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QUANTITATIVE CROWDEDNESS MEASURE FOR EVALUATION OF HAZARD AVOIDANCE SMARTPHONE APPS FOR VISUALLY IMPAIRED AT STATION PLATFORM

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Abstract. *Accidents in which visually impaired persons falling off station platforms have occurred repeatedly. These accidents are often caused by misunderstandings, loss of direction, and other factors that prevent correct recognition of the actual surroundings. Although the installation of platform doors is crucial, it is more important that visually impaired individuals can navigate around their surroundings and avoid potential hazards. In our study, we are conducting research on the use of smartphones to support the safe walking of the visually impaired. The application uses a camera to scan the surroundings, identify various objects based on the acquired RGB images, and then alert the user when a dangerous situation is detected. In our previous study, we confirmed that the system can detect steps, stairs, bicycles, and other objects which is an effective method to detect dangerous situations. Currently, we are extending the application to specialize in preventing the accident of falling from station platforms. Due to the fact that the application decides dangerous scene based on images captured by digital cameras, the accuracy of the detection would be getting worser when target objects are hidden by human; in other words, the crowdedness of the area affects the detection ability. One of requirements to use this app safely is to make clear the detection ability of the app with varying the crowdedness. To do this, we need to quantitatively define the crowdedness. In this paper, two measures, a range-based measure and a weighted distance measure, classified as local density are employed as quantitative crowdedness measures. This paper reports the experimental results comparing the two crowdedness measures, and examines which is more effective for the purpose. We conducted this experiments using a human location measurement system that can track the location of people walking and obtain their coordinates. This crowdedness measure can be applicable to evaluation criteria for apps with the same purpose of our app.*
Keywords: Quantitative crowdedness measure, Range-based measure, Weighted distance measure, Smartphone app, Visually impaired persons

1. **Introduction.** According to the Railway Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) Japan, there were 1,429 cases of falls from platforms in FY2021, out of which 28 cases involved the visually impaired [1]. Throughout a period of 10 years from FY2012 to FY2021, there were 677 instances of falls by visually impaired

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people, 19 of which resulted in fatalities due to contact with trains. Besides that, a hearing survey on visually impaired people conducted by Mizuno and Takauchi said that 76.0% of the responding visually impaired people had experienced falls from the station platform, and 91.0% had experienced a near-miss on the station platform [2]. Some examples which are extremely common include mistaking the edge of the platform for a staircase, misunderstanding the position or direction in which they were proceeding and mistaking the arrival of the train. There are many reasons to the cause of such accidents.

