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EVALUATION MODEL OF FUZZY DATA AND NEURAL NETWORK IN MARTIAL ART COMPETITION

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ABSTRACT

Due to the ambiguity of the results given by the referee in Martial art competition, the design of a set of fair and impartial, scientific and rational evaluation system is particularly important. This paper builds a fuzzy comprehensive evaluation model based on the fuzzy number theory. As this model has a high degree of subjectivity, this article combines RBF neural network model and data envelopment analysis method with fuzzy comprehensive evaluation model and establishes two kinds of evaluation model as fuzzy data envelopment analysis and fuzzy neural network, solving the reliability and scientific issue of the evaluation result appropriately.

Keywords: *Martial Art, Fuzzy Data, Neural Network*

1. INTRODUCTION

Martial art in abroad is mainly focused on the quantization and digitization of the athletes' training who have good physical ability. In this way, the overloading physical training can enhance the athletes' ability in a short period of time and may possibly cultivate an outstanding athlete in two or three years. However, this quick success of training often results in the early ending of the athlete's professional career. Quantization and digitization possess certain advantages but it is not perfect and appropriate for different people and culture. Chinese Martial art should maintain its own unique advantages in the developing process as well as absorbing scientific management mode and advanced training methods from the west [1-3].

In Martial art competitions, refinement of marking criterion, shorter competition time and difference of referee' ability, et al, all affect martial arts athletes' practice level and completion result [4-6]. Therefore, it is particularly important to design a set of a set of fair and impartial, scientific and rational evaluation system. All these factors have certain degree of fuzziness, such as the scores are usually subjectively determined given by the referee, and artificially subjective effects are also reflected in the formulation of evaluation standard [7-9].

This article builds a fuzzy comprehensive evaluation model on the basis of fuzzy number theory. Due to the high subjectivity of this model, this research combines RBF neural network model and data envelopment analysis method with fuzzy comprehensive evaluation model, enhancing the reliability and scientificalness of this evaluation model.

2. EVALUATION MODEL OF FUZZY DATA ENVELOPMENT ANALYSIS

Data envelopment analysis is a model based on mathematical programming (including linear programming, multiple objective programming, and et al.) and evaluates the relative effectiveness between decision making units with multi-inputs and especially multi-outputs. The advantage of this model is the accuracy of the objective data, but it is often difficult to find accurate data of indicators and factors in practical life, as a result this model is of certain fuzziness [2, 3, 7]. This article complements the fuzziness of fuzzy comprehensive evaluation with the accuracy of data envelopment analysis and builds a fuzzy comprehensive evaluation model of data envelopment analysis. There are mainly three steps in this process: the first step is the blurring operation of the non-quantitative indexes' weights; the second step is refined calculation of the quantitative indexes' weights using data envelopment analysis and fuzzification of the operation result; the third step is fuzzy comprehensive evaluation of the above results and reaching a final evaluation conclusion.

Suppose that the number of evaluation units, evaluation indexes, quantitative indexes and non-quantitative indexes is and respectively.

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2.1. Blurring Operation of Non-Quantitative Weights

If $C=(c_1,c_2,\cdots,c_q)$ is the factor set and $V=(v_0,v_1,\cdots,v_{p-1})$ is the comment set, then the comprehensive evaluation matrix is:

$$R_j=\begin{bmatrix} r_{j10} & r_{j11} & \cdots & r_{j1(p-1)} \\ r_{j20} & r_{j21} & \cdots & r_{j2(p-1)} \\ \cdots & \cdots & \cdots & \cdots \\ r_{jq0} & r_{jq1} & \cdots & r_{jq(p-1)} \end{bmatrix},$$

$j=1,2,\cdots,m$,

$A_j=(a_{j1},a_{j2},\cdots,a_{jq})$ is the weight array. Therefore, the non-quantitative index weight of decision making unit numbered j in blurring operation is:

$$B_j=A_jR_j=(a_{j1},a_{j2},\cdots,a_{jq})\begin{bmatrix} r_{j10} & r_{j11} & \cdots & r_{j1(p-1)} \\ r_{j20} & r_{j21} & \cdots & r_{j2(p-1)} \\ \cdots & \cdots & \cdots & \cdots \\ r_{jq0} & r_{jq1} & \cdots & r_{jq(p-1)} \end{bmatrix}=(b_{j1},b_{j2},\cdots,b_{jp})$$

2.2. Data Envelopment Calculation of Quantitative Weights

Assume that $X_j=(x_{1j},x_{2j},\cdots,x_{nj})^T$, $Y_j=(y_{1j},y_{2j},\cdots,y_{sj})^T$ stands for the input and output vector of the evaluation unit $DMU_i(1\le i\le m)$ numbered i, in which $j=1,2,\cdots,m$ and every vector coordinate is positive number.

