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Research and application of computers in mathematics research

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ABSTRACT

With the widespread use of the computer, development of mathematical software and the rise and constantly improve of higher university education, the combination of computer and mathematical education is more and more. This paper studies the application of computer in university mathematics teaching and uses advanced mathematics courses to show this application. In this paper, we mainly use the combination degree of computers and advanced mathematics to construct one evaluation system. Because influencing factors are fuzzy, so we use fuzzy theory to construct this evaluation system. But the fuzzy mathematical theory has a high degree of subjectivity. So we combine neural network theory and data envelopment analysis theory with fuzzy theory. Finally, we get the comprehensive evaluation system. Experiments show satisfactory results.

Key words: Data envelopment analysis, Neural network, Fuzzy theory, Mathematics Education

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INTRODUCTION

Training objectives of universities are that the students should have rich professional knowledge and practical ability. Then they possess high comprehensive quantity and can be adapt to market economy. In the process, mathematics education has a very important role to improve the overall quality of students. Now there are lots of problems in the university mathematics teaching and the mathematical basis of the university students is very poor and they do not like to study mathematic. Teachers often take emphasis on book knowledge and computing ability, so they always ignore the sense of innovation and practical ability of students. All of these are not in favor of higher mathematics education and then do not meet modern education [1].

Mathematics education has important links with the modern education. Mathematics curriculum should pay attention to the application of modern means and give full consideration to the impact of computer mathematics. Students should see modern technology as a powerful tool for solving problem and learning mathematics [2]. Then they freed from the boring learning, so they invest more time and energy to the mathematical reality and exploratory activities. Using computer technology in mathematics education can help students to research on mathematical knowledge, optimize their cognitive structure and develop students' innovative consciousness, and then students can dialectically use various way of thinking to create mathematical thinking [3].

In today's computer-aided instruction booming, the most important issue is how to better allow the computer to play its due role in the teaching of mathematics [4]. In recent years, with the rapid development of computer technology and the deepening of teaching reform of higher education in university, contradiction between the professional courses and foundation courses is more prominent [5]. The widespread use of the computer, development of mathematical software and the rise of higher education in university and constantly improve put forward new demands of the mathematics curriculum. It is all known that mathematics curriculum has significant relationship with the quality training of professionals [6]. Although computers have very obvious advantages in teaching and degree of intelligence of computer educational software has also been a very big step forward, but there is an unavoidable fact: computer education is seriously out of line and mathematics education. Many universities are still using traditional teaching philosophy and they lack of insufficient understanding of computer technology and mathematics teaching [7].

In this paper, we mainly study the application of computer in university mathematics teaching. Next we use advanced mathematics courses to show this application. Then we use the combination degree of computers and advanced mathematics to construct one evaluation system. Because the evaluation criteria for each school are different and there are a lot of subjective factors affecting evaluators, so these factors are fuzzy [8]. Thus, we use fuzzy theory to construct this evaluation system. But the fuzzy mathematical theory has a high degree of subjectivity. Then we use neural network theory and data envelopment analysis theory to improve the evaluation system. Finally, we get the reliable, fair, rational and scientific comprehensive evaluation system.

FUZZY DATA ENVELOPMENT ANALYSIS EVALUATION MODEL

Data envelopment analysis uses mathematical programming model to evaluate the relative effectiveness of the decision-making unit of the multiple input and multiple output. It has the advantage of objective data accuracy, but in the real life it is difficult to find indicators factors accurate data, so it has fuzziness. Then this paper combines the accuracy of the data envelopment analysis with the fuzziness of fuzzy comprehensive evaluation, so we get fuzzy comprehensive evaluation model of data envelopment analysis. The steps of this model are the following: the first step is that we fuzzy compute non-quantitative index weights; the second step is that we use data envelopment analysis to accurately calculate the quantitative indicators weight; the third step is that fuzzy comprehensive evaluation of the above results to arrive at a final evaluation results.

If the model has m evaluation units(c+d) evaluation indicators, c quantitative indicators and d non-quantitative indicators.