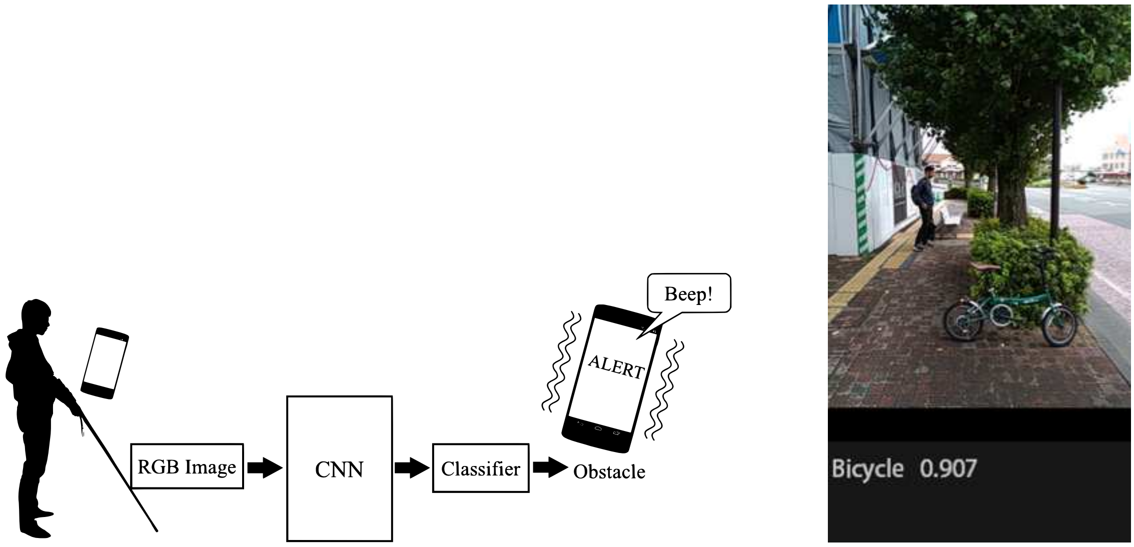
Some implementations had been made to prevent the recurrence of accidents involving the visually impaired from falling off the platform. This includes installing platform doors and tactile bricks with inner lines indicating the edge of the platform. However, it is insufficient as only a small fraction comprising only 9% of the stations have the platform door installed and with more than 10,000 passengers travelling on the platform daily, the effectiveness of the tactile bricks had been greatly reduced. Currently, MLIT is conducting demonstration tests regarding the fall prevention measures which uses new technologies such as Al as a further safety measure [3]. For example, one would be utilizing AI cameras to detect for visually impaired person and smoothly connect them to station staff assistance. Next would be alerting visually impaired person who is at the edge of the platform. Lastly, the other approach being considered is using smartphones to guide visually impaired persons by reading QR codes attached to the tactile bricks. Several such methods have been proposed for the same purpose, but they are not yet adequate.

Falls accidents of visually impaired persons are not limited to station platforms but also at stairways and streets with steps. They constantly face different types of danger in their daily lives. To solve this problem, it is necessary to rely on station attendants, but most importantly for the visually impaired persons to be able to recognize the surrounding situation and to avoid danger by themselves. To this end, many studies on the methods to recognize surrounding situations and detect hazards had been conducted. The authors' research group had developed a walking support smartphone app for the visually impaired that recognizes and notifies them when dangerous situations are detected in their surroundings [4, 5]. At the experimental level, the system had been verified to be sufficiently capable of detecting obstacles when walking such as stairs and abandoned bicycles. In this study, we develop an improved smartphone application, which specializes in preventing accidents that involve falls from station platforms.

We verify the usefulness and safety of the app by conducting verification experiments at the station platform in the presence of multiple people. For objective verification, it is necessary to quantitatively measure the degree of crowdedness of people and to use the degree of crowdedness as an index for the verification. For example, to what level of crowdedness can be detected a dangerous situation, and the number of dangerous situations can be detected as the indicator increases. In this paper, two measures, a range-based measure, and a weighted distance measure, classified as local density are employed as quantitative crowdedness measures. We conducted experiments using a human location measurement system that can track the location of people walking and obtain their coordinates to calculate the crowdedness measures. This paper reports the experimental results comparing the two crowdedness measures, and examines which is more effective for the purpose in which a crowdedness measure suitable for evaluating the performance of smartphone apps. This crowdedness measure can be applicable to evaluation criteria for apps with the same purpose of our app.

