Modeling and analysis of medium speed maglev vehicle network based on CPN

Yibo Jiao¹, Xiangqian liu¹, Xiaoyong Chen²

¹Beijing Jiaotong University, School of Computer and information Technology, Beijing, China
²China Railway Jinan Group Co., Ltd., General engineer room, Jinan, China

Abstract. With the upsurge of magnetic levitation construction and research in China, in order to improve the running speed of mid-low-speed maglev train, the 13th Five-Year Science and Technology Major Proposal put forward a medium speed maglev solution with long stator synchronous traction. According to this new plan, the magnetic levitation subsystem, including the control system, needs re-co-ordination design, and the car network system must be changed accordingly. In this paper, based on the original scheme, a new magnetic levitation vehicle network system is designed to meet the needs of localization. In this paper, colored Petri nets are used to model and analyze the original scheme and the improved scheme. It proves theoretically that the improvement scheme is superior to the original scheme in failure rate and can meet the actual project requirements.

1 Introduction

Maglev is the recent rise of transport, with fast, small impact on the environment and so on [1]. With the maglev line in Changsha and Beijing "S1 line" have been opened up operations, set off a boom in magnetic levitation and research. In order to improve the running speed of medium and low speed maglev train, the 13th Five-Year Science and Technology Major Proposal put forward a long-stator synchronous traction medium speed maglev program. For this new scheme, all subsystems including the control system need to re-co-ordinate the design, While the on-board operation control system also needs to be changed accordingly as part of the operation control system. At the same time, it needs to be pointed out that in the process of localization, it follows the technical route of foreign countries or combines with the latest technological trends. There are many disputes over adopting new architecture and agreement. The purpose of this paper is to use the method of formal analysis, Research, for a new generation of medium-speed magnetic levitation vehicle control system to do some design.

2 Scheme Introduction

2.1. Origin Scheme

Figure 1 is a schematic diagram of the maglev vehicle communication network in the original solution. In the scheme, there is one communication antenna at the rear of the car, the rear of the car is connected to the MRCUB via the RS232 bus, the MRCUA and MRCUB are connected to the vehicle safety computer1 (VSC1) is connected and VSC1 and VSC2 are connected via Ethernet [2].

The original design has a serious flaw that VSC1 and VSC2 have different effects. VSC1 receives the message of two MRCU modules and then forwards the message to VSC2. In this scenario, VSC1, as the main vehicle-mounted security computer, plays a much greater role than VSC2. Some control signals such as "1st brake current cut-off", "2nd brake current cut-off", "free flow receiver" and other commands are controlled by VSC1 and VSC2 at the same time, but for some control signals such as "Right Door ", "Open Left Door "and other instructions are only controlled by VSC1. This design will cause some interference to the safe operation of the train. If VSC1 fails during operation, VSC2 can not take over the operation of VSC1 because it does not have all the functions. What VSC2 can do is guide the safety of the maglev train.

In addition, the original program there are several drawbacks: One of them is to place MRCUA and MRCUB in the front of the car. If MRCUA and MRCUB are damaged in the same way as a whole or other accidents occur, the maglev vehicle loses contact with the decentralized control system or with the central control system. The basic functions of the whole car may be damaged, which is not in line with the principle of redundant design; In addition, due to the technical limitations of the time did not use real-time performance better Ethernet, such as Industrial Ethernet Ethernet Powerlink and other technologies.
2.2 Improve Scheme

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In order to overcome the shortcomings of the original vehicle network system, this paper discusses the design of a new vehicle network system based on the original vehicle network system, the schematic diagram of improved vehicle network shown in Figure 2.

Relative to the original scheme, this article made the following modifications in the car network:

(1) The MRCUA and MRCUB are placed on the front and the rear respectively, so that even if the front of the car is severely damaged, a complete set of equipment for parking spaces can work safely.

(2) Connect MRCUA and MRCUB with two VSC1 and VSC2 on-board safety computers, respectively, and add 4-channel communication based on the original two-channel communication, so the security is higher.

(3) Replacement of outdated technologies in the in-vehicle network, such as replacing the traditional Ethernet with real-time better industrial Ethernet.

(4) The VSC2 at the rear of the vehicle communicates with both MRCUs not as a secondary computer system. As long as one of the two on-board safety computers is in operation, the entire maglev train can run safely.

(5) The two VSCs can still communicate with each other, which is mainly used to compare the obtained information and leave the correct information frame with the minimum delay.

3 CPN Modeling

3.1 Origin Scheme

CPN is a kind of advanced Petri nets. On the basis of Petri nets, the concept of color set is added to facilitate the analysis of discrete events such as concurrency and synchronization, which greatly reduces the model complexity[3].

The CPN is represented by a nine-tuple: 
\[ CPN=(\Sigma,\mathcal{P},\mathcal{T},\mathcal{A},\mathcal{N},\mathcal{C},\mathcal{G},\mathcal{E},\mathcal{I}) \] (Wei, Z. 2012) where
- \( \Sigma \): limited non-empty color collection;
- \( \mathcal{P} \): limited place collection;
- \( \mathcal{T} \): limited transition collection;
- \( \mathcal{A} \): limited arc collection, satisfies \( \mathcal{P} \cap \mathcal{A} = \mathcal{P} \cap \mathcal{T} = \mathcal{T} \cap \mathcal{A} = \emptyset \);
- \( \mathcal{N} \): node function, defined as mapping: \( \mathcal{A} \rightarrow \mathcal{P} \times \mathcal{T} \cup \mathcal{T} \times \mathcal{P} \);
- \( \mathcal{C} \): color function;
- \( \mathcal{G} \): security function;
- \( \mathcal{E} \): arc expression function;
- \( \mathcal{I} \): initialize function;

In this paper, the executable model of Maglev communication system is constructed by CPN.