If $v=(v_1,v_2,\cdots,v_n)^T,u=(u_1,u_2,\cdots,u_s)^T$

Means the weight vector of the input and output, then the linear programming model can be determined by Charnes-Cooper transformation:

$$\begin{cases} \max \mu^T Y_{j0} \\ s.t. \quad \omega^T X_j-\mu^T Y_j\ge 0,\ j=1,2,\cdots,m \\ \omega^T X_{j0}=1 \\ \omega\ge 0,\mu\ge 0 \end{cases}$$

Apply the data into this model and the optimal solution obtained is the accurately calculated quantitative index weigh.

Although the data result from data envelopment analysis method is more objective and persuasive, it does not possess such perceptive cognition as "excellent, good, qualified and unqualified" and membership form as in fuzzy comprehensive evaluation. As a result, the fuzzification of the result by membership function is conducted in this article.

The operation result from the data envelopment analysis can be regarded as the degree of membership of the comment set $V=(v_0,v_1,\cdots,v_{p-1})$, assuming that $r=(r_0,r_1,\cdots,r_{p-1})$ is the membership, then:

$$r_j=\begin{cases} \dfrac{x-(j-1)\frac{1}{p-1}}{\frac{1}{p-1}} & ,(j-1)\frac{1}{p-1}\le x<j\frac{1}{p-1} \\ \dfrac{(j+1)\frac{1}{p-1}-x}{\frac{1}{p-1}} & ,j\frac{1}{p-1}\le x<(j+1)\frac{1}{p-1} \\ 0 & \end{cases},$$

$r_j\in[0,1],\ j=0,1,\cdots,p-1$ 。

Substitute B_j' into the above equation and the degree of membership is $B_j=(b_{j1},b_{j2},\cdots,b_{jp})$.

2.3. Comprehensive evaluation

Conduct comprehensive evaluation of the above result. The comprehensive evaluation matrix is:

$$R_j=\begin{bmatrix} B_{j1} \\ B_{j2} \\ \cdots \\ B_{jk} \end{bmatrix},\ j=1,2,\cdots,m$$

In which k means the total number of all indexes (quantitative and non-quantitative). Suppose that $A_j=(a_{j1},a_{j2},\cdots,a_{jk}),j=1,2,\cdots,m$, means the weight, then $B=A$ and

$$R\Rightarrow B_j=(a_{j1},a_{j2},\cdots,a_{jk})\begin{bmatrix} B_{j1} \\ B_{j2} \\ \cdots \\ B_{jk} \end{bmatrix}=(b_{j1},b_{j2},\cdots,b_{jp}),\ j=1,2,\cdots,m$$

Based on the maximum membership principle, the final result after comprehensive evaluation is

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$B_j = (b_{j1}, b_{j2}, \cdots, b_{jp})$, and the maximum value b_{ji} is corresponding with the v_i in $(v_0, v_1, \cdots, v_{p-1})$.

3. EVALUATION MODEL OF FUZZY NEURAL NETWORK

RBF neural network [8, 9] is able to simulate the partial adjustment of the human brain and receiver domain of mutual coverage. There is no local minimum problem and it is easy and fast to learn with a high fitting precision. It can change the weight value of indexes in fuzzy comprehensive evaluation model, making it more in line with the practical situation. The determination of the index weight value is particularly important in fuzzy comprehensive evaluation model.

3.1. Introduction of RBF neural network

Radial Basis Function (RBF) neural network is a kind of neural network put forward by J. Moody and C. Darken in the late 1980's, and a special three-layer feed-forward network with a single hidden layer. As it simulates the neural network structure of the partial adjustment and receiver domain of mutual coverage in human brain, RBF is considered to a local approximation network.