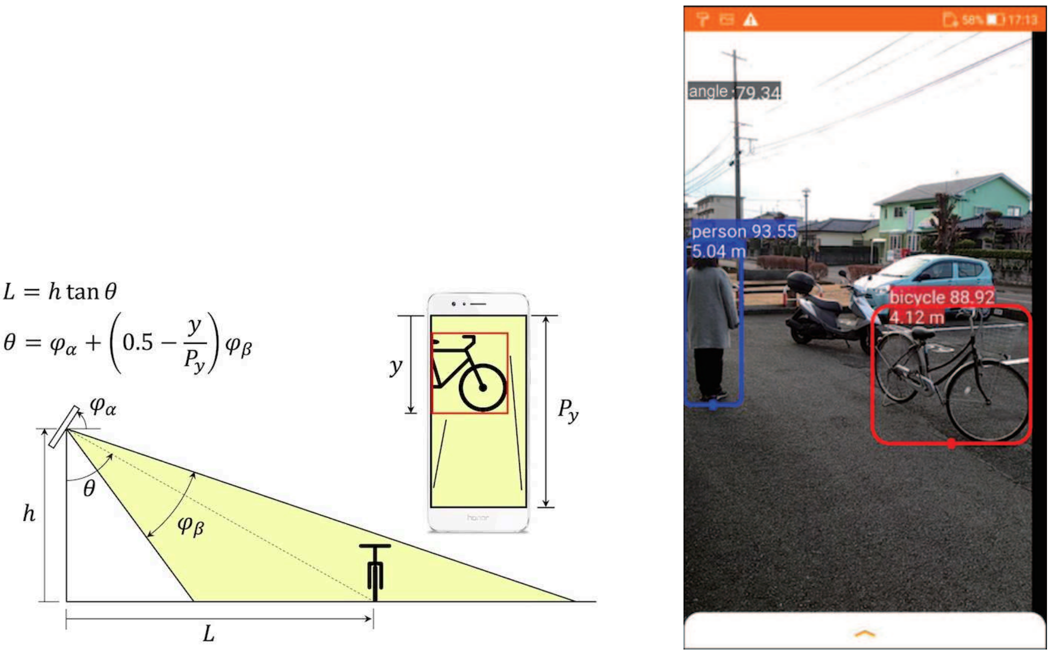
2. Hazard Avoidance Smartphone App for Visually Impaired.

2.1. Obstacle detection for walking assistance. The smartphone application which we are developing has a function that allows visually impaired individuals to wear the smartphone at chest level and alerts them if the area scanned shows a dangerous situation.



(a) System flow diagram (b) Screenshot

FIGURE 1. Obstacle detection smartphone app using CNN



(a) Distance estimation (b) Screenshot

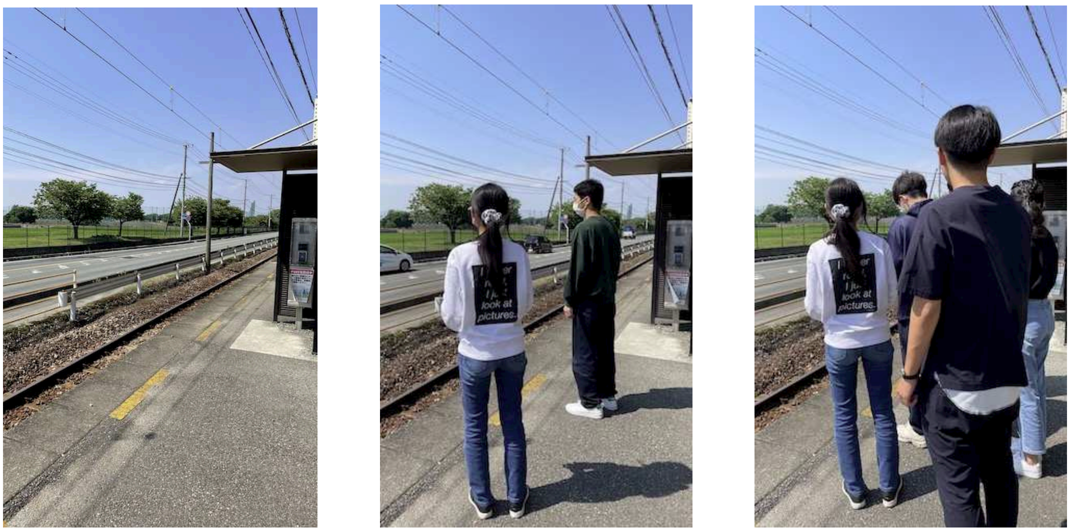
FIGURE 2. Obstacle detection smartphone app using YOLOv5

The first app shown in Figure 1 that we developed used Convolutional Neural Networks (CNN), a deep learning technique. This application can detect bicycles, stairs, sidewalks, and crosswalks, but it could only detect one object at a time [4, 5]. The next app uses a software called YOLOv5 [6] that can detect multiple objects and estimate the distance based on the degree of angle it was tilted and the view angle of the camera as shown in Figure 2 [7].

