Colorimetric Characteristics of the Proof Print Produced by Photographic Process and Comparison to Conventional Color Prints

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Abstract

In our laboratory, it is continuing to analyze the colorimetric characteristics of various process color prints and proofs produced by photographic or electrophoto-graphic process. This paper reports the colorimetric characteristics of proof "COLOR ART" produced by photographic process comparing to those of conventional process color prints. At first, the distribution characteristics of reproduced color patch data of proof print is investigated. The characteristics observed can be summarized as follows;

1. For example, coordinates of colorimetric data corresponding C = constant and variable M and Y are on the flat plane in L* a* b* color space.
2. The same phenomena can be observed in cases of M = constant and Y = constant.
3. The coefficient of the plane equation is expressed as the function of C, M or Y percent value and can be approximated by using the quadratic equation.

On the basis of these phenomena, the conversion method from CMY to L* a* b* and vice versa is proposed.

The evaluation of the conversion method can be performed by ΔE values between predicted L* a* b* values and measured L* a* b* values. The precision of predicted values for proof indicates most of ΔEs are less than 5. ΔE values for various process prints when quadratic equations are applied to coefficients' approximation are improved as shown in figures.

In conclusion, the conversion method developed surely provide an reproduction technique available for various types of prints.

1. Introduction

The introduction of electronics into the graphic arts has allowed printing to become much more open processes and led to an increased dependence on more analytically-based processes including digital proofing and imaging technology. These processes impose increasingly stringent requirements for consistency and predictability in the hard copy producing processes. In order to meet these requirements, the relationship between the realized colorimetric values and input CMY(K) dot percent data has to be characterized for various hard copy processes.

In NIP 12 conference held in San Antonio, the authors reported about the color gamut of printed materials produced by our laboratory and the approximation method for converting back and forth between L* a* b* values and CMY dot percent values.

The approximation was performed on the basis of the phenomena that coefficients of flat plane equations on which plane the colorimetric data of patches corresponding to C = constant and variable M and Y distribute depend on C values and are independent on M, and Y values. Also, for conditions of M = constant and variable C and Y, or Y = constant and variable C and M, colorimetric data of color patches show similar characteristics in L* a* b* coordinates.

In our former report, approximation of coefficients was performed by the linear equation of C, M, or Y, and ΔE exceeds 10 in some patches.[1]

This paper studies about how to reduce the ΔE less than 5.0. Measurements and analysis are mainly performed by using the proof and its results are compared with various prints.

As shown in following chapters our analytical method seems to be applicable for every type of color reproduction system. We believe that the proposed conversion algorithm using transformation formula will provide the new realistic color space conversion techniques as same as LUT method.

2. Samples Used

2.1 Color Patches Measured

As for the estimation of color prints, color patches defined in the ISO 12642 (Output Targets) are used.[3]

As a color proof, the reproducibility of COLOR ART (Fuji Film) is examined. Patches defined by combination of every five dot percent values of CMY are produced by photographic process.

2.2 Samples

Following samples are investigated

Type of Paper	Type of Screen
1.Type 1 paper	175 line/inch (lpi) square dot, 21µm stochastic, 16µm stochastic
2. Chemical Paper	175 lpi square dot, 21µm stochastic, 16µm stochastic
3. News Paper	175 lpi square dot, 100 lpi square dot, 21µm stochastic
4. Proof	produced by photographic process

2.3 Producing Condition

Printed samples are produced by using the color proofing machine. Standard commercial PS plates are used.

However, print process from film to PS plate was carefully controlled to get the qualified color separation image on the plate.

The printing sequence of Type 1 paper and synthetic paper is C-M-Y-K , and for the newsprint changes to M-C-Y-K. Aimed densities of solid portions on the Type 1 paper and synthetic paper are C:1.50, M:1.47, Y:0.97 and K:1.75, and those of newsprint are C:0.85, M:0.88, Y:0.96, K:1.05. The colorimetric characteristics of process inks used are same as those specified in ISO 12647/2.[2]

2.4 Measurement Devices

The measurement is performed by X-rite 938 Spectrophotometer which is specified by the ISO 13655 standard. Conditions are D50 light source, 2 degree observer, 0/45° geometry, black backing and status T.

