Research on Risk Assessment of Waterway Dangerous Goods Transportation Based on Artificial Neural Network Algorithm

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Abstract. In order to improve the accuracy of the risk assessment of dangerous goods transportation in waterways, a particle optimization neural network method for risk assessment of waterway dangerous goods transportation is proposed. Firstly, the risk evaluation index of waterway dangerous goods transportation is selected by expert system, then the weight of evaluation index is determined by expert scoring method. Finally, the index weight is input into BP neural network for learning. BP neural network parameters are optimized by particle swarm optimization algorithm to obtain waterway dangerous goods transportation. Risk assessment level. The simulation results show that compared with the traditional waterway dangerous goods transportation risk assessment model, the particle optimization neural network accelerates the risk assessment of waterway dangerous goods transportation and improves the accuracy of waterway dangerous goods transportation risk assessment.

Introduction

With the rapid development of the national economy, industrial and agricultural production, and the continuous improvement of people's living standards, China's demand for dangerous goods such as petroleum, liquefied petroleum gas and chemical raw materials is growing. Dangerous goods waterway transportation due to the dangerous nature of the item itself and various restrictions on water transport conditions, combined with the harsh environment, increases the risk of transportation [1]. Dangerous goods are flammable, explosive, corrosive and radiation [2]. They are prone to leakage, fire and even explosions during water transportation and loading and unloading, causing catastrophic consequences such as ship damage, capital loss and environmental pollution [3]. In order to enhance the safety of dangerous goods waterway transportation, this paper mainly uses particle swarm BP neural network model to carry out risk assessment of waterway dangerous goods transportation from five aspects: human factors, cargo factors, environmental factors, ship factors and management factors.

Waterway Dangerous Goods Transportation Risk Assessment System

According to the transportation characteristics and requirements of the “Rules for the Dangerous Goods by Waterway Transportation” and the “International Dangerous Goods Transportation Rules”, the risk assessment of waterway dangerous goods transportation needs to follow the principles of systemic, scientific, compliance and operability. A set of indicators for risk assessment of dangerous goods transportation is established for the situation considered by the ship's internal and external auditing agencies in the review of dangerous goods transportation and the need for data synthesis. According to the preliminary selection of the risk assessment index system for waterway dangerous goods transportation, according to the adjustment principle and method of the evaluation index system, through the means of deleting, reorganizing, adding and merging indicators, the risk evaluation index system for waterway dangerous goods transportation is finally established, as shown in Table 1.

The purpose of risk assessment of waterway dangerous goods transportation is to quantitatively grasp the risk status of waterway dangerous goods transportation, combined with the adjustment principle of evaluation indicators, integrate and optimize the primary selection indicators, and

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finally establish a comprehensive, operational, scientific Waterway dangerous goods transportation risk assessment indicator system.

Table 1 Risk Assessment Index System for Waterway Dangerous Goods Transportation

Target layer	Criteria layer	Indicator layer	Indicator description
Waterway dangerous goods transportation risk evaluation index system	Safety awareness and personnel quality U_1	Crew safety awareness U_{11}	Captain and crew safety awareness
		Crew quality U_{12}	Theoretical culture, technical business and other qualities
	Regulations and management systems U_2	Dangerous goods transportation regulations U_{21}	International Code of Ethics and Waterway Code
		Regulations and systems U_{22}	Shipping company regulations and systems
	Ships and equipment U_3	Ship U_{31}	Dangerous goods transport ship performance status, etc.
		Route U_{32}	Planned route design status
	Theoretical changes and packaging U_4	Theoretical changes in dangerous goods U_{41}	Physical and chemical changes
		Packaging of dangerous goods U_{42}	Packaging, inspection, design, etc.
	Other factors U_5	Emergency Rescue U_{51}	Emergency rescue plan and facilities, etc.
		Natural environment at sea U_{52}	Sea conditions, visibility, etc.