2.2. **Hazard avoidance on station platforms.** The software is now being enhanced to avoid hazards on the station platform after accidents involving visually impaired people losing their lives after falling from the station platform. This app can detect different situations such as user being too close to the railway tracks, when the visually impaired away from the tactile bricks and heading toward the railway tracks such as in Figure

(a) Railway tracks (b) Platform edge (c) Opened train door

FIGURE 3. Situations to be detected for hazard avoidance guidance



(a) Nobody (b) A few (c) Four or five

FIGURE 4. Differences in the visibility of tracks depending on passenger number

3. We would also like to include a new function to check on the position of the trains' door before boarding. When testing the usefulness of this app, we need to consider the passengers in the vicinity. When there are no other passengers, nothing obstructs the view of the tracks, but when there are other passengers, the tracks may be partially or completely covered, making detection impossible (Figure 4). Therefore, it is necessary to verify to what extent can the detector still perform accurately without being affected by the degree of congestion in the vicinity, and to show that hazard avoidance by the application works effectively even in crowded areas.

3. Quantitative Crowdedness Measures.

3.1. Previous studies. Various methods had been proposed for quantitative crowdedness measures. Most of these considered the crowding of people in relation to their walking speed, such as situation analyses that crowding of people rush to emergency exits. Duives et al. compared several quantitative crowdedness measures for movement from a wide aisle through a narrow door [8]. Whereas Jia et al. dealt with the degree of comfort when moving towards a direction when congested/overcrowded, comparing movement speed and local density [9].

3.2. **Local density.** This paper does not consider movement speed but compares the following two measures related to local density.

(1) Range-Based Measure (RBM). Range-based measure, also known as "Counting Measure", indicates the degree of the crowd in accordance with the number of people within a specific radius. In this paper, the number of people is used as an indicator, where circles of radius r touch or overlap each other as shown in Figure 5. The radius r is derived from the Peri-Personal Space (PPS), but is not uniquely determined, as it varies depending on the situation. Here, the value PPS is set to 0.8 m and the radius r is set to 0.4 m, with reference to the paper by Jia et al. [9].

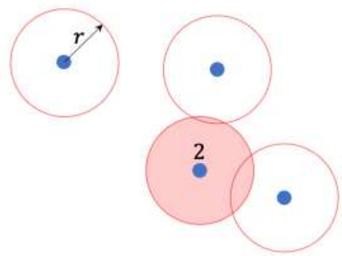
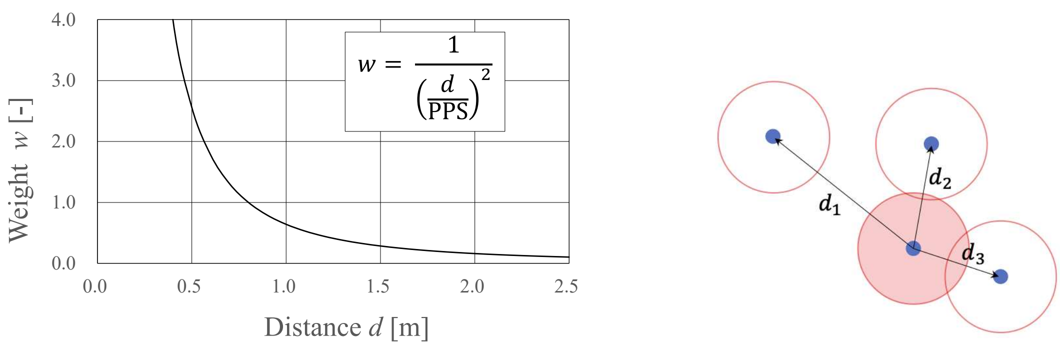


FIGURE 5. Concept diagram of range-based measure

(2) Weighted Distance Measure (WDM). This measure is a method for calculating the value by the distance d to the position of a neighbourfood. It uses a weight function

$$w = \frac{1}{\left(\frac{d}{\mathrm{PPS}}\right)^2} \tag{1}$$

as shown in Figure 6(a). This weight function takes a value of 1.0 when the distance d equals the value PPS, with higher values as the distance gets closer and lower values as the distance gets further away.



