**Development of Road-rail Vehicle Mistaken Entry Detection System Utilizing High-precision GPS**

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Abstract

In order to prevent collision between trains and road-rail vehicles, we have been developing a system to detect mistaken entry of road-rail vehicles that utilizes high-precision GPS. In our previous study, we achieved accurate position detection of a road-rail vehicle on a railway track. And we have completed preparation of a prototype device that emits an alarm when necessary by collating detected position data with data of track closure. In this paper, we provide an overview of the system as well as the results of the performance evaluation in test use.

**Keywords:** RTK-GPS, Maintenance car, Road-rail vehicle, Railway track closure, Detection of mistaken entry

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1. **Introduction**

As a result of the February 2014 collision accident between a train and heavy construction machinery (road-rail vehicle) in the yard of Kawasaki Station on the Keihin-Tôhoku Line, the Safety Research Laboratory has developed the “maintenance vehicle location system” to detect mistaken entry of road-rail vehicles as a tangible measure against such accidents. In research up to now,\(^1\) we have been able to accurately detect road-rail vehicles using high-precision GPS (Real Time Kinematic-GPS, RTK-GPS), and we have completed a prototype of a device to notify maintenance personnel of danger according to the situation by comparing that location information and ATOS* line closure information. This paper gives an overview of the system and provides an outline the results of performance tests on commercial lines performed up to this point.

* Autonomous Decentralized Transport Operation Control System with functions for train traffic control, passenger guidance, and plan management for maintenance work

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2. **Overview of Maintenance Vehicle Location System**

2.1 **Overview of Detection of Mistaken Entry**

Fig. 1 is an outline of the concept of the system. It constantly detects the location of road-rail vehicles, compares that location information with status of start of track closure, and outputs an alarm if a road-rail vehicle occupies track where track closure has not started. Information required for that comparison is obtained by the following means.

1. **Road-rail vehicle location information**
   Obtained by positioning information from RTK-GPS receiver equipped to road-rail vehicle.

2. **Track closure status**
   Obtained from ATOS via general-purpose network.

Fig. 2 shows an image of detection when a road-rail vehicle mistakenly enters track where closure is not started. The system constantly compares road-rail vehicle location and track closure start status of neighboring track, so an alarm can be output immediately if a road-rail vehicle mistakenly enters track. And even when a road-rail vehicle is moving on rails after mounting the track, a caution notice or alarm can be output according to the situation if it mistakenly intrudes into a not-closed section.
2.2 System Composition
Fig. 3 shows the configuration of the system. Main devices the system is composed of are as follows.

(1) Maintenance vehicle location system server
Sends to onboard devices work plan and track closure start status obtained from ATOS via general-purpose network. This is the central device of the system.

(2) Compensation information delivery server
Has function to send to the onboard device compensation information required for positioning by RTK-GPS.

(3) Status monitoring device
Has function to monitor operating status of devices that the system is composed of.

(4) Onboard device
The onboard device is equipped to the road-rail vehicle, and it has a screen operated by maintenance personnel. It has functions to detect road-rail vehicle location by RTK-GPS and gyro sensors, compare that to track closure start status received from the maintenance vehicle location system server, and output an alarm if needed. Fig. 4 shows a prototype of the onboard device. It was produced to confirm functions, so it is of a configuration where it is combined with existing devices and weights approx. 14 kg.

2.3 Alarm Details
Table 1 is a list of alarms output by the onboard device. The onboard device has a function to automatically determine whether or not the road-rail vehicle has mounted the rails, so alarms are output according to the mounting status. And it has functions to illuminate a revolving light and sound a buzzer if necessary. Maintenance personnel can thus recognize the alarm status without directly checking the screen.

<table>
<thead>
<tr>
<th>№</th>
<th>Mounting status</th>
<th>Alarm type</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Not mounted</td>
<td>Mistaken entry</td>
<td>Alert at approach by road-rail vehicle carry-in route, etc. to track where closure has not started.</td>
</tr>
<tr>
<td>2</td>
<td>Mounted</td>
<td>Mounted on wrong track</td>
<td>Warn when road-rail vehicle mistakenly mounts track where there is no plan for road-rail vehicle mounting (track where track closure is planned as protective closure of adjacent track).</td>
</tr>
<tr>
<td>3</td>
<td>Mounted</td>
<td>Approach caution</td>
<td>Warn when start or end of closed section is 30 m ahead while moving on rails after mounting track.</td>
</tr>
<tr>
<td>4</td>
<td>Mounted</td>
<td>Out of section with obstruction set</td>
<td>Alert when mistakenly intruding into a not-closed section while moving on rails after mounting track.</td>
</tr>
</tbody>
</table>

3. Performance Confirmation

3.1 Commercial Line Tests
(1) Overview
The following performance confirmation tests were performed on commercial lines. Fig. 5 and Fig. 6 show the tests being carried out.
- Period: January to March 2016 (total of 15 times)
- Place: Keihin Tohoku, Nanbu, Yokosuka, and other lines near Kawasaki Station
- Content: Mount and dismount road-rail vehicle to and from track to simulate actual work and confirm alarm output.

