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RESEARCH ON SECONDARY COLOUR OPTICAL DOT GAIN MODEL IN ELECTROSTATIC DIGITAL COLOUR PRINTINGS

Xiao-zhou Li, Jing-jing Liu, Xue-lin Li, Yu Liu, Ai Xu

Original scientific paper
Screening dot is the basic printing element to reproduce continuous image and to form the printing image. Printing quality depends on the transfer quality of the screening dot. It is important to control the dot gain, sharpening, deformation, doubling and slur. In practice, some specific quality control techniques are used to monitor the screening dot variation. For dot gain control technique, multi-colour scales are often used to investigate dot gain or tone change. This article aims to investigate the secondary colour dot gain in electrostatic digital printing, by considering dot gain of the colour scales, Cyan, Magenta, Yellow, Blue, Red and Green. The relations between secondary colour dot gain and primary colour dot gain are studied. Three primary colour scales, Cyan, Magenta, Yellow, and three secondary colour scales, Blue, Red and Green, are designed from 2 % to 90 %. The colour scales are output by electrostatic colour press and measured by spectrophotometer. The dot gain of the secondary colour scales is modelled according to the dot gain rules of the primary colour scales using multiple linear regression method. The results illustrate that the dot gain of secondary colour changes with the dot gain of primary colour scales synchronously, and that further research is needed to make for dot gain compensation and printing process control.

Keywords: *dot gain; Murray-Davis formula; multiple linear regression; primary colour scale; secondary colour scale*

Istraživanje modela sekundarnog kolorno optičkog rasterskog prirasta u elektrostatičkim digitalnim kolornim otiscima

Izvorni znanstveni članak
Rasterski element je osnovni tiskarski element u reprodukciji kontinuirane slike i stvaranju otisnute slike. Kvaliteta tiskanja ovisi o kvaliteti prijenosa rasterskog elementa. Važno je pratiti prirast rasterskog elementa, izoštravanje, deformaciju, udvostručenje i pojavu mrlja. U praksi se koriste neke specifične tehnike nadgledanja kvalitete u praćenju promjena rasterskih elemenata. Kao metoda praćenja prirasta rasterskih elemenata često se koriste multi kolorimetrijske skale za istraživanje prirasta rasterskih elemenata ili promjene tona. Cilj je ovoga rada ispitati prirast rasterskog elementa sekundarne boje kod elektrostatičkog digitalnog tiska, razmatrajući prirast rasterskog elementa kolorimetrijskih skala ciana, magente, žute, plave, crvene i zelene. Proučavaju se odnosi između sekundarnog kolorimetrijskog prirasta rasterskih elemenata i primarnog kolorimetrijskog prirasta rasterskih elemenata. Tri primarne kolorimetrijske skale, cian, magenta, žuta, te tri sekundarne kolorimetrijske skale, plava, crvena i zelena, dizajnirane su od 2 % do 90 %. Kolorimetrijske su skale postavljene elektrostatičkim tiskom u boji te mjerene spektrofotometrom. Prirast rasterskog elementa sekundarnih kolorimetrijskih skala modeliran je u skladu s pravilima o prirastu rasterskih elemenata kod primarnih kolorimetrijskih skala primjenom metode višestruke linearne regresije. Rezultati pokazuju da se prirast rasterskog elementa sekundarne boje mijenja istodobno s prirastom rasterskog elementa primarnih kolorimetrijskih skala, i da je potrebno daljnje istraživanje za kompenzaciju prirasta rasterskog elementa i kontrolu postupka tiskanja.

Ključne riječi: *prirast rasterskog elementa; Murray-Davis formula; višestruka linearna regresija; primarna kolorimetrijska skala; sekundarna kolorimetrijska skala*

1 Introduction

Screening dot is the basic unit to form printing tone level and to reproduce colour in printing process [1, 2]. And it is the basic unit of halftone image. Colour reproduction, tone level reproduction, and image texture reproduction are determined by the screening properties in colour printing [3, 4]. Dot gain is an inherent property for printing in actual production process [5]. What we should note is that dot gain has a great effect on colour reproduction in colour printing. For example, the overall contrast of image would change because of dot gain in printing monochrome or colour halftone image [6, 7]. Moreover, the image details and sharpness would lose too. In addition, dot gain also causes the loss of contrast, tinting of shadow tone area, and the sudden change of tone level or colour [8, 9]. Consequently, it is important to control the dot gain and to compensate the tone change caused by the dot gain to ensure the printing quality [10, 11]. Dot gain within a control to a certain extent is good to colour reproduction.

