Application of Genetic Algorithm in Rail Transit Comprehensive Monitoring System

Hui Lin(✉)

Shanghai Interlink Road and Bridge Engineering Co., Ltd, Shanghai 200000, China
472609100@qq.com

Abstract. Over the years, various countries have been committed to studying how to optimize the entire monitoring system, especially for urban rail transit systems. At present, with the continuous development of rail transit, great changes have taken place in its operating environment, working principles, and technical indicators. Rail transit monitoring has played a large role in the development of rail transit. It can effectively solve the problem of failures in the operation of existing equipment and reduce the interference caused by the mutual influence of various subsystems on the line. However, due to the complexity and dynamic characteristics of rail transit, it is inevitable that there will be loopholes in monitoring. At the same time, genetic algorithm searches for the global optimal value by simulating biological evolution and natural selection mechanism, and it also has a good development prospect in the application of global optimization problem. This article adopts experimental analysis method and data analysis method to better understand the data transmission flow of the integrated monitoring system through experimental research, so as to analyze the performance of the system. According to experimental research, the monitoring system used in this experiment has the ability to process a large amount of information at the same time under extreme conditions, and will not cause network paralysis; and while ensuring the stable operation of the system, it also leaves a certain amount of space for future operation transformation.

Keywords: Genetic Algorithm · Rail Transit · Integrated Monitoring System · Control Strategy

1 Introduction

The rail transit integrated monitoring system is a kind of intelligent, advanced and integrated features, and can realize unified control and management of the entire city's rail lines, thereby effectively improving the overall operating efficiency. At the same time, genetic algorithm is a random search optimization method that simulates biological evolution and natural selection. It has the characteristics of fast global convergence and strong robustness. It is widely used in many fields in actual engineering. In order to ensure the safe operation of the entire rail transit, it must be comprehensively monitored and optimized to realize the efficient, safe and stable operation of the overall rail transit

J. C. Hung et al. (Eds.): IC 2023, LNEE 1044, pp. 152–158, 2023.
https://doi.org/10.1007/978-981-99-2092-1_19

system. Therefore, this article focuses on the application of genetic algorithm in rail transit integrated monitoring system to improve its overall operating efficiency.

At present, the research results on rail transit and genetic algorithms are relatively rich. For example, Sun Wang pointed out that the particle swarm genetic algorithm has a good effect on optimization problems, which is conducive to shortening the return interval of rail transit trains to the terminal station and improving operation efficiency [1]. Zhang Dan believes that in recent years, urban rail transit has developed rapidly. The rail transit monitoring system has played an important role in ensuring the safe and efficient operation of trains [2]. Wang Ning proposed that rail transit and conventional public transportation are the two most important components of the public transportation system. At the same time, genetic algorithms have a greater impact on the optimization of public transportation routes [3]. Therefore, this article combines genetic algorithms to conduct in-depth research on the rail transit integrated monitoring system, which has important practical significance and research value for improving the operating efficiency of the urban rail transit system and ensuring the safe operation of the urban rail transit system.

This article mainly discusses these aspects. First, the genetic algorithm and its related research are explained. Then, it discusses the rail transit integrated monitoring system and related research. In addition, the application of genetic algorithm in rail transit train control strategy is also introduced. Finally, in order to better understand the performance of the integrated monitoring system, an experimental study was carried out for the system, and the experimental results and analysis conclusions were drawn.

2 Related Theoretical Overview and Research

2.1 Genetic Algorithm and Related Research

Genetic algorithm is a search optimization algorithm based on natural selection and genetic mechanism. In the case of an optimization problem, it is calculated and solved by imitating the natural evolutionary law of the population. It can also solve the research problems of nonlinear programming and analysis of complex systems.

In nature, gene coding and selection are all operated by imitating animal behaviors to obtain optimal solutions. This optimization method has the characteristics of randomness, strong self-organization ability and good robustness, but it also has some shortcomings. For example, the search space is too large, which can easily lead to premature convergence and insufficient individual diversity [4, 5].

The genetic algorithm first assumes that a group consists of many genetically coded individuals, where each individual is actually a unit with a unique chromosome. Under the premise of survival of the fittest and survival of the fittest, the first generation population was created, which will evolve from generation to generation. In each generation, individuals are selected according to the suitability of individuals in the problem area, and genetic calculations derived from natural genetics are used to combine hybridization and mutation to form a population that represents a new collection. This process will cause the descendants of the population to adapt to the environment more like natural evolution than the previous generation, and find the optimal individual.

