Special edition paper

Development of Image Processing Type Fallen Passenger Detecting System


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A fallen passenger detecting mat and an emergency stop button are provided to stop trains when a passenger has fallen from the boarding platform. However, since the fallen passenger detecting mat is installed only immediately below the train's entrance door, it cannot cover the length area of the track. To solve this problem, we are engaged in the development of a system capable of detecting a fallen passenger over almost the entire length of the track, using the stereo image processing technique employed in ITS technology. This paper introduces an overview, algorithm, and detecting performance of the fallen passenger detecting system using the stereo image processing technique.

● Keyword : Detection of fallen passenger, stereo image processing technique, camera, fallen passenger detecting mat

1 Introduction

The top priority target of JR East is to ensure safe arrival of passengers to their destination. To achieve this target, an emergency stop button, train emergency stop alarm, Braille block, thread line, platform step, fallen passenger detecting mat, etc. shown in Fig. 1 are being installed one after another in major stations in the metropolitan area and stations where the distance between the station platform and train entrance door is increased due to a curve.

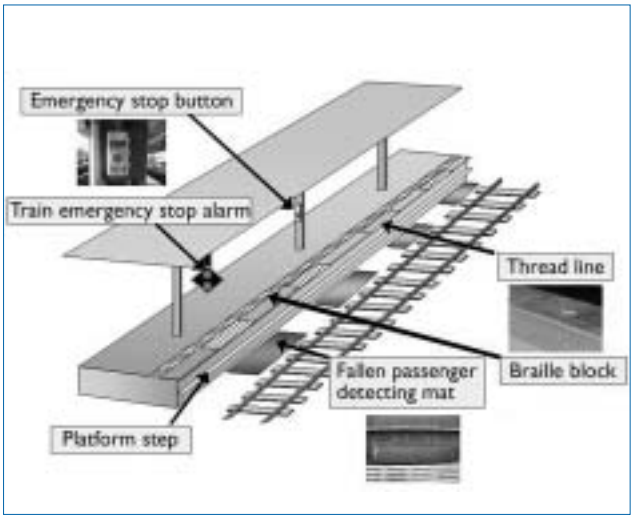

Fig. 1 : Safety measures on station platform

In addition to these devices, we are currently developing a system capable of automatically detecting a fallen passenger over almost the entire length of the track, using the stereo image processing technique employed in ITS technology.

2 Overview

Use of image processing technology based on the stereo camera permits easy removal of the impact of the surrounding environment such as shade and reflected light, which has been difficult to achieve with image processing technology based on a single-lens camera (one camera), and provides the advantage of stereoscopic identification of a subject. We have decided to use this technology to detect a fallen passenger over the entire length of the tracks below the platform.

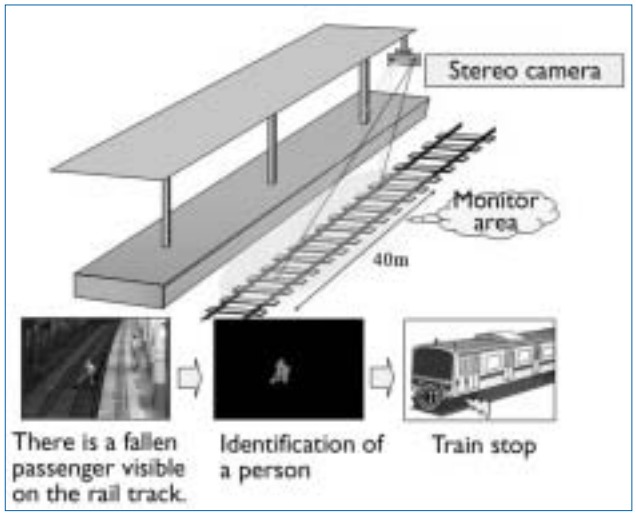

Fig. 2 : Conceptual view of an image processing type fallen passenger detecting system

In this system as shown in Fig. 2, a stereo camera is installed at a position where the entire track surface located off to the lower side can be viewed from the platform. One stereo camera is responsible for monitoring an area of 40 meters. In case a passenger has fallen

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inside the preset monitoring area, a fallen passenger detection processor installed in the station office automatically detects the fallen passenger, and the monitor displays the alarm message, " There is a fallen passenger visible on the rail track." Information on the fallen passenger is immediately reported to the station and train, thereby ensuring safety of the passenger.

