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Research on Life Evaluation of Computer Interlocking System Based on Neural Network

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***Abstract*—Computer interlocking system is the core technical equipment of railway signal, which is an important link to ensure safe and efficient operation and railway station operation. At present, China railway computer interlocking system of life cycle management approach mainly refers to the relevant provisions of the traditional relay interlocking equipment, lack of the service life for electronic equipment in the system of analysis and evaluation methods, which largely limits the service life of computer interlocking system of scientific management. This paper, starting from the architecture of the interlocking system, studies a method to evaluate the life of a computer interlocking system based on neural network, in order to realize the scientific predictive evaluation of the service life of the interlocking system. It can provide reference for the operation and management of computer interlocking system in China.**

Keywords—computer interlocking system; life evaluation; BP neural network

I. INTRODUCTION

Computer interlocking system is the core technology of railway signaling equipment, which plays a key role in transportation and production. The system is based on signal machine, switch machine and track circuit [1]. It uses electrical and electronic equipment to collect the usage or operating status of track circuit, signal machine and switch equipment, and control the position of signal generator and switch. The main function is to control the train's operation in the station, and to control the interlocking logic of the station in real time, so as to ensure the operation efficiency and safety of the train [2].

The reliability and safety of computer interlocking system are closely related to the safe operation and efficient transportation of trains. However, the life cycle management of computer interlocking system in our country is not standardized and lacks scientific and reasonable basis. The "Railroad Signal Maintenance Rules" issued by the former Ministry of Railways stipulated that the general overhaul period of signal equipment should be 15 years. From the perspective of management and operation, the provisions of this term follow the traditional management methods of relay interlocking equipment. However, such a management measure does not have sufficient theoretical basis for the electronic interlocking system based on electronic equipment [3-4]. In fact, the electronic interlocking system based on computer has greatly improved the reliability and other aspects than traditional relay interlocking. The service life of the computer interlocking system equipment should also be better than the traditional station interlocking equipment. Therefore, the use of relay interlock system life management approach will cause some problems. If the actual service life of the interlocking system is longer than a reasonable life expectancy, it will affect the safety of the system operation and use. If the service life of the interlocking system is shorter than a reasonable life expectancy, investment and technical waste will be caused. In the actual operation and maintenance process, under normal circumstances, the actual service life of the system generally does not exceed the life cycle of the life management approach, resulting in waste [5-6].

With the rapid development of China's railways, computer interlocking systems have also developed rapidly. However, in the field of railway signaling, there are few researches on the design of system or equipment life assessment theories. The purpose of this paper is to solve the problem of the life cycle of interlocking systems. According to the scientific basis of this issue, an intelligent method is proposed to combine the operation principle and hardware structure of the computer interlocking system with the related methods of artificial intelligence to scientifically and reasonably evaluate the remaining service life of the computer interlocking system in service. It is of practical significance to provide a scientific basis for the maintenance and replacement of the lock system equipment and to ensure the safe operation of the system and to effectively improve the system's efficiency of use and return on investment and to improve the operation and maintenance management level of the railway interlocking equipment.

II. COMPUTER INTERLOCKING SYSTEM

Computer interlocking system regards the computer, relay devices and other devices as a component, can be fault-oriented security real-time control system. At present, the computer interlocking system has three main formats, namely, two by two, dual hot standby and three by two [3]. Among them, the double machine hot standby computer interlocking, are most used in China, and the localization of the degree is higher. The interlock system on the logical structure can be divided a chance words layer, safe operation, implement the presentation layer and equipment layer. The hierarchy diagram

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of the computer interlocking system is shown in Figure 1, wherein secure communication is adopted between layers, and communication information between layers is ensured to be transmitted securely.

