Recent Trends and Topics in Research and Development Related to Transportation and Traffic Planning Technology

Kunihiro KAWASAKI
Signalling and Transport Information Technology Division

The signalling and transport information division of RTRI aims to contribute to enhancing safety, reliability, and convenience through research and development in signalling systems, communication network technology, transportation planning and traffic management, and condition monitoring technology for railway facilities. This paper outlines the recent trends in research and development aimed at new train operation and control technology for safer and more stable transportation services. This paper further reports on recent development in technology for detecting obstacles on the track, to reduce railway traffic accidents.

Keywords: traffic control, radio-based train control system, level crossing obstacles detection, track obstacles detection

1. Introduction

The past several years have seen earthquakes and meteorological disasters such as heavy rain events and typhoons causing serious damage to the affected areas. This is especially true with rain events, which have increasingly been not just heavier than anticipated but in the form of a localized downpours, causing massive damage. The railways have also been increasingly badly affected in various ways, typically with facilities sustaining damage and train operations being disrupted. In traffic control, a wide range of actions have been studied and implemented to put top priority on safety through train operation control based on meteorological updates and systematic train service cancellation, while minimizing the suspension of transport services and restoring train operations to normal as swiftly as possible.

RTRI has been developing methods and systems that support traffic control, which is the basis for safe and undisrupted train service. These efforts are aimed at automating or streamlining part of the current traffic control operation and lessening the burden on those involved in traffic control to help make the transport service safer and less likely to be disrupted. Faced with the increase mentioned earlier in more serious meteorological disasters and other possible events of proportions not experienced thus far, however, the current train operation and control systems should be upgraded to levels capable of adapting flexibly and swiftly to changing traffic, meteorological and other conditions.

The majority of non-natural disaster related railway accidents involve level crossings and track incursions. According to Rail Transport Safety Statistics for FY2017 issued by the Ministry of Land, Infrastructure, Transport and Tourism, 435, or 65%, of the 665 railway accidents in FY2017 247 involved level crossings and 188 were due to track incursions. To further improve safety and punctuality in normal operation, there is a pressing need to develop systems that support or assist drivers in track monitoring.

In transport planning, RTRI has been developing and proposing methods for demand estimation based on available data in response to a growing need for station specific demand forecasts of daily and hourly demand, and other “micro” sources of demand, in addition to area-wide and annual demand forecasts. RTRI has also been advancing studies on the quantification of railway’s social value and on supporting decision making following the occurrence of natural disasters. RTRI’s plans going forward are to coordinate work on studies into transport planning with studies on new train operation control systems, which will be discussed later in this paper, to eventually develop methods that will ensure that decisions made following the occurrence of a natural disaster are reflected in train operation control, to apply the results of this coordinated work to evaluate the effect of introducing new train operation control systems.

While R&D in transport planning will be discussed in detail in relevant papers in this issue, this paper focuses on train operation control systems that are being planned, estimated and evaluated. Specifically, this paper will, after briefly presenting past development efforts for traffic control support systems, discuss efforts being made to develop train operation control systems for practical application capable of flexibly adapting to various situations including disasters. This paper also presents work on the development of early detection systems for obstacles on level crossings and tracks that are designed to help prevent railway accidents.

2. Trends in the development of systems that support train operation and control

2.1 Traffic control support systems

Currently, train timetables are prepared and traffic is controlled on the basis of departure and arrival times at stations. To maintain highly convenient transport services, various support systems have been developed that can efficiently generate train timetables that meet the needs or offer appropriate traffic operation arrangement when delays arise.

To support the generation of train timetables, the use of computers was proposed in the 1950s and the “OPERUN Plan” project was launched by the then Japanese National Railways in the 1960s. This marked the beginning of attempts to modernize the train operation information processing system [1]. Subsequently, progress in computer technology led to the development of practical support
systems. In the 1990s, train timetable generation systems were introduced among railway operators. In recent years, cloud-based transport planning systems, which enable railway operators to select and use required features, are being developed [2]. These support systems enable, among other things, efficient checking of train timetables, data sharing among operations concerned and centralized creation of ledger sheets. These systems have also helped improve information provision to passengers and thus customer convenience such as by showing train timetables directly on the displays at stations.

