Advanced Fall Detection System using 3D LiDAR to Support Safety on Curved Railway Platforms

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More than 2,000 accidents involving people falling off platforms or coming in contact with trains occur at railway stations in Japan every year[1]. Japan's Ministry of Land, Infrastructure, Transport and Tourism has been promoting both physical measures, such as platform screen doors, and operational measures, such as guidance/warnings from station staff, to improve platform safety. In recent years, measures utilizing sensing technology have also been promoted to prevent visually impaired people from falling off the platforms[2]. Platform screen doors are the most effective in preventing falls and train contacts, but at many stations, installation is difficult due to issues with platform structure, and maintenance costs.

In a co-creation effort with a railway operator, OKI has developed an advanced fall detection system using 3D Light Detection and Ranging (hereafter referred to as LiDAR) to address and overcome issues related to the installation of platform screen doors. In addition, OKI has achieved improvements in station staff operations[3].

This article introduces the LiDAR sensing technology that OKI has developed to address the issue of people falling through gaps between trains and curved railway platforms.

Overview of LiDAR Fall Detection System

The 3D LiDAR Fall Detection System primarily consists of a server that performs fall detection processing using 3D point cloud data obtained from LiDARs installed on the platform, and a device that displays an alert on the screen (**Figure 1**). In this system, one LiDAR unit detects people in an area equivalent to the length of two train cars (approximately 40 m) along the edge of the platform. Each device is connected via a network, allowing processing on a remote server and notifying abnormalities not only to platform signals but also to a remote monitoring terminal.

The system development proceeded with the goal of achieving the following three safety functions:

1) Detection of falls into gaps between platform and train (when train is at the station)
2) Detection of intrusions onto tracks (when train is not at the station)
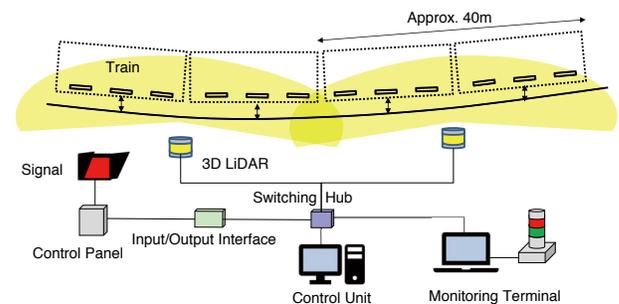3) Detection of people remaining on platform (when train is / not at the station)

Figure 1. System Configuration

Function 1) utilizes signals, such as an approach signal, and detects people caught in the gap between the train and the platform from the time the train stops until it departs. Function 2) detects people who have entered the tracks from the platform from the time a train leaves and the next one arrives. Function 3), for example, detects people in the area between the yellow tactile blocks and the edge of the platform. These detection functions are designed to allow for flexible adjustment of the detection area and notification timing to suit the station structure and operational procedures. Functions 1) and 2) have already been commercialized through co-creation with a railway operator. Function 3) is being independently studied and developed by OKI.

Railway Platform Sensing using LiDAR

To sense a wide area along the platform edge, sensors with a wide field of view and a long detection range offer advantages in terms of installation and maintenance costs. Furthermore, by using LiDAR to sense people within the detection area in three-dimensional space, falls can be detected with high accuracy even on platforms with complex shapes and narrow spaces. First, the LiDAR's scanning and resolution will be explained. This will be followed by the description of a detection area when LiDAR is installed on a curved platform.

(1) LiDAR's Scanning and Resolution[4)]

LiDAR is a device that simultaneously emits multiple lasers in two dimensions to scan (measure) objects in three-dimensional space with high accuracy. To cover the wide area along the platform edge, the detection system uses a rotating LiDAR with a 360° horizontal field of view, which emits lasers at regular intervals in both the horizontal and vertical directions, as shown in **Figure 2**.
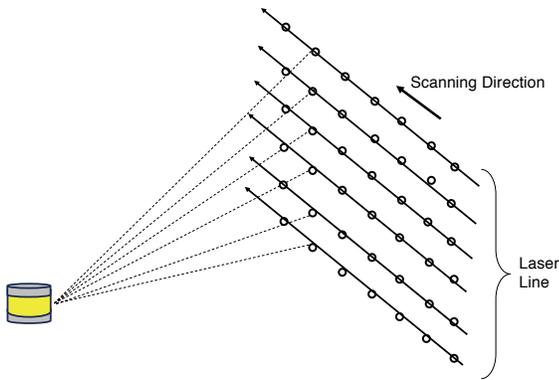

