Ecological Evaluation of Leather Industry by Neural Network

CHENG SHUQIANG[1] and LUO JUAN[1,2]*

[1] *School of Economics and Management, Shaanxi University of Science and Technology, Xi'an, Shaanxi 710021, P. R. China*

[2] *Shaanxi College of Communication Technology, Xi'an, Shaanxi 710018, P. R. China*

Abstract

At present, the production process of the leather industry is gradually developing towards being green and pollution-free. Therefore, an ecological evaluation of the leather industry is particularly important. In this paper, an ecological model of leather industry was established by using a BP (Back Propagation) neural network, and the appropriate indicators such as wastewater, COD, BOD, SS, Cr, S^{2-} were selected for evaluation. The evaluation method improves the quality of evaluation of the ecological leather industry, and provides a reference for the evaluation of the ecological chemistry industry, which is conductive to the better realisation of the green development of the leather industry.

摘要：

目前，制革工业生产过程正逐渐向绿色化、无污染的方向发展，因此，对皮革工业进行生态化评价尤为重要。本文利用BP神经网络建立皮革工业生态化模型，并选择合适的指标如废水、COD、BOD、SS、Cr、S2-等污染物进行评价。该评价方法改善了皮革工业生态化的评价质量，同时也为生态化工业评价提供了参考依据，有利于更好地实现皮革工业的绿色发展。

1 INTRODUCTION

The tannery industry, as one of the traditional industries in China, has a long history of development and has gradually become one of the pillars of light industry. But, at the same time, the leather industry is also a seriously polluting industry, the pollution mainly comes from two aspects,[1] one is the solid waste of leather produced in the process of leather processing, including meat residue, wool, grease, leather trimmings *etc.,* as well as amino acids, polypeptides produced by the decay, oxidation and hydrolysis of these solid wastes. The second is from chemical materials used in leather processing, such as lime, sulfides, industrial salts, various acids and bases, organic dyes *etc*. In recent years, sustainable development as an overall strategy of social and economic development in China has gradually become popular. If the leather industry wants to achieve sustainable development, it must take 'green chemistry' and 'ecological chemistry' as the development goals of enterprise.[2] This paper evaluates the ecology of leather industry from the aspects of main output and pollutant discharge: (wastewater, COD, BOD, SS, Cr, S^{2-}, waste collagen and sludge) in the leather production process.

2 ECOLOGICAL EVALUATION OF THE LEATHER INDUSTRY BASED ON NEURAL NETWORK

2.1 Research method

Artificial Neural Networks (ANNs), also known as Neural Networks (NNs) or Connection Models, are non-linear adaptive systems[3] They can be expressed by mathematical models or simulated by computer programs.[4] This network relies on the complexity of the system degree, by adjusting the interconnection between a large number of internal nodes and can easily and effectively deal with non-linear problems, and ultimately achieve the purpose of processing information. The learning of an artificial neural network is also called training. It refers to the process of adjusting the parameters of the neural network when it is stimulated by the external environment to make the neural network respond to the external environment in a new way. In classification and prediction, an artificial neural network (ANN) mainly uses a guided learning method, that is, adjusting the parameters of ANN according to the given training samples to use the output of ANN close to the known sample class markers or other forms of dependent variables.

An artificial neurone is the basic information processing unit of an artificial neural network operation. The model of the artificial neurone is shown in Fig. 1, which is the basis of the design of the artificial neural network. An artificial neurone pairs input signals $X = [x_1\ x_2......x_m]^T$ Output y by $y = f(u + b)$ Among them

$$u = \sum_{i=1}^{m} w_i x_i$$

There are three main expressions of activation function.[5]

