

Neural Network Based Color Recognition for Bobbin Sorting Machine

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Abstract

Winding is a key process in the manufacturing process of textile industry. The normal and effective operation of winding process plays a very important role on the textiles' quality and economic effects. At present, a large proportion of bobbins which collected from winder still have yarn left over. The bobbin recycling is severely limited and quick running of winder is seriously restricted, the invention of the automatic bobbin sorting machine has solved this problem. The ability to distinguish bobbin which has yarn left over from the rest and the classification accuracy of color are the two important performance indicators for bobbin sorting machine. According to the development and application of the color recognition technology and the artificial intelligence method, this study proposes a novel color recognition method that based on BP neural networks. The result shows that the accuracy of color recognition reaches 98%.

Keywords: color recognition, bobbin sorting machine, BP neural network

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1. Introduction

Bobbin sorting machines has been widely used in the textile industry. They can classify the bobbins according to their colors and pick the empty bobbins out. The color recognition system is one of the most important parts of bobbin sorting machine. The bobbin sorting machines helps to improve the quality of textile and increase the yield of textile. Therefore, it is very important to establish the color recognition simulation system of bobbin sorting machines. It also has high theoretical significance and practical value [1].

There isn't a fixed physical relationship between the features for color recognition and the types of color. Therefore, the traditional mechanism modeling methods are not satisfied the needs of color recognition of bobbin sorting machines. In recent years, the artificial intelligence methods have been developed to a significant level. And the Artificial Neural Network (ANN) is one of the most popular algorithms. ANN has good abilities for solving nonlinear problems. Thus, a neural network is often viewed as a "universal approximator". That is, neural networks have the ability to provide flexible mapping between inputs and outputs [2-5]. The ANN strategy has been used widely in the field of color recognition. Yuling Jiang [1] proposed a SOM algorithm for machine eye color recognition, and established an ANN model of color recognition. Xinliang Lu [6] used ANN based color recognition method on the RoboCup field. A three layers neural network is established for color recognition. Xuyu Li [7] built the color recognition based on Elman neural network. In the process of applications, ANNs exhibit good performance.

The remainder of this paper is organized as follows. In section 2, we present background information about Color Space and BP Neural Network, then a color recognition system based on the BPNN is established for bobbin sorting machine. Section 3 shows the experiments for the color recognition system for bobbin sorting machine by using BP neural network method. Conclusions from this study are summarized in section 4.

2. Research Method

2.1. Color Space

Human eye is more sensitive to red, green and blue lights, it is like a three-color receiver system. It has been proved that every natural color can be achieved by using different proportions of red, green, and blue (Figure 1). Normally, a color can be described by three

relatively independent attributes, and these three variables constitute a space coordinates, namely, a so-called color space. Therefore the study of color character of bobbin must be conducted in a specific color space. In our study, we refer to three different color spaces, i.e. RGB color space, CIE XYZ color space and Lab color space.

