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Research on Color Consistency for Color Marketing in Electronic Business System-----Taking Photographed Input Images for Examples

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Abstract

Color consistency is one of the key techniques for color marketing in color reproduction in electronic business system. A new color management model is presented based on analyzing the color rendering principles of digital camera color sensors. First, the standard color target for scanner is taken for experimental sample, and color blocks in color shade district are taken to substitute complete color space which can solve the difficulties of experimental sample selecting. Second, the paper introduces data collecting method and preprocesses collection data to create data bases to deduce the model. Third, BP Neural Network algorithm is improved through optimizing network structure, adjusting steps to speed up model's convergence and to build the selection strategy more conducive to the overall search, and then a new model for color correction of color sensors of digital camera is analyzed and deduced. Finally the experimental results show that the model can improve color management accuracy of color digital camera and can be used in color management in electronic business system practically.

Keywords

Color Reproduction, Color Management, BP Neural Network, Photographed Input Image.

1. Introduction

With the rapid development of electronic business, color consistency has become increasingly important in electronic marketing. As an indispensable image input device for electronic business system, color consistency of digital camera has developed into a research focus in related fields. As a matter of fact, digital camera involves a comparatively great color difference in taking photographs and the same object produces images with different color for different photograph conditions. Nevertheless, the color requirements for such industries as e-commerce, packaging and printing are quite high. For example, the same product represents its true color both under different photograph conditions and by different cameras. Because of different color characteristics described or represented by different equipment's, the different coloration space and the impossibility of direct conversion, the shooting results always come out as different RGB values for the same original sample or different colors displayed from the same RGB value. Thus, great troubles are generated in color identification as well as in consumers' understanding with the result of unnecessary damage. Therefore, color control of digital camera has become one of the most difficult pivotal technologies.

The major task of color management is to solve the difficulities of converting images between different color spaces with the view to minimize the distortion during the whole duplication process. The basic approaches involve three steps: first, a referential color space independent of equipments is selected; second, the equipments are characterized; finally, a relationship between the color space of each equipment and the referential color space independent of any

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equipment is established to provide a definite approach for data files when transferring between different equipments. The main focus here is to study the realization of precise color conversion between the RGB space that is dependent on equipment and the XYZ space that is independent through the means of digital camera color management. The XYZ color space mentioned is a universal standard color space that is independent color space recommended by CIE [1,2].

As for the image acquisition system, much emphasis is laid on the study of scanner color management. Meanwhile, only a few different concepts are proposed for the study of impending digital camera color management, and the ISO standard file related to digital camera characterization processing is currently in emendation. The current ways of color management for the image reproduction include parameter analysis method and black box method. The former is to construct a mathematical conversion model of RGB and XYZ with the parameters provided by the equipment and materials involved in the conversion. A case in point is to construct a color reproduction curve [3] through the analysis of the photographic features of photographic materials. Because there are various non-linear elements in the optical indicatrixes such as lighting spectrum curve, RGB color filter, characteristic curve of photographic transmission of photographic component and so on involved in the digital equipment, the parameter method has great difficulties when applied to the digital camera. The latter gets rid of the elements related to equipment in the color conversion and regards the overall system as a black box. Only the input and output color values of a certain number of standard color blocks undergo analysis and fitting control. Then, with the help of space relationship, they are interpolated to get the conversion relationship of other blocks. Matrix conversion method, polynomial-fitting algorithm and a conversion method based on BP neural network (BPNN) and machine learning all fall into this category. Black box method controls only input and output values and excludes the intermediate process of color conversion, so the conversion accuracy is not guaranteed. Furthermore, the accuracy of black box method depends on the selection of color blocks and improper selection may result in great error. Whether the color blocks are properly selected also depends on the quantity. Small number blocks result in large error while large number blocks result in low efficiency of algorithm[6-9].

BPNN is used to derive the management model here so as to avoid the difficulties to analyze the complex color reproduction curve of digital camera. Meanwhile, according to the mixture coloration principle of digital camera, the order of single color, double colors and three colors derive the model in turn so as to overcome the defection of low accuracy caused by ignoring the intermediate process of color conversion.

At the same time, the experimental color block selection plays a very important or even decisive role in the subsequent color error correction. As for color sample selection, the prevalent practice is to compile a program in which different kinds of color blocks are generated according to the progression of brightness and aberration and the blocks are mixed to form different colors. This method is that the color blocks are redisplayed after the digital camera is used to generate the color blocks, which is totally in disagreement with the actual image processing procedures. Thus, errors are produced artificially and the ultimate model produces great errors in the actual application. According to the coloration principle of digital camera, IT8/2 standard calibration target for the scanner is selected creatively as the experimental sample to avoid the error produced under the correction of display so as to solve the difficulities of selecting the experimental color blocks. Meanwhile, the color blocks on the standard calibration target are classified, the experimental color blocks of color scale area are selected to derive the model according to the coloration principle of digital camera, and other color blocks verify the model accuracy, so the problem of BPNN convergence speed is solved.