2 Types of dot gain

Dot gain is a phenomenon in printing process which causes printed material to look darker than intended. Usually it is caused by halftone dots growing in area between the primary printing film and the final printed result. It is often defined as the increase in the diameter of a halftone dot during the prepress and printing processes. Dot gain is classified into two types, i.e., mechanical dot gain and optical dot gain. Mechanical dot gain is often caused by the mechanical pressure and the paper slipping caused by the distortion of the blanket in printing process [1, 9]. The dot gain perceived is usually made up by the actions of mechanical dot gain and optical dot gain [12]. However, it is the optical dot gain that leads the key role in digital colour printing, e.g. inkjet printing and xerographic digital printing [13, 14, 15].

2.1 Analysis of optical dot gain

The dot gain would not occur if the outgoing light of dot and blanket parts reflected along the incident plane respectively in digital printing [16, 17]. However, the optical dot gain would occur when some incident light of the dot reflected from the blank part, not from the dot part or some incident light of the blank part reflected from the dot, not from the blank part. It can be shown in Fig. 1.

In Fig. 1, the light causing optical dot gain is near the injection boundary of dot area and paper surface. For incident light 1 injecting from paper surface, some, 1a, reflects from the paper surface while some,1b, injects the paper inside and then goes out from the paper surface except the absorbed. For incident light 2 injecting from dot area, some, 2b, reflects from ink surface, and some, 2d, passes through the ink layer and goes into the paper inside and some of 2d goes out of the paper through the ink layer except the absorbed. So the total amount of outgoing light or related total light reflectivity perceived can be computed as follows:

$$R_{\mathrm{t}} = (1 - A) \times R'_0 + A \times R'_{\mathrm{s}}, \tag{1}$$

where, R_t is total light reflectivity which consists of two parts such as the reflectivity of blank paper surface, $(1-A)\times R'_0$, and the reflectivity of dot area, $A\times R'_s$. A is dot area. R'_0 is the effective reflectivity of paper, and R'_s is effective reflectivity of solid dot.

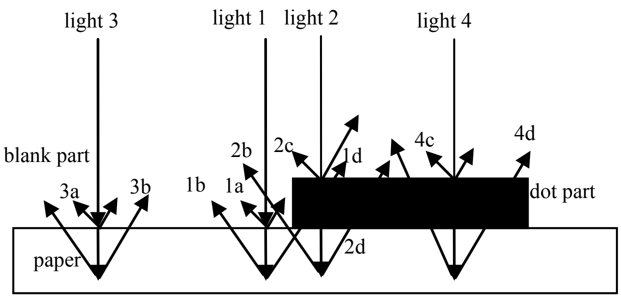

Figure 1 Optical dot gain
1a – light reflected from paper surface of light 1; 1b – light transmitted from paper inside to paper surface of light 1; 1d – light transmitted from paper inside through ink layer to ink surface of light1; 2b – light transmitted from paper inside to paper surface of light2; 2c – light refected from ink layer surface of light 2; 2d – light transmitted from paper inside through ink layer to ink surface of light 2; 3a – light reflected from paper surface of light 3; 3b – light transimtted from paper inside to paper surface of light 3; 4c – ligh reflected from ink layer surface of light 4; 4d – light transimtted from paper inside through ink layer to ink surface of light 4

2.2 Relation between density and dot area

The effective method to measure the cluster dot area is to measure the dot area density. And it is widely used in many colour measuring equipments. Simultaneously, a number of studies indicate that solid density has more influence on dot gain than any other factors in measuring dot gain process [3, 14, 18]. Density in printing process is usually optical density. It can be computed by logarithmic computation of the amount of incident light and outgoing light as follows:

$$D = \lg \frac{R_{\mathrm{in}}}{R_{\mathrm{out}}}, \tag{2}$$

in which, D is optical density. R_{in} is the amount of incident light. And R_{out} is the amount of outgoing light.