Risk Assessment Model Based on Particle Swarm Optimization BP Neural Network

Principles of Risk Assessment for Waterway Dangerous Goods Transportation. The principle of risk assessment for waterway dangerous goods transportation is to determine the content and scope of the evaluation under the guidance of its evaluation standard, and then evaluate the relevant evaluation methods. Out of the network security level, the waterway dangerous goods transportation risk evaluation mathematical model is as follows:

$$\textit{Waterway dangerous goods transportation risk} = f\left(x_1, x_2, \cdots, x_i, x_m\right) \quad (1)$$

In which, x_i indicates the waterway dangerous goods transportation risk evaluation factor, and f represent the waterway dangerous goods transportation risk evaluation model

From the waterway dangerous goods transportation risk evaluation model, it is very important to select the risk evaluation factor and the risk evaluation model. Waterway dangerous goods transportation risk has the characteristics of uncertainty and non-linearity. Therefore, BP neural network with very strong nonlinear approximation capability is used as the waterway dangerous goods transportation risk evaluation model, and the experts choose waterway dangerous goods transportation risk factors and score them to determine the weight of the results, so as to improve the accuracy of waterway dangerous goods transportation risk evaluation.

Waterway Dangerous Goods Transportation Risk Level Setting. According to the risk assessment of dangerous goods on waterways over the years, the risk assessment status of dangerous goods transported by waterways is generally divided into five grades, that is $S = \{0 \sim 0.17, 0.17 \sim 0.33, 0.33 \sim 0.5, 0.5 \sim 0.67, 0.67 \sim 1\}$, as shown in Table 2.

Table 2 Risk level division

Risk value	Risk status
0~0.17	Low risk
0.17~0.33	Slightly lower risk
0.33~0.5	General risk
0.5~0.67	Higher risk
0.67~1	High risk

Particle Swarm Optimization BP Neural Network. Neural network is essentially a simulation system for the human brain's thinking process. Its core is the mathematical models and algorithms, and the physical implementation is computer software. Just like thins are composed of atoms, neural network is composed of many interconnected neurons. Figure 1 shows the basic work principle of neurons, and the mathematical expression is as follows:

$$y = f\left(\sum w_i x_i\right) \tag{2}$$

Where x_i and y are respectively the input and output. w_i is weight coefficient. f is characteristic function, which reflects the mapping relationship between inputs and outputs, and it is usually a nonlinear function.

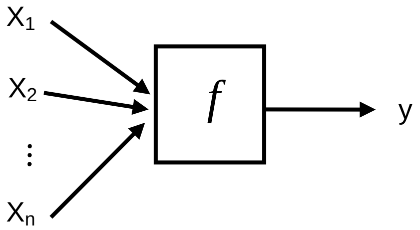

Figure 1 The neuron model

This seemingly simple model will produce a powerful neural network combing different network topology and network algorithms together. Neural network consists of input layer, hidden layer and output layer, which is shown in Figure 2.

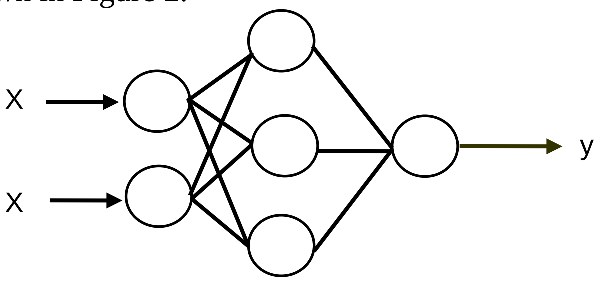

Figure 2 The connection model of neural network

With a lot of development of neural networks, it was found that no matter how the organizational structure of the network it is, It is always has the following two characteristics:

Self-learning. Neural networks can be modified according to the external environment of their own behavior in order to adapt to the external environment, which is mainly due to its learning process. Learning is often the first step in using neural networks. When a group of information is input, neural networks can continue to adjust its internal parameters (or say weighting coefficient), and eventually produce a series of consistent output.

Generation. Once after the self-learning, the response of neural network, to some extent, to the reducing of input information and their own local defects are no longer sensitive. This mechanism can make the neural network has a strong fault tolerance and reduce the input data quality requirements.

BP neural network has strong nonlinear approximation ability, simple algorithm and easy realization, but it is easy to fall into local extremum, so it is difficult to guarantee convergence to global minimum point, and global search ability is not strong. In addition, the BP neural network is a gradient descent algorithm based on back propagation, and its convergence speed is slow and the learning effect is unsatisfactory. In order to overcome the limitations of the BP neural network itself, this paper uses the PSO algorithm to optimize the BP neural network. The optimization steps are as follows:

1) Initialize the structure, transfer function, target vector and so on of BP neural network.

