Maximum Dynamic Range Of GCR Based On Metamerism And Application

Guang-wu Lv, Peng Cao, Yuan Huang

Abstract: It is of great value to reduce amount of ink usage and solve the restriction of color printing image quality of reproduction, the more accurate Gray Component replacement (GCR) mathematical model of CMYK color printing and maximum dynamic range of replacement has been researched. The scientific contribution of this paper is in using the metameric data of color space conversion collected through experiments, and then the ridge regression algorithm has been created for constructing a GCR mathematical model to characterize the optimal GCR maximum dynamic range of the metameric image printed which suitable to embed watermark information. The gradient descent method enables the C, M, Y (Cyan, Magenta, Yellow) values of metameric data solved by customizing the K (Carbon ink) channel data and the RGB color data, information hiding and printing anti-counterfeiting achieved by the K channel image, information will be recognized by applying special instruments in the Infrared wavelength range. This model is utilized to meet the challenge of printing information anti-counterfeiting and saving of printing ink, also deal with the basic problem of the maximum dynamic range of metameric GCR based on common CMYK ink. The effect of metameric image, with anti duplication and anti-counterfeiting properties, modulated be verified after printing and testing by this model. it, simultaneously, provided with the preponderance of good effect of information protection and full coverage of information.

Index Terms: Gray Component Replacement (GCR), Metamerism, Maximum Dynamic Range, Information Hiding.

1 INTRODUCTION

Metamerism technology is commonly applied in color reproduction, color space conversion, spot-color matching of ink, toner saving and other aspects for the same visual response characteristics generated with different stimuli in the range of visible spectrum, the demand for authenticity identification of various commodities is also in growing [1]. The color image in RGB color format is converted to CMYK color format for printing with optimal ink amount ratio in color reproduction. Enhancing the quality of the image printed with K (Black) generation, under color removal (UCR), gray component replacement (GCR) and other methods, more CMYK combinations are also produce richer color information [2], [3], [4]. To deal with the problem of rich image details in the process of color reproduction, The appropriate CMYK combinations, minimum amount of ink with the same visual response, has been indexed to save ink or toner, that is to say the image reproduced has the same image appearance as the original image. Gray component replacement (GCR) based on metamerism, which makes different CMYK combinations in a certain range shows the similar hue features under the same light source and the different hue features under the distinct light source, that makes the demand of information hiding, document security protecting and commodity authenticity identification grow rapidly. In recent years, Žiljak, V. Iljak, T. Fritz [5], [6], [7] adopt CMYK printing ink or toner for two-color separation method, hiding information in the infrared band to achieve the effect of information protection, combined K (Black) ink which the response band of 1000nm is still visible clearly in the infrared band (IR) has great visual response characteristics with C, M, Y (Cyan, Magenta, Yellow) and others (the response band is mostly in 400nm-800nm) in the infrared band (the band of 1000nm) without visual respond characteristics.

However, the research, based on the condition of metamerism, on how to replace the data accurately between CMY and K in an effective range is still vague. The existing methods, lack of scientific basis for adjusting the range under the condition of metamerism, are mainly based on the experience of parameter adjustment method, which results to the inaccuracy of manual color matching, inferior quality of printing appearance of problems such as poor anti-counterfeiting effect and color reproduction easily in the printing process. we proposed the maximum dynamic range of GCR under the condition of metamerism, and the mathematical models has been given. Through the analysis of the experimental results, it proved that the mathematical model is effective and practical.