(a) Weight function (b) Concept diagram

FIGURE 6. Weighted distance measure

The sum of the weights for the number N of the neighbourhoods

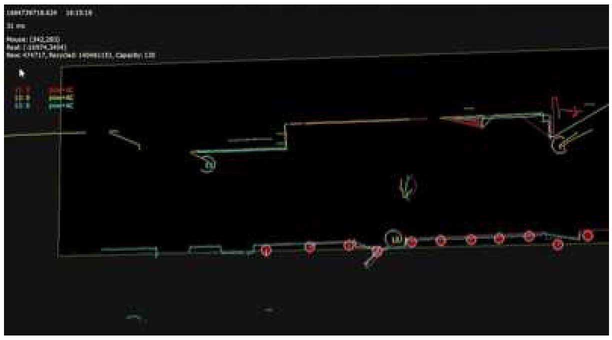
$$\rho_{\mathrm{WDM}} = \sum_{i=1}^{N} w_i = \sum_{i=1}^{N} \frac{1}{\left(\frac{d_i}{\mathrm{PPS}}\right)^2} \tag{2}$$

as shown in Figure 6(b) is a crowdedness measure that is called weighted distance measure ρ_{WDM}, where the value PPS is also set to 0.8 m to make the conditions the same as for Range-Based Measure (RBM).

4. Experiments.

4.1. LRF and human tracker. To verify whether the crowdedness measure is appropriate, we measured the standing positions of several people. Laser Range Finder (LRF) UTM-30LX-EW manufactured by HOKUYO AUTOMATIC Co., Ltd., has a scan angle of 270 degrees and can detect objects within a range from 0.1 to 30 meters used in this experiment. The three LRF sensors and a software called Human Tracker by ATR-Promotions Inc. had been used. The three LRF sensors are placed around the measurement area to collect data. Whereas the Human Tracker software uses the scanned data from the LRF to detect, track and measure the position of the person standing. These data can be obtained through a CSV file. Figure 7 shows the detection and tracking of a person's position.

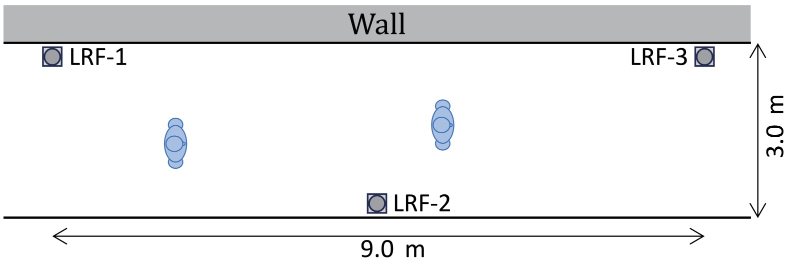
(a) Top view



(b) Screenshot of the software

FIGURE 7. Person position detection and tracking

4.2. Experiment setup. The experiment was conducted in a 3.0 m wide corridor. As shown in Figure 8, three LRF sensors were deployed, and a 9.0 m section was used as the measurement area. We measured the positions of people in situations where one to nine people were walking or closely clustering in the measurement area.