To compute the dot area of printed matter, D_s was set as the solid density and ρ_s as the corresponding reflectivity, then the relation between the density and reflectivity can be shown as follows:

$$D_{\mathrm{s}} = \lg \frac{1}{\rho_{\mathrm{s}}}. \tag{3}$$

Theoretically, set the reflectance of the blank area of the substrate, e.g., paper, as 1. Set the dot area on the paper is a, so the rest area of the paper is $1 - a$. Then the corresponding reflectance is $a\times\rho_s$ and $1 - a$ respectively. So the total reflectance of the substrate can be computed as follows:

$$\rho = a \times \rho_{\mathrm{s}} + (1 - a). \tag{4}$$

It is shown in Fig. 2 as follows:

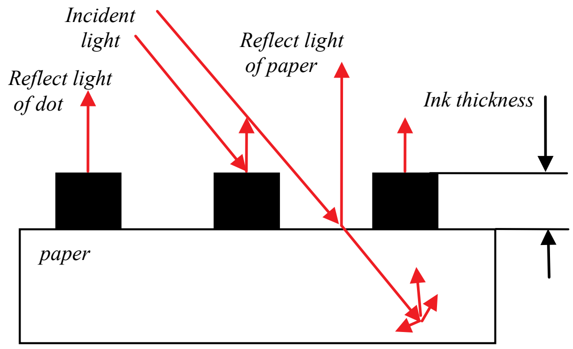

Figure 2 Computation of dot density and dot area

Thus, D_t, the reflectance density of the dot area, a, can be computed as follows:

$$D_{\mathrm{t}} = \lg \frac{1}{\rho} = \lg \frac{1}{a \times \rho_{\mathrm{s}} + (1 - a)} = \lg \frac{1}{1 - a(1 - \rho_{\mathrm{s}})}. \tag{5}$$

According to Eq. (3), ρ_s can be computed as follows:

$$\rho_{\mathrm{s}} = 10^{-D_{\mathrm{s}}}. \tag{6}$$

Then plug Eq. (6) into the Eq. (5) and D_t can be computed as follows:

$$D_{\mathrm{t}} = \lg \frac{1}{1 - a(1 - 10^{-D_{\mathrm{s}}})}. \tag{7}$$

For random cluster dot area, the reflectance density D_t can be measured by densitometer or spectrophotometer. Finally, the cluster dot area can be computed according to Eq. (5), Eq. (6) and Eq. (7):

$$a = \frac{1 - 10^{D_{\mathrm{t}}}}{1 - 10^{D_{\mathrm{s}}}}, \tag{8}$$

in which, a is the cluster dot area of printing sample to be measured. D_t is reflectance density, and D_s is solid density. Eq. (8) is the famous formula to compute the relation between dot area and dot density, i.e., Murray-Davis formula [5, 19, 20, 21]. Although some corrections have been done to the formula by the researchers in this area, e.g., Yule-Nielson formula [21, 22]，Murray-Davis formula remains to be the most popular model in measuring dot area and dot density. In this paper, Murray-Davis formula was used to compute the relation between dot area and dot density.

3 Modelling and experiment part

3.1 Development, analysis and hypothesis of secondary colour scale dot gain model

Given the primary dot area of primary dot area is S_0 and the measured dot areas of primary are S_C, S_Y, and S_M respectively. So the corresponding secondary colour scale dot areas are S_B, S_R, and S_G. Theoretically, the final perception of dot paralleling is the same as that of dot overprinting according to halftone image reproduction law [23]. For secondary colour scale, *Blue* is made up by primary colour *Cyan* and *Magenta* scale. There would be several cases as follows:

Case 1: *Cyan* and *Magenta* colour scale do not overlap at all (Fig. 3). So the total dot gain of this scale can be shown as follows:

$$\Delta S_{\mathrm{B}} = \Delta S_{\mathrm{C}} + \Delta S_{\mathrm{M}}, \tag{9}$$

in which, ΔS_C is dot gain of *Cyan* colour scale. ΔS_M is dot gain of *Magenta* colour scale. ΔS_B is dot gain of secondary colour, *Blue* colour scale.

Figure 3 Case 1: *Cyan* dot does not overlap with *Magenta* dot at all

Case 2: *Cyan* and *Magenta* colour scale overlap completely (Fig. 4). So the total dot gain of blue scale can be shown as follows:

$$\Delta S_{\mathrm{B}} = \max\,(\Delta S_{\mathrm{C}}, \Delta S_{\mathrm{M}}), \tag{10}$$

where, ΔS_B, ΔS_C and ΔS_M have the same meaning in Eq. (9). Max is to find the maximum dot gain from *Cyan* dot gain and *Magenta* dot gain.

Figure 4 Case 2: *Magenta* dot overlaps *Cyan* dot completely

Case 3: *Cyan* dot area partly overlaps *Magenta* dot area (Fig. 5). For this case, secondary colour, *Blue*, consists of both overlapping and paralleling case. So the total dot gain can be shown as follows:

$$\Delta S_{\mathrm{B}} = S_{\mathrm{C}} + S_{\mathrm{M}} - \Delta S - 2S_0, \tag{11}$$

in which, ΔS is the overlapped dot area. S_0 is the primary dot area.

