Price Estimation Model of Jade Bracelet Based on RBF Neural Network

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Abstract. ‘Gold prices but no price jade’ means the prices of jade bracelet market will fluctuate dramatically because of raw materials, processing technology and supply and demand. Jade bracelet is the most important jade products in China, the price is more difficult to grasp. Eight major factors are selected to simulate the price of jade bracelet, based on the data in 2014-2016, and then the price of real trading jade bracelet in 2017 is forecast.

1. Introduction
Jade is an important high-value accessories in the Chinese culture, and it’s price estimation is an indispensable link in the activities like insurance, auction, pawn, mortgage, liquidation, taxation, donation, and justice. The price estimation of jade jewelry in our country is still in its infancy, and there is a clear deficiency compared with the price estimation of gemstone jewelry and gold jewelry. ‘Gold prices but no price jade’, which describes the current situation of the valuation of the jade jewelry. Large amount of transactions and high standardization of jade jewelry makes its price a signpost in jade jewelry trading market.

The price of jade bracelets is influenced by many factors, not only internal factors, like water, species, color and flaw, but also some human factors attached to it, like shape, beauty, processing technology and personal preference, they affect the price of the jade bracelet synthetically. It is of great significance to the standardization of the jadeite market to establish a price estimation model for jade bracelets. There are few related studies abroad because the consumption of jade products is mainly concentrated in the cultural sphere of China.

At present, there are many researches and applications on artificial neural network both at home and abroad, but there are few studies on the price estimation of jade bracelet.

(1) In recent years, domestic researchers have made some achievements in the study of the price estimation theory and method of jadeite bracelets. Zhang Beili thinks that the price estimation approaches of jade jewelry are mainly: cost approach, market comparison approach, income approach [1]; Qiu Zhili thinks that the approaches of price estimation of jade jewelry are mainly cost approach, jadeite price curve approach and jadeite factor economic model valuation approach [2], the coefficient of each quality influencing factor on the price is determined, and the price estimation model of the jade bracelet in the domestic market is put forward through the market survey; Li Ji elaborated the classification of jade factors, and analyzed the impact of various factors on the valuation [3]; Cai Yitao using Delphi method to determine the relationship between the weights and the weight between the
various quality factors, that the method can be used for valuation calculations [4]; Sun Jingyu use Delphi method to calculate the weight between the various quality factors in order to reduce the deviation caused by bias in the assessment results [5]; Yang Diwei established the jade valuation model using three layers of feedforward BP (Back-Propagation, BP for short) neural network and conducted a comprehensive evaluation of the jadeite sample of a merchant of China University of Geosciences (Wuhan) Academy Court Jewelry [6].

(2) Due to its applicability and flexibility, artificial neural network is more and more widely applied to all aspects of scientific research. The application of BP neural network has gradually matured, for example, the forecast of price of stock index futures [7], the forecast of market [8], the forecast of Ningxia water resources demand [9] and so on. BP neural networks are designed for predictive research. However, it also has the shortcomings of only local optimum, long training time and slow convergence speed, so the prediction effect of the BP neural network model remains to be improved. The RBF neural network was proposed by Moody J and Darken C in 1980s, it is a globally approximated forward learning network, and it contains three network layers, input layer, output layer and a hidden layer. Based on the structure and characteristics of RBF, it has been applied in the prediction of pipeline depletion depth for oil transportation [10], prediction of volume of civil aviation passenger [11], prediction of the exchange rate of RMB exchanges [12], prediction of consumer index [13] and so on. Relevant research shows that RBF neural network is suitable for solving nonlinear problems, and the learning speed is fast, the result is accurate and reliable.

Overall, the valuation model at home and abroad is based on the linear model, such methods are applicable for the valuation of the general jade jewelry, but after a certain factor of jade product is greater than a certain value, they present a non-linear relationship. Although a nonlinear BP neural network model has been established, the jade ring samples are from a jewelry store in Wuhan City, and its small sample size does not have the representativeness of the Chinese market, and there is no comparison of the feasibility of the results, it can’t be universally applied. Therefore, it is of great academic and practical significance to study the valuation of jade bracelet through the RBF network.