3 Stereo image processing

3.1 Principle

3.1.1 Distance detection

When a subject has been detected by a stereo camera, the right and left images each appear as shown in Fig. 3. In this case, measurement is made of the deviation in the number of pixels from the left image with respect to the right image as a reference on the image processing board. This deviation is called "parallax." Distance Z can be geometrically calculated from equation (1).

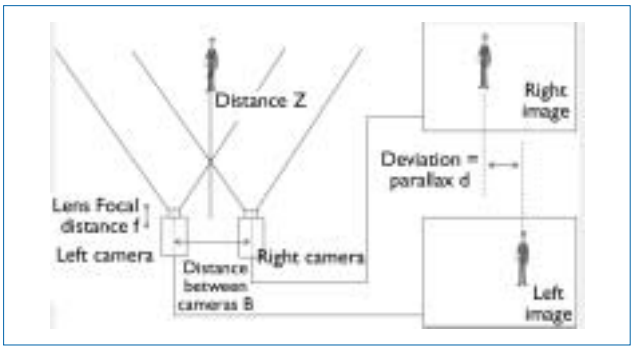

Fig. 3 : Working out distance to the subject

$$\text{Distance } Z = \frac{\text{Distance between cameras B} \times \text{focal distance of lens f}}{\text{Parallax d}} \qquad (1)$$

3.1.2 Detecting a stereoscopic image

Fig. 4 shows the concept of working out the height of a subject. Here "X" is defined as the position crossing the ground on the extension running from a camera through the head of the subject. In this case, the ratio of the distance "a" from the camera to the ground X with respect to the distance "b" from the camera to the head is the same as the ratio of distance "zo" on the optical axis with respect to the distance z. The height "h" of the subject in this case can be worked out according to equation (2), based on the principles of triangulation.

In this manner, a subject can be captured stereoscopically.

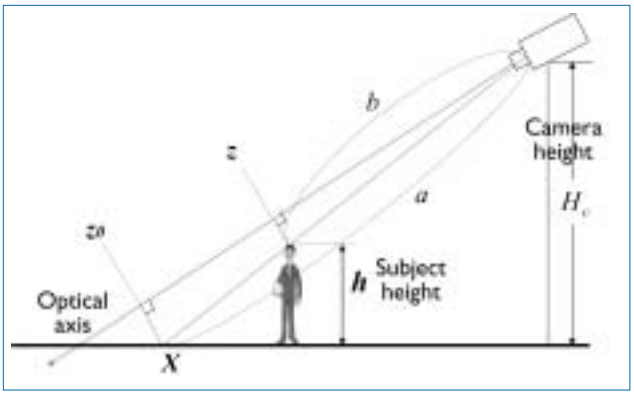

Fig. 4 : Working out the height of a subject

$$\text{Subject height } h = \text{camera height } Hc \times \left(1 - \frac{b}{a}\right) = Hc \times \left(1 - \frac{z}{z_0}\right) \qquad (2)$$

3.2 Characteristics of stereo image processing

When a moving object is to be detected by image processing using one camera, it is a common practice to use a background difference method for comparison with the immediately preceding image (or reference image). However, when assuming that this method is applied to outdoor places such as a station platform, there may be a strong impact from surrounding embodiments such as shade and train lights. To solve this problem, we use the stereoscopic image processing method based on two cameras.

The stereoscopic image processing method has the following advantages.

(1) Easy measurement of the distance to the subject

(2) Resistant to disturbances, such as outdoor shade and light

Since the distance to the subject and its height can be identified, it is easy to identify the difference between a person and a small object, which had been considered difficult when one camera was used. Further, the shade occurring on the track is reduced to zero in height. In detecting a fallen passenger, all that has to be done is to preset the detection height in advance. This allows for easy removal of the impact of shade.

4 Configuration of image processing type fallen passenger detecting system

This system comprises multiple stereo cameras installed on the station platform and a fallen passenger detection processor installed in the station office. Fig. 5 shows the test system configuration.

