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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (19): 5201-5205, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.5201.5205

Comprehensive Evaluation Model Research of Regional Sports Industry's Competitiveness Based on Fuzzy Theory

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Abstract: Regional economic development is the foundation of the country's overall economic development and regional sports industry is the basis for the overall development of sports industry. Therefore, in order to enhance the competitiveness of the sports industry, we must improve the competitiveness of regional sports industry. At present many scholars at home and abroad have carried out relevant research on the evaluation of industrial competitiveness and got evaluation model of all kinds of industrial competitiveness. But they are mostly qualitative analysis with more or less subjectivity. On this basis, this study makes further revisions and expansion. Through fuzzy theory, neural network model and principal component analysis, it establishes a comprehensive and objective evaluation system, gets a scientific and impartial comprehensive evaluation model of regional sports industry's competitiveness and put forwards the keys and methods to improve competitiveness.

Key words: Sports industry, neural networks, principal component analysis, assessment model

INTRODUCTION

In the 21st century, with expand of the size and income of the sports industry, the economic functions of sports are more prominent and continue to expand. From sports fitness facilities, recreational facilities, a variety of sports training to the selling of sports competitions' tickets, sports goods, sports advertising and broadcast rights, from the production of a variety of sporting goods and drinks to the management of sports stadiums and sports tourisms, from the extends of the intangible assets to the sales of all kinds of sports lottery, the sports industry has been integrated into our daily lives and the market economy (Tan and Yu, 2005). Sports industry is an already globalize industry, in Europe and America, the sports has been promoted from the concept of movement to the industry sector and has become an industry sector (Zhang and Wang, 2011). Even in other countries, the sports industry has become an important industrial sectors of the national economy, sports industry has shown rapid, world development trend (Tian *et al.*, 2012). China's sports industry started late, since the reform and opening up it gets a real development. With the deepening of China's market economy, the sports industry has shown strong growth potential and has become a new growth point of GDP, but the proportion is still low and it reflects the regional feature. Currently, the regional disparities affect the development of China's sports industry. However, from the world's point of view, the prospects of China's sports industry are very bright; major leagues such as the U.S. NBA, five soccer leagues etc. are constantly upgrading the market share in China (Yang, 2012).

The development of regional economic is the development foundation of the national economy as a whole (Dong and Guo, 2012). Therefore, taking into account the development of the sports industry, the regional sports industry is the basis of the overall development of sports industry (Zhou and Li, 2011). So, in order to enhance the competitiveness of China's sports industry, we must take the sports industry of developed regions as the center, gradually radiates, layering promotes, tries to achieve coordinated and sustainable development of China's sports industry (Huang, 2012). However, the evaluation system of sports industry's competitiveness is a comprehensive evaluation system. In the past, some scholars often decided the selection and assignment of evaluation index by expert, so the results have a certain degree of subjectivity. And the correlation of some indexes is relatively large, so it is likely to cause overlapping indicators; the selected indicators' weight has some errors (Zhang, 2013).

This study uses the neural networks and principle component analysis method to establish the comprehensive evaluation system of sports industry's competitiveness. By the study, we hope that the system can more objectively determine the indicators and a weight, impartially and scientifically evaluate the competitiveness of the regional sports industry and provide a theoretical reference for social decision-making level. This study thinks that the development of China's sports industry should be centered to enhance the competitiveness, so in-depth study of regional competitiveness of the sports industry has an important theoretical value and a wide range of practical significance.

PRINCIPAL COMPONENT ANALYSIS

Through referring to a large literature, this study considers the main factors affecting the competitiveness of regional sports industry include demographic factors, regional factors, economical factors, technological factors and governmental factors. On this basis, it establishes 16 indicators covering these five factors. Meanwhile, it selects the data of six provinces and municipalities for some 4 years from China Statistical Yearbook a nd study. Firstly, this study uses the principal component analysis to process the data of the 6 provinces, municipalities (Beijing, Shanghai, Anhui, Liaoning, Jiangxi, Yunnan), obtains that the test value of Kaiser-Meyer-Olkin is 0.756. Therefore, the established indicators are appropriate for factor analysis and then get the eigenvalues and the contribution rate of the main factors. The study found we can select four common factors from the 16 indicators. So, we use four common factors instead of 16 indicators to achieve the objective of simplifying. Then these 4 common factors are analyzed and found that each common factor has its own meaning. Based on these meanings, these four common factors, respectively named as the core competitiveness v_1, external demand competitiveness v_2, inherent elements competitiveness v_3 and the external environment competitiveness v_4. Thus we get the comprehensive evaluation system index of regional sports industry's competitiveness consisting of four common factors. Therefore, the integrated value (denoted by V) of the regional sports industry's competitiveness is equal to the sum of the four common factors multiplied by their respective weight, namely:

