A FCM, Grey Model, and BP Neural Network Hybrid Fashion Color Forecasting Method

Ran Tao, Jie Zhang(✉), Ze-Ping Lv, You-Qun Shi, and Xiang-Yang Feng

School of Computer Science and Technology, Donghua University, Shanghai 201620, China
{taoran, yqshi, fengxy}@dhu.edu.cn, 644864976@qq.com, 1025999102@qq.com

Abstract. In view of the low prediction accuracy of the existing fashion color prediction methods, this paper propose a fashion color forecasting method used the spring and summer women's fashion color data released by the International Fashion Color Committee from 2007 to 2013. In preprocess stage, the Pantone color system is used as the color quantization basis, the fuzzy c-means is used to cluster the sample data at first, and a FCM algorithm is used to statistic the color categories in different time series. In forecasting stage, both the grey model and BP neural network are used respectively to construct the fashion color hue prediction model from the statistical results generated from FCM. In evaluation stage, the mean square error is used to compare the prediction effect. The results show that the grey model based on FCM has the smallest error and has the best prediction effect. The proposed model can be used to predict the future fashion color, which can help the apparel industry stakeholders to grasp the trend of the future fashion color and make design and production plan more effectively. The FCM and grey model hybrid prediction method shown in this model also can be used in other small sample data prediction scenario.

Keywords: Clothing fashion color prediction · Fuzzy c-means · Grey model · BP neural network

1 Introduction

Color is an important factor to improve the competitiveness of commodities in the textile and garment industry [1]. Studies show that appropriate color design can bring 10%–25% added value to the product without increasing the cost [2]. Popular color refers to the color that is generally welcomed by people in a certain period and a certain consumer group. It is the direction of fashion and plays an important role in product marketing [3]. Stakeholders in the apparel industry need to participate in the design, sample, ordering, marketing and sales of clothing according to the predicted fashion color. Establishing a high-precision and objective fashion color prediction model is a major research topic in the apparel industry [4].

Color research institutions, such as Inter Color, Pantone, Merck, etc., are specialized in the research, prediction and release of popular colors. However, the

L. Uden et al. (Eds.): KMO 2019, CCIS 1027, pp. 97–109, 2019.
https://doi.org/10.1007/978-3-030-21451-7_9

confidentiality of popular colors hinders the spread of prediction techniques, methods and finalization, and restricts the embodiment of economic value of popular colors. For example, the international fashion color can only be shared directly in the member states and is not open to the public, and the prediction process has not been made publicly. For most non-member companies, the timeliness and accuracy of the clothing trend information is still an urgent problem to be solved [5].

At present, the research theories applied to predict the trend of popular colors mainly include grey system theory [3], neural network [6], grey neural network [7], multi-swarm cooperative evolutionary algorithm [8], and other combination theories [9]. These research methods provide an important reference for the prediction of popular colors, but the research on fashion color is still in the exploration stage, and the prediction performance of color is still insufficient and controversial [10].

Aiming at the low prediction accuracy of fashion color, we proposed a FCM, grey model, and BP neural network hybrid fashion color forecasting method, and using the mean square error (MSE) as the comprehensive evaluation index of prediction effect.

The rest of the paper is organized as follows: The second part summarizes the research status of popular color trend prediction, FCM algorithm, grey model and BP neural network. The third part introduces the process of fashion trend forecasting and theoretical analysis. The fourth part shows the experimental process comparative analysis. The conclusion and the future research were given in the last part.

2 Related Literature Review

The quantification and classification of color is the basis for the study of fashion color prediction and is an important factor affecting the accuracy of prediction [11]. The determination of boundary value of hue interval is an important basis for realizing the statistics of hue quantization data. Pantone color system uses the color coding of six numbers to indicate the value of lightness, hue and purity attributes of the color. The hue is represented by a circle, and the hue value ranges from 1 to 64. However, there is no labeling of color classification in the Pantone color system. Therefore, the determination of boundary values of 10 types of color intervals in Pantone phase ring is an important basis for the prediction of fashion color. Chang [5] proposed a color quantization method and classification standard based on the Pantone color system and they have been applied to the literature [12] and so on. However, in the literature [12], the final spring-summer color reproduction accuracy is 60%, and the result is not satisfactory. Therefore, this paper proposes to quantify the data using the Pantone color space and classify the data using the FCM-based method.