2) Set the size of the particle swarm, the dimension of the parameter, the number of iterations, the momentum coefficient, the initial position of the particle and the initial velocity.

3) Using the training set to train the BP neural network, the fitness value of each particle is evaluated.

4) Compare the current value of each particle with the historical best value, and if the current

value is better than the historical best value, save the current value of the particle as the historical best value of the individual. Compare the current value of the particle group and its historical best value, if its current value is better, save the current value for its historical global best value.

5) Calculate the inertia weight.

6) The position and velocity of each particle are updated to record the system fitness error for each particle and particle group, respectively.

7) Determine the system fitness value error, if the error reaches the set error limit or exceeds the maximum allowable number of iterations, the training is over. The historical global optimal position of the particle is the optimal weight and the optimal threshold of the BP neural network.

Waterway Dangerous Goods Transportation Risk Evaluation Model. In this paper, the PSO-BPNN model is used to evaluate the waterway dangerous goods transportation risk. Firstly, the waterway dangerous goods transportation risk evaluation index system is constructed. Then, the BP neural network is optimized by particle swarm optimization algorithm, and the optimal weight and optimal threshold of BP neural network are obtained. Finally, the optimized BP neural network model is used to evaluate the waterway dangerous goods transportation risk. The concrete steps are shown in Figure 3.

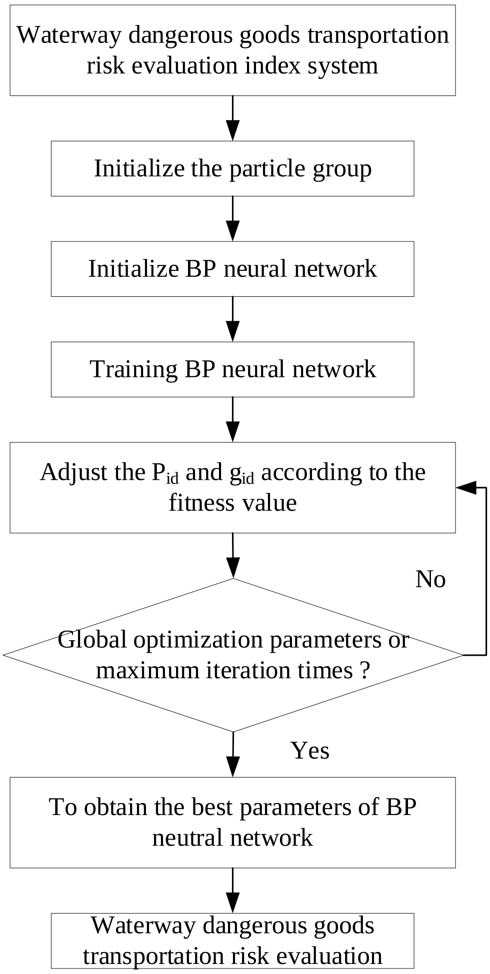

Figure 3 Evaluation process of transportation risk of dangerous goods in waterway

Case Study

In order to analyze the risk degree of dangerous goods carried by ships, combined with the above-mentioned risk assessment model based on particle swarm optimization BP neural network, the evaluation data and weight data of each index information are collected by expert scoring method, and the risk results are comprehensively obtained.

Based on the actual situation of each dangerous goods vessel sailing on the Yangtze River and along the coast, and relying on the investigation of the crew members at the time, the expert group scored the degree of membership of each risk assessment indicator as shown in Tables 3 and 4, respectively. Finally, the comprehensive scores of the indicators of 10 ships were obtained.