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2. Coloration Principle of Color Sensor of Digital Camera

The coloration principle of digital camera is quite complicated with small difference of different types of cameras. But generally speaking, the color values of each color are sensitized with different CCDs and a RGB value is worked out in signal processing. For instance, in a four million pixel CCD, there are one million sensitization units to sensitize red and blue respectively and two million to sensitize green. More pixels are devoted to green because human eyes are more sensitive to it. The study of human eyes indicates that upon effectively controlling the quantity of stimulus of the three additive primary colors of R, G and B coming into human eyes, the surface color of every object of the natural world is controlled. In color mixing, the three primary colors of R, G and B can be mixed to developed more colors and have the largest color domain. The coloration principle of digital camera is like this: the mixture of red and blue produces magenta,the mixture of green and red produces yellow,the mixture of green and blue produces cyan,the mixture of red,green,and blue produces white.

3. Data Collection

3.1. Measuring Equipment and Calibration Target

The Colortron Equipment is used here as color measuring equipment and Canon PowerShot G2 with 5 million pixels is used as the digital camera.

The standard test calibration target for scanner---IT8/2 calibration target used in this experiment was made by AgFa Corp. in 2005 with the serial number of 5x7c60103xx. Its coloration material is qualified for ISO12641 standard reflective color calibration target, as is shown in Fig. 1. Among its color scale area, there are three lines (column 13~ column 15) of color blocks of the three subtractive primary colors of yellow (Y), magenta (M) and cyan (C) extending from light to dark, three lines (column 17~19) of color blocks of red (R), green (G) and blue (B) extending from light to dark and still one line (column 16) of neutral color with increasing ash. Column 17~19 are the mixtures of two of Y, M and C three subtractive primary colors while column 16 are mixtures of Y, M and C three subtractive primary colors.

Fig. 1 Diagram of standard test calibration target

3.2. Data Measurement

To make measurement closer to the objective reality, the measured results of both calibration target and color values on the photograph images are recorded to reduce various errors resulted from impersonal measuring conditions.

(1) After 15 minutes of scanner preheating and white porcelain board demarcation, the picture of the whole calibration target is taken to measure its RGB and XYZ values. RGB value adoption range is 0~255 while the value adoption range of all the input values in BPNN is 0~1. As a result,

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all element values in RGB value database are normalized, i.e. database values are R/255, G/255 and B/255.

(2) Use the default setting to measure the RGB values of color blocks in the color scale area of the calibration target with Colortron. And after the normalization, a conversion RGB value database is built up for intermediate conversion to derive the color management model. Then, use Colortron to measure the RGB values of all the color blocks on the calibration target, and after the normalization, the verification database is established for model accuracy verification.

(3) Use Colortron to measure the XYZ values of color blocks in the color scale area of the calibration target to build up a conversion XYZ value database for intermediate conversion. Then, use Colortron to measure the XYZ values of all the color blocks on the calibration target to build up the verification XYZ value database for model accuracy verification.

4. Realization of Algorithm

4.1. BP Neural Network (BPNN)

BPNN has clear advantages in depicting non-linear relationship and strong function simulating capability. It not only has input and output-layer node, but also hidden-layer node. Its hidden-layer neurons adopt S type variation function and output-layer neurons use pure linear conversion function so that BPNN can be close to the corresponding relationship between any functions and data if there are enough hidden layers and neurons theoretically. Therefore, in the study of color management, the mapping relations among the color spaces of different equipment's can be derived through the training of standard output data and measurement data to complete their conversion. BPNN is generally consisted of three layers of neurons.

4.2. Monochromatic Model Derivation

Input is R, G and B values of monochromatic color blocks of Red, Green and Blue in the RGB values database of color scale area and reasonable output is X, Y and Z values in XYZ standard database to train the relations of monochromatic RGB and XYZ values. The algorithm is subject to BPNN generally. The people who applied the BPNN know that this model needs long time for large data training. So the model here was processed as follows in the actual application so as to speed up the model's convergence, whose detailed application flow is shown in Fig. 2.

