Shortest Time Tunnel Rescue Based on Fuzzy Logic Algorithm

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Abstract: Aiming at the problems of evacuation and rescue after a tunnel disaster, a network model of tunnel and roadway is established, and a heuristic function design idea for searching in three-dimensional space is given. According to this idea, the data structure design is carried out to improve the algorithm, and the comprehensive weight of the roadway is obtained by using fuzzy logic data fusion technology, and the comprehensive weight is combined with the improved fuzzy logic algorithm to complete the shortest time path for emergency rescue of tunnel disasters. To obtain, speed up the system calculation speed and improve rescue efficiency. During the operation of the tunnel, because some special circumstances will cause tunnel operation problems, these problems are collectively referred to as tunnel abnormal events. Through the establishment of an automatic detection and disposal system for tunnel abnormal events, automatic event detection, emergency rescue of personnel and timely disposal of accidents can be carried out when abnormal events occur. To this end, the article discusses the characteristics of urban underground tunnel accidents through the analysis of past tunnel accidents, and analyzes the improvement measures of tunnel rescue, hoping to provide some references for ensuring the harmonious development of the city. The main work of this paper is to aim at the current problems of the weighted fuzzy logic control algorithm, summarize the basic modes of tunnel rescue, and analyze the effect and time of tunnel rescue under different modes through simulation and experimental research.

1. Introduction

In recent years, in the process of gradual improvement of the urban transportation system, the construction of underground tunnels in various parts of our country has been strengthened, which has greatly reduced the burden of urban transportation and increased the utilization rate of land [1]. However, tunnel disasters, especially in highway tunnels, occur at any time, and the possibility of tunnel collapse, fire and explosion is high, which has aroused public attention to the dangers of tunnels [2]. Therefore, in order to better deal with the occurrence of tunnel dangers and improve the practical efficiency of tunnel structures, we should start from the existing data to analyze the dangerous characteristics of urban underground tunnels and the countermeasures for tunnel structures [3]. During the operation of the tunnel, due to the complexity of the traffic environment and the particularity of the tunnel's spatial structure, abnormal events are prone to occur in the tunnel. It is necessary to use automatic detection devices to obtain information in time, establish an incident handling and rescue system, and share incident information with relevant emergency departments, improve the efficiency of emergency rescue. Tunnel rescue is an important part of carrying out rescue work. To lay a solid foundation of tunnel rescue skills and improve the ability to use the learned tunnel knowledge to solve practical problems has an important supporting role in training rescue technical professionals [4].

In the process of tunnel operation and use, sudden accidents directly threaten people's lives and safety. Once a major accident occurs, how to reduce the casualties caused by the accident is very important. After a tunnel disaster occurs, the tunnel structure is often destroyed, the internal environment changes, and secondary disasters are prone to occur. Before the rescue work, the internal and external environment of the tunnel and the tunnel structure must be evaluated, and the rescue work can be carried out after the conditions are suitable [5]. Since there are very few escape routes in the tunnel, there is only one route into and out of the tunnel. There is often only one route from the accident site to the ground or other safe locations under the tunnel. The shortest rescue

plan is formulated according to the number of people in the tunnel and the current situation of the tunnel. It can avoid and reduce casualties, and it can prevent blindly taking emergency measures and laboring the people and money [6]. The shortest time tunnel rescue based on the fuzzy logic algorithm can combine the tunnel weight with the fuzzy logic algorithm to generate a rescue path with the shortest time [7]. Therefore, studying the effectiveness of dangerous disaster control, tunnel disaster monitoring, disaster suppression and tunnel rescue system in the case of tunnel rescue when a major disaster occurs in a tunnel is of great significance for the safety of personnel and tunnel use [8].

Foreign countries have done a lot of research work in disaster prevention, evacuation and rescue of long tunnels. Hitoshi Kurioka, Yasushi Oka, Hiroomi Satoh, Osami Sugawa used 1/10 scale, 1/2 scale, full scale and rectangular and horseshoe-shaped cross-section tunnels to conduct experiments in order to study the fire situation of a certain tunnel [9]. O. Mégret O. Vauquelin, proposed a semi-empirical model to determine the physical characteristics of tunnel fires. F. Colella, G. Rein, R. Borchiellini, R. Carvel, J. L. Torero, V. Verda, proposed a new method for modeling tunnel ventilation flow under environmental conditions (cold flow). Chinese scholars have also learned and summarized the experience and lessons of disaster prevention in long and large tunnels abroad. Extensive and in-depth research work has also been carried out in the theory, design and practice of disaster prevention, evacuation and rescue of long tunnels in China [10]. Wang Nianyan and others carried out a comprehensive research on the disaster prevention and evacuation and rescue technology of railway tunnels; Hong Lijuan and others summarized the characteristics and dangers of fires in the tunnel, and introduced relevant experimental research results; Xu Zhisheng and others carried out the tunnel fire simulation experiment, And used software to carry out numerical simulation, and put forward rescue and evacuation requirements; Zhang Xuebing and others analyzed the evacuation problem in the long-distance subway section, and studied a variety of mathematical models of evacuation methods. Other scholars have also done related research.