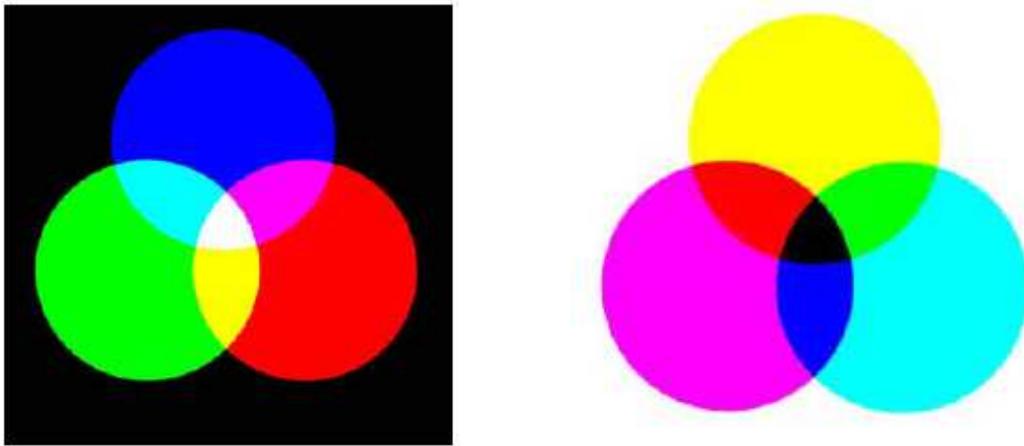


Figure 1. Diagram of trichromatic principle

1. RGB color space

According to trichromatic principle, every color can be achieved by using different proportions of red, green, and blue. Therefore it can be represented in a three-dimensional space, RGB color space. The value of each variable is ranging from 0 to 255, the color gets brighter when the number gets higher (Figure 2) [8-9].

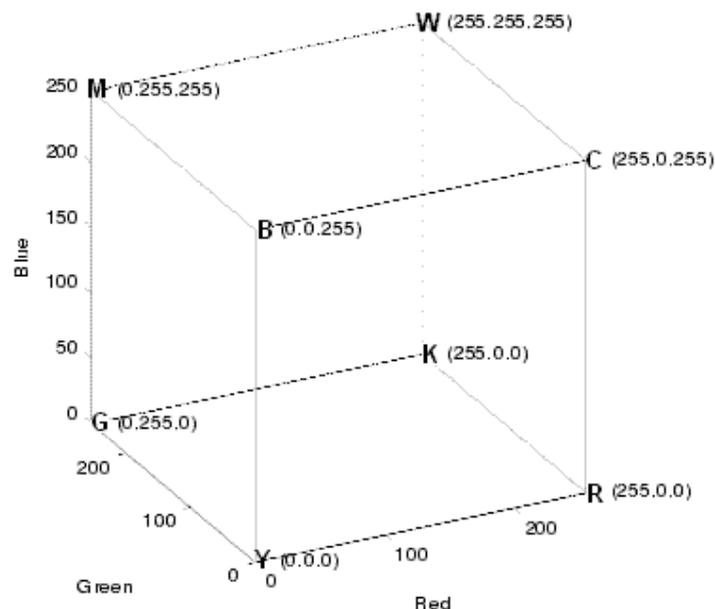


Figure 2. Three orthogonal axes represent R,G and B respectively. The maximum of these three variables is 255. The eight apexes represent red (R), green (G), blue (B), purple (C), cyan (M), yellow (Y), white (W) and black (K) in printing color.

2. CIE-XYZ color space [10]

CIE-XYZ color space based on CIE-RGB color space, it is established by three false color X, Y and Z. It successfully keep negative value from happening like in the CIE-RGB color space. Besides, the CIE-XYZ color space is more convenient and visual. In CIE-XYZ color space, the values of three-primary colours which match each color of the equal energy spectrum are being normalized. Here, X represents red primary colours, Y represents green primary colours and Z represents blue primary colours. They are not so-called physically real colours, but three made-up colours. The mathematical manipulations between CIE-RGB and CIE-XYZ are as follow:

$$\begin{aligned} X &= 0.490R + 0.310G + 0.200B \\ Y &= 0.177R + 0.812G + 0.011B \\ Z &= 0.010G + 0.990B \end{aligned} \quad (1)$$

3. CIE Lab Standard and transformation from RGB color space to Lab color space

The color information (R, G and B) of bobbin and yarn is collected by the color sensor. The membership of collected color should be consistent with the color be seen by eyes. So the CIE1976Lab standard is used to transform the color from RGB color space to Lab color space. First, the color image from color sensor is transformed from RGB space to XYZ space by the following transformation matrix.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.5164 & 0.2789 & 0.1792 \\ 0.2963 & 0.6192 & 0.0845 \\ 0.0339 & 0.1426 & 1.0166 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (2)$$

Second, the image is transformed from XYZ space to Lab space by the following formulas:

$$\begin{aligned} L &= 116 \left(\frac{Y}{Y_n} \right)^{\frac{1}{3}} - 16 \\ a &= 500 \left[\left(\frac{X}{X_n} \right)^{\frac{1}{3}} - \left(\frac{Y}{Y_n} \right)^{\frac{1}{3}} \right] \\ b &= 200 \left[\left(\frac{Y}{Y_n} \right)^{\frac{1}{3}} - \left(\frac{Z}{Z_n} \right)^{\frac{1}{3}} \right] \end{aligned} \quad (3)$$