Figure 5 Case 3: *Cyan* dot area partly overlaps *Magenta* dot area

Therefore, dot gain of secondary colour scale, ΔS_B, can be illustrated as the function of dot gain of the primary colour scale, ΔS_C and ΔS_B. And it can be expressed as follows:

$$\Delta S_{\mathrm{B}} = f(\Delta S_{\mathrm{C}}, \Delta S_{\mathrm{M}}). \tag{12}$$

Further it can be shown as:

$$\Delta S_{\mathrm{B}} = a \times \Delta S_{\mathrm{C}} + b \times \Delta S_{\mathrm{M}} + c, \tag{13}$$

in which, c is adjustment coefficient. And this prototype model of dot gain of secondary colour scale is developed. Similarly, the prototype of dot gain of secondary colour scale, *Red* and *Green*, can be formed using the same method above. In this paper the prototype model is simulated using Multiple Linear Regression method as follows.

3.2 Multiple Linear Regression

Secondary colours, *Red*, *Blue* and *Green*, are obtained by overlapping or paralleling the primary colour, *Cyan*, *Magenta* and *Yellow* in this paper. So the dot change of *Red*, *Green* and *Blue*colour scale is determined by the dot change of *Cyan*, *Magenta*, and *Yellow* colour scale. In particular, the dot change of *Blue* colour scale is determined by *Cyan* colour scale and *Magenta* colour scale. The dot change of *Red* colour scale is determined by *Yellow* colour scale and *Magenta* colour scale. And the dot change of *Green* colour scale is determined by *Yellow* colour scale and *Cyan* colour Scale. According to the above analysis, multiple linear regression method is used to analyze the dot gain of secondary colour scale in this paper.

The common form of multiple linear regression model can be shown as follows:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki} + \varepsilon_i, i = 1, 2, \ldots, n. \tag{14}$$

In which, k is the number of variables. $\beta_j (j = 1, 2, \ldots, k)$ is regression coefficient.

For the parameter estimation of Eq. (14), it can be done by least square method or maximum likelihood estimation method under the condition of satisfying the minimum of error sum of squares. Given $(x_{11}, x_{12}, \ldots, x_{1p}, y_1), \ldots, (x_{n1}, x_{n2}, \ldots, x_{np}, y_n)$ to be a group samples, and maximum likelihood estimation method is used.

Set $\hat{b}_0, \hat{b}_1, \ldots, \hat{b}_p$. When $b_0 = \hat{b}_0, b_1 = \hat{b}_1, \ldots, b_p = \hat{b}_p$, $Q = \sum_{i=1}^{n} (y_i - b_0 - b_1 x_{i1} - \ldots - b_p x_{ip})^2$ has the minimum value. Take partial derivative to each component of Q and make them equal to zero, i.e.,

$$\begin{cases} \dfrac{\partial Q}{\partial b_0} = -2\sum_{i=1}^{n} (y_i - b_0 - b_1 x_{i1} - \ldots - b_p x_{ip}) = 0 \\ \ldots \\ \dfrac{\partial Q}{\partial b_j} = -2\sum_{i=1}^{n} (y_i - b_0 - b_1 x_{i1} - \ldots - b_p x_{ip}) x_{ij} = 0 \end{cases} \tag{15}$$

$j = 1, 2, \ldots, p.$

And Eq. (15) is simplified to Eq. (16) as follows:

$$\begin{cases} \sum_{i=1}^{n} y_i = b_0 n + b_1 \sum_{i=1}^{n} x_{i1} + b_2 \sum_{i=1}^{n} x_{i2} + \cdots + b_p \sum_{i=1}^{n} x_{ip} \\ \sum_{i=1}^{n} x_{i1} y_i = b_0 \sum_{i=1}^{n} x_{i1} + b_1 \sum_{i=1}^{n} x_{i1}^2 + b_2 \sum_{i=1}^{n} x_{i1} x_{i2} + \cdots + b_p \sum_{i=1}^{n} x_{i1} x_{ip} \\ \cdots \\ \sum_{i=1}^{n} x_{ip} y_i = b_0 \sum_{i=1}^{n} x_{ip} + b_1 \sum_{i=1}^{n} x_{ip} x_{i1} + b_2 \sum_{i=1}^{n} x_{ip} x_{i2} + \cdots + b_p \sum_{i=1}^{n} x_{ip}^2 \end{cases} \quad (16)$$

