Specification of Receiving-Departure for Automatic Train Protection and Block System

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This paper presents a formal specification and analysis of the procedure of train receiving-departure for the Automatic Train Protection and Block (ATPB) railway system, which is mainly with on-board equipment. When a train approaches, arrives at, and departs from the station, the state space model of train, signal and point are formally specified by state transition diagram. The specification contributes to the future development and application of the ATPB system.

Key Words：ATPB, Railway System, Formal Method, state transition

1. Introduction

As the effect of depopulation and competition from automobile is getting heating up, the survival condition for local train line is facing with severe challenges. It is a critical to improve the competitiveness of existing railways. Though there are several powerful railway systems [1-3], they are all too expensive.

Regarding these problem, the author proposed a novel radio railway system, i.e. Automatic Train Protection and Block (ATPB) [4]. Its greatest advantage is a large use of universal and mature technologies, which could control the cost effectively with few increment of trackside device. For example, the communication network is accomplished by common mobile telephone network, such as *docomo*, *SoftBank* and *au*; and the position detection of the train is realized by GPS signals and necessary auxiliary equipments. Then how to describe the ATPB system precisely is a key problem. Until now, several railway systems have been analyzed by Formal Methods (FMs) [5, 6]. However there is no specification about the procedure of a train approaching, arriving at, and departing from a station.

The rest of this article is organized as follows. In sections 2, we describe an overview of the operations of a train approaching, arriving at, and departing from a station. In section 3, the state transition diagram of train, signal and point are presented. And at last, we conclude the paper in section 4.

2. System Overview

Considering Fig. 1, the processes of a train approaching, arriving at and departing from the station in NORMAL direction are depicted as follows: For convenience, just the key equipments for normal direction are showed in Fig. 1, and the symbols are interpreted as, (1) 19R is receiving signal, and 20R is departure signal; (2) 19P and 20P are points close to station St10; (3) variables x, y and z represent the distance from train T1 to 19P, 20R and 20P respectively; (4) A, B and C are the detecting position of approach, arrival and departure; and (5) a, b and c denote the distance between A and 19P, B and 20R, 20P and C respectively. The process of a train passing through a station is briefly described as follows, (a) when it arrives at A, it sends an approach message to control center, and if all conditions are met, the train pulls into the station, else stop; (b) when it stop at B, then it sends an arrival message to control center; and (c) once received the departure message, it starts off, and when it reach C, it sends the departure message. Once even if only one train becomes out of contact with control center, all trains on the line will stop. Furthermore, control center updates the line information real-time, and Automatic Train Stop (ATS) system supervises the movement of train all the time, preventing the accident resulting from over speed.

Generally, we can design software in according with the specification such as above. However, we are aware that the specification by natural language is usually ambiguous. So in order to avoid this, the process above will be specifically mathematically in section 3.

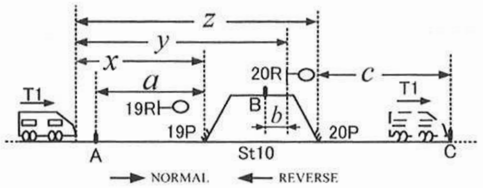

Fig. 1 Description of Receiving and Dispatching train

3. State transition diagram

In this section, we make a quantitative specification about the state of train, signal and point by state transition diagram, which is a formal method for a process of mixed discrete-continuous system.

3.1 Train

The Fig. 2 models the sate of a train approaching, arriving at and departing from a station. As explained before, and $\dot{x}$ is the speed, which is equal to $\dot{y}$ and $\dot{z}$. The set {*far, near, arriving, departing*} denotes the position relationship between train and the next station. Sets {*approach, arrival, departure*} and {*receiveOk, departOk*} are the messages sent by train and control center respectively. The event denotes a message from train to control center. Conversely, the event denotes a message from control center to train. t is communication time; and δ is the deadline.

3.2 Signal

The Fig. 3 models signal, where u is a symbolic constant, which represents the time of the yellow; t is a clock for measuring elapsed time. When a *set* event is received, the signal turns green, and when a *reset* event received the signal turns yellow within u seconds, and then turns red at last.

3.3 Point

The Fig. 4 models the point, whose state is denoted by a set {*normal, upping, downing, opposite*}. The variable x represents the position of throw rod. Initially, the point is in normal state ($x = 0$). When an *up* event is received, the throw rod starts moving at a same rate. When the point reaches the opposite position, it stops. Inversely when the *down* event is received, it returns back to normal position.

4. Conclusion

This paper described the state transition diagram of train, signal and point, by which their process are expressed clearly without understanding deviation, which is the basis of system safety. What`s more important is that we have analyzed the parameters of system mathematically, such as the safety stopping distance a, b, c in Fig.1. And in future we will make simulate the ATPB system before implementation.

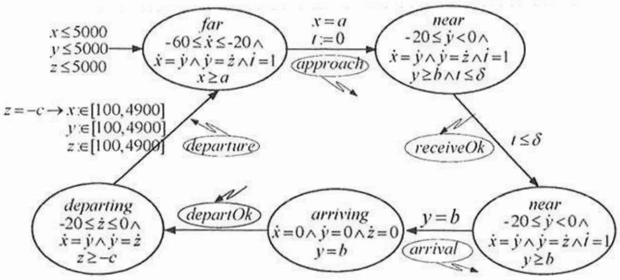

Fig. 2 Train

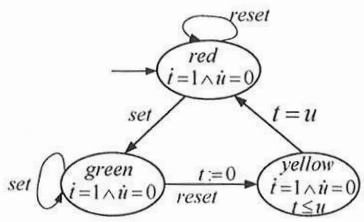

Fig. 3 Signal

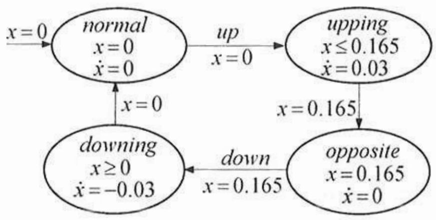

Fig. 4 Point

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