FCM algorithm is an unsupervised fuzzy clustering algorithm, which uses initialization to determine the number of initial clustering centers, and iteratively changes the clustering center to make the spacing between clustering centers less than the given constraint conditions, so as to obtain the minimum value of the objective function [13]. At present, the FCM algorithm has been effectively applied in the fields of medical imaging, digital watermarking, target recognition and image separation [14]. This paper creatively applies the FCM algorithm to the data processing stage of color prediction.

The grey prediction model is a dynamic prediction model based on the grey system theory. The most widely used model is the GM(1,1) model. The grey prediction model is suitable for the prediction of social and economic systems with large factors, complex structure, wide coverage, and comprehensiveness, as well as the main behavioral characteristics, such as total population, total output, national income, consumption level, and productivity [15]. The factors influencing the change in fashion colors are uncertain, and the relationship between fashion colors is uncertain. Therefore, it is feasible to apply the grey model to the prediction of fashion colors.

The Back Propagation (BP) neural network was proposed by the team of scientists led by Rumelhart and McClelland in 1956. It is widely used in many fields such as finance, medicine, and electric power, and has important research value. The Kolmorov continuity theorem in neural network theory shows that the BP neural network can approximate a non-linear continuous function with any accuracy [16], which indicates that the prediction of fashion color by applying it is based on theory.

In terms of clothing color prediction, YZ Wu and others from Donghua University discussed the application of the grey model and BP neural network model in the study of clothing color [17], the study used the spectrophotometer to quantify the color classification, and then adopt the grey model and BP neural network and improve the combination grey BP network, studies show that grey BP model prediction effect is best, the study further developing the color prediction research train of thought; LY Chang of Jiangnan University and others proposed the quantification and prediction of fashion color, and compared the prediction efficiency of the model by changing the length of the time series, and also realized the color brightness and purity [5].

3 A FCM, Grey Model, and BP Neural Network Hybrid Fashion Color Forecasting Method

3.1 Research Process

In order to predict future fashion color from small sample data, we designed this hybrid fashion color forecasting method, shown as Fig. 1.

The input of this process is the historical fashion color released by the International Fashion Color Committee, and the output is the predicted hue ratio of future fashion color. There are 6 steps in this process, shown as follows:

Step 1: Collecting the historical fashion color data in the form of the Pantone color;
Step 2: Extracting the hue H value from the collected Pantone color data;
Step 3: Clustering the H values with the use of FCM algorithm, the results are various cluster centers and a membership matrix;
Step 4: Calculating the hue ratio for each color class in different years from the results of 3;
Step 5a: Predicting the future fashion color with the use of the grey model and calculating the MSE;
Step 5b: Predicting the future fashion color with the use of the BP neural network and calculate the MSE;

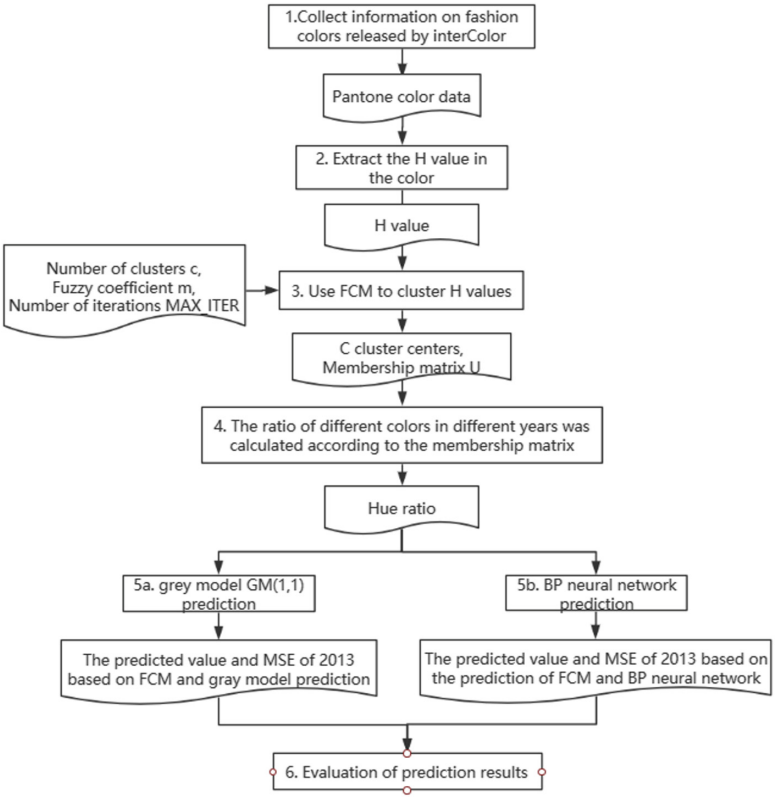

Fig. 1. The proposed FCM, GM, and BP neural network hybrid prediction process.