Then set

$$Y = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{pmatrix}, X = \begin{pmatrix} 1 & x_{11} & x_{12} & \cdots & x_{1p} \\ 1 & x_{21} & x_{21} & \cdots & x_{2p} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ 1 & x_{n1} & x_{n2} & \cdots & x_{np} \end{pmatrix}, B = \begin{pmatrix} b_0 \\ b_1 \\ \vdots \\ b_p \end{pmatrix}$$

respectively, Eq. (17) can be set as follows:

$$X'Y = X'XB. \quad (17)$$

Therefore, maximum likelihood estimator is obtained:

$$\hat{B} = \begin{pmatrix} \hat{b}_0 \\ \hat{b}_1 \\ \vdots \\ \hat{b}_n \end{pmatrix} = (X'X)^{-1} X'Y. \quad (18)$$

So the estimator of $u(x_1, x_2, \cdots, x_p) = b_0 + b_1 x_1 + \cdots + b_p x_p$ is:

$$\hat{y} = \hat{b}_0 + \hat{b}_1 x_1 + \cdots + \hat{b}_p x_p. \quad (19)$$

And Eq. (19) is the p variables experience linear regression equation. In this paper, secondary colour scale consists of two primary colour scales, so set p = 2. And such process is to solve the two variables linear regression equation.

3.3 Experiment

Dot gain is inevitable in printing process. Even in non-impact printing, optical gain is still in dot area [14]. Six colour scales were designed and output in this paper (Fig. 6). From the top to the bottom the colour scales are *Cyan*, *Magenta*, *Yellow*, *Blue*, *Green* and *Red* respectively. And static digital printing was chosen as the output mode and the dot area of primary colour scale, *Cyan*, *Magenta* and *Yellow*, were measured. The dot areas of second colour scale, *Blue*, *Red* and *Green* were also measured. 500 samples were output using Konica Minolta bizhub Press C6000 and about 50 samples were extracted randomly and measured by spectrophotometer. The average values are shown in Tab. 1 and Tab. 2. And coated color laser printing paper was used as printing substrate. The weight is 120 g/m^2. X-Rite SpectroEye LT was used to measure the color patch with the viewing condtion of D65, 2° standard viewing angle and 45°/0° of geometry. CIE1931 standard observers was used in this paper.

Figure 6 Colour scales of *Cyan*, *Magenta*, *Yellow*, *Blue*, *Green* and *Red*

Table 1 Primary colour dot area

Dot area of primary colour scale																
Primary dot area		0	2	4	6	8	10	20	30	40	50	60	70	80	90	100
Output dot Area	*C*	0	6	9	14	18	19	34	46	57	64	77	86	93	98	100
	M	0	4	10	14	17	19	30	42	54	63	76	84	92	98	100
	Y	0	4	10	15	18	21	35	50	63	71	82	88	94	99	100

Table 2 Secondary colour dot area

Dot area of secondary colour scale																
Primary dot area		0	2	4	6	8	10	20	30	40	50	60	70	80	90	100
Measured dot area	*B*	0	6	13	19	21	24	41	54	64	75	84	91	94	98	100
	G	0	4	9	16	20	23	35	52	64	72	82	89	94	99	100
	R	0	6	13	21	24	28	42	59	73	80	89	93	96	99	100

4 Results and discussion

The research in this paper comprised the research of dot gain of primary colour *Cyan*, *Yellow* and *Magenta*, dot gain of secondary colour *Blue*, *Red* and *Green*, and the relation model between secondary colour and primary colour. The results of the research were put into correlation in order to get the objective recommendations of the relation between secondary colour dot gain and primary colour dot gain for the xerographic digital printing.

4.1 Primary dot gain curves

The research of dot gain was performed on fields of the colour scales in the range from 2 to 90 % screen value. By calculation of dot gain for the designed colour scales the curves for the primary colour were constructed as the average value of all *Cyan*, *Magenta* and *Yellow* samples. The obtained results are shown in Fig. 7.

In Fig. 7, dot gain of *Cyan*, *Magenta* and *Yellow* is basically the same in the high-light area. Dot gain of *Yellow* is the most obvious or serious in light area (20 ÷ 40 %) and mid-tone area (40 ÷ 60 %), while dot gain of *Magenta* is less serious in the same area. However, dot gain of the three primary colour scales tends to be basically the same in the shadow area (70 ÷ 100 %). The point is that dot gain is most serious in 40 % tone area, not in 50 % tone area because it is dependent on dot shape.