2. Algorithm Establishment

2.1 Fuzzy Logic Algorithm

Fuzzy logic refers to the use of fuzzy logic inferences in order to imitate the human brain to make comprehensive judgments on things, and is mainly used to solve the problem of regular transmission of information.

2.1.1 Algorithm structure

Fuzzy logic algorithms generally include five main parts: variable definition, fuzzification, knowledge base, logical judgment and defuzzification.

Define variables: Define variables in the fuzzy logic control process. General fuzzy variables include output error E, output error rate of change EC, and state input value U.

Fuzzification: Convert input variables into appropriate ways, and use linguistic variables to explain the changing process of physical quantities.

Knowledge base: Knowledge base can be divided into two categories according to function: database and rule base. Among them, the database mainly contains several guidelines for dealing with fuzzy data, and the rule database contains control rules that describe control objectives and strategies.

Logical judgment: Based on fuzzy logic inference method, in order to distinguish things, simulate the thinking mode of the human brain, and obtain the final fuzzy logic judgment control signal.

Defuzzification: The solution obtained through fuzzy inference is directly converted into a control signal that can be received in the system, and the input value is input into the system.

2.1.2 Algorithm principle

Fuzzy logic control system generally consists of four parts: multiple control variables and

membership functions, variable fuzzification and defuzzification, fuzzy rules and fuzzy inference algorithms.

(1) Membership function

In fuzzy theory, the fuzzy set A of the input and output vector x is defined by the function $\mu_A(x)$, which is called the membership function of set A:

$$\mu_A(x) : X \longrightarrow [0,1] \tag{1}$$

If x completely belongs to A, $\mu_A(x)$=1; x does not belong to A, $\mu_A(x)$=0; part of x belongs to A, 0<$\mu_A(x)$<1.

The membership function defines the value between the variable spaces matched by the membership [0,1].

The membership function is determined by knowledge acquisition or data. There are many ways to generate the number of members of each variable based on numerical data.

(2) Generation of fuzzy rules

The format of the fuzzy rule is as follows. IF x is ATHEN y is B, where A and B are linguistic values defined as fuzzy sets of domains X and Y. "X is A" as the premise and "y is B" as the conclusion

The commonly used fuzzy rule generation methods are FPA algorithm, Wang & Mendel algorithm and fuzzy decision tree algorithm. The research in this article consists of 7 inputs and 1 output. Therefore, this article uses Wang & Mendel algorithm to generate fuzzy rules. Using the Wang & Mendel algorithm can greatly reduce the number of rules in the rule base, reduce useless or repeated rules, and make the propagation rule base simpler and clearer.

2.2 Wang & Mendel Algorithm

The Wang & Mendel algorithm is divided into two parts: the input layer and the output layer (ie Kohonen layer). Let the total number of samples be n, and the input of the p-th sample can be expressed as follows:

$$X^p = (x_1^p, x_2^p, \ldots, x_i^p, \ldots, x_n^p)^T \tag{2}$$

Definition 1: Winning node For a given sample $x \in R^m$, the output y(win) of the sample corresponding to the prototype vector closest to x is called the winning node.

$$y(win) = \arg\min_{1 \le i \le n}\{d(\omega_i, x)\} \tag{3}$$

Among them, n is the number of samples, d is the Euclidean distance formula, and ω_i is the prototype vector.