- *Guang-wu Lv is currently pursuing masters degree program in Beijing Institute of Graphic Communication, China, PH-13590052494. E-mail: guangwulv@163.com*
- *Peng Cao is the director of Beijing Key Laboratory of Signal and Information Processing for High-end Printing Equipment in Beijing Institute of Graphic Communication, China, PH-13311010311. E-mail: pcaorf2012@163.com*
- *Yuan Huang is currently pursuing masters degree program in Beijing Institute of Graphic Communication, China, PH-18811512325. E-mail: 2522939876@qq.com*

2 EXPERIMENTAL DESIGN

2.1 Conversion Algorithm between RGB and CMYK

RGB[1] color space and CMYK[2] color space, as common color display and printing models, are need to be converted between the two. When images need to be printed in CMYK format, images in RGB format has always been as input information [8]. The conversion from RGB to CMY involves the relationship between complementary colors. Subtractive primary colors C, M, Y are complementary colors of additive primary colors R, G, B, as in (1).

$$\begin{aligned} C &= 1 - R \\ M &= 1 - G \\ Y &= 1 - B \end{aligned} \tag{1}$$

The conversion process from CMY to CMYK [9] involves K (Black) color generation, under color removal (UCR), gray component replacement (GCR) and other methods. The process of CMY converts to CMYK as in (2) .

$$
\begin{aligned}
&K=\min(C,M,Y)\\
&C'=(C-K)/(1-K)=(1-R-K)/(1-K)\\
&M'=(M-K)/(1-K)=(1-G-K)/(1-K)\\
&Y'=(Y-K)/(1-K)=(1-B-K)/(1-K)
\end{aligned}
\tag{2}
$$

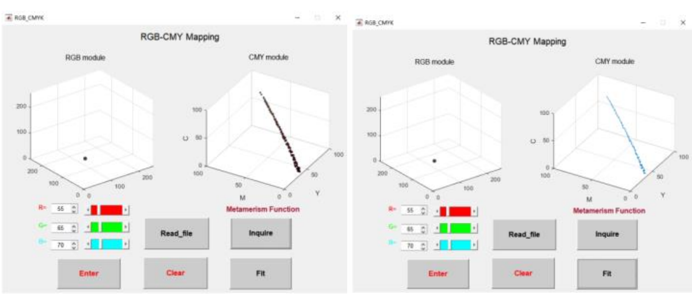
where:
C'=Cyan be converted
M'=Magenta be converted
Y'=Yellow be converted

Approximately, the equation of CMYK to RGB as in (3).

$$
\begin{aligned}
&R=(1-C)*(1-K)\\
&G=(1-M)*(1-K)\\
&B=(1-Y)*(1-K)
\end{aligned}
\tag{3}
$$

2.2 Research on Maximum Dynamic Range

Generating full gamut KCMY-RGB data, cleaned by MySQL [10], if which the R, G, B values are determined, the C, M and Y values corresponding to the K values indexed has been obtained. A dynamic query system of metamerism is designed by associating MySQL with MATLAB, as shown in Figure 1. Figure 1 (a) illustrates metamerism dynamic query system and corresponding CMY scatter plot when r=55, g=65, b=70, and Figure 1 (b) shows the CMY curve fitting diagram. When dragging the slider or inputting different RGB values, the corresponding scatter diagram and spatial fitting diagram will be obtained.



(a) (b)

Fig. 1. Dynamic Query System of Metamerism and Corresponding CMY Scatter Plot(a), CMY Curve Fitting Diagram(b).

To verify the eye recognition difference of metameric data, RGB gray values ranging from 0 to 255, 4 groups of data are randomly selected according to CMY of distinct K indexes in metameric data. Four number below the color block are K C M Y, and K values is distributed within the maximum range K_{min} to k_{max} of metameric data when the R, G, B values are known. The maximum dynamic range of all gray levels is shown in Figure 3. Four groups of data selected are RGB = 40-40-40, 80-80-80, 150-150, 180-180-180. Some metameric blocks of these RGB values are shown in Table 1.

