluorescent light. However, the fluorescent dye emits fluorescence under irradiation with a black light, which is an ultraviolet light with a long wavelength. A simple shape is painted on the clothes of elderly people with dementia using fluorescent dye. The patients are not aware that fluorescent dye is painted on their clothes.

Fig. 1 shows an outline of the proposed system, which can be installed in a nursing home. A black light source and video camera are set up on the ceiling of an entryway. When people pass near the video camera, black light is emitted, and the video camera captures a sequence of images. If fluorescence is detected by the system, the person is identified as the patient. In the present study, we aimed to develop a system that informs the caregiver that the patient has left the premises before serious trouble can occur.

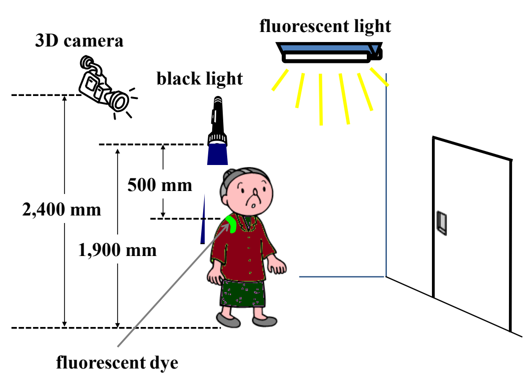

Figure 1. Overview of the measurement environment.

III. PRELIMINARY EXPERIMENT

A. Instruments

A black light (FPL27BLB, Sankyo Electronics, Japan) and 3D video camera (Kinect™, Microsoft Corporation) were installed in parallel (Fig. 2) and were placed 350 mm from the experimental cloth in the vertical direction. The video camera simultaneously obtained the image and depth value of the image. Three colors of fluorescent dye (black light ink, SO-KEN, Japan) were painted on 9 different colored cloths (white, gray, dark gray, black, red, orange, green, olive and blue). Red, green and blue dye was painted in the shape of a rectangle (200 × 40 mm) on the cloths, as shown in Fig. 3. The rectangles were spaced at intervals of 15 mm. An image with a resolution of 320 × 240 pixels and 24 bits was captured under a fluorescent light in a darkroom.

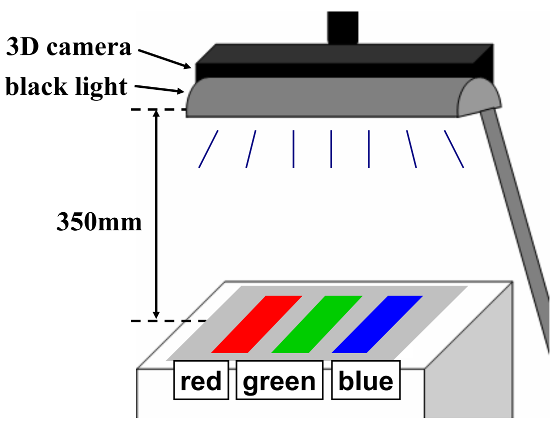

Figure 2. Set-up for preliminary experiment.

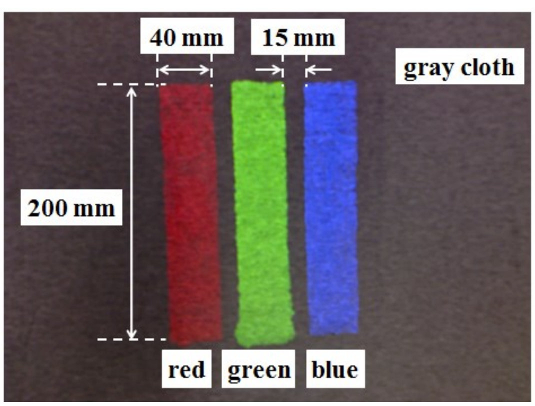

Figure 3. Typical example of a captured image.

B. Image processing

The basic concept of the image processing system can be described as follows: red, green and blue fluorescent colors are detected according to the raster scan method. When fluorescence color is detected on the image, the center of gravity of the area of fluorescence color is calculated. If the center of gravity moves to an exit door, the system indicates that the patient is going outside.