RTRI has been developing methods and systems to support traffic control including the “SPEEDY,” which automatically calculates train performance curves based on which train timetables are developed, those which create transport plans and those which automatically create traffic operation arrangements and rosters for crews. Some of those achievements have already been used by railway operators. The systems that were developed have since been undergoing continuous study for improvement in terms of functionality and performance. New areas have also been explored including methods for identifying patterns based on past train timetables to create traffic operation arrangements and the method [3] for predicting traffic conditions around 30 minutes in advance using machine learning technology.

2.2 New train operation control system based on detailed position information [4]

Radio-based train control systems [5] have been introduced for practical application in recent years that closely monitor train locations, speeds and other parameters to safely control trains using radio communication and database technologies. Radio-based train control differs greatly from the conventional safety equipment in two points: it is capable of continuously monitoring train positions and sending control data directly to each train. More active utilization of these features for traffic control enables new ways of train operation control that are not possible with the current systems.

For example, with the current traffic control, if the preceding trains are delayed in urban and other areas, relevant trains are made to run at speeds permitted by the signaling system, which can force the following trains to temporarily stop before the stations. If it were possible to closely monitor and control train positions when the preceding trains are delayed, it would be possible to finely adjust the speeds of the following trains heading for the stations, which would then make it possible to shorten headway and keep the spread of delay. Secondly, trains can be stopped or slowed based on decisions regarding train operation that are made using the real-time hazard mapping system [6] when a natural disaster occurs or using real-time data from the system for detecting obstacles on tracks described in Section 3, both being developed by RTRI. Thirdly, if certain sections are closed due to accidents or maintenance operation, trains can be flexibly diverted on to alternative tracks to maintain convenience while allowing maintenance to continue even in daytime, which provides increased freedom of operation for railway operators.

Achieving this type of train operation control requires the departure order of running trains to be controlled and timed route control to be executed smoothly in real time. Since FY2015, RTRI has been developing a system that combines traffic control with safety control via an information network to predict traffic conditions based on train operation information and recalculate train performance curves in real time to control individual trains and their routes (Fig. 1).

The system uses a map on which the vertical axis represents continuous train positions, departing from discrete stations or other units seen on conventional train schedule diagrams. The area occupied by a train on the map is represented by a "band." Trains can be operated safely without colliding by keeping ensuring these "bands" remain apart and do not overlap. At the same time, traffic control can be achieved by shifting and/or reshaping (tilting more or less) the bands.

The following technologies are being developed as they are essential for realizing the train operation control system shown in Fig. 1: 1) algorithms for safely controlling trains based on detailed information on train positions and the conditions of facilities and other components; 2) technologies [8] for collecting detailed transport information in real time to predict train operation; and 3) technologies to automatically calculate train operation plans in real time based on the prediction (Fig. 2). Figure 3 shows a possible application of the control algorithm being developed, in which the separation of a train nearing a station from the preceding train is controlled.

With the conventional fixed block system, if the departure of the preceding train is delayed, the train needs to be stopped before the block section the preceding train is in. On the other hand, with the train operation control system being developed, the departure time of the preceding train is predicted and, based on the prediction, the train is allowed to continue heading towards the station at a speed that can maintain a safe distance with the train in front and thereby does not need to be stopped before the home

![Fig. 1 Integrated traffic and train control with an information network](image-url)
3. Development of technologies for detecting obstacles on tracks

The rapid sophistication of sensing technology of cameras, radars and other devices and condition judgment and prediction technology of image processing and machine learning that has been taking place in recent years is raising the possibility of realizing a system capable of automatically detecting obstacles on the route ahead of a running train, a technology that has thus far been difficult to achieve. RTRI has been advancing the research and development of technologies capable of automatically detecting obstacles in level crossings and tracks using the latest ICT with the aims of lessening crew burden and contributing to the realization of automatic train operation.

Level crossing and track obstacles detection technology is not just essential in automatic train operation of tomorrow but effective in enhancing safety by supporting drivers in non-automatic train operation. For these reasons, RTRI has been working on the technology as one of its top priorities to enable early practical application.

This section presents technologies for detecting humans and other obstacles on level crossings and tracks.