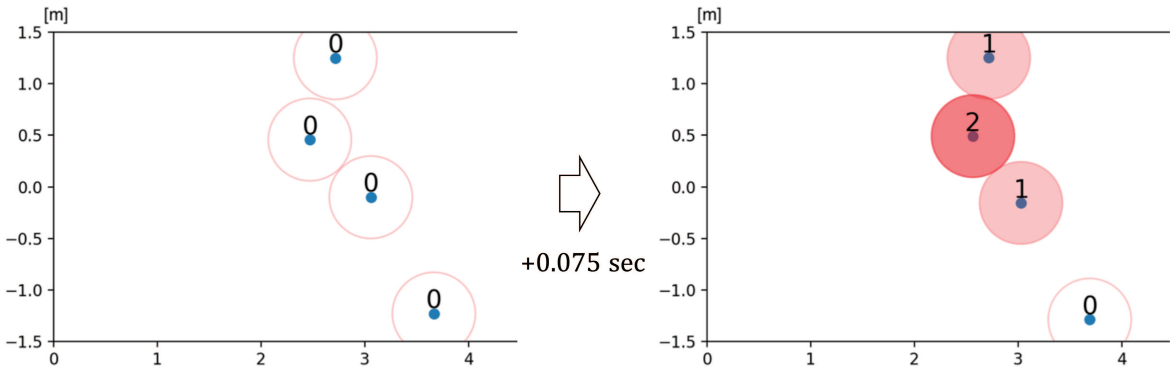


(a) Dimensions map

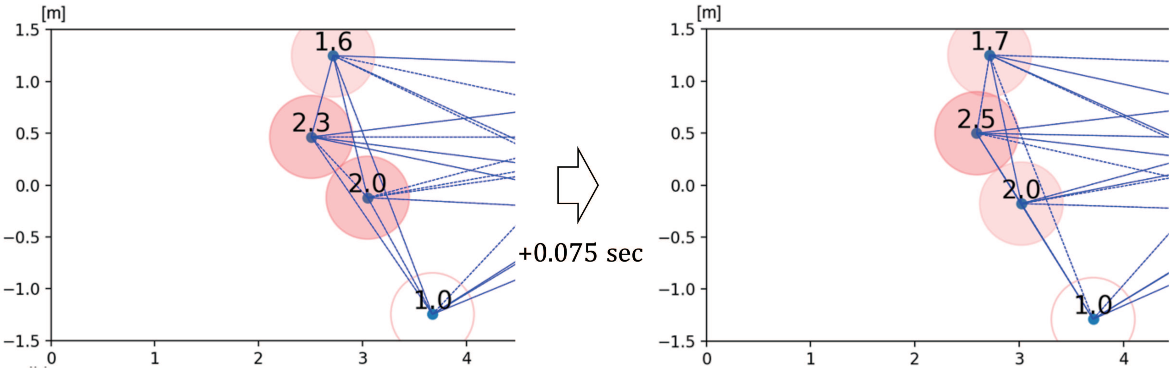
(b) Scene

FIGURE 8. Experimental environment

4.3. Experimental results. Figure 9 compares the differences in the crowdedness measures that change with slight time differences. The numbers in the figures indicate the degree of crowdedness. The higher this value means that the local density is higher, i.e., there are more people in the neighbourhood. Figure 9(a) shows the result of the Range-Based Measure (RBM). The crowdedness measures of the people at a certain time were 0, but only 0.075 seconds later these changed to 1 or 2, even though the people had hardly moved at all. Since RBM is a method of counting the number of people within a defined distance, the measured value changes discretely. Figure 9(b), on the other hand, using Weight Distance Measure (WDM) does not show much shift in result after 0.075 seconds.



(a) Range-based measure, discrete change



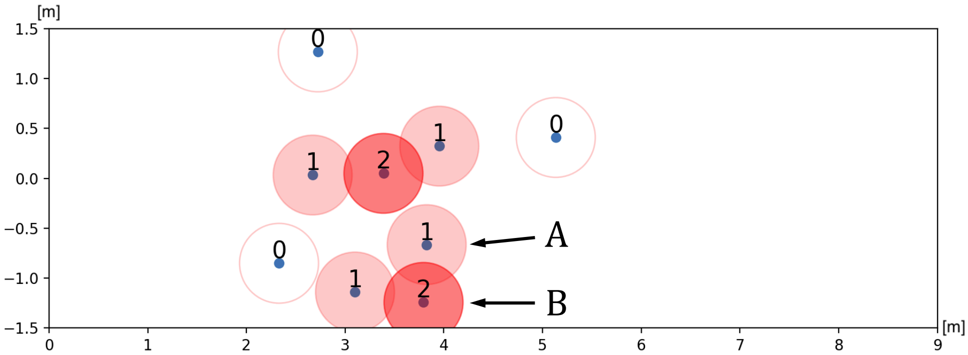
(b) Weighted distance measure, continuous change

