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Research on integrated regional fire management evaluation based on fuzzy neural network

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Abstract: Nowadays, the problem of false alarms in fire alarm systems when no fire has occurred is increasingly becoming a problem that plagues the reliable operation of building fire alarm systems. Therefore, this paper conducts an in-depth study of this problem based on fuzzy neural network model. In this paper, we use the frequency of fires, component failure rate, component reliability, and component false alarm rate as indicators to establish a fuzzy neural network-based management evaluation model, and use fuzzy neural network topology and related algorithms to solve the problem, and finally propose a plan: for M brigade, we can consider replacing fire alarm components with higher reliability; for G brigade, the frequency of fires in the area is low, and we need to strengthen the management For I brigade, we can consider replacing the fire alarm components with higher reliability, while achieving a balance with the reliability of the components. We combine the conclusions obtained from the problem and propose six more reasonable and scientific recommendations for the management and maintenance of each component of the fire alarm system.

1. Introduction

1.1 Background

The fire alarm device sends out a fire alarm signal. The cause of false alarms can be intentional, false actions or accidental factors. Whether it is the cause of the detector, or environmental reasons, human factors, other reasons, as long as no fire occurred but reported a fire signal, are called false alarms. According to the survey, the smoke detector false alarm rate in the United States is about 19.4 times / 1000000h; Switzerland's fire detector false alarm rate of about 4.2 times / 1000000h; Japan's fire detector false alarm rate of about 7.4 times / 1000000h; Germany's fire detector false alarm rate of about 1.1 times / 1000000h. In the case of strengthening the management of fire protection facilities The probability of false fire alarm is getting lower and lower, but the problem of false alarm without fire is increasingly becoming a difficult problem for reliable operation of building fire alarm system[1].

1.2 The main work of this paper

In this paper, based on the basic data, we quantify the bottom three fire brigades, establish a fuzzy neural network evaluation model, quantify and analyze the fire frequency, component failure rate and component reliability rate of the jurisdiction as indicators, and propose improvement plans respectively. And according to the conclusion, a series of reasonable opinions are proposed with reference to certain literature and the research background[2].

2. Model Preparation

2.1 Model Assumptions

Assumption 1: The trend of the number of fires in the city under study in one year is similar to the number of fires and the trend of the number of fires in each month of the country in 2021.

Assumption 2: That the underlying fire-related data are real and reliable.

Assumption 3: the sensitivity of fire detectors can be predicted by algorithms.

Assumption 4: Detector failure is not affected by other factors.

2.2 Definition and Symbol Description

Symbol Definition	Symbol Description
i	The original value of the indicator for the jth indicator of the evaluation object
P_{ij}	Indicator characteristic weights for each type of component
m	Number of fire detector evaluation indicators
Z_{min}	The minimum value of the jth indicator

3. Model building and solving

3.1 Solution ideas

According to the the comprehensive management level of each fire brigade, for this reason we establish a management evaluation model based on fuzzy neural network, and the specific ideas are shown in Figure 1.