The structure of RBF neural network is a three layer feed-forward network, similar to that of multi-layer feed-forward network. The first layer is the input layer, formed by signal source joints; the second layer is hidden layer, in which the number of hidden units is dependent on the described problem and the transformation function of hidden units is RBF, which is a damped nonlinear function but of central and radial symmetry; the third layer is the output layer, responding to the effect of input mode. Because the mapping of input to output is nonlinear and the mapping of hidden layer space to output space is linear, it can greatly accelerate the learning speed and avoid the local minimum problem, shown in Fig.1.

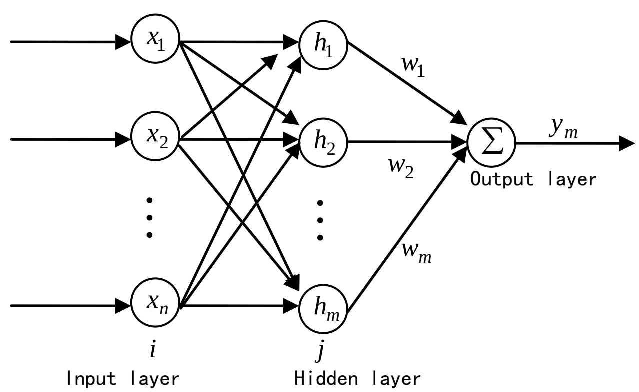

Fig.1. Structure Chart

RBF neural network is able to approximate any continuous function with arbitrary precision and especially fit for the classification problem. The approximation chart is shown in Fig.2.

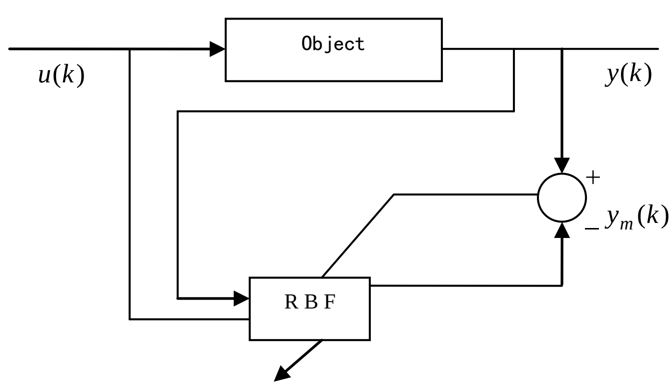

Fig.2. Approximation Chart

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Suppose that $X=(x_1,x_2,\cdots,x_n)^T$ is the network's input and $H=(h_1,h_2,\cdots,h_m)^T$ is the base vector in radial direction, in which h_j means the center vector of Gaussian function $h_j=e^{-\frac{\|X-C_j\|^2}{2b_j^2}}$ $(j=1,2,\cdots,m)$ and the number j node in network $C_j=(c_{1j},c_{2j},\cdots,c_{nj})^T$. Base width vector is $B=(b_1,b_2,\cdots,b_m)^T$, and b_j is the base width parameter of the node point. Weight vector is $W=(w_1,w_2,\cdots,w_m)$, and the output of the network in time k:

$$y_m(k)=wh=w_1h_1+w_2h_2+\cdots+w_mh_m.$$

To reach an ideal output $y(k)$, this article gets a performance index function as:

$$E(k)=\frac{1}{2}(y(k)-y_m(k))^2.$$

3.2. Modeling

Supposing that $X=(x_1,x_2,\cdots,x_m)$ is the network input, then the number of input is m and the number of output and evaluation grade is n. The connection weight between the second layer and the third layer in the network w_i is the weight value of the index in fuzzy comprehensive evaluation model.

The first layer: the input layer

As can be seen from Fig.1, the total number of neuron in the input layer is m, so the input and output are accordingly:

$$I_i^1=x_i$$

$$O_{ij}^1=x_i,\quad i=1,2,\cdots,m,\quad j=1,2,\cdots,n\text{。}$$

The second layer: the hidden layer

The evaluation grade of RBF neural network is n. Judging from Fig.1, the hidden layer contains $m\times n$ neuron. In this paper, the evaluation grade is divided into four levels: $\{A_{ij}\}$ = {excellent, good, qualified, unqualified }, i.e. $n=4$. Therefore, four parameters a_1,a_2,a_3,a_4 are needed for the four fuzzy subsets. Membership function $\mu(x)$ is presented in the form of trigonometric function, shown in Fig.3.