Step 6: Evaluating the prediction results.
The FCM algorithm, grey model and BP neural network are the main steps in this process, discussing as follows.

3.2 FCM Algorithm

The FCM divides the n hue samples x_i (i = 1, 2, …, n) into c fuzzy groups, then finds the cluster center of each group of colors so that the objective function of the non-similarity index is minimized. The total membership degree of all samples is 1. As shown in Formula (1), u_{ij} indicates the membership degree of the sample I to the clustering center j.

$$\sum_{i=1}^{c} u_{ij} = 1, \forall j = 1, \ldots, n \tag{1}$$

The generalized form of the objective function of FCM is shown as Formula (2), c_i represents the clustering center of the class i; The distance $d_{ij} = \left\| c_i - x_j \right\|^2$ represents the cluster center of the samples i and j, m is the weighted index, and U is the membership matrix.

$$J(U, c_1, c_2, \ldots, c_c) = \sum_{i=1}^{c} J_i = \sum_{j=1}^{n} \sum_{i=1}^{c} u_{ij}^{m} \left\| c_i - x_j \right\|^2 \tag{2}$$

The specific steps of the FCM clustering algorithm are as follows:

Step 1: Set the number of clusters c, the fuzzy coefficient m (usually taken as 2), the maximum number of iterations MAX_ITER, and the minimum error **δ**;
Step 2: The membership matrix U is initialized so that it satisfies the condition in Formula (1). Where U = c×n, where c is the number of cluster centers and n is the total number of samples;
Step 3: Use Formula (3) to calculate the color clustering center *ci*, i = 1,2,…, c;

$$c_i = \sum_{j=1}^{n} u_{ij}^{m} x_j \Big/ \sum_{j=1}^{n} u_{ij}^{m} \tag{3}$$

Step 4: Use Formula (4) to calculate the distance matrix from each sample point to the cluster center and obtain a new membership matrix.

$$u_{ij} = 1 \Big/ \sum_{k=1}^{c} \left(d_{ij} / d_{kj} \right)^{2/(m-1)} \tag{4}$$

Step 5: Calculate the objective function value J according to Formula (2) and evaluate whether the iterative process is terminated. Set the minimum error to $\delta = |J_t - J_{t-1}| / J_t$. If the value is less than the given convergence precision **δ** or the number of iterations exceeds MAX_ITER then the algorithm stops, otherwise it returns to the third step.

The hue is clustered by FCM, and ten cluster centers i (i = 1, 2, …, 10) and the membership matrix U are returned. Cluster the hue through FCM, and return ten clustering centers i (i = 1, 2, …,10) and the membership matrix U. By processing the membership matrix, the hue value interval of each class of colors can be obtained [mini, maxi], where i represents the class i in the clustering center of class 10. mini represents the minimum hue value of the clustering center of class i, and maxi represents the maximum hue value of the clustering center of class i. Individual unclassified hue values are automatically assigned to the adjacent interval with a larger span of hue values. The frequency of each color phase in different years can be obtained through statistics, and the proportion of each color phase can be calculated through Formula (5):

$$R_i = \frac{v_i}{V} \times 100\%, i = 1, 2, ..., 10 \tag{5}$$

In Formula (5), *Ri* represents the proportion of the ith color in different years, vi represents the number of colors appearing as the cluster center of the ith class; i

represents the ith class in the 10-type cluster center; V represents the total number of colors contained in the finalization of fashion colors in a certain year.