TABLE 1
PART OF RGB AND ITS CORRESPONDING KCMY VALUES AND COLOR BLOCKS

RGB-Value	KCMY Value and its Color Block				
40-40-40	30 95 100 94	40 92 96 88	50 89 90 82	80 65 57 55	90 46 37 38
80-80-80	5 79 72 66	25 82 64 25	45 61 51 49	55 52 44 41	75 25 20 20
150-150-150	10 42 33 31	20 36 27 27	30 22 16 16	40 18 13 14	50 3 4 4
190-190-190	11 22 16 16	17 17 13 13	20 14 10 11	28 6 5 5	30 3 4 3

For exploring the maximum dynamic range of gray component replacement (GCR), the gray level of the whole data is extracted, and the metameric data with gray level between 0-255 is obtained. After data cleaning, the single mapping datas from KCMY to RGB are gained. Ridge regression algorithm added disturbance term in the regression process, and the unbiased least square method is abandoned for reducing the accuracy to obtain more realistic regression coefficient [11]. The penalty term of L_2 norm regular term is added to the original loss function to make the change trend in the whole range closer to the real value. The loss function as in (4).

$$J(\beta)=\frac{1}{2m}\sum_{i=1}^{m}(\beta^T\bullet x_i-y_i)^2+\lambda\sum_{i=1}^{m}\|\beta\|_2^2,\lambda\geqslant 0; \tag{4}$$

Where:
$J(\beta)$ =Loss Function
β = Regression Coefficients
m =Number of Samples
λ =Regularization Parameter
x_i =Independent Variables
y_i =True Values

Observing the ridge trace curve of ridge regression as shown in Figure 2, we get $\lambda=10^{-8}$. The design parameters of the ridge regression algorithm are shown in Table 2. According to ridge regression algorithm, the maximum dynamic range of K in its gray range is gained, as shown in Figure 3.

TABLE 2
RIDGE REGRESSION PARAMETER DESIGNED

Iterations	Learning rate	Regularization parameter	Polynomial degree
1200000	0.00000006	0.00000001	11

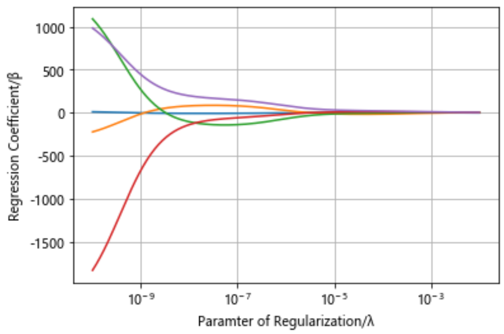


Fig. 2. Different Ridge Trace Curves

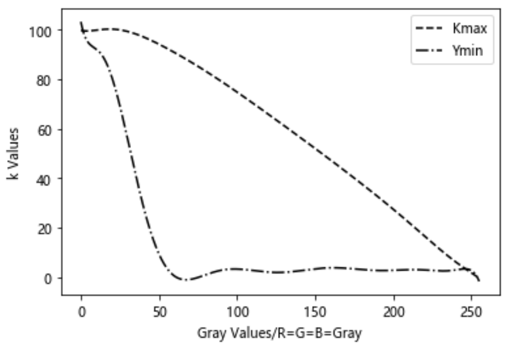


Fig. 3. Maximum Replacement Range of k for All Gray Scales

Figure 2 illustrates the abscissa is expressed as the regularization parameter, the ordinate is expressed as the regression coefficient, as in (5). Equation (6) represents the product of regression coefficient and independent variable, and the matrix form of predictive values y_i . x_i and y_i are shown in (7), (8).

$$\beta = (X^T X + \lambda I)^{-1} X^T Y \quad (5)$$

$$y_1 = \beta_1 x_{11} + \beta_2 x_{12} + \ldots$$
$$y_2 = \beta_1 x_{21} + \beta_2 x_{22} + \ldots \quad (6)$$
$$\ldots$$

$$X = (x_1, x_2, \ldots, x_n) = \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1n} \\ x_{21} & x_{22} & \ldots & x_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ x_{n1} & x_{n2} & \ldots & x_{nn} \end{bmatrix} \quad (7)$$

$$Y = (y_1, y_2, \ldots, y_n)^T \quad (8)$$

Where:
λ =Regularization Parameter
I =Unit Matrix
X =Matrix Form of the Variable x_i as in (7)
Y=Matrix Form of the Predictive Value y_i as in (8)