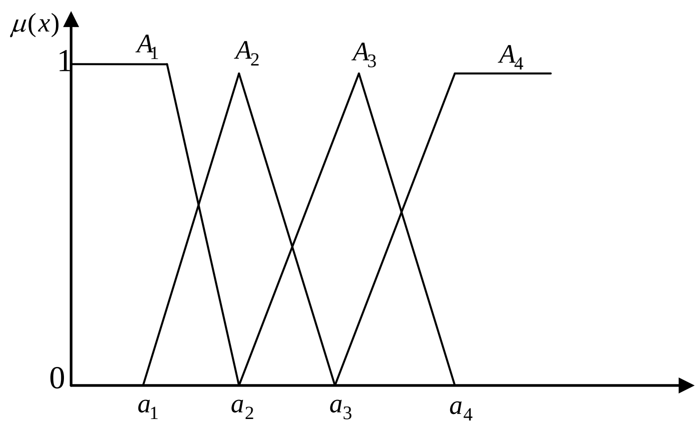

Fig.3. Membership Function

When the input is as $I_{ij}^2=O_{ij}^1$, $i=1,2,\cdots,m$, $j=1,2,\cdots,n$, the hidden layer outputs the membership value of each level as follows:

$$O_{ij}^2=A_{ij}(x_j)\text{。}$$

The third level: the output level

The output layer mainly conducts a comprehensive evaluation of the input indexes. The obtained evaluation grade and vector are:

Input: $I_{ij}^3=O_{ij}^2$

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Output: $O_i^3 = \sum_{j=1}^{m} w_j I_{ij}^3$

In which $i = 1,2,\cdots,m$, $j = 1,2,\cdots,n$.

Yet RBF neural network has several shortcomings, such as slow convergence rate and local minimum of energy. This article adopts a modified network and improves the connection weight of the network, making the weight value of the indexes in fuzzy neural network evaluation model more suitable for practical situation.

This paper calculates the output value by the reverse of the network and gets the error between the output value and the actual value. Then correct the network's connection weight by the value obtained from the forward of the network, which reduces the network error.

Supposing the output error is $d_p = t_p - y_p$, the error function can be expressed as $e_p = \frac{1}{2}(t_p - y_p)^2$. In this article, gradient descent method in RBF neural network learning algorithm is introduced to amend the weight vector W , aiming at reducing d_p and increasing the computational accuracy. The gradient descent method is shown in the following text:

If

$$w_j(k) = w_j(k-1) + \eta h_j(y(k) - y_m(k)) + \alpha(w_j(k-1) - w_j(k-2))$$

and $\Delta b_j = (y(k) - y_m(k)) \times w_j h_j \frac{\|X - C_j\|^2}{b_j^3}$,

$$b_j(k) = b_j(k-1) + \eta \Delta b_j + \alpha(b_j(k-1) - b_j(k-2))$$

.

$$\Delta c_{ij} = (y(k) - y_m(k)) \times w_j \frac{x_j - c_{ij}}{b_j^2}$$,

Then

$$c_{ij}(k) = c_{ij}(k-1) + \eta \Delta c_{ij} + \alpha(c_{ij}(k-1) - c_{ij}(k-2))$$,

in which η means the learning speed and α means momentum factor. Based on Jacobean array, a final result can be achieved:

$$\frac{\partial y(k)}{\partial u(k)} \approx \frac{\partial y_m(k)}{\partial u(k)} = \sum_{j=1}^{m} w_j h_j \frac{c_{1j} - x_1}{b_j^2}$$.

Supposing that ΔW is the adjusted value of W , the iterative algorithm formula of ΔW based on gradient descent method is:

$$\Delta W^{(n)} = -\eta \frac{\partial e_p}{\partial W} + \alpha \Delta W^{(n-1)}$$.

Precede iteration utilizing the formula of ΔW and end the network training until the error meet the requirements.