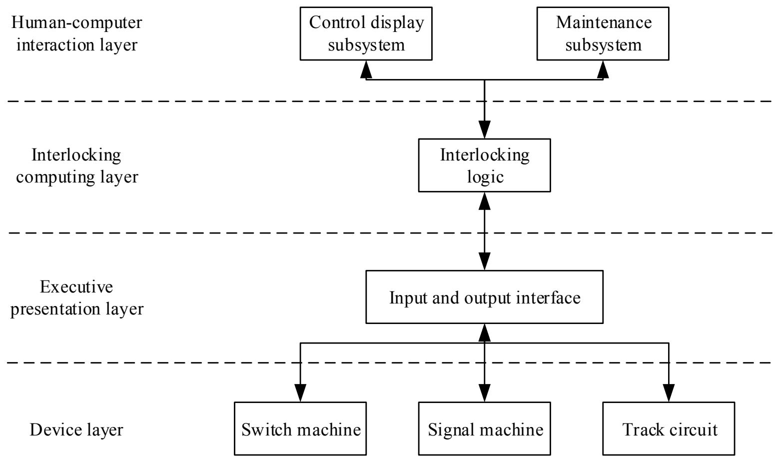

Figure 1. Computer Interlocking System Hierarchy

The equipment composition of the two-machine heat standby interlocking system is shown in Figure 2, and the system is composed of operation representation machine, interlocking machine, collection unit, driving unit and maintenance machine and other components. The operation of the two series is connected to the machine, and it is connected to the maintenance machine and other connected interlocking machine [4]. The interlocking machine is connected up with the operation indicating machine, which is connected to the collection unit and drive unit of the respective departments, and the wiring of the interface is connected down. The communication mode between man-machine dialogue and interlocking machine or between interlocking machines in double machine hot standby interlocking system are of many ways. In the first place, serial communication was adopted. With the development of technology, Ethernet is now used for information transmission.

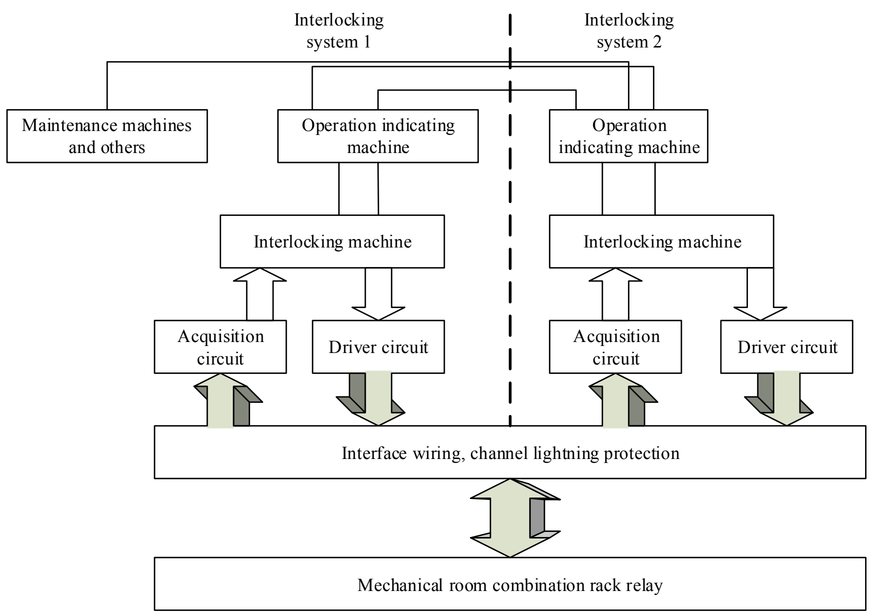

Figure 2. Dual hot standby system architecture

III. BP NEURAL NETWORK

A. The basic principle

BP neural network is a feedforward neural network, and the network structure is usually with three or more layers [7-8]. The model structure includes the input layer, the hidden layer and the output layer, where the hidden layer can be one or more layers, and the basic structure is shown in Figure 3 [9]. The learning rule of BP neural network is to use the gradient descent method. The learning process of the network can be divided into two parts, positive learning and reverse propagation, and the input signal propagates in the network in the positive direction from input to output. The error of training data adjusts and distributes the network weights and thresholds by backpropagation. When the square error of network verification is the minimum, it is considered as the best condition, and based on this, a neural network with the best condition is established.