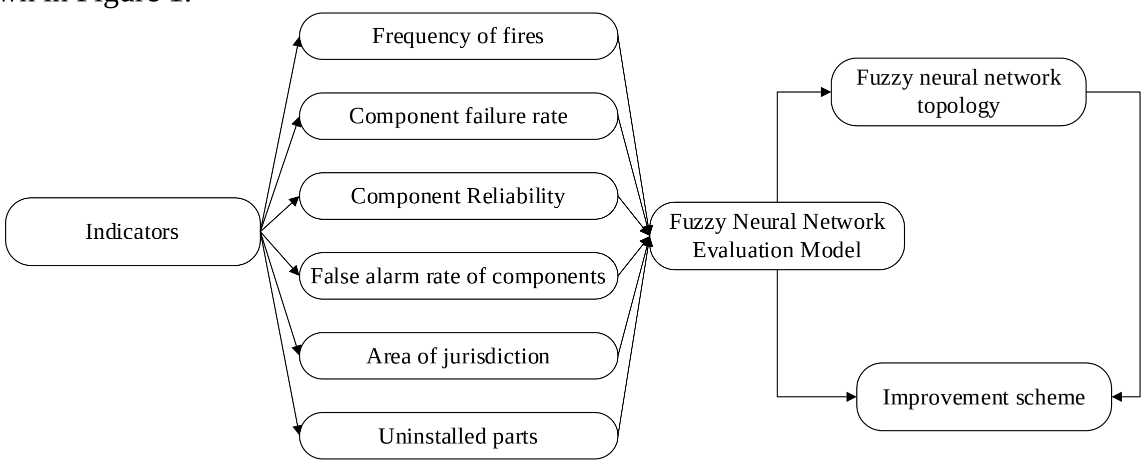

Figure 1 Flowchart of ideas

3.2 Fuzzy neural network evaluation model building

(1) Modeling preparation

The number and accuracy of alarms for various fire detector types are shown in Table 1.

Table 1 Number of alarms and accuracy of various fire detector types

Type	Fire Alarm Accuracy	Number of uses
Point type smoke detector	0.005817712	18363
Point type cigarette lighting	0	5
Flame Detector	0	6
Manual alarm button	0.009137984	2367
Point type warm smoke	0	3
Signal Valves	0	9
Intelligent photoelectric probe	0.009710468	5088
Point type temperature sensor	0.005377125	1671
Pressure switch	0	1
Composite detector	0	45
Fire hydrant	0	5
Gas detectors	0	34
Line beam smoke detector	0.001556824	66
Light beam smoke detection	0.05	24
Intelligent photoelectric detector	0	9
Intelligent temperature sensing	0	5

The number of fires that occurred in the city between June 1 and June 18 in brigades A, B, and C ......R was summarized as shown in Figure 2.

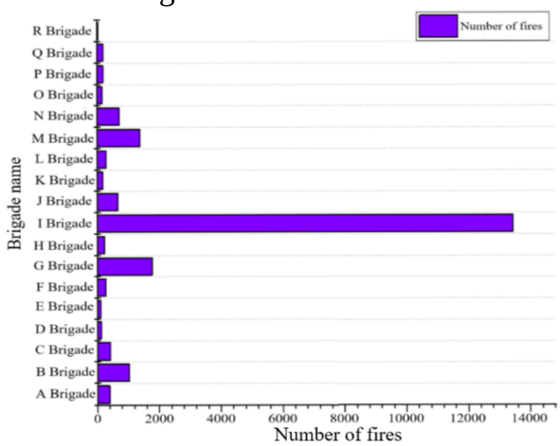

Figure 2 Number of fires in each brigade area

(2) Fuzzy neural network model

The fuzzy neural network model, also known as T-S fuzzy, is an adaptive fuzzy system that not only updates automatically, but also continuously corrects the subordinate functions of fuzzy subsets. t-S fuzzy system is defined in the form of "if-then" rules, and in the case of rule H^i, the fuzzy inference is as follows[3].

$$H^i\text{: } If \quad x_1 \text{ } is \text{ } A_1^i, x_2 \text{ } is \text{ } A_2^i, \cdots, x_k \text{ } is \text{ } A_k^i \text{ } then \text{ } l_i = P_0^i + P_1^i x_1 + \cdots + P_k^i x_k \tag{1}$$

Suppose that for the input quantity $X=[x_1,x_2,\cdots,x_k]$, the affiliation of each input variable x_j is first calculated according to the fuzzy rule.

$$\mu A_j^i = \exp\left(-\left(x_j - c_j^i\right)^2 / b_j^i\right), j = 1,2,\cdots,k; i = 1,2,\cdots,n \tag{2}$$

The affiliation degrees are fuzzy calculated by using the fuzzy operator as a concatenated multiplicative operator.

$$\omega^i = uA_j^1(x_1) \times uA_j^{21}(x_1) \times \cdots \times uA_j^k(x_k), i = 1,2,\cdots,n \tag{3}$$

Calculate the output value l_i of the fuzzy model based on the fuzzy calculation results.

$$l_i = \sum_{i=1}^{n} \omega^i (P_0^i + P_1^i x_1 + \cdots + P_k^i x_k) / \sum_{i=1}^{n} \omega^i \tag{4}$$

(3) T-S fuzzy neural network

The T-S fuzzy neural network is divided into four layers: input layer, fuzzification layer, fuzzy rule calculation layer and output layer. The input layer is connected to the input vector x_i, and the number of nodes is the same as the dimension of the input vector. The fuzzification layer uses the affiliation function (1) to fuzzify the input values to obtain the fuzzy affiliation value μ. The fuzzy rule calculation layer uses the fuzzy concatenation formula (2) to obtain ω. The output layer uses equation (3) to calculate the output of the fuzzy god network.