Here, (X, Y, Z) are three Eigen values of collected color. (X_n, Y_n, Z_n) are the stimulus values of stimulus reflected from objects to the observer in the eyes, when the illuminants with CIE standard irradiation in the diffuse reflectance of the object can be fully realized. Generally, $X_n = 95, Y_n = 100, Z_n = 108.89, X/X_n > 0.008856, Y/Y_n > 0.008856$. L indicates the brightness, a, b are color components which reflect the size of the chroma. When one of $X/X_n, Y/Y_n$ and Z/Z_n is bigger than 0.008856, the formulas will be:

$$\begin{aligned} L &= 903.3 \left(\frac{Y}{Y_n} \right) \\ a &= 3893.5 \left(\frac{X}{X_n} - \frac{Y}{Y_n} \right) \\ b &= 1557.4 \left(\frac{X}{X_n} - \frac{Y}{Y_n} \right) \end{aligned} \quad (4)$$

2.2. BP Neural Network and Color Space Transformation Based Color Recognition

It has been proved that for any continuous function with a closed interval can be used with a BP neural network which contain hidden layer to achieve functional approximation from N-dimension to M-dimension, therefore, in our study, we establish a BP neural network with three layers.

The process of establishment of BP neural network is the process of solving the various parameters of the network structure. After the selection of the number of hidden layers, the selection of network structure parameters including the number of nodes of the input layer, output layer and hidden layer and the selection of initial weight and algorithm. Here, the the number of the input nodes and output nodes are determined by the actual problem. In the study of color recognition, each color has three Eigen values R, G and B, therefore, the number of nodes of input layer is 3. After the investigation of bobbin color and yarn color in textile mills, we will need to distinguish purple, green and yellow. Therefore, the number of nodes of output layer is 3. The number of nodes of hidden layer is determined by an empirical formula:

$$m = \sqrt{n+l} + \alpha \quad (5)$$

Here, m is the number of nodes of hidden layer, n is the number of nodes of input layer, l is the number of nodes of output layer, α is regulation parameter, $\alpha \in 1 \sim 10$. By using simulation comparison, the network achieves the best performance when the number of nodes of hidden layer is 10. The model diagram of BP neural network based color recognition is shown in Figure 3.

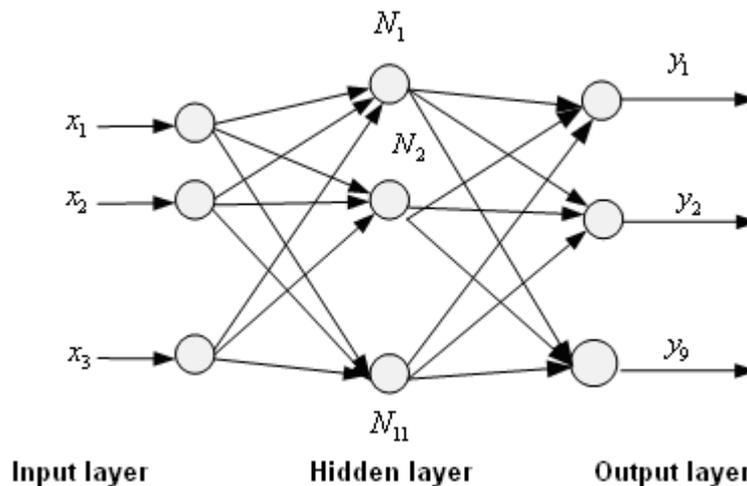


Figure 3. The model diagram of BP neural network based color recognition

2.3. Adaptive Change of Learning Rate

The derivation of the BP neural network algorithm base on the gradient method, the learning rate α and β represent the amplitudes of adjustment. There are many contradictions between learning rate and convergence rate. At the flat area, the learning rate is relatively small, resulting in the increase in the number of interactions, and the convergence is slow. However, at the part where dramatic changes existed, the learning rate is large, resulting in the increase of error and the number of interactions, affecting the convergence rate. The contradiction between learning rate and convergence rate can be solved by dynamic change of the learning rate according to the error trend, namely, adaptive change of learning rate [11].