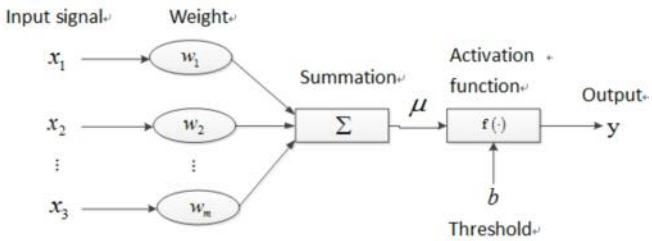
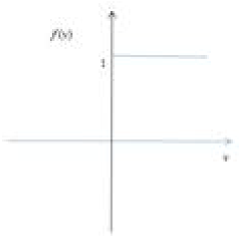
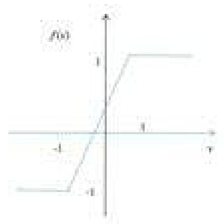
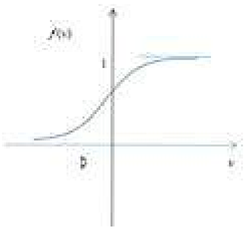


Figure 1. Artificial neurone model.

* Corresponding author: Luo Juan, E-mail: 18066669992@163.com

TABLE I
Activation function diagram

Activation function	Expression form	Graphical	interpretative statement
Domain value function (step function)	$f(v)=\begin{cases}1 & v\geq 0\\ 0 & v<0\end{cases}$		When the independent variable of the function is less than 0, the output of the function is 0; when the independent variable of the function is greater than or equal to 0, the output of the function is 1. With this function, the input can be divided into two categories.
Piecewise linear function	$f(v)=\begin{cases}1, & v\geq 1\\ v, & -1<v<1\\ -1, & v\leq -1\end{cases}$		The amplification coefficients of the function in the linear range (-1,+1) are identical, and the activation function in this form can be regarded as an approximation of the non-linear amplifier.
Nonlinear transfer function	$f(v)=\frac{1}{1+e^{-v}}$		The unipolar S-type function is a continuous function from R to [0,1] closed interval in real number field, which represents the continuous state neurone model. Its characteristic is that the function itself and its derivatives are continuous, which can reflect the superiority of mathematical calculation.

The learning algorithm of BP-NNS is the delta learning rule, and its objective function is adopted.

$$E=\frac{1}{2}\sum_{k=1}^{N}[Y_k-T_k]^2$$

The feature of a BP algorithm is to estimate the error of the direct pre-amble layer of the output layer by the error of the output layer, and then update the error of the former layer by using this error estimate, so that the error estimates of all other layers can be obtained by propagating backward layer by layer (Fig. 2).In this way, the process of transferring the error value displayed by the output layer to the input layer of the network step by step in the opposite direction of the input transmission is formed.

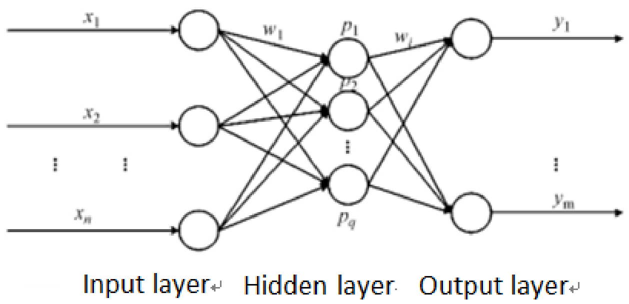


Figure 2 . BP Neural Network Model.

The learning process of BP-NNS includes two parts: forward propagation and reverse propagation[6] (Fig. 3). Among them, the information is propagated forward and the error is propagated backward. In this process, the learning process of the network is repeated and corrected until the output of the network matches the output of the target.

