Application of artificial neural networks for Chemical Industry Safety Production: A review

Abstract: Chemical industry as a national pillar industry, safety management is particularly important; Safety evaluation is to use relevant technical which evaluate the risks of the enterprise's production process. The key is the selection of evaluation methods and means, which can directly affect the effect of the evaluation. But because the object of safety evaluation is affected by many factors, it pays attention to the non-linear relationship between the action factor and the state. Artificial neural network can make use of the threshold value between neuron nodes and the connection weight value between nodes based on artificial function to carry out non-linear mapping input and output in advance, which has obvious advantages in dealing with non-linear complex problems.

Keywords: artificial neural network, chemical industry, safety evaluation

1 Introduction

As a key pillar enterprise of the national economy, the chemical industry has played a pivotal role in the development of our country's national economy for a long time. Due to the particularity of chemical products, the production behavior of chemical enterprises is a high-risk operation, which has the characteristics of inflammable, explosive, high temperature and high pressure, toxic and harmful, etc., and safety issues are particularly prominent [1]. Attaching importance to safety evaluation and establishing a safety production evaluation system for chemical companies is an important guarantee for the safety of chemical companies. Attaching importance to safety evaluation and establishing a safety production evaluation system for chemical companies is an important guarantee for the safety of chemical companies. The artificial neural network constructs a chemical safety evaluation model, which has certain guiding significance for safety production management, improves the quality of safety evaluation of chemical enterprises, ensures safe production, strengthens hazard prevention, reduces the probability of accidents, and reduces property losses and casualties, which has a positive and significant effect[2-4].

2 Artificial neural networks

2.1 Overview of artificial neural networks

Artificial neural networks (ANN), referred to as Neural Network (NN), in the field of machine learning and cognitive science, is a kind of imitating the structure and function of biological neural network (animal's central nervous system, especially the brain) Mathematical model or calculation model, used to estimate or approximate the function. The neural network is calculated by connecting a large number of artificial neurons. In most cases, the artificial neural network can change the internal structure on the basis of external information. It is an adaptive system and, in layman's terms, has a learning function. Modern neural network is a non-linear statistical data modeling tool. Neural network is usually optimized through a learning method based on mathematical statistics. Therefore, it is also a practical application of mathematical statistical methods. Through statistical standard mathematics methods, we can get a large number of local structural spaces that can be expressed by functions. On the other hand, in the field of artificial perception in artificial intelligence, we can make decisions about artificial perception through the application of mathematical statistics (that is, through statistics The method of learning, artificial neural network can have simple decision-making ability and simple judgment ability like people), this method has more advantages than formal logical reasoning calculus. Like other machine learning methods, neural networks have been used to solve a variety of problems, such as process control and optimization **Error! Reference source not found.**, image recognition and single processing **Error! Reference source not found.**, forecasting**Error! Reference source not found.**, traditional Chinese medicine processing**Error! Reference source not found.**, aquatic products**Error! Reference source not found.**, security risk assessment**Error! Reference source not found.**, intelligent driving**Error! Reference source not found.**,and so on[23-26].

2.2 Basic Principles

Artificial neural network is a non-linear, adaptive information processing system composed of a large number of interconnected processing units. It mimics the human brain neuron network for abstraction, and then establishes a certain mathematical model. By adjusting the interconnection relationship between a large number of nodes in the model to process the information [27,28].

The complete algorithm structure of traditional ANN is composed of at least three different layers: input layer, hidden layer and output layer (Figure 1). Each layer is composed of a certain number of neurons. In the input layer, many neurons accept a large number of non-linear input messages. The input message is called the input vector. Hidden layer is a layer composed of many neurons and links between the input layer and the output layer. The hidden layer can have one or more layers. The number of nodes in the hidden layer is variable, but the larger the number, the more significant the nonlinearity of the neural network, so that the robustness of the neural network (the characteristic that the control system maintains certain performance under the perturbation of a certain structure, size and other parameters) is more significant. It is customary to choose a node that is 1.2 to 1.5 times the input node. In the output layer, messages are transmitted, analyzed, and weighed in neuron links to form output results. The output message is called the output vector [29,30].

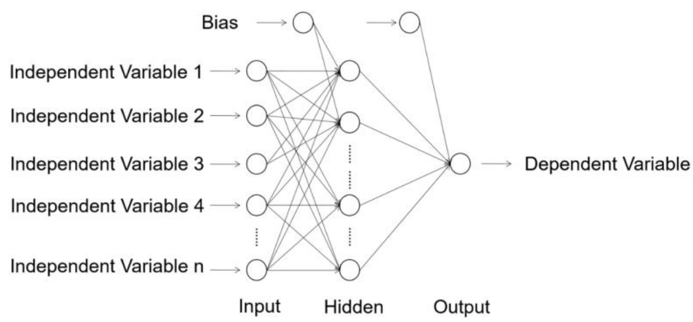

Figure 1. Algorithmic structure of a typical artificial neural network (ANN).