Figure 3 shows the abscissa is expressed as the gray scale ranging 0 to 255, and the ordinate is expressed as the K_{min} and K_{max} values. Grey component replacement (GCR) is a vital method for studying metamerism, and scope of replacement of K_{min} to K_{max} is expressed as in (9). The GCR process is shown in Figure 4. The dynamic range of $(C,M,Y)_{min}$ and $(C,M,Y)_{max}$ corresponding to K_{max} and K_{min} of all gray levels are shown in Table 3.

$$\{K_{max}, C_{min}, M_{min}, Y_{min}\} \overset{GCR}{\Rightarrow} \{K_{min}, C_{max}, M_{max}, Y_{max}\} \quad (9)$$

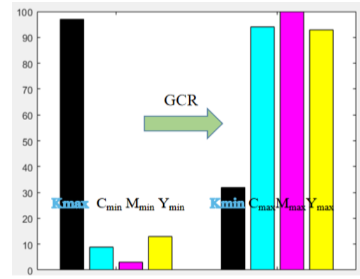
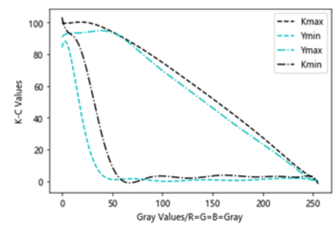
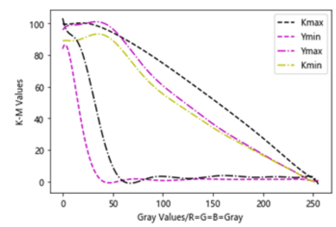
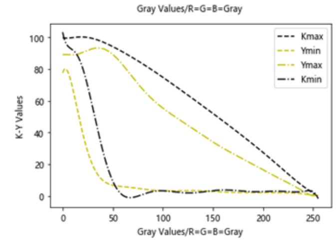


Fig. 4. Schematic Diagram of GCR

TABLE 3
$(C,M,Y)_{MIN}$ AND $(C,M,Y)_{MAX}$ CORRESPONDING TO K_{MAX} AND K_{MIN}

Minimum and maximum	Corresponding dynamic range curve
K-C	
K-M	
K-Y	

According to the defined range of K for each gray level in Figure 3, the $(C, M, Y)_i$ values indexed by K_i values can be obtained when the gray level determined. That is, with the values of R, G, B and K are known, the values of C, M and Y gained by stepwise regression [12], as in (10) , Equation (11) and (12) are the extension of (10).

$$C_i = fc - del\_f_{c1}$$
$$M_i = fm - del\_f_{m1} \quad (10)$$
$$Y_i = fy - del\_f_{y1}$$

$$fc = f_c(cons, R, G, B, K_i, K_i^2)$$
$$fm = f_m(cons, R, G, B, K_i, K_i^2) \quad (11)$$
$$fy = f_y(cons, R, G, B, K_i, K_i^2)$$

where:
cons=Constant
$del\_f_{c1}, del\_f_{m1}, del\_f_{y1}$ =Correction Terms of the Function, as in (11).

$$
\begin{aligned}
del\_f_{c1} &= a_c + b_c * Gray + c_c * Gray^2 \\
del\_f_{m1} &= a_m + b_m * Gray + c_m * Gray^2 \\
del\_f_{y1} &= a_y + b_y * Gray + c_y * Gray^2
\end{aligned} \quad (12)
$$

where:
$a_c/b_c/c_c$=Coefficients to Calculate del_f_{c1}
$a_m/b_m/c_m$=Coefficients to Calculate del_f_{m1}
$a_y/b_y/c_y$=Coefficients to Calculate del_f_{y1}
Gray=R=G=B

