A New Method of Resistor's Color Rings Detection Based on Machine Vision

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***Abstract*—It is one of the common tasks of machine vision defect detection to judge whether the resistance of PCB board is correct or not. The traditional detection method is to use the color industrial camera to take pictures, then transform the image from the RGB color model to the HSI / HSV color model, according to different colors in the new color space have different characteristics to split it out. However, this method can not meet the requirements of industrial which asked to detect a variety of defects in one workplace, and the segmentation threshold is difficult to set due to the resistance's mirror reflection. Therefore, this paper presents a new color ring recognition method which use Retinex algorithm and BP neural network classifier to distinguish color rings and use the image took by black and white industrial camera. Experiments show that the method has high accuracy and can meet the requirements of industrial defect detection.**

***Index Terms*—Machine vision, Color rings, Retinex, Neural network classifier**

I. Introduction

Defect detection of electronics industry use machine vision is universal for now. And color rings resistor is the most common electronic components in electronics industry[1]. Machine vision defect detection system often asked to check out resistor in PCB board which resistance value suitable or not. According to the Chinese national standard GB/T2691-2016/IEC60062:2004, users can identify resistance value of the color rings resistor by twelve color: black, brown, red, orange, yellow, green, blue, purple, gray, white, gold and silver.

To transform the photo's color model from RGB to HSI or HVS[2] [3], setting thresholds to segment photo, and finding out the value of resistor which is the normally plan in resistor defect detection by machine vision at present. But compared with other defect detection projects which often use black and white industrial camera, it need camera to take color pictures. So the machine vision defect detection system should increase more expensived color industrial camera and a new workplace.

Therefore, this paper propose a new method to distinguish color rings by black and white photo. It uses black and white industrial camera to take pictures in fixed defect detection source, then do some image preprocessing, especially use Retinex algorithm processing picture to remove some light effects, finally use neural network classifier to distinguish color rings. The experiments proves that the method has high reliability and can be applied to the actual industrial production and application.

This paper is organized as follows: The second section introduces the traditional method which transform RGB picture to HSI color model; the third section proposes a new method use neural network classifier to distinguish color rings; Finally, the experiment, confirm the new method can effectively identify the resistance color rings as the traditional method.

II. Method of Color Ring Distinguish Based on HSI Color Model

According to the Chinese national standard, the color rings resistor use twelve color to mark resistance value: black, brown, red, orange, yellow, green, blue, purple, gray, white, gold and silver. Each color represents a valid number or multiplier(show in table I), can read the resistance value by the color ring arrangement(show in figure 1).

TABLE I
Resistance value corresponds to the color

Color	Effective Number	Multiplier	Allow Deviation
silver	-	10^{-2}	$\pm 10\%$
gold	-	10^{-1}	$\pm 5\%$
black	0	1	-
brown	1	10	$\pm 1\%$
red	2	10^2	$\pm 2\%$
orange	3	10^3	$\pm 0.05\%$
yellow	4	10^4	-
green	5	10^5	$\pm 0.5\%$
blue	6	10^6	$\pm 0.25\%$
purple	7	10^7	$\pm 0.1\%$
gray	8	10^8	-
white	9	10^9	-

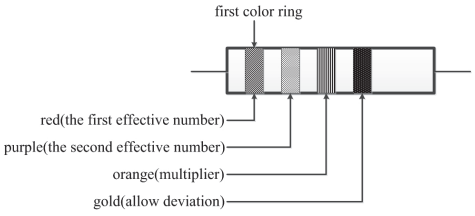


Fig. 1. Resistance value is 27,000 Ω and allow deviation is $\pm 5\%$

The HSI color space is very important color model for image processing applications because it represents colors similarly how the human eye senses colors. It represents every color with three components: hue(H), saturation(S), intensity(I)[3]. The figure 2 illustrates how the HIS color model represents colors.