The pseudo code for the FCM algorithm is as follows:

```
Algorithm: FCM algorithm
Data: hue sample set N, objective function precision δ, number of clusters c, blur coefficient m (usually 2), maximum iteration number MAX_ITER
Result: c cluster centers, belonging to the matrix U
1  Begin
2  Call pd.read_csv to read the sample data x.csv
3  Set c, m, MAX_ITER, δ
4  Membership_mat = initializeMembershipMatrix()  // Initialize the membership matrix
5  While iterations <= MAX_ITER or precision <δ do
   Cluster_centers=calculateClusterCenter(membership_mat)
                                                  //Calculation Cluster Center
   Membership_mat,data=updateMembershipValue(membership
   _mat,cluster_centers)
   //Update membership getClusters(membership_mat)
   //Get clustering results
6  End
7  Foreach cluster_centers
   Find the maximum value max, minimum min  // various color intervals
8  End
```

3.3 Grey Model

The idea of the grey model is to directly transform the time series into differential equations, thus establishing a dynamic model of the evolution of the abstract system. This method is mainly used for single-sequence first-order linear dynamic models, namely Grey model(1,1), referred to as GM(1,1), which represents a first-order, one-variable differential equation model. The main steps of clothing color prediction based on the GM(1,1) grey model are shown in Fig. 2:

In the process of modeling the popular color prediction based on the grey model, it is necessary to establish a grey model for each type of color data, and set the original color sequence of a certain color to $x(0)(t)$, $x(0)(t)$ represents data of a certain type of color in different years; generates a sequence $x(1)(t)$ by accumulating formula (2),the accumulation process can weaken the randomness of the original data, so that it presents a more obvious characteristic law; establish a first-r differential equation for the generated sequence, such as formula (3), that is, the GM model, where a is the whitening coefficient, which reflects the variable Development trend, $a \in [0, 1]$, b is the endogenous control grey; solve the differential equation to get the predicted value of a certain color $\widehat{x}^{(1)}(t+1)$; Since the predicted value at this time is a sequence generated by accumulation, it needs to be reduced, as in formula (5), and finally obtained

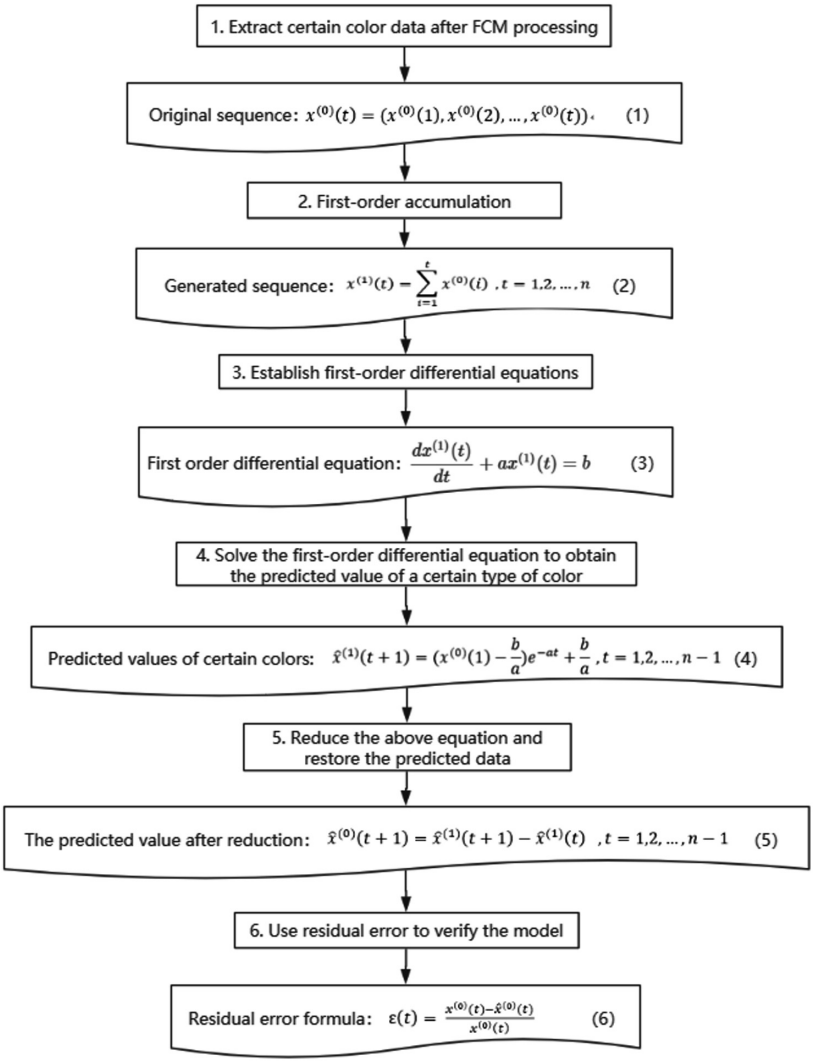

Fig. 2. Fashion color prediction steps based on the grey model.