3.3. Application

Assume that the number of evaluation indexes is m, and they are A_1, $A_2, \cdots, A_m$. These indexes covers all the competition requirements for Martial art athletes in routine competition, such as strength, rhythm, style, coordination, content and structure, etc. Suppose that the number of Martial art athletes taking part in the competition is n and they are expressed as B_1, $B_2, \cdots, B_n$. If $A = \{A_1, A_2, \cdots, A_m\}$ and $B = \{B_1, B_2, \cdots, B_n\}$, there reaches the following matrix:

	B_1	B_2	……	B_n
A_1	X_{11}	X_{12}	……	X_{1n}
A_2	X_{21}	X_{22}	……	X_{2n}
⋮	⋮	⋮	⋮	⋮
A_m	X_{m1}	X_{m2}	……	X_{mn}

In which X_{ij} is the membership of the Martial art athlete under index A_j and $0 < X_{ij} < 1$. Therefore it can be concluded that when the value of X_{ij} is smaller, the athlete's level and ability under this index is low comparably; and vice verse.

In this research, the obtained membership under each index is given a weight. Then calculate the average of the weights. The average value is considered to be the final result of the Martial art athlete, that is $Q_j = \sum_{i=1}^{m} \frac{W_i X_{ij}}{m}$.

Suppose that there are t referees and evaluation grade is m, $C_1, C_2, \cdots, C_m$. Provide that the evaluation grade decrease with the increase of index C_i , i.e. decreasing function. Referees would give an evaluation result to each Martial art athlete in such way as the following:

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$$\begin{array}{ccccc} & C_1 & C_2 & \cdots\cdots & C_m \\ A_1 & Q_{11} & Q_{12} & \cdots\cdots & Q_{1m} \\ A_2 & Q_{21} & Q_{22} & \cdots\cdots & Q_{2m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ A_m & Q_{m1} & Q_{m2} & \cdots\cdots & Q_{mm} \end{array}$$

According to national regulation, the evaluation indexes are classified into 8 groups in this paper as $A_1, A_2, \cdots, A_8$ and evaluation grade is divided into 5 groups, $C_1, C_2, \cdots, C_5$ as excellent, good, qualified, unqualified and poor. A Martial art Championships in certain year as a example, this article reaches to the weight value of the eight evaluation indexes $A_1, A_2, \cdots, A_8$ are respectively 0.17, 0.18, 0.13, 0.14, 0.12, 0.15, 0.08, 0.09. Select 6 Martial art athletes randomly and get the evaluation results from the referees. The processed result is shown in Table.1.

Table.1. Evaluation Result

	C_1	C_2	C_3	C_4	C_5
A_1	0.3	0.5	0.01	0	0
A_2	0.1	0.4	0.5	0.1	0
A_3	0.4	0.2	0.3	0	0.2
A_4	0	0.09	0.3	0	0.6
A_5	0.4	0	0	0	0.6
A_6	0.2	0.4	0	0	0.4
A_7	0	0.2	0.6	0.2	0
A_8	0.2	0	0	0	0.8

The evaluation matrix of the evaluation indexes is:

$$R = \begin{pmatrix} 0.3 & 0.5 & 0.01 & 0 & 0 \\ 0.1 & 0.4 & 0.5 & 0.1 & 0 \\ 0.4 & 0.2 & 0.3 & 0 & 0.2 \\ 0 & 0.09 & 0.3 & 0 & 0.6 \\ 0.4 & 0 & 0 & 0 & 0.6 \\ 0.2 & 0.4 & 0 & 0 & 0.4 \\ 0 & 0.2 & 0.6 & 0.2 & 0 \\ 0.2 & 0 & 0 & 0 & 0.8 \end{pmatrix}$$

According to the calculation formula of fuzzy comprehensive evaluation, the final evaluation result is:

$$Q = A \times R = (0.17\ \ 0.18\ \ 0.35\ \ 0.29\ \ 0.01)$$

And

$$A = (0.17\ \ 0.18\ \ 0.13\ \ 0.14\ \ 0.12\ \ 0.15\ \ 0.08\ \ 0.09).$$

As can be seen from the above final evaluation result, 17% of the referees consider the athlete's ability in this competition to be excellent; 18% of the referees consider the athlete's ability in this competition to be good; 35% of the referees consider the athlete's ability in this competition to be qualified; 29% of the referees consider the athlete's ability in this competition to be unqualified; 1% of the referees consider the athlete's ability in this competition to be poor. Then the final result of this athlete can be determined, combining the corresponding grade of the five evaluation grade.

$$Q = \frac{0.17^2 \times 3 + 0.18^2 \times 2.5 + 0.35^2 \times 2 + 0.29^2 \times 1.5 + 0.01^2 \times 1}{0.17^2 + 0.18^2 + 0.35^2 + 0.29^2 + 0.01^2} = 2.01$$

Similarly, the other five athletes' final results are 2.16, 2.10, 2.13, 2.25, and 2.32.