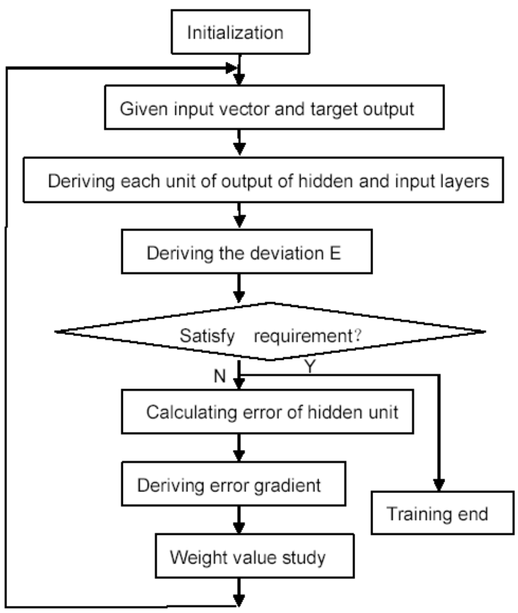

Fig. 2 Application flow of the model

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4.2.1. Confirmation of BPNN Weight and Threshold

Because of the non-linear characteristic of BPNN, the initial weight value and threshold have important effects on convergence speed of BP model. A key need is that the initial weight value makes each neuron close to zero in the accumulative input. In the actual algorithm of this experiment, the weight value and threshold are random number among -0.5~0.5 to make adequate adjustment with regard to the real convergence.

4.2.2. Network Structure Optimization

The algorithm trains the mapping relations between RGB and XYZ by RGB input and XYZ output. If the network structure is not optimized and there is only one hidden layer, RGB values are trained in 288 color blocks of calibration target which needs more than three hours.

First, according to the coloration principle of scanning object, there are only 36 input color blocks in the monochromatic algorithm so as to greatly reduce the model calculation amount and improve the algorithm efficiency.

Second, three layers of BPNN can realize the close corresponding relations between any functions and data theoretically. If RGB values are the input and XYZ are three input and output model structure of the output on normal basis, the amount of computation will be added greatly. For example, when three-layer, three-input and three-output network structures are used, the hidden-layer node is 70. After 84 color blocks of color scale area here are trained for one and half hours, average error is $E = 10$. Therefore, network structure here is optimized as: three-layer network structure with three inputs and one output, i.e. RGB values are inputted each time and the corresponding relations between RGB and XYZ functions are trained separately, so the algorithm efficiency and accuracy are obviously improved and the network structure used here is the one with one hidden layer, three inputs and single output.

4.2.3. Speeding up Network Convergence.

The selection of step length is very important in BP study. If the step length is large, the convergence will be fast. But oversize step length can result in the oscillation; small step length can avoid the oscillation and result in the slow convergence speed. Here uses the method of adding momentum term η shown in Formula 1.

$$w(n+1) = w(n) + \alpha \Delta w(n) + \eta \Delta w(n-1) \tag{1}$$

In Formula 1, $w(i)$ means the weight value and threshold of input layer and hidden layer, $\Delta w(i)$ means the weight value and threshold adjustment value derived from the gradient method, α means the constant, adoption value here is 0.3~0.5,and n means the iteration times. The third item in the formula memories the corrected direction of the last layer of weight value. When this layer of iteration error ΔE is less than zero, the function is convergent toward minimum value, so it is shown that the adjustment direction is right to enlarge the step length and speed up the convergence; when ΔE is more than zero, the function is not convergent, so it is shown that the adjustment direction is wrong to reduce the step length. The experiment shows that it is the most proper for η adoption value of 0~0.02 when ΔE is less than zero in the algorithm here.

With the help of the BP Neural Network algorithm previously devised, the single-color correction results can be realized. Table 1 shows the correction results of single color Red. X_b, Y_b, Z_b, X_q, Y_q, Z_q and ΔE in table 1 stand for the measured values of X, Y, Z (standard), the values of X, Y, Z computed by the modification model and the aberration between them respectively, in which, ΔE can be calculated by formula 2.

$$\Delta E = \sqrt{(X_b - X_q)^2 + (Y_b - Y_q)^2 + (Z_b - Z_q)^2} \tag{2}$$

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Table 1. Single color results of red

No.	X_b	Y_b	Z_b	X_a	Y_a	Z_a	ΔE
1	92.2	96.91	103.3	93.5	96.9	103.9	1.4
2	85.5	88.1	87.5	86.0	89.0	88.4	4.4
3	77.1	75.6	71.0	79.8	77.5	72.1	3.5
4	68.6	64.3	56.0	70.8	67.8	57.1	4.3
5	60.3	54.1	42.1	62.9	55.6	45.0	4.2
6	54.3	47.0	33.2	57.8	49.6	35.7	5.1
7	45.7	36.7	22.6	47.0	38.9	25.7	4.0
8	38.0	28.4	15.0	40.3	30.4	16.6	3.4
9	31.7	21.8	9.4	33.0	23.4	10.6	2.4
10	27.1	17.4	6.3	29.5	18.6	7.3	2.8
11	22.4	13.2	3.9	22.8	13.5	4.2	0.6
12	19.2	10.9	2.9	19.2	10.9	2.9	0

4.3. Dichromatic Model Derivation

According to the coloration principle of digital camera, the mixture of red and blue produces magenta, the mixture of red and green produces yellow, and the mixture of green and blue produces cyan. Their formulas are M=R+B,Y=G+R and C=G+B. Taking magenta as an example derives the relations of dichromatic RGB values and XYZ values, input data is the dichromatic color block in the scale area of calibration target, but the initial model of input is shown in Formula 3.

$$X(m) = \sum(X(r) + X(B)) \tag{3}$$

Because the additive coloration is not simple linear relation, the error in Formula 2 is corrected through inputting RGB values and XYZ values of magenta block, and corrected again through BP model. But if the initial model confirms general direction, the convergence speed of BP model can be quickened greatly.