For the sample set $x \in R^m$, a certain number of iterative training is performed, and at each iteration, the prototype vector of the algorithm is updated using the following formula:

$$\omega_i(t) = \omega_i(t-1) + \alpha(t) \cdot neigh_{y(win),i}(t) \cdot (x - \omega_i(t)) \tag{4}$$

Among them, $\alpha(t)$ is the learning efficiency factor that monotonically decreases with the number of iterations t:

$$\alpha(t) = \alpha_0 exp\left(-\frac{t}{\tau_i}\right), t = 0,1,2,\ldots,n \tag{5}$$

Among them, α_0 is the initial value of the learning efficiency factor, generally taking a value close to 0.1; $neigh_{y(win),i}(t)$ is the domain function, and this article uses Gaussian domain function:

$$neigh_{y(win),i}(t) = exp\left(-\frac{\|o_i - o_{y(win)}\|^2}{2\sigma^2(t)}\right) \tag{6}$$

Among them, o_i and $o_{y(win)}$ are the output coordinates of the sample i and the best matching unit, and $\sigma(t)$ is the width of the neighborhood that decreases monotonically with t, and $\sigma(t)$

converges as $neigh_{y(win),i}(t)$ approaches 0:

$$\sigma(t) = \sigma_0 \exp\left(-\frac{t}{\tau_2}\right) \tag{7}$$

3. Modeling method

3.1 Chaotic time series prediction model based on Volterra

Most chaotic time series forecasts use Volterra function models. The second-order Volterra model can effectively predict low-dimensional chaotic time series. At the same time, it also considers nonlinear terms, which is exactly in line with the nonlinearity and short-term stability of chaotic time series.

The expansion of the discretized Volterra series is:

$$\begin{aligned} x(n+1) &= F(X(n)) \\ &= h_0 + \sum_{m=0}^{+\infty} h_1(m)x(n-m) \\ &+ \sum_{m_1=0}^{+\infty}\sum_{m_2=0}^{+\infty} h_2(m_1,m_2)\,x(n-m_1)x(n-m_2) + \ldots + \\ &\sum_{m_1=0}^{+\infty}\sum_{m_2=0}^{+\infty}\ldots\sum_{m_p}^{+\infty} h_p(m_1,m_2,\ldots,m_p)x(n-m_1)x(n-m_2)\ldots x(n-m_p) + \ldots \end{aligned} \tag{8}$$

Choose the second-order Volterra model, the formula is as (9):

$$\hat{x}(n+1) = h_0 + \sum_{i_1=0}^{N-1} h_1(i_1)x(n-i_1\tau) + \sum_{i_1,i_2=0}^{N-1} h_2(i_1,i_2)x(n-i_1\tau) + e(n) \tag{9}$$

The input of the linear adaptive FIR filter is defined as X(n), and the coefficient vector is defined as H(n)

$$X(n) = [1, x(n), x(n-1), \ldots, x(n-m+1), x^2(n), x(n)x(n-1), \ldots, x^2(n-m+1)]^T \tag{10}$$

$$H(n) = [h_0, h(0), h(1), \ldots, h(m-1), h_2(0,0), h_2(0,1), \ldots, h_2(n-m+1)]^T \tag{11}$$

Since the coefficients of the Volterra model can be directly determined by the linear adaptive FIR filter algorithm, formula (9) can be expressed as:

$$\hat{x}(n+1) = H^T(n)X(n) \tag{12}$$

4. Evaluation Results and Research

In order to understand the shortest time required for safe evacuation in tunnel emergency rescue, theoretical calculation or simulation can be used to simulate the tunnel rescue situation, so as to understand the shortest tunnel rescue time.

Take a general express train trapped in a suddenly dangerous tunnel as an example: car 01 is a baggage car, car 02-08 is a hard sleeper (rated passenger number 66/car), 09 car is a soft sleeper (rated passenger Number 36/car), 10 cars are dining cars, 11-17 cars are hard-seat cars (rated number of passengers 118/car, coach coach 112/car), 18 cars are air-conditioned generator cars. After considering 20% overload (overload only considers hard-seat cars), all hard-seat cars have a total of 980 passengers, and the number of passengers in the entire train is 1484. The staff composition is shown in Figure 1.

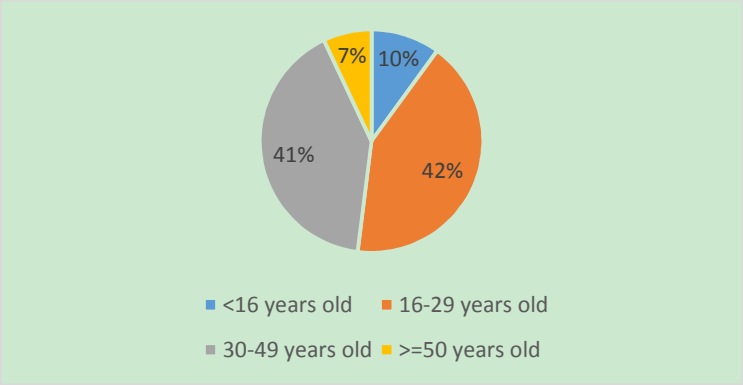

Figure 1. Ratio of personnel composition

Since the train is in the tunnel where the accident occurred, the evacuation of the people in the tunnel may encounter uneven roads and roads with heavy smoke, so the evacuation speed of the evacuation of the people will be different, so for the rigor of the experiment, it needs to be blurred The logic algorithm fuzzy estimates the evacuation speed of different people in different types of environments. The value of the evacuation speed of different people is shown in Table 1.

