Supporting Safe Walk of a Visually Impaired Person at a Railway Station Platform Based on MY VISION

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Abstract

For a visually impaired person, platforms of railway station are places where there is a risk of falling. This paper proposes a system that prevents fall of a visually impaired person from the platform by use of self-viewpoint images provided from MY VISION, an ego camera system attached to a user. The edges of the platform are detected by region segmentation and line segment detection on the self-viewpoint images. The performance of the proposed system was experimentally examined and satisfactory results were obtained.

Keywords: MY VISION, Depth image, Line Segment detection.

1. Introduction

According to the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), an average of 3177 accidents involving falls from platforms of railway station occurred nationwide every year between 2010 and 2016, of which an average of 76 accidents involving person with visibility difficulties occurred annually [1]. According to a questionnaire conducted by a group of visually impaired persons, about 40% of the respondents said that they had fallen from a platform, and about 60% said that they had almost fallen from a platform, making platforms a dangerous place for visually impaired person to move [2]. However, the installation of platform doors requires several hundred million yen per railway station.

The number of railway stations with platform doors in Japan from the end of FY 2006 to the end of FY 2008 was 465. The number of railway stations with platform doors in Japan at the end of fiscal year 2008 was 783, and it is not realistic to install platform doors at all railway stations nationwide. Therefore, it is necessary to develop an inexpensive system that can prevent a person from fall. However, the use of a white cane requires training for a certain period of time and also has the disadvantage of a narrow range of probe. Therefore, in this study, the edge of the platform is detected with the aim of realizing safe movement for a visually impaired person when they use railway stations.

Conventional researches on detecting steps include the methods such as segmenting a region that is in the same plane [3][4], using the Hough transform [5]. In addition, researches using MY VISION include [7][8]. In contrast to these methods, we use an RGB-D camera, Line Segment Detector [9] and Graph Based Segmentation [10] to detect the edge of the platform.

2. Obstacle Detection

Initially, the coordinate system of the input depth image is transformed from the camera coordinate system to the world coordinate system by the following formula.

$$X(x,y)=\frac{(2x\text{-}width)}{width}\,d\tan\left(\frac{\theta_h}{2}\right) \quad (1)$$

$$Y(x,y)=\frac{(height\text{-}2y)}{height}\,d\tan\left(\frac{\theta_v}{2}\right) \quad (2)$$

$$Z(x,y)=d \quad (3)$$

The gradients of Y and Z with respect to the change in y-coordinate and the gradients of X and Y with respect to the change in x-coordinate are then determined as follows;

$$\frac{dY(x,y)}{dy}=Y(x,y)-Y(x,y+k) \quad (4)$$

$$\frac{dZ(x,y)}{dy}=Z(x,y)-Z(x,y+k) \quad (5)$$

$$\frac{dX(x,y)}{dx}=X(x,y)-X(x+k,y) \quad (6)$$

$$\frac{dY(x,y)}{dx}=Y(x,y)-Y(x+k,y) \quad (7)$$

If the angle of the change of the gradient of the Z-coordinate to the gradient of the Y-coordinate in the coordinate (x,y) and the angle of the change of the gradient of the X-coordinate to the gradient of the Y-coordinate are larger than the threshold, respectively, it is judged that there is an obstacle in the area, and the area where the obstacle exists is excluded from the search area of the platform edge. The procedure is formulated by the following equations;

$$d\_YZ(x,y)=\arctan\left(\frac{\frac{dY(x,y)}{dy}}{\frac{dZ(x,y)}{dy}}\right) \quad (8)$$

$$d\_YX(x,y)=\arctan\left(\frac{\frac{dY(x,y)}{dx}}{\frac{dX(x,y)}{dx}}\right) \quad (9)$$

$$object=\begin{cases}1 & if\, d_{YZ}>th\ \ OR\ \ d_{YX}>th\\ 0 & \end{cases} \quad (10)$$

3. Estimation of the Ground Area

Graph Based Segmentation (GBS) is applied to the obstacle-free area obtained in the previous step, and the area containing the point g_c (width, height/2) is estimated as the ground area.

GBS is a method of segmenting and merging images into areas with similar features.

4. Platform Edge Detection

The Line Segment Detector (LSD) is used to detect the line segments in the image of the area obtained in the previous step, which is free from obstacles and is the ground. The line segments obtained in this step are merged using the least squares method to detect the line segments that are the edges of the platform.

This line segment is represented by a linear equation $y = ax$ using the coordinates (x,y) in the image, and its slope determines the direction of the edge of the platform as seen by the visually impaired person.