2. The principle and method of rbf neural network model

RBF neural network usually contains input layer, hidden layer and output layer, is a forward network. The first layer is the input layer, composed of signal source nodes, to accept signals and data input from the outside world. The second layer is the hidden layer, which is between the input neurons and the output neurons that can’t be observed externally. The transformation function is a locally distributed non-negative and nonlinear function, which is radially symmetrical and attenuated to the center. The number of hidden layer cells is determined by the needs of the described problem. The third layer is the output layer that outputs the processing results of the nervous system, and the output of the network is a linear weighted sum of the hidden unit output. RBF neural network is an organic unity of linear and nonlinear, that is, there is a non-linear mapping from the input layer to the hidden layer, and there is a linear transformation from the hidden layer to the output layer.

Radial basis function is used as activation function of hidden layer of RBF neural network, and it is usually defined as a monotonic function of the Euclidean distance between any point and a certain center in space [14]. The most common radial basis function is a Gaussian function, its formula is as follows:

\[ R(x_p - c_i) = \exp\left(-\frac{1}{2\sigma_k^2}\|x_p - c_i\|^2\right) \]  (1)

In the formula : \( x_p \) means the input vector, \( c_i \) means the center of the Gaussian function, \( \|x_p - c_i\| \) means the norm of \( x_p - c_i \), \( \sigma_k \) means the kth perceived variables, it determines the width of the base function around the center. The output of the RBF network model using Gaussian function as a basis function is a linear weighted sum of the output of hidden layer neurons, the formula is as follows:

\[ y_i = \sum_{i=1}^{h} w_{ij} R(x_p - c_i) \]  (2)

In the formula: \( x_p = (x_1^p, x_2^p, ..., x_3^p)^T \) means the pth input sample, \( p=1,2,...,p \), and there are p input
samples. \( w_{ij} \) means the connection weights of hidden layer to the output layer. \( h \) means nodes number of hidden layers, \( i=1,2, \ldots, n \), there are \( n \) output nodes. \( y_j \) means the actual output of the \( j \)th output node of the network's corresponding input sample.

3. The construction of the price estimation model of jade bracelet
RBF neural network is constructed by using NEWRB (P, T, err_goal, spread) function in MATLAB software toolbox, P means the input vector, T means the desired output vector, err_goal means the mean square error, spread means the distribution density of radial basis functions. Take the relevant data from 2014 to 2016 as a learning sample for network training. 8 factors (water, species, color, flaw, technology, weight, demand index, supply index) that affect the price of jade bracelets were used as input samples, and actual sales price of jade bracelet were used as output samples. The network model that has the closest target output to the expected output is found out by constantly adjusting the value of spread to change the prediction accuracy of the network.

3.1. Analysis and selection of influencing factors
According to the results of expert consultation, the price of jade bracelets is mainly affected by six internal factors, namely water, species, color, flaw, technology and weight of jade bracelet jewelry, as well as demand index and supply index. Water means transparency, the jade bracelet with crystal shiny, transparent and clear is for the top grade. The so-called "glass" means highly transparent jade. The better the water, the more transparent and the more valuable the jade bracelet. The species is the texture and structure of jade, the more delicate texture, and the more crystal clear jade, the more valuable the jade bracelet. Besides, the jade bracelet with uniform and positive, thick and green color is for the top grade, and the more valuable the corresponding jade. Flaw means defects, some defects of jade will only affect the beauty of jade, and some directly affect the value of jade. The flaw of jade will affect the value of the jade in varying degrees. Technology refers to jade engraving, it is important to suit technology to condition of jade. The subject, form, technology and proportion of a jade will affect the overall effect, made according to the material is an important foundation of jade creation and technology form, and the jade bracelet that art beats nature is for the top grade. The technology has an important influence on the value of jadeite. The more exquisite the technology is, the more valuable the corresponding jade. Weight has a direct impact on the value of jadeite. In addition to the internal factors of jade, the price of jade bracelet will naturally be influenced by the supply and demand factors. If the supply is larger than the demand, the price will fall accordingly, and if the supply is not available, the price will rise naturally.