The idea of adaptive change of learning rate: First, choose an initial learning rate, if the error increases after iteration, then the learning rate is multiplied by a number between 0 and 1. If the error decreases after iteration, then the learning rate is multiplied by a number larger than

1. In the network training process, the learning rate will be adjusted only after the entire sample library finish the learning process [12]. The adjustment formula is shown below:

$$\alpha(n+1) = \begin{cases} \alpha(n)P, \Delta E < 0 \\ \alpha(n)Q, \Delta E > 0 \\ \alpha(n), \Delta E \end{cases} \quad (6)$$

Here, $\Delta E = \Delta E(n+1) - \Delta E(n)$, $P > 1$, $0 < Q < 1$. For another coefficient β , the same method can also be used. We chose the initial learning rates as follow: $\alpha = 0.04$, $\beta = 0.04$. The adjustment factor of learning rate: $P = 1.2$, $Q = 0.8$.

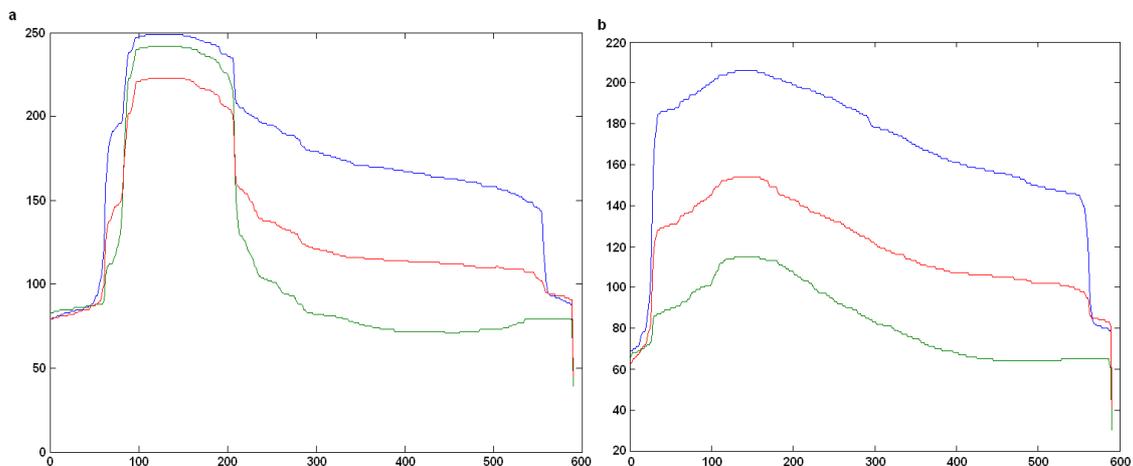
3. Results and Analysis

The image of yarn coiled bobbin captured by a CCD camera is shown in Figure 4.



Figure 4. Image of yarn coiled bobbin

The color recognition algorithm is the core of the whole system, the wave forms of three primary colours of different bobbins are shown in Figure 5.