Each neuron is connected to all neurons in the next layer. Each connection represents a weight that contributes to the accessory. Under the appropriate activation function, the optimized combination of weights can generate predictions for the dependent variable:

$$NET = \sum_{i,j}^{n} w_{i,j} x_i + b \tag{1}$$

$$y = f(NET) \tag{2}$$

Where $w_{i,j}$ represents the weight value of a connection, x_i represents an inputted independent variable, and b represents a bias. Among them, the output function has many forms, the common ones are: proportional function, quadratic function, hyperbolic function, m -type function, Y -type function, etc. Each node of the neural network has a state variable; the node and the node are connected by the connection weight coefficient, and each node has a deviation b and a nonlinear transformation function $f(NET)$ [31-33].

2.3 Basic characteristics

Artificial neural network is a non-linear adaptive information processing system composed of a large number of processing units. The elimination of this system is established on the basis of the results of modern neuroscience research, through neural network processing, to simulate information through the memory information of the brain. Mainly have the following characteristics:

Non-linearity is a common feature in nature. Non-linear phenomena are like the wisdom of the brain. Artificial neurons are in two different states of inhibition or activation. The neural network has better performance, can greatly improve the storage capacity of the network, and reduce the fault tolerance of the network[34,35].

Non-limiting, neural networks usually consist of many neurons. The characteristics of a single neuron can determine the behavior of the entire system, and it also depends on the results of the interaction between the units. Simulate the brain through the connections between units, a typical example is associative memory[36].

Non-constant qualitative, the information processed by the neural network and the nonlinear dynamic system are constantly changing. Iterative process is usually used to describe the evolution process of dynamic system[37].

Non-convexity, usually refers to a specific state function, under certain conditions, affect the evolution direction of a non-convex system. For example, the relative steady state of the system corresponds to the extreme value of the energy function. A non-convex function means that it has multiple extreme values. Therefore, the system has multiple stable equilibrium states, which causes the system to evolve into diversity[38].

2.4 Classification

Artificial neural network can be divided into feedback network and feedforward network in terms of structure[39].

Feedforward network: The network information advances layer by layer from the input layer to the various Tibetan layers and then to the output layer.

Feedback network: All nodes in the feedback network have information processing functions, and each node can receive input and output at the same time.

2.4.1 Feedforward neural network

The feedforward neural network is the simplest kind of neural network. It adopts a unidirectional multilayer structure, each neuron is arranged in layers, and each neuron is only connected to the neuron of the previous layer. Receive the output of the previous layer and output it to the next layer without feedback between the layers. As shown in Figure 1[4, 40].

2.4.2 Feedback neural network

Feedback neural network, also known as recursive network, regression network, is a neural network system that connects the output to the input layer after a step time shift. In this type of network, neurons can be interconnected, and the output of some neurons will be fed back to neurons in the same layer or even the previous layer. Common ones are Hopfield neural network, Elman neural network, Boltzmann machine, etc [41].

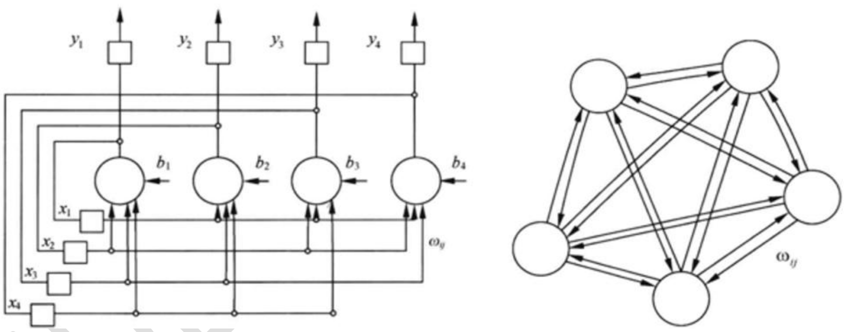

Figure 2. Feedback neural network.

2.4.3 The main difference

(1) There is no connection between the neurons in each layer of the feedforward neural network. The neurons only accept the data from the upper layer, and then pass to the next layer after processing. The data flows forward; the neurons between the layers of the feedback neural network are connected, and the data can flow between the same layers or feed back to the front layer.

(2) The feedforward neural network does not consider the time lag effect of output and input, and only expresses the mapping relationship between output and input; The feedback neural network considers the time delay between output and input, and needs to use dynamic equations to describe

the model of the system.

(3) The learning of feedforward neural network mainly adopts error correction method (such as BP algorithm), the calculation process is generally slow, and the convergence speed is relatively slow; the feedback neural network mainly adopts Hebb learning rules, and the calculation convergence speed is generally fast.

(4) Compared with feedforward neural networks, feedback neural networks are more suitable for applications in associative memory and optimized calculations [42-44].