3.2. Data sources
There are many factors affecting the price of jade, including the internal factors, economic factors and supply and demand factors. Due to the economic development and market supply are not the same in different years, the price of jade varies from time to time, data of different years of jade bracelet samples need to be collected. The economic development of the trading year and the market supply and demand are the factors that affect the input of price estimation of the jade bracelet.

According to the literature, this study mainly selects 8 main factors that affect the price of jade bracelet, including six internal factors like water, species, color, flaw, technology, weight, and two market factors like demand and supply. The actual transaction data of 799 representative jade bracelets of the major jade jewelry firms in China from 2014 to 2016 are selected as the sample data. The gold and silver jewelry retail price index is used as the demand index of jade bracelets of the 2014-2016. The supply index is calculated by combining the annual output quantity and supply quantity of jade from 2014 to 2016.

The 799 samples were randomly divided into two groups, 750 samples of them were model training samples and 49 samples were model test samples. Since the data is obtained from actual market sales, the data is relatively independent and satisfies the requirements of overall and random.
4. Results and analysis

4.1. Data preprocessing
When the raw data is entered into a neural network for prediction, it will affect the learning speed of the neural network, and there will be a deviation from the result of the forecast, therefore, it is necessary to standardize and normalize the original data. Usually the activation function of neuron in neural network prediction is Sigmoid function, and the neural network can accurately approximate the function. The range of input of the Sigmoid function is [0,1], so the sample data is normalized to the [0,1], the normalization formula is as follows:

\[ x_k' = \frac{x_k - \min(x_n)}{\max(x_n) - \min(x_n)}, \quad k = 1,2, \ldots, N \]  

(3)

\( \min(x_n) \) means the minimum value of sample \( x_n \), \( \max(x_n) \) means the maximum of sample \( x_n \), \( x_k \) means unprocessed input sample of neural network, \( x_k' \) means the input sample after normalization processing.

4.2. Accuracy test and error analysis of RBF neural network
This paper simulates based on the data of actual transaction jade bracelet (training sample) of 2014-2016, after repeated tests, finally determines the number of nodes in the hidden layer, that is, when \( c_i \) in the formula (2) is 30, the best model training error is almost zero, it shows that the output of the network can well approximate the nonlinear function \( Y_i \), that is, the fitting ability of RBF neural network model is excellent. In order to verify its validity, the data of jade bracelets for actual transaction in 2016 are selected for prediction, the prediction results and simulation results are shown in Table 2 and Figure 1 (a).

In order to further verify the feasibility and effectiveness of RBF neural network method, use BP neural network method to simulate, in the same time, and compared with the RBF neural network simulation results. The results of BP neural network simulation are shown in Table 2, Figure 1 (b). The more close the simulated value is to the actual value, the more consistent the simulated value with the actual value. It is known from the figure that the simulation and prediction effect of RBF neural network are better.

The average error (MAE), the root mean square error (RMSE) and the mean absolute percentage error (MAPE) were used to evaluate the prediction accuracy of the two prediction methods.

| Table 1. Statistical error of different prediction methods |
|---------------------------------|----------|----------|----------|
| Prediction methods | MAE      | RMSE     | MAPE%    |
| RBF                | 4.7850   | 9.5393   | 4.9857   |
| BP                 | 6.2547   | 12.6673  | 7.8115   |
Table 2. Price prediction of jade bracelets from different methods