Equation (10) is employed in the experimental design of information hiding. Two K values are used to sign whether there is a watermark at a specific pixel position in the K channel. They are metameric data in every pixels between the two K values definited and corresponding variable CMY values combination and the original CMYK. After experimental testing, if K value is less than 15, such as K=10, the effect with the help of infrared device detection like no trace, while K is greater than 18, such as K=20 or even more, the information can not be hidden well, resulting the information to be obvious from visible light. This means that the smaller the K value of the watermark information, the more difficult it is to detect whether there is a watermark. The larger the K value, the less information can be hidden. K=12 is used to indicate no watermark, K=15 and K=18 indicate the effects of two watermark hiding have been compared. The coefficients of function regression term fc/fm/fy in (10) and (11) are given in Table 4. When K are 12, 15 and 18, the correction coefficients of function parameters in (10) and (12) are given in Table 5, Table 6 and Table 7.

TABLE 4
WEIGHTED COEFFICIENTS OF FC/FM/FY

K=18	cons	R=G=B=Gray	K	K^2
C_i	144.5144	-0.682268	-0.5004901	-0.00337789
M_i	138.8024	0.691343	-0.4497	-0.00396331
Y_i	126.229	-0.618894	-0.435576	-0.00278934

TABLE 5
CORRECTION TERM COEFFICIENT WHEN K=12

K=12	$a(a_c/a_m/a_y)$	$b(b_c/b_m/b_y)$	$c(c_c/c_m/c_y)$
del_f_{c1}	20.1	-0.1708	0
del_f_{m1}	-5.1	0.2905	-0.001788
del_f_{y1}	-10.2	0.3523	-0.001949

TABLE 6
CORRECTION TERM COEFFICIENT WHEN K=15

K=15	$a(a_c/a_m/a_y)$	$b(b_c/b_m/b_y)$	$c(c_c/c_m/c_y)$
del_f_{c1}	18.3	-0.1613	0
del_f_{m1}	-6.5	0.3027	-0.001829
del_f_{y1}	-10.8	0.3560	-0.001956

TABLE 7
CORRECTION TERM COEFFICIENT WHEN K=18

K=18	$a(a_c/a_m/a_y)$	$b(b_c/b_m/b_y)$	$c(c_c/c_m/c_y)$
del_f_{c1}	16.4	-0.1444	0
del_f_{m1}	-8.9	0.3377	-0.00194
del_f_{y1}	-11.1	0.3467	-0.001886

2.3 Experimental Design of Metamerism and Information Hidding

The metameric data values of KCMY-RGB with gray scale ranging from 0 to 255 are selected, and the CMYK format carrier image with gray gradient has been designed to protect image information, as shown in Figure 5. The watermark image with information is hidden in the carrier image, and whether the information is hidden judged by eye observation and infrared device detection. In all the examples in respect of our experiment, as the response of K (Black) ink can be clearly seen at 1000nm [13], [14], [15], the main substance to hide the information is K (Black) ink.

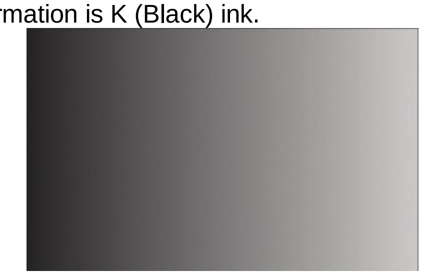


Fig. 5. Carrier Image

According to the maximum dynamic range in Figure 4 and table 3, when r = g = b = gray = 40, the $(CMY)_{max}$ corresponding to K_{min} has approached saturation (close or equal to 100%), When r = g = b = gray = 220, the (CMY) mix corresponding to k_{max} is close or equal to 0. Therefore, when the K value is 12/15/18, the range of gray scale that information can be hidden is 40-220. In order to hide the watermark image into the carrier image, the K value of the watermark information is separated according to its gray information. The algorithm steps of information hiding are shown in Table 8.