$$V = v_1\times0.23+v_2\times0.338+v_3\times0.155+v_4\times0.089$$

According to the weight of each factor (Table 1), we can calculate the score for each common factor:

$$v_1 = 0.122a_1 + 0.199a_2 + 0.21a_3 + 0.179a_4 + 0.154a_5$$

$$v_2 = 0.22b_1 + 0.255b_2 + 0.278b_3 + 0.267b_4$$

$$v_3 = 0.356c_1 + 0.377c_2$$

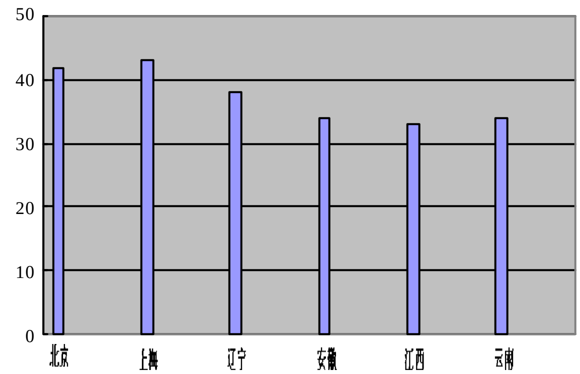

Fig. 1: Competitiveness of regional sports industry

Table 1: Weights of evaluation index

v_1		v_2		v_3		v_4	
a_1	0.122	b_1	0.220	c_1	0.356	d_1	0.698
a_2	0.199	b_2	0.255	c_2	0.377	d_2	0.385
a_3	0.210	b_3	0.278				
a_4	0.179	b_4	0.267				
a_5	0.154						

$$v_4 = 0.698d_1 + 0.385d_2$$

Through the above formula, combined with the selected data, we draw the integrated value of the sports industry competitiveness for the six provinces and municipalities, as shown in Fig. 1.

From the above chart, the competitiveness of Shanghai's sports industry is the strongest and Jiangxi is the weakest. Meanwhile in the sports industry competitiveness, the core competitiveness occupies the most important position. Therefore, the key to improve the competitiveness of regional sports industry is to enhance its core competitiveness.

COMPREHENSIVE EVALUATION MODEL OF FUZZY NEURAL NETWORK

RBF neural network can simulate the receptive field of the partial adjustment and covering each other in human brain, the local minimum problem does not exist and the learning speed is fast with high fitting precision. It can change the index weights of fuzzy comprehensive evaluation model, to make it more conform to realistic condition; also in the fuzzy comprehensive evaluation model, to determine the index's weight value is particularly important.

Introduction on RBF neural network: Radial Basis Function (RBF-Radial Basis Function) neural network is a neural network composed by Moody and Darken in the late 1980s as which is three layer feed-forward networks with a single hidden layer. Since, it simulates the neural network structure of partial adjustment, covering each other and receiving domain in human brain, therefore, RBF network is a local approximation network.

Similar with the structures of multilayer forward network, RBF neural network is a three layer feed-forward network. The first layer namely the input layer is composed by the source node; the second layer is the hidden layer, the number of hidden units depend on the needs of problems described, the transformation function of the hidden units is RBF, it is the damping nonlinear function that is radial symmetrical with the center of symmetry; the third layer is the output layer, it responds to the action of input mode. Since, the mapping from the input to the output is non-linear and the mapping from the hidden layer space to the output space is linear which can greatly accelerate the learning speed and avoid local minima problems as shown in Fig. 2.

RBF neural network can approximate any continuous function with arbitrary precision, particularly suitable for solving classification problems and the approximation figure is shown in Fig. 3.

