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Research on Color Consistency for Color Marketing in Electronic Business System

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Abstract: Color consistency for color marketing in electronic business system is one of important factors for online customers to choose products, so it is the key techniques to guarantee color consistency when color image transmit and converse among different color reproduction image devices in electronic business system. The paper, taking scanned input image for examples, advances a new color management model to keep color consistency through analyzing color rendering principle of scanners. First the parameters of Yule-Nielson equation are reinterpreted, making them can be used for non-printing dot image which only can be used for printing dot image originally; Second, standard color target is taken for experimental and color blocks in color shade district is taken to substitutes for complete color space which solves the difficulties of experimental color block selecting; Third, Yule-Nielson equation is used to deduce the model for scanner color management gradually though single color, double color and tricolor conversion correction, and polynomial curve generation algorithm is designed to fit error curve of single color, double color and tricolour. Finally, the experimental results show that the model can improve scanner color management accuracy and can guarantee color consistency for scanner in its engineering application.

Keywords: Color consistency, Color management, Yule-Nielson equation, Polynomial curve generation algorithm

1. Introduction

With the rapid development of domestic and overseas high technology, scanner, a popular image input device for electronic business system, has developed into an indispensable product or tool in computer multimedia processing. As a matter of fact, scanner involves a comparatively great color difference in input image and the same object may produce images with different colors for different scanning conditions. Nevertheless, color requirements for such industries as electrical business, packaging and printing are quite high. For example, the same product represents its true color both in different scanning conditions and by scanner of different brands. Because of the different color characteristics described or represented by different equipments, their different imaging space and the impossibility of direct transformation, 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 color damage. Therefore, color control of scanner has become one of the most difficult pivotal technologies.

The major task of color management is to solve the question of transforming images between different color spaces with the view to minimize the distortion during the whole duplication process. The basic approach involves three steps: first, a referential color space independent of equipments is selected; second, the equipment are characterized; finally, a relationship between the color space of each equipment and the referential color space independent of any 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 transformation between the YMC space that is dependent on equipments and the XYZ space that is independent through the means of scanner color management. The XYZ color space mentioned is a universal standard color space that is independent of equipments recommended by CIE [1] [2].

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As for color management of image acquisition systems, much emphasis is laid on the study of scanners. The current ways of color management include parameter method and black box method. Parameter method is to construct a mathematic transformation model of YMC and XYZ with the parameters provided by the equipments and materials involved in the transformation. A case in point is to construct a color reproduction curve through the analysis of the color features of printers [3]. Due to the extraordinary complexity of the color characteristics curve of the specific equipment, the specific dye or oil and even the specific paper involved in scanner and the various non-linear elements, parameter method holds great difficulty when applied to scanner. Black box method gets rid of the elements related to equipments and regards the overall as a black box. Only the input and output color values of a certain number of standard color blocks undergo the processes of analysis and fitting control. Then, with the help of space relationship, they are interpolated for transformation equation of other blocks. Matrix transformation method,polynomial-fitting algorithm and a transformation method based on 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 transformation, transformation accuracy is not ensured. Furthermore, the accuracy of black box method depends on the selection of blocks and improper selection may result in great error. Whether the blocks are properly selected also depends on the number. Small number results in great error while large number results in low efficiency of algorithm[3,4,5,6,7,8].

The Neugebauer Equation and the Yule-Nielson Equation are the ideal imaging mathematic models for printing dot images and can only be applied to printing dot images. The parameters of the dot percentage of the two equations are reinterpreted as color percentage here in order that the modified equation can be extended to be applied to the non-dot images of scanner. Then, in terms of polynomial fitting algorithm, aberrations of scanner are studied through the three levels of single color, double colors and three colors and the equation is modified level by level. In so doing, a new approach is come up with for scanner color management.

2. Rendering Principle of Scanner

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 the color mixture, the three primary colors of R, G and B can be mixed to developed more colors and have the largest color domain. Therefore, yellow is selected to control the blue light because it is a complementary color of blue to control (absorb) the blue light effectively; in a similar way, the green's complementary color— Magenta is selected to control the green light; the red's complementary color— Cyan is selected to control the red light. Changing the thickness (or density) of yellow, magenta and cyan can easily change the absorbing capacity of three primary color lights of red, green and blue and complete the quantity of stimulus value of red, green and blue controlling to enter human eyes. Therefore, yellow, magenta and cyan are called three subtractive primary colors.

3. Data Collection

The Colortron Equipment is used here as color measuring equipment and Philips 220EW8 with resolution 1680*1050 is used as color scanner.IT/2 calibration target, the standard test calibration target for scanner, was made by AgFa Corp. in 2005 with the serial number of 5x7c60103xx. Its imaging material is qualified for ISO12641 standard reflective color calibration target, as is shown in Fig. 3. Among its color scale area, there are three lines (column 13∼ column 15) of 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 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 mixtures of two of the three subtractive primary colors while column 16 are mixtures of the three subtractive primary colors.