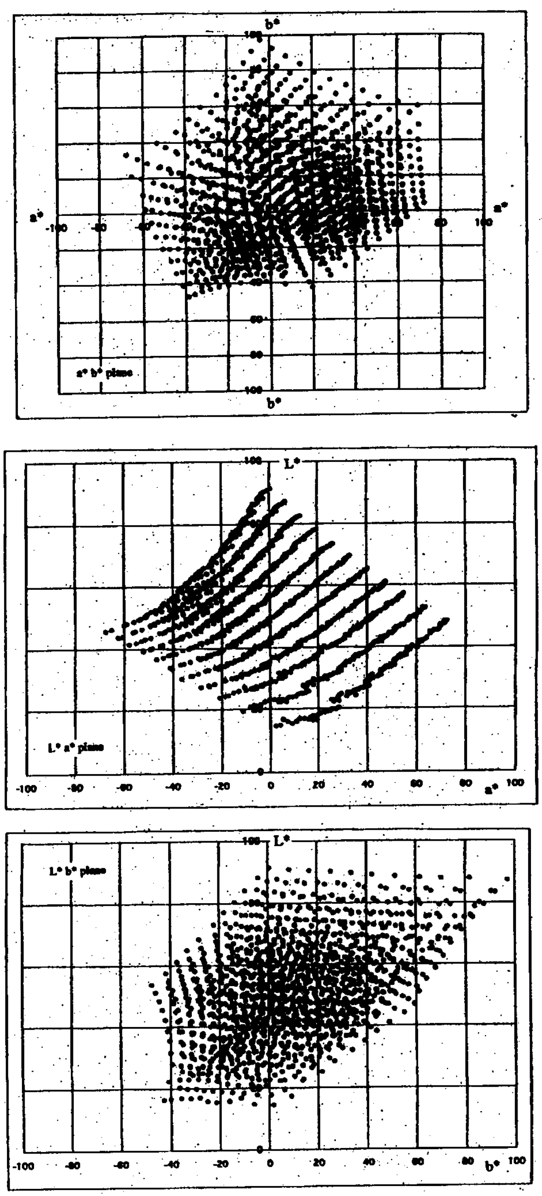

Figure 1. Distribution of measured data. It shows the reproducible gamut of proof "COLOR ART"

3. Results

3.1 Distribution of Colorimetric Values

Figure 1 shows the distribution of measured colorimetric data for proof "COLOR ART". The shape of gamut is almost same as the shape of various process prints. Colorimetric data corresponding to the same C value and variable M and Y values are on the flat plane in L* a* b* coordinates. Also, for constant value of M or Y colorimetric data are on the respective flat plane as well as C. Formulas which represent the flat plane in L* a* b* coordinates are shown by Equation (1) for C, M and Y.

$$\begin{aligned} L^* &= \alpha(C) + \beta(C)a^* + \gamma(C)b^* \\ L^* &= \alpha(M) + \beta(M)a^* + \gamma(M)b^* \\ L^* &= \alpha(Y) + \beta(Y)a^* \gamma(Y)b^* \end{aligned} \qquad (1)$$

Figure 2 shows precisely the colorimetric data are located on a flat plane when M = 70% and C = 10% as examples. The lateral axis corresponds to measured values and the vertical axis corresponds to predicted values. Dots on the 45 degree line indicate the predicted L* values calculated by Equation (l) coincide with the measured L* values. The precision can be confirmed by this method. For every type of prints we investigated, these phenomena is concluded and is basis of our conversion algorithm.

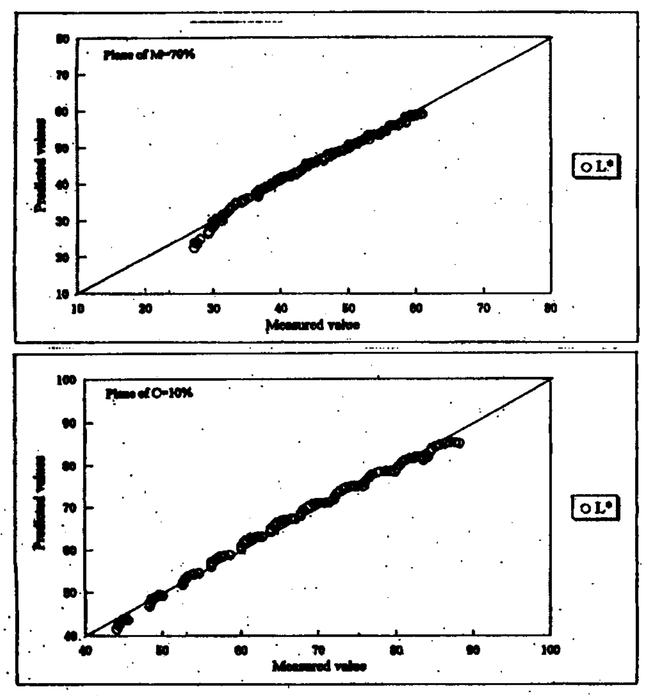

Figure 2. Relationship between measured L values and predicted L* values on M = 70% and C = 10% planes*

3.2 Coefficients' Approximation

The coefficient values α, β, γ in Equation (1) are the function of dot percent values of C, M or Y inks.