2.5 Artificial neural network learning rules

The learning rules of artificial neural networks are actually a way of network training. The purpose is to modify the weights of neural networks and adjust the thresholds of neural networks so that they can better complete some specific tasks. At present, neural networks have two different learning methods: tutored learning (also called supervised learning) and unsupervised learning (also called autonomous learning). [1,34,45]

2.5.1 Supervised learning

The so-called supervised learning is a process in which the neural network requires training data to be supervised during the training process. This process is a process of continuously adjusting the weight under the effect of the expected output, that is, when the training data is input into the neural network after training. After learning the output, the network compares the output with the expected output. If the output of the neural network is within the allowable range of errors compared to the expected output, then the neural network learning can be considered to have been completed. If it is not within the allowable range of errors, the neural network must continuously adjust the weights set to reduce the error, so that the output of the neural network is closer to the expected output, until the error is within the range allowed by the error, and the training ends. Therefore, it can be seen that the learning process with a mentor is a process of weight adjustment under the expectation of supervision. In this process, the change of the weight of the neural network reflects the learning process of the entire network. The final adjusted weight is this nerve. In this way, after continuous supervised learning, a neural network model with preliminary intelligence has been basically established.

2.5.2 Unsupervised learning

The difference between unsupervised learning, also known as autonomous learning and supervised learning, is that unsupervised learning does not have an external supervision mechanism. It has no expected output. The training data is not included in the output after being input into the network by the input layer. The entire neural network checks the characteristics and rules of the training input data, and formulates a judgment standard1. The network refers to this standard to adjust the weight. This kind of unsupervised learning can be considered as a kind of self-organized learning. The discrimination criteria formulated before training are also pre-set rules such as competition rules. Through the cooperation between the neurons, the network weights are continuously adjusted to respond to the input mode excitation until the entire neural network forms an ordered state.

3 Chemical safety production evaluation system

Chemical industry is one of the pillar industries of the national economy. The development of chemical industry is of great significance for promoting the development of industrial production, maintaining steady economic growth, meeting people's daily needs, and improving people's quality of life. The chemical production system is a large and complex integrated system. The safety assessment of the production status of the chemical production system involves a wide range of issues and many factors need to be considered. Commonly used evaluation methods include hazard and operability research, preliminary risk analysis, fault tree analysis, event tree analysis, fault type and impact analysis, safety checklist method, index evaluation method, LEC evaluation method, etc. These evaluation methods have shortcomings of one kind or another, and cannot accurately play the role and effect of safety evaluation[46].

The occurrence of production accidents in chemical enterprises has the characteristics of randomness, ambiguity and uncertainty, which determines that the changes of the system state do not follow specific laws or effects. The entire accident system is a non-linear dynamic process, similar to artificial nerves. Adapted to the typical characteristics of the network-non-linear dynamic characteristics. This coupling determines the feasibility and strong adaptability of artificial neural networks in safety evaluation. The nonlinear dynamic safety evaluation model can completely solve the problems that cannot be solved by traditional safety evaluation methods[47].

4 Application advantages

4.1 BP neural network structure in the design of evaluation system

Taking the BP neural network structure as an example, the embodiment of the BP neural network model is realized through the design of the evaluation system. It is the most commonly used neural network topology. The BP network model is composed of four models: self-training model, calculation error model, transfer function model and input-output model. Mainly used in security system evaluation: first determine the hidden layer, output layer and input layer of the neural network, the number of nodes, the structure level, and the topological structure to make the information specific. The neural network is associated with the relevant parameters in the safety management evaluation system, and the corresponding relationship with the topological structure is established, such as the type, quantity and characteristics of the parameters related to the neural network and the safety evaluation system, and the expression mode management evaluation system and various characteristics of the system are determined. Select learning samples to provide neural networks for training, try to collect comprehensive samples, the more samples they have, the more comprehensive they will learn about neural networks. Try to select multiple samples and be representative. In the safety production process of the enterprise, it is also based on their own safety status. Below, represented by the sample, the training process of the sample is actually a process of weight correction and error reduction between network nodes[48,49].

4.2 The advantages of artificial neural network in the evaluation system

(1) Overcoming the limitations of traditional evaluation methods, making the evaluation results more scientific. When using traditional methods to conduct safety production evaluation research, it is necessary to compile various checklists and develop evaluation standards in advance. The assessor must have a wealth of knowledge and practical experience. The evaluation process is easily affected by the subjective factors of the analysts, resulting in unscientific and unobjective evaluation

results. Artificial neural network is based on system theory. Proper optimization and control of the selected independent variables make the evaluation results more scientific.

(2) The safety production evaluation model established by the artificial neural network model conforms to the non-linear function relationship. Regardless of the evaluation methods of risk and operability research, risk analysis methods, accident tree analysis methods, event tree analysis methods, etc., these evaluation methods use linear functions directly or indirectly. However, the chemical production safety evaluation system is a complex system with complex content, many factors to be considered, and large uncertainties. The relationship between the problem of enterprise chemical production and the production evaluation system is not a simple linear function. The artificial neural network model can choose a non-linear function to establish a safety factor[50,51].

5. Conclusion

The chemical industry is a high-risk industry. Whether the safety index system is scientific and reasonable directly affects whether the safety evaluation of the chemical production system can play a role and whether it can reduce the occurrence of safety accidents. Studies have shown that the nonlinear dynamics of neural networks have good compatibility and coupling with the typical characteristics of accidents in chemical enterprises—non-linear dynamics. Based on the characteristics of artificial neural networks, a safety evaluation index system for chemical enterprises has been established. Neural network has unique advantages in solving randomness, ambiguity and uncertainty in safety evaluation[52].

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