2.2 Application of neural network in leather ecology evaluation

2.2.1 Eco-evaluation criteria for the leather industry

In 1988, on the basis of the original 'Leather Industry Water Pollutant Discharge Standard' ('Leather Industry') and 'Comprehensive Wastewater Discharge Standard' (GB8978-1988),[7] a unified 'Comprehensive Wastewater Discharge Standard' (GB8978-1996)[8] was promulgated, which made the tannery industry and other industries have common wastewater pollutant discharge indicators requirement. Referring to the relevant data in the book '*Leather Cleaner Production Technology and Principles*' compiled by Shi Bi *et al.*,[9] we divide the ecological evaluation criteria of the

TABLE II
Emission indices of major pollutants from tannery wastewater (mg/L)

Evaluating indicator	First class standard	Two level standard	Three level standard
Total chromium	1.5 (Sampling at the Exit of Workshop)		
Six valence chromium	0.5 (Sampling at the Exit of Workshop)		
pH value	6~9	6~9	6~9
Chromaticity (dilution multiple)	50	80	–
Suspended solids (SS)	70	150	400
BOD5	20	30	300
COD	100	150	500
Sulfide	1	1	1
Ammonia nitrogen	15	25	–
Formaldehyde	1	2	5
Anilines	1	2	5
Phenol	0.3	0.4	1
Pentachlorophenol and sodium pentachlorophenol (measured by pentachlorophenol)	5	8	10
Cationic surfactant (LAS)	5	10	20
Total Organic Carbon (TOC)	20	30	–
Maximum allowable drainage	Salt wet pigskin: 60m^3/t raw skin; dried cattle hide: 100m^3/t raw skin; Dry sheepskin: 150m^3/t raw sheepskin		

leather industry into three grades (first grade, second grade and third grade). The main evaluation indexes and pollutant emission grade criteria are as follows: GB3459-1983.

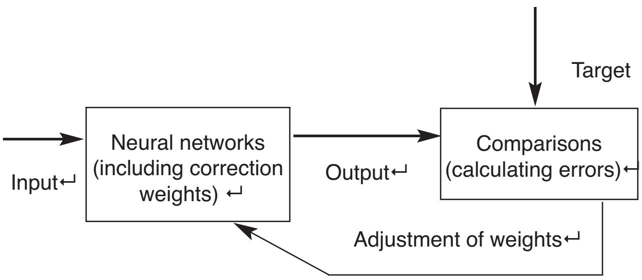


Figure 3. The learning process of BP Neural Network.

2.3 Construction of BP neural network

The construction of a BP neural network needs us to determine several parameters, such as input layer, output layer, network layer, hidden layer node number, transfer function, training method *etc.*[10] For a BP neural network, its structure does not need to be too complex, otherwise it will easily make the simulation accuracy worse. Therefore, this paper chooses a three-layer network structure with a hidden layer. It is necessary to use the existing technology in leather factories in recent years to produce the related pollutants. This paper mainly investigates the discharge of the above 16 pollutant indicators, using this data as input values, taking (100), (101), (001) as input values. The output value represents the first level, the second level and the third level of pollutant emission standards in the leather industry. However, in order to ensure that the variables of the neural network have the same status, improve the sensitivity of the function and prevent the sigmoid function from being over-saturated, the pollution factors should be normalised[11] and their units should be unified. In this paper, a common normalisation method is used to control the data between [0-1].[12] The normalisation formula is as follows:

$$x_i = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

Among them, x_i represents input variables. x_{min} represents the minimum number of input variables. x_{max} represents the largest number of input variables.

For the input data of each node in the hidden layer, the output data of the node can only be obtained through the non-linear transformation of the transfer function. We choose a commonly used transfer function, Sigmoid function,[13] to calculate the back propagation algorithm, namely BP algorithm, is adopted.

The ecological evaluation of the leather industry by BP-NNS is non-linear, and the initial weights will affect the convergence of the whole network. Usually, each input value of neurone is close to zero after initial weighting. In the process of input, transmission and output of the model, the difference between the actual output value and the expected target output value is called the error value. Through repeated training, when the error is less than 0.001, the network reaches the ideal state and stops the network training. After testing, the transfer function expression of the hidden layer is determined as follows:

$$y = \frac{2}{1 + \exp(-2n)} - 1$$

The specific algorithm model of BP neural network is as follows in Fig. 4.

