Intelligent Perception Control System of Railway Level Crossing Gate Based on TRIZ Theory

Zhansen Wang, Haotian Sun, Ke Wu, Chi Zhang, Jianhao Tong
Dalian Jiaotong University, Dalian 116028, China.

Abstract: TRIZ theory is an innovative method to analyse problems and solve them, which is widely used in many fields. In this paper, TRIZ theory is used to improve the design of railway crossing guardrail system. The use of nine-screen analysis, functional analysis, cause-effect chain analysis and other tools to analyse the problem of poor manual control effect in the railway crossing guardrail system, the use of technical contradictions, physical contradictions and other tools to improve the system design, effectively reduce the possibility of danger when cars and pedestrians cross railway crossings, improve the traffic safety and traffic order of the railway level crossing, and reduce the work burden of railway crossing caretakers.

Keywords: TRIZ Theory; Railway Level Crossings; Vibration Sensor; Intelligent Perception; Intelligent

1. Introduction

TRIZ is a set of universally applicable invention theories proposed in 1946 by Soviet inventor Archie Schuller and his colleagues after analyzing nearly 2.5 million high-level invention patents. "TRIZ" is an abbreviation of "Teoriya Resheniya Izobreatatelskikh Zadatch" translated into Latin from Russian, and its full English name is "Theory of the Solution of Inventive Problems". TRIZ theory is widely used in the field of engineering and technology, and is a set of methods and tools for systematically solving various complex problems.[1] In this paper, TRIZ theory is used to analyze the existing defects of the existing railway crossing guardrail system, and finally a suitable scheme is obtained.

2. Describe the Problem

As a junction of railway transportation and road transportation, railway level crossing is a weak link and dangerous section in the safety production of railway transportation, and cars and pedestrians are easy to collide with moving trains. Especially in unattended (no railings) railway crossings, cars and pedestrians rush to the railway level crossings from time to time, there are serious safety hazards[2]. In recent years, with the rapid development of society, the speed of railway trains has been continuously improved, the number of cars has been increasing, and the safety of crossing has become more and more serious[3]. Once a crossing accident occurs, it will not only interrupt the normal operation of the railway, bring serious economic losses, but also cause casualties. Therefore, trains, cars, pedestrians and other means of transportation must observe traffic order in an orderly manner to ensure the safety of life and property.

At present, most of the domestic railway crossing control still adopts manual control methods, but because the level of caretakers is uneven, human negligence and inertia are difficult to avoid, resulting in various deficiencies and errors in the operation link. The main commonly used systems on the market in China are: Embedded control early warning system[4], but when the driver passes through the intersection, he cannot obtain the traffic status of the crossing, and still needs to look at it when passing; Railway level crossing warning system based on radar detection[5], but when there are unknown obstacles and locomotives at the same time, the system is prone to misjudgment and is not reliable enough; Image surveillance railway drone port warning and protection system[6], but the system has high requirements for the working environment of the equipment when used. In view of the above problems, based on TRIZ theory, this paper designs an intelligent perception control system for railway level crossing gates, which effectively improves the management of railway level crossings and improve its security and unmanned level.

3. Analyse the Problem

3.1 Nine-screen Analysis

Through the nine-screen analysis in Figure 1, the current system of this project is "Railroad crossing guardrails". In the past, the system was "Manually controlled railway crossings", mainly relying on manual control to provide crossing management services. The future of the system is "Automated railway crossing gates", which need to be automatically controlled by the corresponding data obtained by the detection device during the train journey.

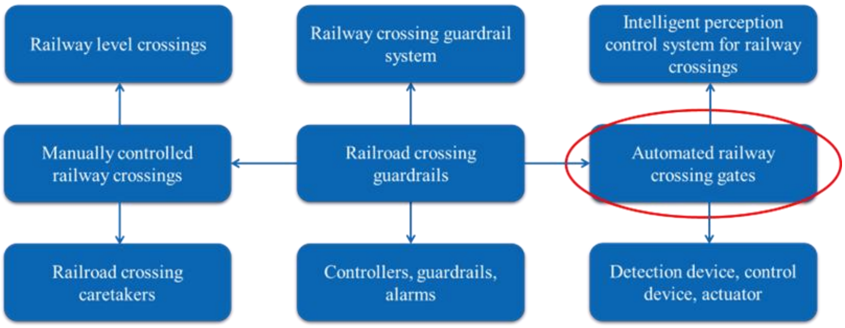


Figure 1. Nine-screen analysis

3.2 Functional Analysis

The functional analysis is divided into three parts, namely component analysis, interaction analysis, and function model.