Figure 3 shows coefficient values α(C), β(C) and γ(C) of COLOR ART proof as a function of dot percent value of C. These curves can be approximated by quadratic equations like Equation (2) respectively.

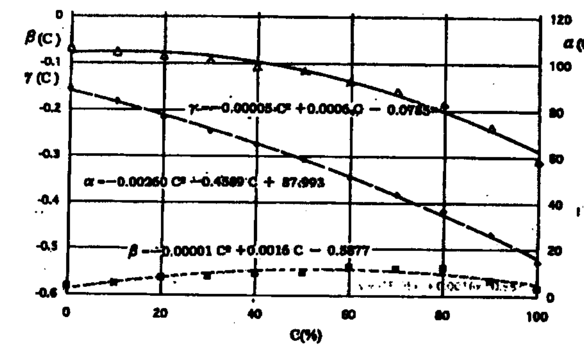

Figure 3. Relationship between coefficients and C dot %.

These approximations are available to every combination of paper and ink without exception.

$$y = a\,x^2 + b\,x + c \qquad (2)$$

where y : α, β, γx : Dot percent values of C, M or Y.

Table 1 shows coefficient values of a, b, c for COLOR ART proof.

Table 1. Coefficient values for proof

Ink	Coeff.	a	b	c
C	α	–0.0026	–0.4589	+87.993
	β	–0.00001	0.0016	–0.5877
	γ	–0.00003	0.0006	–0.0785
M	α	–0.00080	–0.6624	+85.894
	β	0.00004	–0.0067	+0.7587
	γ	0.00001	–0.0012	+0.0454
Y	α	0.0030	–1.0823	+ 92.453
	β	–0.00005	+0.0102	–0.7001
	γ	0.00004	–0.012	+1.5491

By substituting values of Table 1 to Equation (2), then we can decide the flat plane expressed by Equation (1) having real coefficient values.

By using the Equation (1), L* a* b* values corresponding to given CMY values can be predicted and compared with measured values in L* a* b* color space. Figure 4 shows color difference ΔEs between measured colorimetric values and predicted values from Equation (1).

The precision of prediction can be evaluated with ΔE. As for the proof, mean value of ΔE indicates less than 3. For other prints, the application of Equation (2) indicates decreases of ΔE values. Color gamut and ΔE of various prints are shown in Table 2.

3.3 Conversion from CIELAB to CMY

From the relationship expressed by Equation(l) and (2), the calculation of CMY dot percent values from colorimetric values become possible. Equation (3) shows the case of COLOR ART proof.

$$C = -(1.1\,85 \times 10^6 - 4600a^* - 400b^* - 5000L^*) + [(-1,\,185 \times 10^6 - 4600a^* - 400b^* - 5000L^*)^2 - (34a^* - 100b^*) \times (-1.335 \times 10^8 + 870000a^* + 90000b^* + 1.5 \times 10^6 L^*)^{1/2}\ 37a^* + 50b^*$$

M = same type formula . . . . (3)