First, an area of 50 × 20 pixels without fluorescent dye was selected manually. The average intensity of red (*AR*), green (*AG*) and blue (*AB*) in the unpainted area was calculated. Second, all of the pixels in the image were normalized with the average intensity in the unpainted area of the three colors, and the normalized ratio of red (*NR*), green (*NG*) and blue (*NB*) was obtained using (1).

$$\left\{ \begin{aligned} NR &= \frac{R}{AR} \\ NG &= \frac{G}{AG} \\ NB &= \frac{B}{AB} \end{aligned} \right\} \qquad (1)$$

The procedure used to detect pixels painted with red fluorescence dye can be explained as follows: if *NR* was greatest in a given pixel, an evaluation value (*ER*) was calculated by applying (2). If *ER* was equal to or greater than a threshold level of red fluorescence color (*TR*), the pixel was included in the red painted area. In the present study, *TR* = 20 was chosen experientially for each fluorescence color.

$$ER = \left(NR - \frac{NG + NB}{2} \right) \times 100 \qquad (2)$$

Finally, the center of gravity of the red painted area (x_{CER}, y_{CER}) that satisfies the condition of $ER \geq TR$ was obtained using (3).

$$x_{CER} = \frac{\sum_{j=x} j \times ER_j}{\sum_{j=x} ER_j}, \quad y_{CER} = \frac{\sum_{i=y} i \times ER_i}{\sum_{i=y} ER_i} \qquad (3)$$

The green and blue painted areas were detected similarly, and the corresponding centers of gravities were calculated.

IV. SYSTEM EVALUATION

A. Measurement set-up

As shown in Fig. 1, the 3D video camera and black light lamp (LED-128UV375N, Optoelectronics Co., Ltd., Japan) were placed at a height of 2,400 mm and 1,900 mm, respectively. Fluorescent dye was painted on the shoulder area, from the scapula to the clavicle. The black light was placed 500 mm from the fluorescent dye. The conditions used to capture the image were the same as those used in the preliminary experiment.

B. Image processing

First, a background depth image $z'(j, i)$ was captured. Subsequently, if a person was in the image, a differential depth image $\Delta z(j, i)$ was obtained by subtracting the captured depth image $z''(j, i)$ from the background depth image using (4). If Δz was within a specific range, the pixel represented a person. In the current study, the following parameters were set: $30 < T\Delta z < 500$. i and j express the x and y coordinates, respectively.

$$\Delta z(j,i) = z''(j,i) - z'(j,i) \qquad (4)$$

The average intensity in the detected person's area was obtained using the parameters *AR*, *AG* and *AB* in experiment III B to calculate the normalized ratio. Subsequently, *NR* was calculated by applying (1). The center of gravity of each color was obtained by applying (2) and (3).

V. Experimental Results and Discussion

A. Preliminary Experiment

Fig. 4 shows the results obtained from the blue cloth. The left image is the captured image. The right image was obtained using the following image processing procedure: the painted area of each dye was detected by applying (1) and (2), and the centers of gravities of the painted areas were obtained by applying (3). The painted areas were extracted, and the centers of gravities were calculated for cloths of 5 different colors (gray, dark gray, orange, green and olive) using the same method as that for the blue cloth. The red and blue painted areas were not detected on white, black or red cloths. On the white cloth, the blue painted area was not detected because the intensity of blue in the unpainted area of the cloth was strong. The white fiber was dyed with a blue fluorescence dye to appear white. As a result, *AB* in the white cloth had almost the same value as that of *B* in the area painted with blue dye. Thus, *NB* was approximately equal to 1. For the black and red cloths, the red painted areas were not detected because the fluorescence intensities were weak, as the black and red cloths strongly absorbed ultra violet light as well as visible light. Therefore, the values of *NR* were small because *R* presented small values. The value of *ER* in areas painted with red dye displayed smaller values than that of *TR*.

Fig. 5 shows the normalized ratio of areas painted with red, green and blue dyes on 9 different colored cloths. Black bars represent *NR*, white bars indicate *NG* and slashed bars represent *NB*. For the red dye, *NR* was less than 2, and the value of *NG* and *NB* was less than 1 Moreover, the value of *NR* was low, which was indicative of poor reliability and was attributed to the weak contrast in the intensity between the background and painted area. For the blue dye, *NB* presented larger values than *NR* and *NG*, except on white and red cloths.

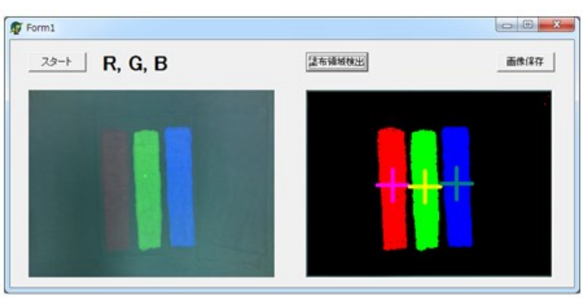

Figure 4. Detection of fluorescent dye on a blue cloth. + indicates the center of gravity of the painted area.