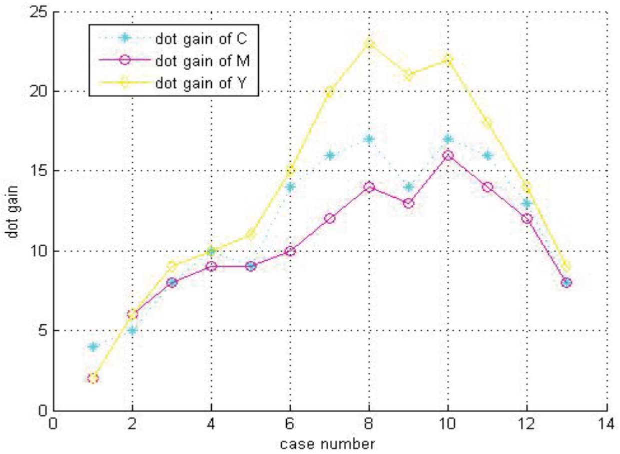

Figure 7 Dot gain of primary colour scales, *Cyan*, *Magenta* and *Yellow*

4.2 Modelling for secondary colour dot gain

According to the above analysis, assume that secondary colour dot gain depends on the primary colour dot gain. For secondary colour *Blue*, its dot gain is based on dot gain of primary colour, *Cyan* and *Magenta* according to the multiple linear regression method. Dot gain of *Blue* is given to have the follow relations with *Cyan* and *Magenta* according to Eq. (19):

$$\Delta B = b_0 + b_1 \Delta C + b_2 \Delta M \,. \tag{20}$$

Similarly, secondary colours *Green* and *Red* have similar relations with primary colour *Cyan*, *Magenta* and *Yellow*.

$$\begin{cases} \Delta B = b_0 + b_1 \Delta C + b_2 \Delta M \\ \Delta G = g_0 + g_1 \Delta C + g_2 \Delta Y \,. \\ \Delta R = r_0 + r_1 \Delta M + r_2 \Delta Y \end{cases} \tag{21}$$

Eq. (21) also can be expressed as:

$$\Delta S(B,G,R) = A \cdot \Delta P(C,M,Y) \,, \tag{22}$$

where, ΔS is dot gain of secondary colour, ΔP is dot gain of primary colour and A is conversion matrix.

50 samples were extracted from the output samples randomly and were measured by spectrophotometer to get the dot gain data. The average data is shown in Tab. 2. Multiple linear regression method was used to compute the related coefficient for Eq. (21) and Eq. (22). And the result is shown as follows:

$$A = \begin{pmatrix} b_0 & b_1 & b_2 \\ g_0 & g_1 & g_2 \\ r_0 & r_1 & r_2 \end{pmatrix} = \begin{pmatrix} -0.6203 & 1.3865 & 0.0955 \\ 0.0033 & 0.0418 & 1.0147 \\ 3.4423 & -0.9240 & 1.8397 \end{pmatrix}$$

Then the prototype of relation between secondary colour scale dot gain and primary colour scale dot gain is developed as follows.

$$\begin{cases} \Delta B = -0.6203 + 1.3865 \Delta C + 0.0955 \Delta M \\ \Delta G = 0.0033 + 0.0418 \Delta C + 1.0147 \Delta Y \\ \Delta R = 3.4423 - 0.9240 \Delta M + 1.8397 \Delta Y \end{cases}$$

So the dot gain of secondary colour scale can be calculated based on the dot area of primary colour scale. Then the measured dot gain (Tab. 2) and calculated dot gain can be compared and some effective analysis can be done. Finally, the effective prototype system for secondary colour scale dot gain compensation and prediction system based on the primary colour scale dot gain can be developed.