Although genetic algorithm has many advantages compared with traditional optimization algorithms, research shows that genetic algorithm also has its shortcomings. One is that the genetic algorithm is too slow to deal with certain problems. Secondly, genetic algorithm is prone to premature phenomenon that makes the algorithm fall into local optimal solution.

As a widely used direct search algorithm, genetic algorithm has applications in many fields, especially in automatic control, planning and construction, combination optimization, disease treatment, image processing, signal processing, artificial life and other fields. At present, genetic algorithms are mainly used for traveling salesman problems, vehicle route optimization problems, route optimization problems, and workshop planning problems [6, 7].

2.2 Rail Transit Integrated Monitoring System and Related Research

With the rapid development of cities and rapid population growth, it has also brought about the problem of traffic congestion. The development and maturity of rail transit technology has made the development of rail transit another important choice to solve traffic congestion. Among them, the integrated monitoring system plays an important role in rail transit. The rapid development of rail transit construction puts forward higher requirements for the integrated monitoring system.

In recent years, integrated monitoring systems have been popularized in major cities across the country. This method is now used in many integrated subway monitoring systems. In this way, the automatic train control system (ATC) works autonomously, which is extremely beneficial to the safe operation of the subway.

At present, the rail transit integrated monitoring system widely used in China is an integrated monitoring system with equipment monitoring as the main body. It can be said that the integrated monitoring system is becoming the development trend of the national urban rail transit automation system. Developed countries often adopt the most advanced technology and equipment, and achieve a high degree of integration, which also reflects a country's comprehensive scientific and technological strength, as well as the level of operation and management.

The main function of the rail transit integrated monitoring system is to realize real-time monitoring and automatic regulation of trains during operation through effective control of the entire urban road network, sections and stations. It can also monitor the

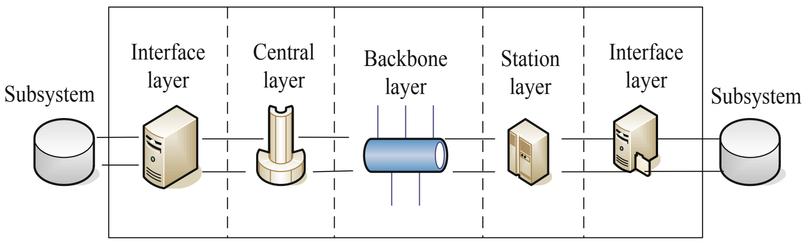

Fig. 1. Network Structure of Comprehensive Monitoring System

information between different road sections and key nodes [8, 9]. The network structure of the integrated monitoring system is shown in Fig. 1.

The rail transit integrated monitoring system is the nerve center of rail transit. The control center is equivalent to the brain of this central system. It detects the operating status of the entire rail transit system and adjusts its operation based on this information.

The function of the integrated control system is related to the operation mode of the rail transit system. The different operation modes of the rail transit system determine the operation mode of the integrated control system. The integrated monitoring system has these functions.

First, under normal circumstances, the control center of the integrated monitoring system is usually responsible for monitoring the entire line and various related professional systems. Turn on or turn off various devices according to the given work process and working mode, and display information such as power system, lighting system, environmental control system and guidance information according to train operation information, passenger flow information of each station, and environmental monitoring information of each station.

Second, the integrated monitoring system plays an extremely important role in the disaster model. When the detection device detects the occurrence of a disaster, the detection device sends an alarm message to the system, and the system automatically switches to the appropriate disaster operation mode according to the type of information received. Alarm information is displayed on the monitoring interface of the integrated monitoring system. In addition, it also includes information such as video images of the disaster area, equipment status, train operation status and location. In the disaster mode, the integrated monitoring system conducts a series of system coupling tests according to the disposal measures of the disaster management center, which greatly improves the ability of the rail transit system to resist disasters.

Third, when the main equipment system (such as power system, traction system, etc.) fails, the system automatically enters the failure mode and plans according to the nature of the failure. According to the requirements of fault management measures, reset the control mode of the equipment operation authority and revoke the remote control authority of the equipment. At the same time, notify the maintenance personnel to eliminate the fault according to the maintenance plan, and the system will return to normal operation after the fault is eliminated [10, 11].