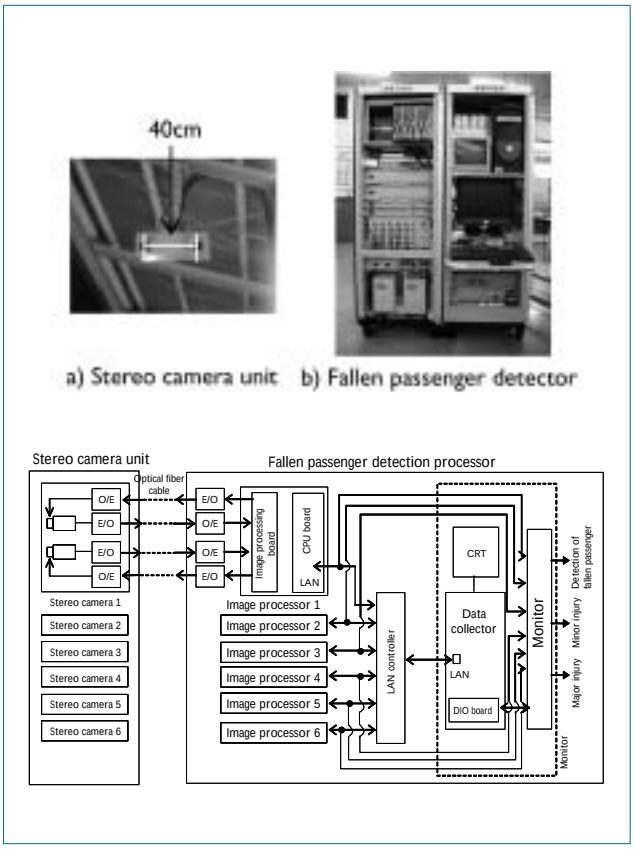

Fig. 5: Configuration of image processing type fallen passenger detecting system

4.1 Stereo camera unit

The stereo camera unit consists of two standard black-and-white monitoring cameras comprising about 380,000 pixels. In the test equipment, a noise-resistant optical fiber cable is used as the transmission cable for connecting the cameras with the fallen passenger detection processor. Thus, an E/O (electric-to-optical) converter and O/E (optical-to-electric) converter are installed inside the stereo camera to carry out conversion between electric and optical signals, thereby transmitting image signals and camera control signals.

Stereo image processing is characterized as follows: To improve the accuracy in distance to the object in equation (1), it is preferred that the distance between cameras B be greater. However, the installation space on the station platform is limited, so we have decided to use a distance between cameras or 40 cm.

For the detection area of the stereo camera, 24.3 meters ahead from immediately below the installation position is assumed as 0 meter, and the detection area of the stereo camera has been determined to be 40 meters from that position. To cover the length of the platform on the Yamanote line measuring 240 m in total (20 m x 11 cars + 20 m, 10 m for room on each of platform ends) using these conditions, six cameras are needed, as shown in Fig. 6.

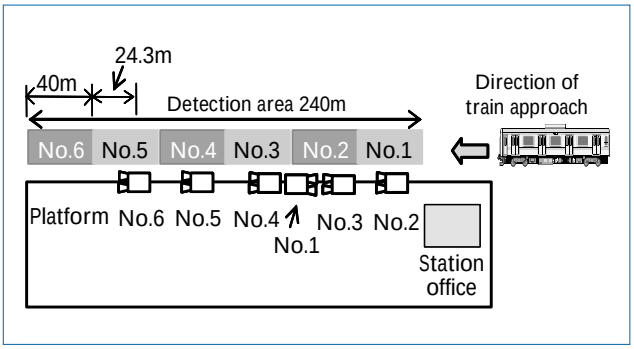

Fig. 6 : Stereo camera installation position and detection area

4.2 Fallen passenger detection processor

The fallen passenger detection processor comprises an image processor, LAN controller and monitor. It is designed to detect a fallen passenger from the platform within one second.

On the image processing board of the image processor, lens feedback control is provided based on the brightness of the right and left images obtained from the stereo camera. At the same time, it extracts the parallax image from the right and left images in 100 ms. On the CPU board it is equipped with, a fallen passenger is detected in 54 ms from when the parallax image is extracted by the image processing board.

To ensure stable detection of the fallen passenger, the speed of fall from the platform and direction of fall are also monitored. To ensure a higher speed in processing for this end, pipeline processing (parallel processing) shown in Fig. 7 is used to reduce the processing time.