5. Derivation of the Distance to the Edge of the Platform

We refer to the left and the right depths of the pixel g_p on the detected line segment closest to the point g_c (width, height/2), and consider the depth of the point closer to the viewpoint as the distance to the home edge D^H_{min}.

$$D = \min_{p=1,2,\dots,p}\left(|g_c - g_p|\right) \quad (11)$$

$$d(x, y, d_e) = D \quad (12)$$

$$D^H_{min} = \min_{d_{e^*}}\left(d(x+1, y, d_{e^*}), d(x-1, y, d_{e^*})\right) \quad (13)$$

The derivation of the distances is shown in **Fig. 1**.

6. Experiment

In this experiment, we acquired depth images using a forward-facing RGB-D camera outdoors and detected the edges of the platform using the proposed method. Then, we evaluated the detected straight line by comparing the detected platform edge with the ground truth. The images

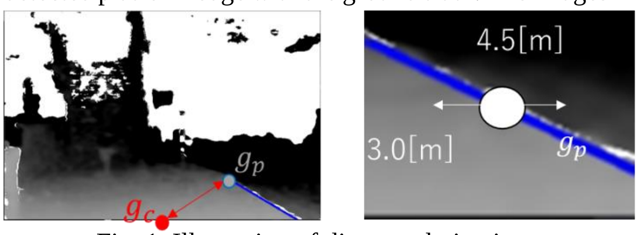
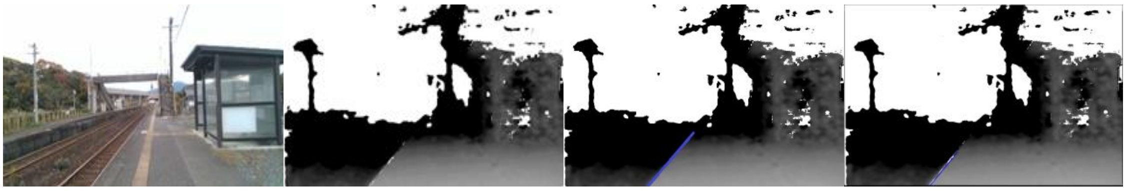


Fig. 1. Illustration of distance derivation.



(a) (b) (c) (d)

Fig. 2. (a) Color image (b) Depth image (c) Ground truth (d) Experimental result. The platform edges and ground-truths detected in the experimental results are marked with blue lines.

used in the experiment were those in which the edge of the platform was in front of or to the left or to the right of the visually impaired person. The images used in the experiment were taken at two railway stations, and the number of images used in the experiment was 88 and 228 at each railway station, giving a total of 316 images. The actual images used in the experiment, the results of the experiment and an example of the ground-truth are shown in **Fig. 2**.

The evaluation of the detected edge is based on the overlap and angle errors defined by equation (14) and equation (15).

$$\boldsymbol{overlap} = \frac{\boldsymbol{GT \cap OA}}{\boldsymbol{GT}} > \boldsymbol{T} \tag{14}$$

$$\boldsymbol{Angular\ error} = |\boldsymbol{a_T} - \boldsymbol{a_d}| < \boldsymbol{T_q} \tag{15}$$

Here *OA* is the area of the home edge detected by the experiment, *GT* is the area of the ground truth, and *T* is the threshold value. In the experiment, we set *T*=0.5, and evaluate the detection success when the overlap value exceeds the threshold, and the detection failure when the overlap value is less than the threshold or cannot be detected. Figure 2 shows an example of an input image, a ground-truth image, and a successful detection. a_T is the angle of the ground-truth, a_d is the angle of the detected line segment, and T_q is the threshold. In this experiment, we set T_q=3°. If the angle error is above the threshold, we consider it false detection, and if it is below, we consider it successful detection.

7. Results

The results of the experiment are shown in **Table 1**.
The percentage of correct position and angle for all images is 92.5% and 81.1%, respectively. The average processing time per image is 664.7ms.

Table 1. Experimental results

	Percentage of positions answered correctly[%]	Percentage of angles correct[%]	Average processing time[ms]
Station A	100	80.9	807.4
Station B	90.0	81.2	606.3

8. Conclusion

This paper proposed a method of detecting the edge of a railway station platform for a visually impaired person using self-viewpoint images, which provides the direction and position of the edge of a platform from the visually impaired person by region segmentation and line detection on depth images acquired by an RGB-D camera. The performance of the proposed method was examined by experiments and satisfactory results were obtained. Further refinement of the method needs to be done so that it may become robust to illumination and weather change, and to the obstacles such as persons on the platform.

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