The learning algorithm of fuzzy neural network is as follows

1) Error calculation

$$e = \frac{1}{2}(l_d - l_c)^2 \tag{5}$$

where l_d is the desired output of the network; l_c is the actual output of the network; and e is the error between the desired output and the actual output.

2) Coefficient correction

$$p_j^i(k) = p_j^i(k-1) - \gamma \frac{\partial e}{\partial p_j^i} \tag{6}$$

$$\frac{\partial e}{\partial p_j^i} = (l_d - l_c) \frac{\omega^i}{\sum_{i=1}^{n} \omega^i} \times x_j \tag{7}$$

where, p_j^i is the neural network coefficient, γ is the network learning rate, x_j is the network input parameter, and ω_i is the product of the affiliation of the input parameters.

3) Parameter correction

$$c_j^i(k) = c_j^i(k-1) - \alpha \frac{\partial e}{\partial c_j^i} \tag{8}$$

$$b_j^i(k) = b_j^i(k-1) - \alpha \frac{\partial e}{\partial b_j^i} \tag{9}$$

where c_j^i, b_j^i are the center and width of the affiliation function, respectively.

3.3 Solving of the model

In this question, a total of 8 influencing factors are selected: fire frequency, component failure rate, component reliability, uninstalled components, component false alarm rate, and precinct area, so the neurons in the input layer of the fuzzy neural network evaluation model are 8[4]. The topology diagram of the constructed fuzzy neural network, as shown in Figure 3.

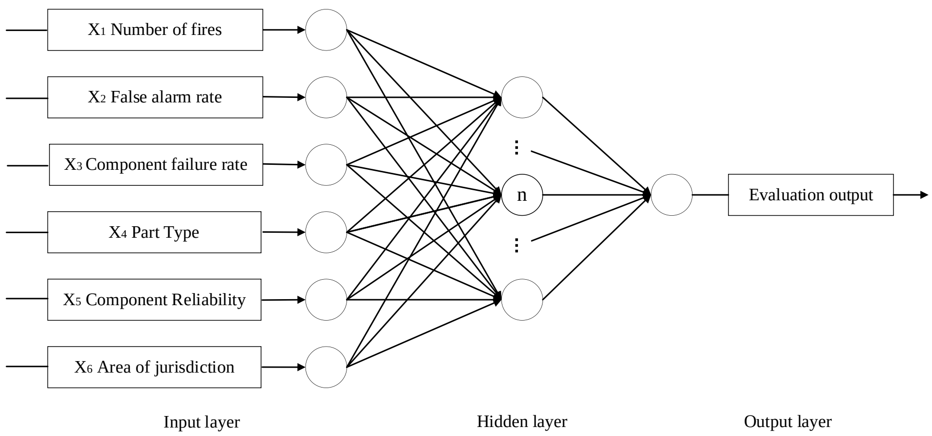

Figure 3 Fuzzy neural network topology

One of the T-S fuzzy neural network based fire brigade comprehensive management level evaluation algorithm flow is shown in Figure 4. Where the fuzzy neural network is based on the input and output dimensions of the training samples, which in turn determines the number of input and output nodes of the neural network. In this problem, since the dimension of input data is 8 dimensions and the dimension of output data is 1 dimension, the number of nodes of the network is determined as 8 and the number of output nodes is 1[5]. Therefore, the constructed network structure is 8-12-1.