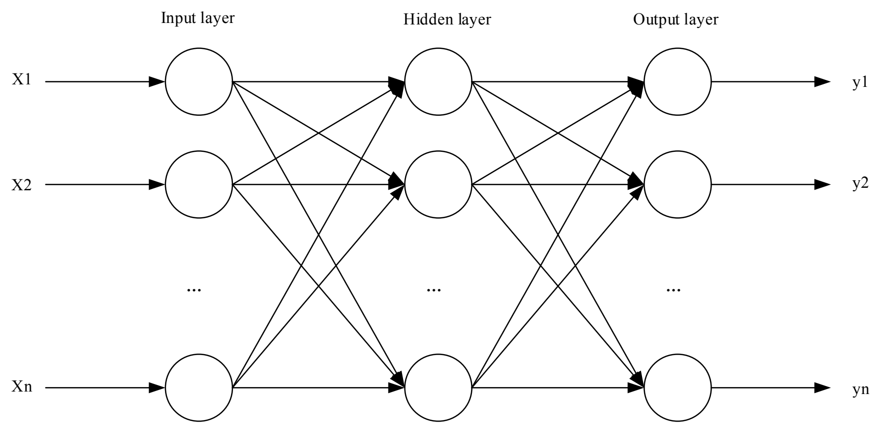

Figure 3. BP neural network structure

The basic steps of BP neural network in data learning and network process are shown in Figure 4.

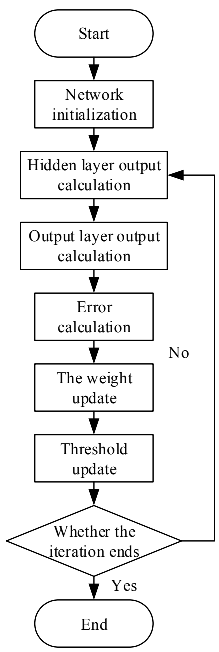

Figure 4. BP neural network training process

B. Collate and generate training data sets

The data obtained from the field cannot be directly trained and need to be preprocessed to prepare for neural network construction and data training. According to the hardware correlation, the two-machine hot standby system is divided into six device level modules, namely operation presentation layer, I series interlocking machine, I system executive layer, II system interlocking machine, II system executive layer, maintenance machine and other layers. The six device-level modules are divided into several unit-level modules according to the internal structure and functions of the device, shown in Table 1.

TABLE I. QUIPMENT CLASSIFICATION AND TRAINING DATA SET OF DUAL COMPUTER HOT STANDBY COMPUTER INTERLOCKING SYSTEM

System components	Input vector	Hardware name	Middle vector	Output vector
Operation presentation layer	x1	Control display - the motherboard	y1	Y
	x2	Control display - communication board		
	x3	Control display - power		
	x4	Control display - electronic disk		
	x5	Display control - peripherals		
	x6	Control display - console unit		
I series interlocking machine	x7	I Department of Interlocking Logic - CPU	y2	
	x8	I Department of Interlocking Logic-IO board		
I system executive layer	x9	I Department of collection unit		
	x10	I Department of the drive unit		
II system interlocking machine	x11	II Department of Interlocking Logic - CPU	y3	
	x12	II Department of Interlocking Logic-IO board		
II system executive layer	x13	II Department of collection unit		
	x14	II Department of drive unit		
Maintenance machine and other layers	x15	UPS power supply	y4	
	x16	Internal board power supply		
	x17	Drive acquisition power		
	x18	Maintenance machine - electronic disk		
	x19	Maintenance machine-CPU		
	x20	Maintenance machine - peripherals		
	x21	Maintenance machine - power supply		

These units are regarded as input and output vectors that neural network can train, and the data are sorted according to the specification of input and output vector of neural network, shown in Table 1. Among them, the input vector $\boldsymbol{X}=\{x_1,x_2,x_3,\cdots,x_{21}\}$ is the unit-level module fault data in the interlocking system, the middle vector $\boldsymbol{y}=\{y_1,y_2,y_3,y_4\}$ is the device level life assessment index, and the output vector $\boldsymbol{Y}$ is the life assessment index of the dual-system thermal backup system.