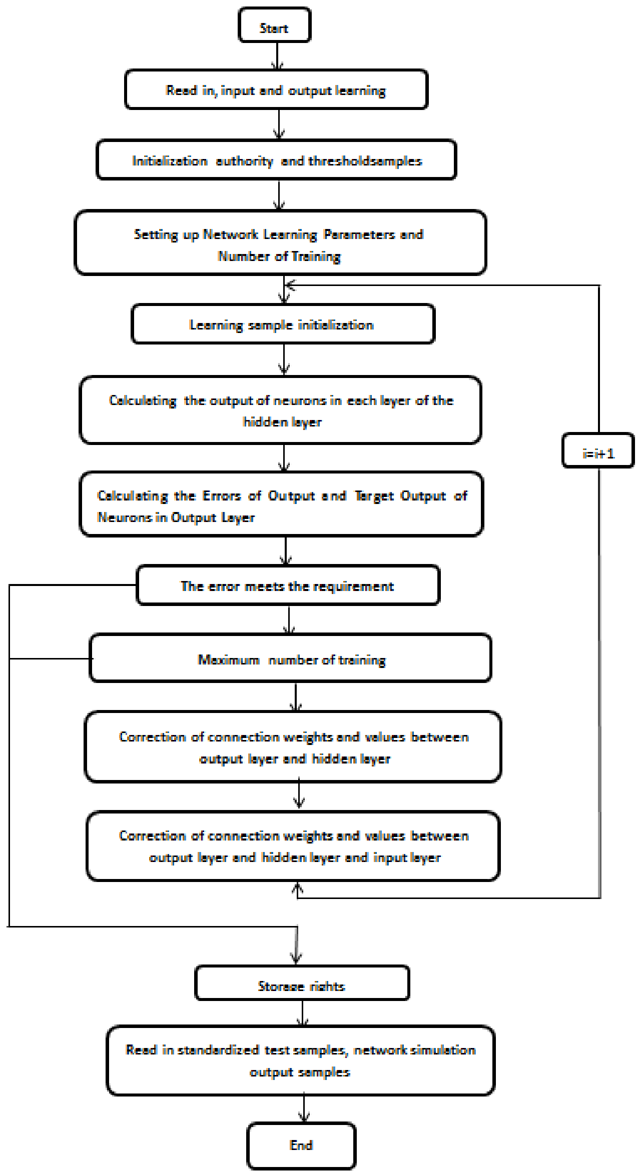


Figure 4. BP neural network flow chart.

3 EXAMPLE OF APPLICATION

3.1 Overview of research

China's leather industry has a long history. In 2013, the leather enterprises above the scale completed the sales revenue of 1168.258 billion yuan, and the output has jumped to the top in the world. However, there are still many problems, such as excess capacity, high energy consumption, heavy pollution, low profits, market chaos and so on. The leather industry in China in the past ten years was taken as the research object for analysis.

3.2 Establishment of leather ecosystem evaluation index

According to the foregoing, according to the reference factors of leather eco-natural system, leather eco-economic system and leather eco-social system and leather industry, the corresponding index layers are established, as shown in Table III. When attributes are positive, the greater the value, the better; when attributes are inverse, the smaller the value, the better.

The evaluation of leather ecosystem should have clear criteria and grading. Referring to the ecosystem assessment method, the classification and corresponding score of leather ecosystem safety assessment are shown in Table IV.

3.3 Data source and processing

The research data are from China Light Industry Yearbook and China Economic and Trade Yearbook. Through the statistics and collation of the relevant indicators of leather industry in the past 15 years, the data are processed dimensionless, and their respective weights are determined by the method of entropy weight, so that the final dimensionlessly results of the index data are between (0-1). The final data are shown in Table V.