Suppose $X = (x_1, x_2,\ldots, x_n)^T$ is the input of the network, $H = (h_1, h_2,\ldots, h_m)^T$ is the radial basis vectors, wherein h_j is the center vector of the Gaussian function:

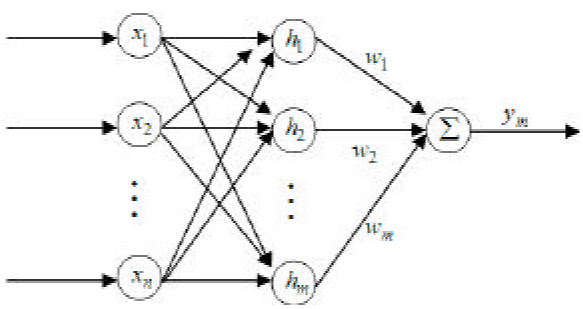

Fig. 2: Structure chart

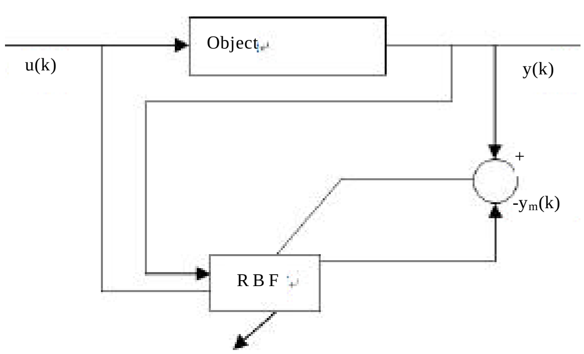

Fig. 3: Approximation figurep

$$h_j = e^{-\frac{\|x-c_j\|^2}{2b_j^2}} \quad (j=1,2,\cdots,m)$$

and the j node of the $C_j = (c_{1j}, c_{2j},\ldots, c_{nj},)^T$ network. Base width vector is $B = (b_1, b_2,\ldots, b_m)^T$, b_j is the base width parameter of the nodes. Weight vector is $W = (w_1, w_2,\ldots, w_m)$ and the output of the network at time k is $y_m(k) = wh = w_1h_1+w_2h_2+\ldots+w_mh_m$.

Suppose the ideal output is y(k) and the performance index function got in this study is:

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

Model building: Assuming $X = (x_1, x_2,\ldots, x_m)$ is the network input and then there are m inputs, n outputs and evaluation levels. In the network, the connection weights w_j of the second layer and the third layer are the index's weight value in fuzzy comprehensive evaluation model.

First layer: Input layer: Figure 1 shows that the input layer totally has m neurons, the input and output is:

$$I_t^1 = x_i$$

$$O_{ij}^1 = x_i,\ i = 1, 2,\ldots, m,\ j = 1, 2,\ldots, n.$$

Second layer: Hidden layer: RBF neural network has n evaluation grades. Fig. 1 shows that there are m´n hidden layer neurons. This article divides the evaluation grades into four categories: $\{A_{ij}\}$ = {excellent, good, qualified, unqualified}, then take n = 4, four fuzzy subsets requires four parameters a_1, a_2, a_3, a_4. In this study, it uses trigonometric functions to represent the membership function $\mu(x)$, as shown in Fig. 4.

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

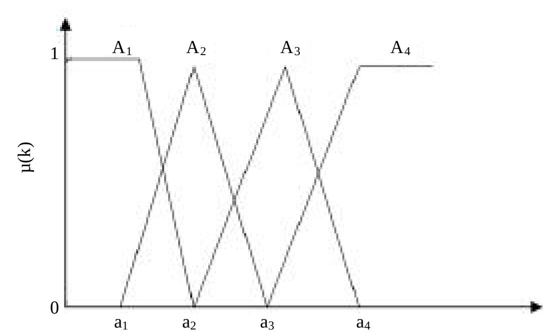

Fig. 4: Membership functions

Third layer: Output layer: The output layer is mainly to complete a comprehensive evaluation of the input index, get its evaluation grade and evaluation vectors:

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

Output:

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

wherein, i = 1, 2,…m, j = 1, 2,…, n.

However, RBF neural network is flawed too, such as slow convergence speed, energy local minima and so on. This study uses an improved network, improves the connection weights of the network, makes the indicator's weight values of fuzzy neural network judgment model is more suitable for actual situation.

This study uses the reverse calculation of the network to calculate the output value, then gets the error of the output value and the actual value and then uses the positive verification of the network to obtain the values, corrects the connection weight values of the network and reduces the error of the network.

Assuming that the output error is $d_p = t_p - y_p$, the error function is:

$$e_p = \frac{1}{2}(t_p - y_p)^2$$

In this study, it uses the gradient descent method in RBF neural network learning algorithm to amend the weight vector W which aims to reduce d_p and increase the accuracy of the calculation. Gradient descent method is as follows.

