Research on Color Consistency for Color Marketing in Network Transaction System Based on Color Management

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Abstract: Color consistency is one of the key techniques for color marketing in color reproduction in network transaction system. A new color management method is presented based on analyzing the color rendering principles of scanned input images. Firstly, the method substitutes color blocks in color shade district in standard color target for complete color space to solve the difficulties of color sample selection. Secondly, contraction-expansion curve fitting algorithm is improved to improve its search efficiency and decrease its calculation. Thirdly, parameters of Yule-Nielson equation are reinterpreted, making them applied for non-printing dot image which only can be used for printed dot image originally and then the color conversion model for scanned images is deduced gradually through single color, double color and tricolor conversion correction. Finally the experimental results show that the model can improve scanner color conversion accuracy and can guarantee color consistency in color marketing in electronic business system in practice.

Categories and Subject Descriptors
I.4.8 [Scene Analysis]: Color; J.1 [Administrative Data Processing]: Business

General Terms
Network Management, Image Processing

Keywords: Color Reproduction, Color Management, Contraction-expansion Curve Fitting, Yule-Nielson Equation

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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. Increasing concern is directed toward the problem of color distortion in the process of transference and reproduction of color images between different type equipment. This is partly because the reproduced color images are expected to manifest the actual colors of the originals, but what is more important is the fact that the color images carry increasing amounts of information to be transferred and presented in accurate digital color signals in order for the receivers to use correctly. However, the colors are related to specific equipments. For instance, the color space that represents the color characteristics of color scanner is the RGB (Red, Green, Blue) space that follows the imaging principle of additive process, while the one that represents the color characteristics of scanning image is the YMC (Yellow, Magenta, Cyan) space that follows the principle of subtractive process. Both RGB space and YMC space depends on their respective equipment materials and it is difficult to transform directly between them or to print images that are identical with the actual effects on the scanner. Consequently, control and transformation of the colors in the process of transference and reproduction of color images between different types of equipments has become one of the most difficult and pivotal techniques as well as one of the research hotspots.

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 digital camera color management. The XYZ color space mentioned is a universal standard color space that is independent of equipments recommended by CIE [1] [2].

The color management of color scanner has three main methods currently. One, establish the relations between digital motivation value of scanner’s color sensor and color tristimulus value by measuring a series of color samples, and set up color look-up tables or fitting color transfer
and have the largest color gamuts. Yellow dye is always the primary color that can be controlled effectively. It is well known that three tristimulus values of three primary color colors and three colors in accordance with the scanner's coloration mechanism, establish its color model, and calculate its color shown through the derivation of the model.

This method contributes to the understanding of the scanner's coloration mechanism and the reduction of the measurement number of color samples, but it is usually more difficult to calculate. This method only considers the impact on the final color from \( R, G \) and \( B \) electron guns of the scanner without taking into account the impact among the three-color electronic guns, so the final conversion accuracy is not high. The first two methods are similar to black box technology, and only control the conversion of several input and output color blocks without taking into account intermediate conversion process, so the accuracy is certainly not high. Three, use such direct fitting color transfer curve as BP neural networks. The accuracy of the algorithm is fair, but in practical application the convergence speed of the model is too slow to be easy to be applied into the practical project [1,2,3,4,5,6,7,8].

Yule-Nielson equation are the ideal mathematical models of printed dot image coloration, so they are only applied to the printed dot image. In this paper, the dot area parameters of two equations are re-explained as the color percentage at first to make the corrected equations applied to the non-printing dot image of color image; then improve the contraction-expansion curve fitting algorithm to enhance the search efficiency and reduce the computation load; and study and make up the color error of color scanner step by step by the order of single color, double colors and three colors in accordance with the scanner’s coloration principle and correct the equations step by step so as to overcome the problem that the black box algorithm does not consider the intermediate color conversion process and cause low accuracy. Thus new methods and approaches are addressed for the color management of scanner.