Figure 2. Rotating LiDAR Scan

With LiDAR that emits lasers at regular intervals as shown in **Figure 2**, the resolution decreases as the distance to an object increases according to eq. (1) in **Figure 3**. Therefore, in order to judge the presence or absence of objects using LiDAR, it is necessary to determine the detectable distance taking into account the distance resolution and the size of the object to be detected.

$$\begin{cases} \Delta x = R \cdot sin(\Delta\theta_H) \\ \Delta y = R \cdot sin(\Delta\theta_V) \end{cases} \quad (1)$$
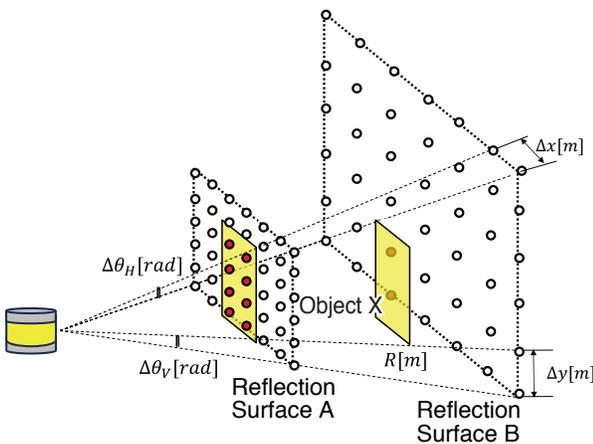

Figure 3. LiDAR's Vertical and Horizontal Resolutions

(2) Detection Area on Curved Platform

Figures 4 and **5** show examples of sensor installation and an image of the detection area, respectively when a LiDAR is installed facing downward to sense the area along the edge of the platform.

As shown in **Figure 4**, installing a sensor on the roof of the platform makes it possible to simultaneously sense both the platform side and the track side. However, it must be noted that a blind spot, which is dependent on the distance from the platform edge to the LiDAR, is created below the platform[5)].
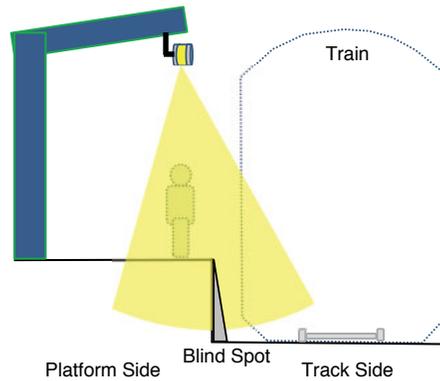

Figure 4. Sensor Installation

Figure 5 shows an image of the detection area when the gap fall detection function is used on a curved platform. In order to properly distinguish between people getting on/off trains and someone who has fallen, it is desirable to spatially define the gap area under the platform as accurately as possible. For this reason, the detection area is desirable to be a curved space on a curved platform. That space defined as the detection area will be referred to as the detection space.
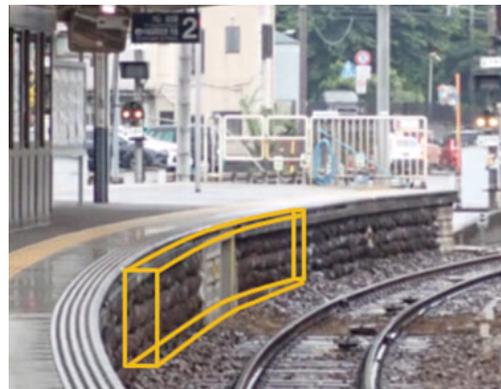

Figure 5. Example of Curved Space Defined as Detection Area (Image)