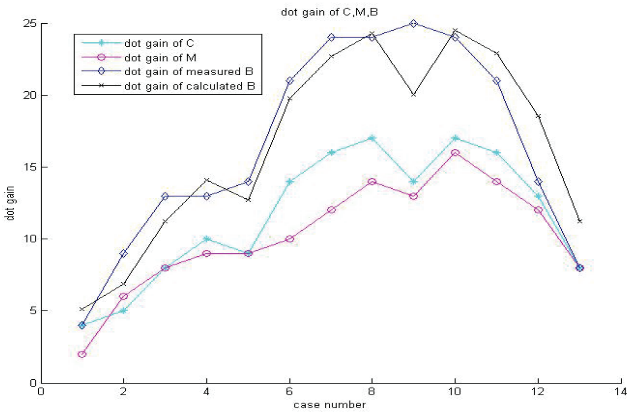

Figure 8 Dot gain of *Cyan*, *Magenta*, measured *Blue* and Calculated *Blue*

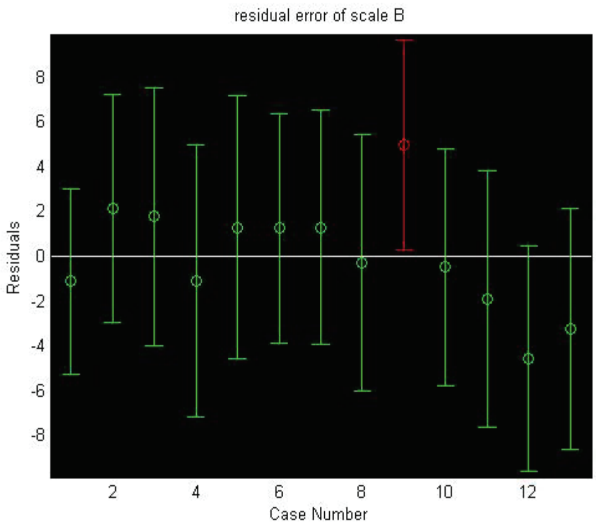

Figure 9 Residual of *Blue* regressed

4.3 Evaluation and discussion

According to the result, Tab. 1 and Tab. 2, the relation between measured dot gain and calculated dot gain of *Blue* based on primary *Cyan* and *Magenta* is shown in Fig. 8. And the residual plot of calculated secondary dot gain is shown in Fig. 9. In a similar way, the relation between measured dot gain and calculated dot gain of *Red* based on primary *Magenta* and *Yellow* is shown in Fig. 10. And the residual plot of calculated secondary dot gain is shown in Fig. 11. For secondary *Green*, the comparison was shown in Fig. 12 and Fig. 13.