2. The Principle of Subtractive Color Process

The study on human eye shows that the surface color of different natural objects can be controlled if the tristimulus value of three primary color \( RGB \) coming to human eye can be controlled effectively. It is well known that three primary color \( RGB \) can be mixed to create more colors and have the largest color gamuts. Yellow dye is always used to control blue light because yellow dye absorbs blue light most effectively and is called the complementary color of blue. Magenta dye is used to control green light because Magenta is the complementary color of green and cyan dye is used to control red light because cyan is the complementary color of red. It is easy to control the absorbing quantum of three primary color and tristimulus value of three primary color entering human eye by altering the densities or thickness of \( YMC \) dyes. So \( YMC \) are called three primary colors of subtractive color process. The principle of color rendering of test specimen can be listed as follows (see Figure 1): Magenta dye mixed with Yellow dye shows Red, Cyan dye mixed with Yellow dye shows Green, Magenta dye mixed with Cyan dye shows Blue,Magenta dye mixed with Cyan dye and Yellow dye shows Black.

\[ R=Y+M : \text{Magenta dye mixed with yellow dye shows Red} \]
\[ G=Y+C : \text{Cyan dye mixed with yellow dye shows Green} \]
\[ B=C+M : \text{Magenta dye mixed with cyan dye shows Blue} \]
\[ BK=Y+M+C : \text{Magenta dye mixed cyan dye and yellow dye shows Black} \]

Figure 1. The Principle of Color Rendering of Test Specimen

3. Data Collection

3.1 Measuring Equipment and Calibration Target

The Colortron Equipment is used here as color measuring equipment and Philips 220EW8 with resolution 1680*1050 as 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. 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. According to the color rendering principle of test sample specimens, the \( Y,M,C,R,G,B,BK \) original datum of the color shade district on color target are used to build a database for establishing color conversion model, and other district datum are used to validate the accuracy of color conversion model in the paper.
transformation. The use Colortron to measure the RGB values of all the blocks on the calibration target to build up verification database for accuracy verification.

(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 Contraction-Expansion Curve Fitting Algorithm

The contraction-expansion algorithm used for non-linear problems is a direct search algorithm that mainly features the contraction and expansion search space. In the contraction step, each unknown parameter is divided into five steps' points each round to calculate their objective function values one by one. The minimal step's point of the objective function values is selected as the central point of the next round, and the step size is reduced to go on the optimum search of several rounds; in the expansion step, the search of five steps' points is the same as above. When each trial is calculated one by one, the deterioration degree of the selected objective function value does not exceed the transition point of threshold \((D)\) as the probable central point. The step size is enlarged to go on the optimum search of several rounds. The contraction step and expansion step are a search process. Meanwhile, the step size of next optimum search is calculated by the location and the number of transition points of search process. The number of transition points performs the feedback and adjustment through the threshold \((D)\) so as to adjust the search's step size [9].

4.1.1 The First Improvement of Contraction-Expansion Algorithm

If there are \(k\) unknown parameters, the number of trial calculation points has \(5^k\) when five steps' points do the trial calculation. When dimension \(k\) is increased, the number of trial points is increased geometrically. When one unknown parameter is one-dimensional, only five trial calculation step points are involved and the workload is not great; if 2-dimensional, the number of trial calculation points each round is \(5^2\). Therefore, it can be conceivable that when the dimension continues to increase, the number of trial calculation step's points each round is increased sharply. Each trial is required to visit objective function and several constraint functions, its complex non-linear programming often needs many optimum search processes to be achieved, and personal computers are generally difficult to finish such a large amount of computation, so complex high-dimensional non-linear programming with many unknown parameters is very hard to achieve global optimization.

The biggest improvement in the algorithm of this paper is to change five steps' points to three. At this time, the number of trial calculation step's point every round is \(3^k\). In the multidimensional circumstances, the step's points can be reduced greatly. For example, in the five-dimension, the number of trial calculation step's points is \(3^5=243\) which is only 7.8% of 3125 trial calculation points of five steps' points. The amount of computation is significantly reduced. If 11-dimensional, the number of trial calculation point of three steps' points is further reduced to 0.36% of five steps' points. The visit number of the objective function and the constraint function is significantly reduced to make some difficult problems solved probably. Of course, three steps' points need more cycle than five steps' points, but the experimental result in this paper proves no great increase degree of cycle process, and the overall optimum result can be also achieved in a short period.