Fall Detection using 3D Measurement Technology

To realize a fall detection system applicable to platforms of various shapes, OKI developed a technology that utilizes surveying equipment, such as RTK-GNSS positioning, and maps the data to a LiDAR coordinate system, providing an accurate estimate of the platform edge's overall shape. **Figure 6** shows the relationship between the LiDAR coordinate system and the detection space when using gap fall detection. The x, y, and z axes of the LiDAR are taken to be along the platform, direction towards the railway tracks, and height of the platform, respectively. The shape of the platform edge is expressed by the function f(x, y), and the space formed together with z is defined as the detection space V. The method for estimating the shape of the platform edge using RTK-GNSS positioning data and the accuracy of OKI's LiDAR human position measurement technology are described below.
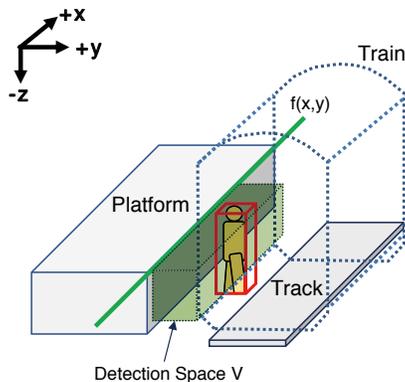

Figure 6. Detection Space and Fall Detection Determination (Patent Pending)

(1) Estimating the Shape of Curved Platform[6]

At the train station used as an example, the gap between the platform and the train was approximately 20cm, therefore centimeter-level measurements were required to define the detection space. RTK-GNSS positioning was used to measure the shape of the curved outdoor platform (roof cover only near the ticket gates). Measurements of the platform edge were made on an actual platform (total length of approximately 160m) by moving the GNSS antenna along the edge. The positioning accuracy was approximately 90% for the fixed solution and approximately 10% for the float solution. Using the acquired positioning data, the platform shape was estimated using a high-order polynomial and mapped onto the LiDAR point cloud (**Figure 7**).
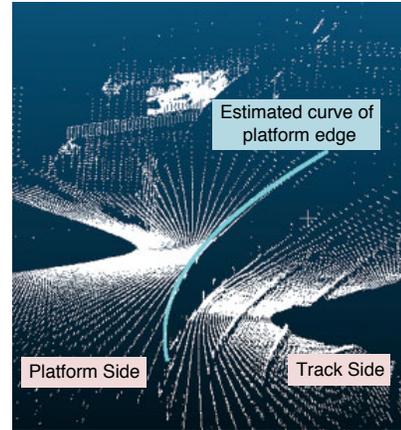

Figure 7. Platform Shape Estimation using Polynomial Approximation with GNSS Positioning (Patent Pending)

(2) Measuring Human Position in 3D Space

To detect a person falling into a gap in 3D space, it is necessary to measure people to the order of centimeters. **Figure 8** shows the results of measuring the 3D positions of a person boarding a train and a person descending into the gap (actual fall test) using OKI's LiDAR human position measurement technology. As shown in the figure, the measured positions in the gap differ for a person boarding the train and a person descending into the gap.
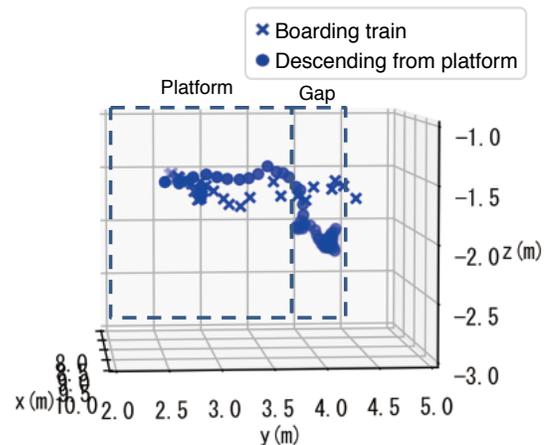

Figure 8. Measurement of Human Positions on Platform

Field Experiment on Railway Platform

Working together with Meitetsu EI Engineer Co., Ltd., OKI installed a LiDAR at Nagoya Railroad's Shin Unuma Station to verify its performance in detecting falls through gaps. Result of the experiment is presented below.