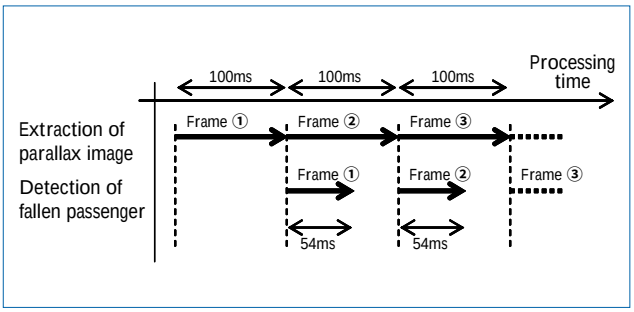

Fig. 7 : Pipeline processing

In normal series processing, 154 ms (100 ms + 54 ms) is needed for each frame. Use of pipeline processing has reduced the time to 100 ms. In order to ensure such high speed processing, one image processor is provided for each stereo camera.

5 Measuring performance

To verify the performance of this sensor system, continuous measurement has been made at two desired positions, and the accuracy and stability has been evaluated. Fig. 8 shows the positions to be measured.

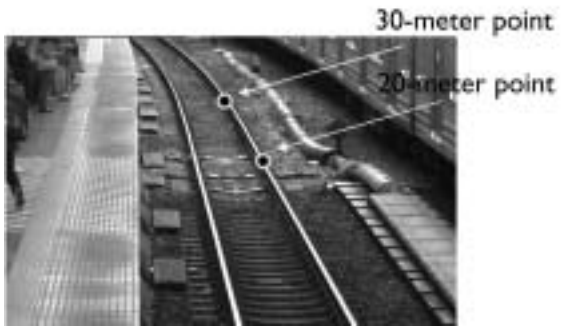

Fig. 8 Positions to be measured

Fig. 9 shows the height of the rail every hour measured at the 20 and 30 meter spots, and Fig. 10 indicates the distribution of the rail height at the 30 meter spot.

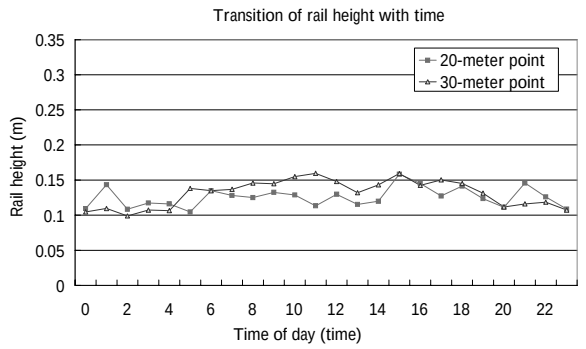

Fig. 9 : Measurement of rail height (transition with time)

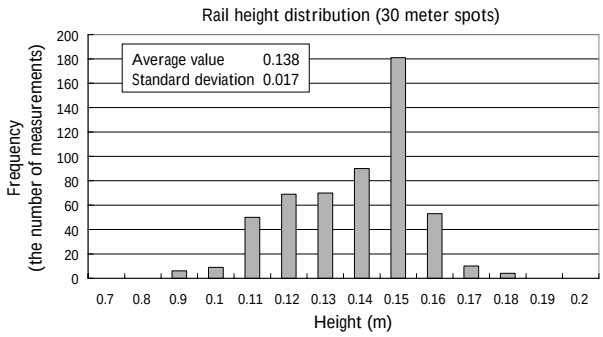

Fig. 10 : Measurement of rail height (distribution)

Since actual measurement of rail height is about 0.145 meters, measurement accuracy is about Å}0.04 meter according to Fig. 9. Further, frequency distribution can be converged within three standard deviations of the average value, according to Fig. 10, so measurement performance can be said to be stable.

6 Flow of detection

Flow of detection is arranged in the order of (1) determination of rail height, (2) train detection where an approaching train is recognized as a train, and (3) detection of a fallen passenger where the passenger have fallen from the platform is detected. Fig. 11 is a flowchart representing the process of detection.