The first step:

Let $C=(c_1,c_2,\cdots,c_q)$ be factor set, $V=(v_0,v_1,\cdots,v_{p-1})$ is remark set, so the comprehensive evaluation matrix is

$$R_j=\begin{bmatrix} r_{j10} & r_{j11} & \cdots & r_{j1(p-1)} \\ r_{j20} & r_{j21} & \cdots & r_{j2(p-1)} \\ \cdots & \cdots & \cdots & \cdots \\ r_{jq0} & r_{jq1} & \cdots & r_{jq(p-1)} \end{bmatrix},\ j=1,2,\cdots,m$$

Where $A_j=(a_{j1},a_{j2},\cdots,a_{jq})$ is weight matrix? Next we fuzzy compute non-quantitative index weights of j-th decision-making unit and then we get:

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

The second step:

Assume $X_j=(x_{1j},x_{2j},\cdots,x_{nj})^T$, $Y_j=(y_{1j},y_{2j},\cdots,y_{sj})^T$ are the input and output vector of i-th evaluation unit $DMU_i(1\le i\le m)$ respectively, where $j=1,2,\cdots,m$ and each vector coordinates are positive. $v=(v_1,v_2,\cdots,v_n)^T, u=(u_1,u_2,\cdots,u_s)^T$ is the input and output weight vector respectively. Then we use Charnels—Cooper transform to get linear programming model:

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

We put the data into the model and then get optimal solution B_j', where B_j' is the accurate calculation of quantitative indicators weight.

Although the obtained data from data envelopment analysis is more objective and more persuasive, but it does not have the "excellent, good, qualified, unqualified" perception and membership form of fuzzy comprehensive evaluation. So this paper uses membership function to fuzzy calculation of these results.

The results after data envelopment analysis can be seen as the membership degree of remark set $V=(v_0,v_1,\cdots,v_{p-1})$. Assume $r=(r_0,r_1,\cdots,r_{p-1})$ is the membership, then we got:

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

, $r_j\in[0,1],j=0,1,\cdots,p-1$.

We put B_j' into the above formula and then get the membership $B_j=(b_{j1},b_{j2},\cdots,b_{jp})$.

The third step:
We comprehensively evaluate the obtained results. The comprehensive evaluation matrix is:

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

Where k is the project number of all indicators. Assume $A_j=(a_{j1},a_{j2},\cdots,a_{jk}),j=1,2,\cdots,m$ is the weight, then we get $B=A$ and

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

.

Next we use maximum membership principle and get the final result after comprehensively evaluating v_i of $(v_0,v_1,\cdots,v_{p-1})$ responding to the maximum b_{ji} of $B_j=(b_{j1},b_{j2},\cdots,b_{jp})$.

FUZZY NEURAL NETWORK COMPREHENSIVE EVALUATION MODEL

The neural network is able to simulate the human brain's receive domain of partial adjustment and overwrite each, and does not have local minimum problems, and have learning fast and high fitting precision. It can change the weight value of the indicators, and to make it more consistent with the actual situation.

RBF neural network is three forward networks. The first layer is the input layer and is composed of a signal source node; the second layer is hidden layer: the number of hidden units is determined by the needs of problem, and transformation function of hidden unit is RBF, which is nonlinear function; the third layer is output layer, it makes the role of the response to the input pattern. Since the mapping of input to output is nonlinear and the mapping of hidden layer space to output space is linear, so we can greatly accelerate the learning speed and avoid local minima problems.

The structure of RBF neural network is the following Figure 1.

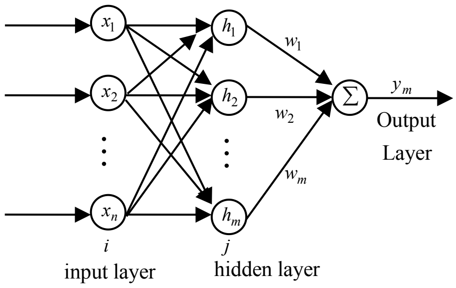

Figure 1: Structure

RBF neural network can approximate any arbitrary precision continuous function, particularly suited to solve classification problems; approximation is shown below Figure 2.