3.2.1 Component Analysis

Through the analysis of 3.1, the component analysis of the railway crossing guardrail system is further carried out, and the subsystem components and supersystem components are obtained, as shown in Table 1.

Table 1 Railway crossing guardrail system components

Subsystem component	Supersystem component
Support part	Harsh environment
Guardrail	Train
Microcontroller processing system	Cars and pedestrians
Signal light	
Judgment device	
Infrared sensor	
Accelerometer	
Motor drive	

3.2.2 Interaction Analysis

After the component analysis of the system, the next step is to perform the interaction analysis. Interaction analysis refers to the analysis of the interaction between two pairs of identifying subsystem components or supersystem components. As shown in Figure 2 below, if there are black dots between the two components, there is an interaction.

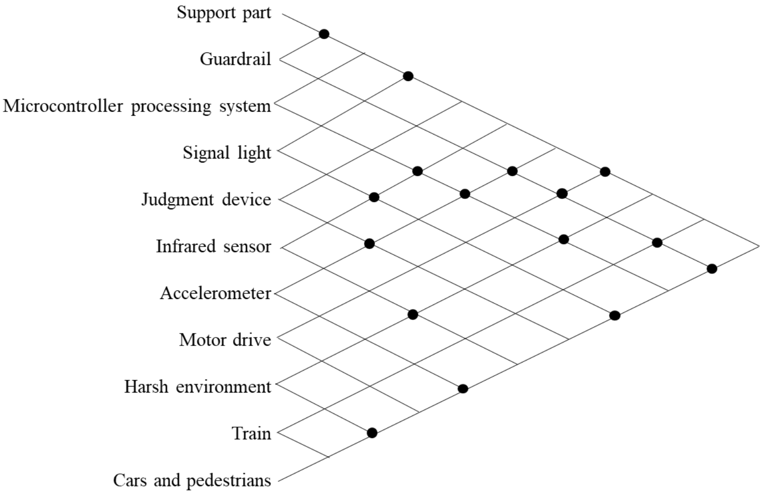


Figure 2. Component interaction analysis diagram

3.2.3 Function Model

Function model is the final stage of a functional analysis of a system. The purpose of this step is to find out the impact of components on the functionality of the system and the harmful effects of components on the system through interaction analysis, the specific analysis is shown in Figure 3.

