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

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Abstract

When individuals with visual impairment go out, public transportation such as trains and buses is commonly used. However, many of them experience accidents, such as falling from train platforms or tripping due to unexpected contact with other passengers. To solve this problem, we propose a method using the MY VISION system which detects obstacles that may pose risks to individuals with visual impairment. The proposed method detects obstacles such as passengers' pillars and platform edges at train stations. We employ an RGB-D camera for capturing frontal views of a user, use depth images to detect the edge of obstacles and level differences, and give warning to the visually impaired user based on the distance between him/her and the detected obstacle. Experimental results show satisfactory performance of the method.

Keywords: Visually impaired, Safety, Train station platform, Obstacles detection, MY VISION

1. Introduction

Public transportation is often used as a means of mobility for individuals with visual impairments, and more than half of them frequently utilize railways [1]. However, approximately 30% of visually impaired individuals have experienced falls from station platforms, resulting in an average of 76 fall incidents annually [2].

There are methods for detecting steps and obstacles to assist visually impaired individuals in walking [3], [4]. However, the methods that use depth images to acquire the walking plane and to detect steps and obstacles are affected by noise, as the distance from the camera increases, it results in a narrow and less accurate detection range. Additionally, some methods use color information, but they are often designed for indoor use and are influenced by the factors such as time of day and weather when used outdoors.

In this paper, we propose a method that detects step edges directly using depth images and determines the distance from the pedestrian to the step. The proposed method, designed to assist visually impaired individuals on station platforms, involves region segmentation using Graph Based Segmentation on depth images and the detection of step lines using Line Segment Detector.

2. Method

2.1 *Obstacles detection*

Initially, the coordinates conversion is performed from the image coordinate system to the camera image coordinate system. The transformation formula is given as follows.

$$X(x,y) = \frac{(x - c_x) \times Z(x,y)}{f_x} \quad (1)$$

$$Y(x,y) = \frac{(y - c_x) \times Z(x,y)}{f_y} \quad (2)$$

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

Here c_x is the optical center in the x-axis direction, c_y is the optical center in the y-axis direction, f_x is the focal length in the x-axis direction, and f_y is the focal length in the y-axis direction.

Changes in $Y(x,y)$ and $Z(x,y)$ with respect to the change in the y-coordinate, as well as the changes in $X(x,y)$ and $Z(x,y)$ with respect to the change in the x-coordinate, are expressed by the following equations.

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

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

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

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

The method computes the change in angle of the gradient of the *Z* coordinate with respect to the gradient of the *Y* coordinate at the point (*x,y*), as well as the change in angle of the gradient of the *Z* coordinate with respect to the gradient of the *X* coordinate. If these angles exceed a certain threshold, the method judges it as an obstacle region. The formula and conditional statement are shown as follows.

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

$$\text{d\_}XZ(x,y)=\arctan\left(\frac{\frac{dX(x,y)}{dx}}{\frac{dZ(x,y)}{dx}}\right) \quad (9)$$

$$\text{d\_}YX(x,y)=\arctan\left(\frac{\frac{dX(x,y)}{dx}}{\frac{dY(x,y)}{dy}}\right) \quad (10)$$

$$object = \begin{cases} 1 & if\, d_{YZ} > t \text{ and } d_{XZ} > th \text{ and } d_{YX} = 0 \\ 0 & otherwise \end{cases} \quad (11)$$

2.2 *Step detection at a station platform*

The method designates the regions at both ends of the area, excluding the obstacle region as candidate regions where steps are present. Graph Based Segmentation (GBS) is applied to these candidate regions. By applying GBS, it is possible to segment and merge regions with similar features in the image. This allows for the detection of steps by dividing regions according to different planes of varying height.

2.3 *Line detection at a step edge*

Line Segment Detector (LSD) is then applied to the candidate regions which contain the steps detected through region segmentation. LSD detects candidate line segments at the edges of planes with different heights. Linear approximation is performed using RANSAC on the endpoints of the line segments detected by LSD to detect the edges of the train platform. The detected lines are represented by the equation $y = ax + b$ using the coordinates (*x*, *y*), and the gradient *a* helps determine the direction of the platform edge from the perspective of the observer. The conditional statements are as follows.

$$Dir = \begin{cases} Right & if\ a > th_1 \\ Left & if\ a < th_2 \\ Front & else \end{cases} \quad (12)$$