Table 1. Evacuation speed values of different types of persons (m/s)

Different types of evacuation speed	Person Type			
	Child	Adult male	Adult women	The elderly
Smoke-free walking speed on flat ground	0.8	1.2	1	0.72
Smoke walking speed on flat ground	0.78	1.17	0.97	0.7
Smoke on uneven ground, walking speed	0.67	1	0.8	0.6

The chaotic time series prediction model based on Volterra is used to simulate the evacuation process of passengers in passenger cars and platforms, and the calculation results are shown in Figure 2.

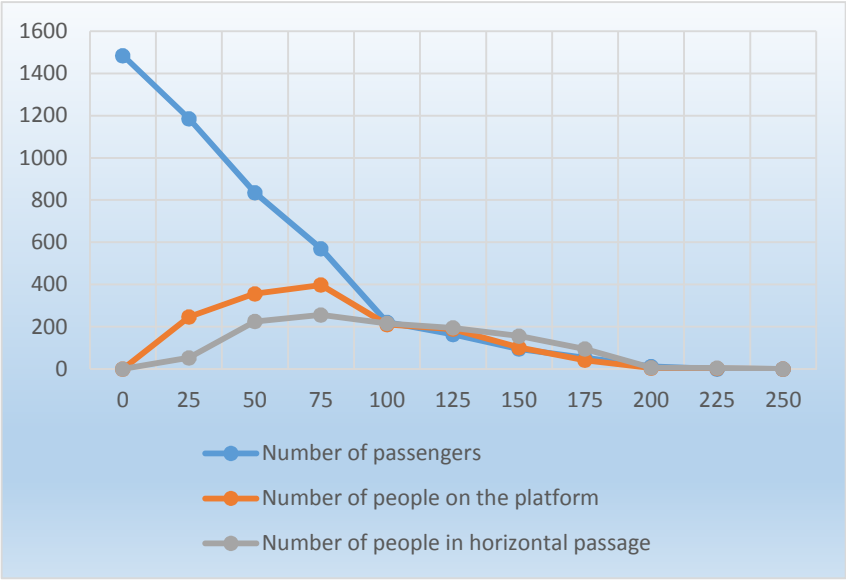

Figure 2. The relationship between the number of people evacuated and time

It can be seen from the data in Figure 2 that the number of people stranded in the carriage decreases exponentially. The time required for all the people to leave the platform is about 228s, and the time required for all the people in the carriage to evacuate to the platform is about 216s.

According to the observation of the evacuation route, the evacuation mainly uses 7 rescue cross channels, and the average evacuation speed is about 33 persons/(min·m).

Using Volterra-based chaotic time series prediction model to simulate the evacuation process of people in passenger cars and platforms, you can roughly know the time to rescue the evacuated people, and you can better set up rescue measures to ensure the safety of the property and life of the people in the tunnel. It can also reduce the death and injury caused by too long rescue time. The data of this test is still very accurate and practical.

5. Conclusion

To sum up, in the rescue of abnormal tunnel events, it is necessary to realize the comprehensive processing of information, instant reminders of related information and event correlation, and the linkage of other information to comprehensively analyze the severity of the event. In emergency rescue, we must deal with abnormal events in accordance with the meaning of the acquired information and the set plan, and the established work level. The disaster prevention and rescue design of the tunnel is closely related to the national conditions of the country where the project is located, the needs of the owner, the project environment, and the characteristics of the project. Before design, it should be fully investigated, in-depth research, and evaluation of the cost and necessity of adopting high standards of economic technology, reasonable selection of safety levels, and determination of suitability. The economic and social development of the project site is based on the objective and law of disaster prevention and rescue standards to avoid difficulties in tunnel rescue caused by over-design and waste. People trapped in the tunnel should be rescued safely in the shortest time. This article introduces the method of tunnel rescue simulation using fuzzy logic method, and analyzes the results obtained by this method and the results obtained by tunnel rescue according to the specification in detail.

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