$\widehat{x}^{(0)}(t+1)$, that is, the predicted value of the color of the class; the other types of colors are separately predicted according to the above steps. Calculate the relative error by Eq. (6), if the relative error of each type of color $|\varepsilon(t)| < 0.1$, that is, to achieve higher accuracy if all kinds of colors $|\varepsilon(t)| < 0.2$, it is considered to meet the general requirements.

3.4 BP Neural Network

The BP neural network is a one-way propagation multi-layer feedforward network. Through the training of sample data, the network weight and threshold are continuously corrected to make the error function fall in the negative gradient direction, approaching the expected output, from the input layer, output layer and hidden. Contains layer composition. Since the fashion color data is less, and the results of the prediction of the popular color are separately analyzed by using different network structures, a 4-7-1 network structure is used for prediction (See Fig. 3).

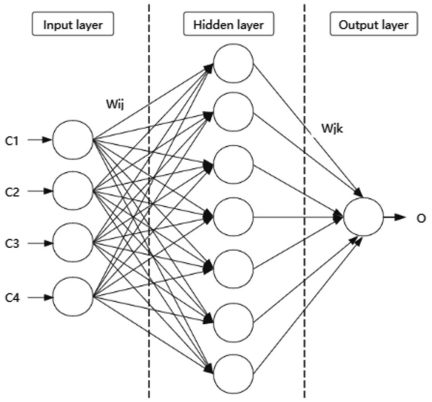

Fig. 3. Topological structure of clothing fashion color based on bp neural network (4-7-1).

The C1, C2, C3, C4 are used to represent the first n years of a certain color respectively. The model is used to predict the color data of the next year. The O is used to represent the target value. Other parameters are discussed in Sect. 4.3.

4 Experiment and Analysis

4.1 Data Selection and Evaluation Criteria

The InterColor's 2007–2013 international spring and summer women's fashion color is used as the research data, and 288 color data are collected.

By extracting the hue information in the Pantone color card, 10 cluster centers are found by FCM. Firstly, set the number of clusters c = 10, the fuzzy coefficient m = 2, the maximum number of iterations MAX_ITER = 1000, the minimum error $\boldsymbol{\delta}$ = 10-5, the initial cluster center is randomly generated using the random() function, and then the Eq. (3) is used to update it. In addition, the membership matrix is updated using Eq. (4). Finally, after the iteration is completed, a more stable color clustering result was obtained. The classified results and classification intervals after processing are shown in Table 1:

Table 1. 10 cluster centers and 10 hue intervals

Hue classification	Class i	Class ii	Class iii	Class iv	Class v	Class vi	Class vii	Class viii	Class ix	Class x
Cluster center	2	6	10	13	17	26	39	44	53	61
Hue value interval	[1, 4]	[5, 8]	[9, 11]	[12, 15]	[16, 21]	[22, 30]	[31, 40]	[42, 48]	[49, 57]	[59, 64]

The color data obtained from the membership matrix returned by the FCM algorithm and obtained by the formula (4) is as shown in Table 2:

Table 2. 2007–2013 international spring and summer women's fashion color hue ratio

Years	Class i	Class ii	Class iii	Class iv	Class v	Class vi	Class vii	Class viii	Class ix	Class x
2007	0.172	0.069	0.103	0.138	0	0.069	0.069	0.103	0.103	0.172
2008	0.279	0.07	0.07	0.186	0.047	0.047	0.023	0.093	0.047	0.14
2009	0.13	0.196	0.087	0.109	0.087	0.087	0.022	0.043	0.087	0.152
2010	0.113	0.151	0.075	0.094	0	0.094	0.019	0.264	0.113	0.075
2011	0.098	0.146	0.122	0.146	0.024	0.073	0.024	0.146	0.098	0.122
2012	0.167	0.167	0.111	0.111	0.028	0.083	0.028	0.111	0.083	0.111
2013	0.075	0.225	0.125	0.1	0.05	0.05	0.05	0.15	0.075	0.1

The mean square error (MSE) was used to judge the prediction result. The MSE formulas are as follows:

$$\text{Absolute error: } e_i = |\widehat{x}_i - x_i| \tag{6}$$

$$\text{Relative error: } \varepsilon_i = e_i / x_i \tag{7}$$

$$\text{Mean square error: MSE} = \frac{1}{n}\sum\nolimits_{i=1}^{n} e_i^2 \tag{8}$$

among them, xi represents true value, $\widehat{x}_i$ represents prediction value, n represents the sample number. Smaller MSE means better prediction efficiency.

