Safety prediction model of fire detection and alarm system based on optimized neural network algorithm

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Abstract: The function of the fire detector is to capture specific fire signals. The sensitivity of the detector determines the sensitivity of the response to the characteristics of the fire severity. The sensitivity and reliability of the detector become the key parameters that the detector needs to consider in balance. Aiming at the problem of the most reliable detector types, we first use MATLAB to calculate the reliability and failure rate of the detectors according to the index weights. Then, the SPSSPRO evaluation TOPSIS method is used to score and rank the detectors, and in descending order, the detector with the highest ranking is selected as the detector with the highest reliability. In response to the problem of alarm accuracy, we first preprocess the data, and find suitable indicators according to the requirements of the topic to establish an intelligent judgment model for the type of regional alarm components. The indicators we find here include the name of the component, the name of the project, the affiliation of the fire department, and the probability of fire occurrence, which can be considered, six indicators of the probability of real alarm, and then uses the principal component analysis method to determine the weight through dimension reduction, and further screens the data, and then predicts the indicators through the method of neural network analysis to determine the alarm accuracy rate.

Keywords: Enumeration method, TOPSIS method, principal component analysis, neural network analysis, fuzzy comprehensive evaluation, gray correlation

1. Introduction

Fire detection and alarm have become an integral part of my country's high-tech industry. The function of fire detectors is to capture specific fire signals[1], convert them into electrical signals, and transmit them to the fire alarm controller to determine according to the alarm algorithm. When the detected signal value or When the change characteristic exceeds the threshold value, it is judged as a fire. The automatic fire alarm system includes fire detectors and manual alarm buttons, and the selection and installation of the detectors will cause false alarms of the detectors. Therefore, the sensitivity of the detector determines the sensitivity of the response[2] to the characteristic of the degree of fire, and the sensitivity and reliability of the detector become the key parameters[3] that need to be considered in balance.

With the improvement of people's living standards, people have higher and higher requirements for quality of life, green environmental protection, health, comfort, etc.; building decoration is becoming more and more common, and new materials are constantly emerging, and the rapid development of science and technology has promoted the development of architecture ; A large number of comprehensive large-scale buildings and super high-rise buildings integrating catering, leisure and entertainment, shopping, office and hotel are constantly emerging, so fire safety is more and more important. Once a fire occurs, it is easy for people to lose their ability to escape due to poisonous gas, high temperature and other reasons. In 2021, the number of fires nationwide will exceed 40,000 per month, and the number of casualties will be more than 100. Therefore, it is particularly important to set up an automatic fire alarm system, which can not only detect fires as soon as possible, alarm in time, and activate relevant fire-fighting facilities to guide and organize people to evacuate. It can also start the corresponding automatic fire extinguishing facilities to extinguish the initial fire and prevent the fire from spreading. The

automatic fire alarm system is an important measure to protect personal and property safety.

With the wide application of fire alarm systems, the requirements for the sensitivity and reliability of fire detectors are also strengthened. Therefore, it is an important task to calculate the reliability and failure rate to evaluate them and help the government select more reliable types of fire detectors. Important issues. In addition, select appropriate parameters to establish an intelligent judgment model for the type of regional alarm components. When a certain type of component within the jurisdiction of a certain brigade sends out alarm information, it can better determine whether it is a false alarm, improve the alarming accuracy[4], and conduct alarm signals sent by the different brigade. Authenticity evaluation and determining the probability that the alarm signal is a real fire can improve the efficiency of fire rescue.

2. Model assumptions

1) It is assumed that the change trend of the number of fires in a city in my country within a year is similar to the number of fires and the change trend in each month of the country in 2021.

2) It is assumed that a normal working fire detector will always alarm when it detects a fire.

3) Assuming that the influence of time is ignored, when the number of multiple fire detectors in a building is the same as the circuit number and these detectors all send out fire alarm signals, it is considered to be the same fire accident.

4) Assuming fire detectors are properly installed.

5) Assume that only the core factors in the problem are considered, and the influence of secondary factors is not considered

6) Make assumptions about the parametric form in the model

3. Model establishment and solution

In this section, we will introduce the establishment and solution of the models for Problem 1 and Problem 2.