2.3 Application of Genetic Algorithm in Rail Transit Train Control Strategy.

When using the genetic algorithm, the train model should be combined with the control strategy to control the "operation" of the train model in advance. Write down the various parameters that can be reflected by the control reserve in order to identify the advantages and disadvantages of the control strategy, so that the train should run in a safer and more energy-efficient manner. The genetic algorithm uses the deterministic selection method. After the mutation operation, the best retention selection method is adopted to obtain the most adaptable chromosomes in the child population and the parent population, so as to extract the best chromosomes from the previous generations. The increase in the calculation speed of the algorithm also increases the convergence of the algorithm [12].

The specific calculation method is shown in formula (1) (2).

$$W_u = R \times d_u / \sum_u d_u \tag{1}$$

$$T = R - \sum_u floor\,(W_u) \tag{2}$$

Among them, Wu is the expected survival number of the u-th individual in the next-generation population, R is the size of the population, and du is the fitness of the u-th individual. The integer part of R is the number of survival of each individual in the next population, and then the individuals are sorted in descending order according to the decimal part, and the first one is added to the next population. *floor*(W_u) function is the floor function.

3 Experiment and Research

3.1 Experimental Background

The stability of the integrated monitoring system directly affects the safe operation of rail transit. The integrated monitoring system must not only ensure a reasonable structure in the planning stage, but also pay attention to the safety of the system, so as to ensure the safety of citizens using rail transit. Under normal circumstances, the system can operate normally. Therefore, we must first analyze and test to verify the performance of the system and troubleshoot in time to deal with disasters or extreme situations. Therefore, it is very necessary to understand the performance of the system.

3.2 Experimental Environment

In this experiment, the test tools will use C306 front-end processor, SystematICS, human-machine interface and excel. The C306 front-end processor is the data center of the distributed data acquisition system of the rail transit integrated monitoring system. It distributes data to different geographic locations through its own serial port, Ethernet, fieldbus and other communication media according to a specific communication protocol. The front-end processor C306 is composed of a power supply module, a CPU module, a serial port module, and an MMI module. These modules are connected through the backplane bus of the C306 device.

3.3 Experimental Process

The purpose of this experiment is to better understand the data transmission flow of the integrated monitoring system, so as to analyze the performance of the system. Therefore, this experiment tests the typical station LAN traffic, LAN traffic, and OCC network traffic of the monitoring subsystems PSD, PA, CCTV, and BAS. Some test results are shown below.

4 Analysis and Discussion

In this experiment, in order to understand the data transmission flow of the integrated monitoring system, the typical station local area network traffic, local area network traffic, and OCC network traffic of the monitoring subsystems PSD, PA, CCTV, and BAS were tested. The test results are shown in Table 1.

Table 1. Data Transmission Flow of Comprehensive Monitoring System

Monitoring subsystem	Typical station LAN flow(Byte)	LAN flow(Byte)	OCC network flow(Byte)
PSD	1700	37600	37500
PA	300	4700	6900
CCTV	900	10600	10800
BAS	9000	19900	19000