Alternatively, for the green dye, *NG* presented the largest normalized ratios on all of the cloths. Thus, the green dye was the best for detecting painted areas.

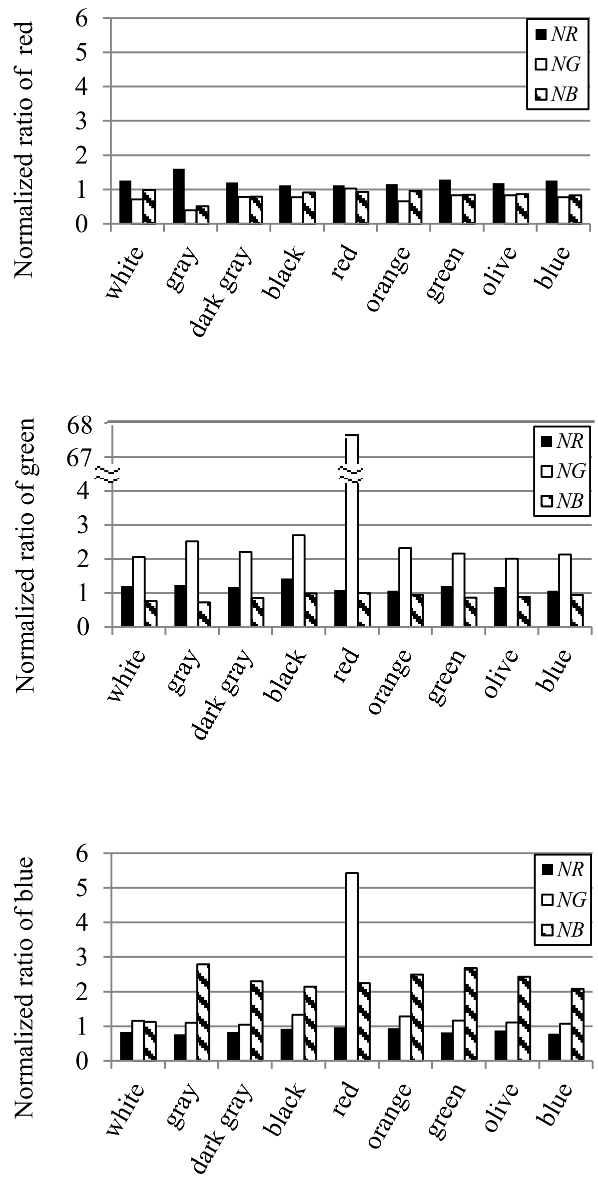

Figure 5. The normalized ratio of the area painted with red dye (top), green dye (middle) and blue dye (bottom).

B. System Evaluation

Fig. 6 shows the detection of a painted area on gray cloth. The left image is a captured image, and the upper right image was extracted from the captured image. The lower right image was obtained using the following image processing protocol: the area painted with green dye was detected by applying (1) and (2), and the center of gravity of the painted area was obtained by applying (3). Fig 7 shows the normalized ratio of the area painted with green dye on each of the 9 different colored cloths. In all of the cloths, the values of *NG* were greater than 1, which indicates that the proposed method extracts green fluorescence dye from different colored cloths.

Figure 6. Example of the detection of green dye (gray cloth).

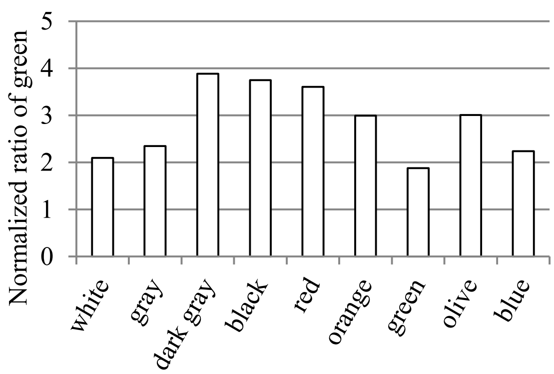

Figure 7. Normalized ratio of green fluorescent dye.

VI. Summary

We aimed to develop a novel image processing support system using a black light and fluorescent dye to prevent elderly people with dementia from wandering. In this preliminary study, an area painted with green fluorescent dye was detected on 9 different colored cloths.

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