Table 3 Transportation of dangerous goods by ship

No.	Ship age	Ship type	Ship tonnage	Main cargo loading
1	12	Chemical / tanker	765	Middle and lower reaches of the Yangtze River and its tributaries, inter-provincial oil tankers and bulk chemical tankers
2	7	Bulk chemicals	545	Intermediary bulk chemical tanker transport in the middle and lower reaches of the Yangtze River and its tributaries
3	9	Bulk chemicals	1025	Intermediary bulk chemical tanker transport in the middle and lower reaches of the Yangtze River and its tributaries
4	8	Tanker	565	Middle and lower reaches of the Yangtze River and its tributaries
5	8	Chemical	536	Middle and lower reaches of the Yangtze River and its tributaries, inter-provincial chemical tankers
6	10	Bulk chemicals	435	Middle and lower reaches of the Yangtze River and its tributaries, inter-provincial chemical tankers
7	5	Tanker	502	Middle and lower reaches of the Yangtze River and its tributaries, inter-provincial chemical tankers
8	7	Bulk chemicals	390	Intermediary bulk chemical tanker transport in the middle and lower reaches of the Yangtze River and its tributaries
9	7	Tanker	393	Middle and lower reaches of the Yangtze River and its tributaries
10	9	Chemical / tanker	598	Middle and lower reaches of the Yangtze River and its tributaries

Table 4 Survey of crew quality and safety awareness

Index	1	2	3	4	5	6	7	8	9	10
U11	0.75	0.25	0.17	0.33	0.28	0.28	0.30	0.75	0.28	0.40
U12	0.52	0.30	0.30	0.48	0.36	0.27	0.19	0.27	0.35	0.45
U21	0.03	0.17	0.33	0.30	0.20	0.30	0.19	0.25	0.17	0.38
U22	0.20	0.28	0.28	0.28	0.33	0.5	0.22	0.29	0.23	0.33
U31	0.98	0.42	0.42	0.36	0.33	0.42	0.33	0.53	0.33	0.50
U32	0.43	0.26	0.26	0.33	0.24	0.33	0.28	0.33	0.27	0.30
U41	0.75	0.43	0.43	0.30	0.32	0.30	0.33	0.30	0.42	0.75
U42	0.28	0.33	0.33	0.33	0.17	0.38	0.28	0.40	0.22	0.33
U51	0.23	0.37	0.37	0.33	0.33	0.33	0.26	0.33	0.33	0.23
U52	0.38	0.26	0.26	0.30	0.30	0.50	0.15	0.33	0.38	0.42

The expert score of the crew quality is based on the investigation of the crew's knowledge level, skills, psychological quality, management status and the crew safety awareness are scored by experts. As the learning sample value of the particle swarm optimization BP neural network, the training sample data obtained is shown in Table 5.

Table 5 sample data

No.	Knowledge level	Skills	Psychological quality	Management status	Safety awareness
1	0.51	0.60	0.44	0.52	0.75
2	0.35	0.42	0.25	0.37	0.25
3	0.22	0.35	0.27	0.28	0.17
4	0.25	0.28	0.49	0.25	0.33
5	0.25	0.33	0.42	0.35	0.28
6	0.25	0.29	0.22	0.28	0.28
7	0.30	0.21	0.15	0.22	0.30
8	0.60	0.20	0.15	0.30	0.75
9	0.23	0.37	0.30	0.36	0.28
10	0.35	0.50	0.40	0.43	0.40

According to the actual situation of each ship, the expected output of each dangerous goods ship is shown in Table 6.

Table 6 Expected output data

No.	Natural environment at sea	Expected output
1	0.381	0.60
2	0.258	0.25
3	0.258	0.36
4	0.298	0.28
5	0.297	0.26
6	0.500	0.42
7	0.153	0.16
8	0.330	0.35
9	0.381	0.31
10	0.415	0.53

It can be concluded from Table 6 that dangerous goods vessels with low risk (0~0.17) are: ship 7; dangerous goods vessels with low risk (0.17~0.33) are: ships 2, 4, 5, 9; In general, the dangerous goods (0.33~0.5) are: ship 3, 8, dangerous goods with high risk (0.5~0.67) are ships 1, 10; There are 0 dangerous goods vessels.

Conclusion

Through the appropriate waterway dangerous goods transportation risk assessment system, based on the particle swarm optimization BP neural network model, the risk assessment of waterway dangerous goods transportation can quickly and efficiently seek global optimization, obtain the best weight and threshold, and realize the dangerous goods to the waterway. The correct evaluation of risks is of great significance for the risk management and transportation of dangerous goods ships.

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