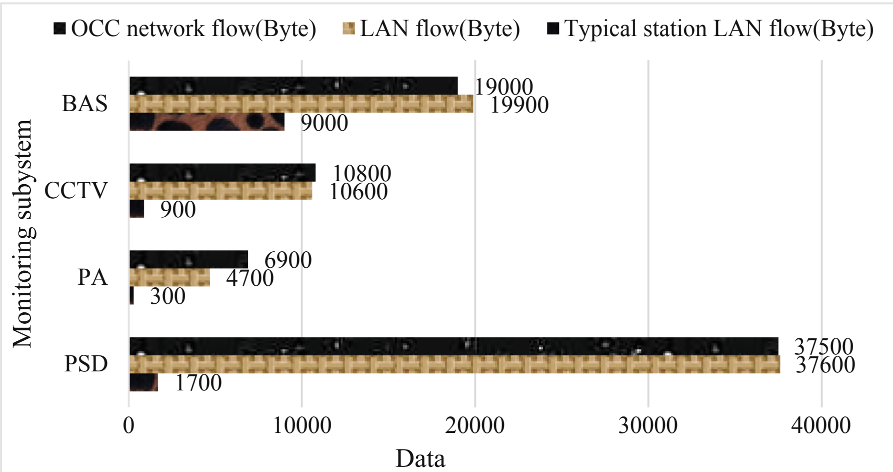

Fig. 2. Data Transmission Flow of Comprehensive Monitoring System

As shown in Fig. 2, the local area network traffic of the monitoring subsystems PSD, PA, CCTV, and BAS are 37600, 1700, 10600, and 19900 bytes, respectively. It can be seen that the monitoring system for this experiment has the ability to process a large amount of information at the same time under extreme conditions without causing network paralysis; and while ensuring the stable operation of the system, it also leaves a certain amount of space for future operation transformation.

5 Conclusion

With the rapid development of rail transit and related technologies, in order to ensure the safe operation of the entire rail transit, it is necessary to monitor the operating conditions of the equipment in the subway station in real time to achieve dynamic control. At the same time, its integrated monitoring system needs to be optimized to ensure the safe operation of rail transit. Genetic algorithm has been widely used at present, it is by imitating the survival of the fittest mechanism in nature, and continuously optimizing the solution space structure to obtain the optimal parameters. Therefore, this article combines genetic algorithm to conduct in-depth research on rail transit integrated monitoring system, which has important practical significance and research value for promoting the informatization construction of urban rail transit.

References

1. Rosell, F., Codina, E., Montero, L.: A combined and robust modal-split/traffic assignment model for rail and road freight transport. Eur. J. Oper. Res. **303**(2), 688–698 (2022)
2. Musina, A., et al.: The psychophysiological status of rail traffic operators and modern approaches to its correction. Public Transp. **14**(3), 635–653 (2021). https://doi.org/10.1007/s12469-021-00272-2
3. Besinovic, N., Wang, Y., Zhu, S., Quaglietta, E., Tang, T., Goverde, R.M.: A matheuristic for the integrated disruption management of traffic, passengers and stations in urban railway lines. IEEE Trans. Intell. Transp. Syst. **23**(8), 10380–10394 (2022)
4. Vujanic, R., Hill, A.J.: Computationally efficient dynamic traffic optimization of railway systems. IEEE Trans. Intell. Transp. Syst. **23**(5), 4706–4719 (2022)
5. Divis, R., Kavicka, A.: Reflective nested simulations supporting optimizations within sequential railway traffic simulators. ACM Trans. Model. Comput. Simul. **32**(1), 1:1–1:34 (2022)
6. Marcelli, E., Pellegrini, P.: Literature review toward decentralized railway traffic management. IEEE Intell. Transp. Syst. Mag. **13**(3), 234–252 (2021)
7. Bärmann, A., Martin, A., Schneider, O.: Efficient formulations and decomposition approaches for power peak reduction in railway traffic via timetabling. Transp. Sci. **55**(3), 747–767 (2021)
8. Zinder, Y., Lazarev, A.A., Musatova, E.G.: Rescheduling traffic on a partially blocked segment of railway with a siding. Autom. Remote. Control. **81**(6), 955–966 (2020). https://doi.org/10.1134/S0005117920060016
9. Mathew, S., Pulugurtha, S.S.: Assessing the effect of a light rail transit system on road traffic travel time reliability. Public Trans. **12**(2), 313–333 (2020). https://doi.org/10.1007/s12469-020-00234-0
10. Ghasempour, T., Nicholson, G.L., Kirkwood, D., Fujiyama, T., Heydecker, B.: Distributed approximate dynamic control for traffic management of busy railway networks. IEEE Trans. Intell. Transp. Syst. **21**(9), 3788–3798 (2020)
11. Zhilyakova, L.Y., Kuznetsov, N.A., Matiukhin, V.G., Shabunin, A.B., Takmazian, A.K.: Locomotive assignment graph model for freight traffic on linear section of railway. the problem of finding a maximal independent schedule coverage. Autom. Remote. Control. **80**(5), 946–963 (2019). https://doi.org/10.1134/S0005117919050126
12. Andreasson, R., Jansson, A.A., Lindblom, J.: The coordination between train traffic controllers and train drivers: a distributed cognition perspective on railway. Cogn. Technol. Work **21**(3), 417–443 (2018). https://doi.org/10.1007/s10111-018-0513-z