FIGURE 9. Results showing changes in crowdedness measure at slight time differences

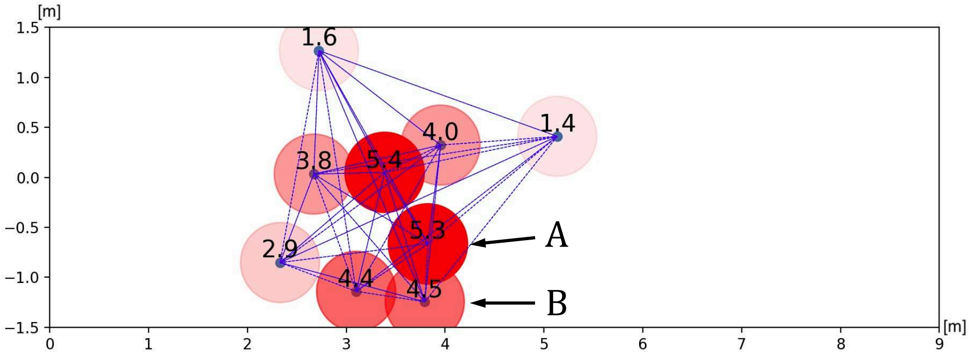
The crowdedness measures used in WDM change continuously and appear to accurately represent changes in the location of people. Figure 10 shows the results in a situation where people are closely clustered together. Figure 10 shows the results of comparing with RBM and WDM in a situation where people are closely clustered together. Here we focus on Person A and Person B. As shown in Figure 10(a), the crowdedness measure taken with RBM is lower for person A as compared to Person B. However, with the WDM method, the crowdedness measure of Person A is reversed and higher, as shown in Figure 10(b). It seems reasonable that Person A, who is surrounded by people, should have a higher value of crowdedness measure than Person B, who is at the edge of the cluster.

4.4. **Discussion.** The results of the experiments conducted in Section 4 show that WDM is better than RBM as a measure of people crowdedness. This measure is obtained by using the distance to people in the vicinity in all 360 degree directions. However, we intend to use this crowdedness measure to evaluate the performance of a hazard avoidance smartphone application to assist visually impaired person in walking, in particular to prevent falling from station platforms, only the direction in which the visually impaired person is facing should be considered, as shown in Figure 11. In Figure 11(a), if the person in red is a visually impaired person using the app, the green area is the area that is taken to the smartphone camera. Only three people are included in that area. So, as shown in Figure 11(b), only the distance to these three people can be used to determine the crowdedness level.

5. **Conclusions.** Our research is to develop a hazard avoidance smartphone app to assist visually impaired person in walking, in particular to prevent accidents involving falling from station platforms. As that app uses RGB images acquired from a smartphone camera to determine dangerous situations, the performance of the app could be degraded if the