3.1 Problem 1 Model establishment and solution

In order to better help the government to select more reliable fire detectors, the comprehensive evaluation TOPSIS method is used. Proceed is shown in Figure 1.
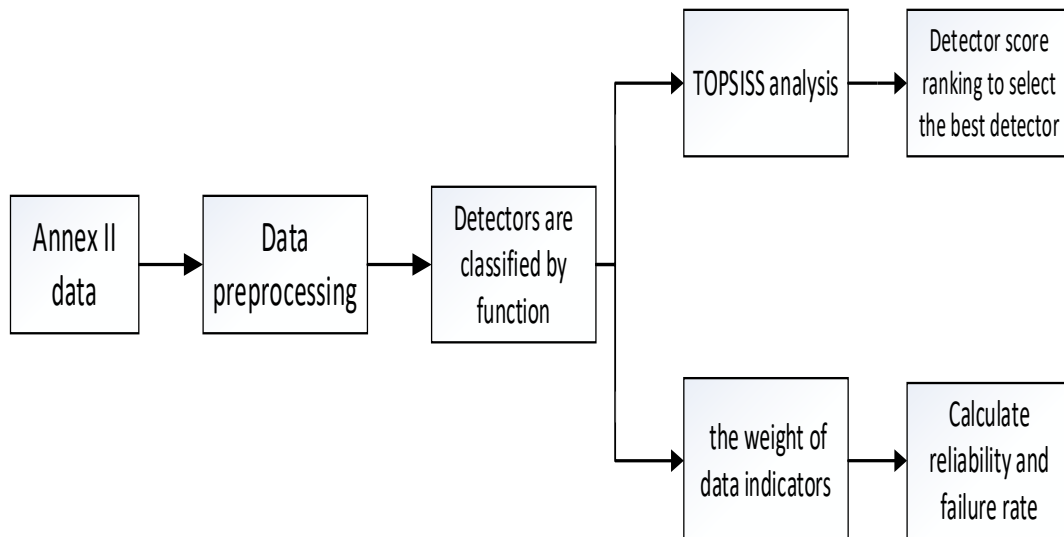

Figure 1: Problem 1 Analysis proceeds

TOPSIS is a specific application of the comprehensive evaluation method. Its basic idea is to sort by detecting the distance between the evaluation object and the optimal solution and the worst solution. If the evaluation object is closest to the optimal solution and farthest from the worst solution, is the best;

otherwise it is not the best. Among them, each index value of the optimal solution reaches the optimal value of each evaluation index. Each index value of the worst solution reaches the worst value of each evaluation index. The rule of program sorting is to compare each alternative with the ideal solution and the negative ideal solution. If one of the alternatives is the closest to the ideal solution, but far away from the negative ideal solution, then this alternative is the best alternative.

According to data analysis and data query, in order to improve the validity of the data, we ignored some less influential factors. We selected the type of components, the number of fire alarms, the proportion of the number of fire alarms, whether it was a false alarm, the number of failures, and the proportion of the number of failures. Six indicators are used for evaluation.

First, classify the data detectors by function, then preprocess and filter the data according to the name of the component, delete it reasonably, and obtain the name of the component, the number of fire alarms, the proportion of the number of fire alarms, whether it is false alarm, the number of failures, and the number of failures. The relationship between these six factors is shown in Table 1.

Table 1: Screening results for six factors

Name	Number of fire alarms	Proportion of fire alarms	False	No, once true	True	Number of failures	The proportion of failures
Signal valves	6	2.33301	0	0	6	8921	0.00251
Beam of light to smoke	40	0.00015	1	1	22	259354	7.30E-0
Pressure switch	1	3.88834	0	0	1	7544	0.00212
Composite detectors	121	0.00047	0	0	51	1574	0.00044
Manual alarm button	6566	0.02553	21	39	2282	2090	0.05883
Smart photoelectric probes	11225	0.04364	42	56	4935	568185	0.15991
Intelligent photodetector	10	3.88834	0	0	5	259354	7.30E-0
Intelligent temperature sensing	2	7.77668	0	0	2	259354	7.30E-0
Gas detectors	28	0.00010	0	0	27	4886	0.00137
Point type warm smoke	1	3.88834	0	0	1	9	2.53297
Point type light cigarette	6	2.33301	0	0	6	2	5.62882
Linear beam smoke	1927	0.00749	1	2	73	2234	0.00062

Then, after data preprocessing, we analyze the reliability and failure rate of the detectors in each building, and the results are presented in Table 2.

Table 2: Component reliability and failure

| Name	Number of fire alarms	Number of fires	Reliability rate	Failure rate
Smart photoelectric probes	11225	109	0.97%	0.1599
Manual alarm button	6566	60	0.91%	0.0588
Point type temperature detector	6881	37	0.54%	0.0649
Linear beam smoke detector	1927	3	0.16%	0.0588
Point-type smoke detector	230357	188	0.08%	0.3910

Finally, we use the SPSSPRO evaluation model TOPSIS method to rank the comprehensive scores of each detector, and the results are shown in Table 3.