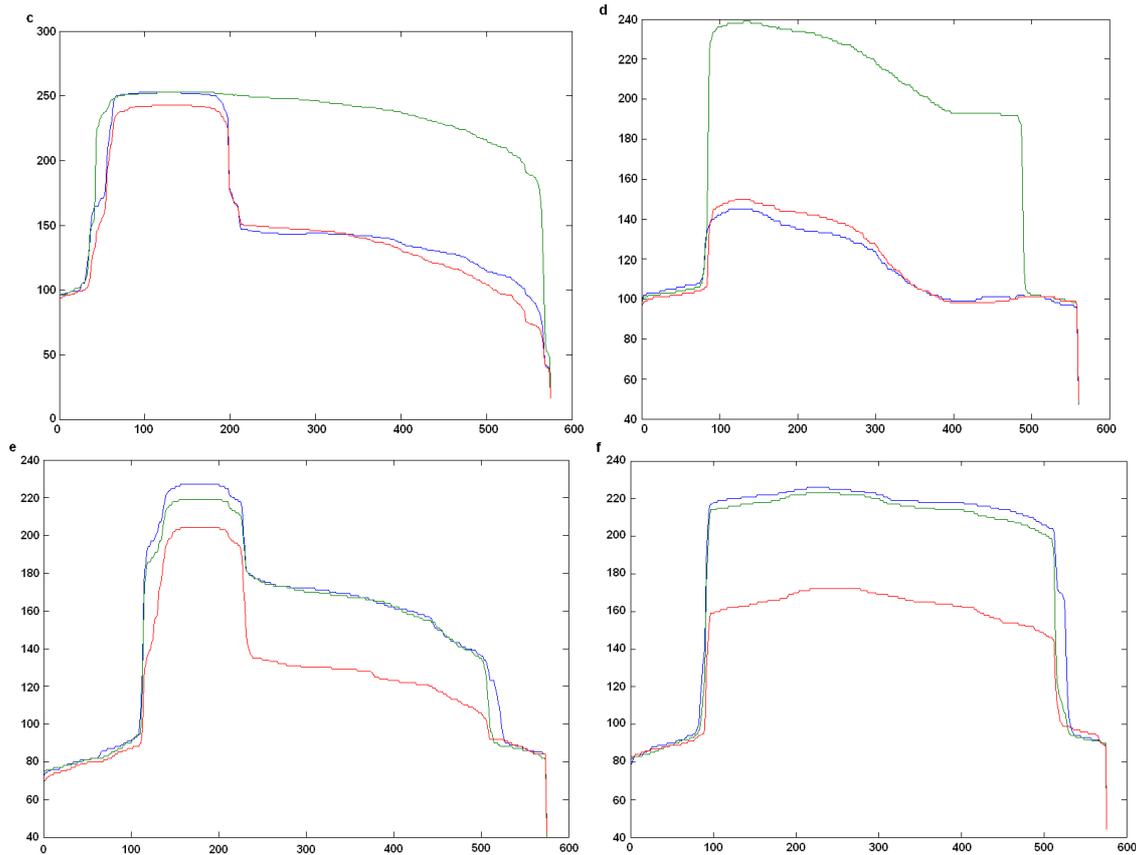


Figure 5. The wave forms of three primary colours of different bobbins. (a) The portion with yarn on purple bobbin. (b) The portion without yarn on purple bobbin. (c) The portion with yarn on green bobbin. (d) The portion without yarn on green bobbin. (e) The portion with yarn on yellow bobbin. (f) The portion without yarn on yellow bobbin

From the results of simulation, in the RGB color space, the portion with yarn has an obvious difference from the portion without yarn. The RGB experimental data of bobbins with different colors are shown in Table 1.

Table 1. RGB experimental data of bobbins with different colors

color	R	G	B
The portion with yarn on purple bobbin	250	250	250
The portion without yarn on purple bobbin	150	110	200
The portion with yarn on green bobbin	240	250	250
The portion without yarn on green bobbin	140	240	140
The portion with yarn on yellow bobbin	200	220	220
The portion without yarn on yellow bobbin	160	220	220

We chose 2200 colours as neural network training set which uniformly distribute in the RGB color space, then we chose another 39 colors as testing set. We acquired different frequency values of Red, Green, Blue and Clear from training set (Figure 6) and transform them from RGB color space to Lab color space as sample set. The normalized sample set is the input of the BP neural network. Then clustered in purple, green and yellow according to the chromatic aberration.