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

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

then $b_j(k) = b_j(k-1)+\eta\Delta b_j+\alpha(b_j(k-1)-b_j(k-2))$. Suppose:

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

then $c_{ij}(k) = c_{ij}(k-1)+\eta\Delta c_{ij}+\alpha(c_{ij}(k-1)-c_{ij}(k-2))$, wherein η is the learning rate, α is the momentum factor. Finally, use the Jacobi matrix to get results:

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

Suppose ΔW is the adjustment value of W, according to the gradient descent method, obtain the iterative algorithm formula of ΔW:

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

Use the formula of ΔW to iterate, when the error meets the requirements, finish the network training.

Application: Suppose there are m evaluation indicators $A_1, A_2,…, A_m$, there are n regions of index evaluation $B_1, B_2,…, B_n$. Suppose $A = \{A_1, A_2,…, A_m\}$, $B = \{B_1, B_2,…, B_n\}$ so we have:

Index	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}

Wherein X_{ij} is the membership degree of region in the index A_j and $0<X_{ij}<1$. Therefore, this study obtains that when X_{ij} is smaller; the competitiveness of this region in the indicator is relatively low, whereas it is relatively high.

In this study, assign weights on the obtained membership of each indicator, then average and the average value can be used as the final score that is:

$$Q_j = \sum_{i=1}^{m} \frac{W_i X_{ij}}{m}$$

Suppose there are t judges, m judgment levels $C_1, C_2,…, C_m$; it is specified that the larger index increases the lower the level C_i becomes, i.e. it is a decreasing function. Thus, for each region the judges will give their scores. For example:

Index	C_1	C_2	……	C_m
A_1	Q_{11}	Q_{12}	……	Q_{1m}
A_2	Q_{21}	Q_{22}	……	Q_{2m}
……	……	……	……	……
A_m	Q_{m1}	Q_{m2}	……	Q_{mm}

In this study, the evaluation index is taken as eight categories $A_1, A_2,…, A_8$ five grades take $C_1, C_2,…, C_5$ corresponding to excellent, good, qualified, unqualified, poor. In this study, take the statistics data of a one-year for an example, the weights of $A_1, A_2,…, A_8$ evaluation index, respectively 0.17, 0.18, 0.13, 0.14, 0.12, 0.15, 0.08 and 0.09. We randomly select six regions, then get the evaluation results, deal with them and get in Table 2.

Table 2: Evaluation results

Index	C_1	C_2	C_3	C_4	C_5
A_1	0.3	0.50	0.01	0.0	0.0
A_2	0.1	0.40	0.50	0.1	0.0
A_3	0.4	0.20	0.30	0.0	0.2
A_4	0.0	0.09	0.30	0.0	0.6
A_5	0.4	0.00	0.00	0.0	0.6
A_6	0.2	0.40	0.00	0.0	0.4
A_7	0.0	0.20	0.60	0.2	0.0
A_8	0.2	0.00	0.00	0.0	0.8

Thus we get the evaluation matrix of evaluation indicators:

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

According to the calculation formula of fuzzy comprehensive evaluation, this study gets the final judgment results:

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

Wherein A = (0.17 0.18 0.13 0.14 0.12 0.15 0.08 0.09). By the final evaluation results the study obtained that, 17% of the judge considers the competitiveness level of the region is outstanding; 18% of judges feels the competitiveness level of the area is good; 35% of judges considers the competitiveness level of the area is qualified; 29% of judges considers the competitiveness level of the region is unqualified; 1% of judges feels that the competitiveness level in the area is poorer. Then, re-use corresponding scores of five levels to get the final score of this area:

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

Similarly, get the scores 2.16, 2.10, 2.13, 2.25, 2.32 of remaining five areas.

CONCLUSION

In this study, it uses the principal component analysis to build a comprehensive evaluation model for regional sports industry competitiveness and the competitiveness is divided into four categories: core competitiveness, external demand competitiveness, internal factors competitiveness and external environmental competitiveness. Through these four levels, the model can conduct the comprehensive evaluation of a region or several regions and give the level, meanwhile this study points out the key and methods to improve competitiveness. In addition, through fuzzy theory and neural network model, it establishes a comprehensive evaluation model of fuzzy neural network. Using the fast learning speed, high fitting precision and other features of neural network, it can change the index weights of fuzzy comprehensive evaluation model, to make it more conform to realistic condition; also in the fuzzy comprehensive evaluation model, to determine the index's weight value is particularly important, so the established model is more fair, equitable, rigorous and scientific.

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