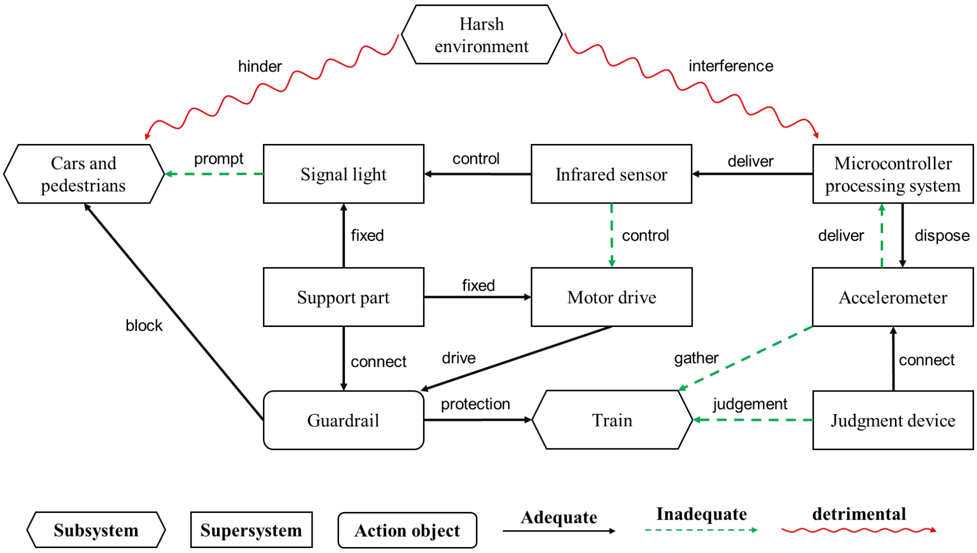


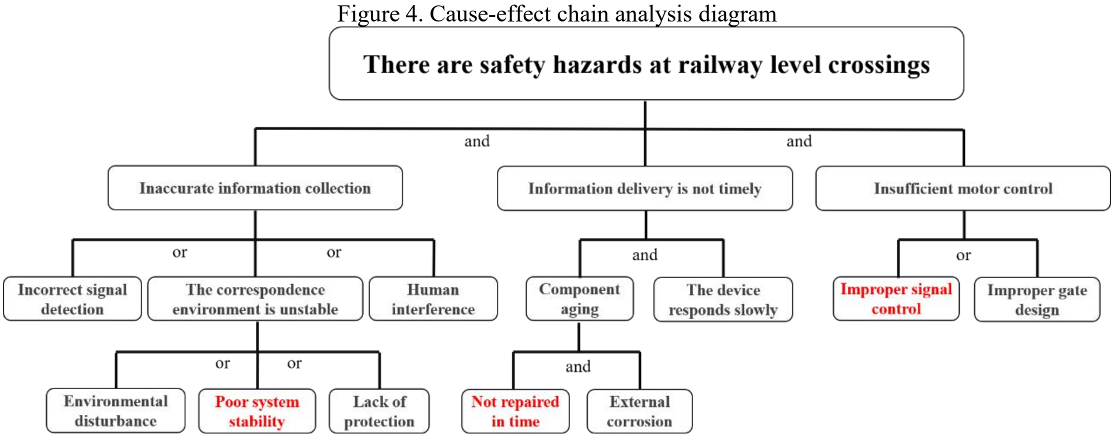
Figure 3. Function model diagram

Through the analysis of the function model, it can be concluded that the main reasons for the potential safety hazards at railway level crossings are: (1) The accelerometer is not accurate enough to collect the arrival signal of the train; (2) The accelerometer transmits information to the single-chip microcontroller processing system in a timely manner; (3) The infrared sensor has insufficient control over the motor drive device.

3.3 Cause-Effect Chain Analysis

Through the analysis of the function model, three results of potential safety hazards at railway level crossings are obtained, and then the root cause of the problem is found step by step from the result to the cause, that is, "the Cause-Effect Chain Analysis", through the analysis can be obtained as shown in Figure 4 of the cause-effect chain analysis diagram.

Figure 4. Cause-effect chain analysis diagram



4. Solve the Problem

By using the nine-screen analysis, functional analysis and cause-effect chain analysis in TRIZ theory, it is concluded that "Poor system stability", "Not repaired in time" and "Improper signal control", these three points are the main reasons for the problem of "safety hazards at railway level crossings".

Through analysis, it is established that technical contradiction 1 is "Poor system stability", technical contradiction 2 is "Not repaired in time", and physical contradiction is "Improper signal control".

4.1 Use Technical Contradictions to Solve Problems

Technical contradictions refer to the mutual constraints between two parameters in the technical system, simply put, contradictions caused by the deterioration of one parameter in the technical system. After we turn the actual problem into a technical contradiction, we can use the contradiction matrix to get recommended innovation principles. Using these innovation principles as inspiration, it is easy to find some feasible solutions to practical problems.

4.1.1 Technical Contradiction 1

In order to solve the problem of "Poor system stability" and improve the stability of the system and the safety of railway crossings, various complex electronic components can be applied in the system to make the work of the system more reliable. However, when the number of electronic components used increases, it increases the frequency of system failures and is not easily noticed.

Improved engineering parameter is: Reliability; Deteriorated engineering parameters is: Detection difficulty.

The technical contradiction is described by engineering parameters and the contradiction matrix is found to obtain the corresponding invention principle, as shown in Table 2.

Table 2 Technical contradiction matrix table (1)

Improved engineering parameter Deteriorated engineering parameters	Reliability(27)
Detection difficulty (37)	27. The principle of cheap alternatives 40. The principle of composites 28. The principle of mechanical system substitution

From the technical contradiction matrix table (1) and 40 inventive principles, "the principle of mechanical system substitution" can be adopted. **Tips for deriving solution:** The accelerometer and infrared sensor can be changed to a vibration sensor. By detecting the vibration frequency of the track to determine the position of the train from the crossing, the stability of the system can be improved.