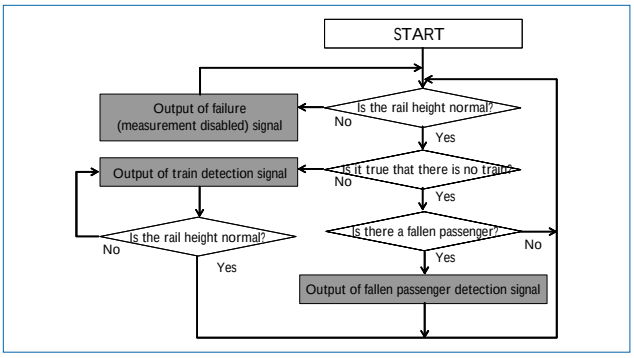

Fig. 11 : Detection flowchart

The following describes the objects for determining the rail height:

(1) Verify a measurement error due to mechanical failure of the camera lens.

(2) Determine if measurement is disabled by mist or snow.

The continued measurement of the rail height provides an error indication function and self-diagnostic function to stop the equipment in the event that the above-mentioned phenomenon has occurred. Then train detection activated. If a fallen passenger has been detected when there is no train, a fallen passenger detection signal is output. If there is a train on the track and a train detection signal is output, train detection signal output will continue until the rail is clearly visible.

7 Detection algorithm

7.1 Detection of fallen passenger

Detection of a fallen passenger is determined according to fallen passenger information from the platform and information on the size.

Fig. 12 shows the detection area.

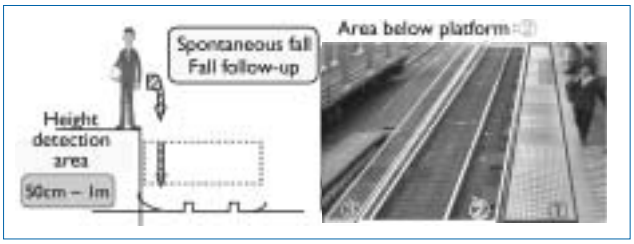

Fig. 12 : Detection area

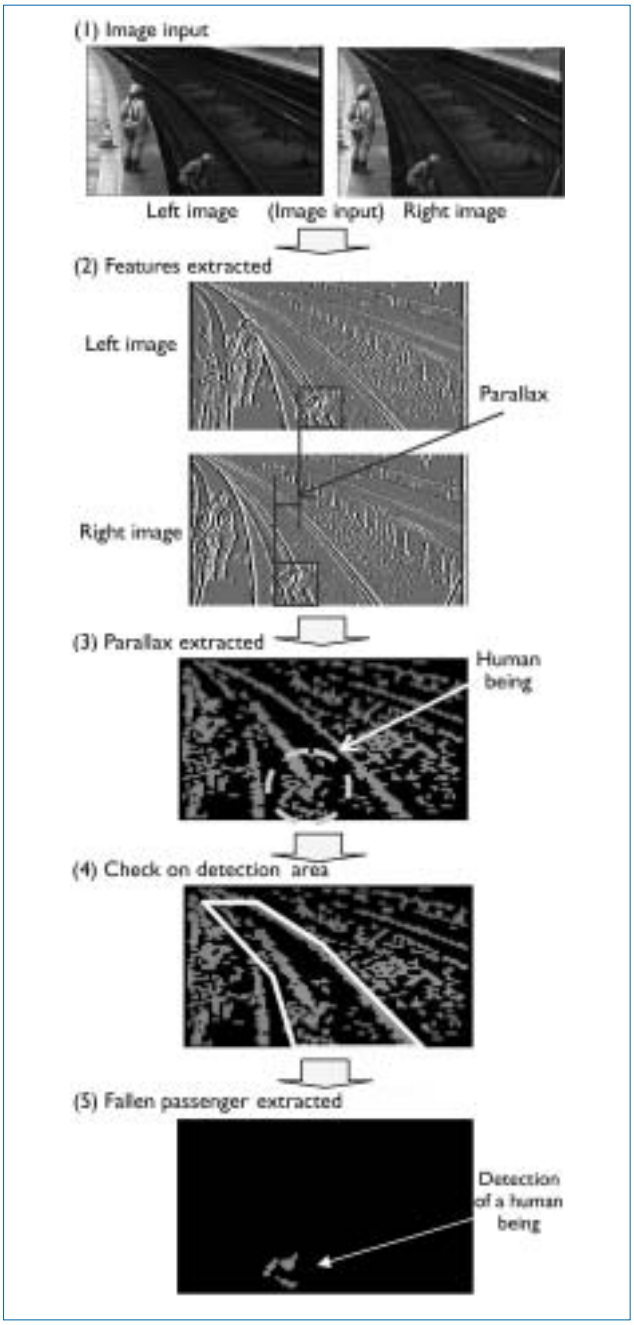

Fig. 13 : Flow of fallen passenger detection

Areas on the right side of Fig. 12 can be divided into the area on the platform (1), the area below the platform (3) and the area outside the track (3). The fallen passenger detection area of this system corresponds to area (2) having a height ranging from 50 cm to 1 m. The system detects a passenger who has fallen into this area. Ordinary fall is spontaneous fall from area (1) to area (2). Thus, information on spontaneous fall from area (1) to area (2) as well as information about fall follow-up are used for this evaluation to improve the accuracy in distinction between an object other than a human.