(2) Test results
There was a slight time lag with the system between actual mistaken entry and alarm output due to specifications of location detection by RTK-GPS and onboard device processing capacity. In the tests this time, we set a range of 2.5 m from track center as being within the track (taking into account 1.9 m clearance gauge plus various errors). Practicality
was verified by measuring detection time from mistaken entry to alarm output.

Fig. 7 shows an example of mistaken entry detection. The rectangle in the figure is the location of the road-rail vehicle detected by RTK-GPS and gyro sensors. In this example, the time from mistaken entry to the track to outputting an alarm was 0.507 seconds. In other cases as well, the longest detection time was less than 1 second, confirming that an alarm could be output immediately after mistaken entry to the track. From this, we were able to judge that the system has detection performance sufficient for practical use.

3.2 Test Use in Actual Work

(1) Overview
In the tests on commercial lines mentioned in the previous paragraph, we confirmed that the system achieves the target performance in areas with RTK-GPS reception. We thus used the system in actual work and confirmed status of operation and performed tasks such as identifying points needing improvement and sorting out requests. The following is an overview of that.
· Period: October to December 2016
· Place: Tokyo Station yard, Nanbu, Tokaido Freight, Hinkaku, Yokosuka and other lines near Kawasaki Station,
· Content: The prototype was used in actual work, and its ease of use was verified and points needing improvement identified.

(2) Results of test use
As a result of test use, we found the performance expected of the system could be for the most part provided in locations with good RTK-GPS reception open to the sky as on the Nanbu Line and at the yard of Shin-Tsurumi signal station as in the commercial line tests introduced in the previous paragraph.

On the other hand, we discovered that RTK-GPS reception was poor in the construction carry-in route of Tokyo and Kawasaki stations, so locations of road-rail vehicles could not be detected for the most part. With the construction carry-in routes of Kawasaki station, location detection by RTK-GPS could be done with no problems in commercial line tests performed about 10 months before test use, but we assume the sky had become blocked as construction progressed, making operation of the system difficult. We thus judged that in addition to work locations where the sky is blocked from the start, detection of road-rail vehicle location by RTK-GPS alone would not be feasible in locations such as those where the reception environment would change with the progress of construction. For that reason, we came to the conclusion that a system that also combines location detection methods other than RTK-GPS would be desirable.

(3) Opinions obtained
As a result of identifying points needing improvement from questionnaires conducted after test use for personnel involved in the work, the main opinions included requests for operation according to the flow of tasks at the worksite and simplification of installation of the onboard device. There were also concerns expressed about the onboard device being heavy and large and the need to install in construction vehicles with limited space. In opinions regarding specifications, there were many doubts about detection of location of road-rail vehicles by RTK-GPS alone.
4. Future Plans

By confirming performance, we found that functional requirements were met in environments where RTK-GPS could be used. However, we found that some improvements would be desirable in actual use. We will therefore continue to work on the following development of a location detection method for road-rail vehicles with an aim to putting it into practical use.

4.1 Addition of System to Complement RTK-GPS

We are working to develop an onboard laser system as a location detection method for places where RTK-GPS signals cannot be received. Fig. 9 shows an image of that system. With this system, laser sensors are installed onboard to measure distance to surrounding structures, and measurement data is compared with that of structures recorded in advance to detect the location of a road-rail vehicle.

This system is not affected by the RTK-GPS reception environment; so by using it in combination with a system that uses RTK-GPS, the locations of individual road-rail vehicles can be constantly detected. We are also aiming to make the main unit of onboard devices equipped with this system as small and light as possible to improve ease of transport and installation. We plan for the onboard device to be installable to vehicles with limited space (road-rail vehicle backhoes, etc.), a task that proved difficult with the prototype.

4.2 Development of System Other Than RTK-GPS

With a system that requires onboard devices to be installed to each road-rail vehicle, a large number of onboard devices would be needed in places such as carry-in routes for large-scale construction using many road-rail vehicles, and that is assumed to drive up costs. We therefore are concurrently working to develop a "wayside laser system" completely different from systems that use RTK-GPS. This system has laser sensors installed at the wayside, and locations where lines are occupied by road-rail vehicles are detected by laser beam blockage. Fig. 10 shows an image of this system.

5. Conclusion

Collisions between trains and road-rail vehicles have major repercussions. So, to prevent such accidents and keep railway passengers and maintenance personnel safe, we intend to continue to work on development to put a mistaken entry detection system into practical use. We have received the cooperation in development thus far from Obayashi Corporation, Tekken Corporation, Kotsu Transport Construction & Engineering Corporation, Nippon Densetsu Kogyo Co., Ltd., and other concerned parties, and we would like to take this opportunity to express our sincere thanks.

Reference:

1) Wataru Tokunaga, Tsutomu Oda, Takayuki Tsurumaru, Jun Yagi, Atsushi Sasaki, Shintaro Hatsumoto, Satoru Harada, "For basic test results for detecting that it has entered by mistake the roadrail that utilizes a high-precision GPS" [Abstract in English], Proceedings of the Jointed Railway Technology Symposium 2015, Paper No. 3707 (December 2015).