4.2 Prediction of GM(1,1) Based on FCM

Taking the hue data of 2007–2012 (See Table 2) as the training sample, the grey model was used to predict the 2013 fashion color hue ratio (See Table 3).

Table 3 shows that the MSE value obtained the FCM and grey models is between 0.000004 and 0.001296. The overall MSE, calculated by the Formula (8), is 0.00028.

The comparison between the forecast results of the grey model based on FCM the finalized information on the 2013 fashion color data is shown in Fig. 4, which shows that the predicted values fit the true values very accurately.

Table 3. Prediction results of 2013 fashion color based on FCM grey model.

Category	Original value in 2013	Predictive value in 2013	Absolute error e	Relative error ε	MSE
Class i	0.075	0.077	0.002	0.027	0.000004
Class ii	0.225	0.189	0.036	0.160	0.001296
Class iii	0.125	0.133	0.008	0.064	0.000064
Class iv	0.1	0.095	0.005	0.050	0.000025
Class v	0.05	0.038	0.012	0.240	0.000144
Class vi	0.05	0.061	0.011	0.220	0.000121
Class vii	0.05	0.042	0.008	0.160	0.000064
Class viii	0.15	0.168	0.018	0.120	0.000324
Class ix	0.075	0.102	0.027	0.360	0.000729
Class x	0.1	0.095	0.005	0.050	0.000025

Fig. 4. Comparison the forecast results of the grey model based on FCM and actual values.

4.3 Prediction of BP Neural Network Based on FCM

In this study, we used a 4-7-1 network structure shown as Fig. 3, set the excitation function to relu function, use the adam function to train the data, set the maximum number of iterations to 1000, and the iteration error is 10-4. The original quantitative data from 2007 to 2010 is constructed as the input of the BP neural network, the output is the predicted data of 2011. Then, the data of 2008–2011 is used to predicted data of 2012. Finally the forecast data for 2013 is achieved (See Table 4).

The overall MSE, calculated by the Formula (8), is 0.0036. The comparison of the prediction results with the 2013 finalization information is shown in Fig. 5.

Table 4 shows that the obtained MSE value is small, between 0.000484 and 0.011025, and the overall MSE is 0.0036. The accuracy of this model is lower than that of the gray model. The possible reason is that the gray model is more suitable for small sample data than the BP neural network.

Table 4. Prediction results of BP neural network based on FCM.

Color	Original value in 2013	Predictive value in 2013	Absolute error e	MSE
Class i	0.075	0.169	0.094	0.008836
Class ii	0.225	0.12	0.105	0.011025
Class iii	0.125	0.181	0.056	0.003136
Class iv	0.1	0.157	0.057	0.003249
Class v	0.05	0.027	0.023	0.000529
Class vi	0.05	0.077	0.027	0.000729
Class vii	0.05	0.024	0.026	0.000676
Class viii	0.15	0.128	0.022	0.000484
Class ix	0.075	0.133	0.058	0.003364
Class x	0.1	0.166	0.066	0.004356

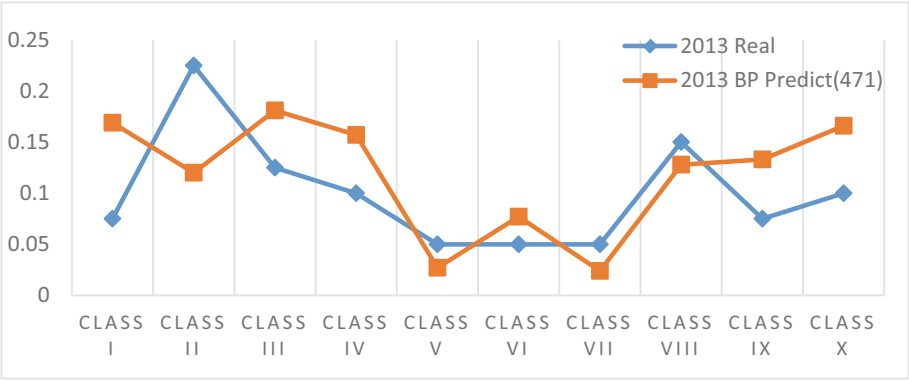

Fig. 5. Comparison of predicted and actual values of FCM-based bp neural network in 2013.