To make measurement more close to the objective reality, measured results of both calibration target and color values on the photograph images are recorded to avoid a variety of errors resulted by impersonal measuring conditions. (1) After 15 minutes of preheating of scannerand white porcelain board demarcation, the picture of the whole calibration target is took and the RBG and XYZ values are measured of the picture. (2) Use the default setting to measure the RGB values of blocks in the color scale area of the calibration target with Colortron and after normalization, to build up a RGB value database for intermediate transformation to derive the color management model. Then, use Colortron to measure the RGB values of all the blocks on the calibration target to build up verification database for accuracy verification.(3) Use Colortron to measure the XYZ values of blocks in the color scale area of the calibration target and to build up a transformation XYZ value database for intermediate transformation. The, use Colortron to measure the XYZ values of all the blocks on the calibration target to build up a verification XYZ value database for accuracy verification.

4. Derivation of Algorithm

4.1. Yule-Nielson Equation

The Neugebauer equation is showed in formula 1 [9].

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = f_w \begin{bmatrix} X_w \\ Y_w \\ Z_w \end{bmatrix} + f_y \begin{bmatrix} X_y \\ Y_y \\ Z_y \end{bmatrix} + f_m \begin{bmatrix} X_m \\ Y_m \\ Z_m \end{bmatrix} + f_c \begin{bmatrix} X_c \\ Y_c \\ Z_c \end{bmatrix} + f_r \begin{bmatrix} X_r \\ Y_r \\ Z_r \end{bmatrix} + f_g \begin{bmatrix} X_g \\ Y_g \\ Z_g \end{bmatrix} + f_b \begin{bmatrix} X_b \\ Y_b \\ Z_b \end{bmatrix} + f_{bk} \begin{bmatrix} X_{bk} \\ Y_{bk} \\ Z_{bk} \end{bmatrix}. \quad (1)$$

in formula 1:

$$\begin{aligned} f_w &= (1-c)*(1-y)*(1-m) & f_r &= y*m*(1-c) \\ f_y &= y*(1-c)*(1-m) & f_g &= y*c*(1-m) \\ f_c &= c*(1-y)*(1-m) & f_b &= c*m*(1-y) \\ f_m &= m*(1-c)*(1-y) & f_{bk} &= y*m*c \end{aligned}$$

In formula 1, y, m, c stands for the dot percentage of the three basic printing colors of yellow, magnate and cyan respectively. When two of them come as zero, a single color Neugebauer equation is developed. For example, the single cyan Neugebauer equation is developed when$y = 0$ and $m = 0$.Just like that, when one of them comes as zero, a double color equation is developed. X_w,Y_w,$Z_w$stand for the tristimulus value when all the three coloring material percentage come as zero, which are coming from the verification database.

X_y, Y_y, Z_y, X_m, Y_m, Z_m, X_c, Y_c, Z_c, X_r, Y_r, Z_r, X_g, Y_g, Z_g, X_b, Y_b, Z_b, X_{bk}, Y_{bk}, Z_{bk} stand respectively for the tristimulus value of yellow, magnate, cyan and the secondary colors, which are coming from the verification database.

The Neugebauer equation is an ideal mathematic model. In 1951, considering all kinds of real circumstances, Yule-Nielson modified the equation with an exponent n (usually n ranges from 0.5 to 0.65)[7]. The Yule-Nielson equation is showed in formula 2.

The parameters y, m, c in the Neugebauer equation and the Yule-Nielson equation stand for the dot percentage of the basic printing colors of yellow, magnate and cyan. Consequently, the equations are only applicable to printing dot imaging while the standard calibration target and many printers employs the imaging method of color addition and cannot be applied to the equations. The parameters y, m, c are reinterpreted as color percentage here to enable color transformation between non-dot images.

$$\begin{bmatrix} X^{\frac{1}{nx}} \\ Y^{\frac{1}{ny}} \\ Z^{\frac{1}{nz}} \end{bmatrix} = \sum_{1}^{8} f_i \begin{bmatrix} X_x^{\frac{1}{n}} \\ Y_W^{\frac{1}{ny}} \\ Z_W^{\frac{1}{nz}} \end{bmatrix}. \quad (2)$$

4.2. Polynomial Curve Generation Algorithm

Presuppose the parameter curve equation as formula 3, in which x, y are the step-length of curve generation.

$$x = f(t), y = g(t), t \in [0,1]. \quad (3)$$

Since the function coefficient of$f(t)$ is presupposed to be a rational number, according to the Langrangian middle value theorem, there is a positive integer$N$. When $N = n^k$, set$\varphi(i) = N \cdot f(\frac{i}{n})$and the $k$degree integral coefficient polynomial$x = f(t)$ can be transformed to formula 4, in which x_i and the remainderz_i are also integers, and $|z_i| \leq N/2$.