3.1.1 The Original Scheme Top Model

In order to verify whether the improved scheme is better than the original scheme and whether it meets the project requirements, under the Windows10 operating system, the CPN Tools tools were used to model the original scheme and the improved scheme, respectively, to compare whether the failure rate meets the requirements.

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Figure 3 is the use of CPN principle of the original program network system to establish the top model, Where the circular element is the place and the square element is transitions.
Fig. 3. the top layer model of the original scheme of the vehicle network system

Fig. 4. improved voting submodel for vehicle network system

The data frame is sent redundantly from the four channels by the car wireless communication system. Two identical data are sent to the place MRCUA, and two identical data are sent to the place MRCUB. After the two data reach the MRCU module, the tokens are triggered by the transition vote1(vote1, vote2, vote3 are sub-transitions, which will be introduced in later articles). If the MRCU module is working normally, the transition MRCUAOk fires to send data frame. Otherwise, the data frame is sent incorrectly. After two transitions 2VSC1 and 2VSC2 firing, the data frame is sent to the VSC1 and the VSC2, respectively. Four channels MRCUA to VSC1, MRCUB to VSC1, MRCUA to VSC2, MRCUB to VSC2; then VSC is triggered by vote3 and vote4, voting information from MRCUA and MRCUB, leaving the correct first-arrival message frame, the last two The information in a VSC initiates the correct first-arrived frame of information when fired by the vote5 transition.

3.2 Improve Scheme

3.2.1 The improve Scheme Top Model

Layered model, Figure 5 is to improve the program top-level model. The data frame is sent redundantly from the four channels by the car wireless communication system. Two identical data are sent to the MRCUA, and two identical data are sent to the MRCUB. After the two data reach the MRCU module, the transition is triggered by the vote1(vote1, vote2, vote3 are sub-transitions). If the MRCU module is working normally, the transition MRCUAOk fires to send data frame. Otherwise, the data frame is sent incorrectly. After two transitions 2VSC1 and 2VSC2 firing, the data frame is sent to the VSC1 and VSC2 respectively. Next, VSC votes the information obtained from MRCUA and MRCUB by transition vote3, leaving the correct first-arrival information frame and finally judging whether VSC1 is working properly. If normal Work, the information frame flows normally into the place Final.

3.1.2 The Original Scheme Vote Sub-Model

vote1, vote2, vote3 Several voting sub-models are almost completely structurally straightforward, taking the vote1 vote sub-model here as an example in figure 4.

Voting submodel data frame flow as follows: When there is a data frame to enter the model, the transition check will be triggered. First check whether there is the current data frame serial number in the place votelist, if not, store the serial number in the votelist and output the data frame to the output place; if the serial number already exists in the place votelist, it means the data Frames are arrived after the data frame, to be discarded. Place mutual play a mutually exclusive role to prevent the two channels at the same time. Place votelist1 and votelist2 are fusion place, they represent the same place.
Fig. 5. improving the top layer model of the vehicle network system

Table 1 comparison test results

| Data sent successfully ratio/% | device-free rate/% |
|-----------------------------|-------------------|
| Original scheme             | Improve scheme     |
| 90                          | 9787              |
| 91                          | 9836              |
| 92                          | 9866              |
| 93                          | 9902              |
| 94                          | 9933              |
| 95                          | 9946              |
| 96                          | 9955              |
| 97                          | 9987              |
| 98                          | 9994              |
| 99                          | 9999              |

Fig. 6. contrast test data folding diagram

4 Experimental Analysis

By simulating the vehicle network model running in the original scheme and the improved scheme, the simulation sends 10000 data frames, starting from the RADIO place and ending with the final place. A number of independent experiments found that the stability of the model is better, and there is not much difference in the data between groups of experiments. Now, taking one of the groups as an example, Table 1 compares the results of the experimental data with the device-free rate of 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, etc. The resulting data frame is obtained from the model (in this experiment, the pros and cons, in the actual project in general the failure rate of equipment is much better than this).

Generally believed that the packet loss rate of more than 99.95 in the network is considered to be applied in the project. It can be seen from Table 3-9 that the original solution still fails to meet the 99.95% standard when the device-free rate is 99%; and the improved solution can achieve packet loss rates greater than 99.95% when the device-free rate is 99% Send data packet. In order to more intuitively show the improved performance of the program, the use of line chart display data, as shown in Figure 6.

5 Conclusions

The train network system project of this project fully considered the project "Twelve Five" key project "research and development of key technologies of high-speed maglev operation control"[6] and medium-speed maglev vehicle network architecture in the past, designed the maglev train network system in this paper, then using colored Petri nets to simulate the original scheme and the improved scheme separately, the conclusion is drawn that the performance of the improved scheme is obviously better than the original scheme on the performance of no-fault rate. This article has certain reference meaning for the future research of maglev rail transit.

This research is supported by the key technology research and equipment development of high speed maglev operation control system with grant number 2016YFB1200602-26, and key technology research and equipment development of medium speed maglev operation control with grant number 2016YFB1200601-B24.

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