TABLE 8
INFORMATION HIDING STEPS

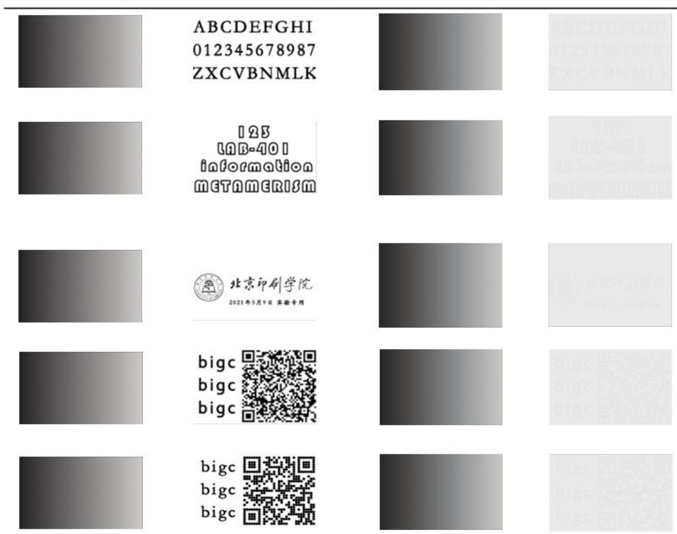
Step	Algorithm Content
Step.1	read Carrier image: img_carry;
Step.2	read Watermark image img_mark;
Step.3	if img_carry(i,j) is suitable for hiding information
Step.4	if img_mark(i,,j) with watermark
Step.5	img_carry_K(i,j)=K_1(15 or 18);
Step.6	calculate with stepwise regression:img_carry_C(i,j)、img_carry_M(i,j)、img_carry_Y(i,j);
Step.7	add correction: del_f_{c1}、del_f_{m1}、del_f_{y1};
Step.8	if img_mark(i,,j) without watermark
Step.9	img_carry_K(i,j)=K_0(12);
Step.10	alculate with stepwise regression:img_carry_C(i,j)、img_carry_M(i,j)、img_carry_Y(i,j);
Step.11	add correction: del_f_{c1}、del_f_{m1}、del_f_{y1};
Step.12	end;end;end;

3 EXPERIMENTAL RESULTS AND ANALYSIS

Some watermark images have been designed [16], whose objects mainly including text, two-dimensional code and logo hidden in infrared area. If K = 12, it means that there is no watermark in the corresponding position of the carrier image and the watermark image. If k = 15 or K = 18, it means that there is watermark in the corresponding position of the carrier image and the watermark image. The hiding effects are shown in Table 9 and table 10.

TABLE 9
INFORMATION HIDING EFFECT WHEN K=12/15

Carrier Image	Watermark Image	Hidden Image	Infrared image



All the experimental examples in Table 9 and table 10 are processed by equation (10) and the algorithm steps in table 8. The experiment is based on the ordered and gradual gray carrier image to hide and protect the information, which the gray scale ranging from 40 to 220. In all case, The infrared information is shielded and hidden under visible light. In the range of infrared wavelength, the band of C, M, Y ink is not visible, while the information of K ink is visible, which means that we can't get the hiding information from the image surface without specific detection tools. For verifying the robustness and practicability of the algorithm, Lena test image is applied as the carrier graph in the experiment to hide information as well, and the effects are shown in Table 11 and table 12.