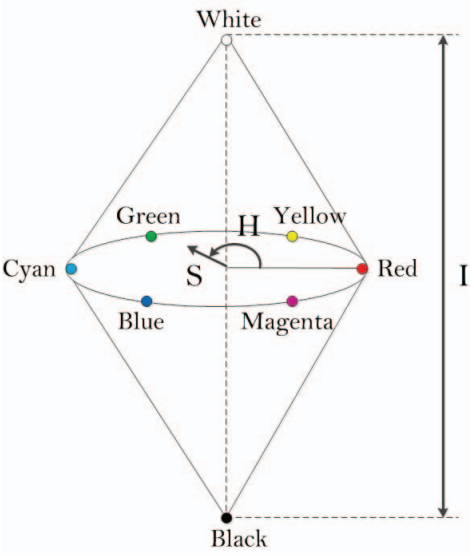


Fig. 2. HSI color model

The Hue component describes the color itself in the form of an angle between [0,360] degrees. 0 degree mean red, 60 degrees is yellow, 120 degrees means green, 240 degrees means blue and 300 degrees is magenta. The Saturation component signals how much the color is polluted with white color. The range of the Saturation is [0,1]. The Intensity range is between [0,1] and 0 means black, 1 means white. The formula convert RGB color model to HSI color model show in (1)[5].Where $\theta = cos^{-1}\left(\frac{(R-G)+(R-B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}}\right)$.

$$H = \begin{cases} \theta, & G \geq B \\ 2\pi - \theta, & G < B \end{cases}$$
$$S = 1 - \frac{3min(R,G,B)}{R+G+B} \quad (1)$$
$$I = \frac{R+G+B}{3}$$

The traditional color rings recognition method uses the median filter and other means to pre-process the image at first. And then using the formula(1) to convert the image from RGB to HSI(show in figure 3), due to the different colors have different Hue, Saturation and Intensity values, selecting a group of appropriate thresholds which can separate different colors(show in figure 4)[6]. Finally, remapping back the image which dividing by the threshold values to the original image, positioning color ring position, and outputing color ring recognition result(show in figure 5).

(a) Pictre in RGB color space (b) Pictre in HSI color space

Fig. 3. RGB picture (left) and HSI picture (right)

(a) Red color segmentation (b) Brown color segmentation

Fig. 4. Color Segmentation

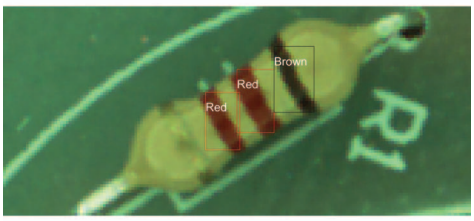


Fig. 5. Distinguish color rings by RGB to HSI

As described above, the traditional color ring recognition method need programmers to spend much time trying to set a good split threshold, while the resistor existence of the mirror reflection problem increases the difficulty of the threshold selection.

III. Method of Color Ring Recognition Based on Neural Network Classifier

In order to solve the above problems, this paper presents a new method based on the black and white industrial camera to take pictures and use the neural network classifier to distinguish the resistor color rings. The flow chart of the method is as follows(show in figure 6): After do some pre-process like filter to the image, use Retinex algorithm to weaken the impact of light on subsequent image recognition[7]. Next, input iamge to BP neural network classifier line-by-line, to get multiple images of different colors which split by neural network classifier. Finally, put the image back to the original image, position the color ring and output result.

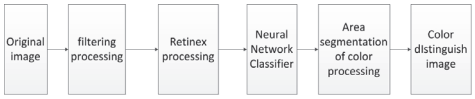


Fig. 6. The flow chart of color recognition by Neural Network Classifier

A. Retinex algorithm

The Retinex algorithm was proposed by Land in 1963, it base on color constancy theory: The color of the object is determined by the object's ability to reflect the light, and the color of the object is not affected by the non-uniformity of the light, with consistency. The Retinex algorithm considers that the image S acquired by the camera is composed of the incident image L and the reflected image R(show in figure 7), by removing the components of the incident image L from the image S, the influence of the light on the image can be greatly reduced, and the basic color characteristics of the image can be restored[8].