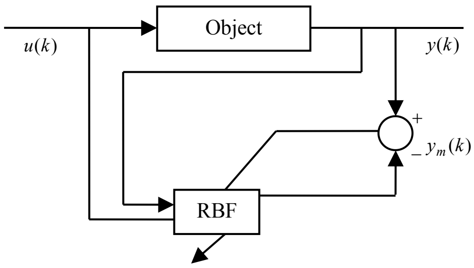

Figure 2: approximation

Let $X = (x_1, x_2, \cdots, x_n)^T$ be the amount of input network, $H = (h_1, h_2, \cdots, h_m)^T$ be radial basis vector, where h_j Gaussian basis is functions. $C_j = (c_{1j}, c_{2j}, \cdots, c_{nj})^T$ is center vector of network j-th node, $B = (b_1, b_2, \cdots, b_m)^T$ is wide base vector, where b_j is base width parameter. The weight vector is $W = (w_1, w_2, \cdots, w_m)$. So, the output of network at time k is $y_m(k) = wh = w_1h_1 + w_2h_2 + \cdots + w_mh_m$.

Assume $y(k)$ is ideal output, we get the performance index function is $E(k) = \frac{1}{2}(y(k) - y_m(k))^2$.

Assume $X = (x_1, x_2, \cdots, x_m)$ is output of network, so we have m input, n output and evaluation rank. In the network, a connection weights between the second and third tiers w_i is the indicator weight value of model.

First layer: input layer. From Figure 1, we have that the input layer has m neurons. The input and output is $I_i^1 = x_i$, $O_{ij}^1 = x_i$, $i = 1,2,\cdots,m$, $j = 1,2,\cdots,n$.

Second layer: hidden layer

RBF neural network has n evaluation ranks. From Figure 1, we know that hidden layer has $m \times n$ neurons. In this paper, we divide the evaluation rank into four kinds, so we take $n = 4$, that is four fuzzy subset, and then we need four parameters a_1, a_2, a_3, a_4.

We use trigonometric function to represent the membership function $\mu(x)$, see Figure 3.

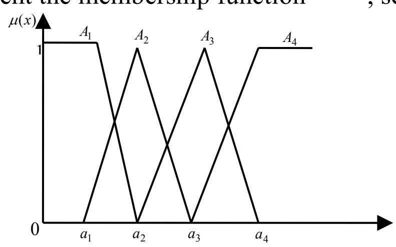

Figure 3: Membership function

When the output is $I_{ij}^2 = O_{ij}^1$, $i = 1,2,\cdots,m$, $j = 1,2,\cdots,n$, the hidden layer will output all levels of membership value $O_{ij}^2 = A_{ij}(x_j)$.

Third layer: output layer
Output layer mainly completes comprehensive evaluation of the input indicators, then we get the evaluation rank and evaluation vector: $I_{ij}^3 = O_{ij}^2$, $O_i^3 = \sum_{j=1}^{m} w_j I_{ij}^3$, where $i = 1,2,\cdots,m$ and $j = 1,2,\cdots,n$.

However, RBF neural network has shortcomings, for example, slow convergence, and local minimum of the energy value and so on. In order to solving this problem, we use modified network to perfect network connection weight.

In the paper, we use the reverse of network to calculate the output value, and then get the error of output value and actual value, and then use the forward of network to test the obtained value and modify the connection weight value, so to achieve the purpose of reducing network error.

Let $d_p = t_p - y_p$ be output error, so the error function is $e_p = \frac{1}{2}(t_p - y_p)^2$. Then, we use the gradient descent method of RBF neural network learning algorithm to modify positive weight vector W, so to achieve the purpose of reducing d_p and increasing the calculation accuracy. The gradient descent method is following Let $w_j(k) = w_j(k-1) + \eta h_j(y(k) - y_m(k)) + \alpha(w_j(k-1) - w_j(k-2))$ and $\Delta b_j = (y(k) - y_m(k)) w_j h_j \frac{\|X - C_j\|^2}{b_j^3}$, so $b_j(k) = b_j(k-1) + \eta \Delta b_j + \alpha(b_j(k-1) - b_j(k-2))$.