With the help of the BP Neural Network algorithm previously devised, the double color correction results can be realized. Table 2 shows the correction results of double color magnate.

Table 2. Double color results of magnate

No.	X_b	Y_b	Z_b	X_a	Y_a	Z_a	ΔE
1	94.7	99.3	108.1	94.3	98.2	108.6	1.3
2	91.4	93.4	105.3	91.5	94.8	105.7	1.4
3	83.8	80.7	98.5	84.8	83.7	99.8	3.4
4	77.4	70.6	92.1	79.7	73.6	93.2	3.9
5	70.7	61.1	84.8	72.0	65.2	86.9	4.7
6	65.6	54.3	79.9	68.6	58.3	82.7	5.7
7	57.7	44.2	71 1	60.7	42.3	74.4	4.8
8	48.3	33.2	60.0	49.8	37.4	62.3	4.9
9	41.3	26.0	51.5	42.6	28.4	53.8	3.6
10	34.3	20.0	42.3	36.5	22.3	44.3	3.9
11	28.6	14.9	35.2	28.9	15.6	35.7	0.9
12	25.9	13.0	31.6	25.9	13.0	31.6	0

4.4. Trichromatic Model Derivation

According to the coloration principle of digital camera, the mixture of red, green and blue produces grey. In line with the same method, three corrections can derive the conversion relations of RGB values and XYZ values, i.e. the conversion relation of RGB space that is dependent on equipments and XYZ space that is independent of equipments.

5. Experiment Confirmation

The model is solved with C language, whose conversion accuracy is shown in Table 3 and Tab 4. Table 3 shows the verification results of 12 blocks in the black scale area of three-color mixture in the fifteenth column of the IT/2 calibration target. Since these are the color blocks of three-color mixture, the errors are total additive three-color errors, so are the area with largest error in color space conversion. Table 4 provides a conversion accuracy statistics for all the 288 color blocks in the calibration target through the algorithm of this paper, the polynomial fitting algorithm which is widely used and has its relatively high conversion accuracy and the BPNN algorithm [6,8] in this experiment. NBS aberration unit is the one adopted by American National Standards Institute. According to the research results of colorimetry, visual equivalency can be acceptable when $\Delta E \le 5\ NBS$ units.

Table 3. Verification data of model grey scale

No.	X_b	Y_b	Z_b	X_a	Y_a	Z_a	ΔE
1	94.9	99.1	103.2	94.0	99.9	103.1	1.2
2	81.4	85.0	90.9	84.0	90.9	98.2	9.7
3	64.1	67.4	70.4	69.9	73.1	80.7	12.1
4	49.5	52.0	54.5	56.3	58.7	64.0	13.4
5	38.4	40.6	42.2	45.2	46.8	48.0	10.9
6	30.5	32.5	33.6	37.0	38.4	42.0	12.2
7	21.3	22.2	23.9	26.1	27.1	29.8	8.8
9	8.9	9.0	10.5	7.5	8.0	9.1	1.8
10	5.2	5.4	6.4	2.7	2.9	3.4	3.4
11	3.3	4.2	4.7	1.0	1.2	1.1	4.6
12	2.0	1.9	3.2	0.5	0.5	0.3	3.5

Table 4. Conversion accuracy statistics of different algorithms

Algorithm	Accuracy(Unit: NBS)	
The algorithm of the paper	Average error	4.59
	Maximum error	9.86
	Number of blocks with an error larger than 5 NBS	12
Polynomial fitting algorithm	Average error	13.17
	Maximum error	28.66
	Number of blocks with an error larger than 5 NBS	73
BPNN algorithm	Average error	9.76
	Maximum error	15.96
	Number of blocks with an error larger than 5 NBS	33

6. Conclusion

With regards to the coloration principle of digital camera, special standard color blocks are selected to stand for the whole color space as the sample data, and BPNN fitting curve is applied to derive the color management model of digital camera through the gradual levels of single color, double colors and three colors and advance new methods and approaches for the color management of digital camera. This experiment shows that the model can realize the efficient

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management for the color conversion of digital camera. Although the derivation process is relatively complicated, only one correction is necessary to get the model for different digital cameras. In conclusion, the algorithm is reasonable and practical for the realization.

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