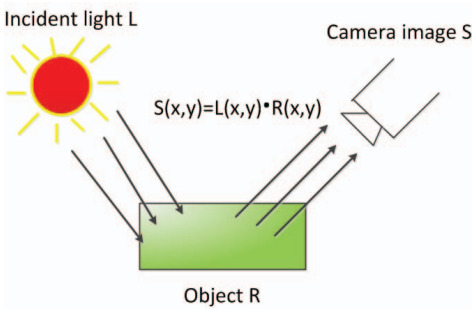
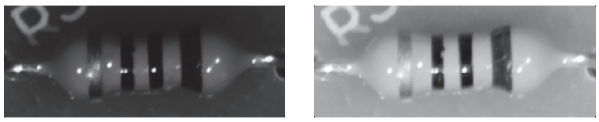


Fig. 7. Retinex algorithm principle

There are many algorithms based on Retinex principle. Among them, Single Scale Retinex (SSR), multi-scale retinex (MSR), multi-scale retinex with color restoration (MSRCR) are widely used. In this paper, use the MSR algorithm to process the image which obtained by black and white industrial camera, the algorithm formula is as follows[9]:

$$r_i(x,y) = \sum_{j=1}^{k} W_j\{logS_i(x,y) - log[S_i(x,y) * F_j(x,y)]\} \quad (2)$$

Where k is the number of Gaussian Surround function, generally have high, medium and low three scales. Meanwhile, the weight of each scale is the same, so $W_1 = W_2 = W_3 = \frac{1}{3}$. $S_i(x,y)$ is the image on each channels, beacause of use black and white industrial camera to take pictures, the iamge just have one channel, the channel number $i = 1$. Finally, transform logarithmic field $r_i(x,y)$ to real field $R_i(x,y)$, $R_i(x,y)$ is the reflected image which reduced the influence of the light(show in figure 8).



(a) The original image (b) The Retinex processed image

Fig. 8. Retinex processing Compared

B. Neural Network Classifier

BP neural network is a classical neural network, which uses the error back propagation algorithm to train the neural network weights, so that the network has a faster convergence[10][11]. BP neural network consists of input layer, hidden layer and output layer, each layer contains a certain number of neuronal cells, the information is transmitted through the connection between the neurons and the layers, but the neurons in the layers are independent of each other[12]. The neuron processes the input information through the activation function and the cell threshold, and the network learns by adjusting the connection weights between the neurons. The logistic function and the softmax function is the most popular activation functions.

$$\sigma(x) = \frac{1}{1+e^{-x}} \quad (3)$$

$$P(i) = \frac{exp(\theta_i^T x)}{\sum_{k=1}^{K} exp(\theta_k^T x)} \quad (4)$$

The BP neural network classifier uses three layers of cell structure, one input layer, one hidden layer and one output layer. Hidden layer use logistic function(formula(3)) and output layer use softmax function(formula(4)). The network train with scaled conjugate gradient backpropagation. The classification principle show in figure 9, input iamge line-by-line, to get multiple images of different colors which split by neural network classifier.

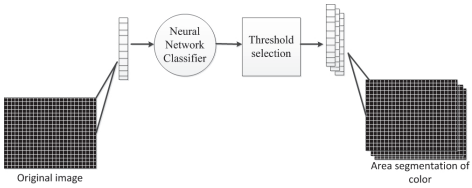
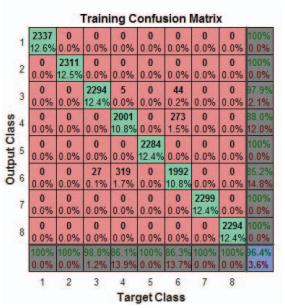
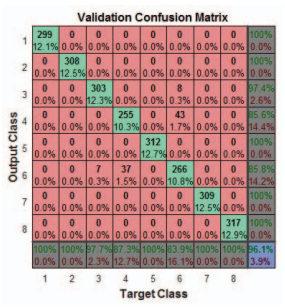


Fig. 9. Classification Principle of Neural Network Classifier

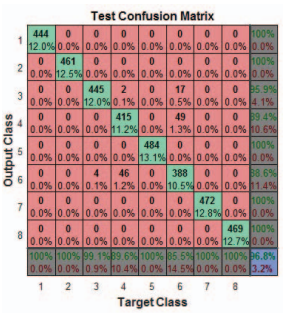
Taking the eight colors of black, blue, brown, green, orange, purple, red and yellow as an example, construct the neural network color classifier, it train results are shown following(show in figure 9 and figure 10). According to figure 10, the area of ROC(Receiver Operating Characteristic) is more than 0.8, it confirmed neural network color classifier have a better effect and strong ability to promote.