TABLE 10
INFORMATION HIDING EFFECT WHEN K=12/18

Carrier Image	Watermark Image	Hidden Image	Infrared Image

TABLE 11
INFORMATION HIDING EFFECT WHEN K=12/15

Carrier Image	Watermark Image	Hidden Image	Infrared Image

TABLE 12
INFORMATION HIDING EFFECT WHEN K=12/18

Carrier Image	Watermark Image	Hidden Image	Infrared Image

Equation (13) is used to analyze the color difference between the carrier image with hidden information and the carrier image without loaded information. The effect is shown in table 13 and table 14.

$$\Delta E = \sqrt{(\Delta R)^2 + (\Delta G)^2 + (\Delta B)^2} \quad (13)$$

TABLE 13
INFORMATION HIDING EFFECT WHEN K=12/15

Watermark Image	Minimum Color Difference(%)	Maximum Color Difference(%)	Average Color Difference(%)
ABCDEFGHI 012345678987 ZXCVBNMLK	0.26	2.48	1.61
125 LAB-401 information METAMERISM	0.25	2.83	1.62
北京印刷学院	0.35	2.27	1.61
bigc bigc bigc	0.95	2.92	1.64
bigc bigc bigc	0.45	2.91	1.64
Informat Hiding 123456789abcdefg QWERTYUIOPASDF 同色异谱信隐藏专用	0.59	2.56	1.51
	0.41	2.58	1.67

TABLE 14
INFORMATION HIDING EFFECT WHEN K=12/18

Watermark Image	Minimum Color Difference(%)	Maximum Color Difference(%)	Average Color Difference(%)
ABCDEFGHI 012345678987 ZXCVBNMLK	0.74	2.34	1.61
125 LAB-401 information METAMERISM	0.25	2.82	1.61
北京印刷学院	0.24	2.38	1.61
bigc bigc bigc	0.98	2.99	1.59
bigc bigc bigc	0.20	2.92	1.61
Informat Hiding 123456789abcdefg QWERTYUIOPASDF 同色异谱信隐藏专用	0.37	2.82	1.48
	0.39	2.42	1.57

Through the design of the experiment and the analysis of the experimental results as shown in Table 9, table 10, table 11 and table 12, it can be seen that in the maximum dynamic range, using the mathematical model proposed, CMY combinations indexed by two different values pair of K (K=12/15 or K=12/18) are selected to carry out corresponding metameric numerical modulation on the pixels of the carrier image, which can be clearly seen. The detecting effect of k=12/15 is relatively shallow, and the detecting effect of k=12/18 is more obvious. The CMYK combination of K=12/18 has a better effect provided that the premise of not affecting information hiding. Moreover, by analyzing the chromatic aberration in table 13 and table 14, which can be found that after the maximum dynamic range of metameric numerical modulation, the conversion chromatic aberration before and after is greater than or equal to 3, the conversion effect is good, and the feasibility of information hiding can be ensured.

4 CONCLUSION

Gray component replacement (GCR) based on metamerism is a fairly significant technology in the printing process. It is often commonly applied in color reproduction, color space conversion, spot-color matching of ink, ink saving and so on. However, in previous work and application in daily life, the proportion and range of gray component replacement are basically small-scale parameter adjustment based on experience, there is no scientific basis for the adjustable range and accuracy under the condition of metamerism. This paper, based on this problem, has put forward a mathematical model by analyzed the data characteristics of metamerism, studied the maximum dynamic range of gray component replacement (GCR) under the condition of metamerism, and applied it to hide information through experimental design and simulation. The experimental results show that the mathematical model is efficient and practical. Compared with the original experience based parameter adjustment method, this study can control the range of replacement accurately according to its maximum dynamic range, which provides a solid scientific basis for color reproduction, spot-color matching of ink, information hiding and so on. In the future, the research data samples and effect optimization should be expand, enhancing the two-dimensional code reading effect, providing reference for information hiding and other related research.

ACKNOWLEDGMENT

Thanks to General Program of National Natural Science Foundation of China(61972042), Beijing Fund-Municipal Education Commission Joint Project(KZ202010015023) and School-level research project of Beijing Institute of Graphic Communication(Ef202001).

REFERENCES

[1] L.-Q. Zhang, “Research on Digital Watermarking Technology of Printed Image,” Master’s dissertation, Dept. Optical Eng., National University of Defense Technology, pp. 20-31, Changsha, Nov. 2005, doi:10.7666/d.y886248.