4.4 Performance Comparison with Other Fashion Color Predictions

In order to comprehensively analyze the superiority of the FCM -based fashion color prediction model, the comparison is based on the prediction model based on the traditional classification method: grey model [10], BP neural network [17]. Taking the mean square error as the evaluation index, the fashion color pairs of various models are shown in Table 5:

Table 5. Accuracy comparison with other fashion color prediction models.

Comparative literature	MSE
FCM-based grey model	0.00028
FCM-based BP neural network	0.0036
Literature [10] grey model	0.0071
Literature [17] BP neural network	0.00067

Table 5 shows that the grey model based on FCM has the smallest MSE value, and its prediction effect is optimal.

5 Conclusion

In order to predict future fashion color from historical fashion color data, we proposed a FCM, grey model, and BP neural network hybrid fashion color forecasting method. By comparing the MSE between them and other prediction methods, we found that the FCM and grey model hybrid forecasting method has highest prediction accuracy. This method can help apparel industry stakeholders to master the future fashion color trends and participate in the apparel ecosystem more effectively, it also can be used in other small sample data prediction scenario.

In the future, other unstructured and semi-structured fashion consultations from social media can be used to improve the prediction accuracy of the FCM and BP neural networks hybrid method.

References

1. Diane, T., Cassidy, T.: Colour Forecasting, pp. 6–23. Blackwell Publishing Ltd., Oxford (2005)
2. Li L.Z.: Color economy and marketing strategy. In: Academic Papers of China Fashion Color Association Academic Annual Conference, pp. 66–71 (2012)
3. Lin, J.J., Sun, P.T., Chen, J.J., et al.: Applying gray model to predicting the trend of textile fashion colors. J. Text. Inst. **101**(4), 360–368 (2010)
4. Liu, G.L., Jiang, Y.: Research on the sensibility of clothing style based on the perceptual cognition of the wearer. J. Text. Res. **11**, 101–105 (2007)
5. Chang, L.X. Quantification and prediction of fashion color. Jiangnan University (2013)
6. Di, H.J., Liu, D.Y., Wu, Z.M.: Prediction of popular color in spring and summer women based on bp neural network. J. Text. Res. **32**(7), 111–116 (2011). 126
7. Choi, T.M., Hui, C.L., Ng, S.F., et al.: Color trend forecasting of fashionable products with very few historical data. Syst. Man Cybern. **42**(6), 1003–1010 (2012)
8. Zhao, L., Yang, L.H., Huang, X.: Prediction of fashion color of clothing using multi-bee colony cooperative evolution algorithm. J. Text. **39**(03), 137–142 (2018)
9. Hu, Z.Q.: Research on the application of trend forecasting of home textile fashion based on grey Markov model and support vector machine. Wuhan Textile University (2018)
10. Chang, L.X., Gao, W.D., Pan, R.R., Liu, J.L.: Application of grey GM(1,1) model in the prediction of popular color hue in international spring and summer women. J. Text. Res. **36**(04), 128–133 (2015)
11. Schwarz, M.W., Cowan, W.B., Beatty, J.C.: An experimental comparison of RGB, YIQ, LAB, HSV, and opponent color models. ACM Trans. Graph. **6**(2), 123–158 (1987)
12. Han, W.: Quantitative analysis, prediction, and application of women's fashion color. Donghua University (2017)
13. Bezdek, J.C.: Pattern Recognition with Fuzzy Objective Function Algorithms. Plenum, New York (1981)
14. Deng, J.L.: Control problems of grey systems. Syst. Control Lett. **1**(5), 288–294 (1982)

15. Wang, X.M.: Grey System Analysis and Practical Calculation Program, pp. 50–54. Huazhong University of Science and Technology Press, Hubei (2001)
16. Yang, C.B.: Improved combined forecasting model based on grey model and artificial neural network and its application [Master's thesis]. Shandong Normal University, Jinan (2009)
17. Chang, L.X., Gao, W.D.: Short-term prediction of international fashion color based on bp neural network. Woolen Technol. **46**(02), 87–91 (2018)