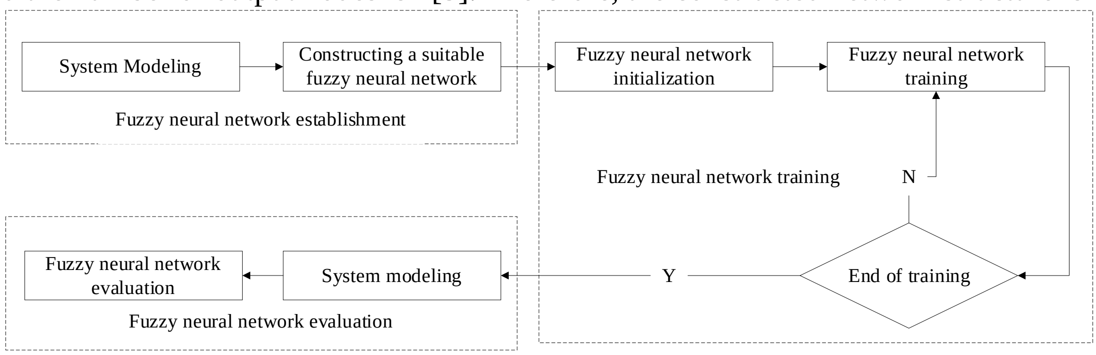

Figure 4 Fire brigade comprehensive management level evaluation algorithm process

The three brigades with the lowest fire alarm reliability rates in the city are G brigade, M brigade, and I brigade. There are more indicators selected for this question, so the results of the analysis are relatively reliable. According to the requirements of the question, only three of the eight influencing factors, i.e., fire frequency, component failure rate, component reliability, uninstalled components, component false alarm rate, and area of the jurisdiction, are shown here, and the three aspects of fire frequency, component failure rate, and component reliability of the fire brigade are calculated using fuzzy neural networks for the three brigades. The scores of the three brigades in terms of fire frequency, component failure rate and component reliability were calculated as shown in Table 2.

Table 2 Quantitative scores of the main indicators of the three jurisdictions

	Frequency of fires in the area	**Component failure rate**	**Component Reliability**
M Brigade	0.01758	0.16548	0.40953
G Brigade	0.02637	0.1182	0.4964
I Brigade	0.01758	0.26004	0.67014

From the scores of each item, improvement options are proposed for each of the three jurisdictions.

(1) For M brigade, it can be seen from the table that the components of this fire brigade have low reliability, and can consider replacing more reliable fire alarm components, such as using intelligent photoelectric probe components, manual alarm button components, etc.; in terms of failure rate, it can choose to replace components with low failure rate, such as point-type point smoke and flame detector components.

(2) For G brigade, it can be seen from the table that the fire brigade has the least reliable components, and can consider replacing more reliable fire alarm components, such as the use of intelligent photoelectric probe components, manual alarm button components, etc.; in terms of fire frequency, the frequency of fires in the district is low, and needs to strengthen management.

(3) For the I brigade, it can be seen from the table that the fire brigade has the lowest reliability of components, and can consider replacing the fire alarm components with higher reliability, such as using intelligent photoelectric probe components, manual alarm button components, etc.; while achieving a balance with the reliability of components.

3.4 Management Recommendations

Reasonable, scientific and reliable advice and recommendations based on the above analysis.

(1) Strengthen the study and practice of management information related to fire alarm system components.

(2) Troubleshoot problems with alarm devices in a timely manner.

(3) Regularly inspect and test fire alarm devices in companies, businesses, homes, and other areas.

(4) Fully verify the wiring and systems of alarm devices and other places to ensure the normal operation of the control system at all times.

(5) Ensure a balanced and reasonable alarm signal component reliability and failure rate.

(6) Replace old fire alarm components and maintain them in a timely manner.

4. Conclusion

The fuzzy neural network evaluation model established in this paper can better quantify and analyze, and has strong self-organization, self-learning and self-adaptive capabilities, which can overcome the one-sidedness of neural network to a certain extent; secondly, the operator can adjust the fuzzy operation rules according to the actual experience, which can solve the problem of blindness of neural network to a certain extent.

The fuzzy neural network evaluation model established in this paper, the model accuracy is not high and the training time is too long. Other algorithms can be used to improve the fuzzy neural network structure. A new type of fuzzy neural network evaluation model for comprehensive management level is established.

The fuzzy object model used in this paper has wider applications in expert scoring system, quality control, performance evaluation, weather forecasting, medical diagnosis, economic management, psychometric and other fields; the established fuzzy neural network model has achieved better applications in pattern recognition, machine learning, fault diagnosis, knowledge acquisition and discovery, decision analysis and support and other fields.

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