[2] J.-Z. Chang, W.C. Kress, “ Black Generation Method for CMYK Color Printer Using Multiple Lookup Tables and Interpolation,” US, 20000741458[P]. 2002-08-22.

[3] W.C. Decker, H.C. Lee, J.L. Zable, “System, Method, and Program for Saving Toner/Ink in A Color Printer Without Sacrificing Image Quality,” US, 19980099113[P]. 2001-11-

06.
[4] T.A. Fischer, C.J. Edge, “Ink Reduction Method,” US, 8542405 B2[P]. 2013-09-24.
[5] Žiljak, I. Pap, Klaudio, et al. “Double Separation Method for Translation of the Infrared Information into a Visible Area,” J. Journal of Information and Organizational Sciences, vol. 33, no. 1, pp. 219-225, Jun. 2009. doi:10.1088/0965-0393/17/7/075005.
[6] V. Iljak, K Pap, “UPRAVLJANJE INFORMACIJAMA U INFRACRVENOM DIJELU SPEKTRA,” J. Informatologia, vol. 42, no. 1, pp. 1-9, Jan. 2009.
[7] T. Fritz, D.A. Jacobsen, M. Talley, “Uses of Metamerism in Printing,” US, 20050166781 A1[P]. 2005-08-04.
[8] D. Agic, L. Mandic, I. ŽILJAK, “Achieving the same Color Visual Output on the Print by Applying CMY and CMYK Combination of Inks,” proc, Predavanje, 10th International Design Conference Design 2008, pp. 19-22, May. 2008
[9] Y. Zhang, Q.-B. Wei, “The Conversion Algorithm of CMY and C'M'Y'K Based on GCR,” J. Packaging Engineering, vol. 31, no. 5, pp. 35-37, May. 2010.
[10] X.-H. Lan, J.-J. Xiong, G. deng, “Application Design Based on MySQL," J. Computer Engineering and Design, vol. 25, no. 3, pp. 442-443, Mar. 2004, doi:10.3969/j.issn.1000-7024.2004.03.037.
[11] E.H. Oghenekevwe, A.K. Florence, A.K. Abidemi, “Poisson Ridge Regression Estimators: A Performance Test” J. American Journal of Theoretical and Applied Statistics, vol. 10, no. 2, pp. 111-121, Jan. 2021, doi:10.11648/j.ajtas.20211002.13.
[12] L. Lexin, R.D. Cook, C.J. Nachtsheim, “Model-free variable selection,” J. Journal of the Royal Statistical Society, vol. 45, no. 6, pp. 285-299, Nov. 2005.
[13] V. Ziljak, K. PAP, “CMYKIR Security Graphics Separation in the Infrared Area,” J. Infrared Physics and Technology, vol. 52, no. 2/3, pp. 62-69, Mar. 2009, doi:10.1016/j.infrared.2009.01.001.
[14] A. Cila, N. Ferrer, F.F. García, “Chemical Composition of Contemporary Black Printing Inks Based on Infrared Spectroscopy: Basic Information for the Characterization and Discrimination of Artistic Prints,” J. Analytica Chimica Acta, vol. 591, no. 1, pp. 97-105, May. 2007, doi:10.1016/j.aca.2007.03.060.
[15] C. Li, C.-y. Wang, S.-J. Wang, “Research on Black Plate Generation Method of Black Ink Hidden Infrared Anti-counterfeiting Image,” proc, Color Science and Technology-2012 2nd China Printing and Packaging Academic Conference Paper Abstract Collection, pp. 6-7, 2012.
[16] S.I. Žiljak, D. Agić, V. Žiljak, “Hidden Infrared Image in A Uniform CMYK Separation Hue,” J. Journal of Graphic Engineering and Design, vol. 3, no. 2, pp. 8-11, Dec. 2012.