It can be seen from the above analysis, with the appearance and development of computer technology, not only simulation and emulation of Martial art movements, but also analysis of movement image and data processing can be achieved by means of computer. As a result, the perfect combination of Martial art and modern science and technology methods has become one of the research hotspots about Martial art in recent year. Computer simulation should conduct comprehensive consideration as Martial art involves various fields, such as body structure, biology, dynamics and kinematics. Usually, human body is regarded as digitization model of multi-particle or multi rigid body. In this research, the acting force among different parts of the human body is taken as a factor affecting the routine

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performance. And a digitized multi rigid body model is formed with the digitization of the human body. Relative research work can be conducted based on this model according to the following simulated workflow Fig.4:

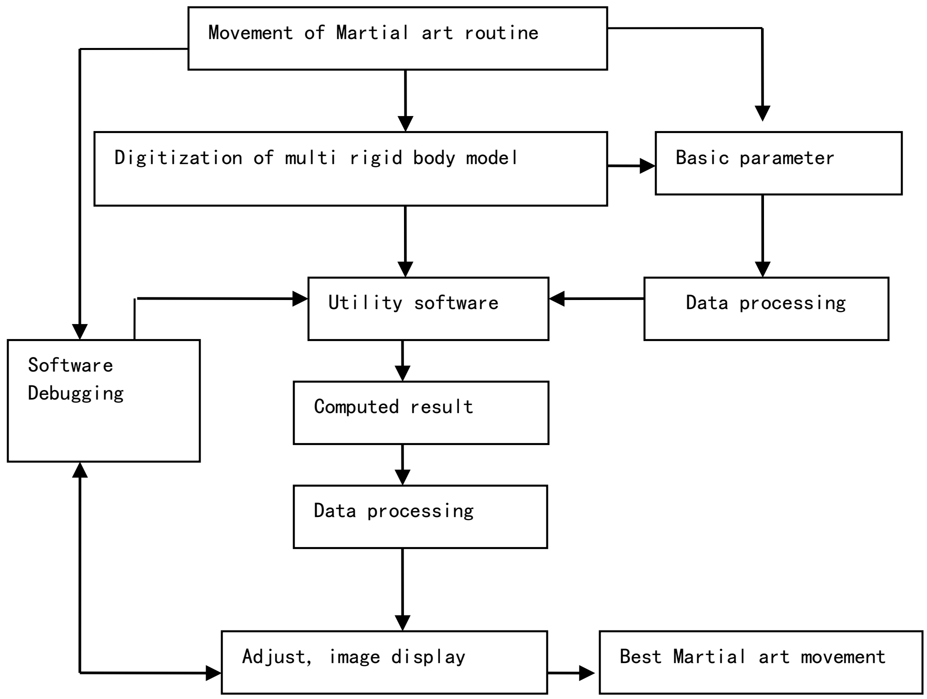

Fig.4. Workflow

4. CONCLUSIONS

In the Martial art competitions, referees give out each athlete's grade in a short time. Obviously, such results contain ambiguity, which directly affected the competition fairness and justness. Whether to the inheritance and development of Martial art or to athletes own development, it is very negative. Therefore, to design a fair, scientific and rational rating system is particularly important. This article constructs a fuzzy comprehensive evaluation model, based on the theory of fuzzy numbers. Due to the high subjectivity of this model, this research combines RBF neural network model and data envelopment analysis method with fuzzy comprehensive evaluation model, and builds two kinds of evaluation model as fuzzy data envelopment analysis and fuzzy neural network finally, this model enhances the reliability and scientificalness of this evaluation model, reaching a satisfactory result.

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