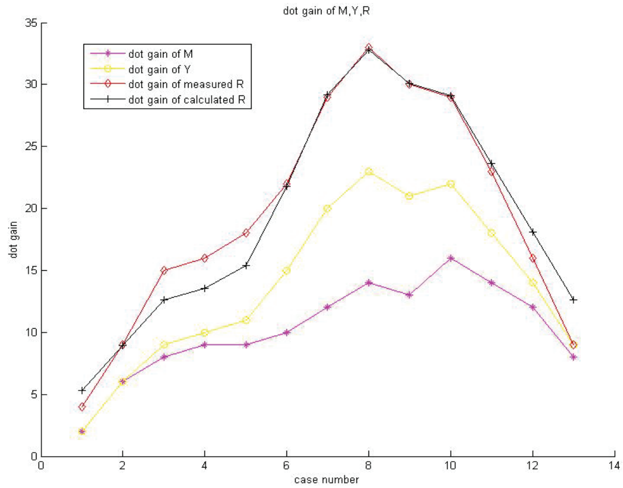

Figure 10 Dot gain of *Yellow*, *Magenta*, measured *Red* and Calculated *Red*

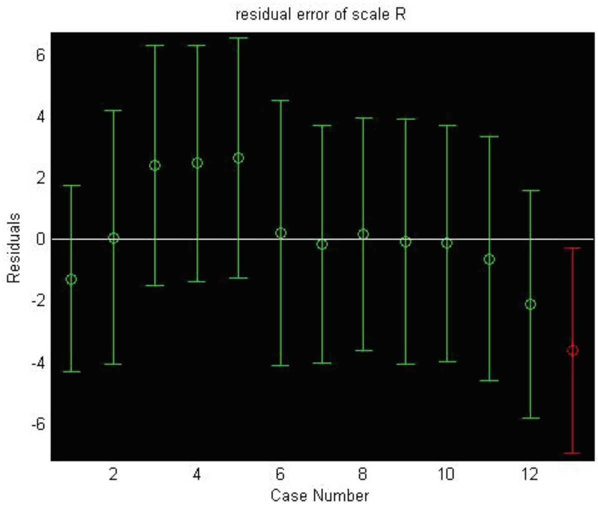

Figure 11 Residual of *Red* regressed

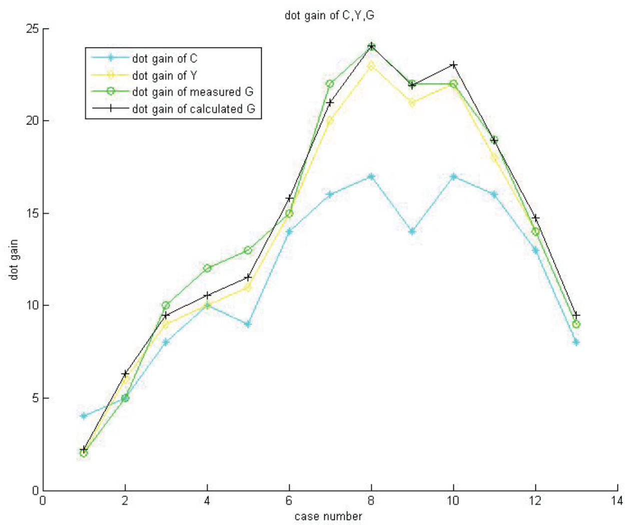

Figure 12 Dot gain of *Cyan*, *Yellow*, measured *Green* and Calculated *Green*

From Fig. 8 to Fig. 13, it is found that the model developed in this paper to calculate and to predict secondary colour dot gain has more efficiency in light-tone and mid-tone area of *Red* and *Green* while has some error in high light tone and shadow tone. For modeling and prediction of *Blue*, it is found that the model has more error than that for *Red* and *Green*, especially in the 50 % tone area. So it is necessary to do some further research to the error area and the model for *Blue*. Moreover, it is also necessary to do research on the other types of printing for secondary dot gain.

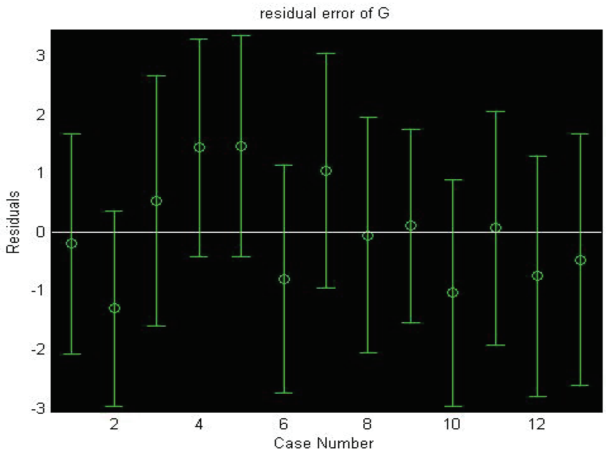

Figure 13 Residual of *Green* regressed

5 Conclusion

The purpose of digital printing is to enable the printing of high efficiency and of high quality reproduction. To obtain the qualitative reproduction depends on a series of parameters, e.g., paper, pigments and equipments, digital prepress image processing. However, one of the most important is the standardized and defined dot gain in a regular production process. Dot gain control is the most effective and simple method to control printing quality. The research in this paper confirmed that the screening dot is the basic printing element to reproduce continuous image and to form the printing image. On the basis of the obtained results and analysis, with the aim of increasing the quality of the printing product, the new dot gain control technologies should be recommended during the digital printing process.

From all the mentioned, the research in this paper established the model of the secondary colour dot gain according to the primary colour dot gain so that it was used to evaluate and to control the dot gain in a larger scope.

The secondary colour dot gain in electrostatic digital printing is studied by considering dot gain of the colour scales, *Cyan*, *Magenta*, *Yellow*, *Blue*, *Red* and *Green*. The relations between secondary colour dot gain and primary colour dot gain are also studied. Three primary colour scales, *Cyan*, *Magenta*, *Yellow*, and three secondary colour scales, *Blue*, *Red* and *Green*, are designed from 2 % to 90 %. The colour scales are output by electrostatic colour press and measured by spectrophotometer. The dot gain of the secondary colour is modeled according to the dot gain rules of the primary colour using multiple linear regression method. The results illustrate that the dot gain of secondary colour changes with the dot gain of primary colour synchronously, and that further research is needed to make for dot gain compensation and printing process control.

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Authors' address

Xiao-zhou Li, Ph.D.
Key Laboratory of Pulp & Paper Science and Technology,
Ministry of Education
Qilu University of Technology
250353, Ji'nan, China
Email: lixiaozhou2000@163.com

Jing-jing Liu, Assistant and researcher
Shandong University of Art & Design
250353, Ji'nan, China
Email: foxliu919@163.com

Xue-lin Li, Assistant and researcher
School of Mechanical and Automotive Engineering
Qilu University of Technology
250353, Ji'nan, China
Email: kjclxl@126.com

Yu Liu, Prof.
School of Computer and Electron Information Engineering
Qilu University of Technology and Shandong Yingcai University
250104, Ji'nan, China
Email: liuyu8619759@163.com

Ai Xu, Assistant Prof.
Qilu University of Technology
250353, Ji'nan, China
Email: lxzrgb@126.com