3.1 Detection of obstacles on level crossings

To detect obstacles on level crossings, a range of systems have been introduced including those that radiate laser beams on to level crossings and those that use laser radars. However, these systems are designed to detect automobiles, and have limitations, including minimum required dimensions of an object to be detected and blind zones. With this in mind, RTRI has been developing a system capable of detecting level crossing obstacles by processing thermal images taken by far-infrared cameras [7]. The system uses machine learning technology to detect level crossing obstacles and offers a high degree of reliability through comparative dual processing (Fig. 4). Up until the end of the last fiscal year, detection performance verification test had been conducted in rainy, snowy and other weather conditions. The test found that obstacles did not go undetected for more than 700 ms. The system detects obstacles based on temperature differences. If the temperature of an obstacle is close to the road surface temperature, the system may either not detect it or detect it erroneously. For these reasons, the algorithm was improved to enable the system to detect obstacles even when the temperature difference is small. Starting this fiscal year, the improved system has been tested at a number of level crossings for detection performance in the hope that it is will be improved to a level sufficient for practical application by the end of FY2020.

In September 2018, a “practical application promotion team” was launched to put to service the far-infrared detection system for level crossing obstacles as early as possible. The team is tasked with promoting research and development for early introduction of the system into the field through sophistication of the image processing technology that has been developed and upgrading the system to perfection as a safety device. The team has since been engaging in a range of activities including the identification of requirements for practical application, understanding user needs, setting performance targets and preparing and modifying R&D plans.

3.2 Frontal obstacle detection using integrated sensors

By the end of FY2016, a frontal obstacle detection technology had been developed. Based on images taken by a camera mounted in the train cab, the system can detect obstacles measuring 30 cm by 30 cm as far as 230 m ahead and has a detection rate of 80% or more for obstacles as far as 150 m ahead. The system is an application of the technology which detects obstacles based on time and spatial differences between images. Using machine learning tech-
odology, the system was also tried on humans. In the trial, the system was found to be capable of, depending on lighting conditions, detecting humans as far as 250 m ahead and had a detection rate of 90% or more for humans as far as 180 m ahead [8].

Detecting obstacles farther ahead requires more than the image processing technology currently used in the system. Therefore, starting this fiscal year, the development of an obstacles detection algorithm has been underway that employs sensor fusion technology to combine cameras with distance sensors to minimize erroneous detections (Fig. 5).

For obstacle detection in curves and mountainous and other sections where the view from onboard cameras is limited, 90 GHz band radar technology [9] which was developed by the end of FY2015 as part of the research and development project for the expansion of radio wave resources under the Ministry of Internal Affairs and Communications is being applied to the current system to develop a technology capable of detecting obstacles as far as 300 m ahead by the end of FY2020. The current efforts will be continued to extend the detection range to 600 m ahead by the end of FY2023.

Condition monitoring combining image processing with machine learning has been advancing rapidly in recent years. The technology could be applied to track monitoring. The current machine learning technology has many issues such as unpredictable detection results in unlearned events and opaque judgment processes leading to the conclusion. These issues must be resolved before the technology can be applied to the monitoring system which directly affects safety. Even if these issues are resolved, however, machine learning technology would have to go through careful examination and verification before it could be applied to the judgment and prediction processes including track monitoring that directly affect railway safety.

4. Conclusions

This paper presented a train operation control system that can flexibly adapt to various situations including natural disasters and technologies for the early detection of obstacles on level crossings and tracks, which are examples of RTRI’s research and development aimed at helping to make train operation safer and less likely to be disrupted. In addition to the work discussed in this paper, RTRI has been advancing R&D on simulation methods for quantitatively evaluating the effects of various traffic control and train operation control methods as well as on infrastructures for integrated information networks for train operation control that can centrally handle information required for railway operation. RTRI has also been engaging in other activities including the development of technologies as the basis for studying types of service and for decision making, making related proposals as well. Some of the examples include hourly, instead of the current daily, demand prediction methods for individual trains and methods for quantitatively evaluating the value of railway services.

Making railways safer and more secure going forward, relies heavily on finding the best ways to collect and utilize every piece of information related to train operation. RTRI will continue its R&D aimed at building and offering more convenient railway services, actively adopting the latest information and communications technology while addressing the current issues, in order to achieve ideal traffic and train operation control.

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Author

Kunihiro KAWASAKI
Director, Head of Signalling and Transport Information Technology Division
Research Areas: Radio Communication Systems for Train Operation and Control, Electromagnetic Compatibility Evaluation