IV. Life Evaluation Model of Computer Interlocking System Based on BP Neural Network

Due to the special redundant structure design of computer interlocking system, the structure and principle of BP neural network and the structure of the system can be rationally combined before the system can be scientifically and reasonably assessed for life. Based on the collation of the data set of computer interlocking system generate, taking the failure frequency of unit-level module $\boldsymbol{X}=\{x_1,x_2,x_3,\cdots,x_{21}\}$ as the input vector of BP neural network and the equipment-level evaluation index $\boldsymbol{Y}=\{y_1,y_2,y_3,y_4\}$ as the output vector of the network, a life assessment model of interlocking system based on BP neural network is established. The structure is shown in Figure 5.

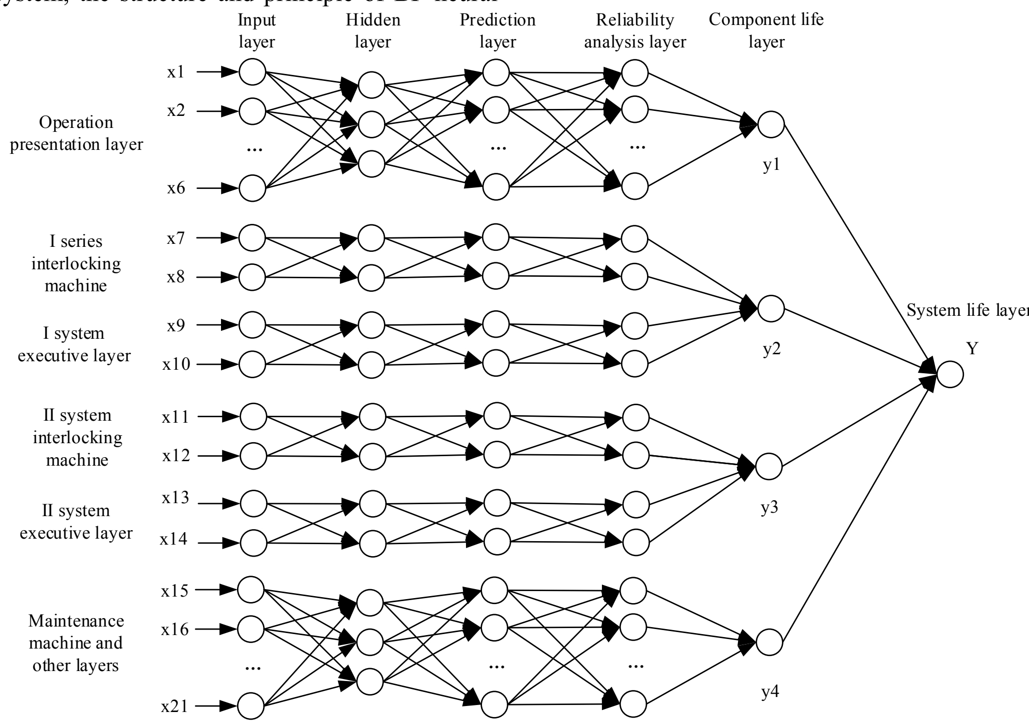

Figure 5. Network structure of computer interlocking system life prediction model

Based on the traditional three-layer BP neural network structure, combining with the characteristics of system structure, a six-layer BP neural network suitable for computer interlocking system is established, which are input layer, hidden layer, "data prediction layer, reliability analysis layer, component life layer and system life layer. The numbers of neurons in input layer, reliability analysis layer and data prediction layer are determined by the dimension of input vector matrix, here is 21. The number of neurons contained in the component life layer is 4, and the number of neurons contained in the system lifetime layer is 1. The number of neurons in the hidden layer is related to the network performance and the error size. When the number of neurons in the hidden layer is too small, the information that the network can use and obtain to solve the problem is too small, and the results have an adverse effect. If the number of neurons is taken too large, it will extend the data training time, and even will generate data "over-consistent" problem. However, at present, there are no methods and formulas for determining the number of neurons in the hidden layer of BP neural network. Most of them rely on experience or continuous experiments. The process of establishing the system neural network model, through comparative experiments, come to a reasonable number of hidden layer neurons size is shown in Figure 5.