4.1.2 The Second Improvement of Contraction-Expansion Algorithm

In the search and calculation of contraction-expansion algorithm, the central point is not adjusted until one round of calculation ends. Five steps' points calculate the objective function values, of which, the trial calculation step's point that minimizes the function value (contraction step) or meet certain conditions (expansion step) is taken as next round of central point.

The contraction-expansion curve fitting algorithm improvement of this paper uses the strategy to instantly adjust the central point. As long as new optimization point appears in the optimum searching process, main parameter points can be the future central point of optimum search immediately. The instant adjustment of central point can speed up the optimum search process to easily achieve the overall optimization of non-linear programming.

4.2 Yule-Nielson Equation

In 1951, considering all kinds of real circumstances, Yule-Nielson modified Neugebauer equation with an exponent (usually \(n\) ranges from 0.5 to 0.65)[5]. The Yule-Nielson equation is showed in formula 1.

In formula 1 The parameters \(y, m, c\) in Yule-Nielson equation stand for the dot percentage of the basic printing colors of yellow, magmate 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.

The results of the simultaneous equations of product of cyan color and yellow color, may come out as calculation in the scale area. Three values of \( y_m c_1 \), the single color correction with

\[
\begin{pmatrix}
\frac{X}{x_c} \\
\frac{Y}{y_c} \\
\frac{Z}{z_c}
\end{pmatrix}
= \sum_1^8 f_j
\begin{pmatrix}
\frac{1}{x_w} \\
\frac{1}{y_w} \\
\frac{1}{z_w}
\end{pmatrix}
\]

In formula 1, \( X, Y, Z \) stand for the tristimulus value of different color. And \( f_j \) can be calculated by the formula 2.

\[
\begin{align*}
\frac{f_w}{X} &= (1 - c) * (1 - y) * (1 - m) \\
\frac{f_y}{Y} &= y * m * (1 - c) \\
\frac{f_y}{Z} &= y * (1 - c) * (1 - m) \\
\frac{f_g}{X} &= y * c * (1 - m) \\
\frac{f_g}{Y} &= c * m * (1 - y) \\
\frac{f_g}{Z} &= y * m * c \\
\frac{f_b}{X} &= (1 - c) * (1 - y) * (1 - m) \\
\frac{f_b}{Y} &= y * m * (1 - c) \\
\frac{f_b}{Z} &= y * (1 - c) * (1 - m)
\end{align*}
\]

(2)

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, the experiment results shows that the calculated three magnate color percentage \( m \) are different because of color errors exist. The difference of three \( m \) can be corrected by the contraction-expansion curve fitting algorithm improved by the paper. Table 1 shows the real experimental results of the single color magnate, \( X_b, Y_b, Z_b, X_q, Y_q, Z_q \) and \( \Delta E \) 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, \( \Delta E \) can be calculated by formula 4.

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

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 \( y_c \), 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 in single color correction, modified Yule-Nielson equation is developed. Table 2 shows the real experimental results of the double color green.

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<th>( Y_b )</th>
<th>( Z_b )</th>
<th>( X_q )</th>
<th>( Y_q )</th>
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Table 1. Single Color Experimental Results of Magnate

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Table 2. Double Color Experimental Results of Green

4.3.2 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 \( y_m c_1 \), 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 \( y_m c_2 \), 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 \( y_m c_1 \) and \( y_m c_2 \) and correcting and modifying the three-color errors and this is the ultimate equation of the demonstration. The final color conversion model for scanner is difficult to write but is easy to realize by computer step by step. Table 3 shows the real experimental results of the three color grey.
5. Experiment Confirmation

The modification model is solved with C language. Table 4 shows a transformation accuracy statistics for all the 288 color blocks through the algorithm of the paper, the polynomial fitting algorithm and the BPNN algorithm[8] which are widely used for its relatively high transformation accuracy. 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 $\Delta E < 5\text{NBS units}$.

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Table 4. Conversion Accuracy Statistics for Different Algorithms

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 digital cameras, 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’s color is realized and new methods and approaches of color management for scanner are proposed. As for different scanner, only one correction is necessary to get the correction coefficient. In conclusion, the algorithm is reasonable and practical.

7. Acknowledgment

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References