Let $\Delta c_{ij} = (y(k) - y_m(k)) w_j \frac{x_j - c_{ij}}{b_j^2}$, so $c_{ij}(k) = c_{ij}(k-1) + \eta \Delta c_{ij} + \alpha(c_{ij}(k-1) - c_{ij}(k-2))$, where η is learning rate, α is momentum factor. Finally, using Jacobean array, we get the result $\frac{\partial y(k)}{\partial u(k)} \approx \frac{\partial y_m(k)}{\partial u(k)} = \sum_{j=1}^{m} w_j h_j \frac{c_{1j} - x_1}{b_j^2}$.

Assume ΔW is the adjusted value of W, using gradient descent method, we get the iterative algorithm formula $\Delta W^{(n)} = -\eta \frac{\partial e_p}{\partial W} + \alpha \Delta W^{(n-1)}$.

We use the formula of ΔW to iterate. When the error is satisfied, we end the network training. Next this paper gives an application.

Assume $A_1, A_2, \cdots, A_m$ are the evaluation indicators and all indicators covering the evaluation requirements of the combination of computer and advanced mathematic. $B_1, B_2, \cdots, B_n$ Are the combination indicators of computer and advanced mathematic. Let $A=\{A_1, A_2, \cdots; A_m\}$ and $B=\{B_1, B_2, \cdots, B_n\}$, then we get:

$$\begin{array}{ccccc} & B_1 & B_2 & \cdots\cdots & B_n \\ A_1 & X_{11} & X_{12} & \cdots\cdots & X_{1n} \\ A_2 & X_{21} & X_{22} & \cdots\cdots & X_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ A_m & X_{m1} & X_{m2} & \cdots\cdots & X_{mn} \end{array}$$

Where X_{ij} is the membership of A_j and $0 < X_{ij} < 1$. So we get that X_{ij} is smaller, this combination of computer and advanced mathematic is lower; X_{ij} is bigger, this combination of computer and advanced mathematic is higher.

In this paper, we assign weight to the membership degree of obtained each indicator and then calculate the mean. So the mean can be seen as the final result, that is $Q_j = \sum_{i=1}^{m} \frac{W_i X_{ij}}{m}$.

Assume there are t evaluators and m evaluation ranks $C_1, C_2, \cdots, C_m$, where they are decreasing functions. Thus for each combination indicator, evaluators will give their evaluation results, for example:

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

This paper takes m=8, that is, there are eight evaluation indicators $A_1, A_2, \cdots, A_8$. Next it takes five ranks $C_1, C_2, \cdots, C_5$ representing excellent, good, qualified, unqualified and poor respectively. We randomly choose one year advanced mathematic scores and then get that the weights of evaluation indicator $A_1, A_2, \cdots, A_8$ are 0.17,0.18,0.13,0.14,0.12,0.15,0.08,0.09. Next we handle these data and get the 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

So we obtain the evaluation matrix:

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

From the formula of fuzzy comprehensive evaluation, we have the final evaluation result:

$Q = A \times R = (0.17\ \ 0.18\ \ 0.35\ \ 0.29\ \ 0.01)$ where $A = (0.17\ \ 0.18\ \ 0.13\ \ 0.14\ \ 0.12\ \ 0.15\ \ 0.08\ \ 0.09)$. From the final evaluation result, we see that 17% evaluators think that this combination is excellent; 18% evaluators think that this combination is good; 35% evaluators think that this combination is qualified; 29% evaluators think that this combination is unqualified; 1% evaluators think that this combination is poor. Then the paper gets the final score by using the score of the five ranks:

$$Q=\frac{0.17^2\times3+0.18^2\times2.5+0.35^2\times2+0.29^2\times1.5+0.01^2\times1}{0.17^2+0.18^2+0.35^2+0.29^2+0.01^2}=2.01$$

Similarly, we can the left scores 2.16, 2.10, 2.13, 2.25, 2.32.

CONCLUSION

With the rapid development of computer technology and development of mathematical software, it has chance for the combination of computer and mathematical education. This paper mainly studies this combination of computers and advanced mathematics. Then on the basis of fuzzy theory, we construct one fuzzy evaluation model. But the fuzzy mathematical theory has a high degree of subjectivity. So we combine neural network theory and data envelopment analysis theory with fuzzy theory to improve the model. Then this paper establishes fuzzy data envelopment analysis evaluation model and fuzzy neural network evaluation model. This paper gives applications and gets the satisfactory results.

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