Table 3: Comprehensive ranking

The index value	Ideal solution distance	Negative ideal solution distance	Composite score index	Sort
Signal valves	0.84581	0.00499	0.00587	8
Beam of light to smoke	0.79677	0.14511	0.15406	3
Pressure switch	0.84639	0.00420	0.00494	9
Composite detectors	0.84314	0.00637	0.00750	7
Manual alarm	0.40654	0.45845	0.53000	2
Smart photoelectric	0	0.84795	1	1
Intelligent photodetector	0.80476	0.14469	0.15239	4
Intelligent temperature sensing	0.80506	0.14469	0.15234	5
Gas detectors	0.84541	0.00356	0.00420	10
Point type warm smoke	0.84795	0	0	12
Point type light cigarette	0.84766	0.00043	0.00051	11
Linear beam smoke detector	0.79412	0.08193	0.09352	6

From Table 3, we can conclude that the comprehensive score of the smart photoelectric probe is 1, ranking first, the manual alarm button score is 0.53000575, ranking second, and so on. . Therefore, the intelligent photoelectric probe is the most reliable. That is, the most reliable detector to help the government select is the intelligent photoelectric detector.

3.2 Problem 2 Model establishment and solution
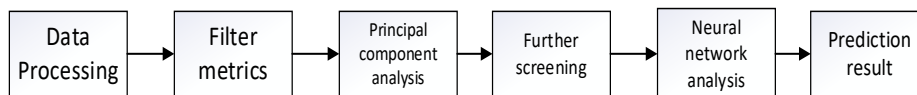
Figure 2: Problem 2 Analysis proceeds

Our algorithmic flow for solving problem 2 is shown in Figure 2. In order to better judge whether it is a false alarm and improve the accuracy of the alarm, principal component analysis and neural network methods [5]are used. Proceed as follows:

(1) Data preprocessing

If there is too much data, it needs to be screened, and more than the data content should be eliminated, and a pair of data should be processed according to the attachment to obtain appropriate indicators.

(2) Choose the right indicator

It can be seen from the content of the title that the appropriate indicators are selected to establish the type of regional alarm components. The indicators we choose mainly include the name of the component, the name of the project, the fire department affiliated, the fire occurrence rate, and the reliability rate and false alarm rate obtained from the data of question 1.

(3) Quantitative conditions defined by multiple influencing factors

By performing principal component analysis on the known data, the selected indicators are further screened by the method of dimensionality reduction. Different weights of multiple influencing factors are obtained, and the conditions for defining the accuracy of the alarm are obtained.

We combine the data, establish a new table and import the table into SPSS, and use the neural network to predict the alarm accuracy rate, so as to determine the probability that each alarm signal in the data is a real fire. The specific results are shown in Table 4.

Table 4: problem 2 results

Affiliated to fire protection agency	True alarm accuracy	Affiliated to fire protection agency	True alarm accuracy
A brigade	2.83%	I brigade	11.62%
B brigade	8.90%	J brigade	2.12%
C brigade	57.17%	L brigade	6.83%
D brigade	3.19%	M brigade	3.61%
E brigade	0	N brigade	6.75%
F brigade	1.74%	P brigade	9.08%
G brigade	8.26%	Q brigade	12.21%
H brigade	5.87%		

We choose the highest value as the quantitative condition to define the true alarm rate and use the above model to judge, that is, when the C brigade with the highest probability is the fire department with the most accurate true alarm rate. Since some indicators cannot be quantified, bringing the fuzzy comprehensive evaluation model into the calculation will not only bring about large errors and uncertainties but also increase the complexity of the model and the amount of calculation. The two indicators of the number of fire alarms and the probability of fire occurrence are temporarily excluded, and only the indicators that are more important and conducive to quantification are considered.

4. Conclusions

This paper uses the TOPSIS method to solve the problem of how determining the most effective and reliable fire alarm. Furthermore, we use the combination of fuzzy comprehensive evaluation and neural network to solve the problem of true rate prediction of fire alarm alarms. The solution effect of the model verifies the efficiency and accuracy of our model.

References

[1] Zhang Fan, Wang Shu. Analysis and synthesis method of multi-channel fire detection signal[J]. Journal of Huazhong University of Science and Technology. 1997(09)

[2] Xie Qiyuan, SU Guofeng. Effect of airflow velocity on response sensitivity of smoke and fire detector [J]. Engineering Science.2005(06)

[3] Xu Xiaohu, Zheng Xin. Research on reliability of automatic fire alarm system[J]. Journal of Safety and Environment. 2012(06)

[4] Lu Boyong. Analysis of causes and countermeasures of false alarms in safety prevention system[J]. Journal of XiangTan Normal University (Natural Science Edition). 2005(02)

[5] Tang Qunfang. Research on fire data processing method based on fuzzy neural network[D]. Hunan University 2011