$$My_i = \psi(y_i) + z_i. \quad (4)$$

For the same reason, k degree integral coefficient polynomial $y = g(t)$ can be transformed to formula 5, in which y_i and the remainder z_i are also integers, and $|z_i| \leq M/2$.

$$My_i = \psi(y_i) + z_i. \quad (5)$$

Also, according to the demonstration of Huang Youdu and others, theorem 1 and theorem 2 hold and determinant H is a Bézier polynomial described with Bernstein bases $\{C_u^i(1-t)^{u-i}t^i, i = 0,1,\ldots u\}$.

Theorem 1. Presuppose $f(t) = \sum_{i=0}^{n} x_i C_n^i (1-t)^{n-i} t^i$, and $|f'(t)| \leq u \cdot \max_{0 \leq i \leq u-1} |x_{i+1} - x_i|$ when defined in the range $[0,1]$.

Theorem 2. Presuppose $\alpha = (1-t)^u$, $C_u^1(1-t)^{u-1}t$, $\ldots$, $C_u^k(1-t)^{u-k}t^k, \ldots, t^u)^T$ and $\beta = (1, t, \ldots, t^u)^T$, then $\beta = H_u^{-1}\alpha$ and $\alpha = H_u\beta$.

The procedures for polynomial curve generation are as follows:

(1)To work out a positive integer n with theorem 2 and them theorem 1 and to transform the curve equation into integral equations 4 and 5 with proper values ofand.

(2)To work out a_k and b_k, the fractional differences φ and ψ, when $i = 0$ through adding up $\varphi(i), i = 0,1\ldots u$, $\psi(i), i = 0,1\ldots v$, The calculating formulas are those of 6 and 7

$$a_k = \sum_{i=0}^{k} (-1)^i C_k^{k-i} \varphi(k-i), k = 1,2\ldots u. \quad (6)$$

$$b_k = \sum_{i=0}^{k} (-1)^i C_k^{k-i} \psi(k-i), k = 1,2\ldots v. \quad (7)$$

(3)To work out the point (x,y) and the remainder z_1, z_2, when $i = 0$ through $Nx = \varphi(0) + z_1$, $|z_1| \leq N/2$ and $My = \psi(0) + z_2$, $|z_2| \leq M/2$.

(4) To mark the first point.

(5) For $i = 1, \ldots n$, loop: if $a_1 - z_1 \prec -N/2$, $x = x-1$, $z_1 = z_1 - a_1 - N$; if $a_1 - z_1 \geq N/2$, $x = x+1$, $z_1 = z_1 - a_1$; otherwise $z_1 = z_1 - a_1$, if, $b_1 - z_2 \prec -M/2$, $y = y-1$, $z_2 = z_2 - b_1 - M$; if $b_1 - z_2 \geq M/2$, $y = y+1$, $z_2 = z_2 - b_1 + M$;otherwise $z_2 = z_2 - b_1$.Mark the point (x,y), $a_k = a_k + a_{k+1}$, $k = 1, \ldots u-1$, $b_k = b_k + b_{k+1}$, $k = 1, \ldots v-1$.

4.3. Derivation Procedures of the Model

First of all, to transform the RGB values of blocks in scale area into their corresponding XYZ values according to the ideal condition equation 8.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 2.7689 & 1.7517 & 1.1302 \\ 1.0000 & 4.5907 & 0.0601 \\ 0.0000 & 0.0565 & 5.5943 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}. \quad (8)$$

4.3.1. Modification of Single Color Errors

To substitute the single color Yule-Nielson equation with the XYZ values in the single color (magnate, for example) transformation database in the calibration target scale area. Three magnate color percentage m with three different values may be the results of the three formulas of X, Y and Z. In theory, the three values of m for the same block should be the same. However, both the analysis of ideal transformation equation coefficient and the experiment results show that the result of formula X is the largest while that of formula Z the smallest because of different errors. Due to the influence of background color in color mixing, the color percentage of scanners apt to enlarge in calculation. Therefore, error correction should be made by setting the minimum percentage value as the threshold value. With the help of the polynomial fitting algorithm previously devised, the largest and the middle color percentage difference value curve equation are $a_d m^2 + b_d m + d_d = 0$ and $a_z m^2 + (b_z + 1)m + d_z$ respectively, which refers to the part of color to be corrected in the equation. The single color Yule-Nielson equation is formula 9 when $c = 0$,and $y = 0$in Yule-Nielson equation.

$$\begin{bmatrix} X^{\frac{1}{n}} \\ Y^{\frac{1}{n}} \\ Z^{\frac{1}{n}} \end{bmatrix} = (1-m) \begin{bmatrix} X_w^{\frac{1}{n}} \\ Y_w^{\frac{1}{n}} \\ Z_w^{\frac{1}{n}} \end{bmatrix} + m \begin{bmatrix} X_r^{\frac{1}{n}} \\ Y_r^{\frac{1}{n}} \\ Z_r^{\frac{1}{n}} \end{bmatrix}. \quad (9)$$

The single color M Yule-Nielson modified equation is formula 10, in which a_d, b_d, d_d and a_z, b_z, d_z are the fitting curve coefficients for the large percentage value subtracting the small percentage value and the middle percentage value subtracting the small percentage value.