| Sample Number | Real Value | Estimation Value of RBF | Estimation Value of BP | Sample Number | Real Value | Estimation Value of RBF | Estimation Value of BP |
|---------------|------------|-------------------------|------------------------|---------------|------------|-------------------------|------------------------|
| 1             | 5          | 5.7041                  | 4.0842                 | 14            | 4          | 8.7922                  | -0.0823                |
| 2             | 5          | 5.2190                  | 4.1501                 | 15            | 4          | 2.9688                  | 4.9614                 |
| 3             | 5          | 5.7626                  | 4.0035                 | 16            | 4          | 3.2218                  | 3.8629                 |
| 4             | 5          | 4.9888                  | 4.1720                 | 17            | 3          | 7.1486                  | 0.8096                 |
| 5             | 5          | 4.8910                  | 4.1803                 | 18            | 3          | 4.4580                  | 2.6020                 |
| 6             | 6          | 6.2331                  | 4.0530                 | 19            | 3          | 3.7106                  | 3.2757                 |
| 7             | 6          | 3.9500                  | 5.4865                 | 20            | 3          | 4.6251                  | -2.4641                |
| 8             | 6          | 4.4095                  | 5.4821                 | 21            | 3          | 5.2345                  | 2.0197                 |
| 9             | 6          | 3.8120                  | 5.4701                 | 22            | 24         | 24.1995                 | 24.6200                |
| 10            | 5          | 5.9344                  | 2.7058                 | 23            | 24         | 24.4306                 | 24.7384                |
| 11            | 4          | 3.4228                  | 3.5910                 | 24            | 24         | 24.7577                 | 24.9468                |
| 12            | 5          | 3.1122                  | 5.1604                 | 25            | 24         | 24.4306                 | 24.7384                |
| 13            | 24         | 23.2959                 | 25.5853                |              |            |                         |                        |

Figure 1. Sample fitting diagram of RBF and BP

5. Summary

5.1. Application of the model
Price is the core of transaction, the established price estimation model can be used in some relevant activities of price estimation of jade bracelet, because of its estimated price of the jade bracelet is close to the market price.

(1) Manufacturer of jade bracelet. Usually, the main task of the jade bracelet manufacturer is to use natural jade as raw material to increase its ornamental performance and decorative performance by
grinding and carving, thus increasing the market value of jade. Generally, the price of the finished jade bracelet is based on the raw material cost and processing cost, it will have a certain guidance function on the purchase of raw materials and the pricing determination of finished products if the jade bracelet manufacturer can estimate the market price of the products made by itself.

(2) Third party. Jade bracelet price estimation is an indispensable link in insurance, auction, pawnshop, mortgage, settlement, tax, donation, and judicial activities. The price estimation model of jade bracelet can guarantee the objective and fair product valuation in all links of the above activities, and simplify price estimation and improve work efficiency. In auctions, pawnbrokers and mortgages, it is often dominated by the merchant with high professional knowledge, they know price of jade bracelet better. So, the jade bracelet owner can know the market price of products by using the price estimation model, and bargain with merchants.

(3) Consumer. The jade bracelet price estimation model can effectively help consumers who have no or lack of experience to know the market price of jade bracelets, and prevent consumers from being cheated due to lack of price information effectively and guide consumers to buy jade bracelets according to their ability. For the jade collector, they can confirm the market price of the jade bracelet.

(4) Market manager. The jade bracelet price estimation model can indirectly help the government to supervise the jade exchange market, control the quality of jade bracelets strictly, supervise transaction of jade bracelets strictly, and punish the trade deception of jade bracelets severely. Besides, it can enhance the transparency of the jade bracelet trading market, reduce the information asymmetry in the trading market, and promote the healthy and rapid development of the jade bracelet trading market.

5.2. Conclusion
China is a country that loves jade and admires jade, the heritage of jade culture runs through China's five thousand years of civilization. RBF neural network price estimation model of jade bracelet is based on the actual transaction data of China in recent years, combining economic development with market supply and demand, and the forecast speed and accuracy are improved, can be widely used in the actual price estimation of jade bracelet products, and it also plays a driving role in regulating industrial market and flourishing jade culture. With the range sample data continues to increase and expand, the jade bracelet price estimation model will be more unified with the market practice, and service the development of jade industry market.

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