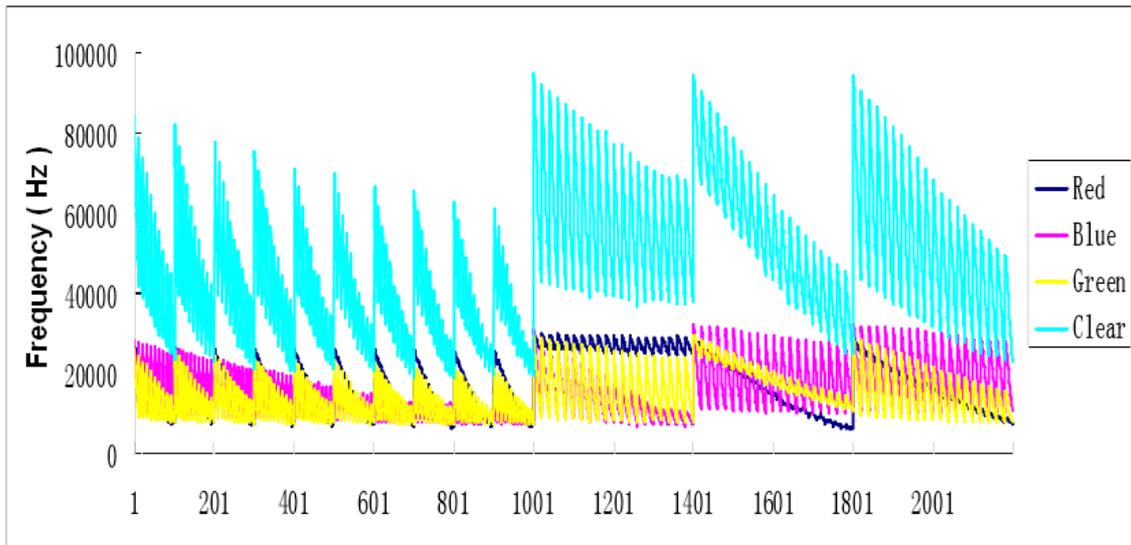


Figure 6. Frequency values of three primary colours of 2200 colors.

We set the eigenvector of normalized sample set and corresponding values in Lab color space as training paris for the training of the BP neural network. Considering the effect of root mean square error and training number, we set the training number as 3000 times and convergence value as 0.001. the curve of learning rate with fixed training number and error goal is shown in Figure 7. The result of clustering of training sample set and testing set are shown in the table 2.

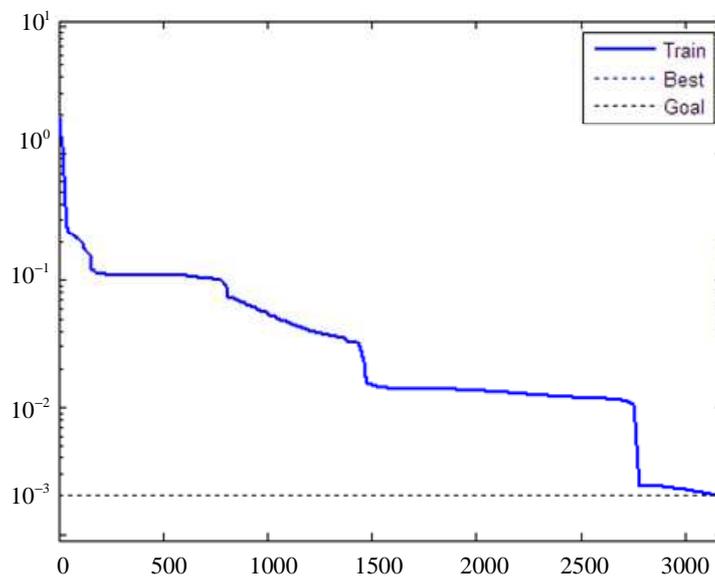


Figure 7. The relation between learning rate and training number, the horizontal axisis training number, the vertical axis is learning rate

Table 2. Result of clustering

Sample	Accuracy (%)	Error Rate (%)
2200 training sample	98.56	1.44
39 testing sample	97.89	2.11

4. Conclusion

In order to fit the needs of color recognition during the process of textile industry, the artificial intelligent algorithm is selected to build the color recognition model for bobbin sorting machine. For improving the performance of color recognition model, BP neural network has been used to build the model. The real data from bobbin sorting machine are used to build and test the models. The experiments show the color recognition model has a good performance of learning and generalization. The color recognition model for bobbin sorting machine can satisfy the needs of textile industry process.

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