3.4 Evaluation results of BP neural network

The BP neural network is trained by inputting the imaginary data and results of each level: for example, 0.91, 0.95, 1.00, 0.9, 0.8, 0.85, 0.60, 0.70, 0.79, 0.40, 0.50, 0.59, 0.39, 0.20, 0.00, and the corresponding grade output results are set as V, V, V, IV, IV, IV, III, II, II, I, I. After learning, the BP neural network can get the indicators. The relationship between values and corresponding grades. Then the dimensionless data in Table V is used as the input data of BP neural network. When the number of hidden layers is 30, the topological structure of BP neural network is 16-30-1 and 16 index input values. Each index input value corresponds to the forward calculation of 30 hidden layers and the reverse calculation of errors. Finally, a grade result is output. The function of hidden layer and output layer is set to Sigmoid and Puelin respectively, the learning rate is set to 0.01, and the maximum number of cycles is set to 5000. The final results are shown in Table VI.

3.5 Analysis of case result

Through the data analysis of the past ten years, it can be found that in recent years, the probability of grade II (unsafe) and grade III (insecurity) appearing in the comprehensive evaluation results of leather ecosystem is more frequent, there is no grade I (very unsafe), the probability of grade IV (safer) appearing is lower, and there is no grade V (very safe), that is, 'Leather ecosystem belongs to the genus of leather ecosystem'. In the ideal state, self-regulation ability is very strong, very safe, and there is no hidden danger of insecurity. The fundamental reason is that China is a developing country and is in the primary stage of socialism. The pursuit of economic benefits is higher than the pursuit of ecological benefits. Therefore, it is difficult to achieve the ideal state of the leather ecosystem in the current state. The idea and method proposed in this paper can be used to evaluate leather ecology.

TABLE III
Evaluation Indicators of leather ecosystem

Target layer	Subsystem layer	Index layer	Attribute	Description
		Raw material skin annual output (tons) (C1)	Beneficial	Reflect whether raw material skin is rich [valuable] or not
		Distribution of raw material skin (C2)	Beneficial	Reflect whether the distribution range of raw material skin is wide or not
		Contents of BOD and COD in tannery wastewater (C3)	Harmful	Reflecting biological and chemical oxygen consumption in tannery eastewater
	Leather Ecology and Nature (B1)	Contents of heavy metal salts, organic solvents and formaldehyde in tannery wastewater (mg/kg) (C4)	Harmful	Reflecting the content of harmful substances in tannery wastewater
		TDS and TSS contents in tannery sludge (C5)	Harmful	Reflecting total dissolved solids and total suspended solids in tannery sludge
Leather Ecosystem (A)		Annual output value of leather products (RMB) (C6)	Beneficial	Revenue of annual output value of leather products
		Annual export value of leather products (RMB) (C7)	Beneficial	Reflecting the export revenue of leather products
		Per capita GDP (RMB) (C8)	Beneficial	Reflecting the economic growth level and the change of the total economic quantity of the country
	Leather Eco-economy (B2)	Per capita annual income (RMB)(C9)	Beneficial	Reflect the level of people's annual income
		Per capita consumption of essential leather products (RMB) (C10)	Beneficial	Reflect people's consumption level of essential leather products
		Per capita consumption of luxury goods such as LV (RMB) (C11)	Beneficial	Reflect the level of people's pursuit of quality of life
	Leather Eco-Society (B3)	Social stability (C12)	Beneficial	Reflecting the degree of social stability
		Urbanisation level (%) (C13)	Beneficial	Reflect the proportion of city and countryside
		Engel coefficient (%) (C14)	Harmful	Reflect the proportion of people's food consumption in total consumption
		Education level of leather industry personnel (C15)	Beneficial	Reflect the level of education of the personnel engaged in leather industry
		Quality level of personnel engaged in leather industry (C16)	Beneficial	Reflect the quality level of personnel engaged in leather industry