4.1.2 Technical Contradiction 2

In order to solve the problem of "Not repaired in time", the number of electronic components used in the system can be reduced, the working stability of the entire system can be improved, and the maintenance work of the system is relatively easy. However, the system may not be able to accurately collect train information, reducing the reliability of the system.

Improved engineering parameter is: Easy serviceability; Deteriorated engineering parameters is: Reliability.

The technical contradiction is described by engineering parameters and the contradiction matrix is found to obtain the corresponding invention principle, as shown in Table 3.

Table 3 Technical contradiction matrix table (2)

Improved engineering parameter Deteriorated engineering parameters	Easy serviceability (34)
Reliability (27)	11. The principle of precaution 10. The principle of pre-action 1. The principle of segmentation 16. The principle of insufficient or excessive action

From the technical contradiction matrix table (2) and 40 inventive principles, "the principle of segmentation" can be adopted to separate the information collection part and the guardrail control part. **Tips for deriving solution:** The railway crossing guardrail system is divided into three parts: perception module, control module and execution module.

4.2 Use Physical Contradictions to Solve Problems

Physical contradiction refers to the inability of a certain parameter in a technical system to meet the mutually exclusive and different needs of the system. The existing physical contradiction is "improper signal control". The opening and closing of the barrier gate needs to be controlled by a signal sent by acceleration. But when the train is about to arrive and when the train is passing, the accelerometer sends the same signal. If low acceleration is used as the door opening signal, the barrier gate is open when the train is about to arrive; If high acceleration is used as the door opening signal, the barrier gate is always closed when the train passes.

So there is such a physical contradiction: when the train arrives and passes, the signal that controls the opening and closing of the barrier gate must be both high and low.

On the basis of summarizing the methods of resolving physical contradictions, the modern TRIZ theory divides the separation principle into four basic types, namely: spatial separation, temporal separation, conditional separation, and whole and partial separation. Through analysis, the principle of separation of whole and part can be used to solve the contradiction.

Tips for deriving solution: The perception module can be divided into two parts and installed on both sides of the crossing on the same track. Perception module 1 detects the arrival of the train and sends a gate closing signal. Perception module 2 detects the passage of the train and sends a signal to close the gate. Control the opening and closing of the gate separately, reduce the inability of the barrier to be effectively opened and closed due to improper signal control, and send the railway crossing safety accident. The mounting locations of the two perception modules are shown in Figure 5 below.

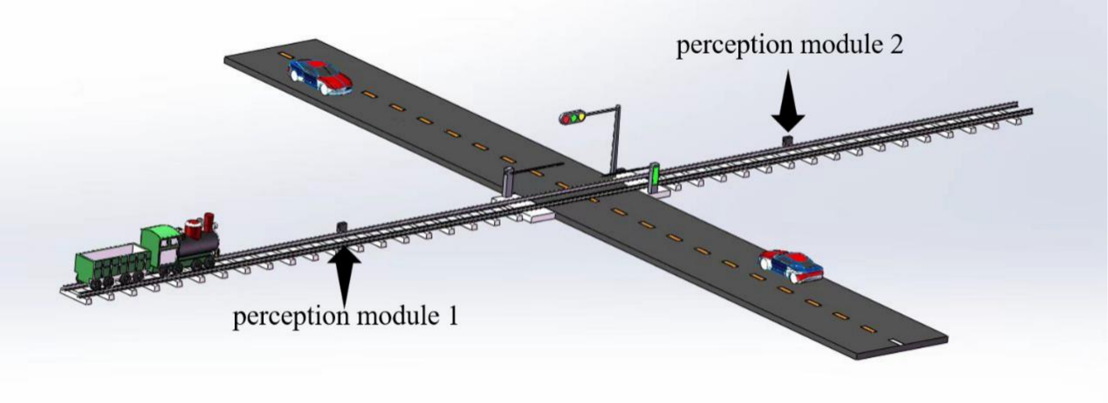


Figure 5. Schematic diagram of the installation location of the perception module

5. Final solution

The above TRIZ theory is used to analyze the existing problems of railway crossing guardrail system and improve the design, and the final solution is obtained: The railway crossing guardrail system consists of three parts: perception module, control module and execution module. The sensor in the perception module uses a vibration sensor and divides the perception module into two parts. The system test scenario is shown in Figure 6 below.