V. Case Study

Taking the fault data obtained from a railway bureau in our country as a background, the life expectancy of the system is evaluated. The system fault data collected from 2012 to 2016 is shown in Table 2.

According to the data constraint format of the present invention, the data in the Table is classified and sorted to obtain the input vector of the life prediction and evaluation neural network. Through the research on the application of computer interlocking system, the differences among stations of different scales mainly focus on the number of some boards, and under the limited conditions of obtaining data, some reasonable assumptions need to be made according to the data already obtained. However, due to the neural network's iterative training process for data, the error is within the acceptable range and will not adversely affect the result. In this case, we use the computer interlocking system which is about to overhaul as the research object and predict the service life of the computer interlocking system after predicting the remaining service life of the system by using the system life assessment model. The above data into the BP neural network for training. Then, we collect and summarize the mean squared error (MSE) of the network during data training and forecasting from 2017 to 2024, shown in Figure 6.

It can be seen from Fig. 6 that the mean square error of the computer network interlocking system is approximately in the interval [0.1,1], which shows that the life assessment model of the computer interlocking system based on BP neural network constructed in this paper has higher accuracy.

TABLE II. FAULT DATA

Faulty parts	**Year**				
	2012	**2013**	**2014**	**2015**	**2016**
Control display - the motherboard	0	1	0	2	4
Control display - communication board	0	1	0	3	5
Control display - power	1	3	0	2	5
Control display - electronic disk	0	1	0	5	6
Display control - peripherals	0	1	0	0	1
Control display - console unit	2	0	1	0	2
I Department of Interlocking Logic - CPU	1	0	1	0	1
I Department of Interlocking Logic-IO board	0	1	0	0	1
I Department of collection unit	0	1	1	0	1
I Department of the drive unit	0	0	0	1	0
II Department of Interlocking Logic - CPU	1	0	1	0	0
II Department of Interlocking Logic-IO board	0	0	0	1	1
II Department of collection unit	0	1	1	0	1
II Department of drive unit	1	0	0	0	1
UPS power supply	0	1	0	0	1
Internal board power supply	0	1	1	0	2
Drive acquisition power	1	0	1	2	2
Maintenance machine - electronic disk	0	1	0	2	3
Maintenance machine-CPU	0	0	0	0	0
Maintenance machine - peripherals	0	3	0	3	6
Maintenance machine - power supply	0	1	0	0	1

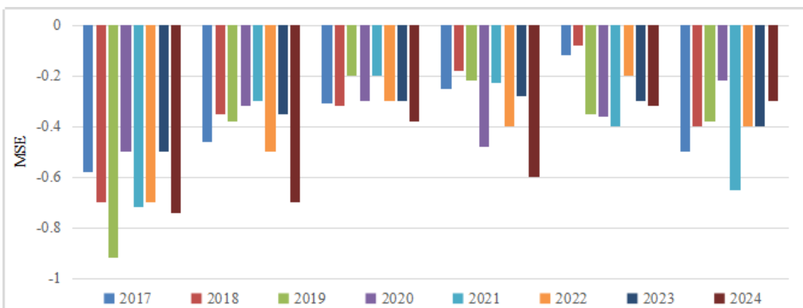

Figure 6. Error of BP neural network life estimation model

VI. CONCLUSIONS

With the rapid acceleration and rapid development of China's railway industry, the computer interlocking system has also received more attention and in-depth research. Based on the analysis of the characteristics of computer interlocking system and the basic principle of BP neural network, this paper proposes a life evaluation model of computer interlocking system with BP neural network. The effectiveness of this model is verified by case study, which provides reference and basis for the replacement and maintenance of computer interlocking system.

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