4.3.2. Modification of Double Color Errors

To substitute the double color Yule-Nielson equation after single color correction with XYZ values of two-color calculation in the scale area. Three values of yc, the product of cyan color and yellow color, may come out as the results of the simultaneous equations of XY, XZ and YZ. With the same method as is in single color correction, double color error can be calculated, the double color difference value equation fitted and double color error correction and modification fulfilled. Thus, the double color modified Yule-Nielson with polynomial fitting algorithm equation is developed.

$$\begin{bmatrix} X^{\frac{1}{n}} \\ Y^{\frac{1}{n}} \\ Z^{\frac{1}{n}} \end{bmatrix} = \begin{bmatrix} (1-(a_d m^2 + (b_d+1)m + d_d))X_w^{\frac{1}{n}} \\ (1-(a_z m^2 + (b_z+1)m + d_z))Y_w^{\frac{1}{n}} \\ (1-m)Z_w^{\frac{1}{n}} \end{bmatrix} + \begin{bmatrix} (a_d m^2 + (b_d+1)m + d_d)X_c^{\frac{1}{n}} \\ (a_z m^2 + (b_z+1)m + d_z)Y_c^{\frac{1}{n}} \\ mZ_c^{\frac{1}{n}} \end{bmatrix}. \quad (10)$$

4.3.3. Modification of Three Color Errors

To substitute the three color Yule-Nielson equation after double color correction with XYZ values of three-color ($BK == Y + M + C$) calculation in the scale area. The value of ymc1, the product of yellow, magnate and cyan, may come out as the result. To substitute the three color Yule-Nielson equation after double color correction with the black standard XYZ values in the scale area. The value of ymc2, the product of yellow, magnate and cyan, may come out as the result. The three-color corrected Yule-Nielson equation is developed after fitting the difference value equations of ymc1 and ymc2 and correcting and modifying the three-color errors and this is the ultimate equation of the demonstration. The description of the modified equation is complicated but its calculation can be easy realized with the help of computer, so the modified equation is omitted.

5. Experiment Confirmation

The proposed model is realized with C language. According to the scanner's rendering principle in the detailed realization, the model adopts the three-layer structure of three inputs and outputs. 84 color blocks in the color scale area represent the color management model of the whole color space, RGB value and XYZ measurement value are input and output values of the model separately. Tab.1 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[4] which is widely used and has its relatively high conversion accuracy and the BPNN algorithm in this experiment[6]. *NBS* aberration unit is one adopted by American National Standards Institute. According to colorimetry, visual equivalency can be acceptable when $\Delta E < 5NBS$ units. X_b, Y_b, Z_b, X_q, Y_q, Z_q and ΔE stand respectively for the standard values of X, Y and Z, the values of X, Y and Z computed by the management model and the aberration between them, in which $\Delta E = \sqrt{(X_b - X_q)^2 + (Y_b - Y_q)^2 + (Z_b - Z_q)^2}$. From this result can show that the model of this paper offers satisfactory color conversion accuracy, and is able to manage the scanner colors with regard to different situations.

Table 1 Conversion accuracy statistics for different algorithms

algorithm	accuracyUnit: *NBS*	
This paper	Average error	4.64
	Maximum error	9.72
	Number of blocks with an error larger than 5*NBS*	8
Polynomial fitting algorithm	Average error	17.21
	Maximum error	31.65
	Number of blocks with an error larger than 5*NBS*	61
BPNN algorithm	Average error	10.48
	Maximum error	21.41
	Number of blocks with an error larger than 5*NBS*	27

6. Conclusion

In the algorithm currently used, the intermediate process of color transformation is excluded and only the input and output values of the sample blocks are controlled. A certain number of standard color blocks undergo the processes of analysis and fitting control. The modification algorithm proposed here has overcome the flaw of lack of transformation accuracy in the level of theory. With regards to the imaging theory of scanner, the paper employs polynomial fitting to correct errors through the gradual levels of single color, double color and three colors and to derive ways of color space transformation equations. Effective management of scanner colors is realized and new methods and approaches of color management for scanner are proposed. As for different scanners, only one correction is necessary to get the correction coefficient. In conclusion, the algorithm is reasonable and practical.

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