It is also possible that a passenger could enter area (2) from area (3), although it would not be likely. Detection is carried out in area (2) only when a human being with a height of 70 cm or more has been determined to be in area (3).

Fig. 13 is a flowchart representing the case where a passenger has fallen into area (2).

(1) -> (2): Extracts features of the image on each of the right and left.

(2) -> (3): Extracts parallax from each of the feature-extracted images.

(3) -> (4): Checks parallax-extracted image against detection area.

(4) -> (5): If the status in area (2) continues for two or more consecutive frames and has a height of from 50 cm to 1 m and a size of 5 or more blocks (a size where a 30 square centimeter box is visible from a distance of 40 meters), the size is evaluated according to the distance. If the size exceeds a certain level, it is extracted as representing a fallen person.

7.2 Train detection

To prevent a train from being mistaken for a fallen passenger, train detection output is carried out for an approaching train, without a fallen passenger being detected (mask processing). Figs. 14 and 15

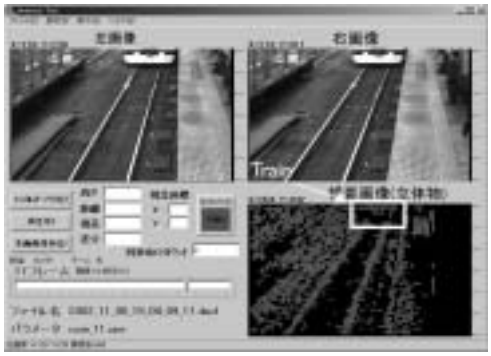

Fig. 14 : Evaluation in train detection (face-to-face cameras)

show evaluation in train detection for each camera direction.

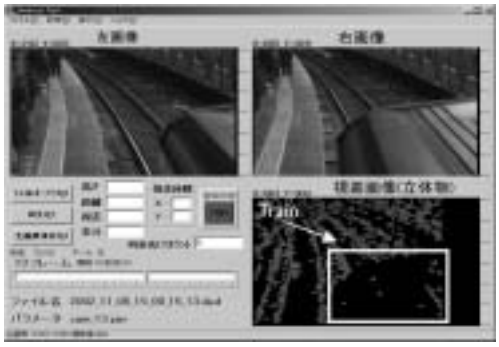

Fig. 15 : Evaluation in train detection (back-to-back cameras)

In both cases, part of both rails becomes invisible when a train approaches. If a train can be recognized, the equipment is masked to show that the train has been detected. Further, after the train has departed, train detection is retained until the entire rail can be identified completely.

8 Result of field test

8.1 Detection of fallen passenger

(1) Test of detecting a fallen passenger

To verify the performance in fallen passenger detection, we have checked detection performances using a fall simulator having a size of an elementary school child. Fig. 16 shows the detection model used in the test, while Fig. 17 shows the background of the test.

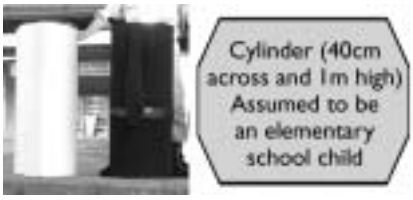

Fig. 16 : Simulator for detection

Fig. 17 : Background of the fallen passenger detection test

Fallen passenger detection tests have been conducted by assuming various cases as shown in Fig. 17. As a result of these tests, it has been verified that there is no omission of detection under even the severest conditions at any time of day or night where the distance for detection is 40 meters. Further, the same test results have been obtained where solar irradiation conditions and time intervals at night are different.

These observations suggest that, when illumination is 100 luces or more on the track and an elementary school child in black uniform has fallen to a spot with a detection distance of 40 meters during a time period at night where detection conditions are the severest, the child will be detected without fail.

