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An approach to eliminate train route setting errors through application of parallel monitoring

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ABSTRACT

Since 1980, there have been over 100 train collision accidents, resulting in many serious injuries and deaths as well as financial losses. In 2013 alone, there were cases of this type of accident in Switzerland, Argentina, America, Portugal and Russia. There are various causes of train collisions, including overrunning signals at danger, setting the wrong train routes, over-speeding, brake failures, etc. Setting the wrong train routes is regarded as the main cause of collisions.

This paper proposes an approach to eliminate train route setting errors by applying parallel monitoring, which can be used to supervise train route setting and operator operation processes based on virtual image technique. Unlike a real interlocking system, this method can link together the traffic planning, operator operation, interlocking execution, train route occupation and releasing, to achieve the purpose of enhancing system safety and efficiency, whilst monitoring operator operations.

The problems with existing train route setting systems are analyzed and a solution is proposed. The principle and methodology of using parallel monitoring to supervise train route setting based on virtual image technique are described. A designed architecture is illustrated and elaborated for a good understanding of the system. A case study of a Stochastic Petri Net (SPN) model using the proposed parallel monitoring is given, based on which the safety of the system is analyzed.

1. Introduction

Since 1980, over 100 deadly train collision accidents have happened worldwide, nearly all of which caused heavy casualties and huge financial losses. The causes of train collisions include overrunning signals at danger, setting the wrong train routes, overspeeding and brake failures. Setting the wrong train routes is one of the main causes. A train route refers to a section of the line which is used for a train to arrive at, depart from or pass through a station. An interlocking system is used to ensure the logical correctness of the train route based on the interlocking relationships among signals, switches and track sections in a station. Although advanced equipment and control technology has been adopted in modern railway signaling systems for train route setting, such as Computer Based Interlocking (CBI), the correctness of train routes has not yet been fully guaranteed. Some cases of train collision accidents which have occurred due to train route setting errors are listed below:

- On 29 April 1997, two passenger trains, namely train 324 and train 818, had a rear-end collision in Rongjiawan Station in China, causing 126 deaths and 230 injuries. The cause of the accident was a mistake by a signalman who, against rules and regulations, sealed the connection terminals of a switch with a diode, causing the interlocking system to arrange the same train route for both train 324 and train 818.
- On 14 February 1994 passenger train 146 had a side collision with freight train 3109 at Zhangming Station. Several cars were derailed and one person was killed. The cause of the accident was the failure of the track circuit, which failed to indicate that three cars of train 3109 had stopped outside a fouling point. As a result, the signalman mistakenly set another route for train 146, which shared the same switch as the route for train 3109.

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- On 14 December 2004, two passenger trains collided in the northern Punjab state of India, killing 50 people and injuring about 150. The accident was caused by the stationmaster, who was grossly negligent. He arranged the same route for a train through the station as a local passenger train on the tracks.
- On 22 September 2006, a maglev train crashed into a maintenance vehicle near the Netherlands border on the test track in Lathen, Germany, killing 25 people and seriously injuring 10 more. The dispatch center wrongly set a route for the maglev train which was occupied by a maintenance vehicle.

In addition to the accidents which have been publicly reported, there have been many other incidents related to setting the wrong train route, which have occurred without leading to accidents. Many wrong train routes are detected in a timely manner by drivers, operators and signalmen, and emergency measures are taken and potential accidents avoided.

Some methods and techniques have been adopted to prevent train collisions. Wang et al. (2015) proposed a concept and a designed architecture for the Next Generation of Train Control Systems (NGTCS), in which parallel monitoring was described as one of the key technologies in NGTCS. (Wang, 2010, 2004a; Ning et al., 2010; Wang et al., 2012; Ning et al., 2011) presented a parallel control and management technique, of which (Wang et al., 2012; Wang, 2006) and (Ning et al., 2011) described the research framework for parallel control and management in China's high-speed railway. (Wang et al., 2008) proposed a virtualization technology with its railway applications. (Wang and Lin, 2011; Wang, 2004b; Gunnika, 2012) carried out research on intelligent control strategies for trains and future train traffic control, including the development and deployment of new principles and systems in train traffic control. (Schmid, 2002; Evans, 2011) introduced control research to Europe and analyzed fatal train accidents on European railways from 1980 to 2009.