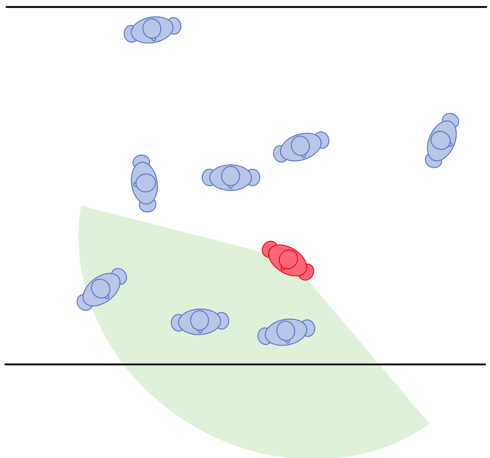


(a) Range-based measure

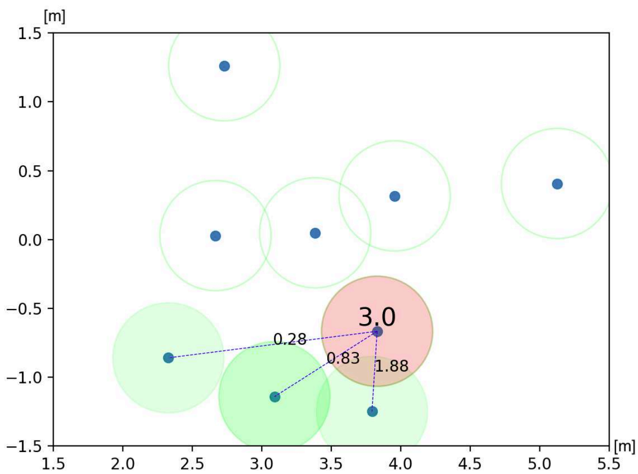


(b) Weighted distance measure

FIGURE 10. Results showing situations where people are closely clustered together



(a) Visually impaired and camera view angle



(b) Crowdedness measure

FIGURE 11. (color online) Crowdedness measure considering the camera view angle

object is shielded when a person is in the image. A crowdedness index was needed to investigate the relationship between people number in the vicinity and the performance of the app.

In this paper, we conducted experiments comparing two types of crowdedness measures, Range-Based Measure (RBM) and Weighted Distance Measure (WDM), as described in Section 4, and the experimental results suggested that WDM is more effective than RBM. In the future, we will evaluate the effectiveness of the smartphone application using the crowdedness measure focusing only on the front, which is also the viewing angle of the camera.

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REFERENCES

[1] Ministry of Land, Infrastructure, Transport and Tourism (MLIT), *Information Related to the Safety of Rail Transportation (R3)*, https://www.mlit.go.jp/common/001519719.pdf, 2022 (in Japanese).
[2] T. Mizuno and K. Takauchi, Bertrand competition in vertically related markets, *Applied Economics Letters*, DOI: 10.1080/13504851.2022.2140101, 2022.
[3] Ministry of Land, Infrastructure, Transport and Tourism (MLIT), *Interim Report of the Study Group on Safety Measures for Visually Impaired at Station Platforms Using New Technologies*, https://www.mlit.go.jp/common/001426521.pdf, 2021 (in Japanese).
[4] M. Shimakawa, I. Taguchi, C. Okuma and K. Kiyota, Smartphone application program of obstacle detection for visually impaired people, *ICIC Express Letters, Part B: Applications*, vol.10, no.3, pp.219-226, 2019.
[5] M. Shimakawa, K. Matsushita, I. Taguchi, C. Okuma and K. Kiyota, Smartphone apps of obstacle detection for visually impaired and its evaluation, *Proc. of the 7th ACIS International Conference on Applied Computing & Information Technology (ACIT2019)*, pp.148-153, 2019.
[6] Ultralytics, *YOLOv5 and YOLOv8*, https://ultralytics.com, 2023.
[7] M. Shimakawa, N. Minami, C. Okuma and K. Kiyota, Smartphone apps for visually impaired that detects obstacles and obtains those distances, *Proc. of the 9th IIAE International Conference on Industrial Application Engineering (ICIAE2021)*, pp.130-134, 2021.
[8] D. C. Duives, W. Daamen and S. P. Hoogendoorn, Quantification of the level of crowdedness for pedestrian movements, *Physica A: Statistical Mechanics and Its Applications*, vol.427, pp.162-180, 2015.
[9] X. Jia, C. Feliciani, H. Murakami, A. Nagahama, D. Yanagisawa and K. Nishinari, Revisiting the level-of-service framework for pedestrian comfortability: Velocity depicts more accurate perceived congestion than local density, *Transport. Res. F: Traffic Psychology and Behavior*, vol.87, pp.403-425, 2022.