(2) Number of fallen passenger detections

The following discusses the number of falls from the station platform in the field test have been detected: Table 1 shows the comparison of the number of detections between the fallen passenger detection mat (hereinafter referred to as "mat") and the image processing type fallen passenger detecting system (hereinafter referred to as "image system")

Table 1: Number of detections as compared to that of the fallen passenger detection mat

	October	November	December	January
Fallen passenger detection mat	2	2	7	2
Image processing type fallen passenger detecting system	2	6	12	5

In November a passenger inadvertently dropped a piece of baggage on the fallen passenger detecting mat from a train stopped at the station, and only the fallen passenger detecting mat operated. This is because mask processing was carried out after detection of the train, and fallen passenger detection was not activated. This was not caused by a failure to detect. Further, if the fallen object is a small

Fig. 18 : An example of the fallen passenger having been detected by the image system alone

article such as a shoulder bag, it is not detected as a fallen passenger due to the size evaluation processing, even before the train enters the station.

Except for the above, whenever a mat detected an object, the image system also made the detection without fail. Fig. 18 shows an example of the fallen passenger having been detected by the image system alone.

8.2 In the test system used in this project

All trains were detected over a period of about four months (about 35,200 trains) from October 2002 to the end of January 2003.

8.3 Measures for detection error

Use of a magic hand can be assumed for picking up a baggage dropped inadvertently at a station. There is a significant possibility of a detection error. To prevent this, the following steps are taken:

8.3.1 Magic hand

When features of a magic hand are extracted, the detected dimension in the longitudinal direction is greater than that in the lateral direction. The percentage of the narrower portion in the detection area is greater. In the case of a fallen passenger, such a peculiar feature does not occur. Thus, it is evaluated as a magic hand, not a fallen passenger.

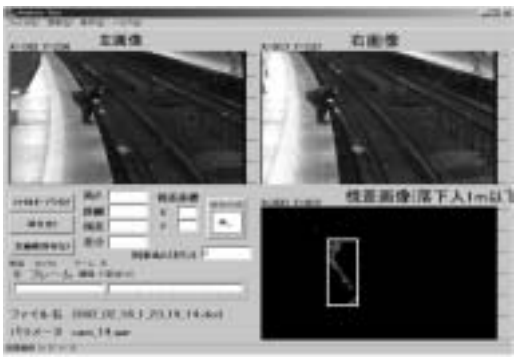

Fig. 19 : Magic hand

8.3.2 Newspapers, rubbish bags, and crows

Newspapers, rubbish bags, and crows can be excluded by evaluation according to the information on fallen passenger detection discussed in 7.1. Even if a newspaper or rubbish bag has fallen from area (1) to area (2), the speed of fall is not the same as that of a human. When something enters from area (3), and its height does not exceed 70 centimeters, or even when a crow starts out or flutters on the track, it is excluded by the information about fall follow-up. Although it does not occur frequently, several sheets of newspaper may fall from the platform together, or a crow may alight in a way similar to spontaneous fall. In such cases, it may be identified as a human falling from the platform.

Fig. 20 Measures against newspapers, rubbish bags, and crows

8.3.3 Evaluation of the measures against identification error

Table 2 shows the result of evaluating the measures against identification errors. A small animal such as a cat is handled by size evaluation in relation to the distance. When a passenger's baggage has been placed over the area below the platform, it is not detected since it is located outside of the height detection area. It has been verified in the test that these objects are not detected as fallen passengers. In the test, newspapers, rubbish bags, and crows were actually detected at a rate of once a month, although frequency is very small.

Apart from the above-mentioned objects, no detection errors occurred when exposed to wind, rain, solar light and train light when we checked the impact of the natural environment. It has also been verified that snow falling in the metropolitan area is not detected.

Table 2 : Evaluation of the measures against identification error

	Identification error
Small animals such as a cat and a rat	○
Magic hand	○
Bulky baggages extending beyond the platform side	○
Newspapers, rubbish bags, and crows	△

○ : Impossible △ : Rarely possible

9 Conclusion

In the field test carried out so far, it has been confirmed that there is almost no error of either false-negative or false-positive detection. From here on, we will make further efforts to subsequently continue this study, including the study on the impact caused by differences resulting from track curvatures, level of illumination, and direction of travel of the train.