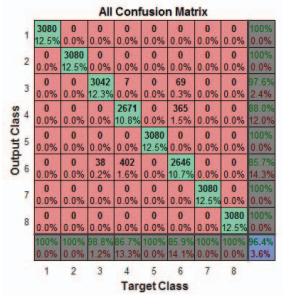
(a) Train confusion



(b) Validation confusion

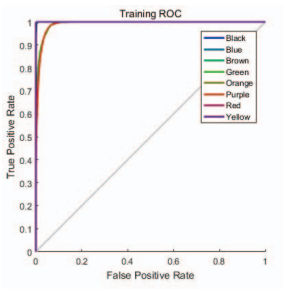


(c) Test confusion

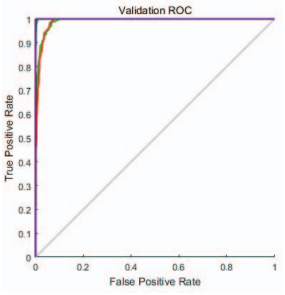


(d) All confusion

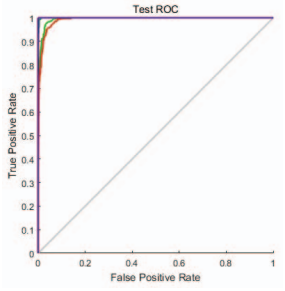
Fig. 10. Neural network classifier test results:Confusion



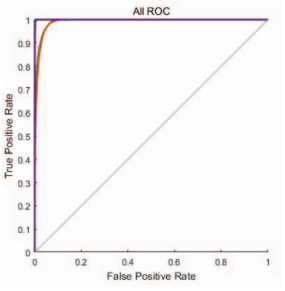
(a) Train ROC



(b) Validation ROC



(c) Test ROC

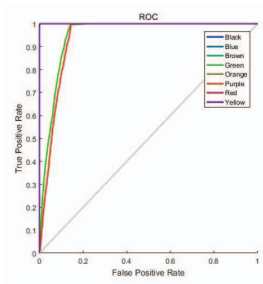


(d) All ROC

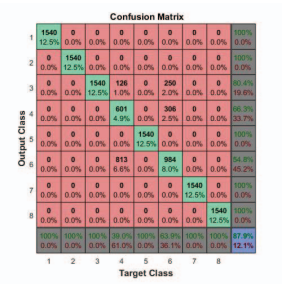
Fig. 11. Neural network classifier test results:ROC

IV. Expermental Result

To test the BP neural network classifier, some color card images which take by black and white industrial camera have been seleted. Figure 12 shows the practical effect of the classifier which have 87.9% correct rate and well ROC. It can distinguish all eight colors well(show in figure 13).



(a) ROC



(b) Confusion

Fig. 12. Neural network classifier test results

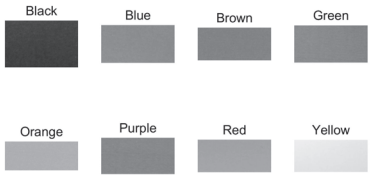


Fig. 13. Distinguish color card by Neural Network Classifier

Next, use resistance to test neural network classifier. Input the image which take by black and white industrial camera and uesed MSR processed(as figure 8(b)). The neural network classifier output the separate images ablout different colors(show in figure 14). Finally, according separate iamges position the color rings and show it in the original image(show in figure 15).

(a) Neural Network Classifier distinguish black color

(b) Neural Network Classifier distinguish brown color

Fig. 14. Retinex processing Compared

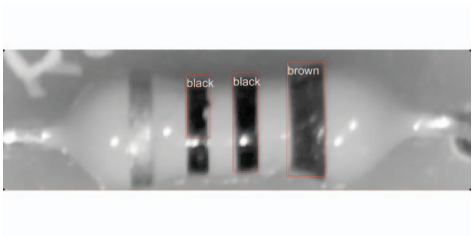


Fig. 15. Distinguish color rings by Neural Network Classifier

V. Conclusion

This paper presents a new color rings classification method based on black and white industrial camera images. Experimental verification the neural network classifier can distinguish color rings very well. Meanwhile, this method also has a generalization significance, it can meet requirement of Industrial defect detection which ask to detect a variety of defects just in single station.

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