2.4 *Distance from a step edge*

Let g_c be the point where the user of the proposed method is standing. It is defined as g_c= (width/2, *height*). Let g_p be a point on the detected line segment. Referring to the depth information on the left and the right of the point g_p which is the nearest point from g_c , the distanceD^H_{min} is defined as the distance from the platform edge to the user. It is formulated as follows.

$$D = \min_{p=1,2,\ldots,p}(|g_c - g_p|) \quad (13)$$

$$d(x, y, d_e) = D \quad (14)$$

$$D^H_{min} = \min_{d_{e^*}}(d(x+1, y, d_{e^*}), d(x-1, y, d_{e^*})) \quad (15)$$

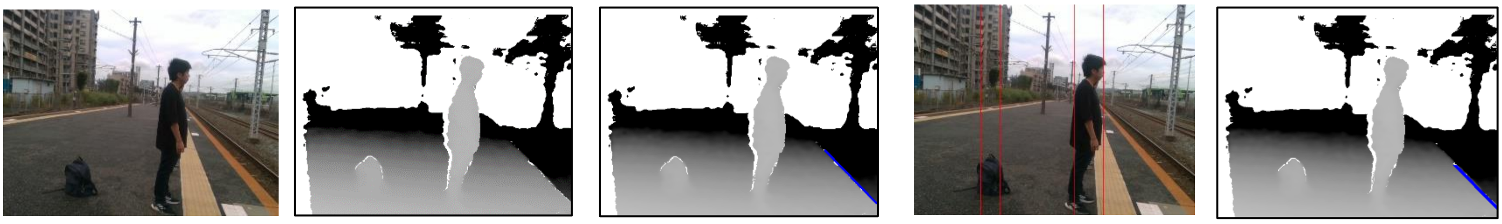
3. Experimental result

In the performed experiment, an RGB-D camera was mounted on the chest of a subject, and video taking was conducted at a train platform. The proposed method was applied to the captured depth images, and comparison with ground truth was performed to assess the accuracy of the method. Experimental videos were captured in four situations involving obstacles such as people and luggage. Each video consists of 95 frames. Accuracy evaluation is done using the following formula.

$$\boldsymbol{overlap} = \frac{GT \cap OA}{OA} > T \quad (16)$$

$$\boldsymbol{angular\ error} = |a_{GT} - a_d| < T_{q_a} \quad (17)$$

$$\boldsymbol{distance\ error} = |b_{GT} - b_d| < T_{q_b} \quad (18)$$



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

Fig.1. Experimental result : (a) Original color image, (b) depth image, (c) ground truth, (d) obstacle detection, (e) result of platform edge detection （in blue color）

Table 1. Experimental result

Location	Obstacle	Percentage of correct line segment location [%]	Percentage of correct angles [%]	Percentage of correct distance [%]
The left platform edge	Person	100	94.5	98.6
The right platform edge	Person	100	91.0	98.0
The left platform edge	Person & luggage	100	88.0	97.0
The right platform edge	Person & luggage	98.1	92.7	89.0

Here GT represents the area of the ground truth line segment, OA represents the area of the line segment detected by the proposed method, and T is the threshold. In this experiment, T is set to 0.5. The success of the detection is determined when the ratio of overlapping line segment areas exceeds the threshold. a_{GT} represents the distance on the image between the midpoint of the ground truth line segment and g_c, whereas a_d represents the distance on the image between the midpoint of the detected line segment and g_c. T_{q_a} is the threshold. In this experiment, T_{q_a} is set to 15 pixels. The success of the detection is declared when the error between a_{GT} and a_d is below the threshold. b_{GT} represents the angle between the ground truth line segment and the x-axis, and $b_d$represents the angle between the detected line segment and the x-axis. T_{q_b} is the threshold. In this experiment, T_{q_b} is set to 5 degrees. The success of the detection is declared when the error between b_{GT} and b_d is below the threshold. An example of experimental results is shown in Fig. 1.

The overall experimental results are presented in Table 1. The average accuracy for line segment position, line segment angle, and line segment distance were 99.5%, 91.6%, and 95.6%, respectively.

4. Conclusion

This paper proposed a method of detecting the edges of steps on a train platform automatically using a chest-mounted RGB-D camera. This camera captures frontal scenes of a user with visual impairment, when he/she is walking. By detecting platform edges, the proposed method is able to contribute to the safety of a user with visual impairment who takes a train. Future work includes improving the proposed method for real-time processing and conducting validation experiments.

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