TABLE IV
Criteria for classification of leather ecosystem safety levels

Grade	State	Describe	Score
V	Very safe	Leather ecosystem belongs to the ideal state. It has strong self-regulation ability and is very safe. There is no hidden danger of insecurity.	> 0.9
IV	Safer	Leather ecosystem is in good condition, with strong self-regulation ability, relatively safe and less potential safety hazards.	0.8~0.9
III	Interim Safety	Leather ecosystem belongs to a critical state, and its self-regulation ability is ordinary. It is safe for the intermediary and has a certain degree of potential safety hazards, which should be paid great attention to.	0.6~0.8
II	Less secure	Leather ecosystem belongs to a poor state, with poor self-regulation ability, unsafe and more potential safety hazards.	0.4~0.6
I	Very unsafe	Leather ecosystem is in a very poor state. Its self-regulation ability is very weak, and it is very unsafe. The ecological problems are prominent and severe.	< 0.4

TABLE V
Dimensionless data of BP neural network in leather ecosystem in recent ten years

System particular year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
C_1	0.72	0.62	0.52	0.47	0.66	0.75	0.84	0.89	0.71	0.74
C_2	0.68	0.65	0.52	0.40	0.67	0.70	0.80	0.87	0.76	0.72
C_3	0.70	0.61	0.56	0.44	0.61	0.73	0.85	0.87	0.73	0.71
C_4	0.74	0.63	0.57	0.44	0.65	0.77	0.80	0.82	0.75	0.77
C_5	0.70	0.60	0.55	0.41	0.65	0.73	0.81	0.85	0.72	0.77
C_6	0.73	0.65	0.57	0.43	0.65	0.70	0.84	0.84	0.70	0.76
C_7	0.68	0.65	0.58	0.47	0.62	0.69	0.81	0.81	0.77	0.70
C_8	0.82	0.79	0.79	0.82	0.85	0.84	0.82	0.79	0.79	0.81
C_9	0.83	0.80	0.77	0.83	0.83	0.83	0.82	0.80	0.82	0.79
C_{10}	0.62	0.61	0.62	0.63	0.64	0.61	0.59	0.63	0.63	0.60
C_{11}	0.38	0.32	0.34	0.34	0.40	0.44	0.41	0.39	0.44	0.45
C_{12}	0.90	0.79	0.58	0.89	0.80	0.89	0.78	0.84	0.81	0.83
C_{13}	0.44	0.50	0.53	0.65	0.77	0.83	0.88	0.85	0.86	0.88
C_{14}	0.41	0.39	0.40	0.43	0.44	0.35	0.38	0.37	0.37	0.34
C_{15}	0.40	0.46	0.55	0.67	0.74	0.79	0.88	0.87	0.93	0.90
C_{16}	0.44	0.47	0.56	0.69	0.74	0.82	0.82	0.80	0.81	0.83

TABLE VI
Grade evaluation results of BP neural network for leather ecosystem in recent ten years

Particular year	Evaluation results of ecological security of subsystems			
	Leather ecology and nature (B1)	Leather economy (B2)	Leather Eco-society (B3)	Leather ecosystem Comprehensive results (grade)
2009	0.71	0.67	0.52	III
2010	0.62	0.64	0.49	II
2011	0.54	0.62	0.53	II
2012	0.42	0.58	0.65	II
2013	0.65	0.66	0.72	II
2014	0.73	0.68	0.73	III
2015	0.82	0.91	0.92	IV
2016	0.85	0.80	0.82	IV
2017	0.73	0.70	0.77	III
2018	0.75	0.69	0.77	III

4 CONCLUSION

In the ecological evaluation of leather industry, there is no systematic, complete and effective evaluation mechanism. Using the evaluation mechanism of a BP neural network, the prediction results of pollutant indexes in the leather industry can be obtained relatively accurately. Compared with the complex and high-cost mechanism model, the neural network model is more suitable. The forecasting environment with a strong influence of complex and uncertain factors can not only realise the grade evaluation of the ecology of leather industry, but also minimize the error of the comprehensive evaluation of the pollutants in leather industry, improve the evaluation quality of the ecology of leather industry, and provide a reference basis for the evaluation of the ecology and chemical industry. In order to better realise the green development of leather industry.

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