A parallel monitoring method of train route setting, which is used to eliminate train route setting error is presented in this paper. It uses a virtual mirror image technique to monitor train routes and the route set-up process in real time, which can effectively improve the correctness and safety of train route setting. This paper is the follow-up and application of the parallel monitoring technology proposed in (Wang et al., 2015).

2. The problems with train route setting in existing signalling systems and an improved method

To ensure train operation safety, a train control system should have overall control on the safety-critical elements, such as train route, train interval, train speed, temporary speed restriction and operation supervision. The train route is shown at the top of Fig. 1. In an existing signaling system, the self-discipline control technique is used for train route setting in a Computer Based Interlocking (CBI) system. In this paper, parallel monitoring is added to monitor the equipment status and the operator operation.

2.1. Train route control method

In order to realize train overtaking and passing, some track sections, switches and signals are installed in stations for setting up train routes, which must be set correctly to avoid train conflicts.

A station operator is mainly responsible for train route setting, including block handling, route arranging and signal controlling. He should, according to the train timetable, push the route buttons of the interlocking device to select a route for the specified train. The route controls include: route election row, locking opening signals and unlocking (Zhixi, 1999; Mocki and Vlacic, 2013).

2.2. Several cases of setting erroneous train route

There are several essential factors related to train route setting, including the operation of the operators and the execution of the interlocking. Several cases of setting erroneous routes include (Hasanzadeh and Sandidzadeh, 2008; Mulazzani, 1987; Lee et al., 1985):

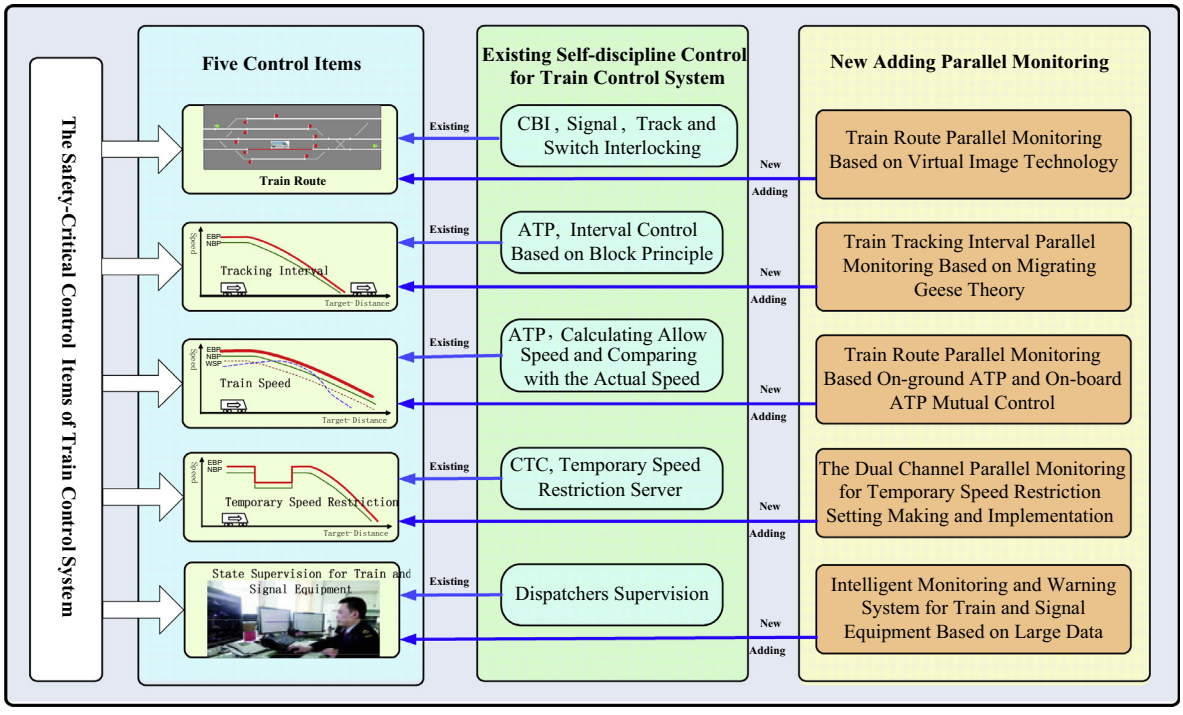

Fig. 1. The existing self-discipline control and newly-added parallel monitoring.