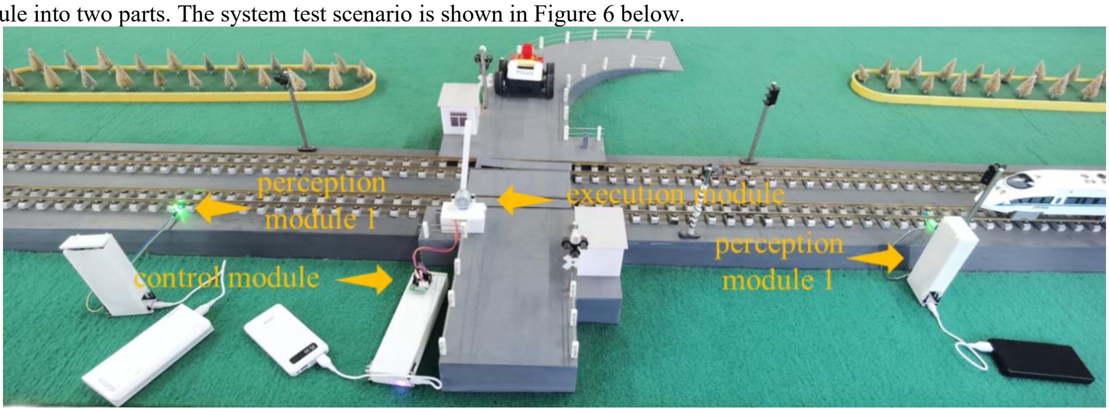


Figure 6. Test scenario of intelligent perception control system of railway level crossing gate

The working principle of each part of the system is as follows:

5.1 Perception Module

The perception module includes sensing hardware, vibration acquisition, and information transmission. The vibration sensor and the ESP32 microcontroller that receives the signal are jointly connected to the PCB board. The sensor senses the vibration frequency of the track to determine the position of the train from the crossing, and transmits the information to the ESP32 microcomputer, after receiving the signal, the blue indicator lights up and sends the information to the control module.

5.2 Control Module

The control module includes control hardware, information reception and sending instructions. In order to avoid the unstable transmission signal of the communication module that comes with the ESP32 microcontroller, this project adds NRF24L01 to realize the mutual communication between the modules, and forms a wireless communication module with the ESP32 microcontroller, so that the two ESP32 microcontroller in the perception module and control module can achieve wireless communication through signals.

5.3 Execution Module

The actuation module includes gates, warning lights and buzzers. The execution module and the control module are connected to form a gate control system, and the gate, warning light and buzzer are driven by the information received by the ESP32 microcontroller in the control module, so as to realize the automatic control of the gate. Among them, the gate is driven by a stepper motor, and the project uses Python language to compile high and low level programs, so as to realize the four-step 90° rotation of the stepper motor.

6. Innovative features

This project realizes the intelligent control of railway crossing gate system by the collaborative work of the perception module, control module and execution module, by detecting vibration signals, predicting the train position in advance, and driving the execution module to close the gate. The use of the system is not limited by weather, environment and other factors, which overcomes the drawbacks of manual monitoring, reduces the work burden of railway crossing management personnel, and realizes the reduction of railway crossing management. It can effectively reduce the possibility of danger when crossing railway crossings, improve the traffic order of railway crossings, reduce the occurrence of traffic accidents, realize the safety of railway crossings, and promote the development and construction of smart cities and smart transportation[7] .

7. Conclusion

This paper selects topics from practical engineering problems, and uses TRIZ theory to analyze and solve the influence of insufficient manual control of existing crossing guardrail systems. A variety of TRIZ tools are used to specifically solve the safety of railway level crossings. On the basis of the description of the engineering problem, through the nine-screen analysis, functional analysis and cause-effect chain analysis, three reasons for the potential safety hazards of railway level crossings are obtained. Then the technical contradiction and physical contradiction tools are used to solve the problem respectively, and the scheme improvement is obtained. Finally, a "railway level crossing gate intelligent perception control system" was designed. It realizes the intelligence of the railway crossing gate system and improves the timeliness of the control and execution of the railway crossing gate. It plays an important role in the development of intelligent and modernization of railway construction. This paper uses TRIZ theory to successfully solve problems in practical engineering applications, and provides new ideas for solving practical problems in the future.

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