Figure 9. LiDAR Installation (Nagoya Railroad's Shin Unuma Station)

As explained in **Figure 4**, the LiDAR was installed approximately 3m above the platform, facing downward (**Figure 9**). The detection space was defined using a high-order polynomial approximation curve as a line segment for two train cars, based on the train's stopping position, and extending approximately 1m below the platform. As a test subject, a dummy modeled after a first-grade elementary school student[7] was created and placed in the gap under the train door for evaluation.

Figure 10 shows the result of detecting the dummy from the LiDAR point cloud. Although the gap at the evaluation position was only about 20cm, it can be seen that the dummy (point cloud within the detection frame) was successfully detected. Furthermore, by defining the detection space as a curved space that only extends below the platform, it was confirmed that false detections during actual operating hours can be kept extremely low.
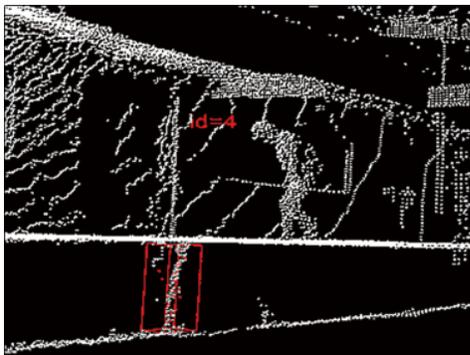

Figure 10. Result of Gap Fall Detection (Child-Sized Dummy)

Future Initiatives

As part of the "Railway Digital Transformation Solutions" aimed at transforming railway operation, OKI has developed an "Advanced Fall Detection System" using 3D LiDAR. The system is currently in operation at two stations on the Nagoya Railroad's Inuyama Line. The use of RTK-GNSS positioning is still under research and is not implemented in the operational system.

OKI's future initiatives include research and development of sensing technologies and support systems that will integrate with ATC/ATS for safe autonomous operation (GoA3, GoA4)[8], currently being studied by Japan's Ministry of Land, Infrastructure, Transport and Tourism.

Acknowledgment

■ References

1) Railway Bureau, Ministry of Land, Infrastructure, Transport and Tourism: Information on the Safety of Railway Transport (FY2023) (in Japanese)
2) Cabinet Office, Government of Japan: White Paper on Traffic Safety, Japan (2025) (in Japanese)
3) Yoichi Tsuchiya, Hiroyuki Takahashi, Takayuki Iwakura, Shuya Takahashi: Solution for Detecting People and Vehicles Standing in Railroad Crossings using "AI Edge," OKI Technical Review, Issue 240, Vol. 89 No.2, pp. 12-15, November 2022 (in Japanese)
4) Michiyo Hiramoto: Current Status of Infrastructure-Cooperative Sensor Measurement Technologies and V2X Communication Technologies Supporting Autonomous Driving, Electrical Calculations March 2024 Issue, pp. 16-22 (in Japanese)
5) Michiyo Hiramoto, Shunji Okamoto, et. Al: LiDAR-Related Technologies for Technology Development and Applications, 2025, Johokiko (in Japanese)
6) Shuhei Ooishi, Kazuki Kobayashi, Michiyo Hiramoto: Proposal of Modeling and Utilization of Structure Shapes Using RTK-GNSS, IEICE General Conference, 2025 (in Japanese)
7) Ministry of Education, Culture, Sports, Science and Technology: School Health Statistics Survey, Japan (2024) (in Japanese)
8) Ministry of Land, Infrastructure, Transport and Tourism: Report on Automatic Train Operation Technologies, 8th Meeting of the Committee for Automatic Train Operation Technologies, 2022 (in Japanese)

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TIPS 【Glossary】

RTK-GNSS (real-time kinematic GNSS) Positioning
This method uses correction signals from a reference point to determine the position of an observation point with high precision. By estimating the integer ambiguity and phase of the carrier wave, centimeter-order positioning accuracy is achieved. A solution in which true integer ambiguity is resolved is called a fixed solution; otherwise, it is called a float solution.

ATC (Automatic Train Control)
A device that ensures appropriate train spacing required for safe autonomous railway operation.

ATS (Automatic Train Stop)
A device that stops trains at the appropriate position using information from ground-based signals and other sources.