Y = same type formula

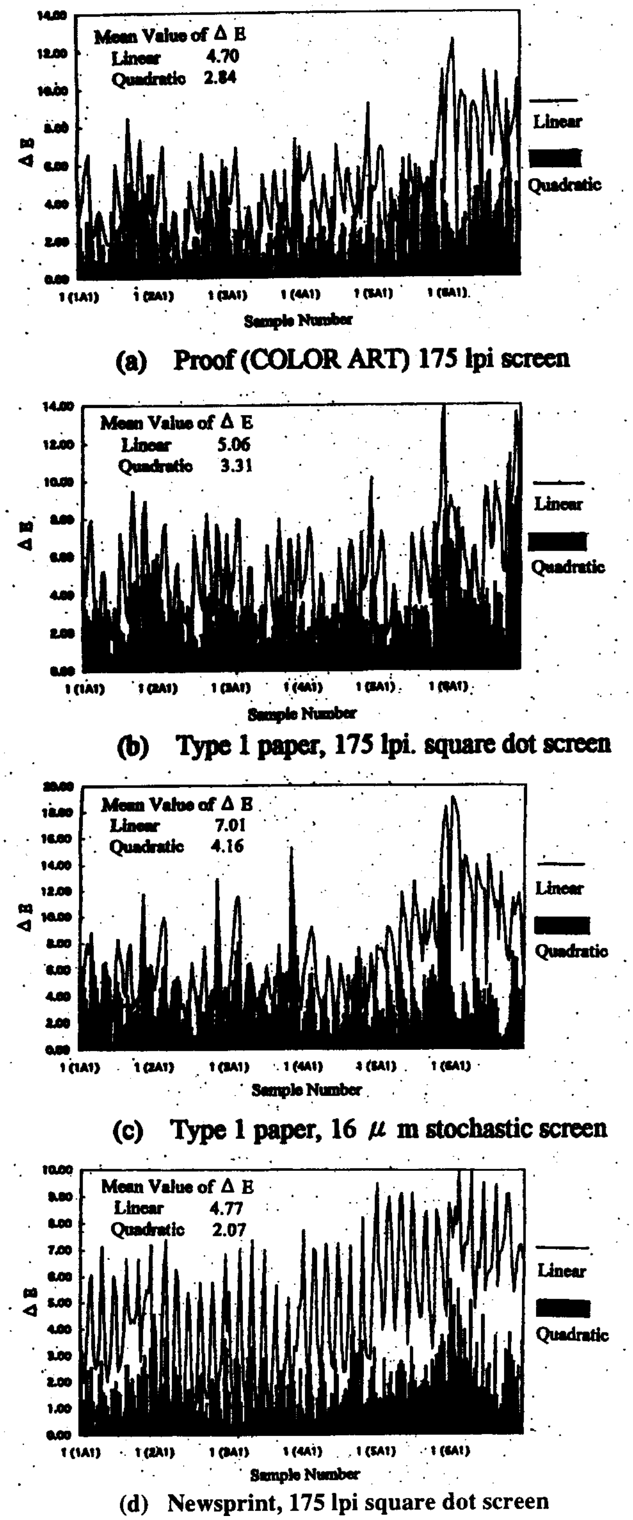

Figure 4. ΔE characteristics of various prints and a proof

Figure 5 shows the comparison of aimed dot percent values of M and Y and values calculated with Equation (3) for measured L* a* b* values corresponding to respective C, M, and Y values.

Table 2. Maximum L* a* b* range and ΔE of prints

Objects	L*	a*	b*	ΔE
Type 1				(1) (2)
175 lpi	2.94-92.7,	-72.6-70.6,	-51.2-93.9,	5.06 -> 3.31
16µm	2.78-92.5,	-70.9-70.4,	-50.6-93.2,	7.01 -> 4.16
Chemical Paper				
175 lpi	4.70-94.5,	-72.6-71.8,	-52.5-96.8,	
16µm	3.71-94.4,	-68.7-69.8,	-51.1-88.4	
Newsprint				
175 lpi	22.3-79.2,	-41.3-45.3,	-28.0-58.7,	4.77 -> 2.07
100 lpi	25.9-79.6,	-39.1-45.3,	-29.6-59.1	
21µm	21.9-79.7,	-40.7-47.6,	-29.6-59.1	
Proof (COLOR ART)				
175 lpi	14.5-91.3,	-67.6-72.3,	-47.2-97.2,	4.70 -> 2.84

where ΔE shows mean value of color differences

(1): values approximated by linear equation.

(2): values approximated by quadratic equation.

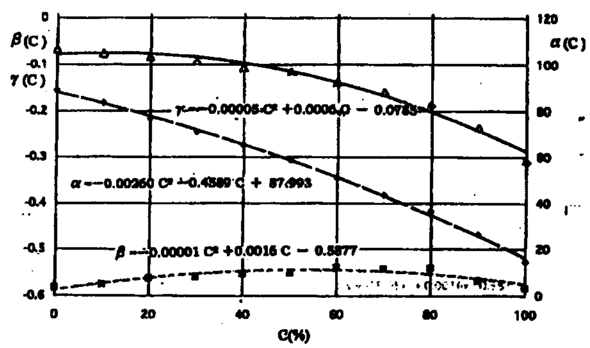

Figure 5. Comparison between specified dot percent values and values calculated by Equation (3) for measured L a* b* values corresponding to C, M and Y (=40%) values*

Conclusion

The conversion algorithm between L* a* b* values and C, M, Y dot percent values is studied. This study is based on the following phenomena when gamut investigation of process prints was performed.

1. All colorimetric values corresponding to constant value of one ink dot percent (e.g., C = constant, variable M and Y)are on a flat plane in L* a* b* color space.
2. Coefficients of equations which define flat planes are represented as the function of specified ink dot percent values (e.g., function of C values).
3. Each coefficient can be approximated by linear or quadratic equation. By using these relations, L* a* b* values are converted to C, M, Y dot percent values required from various color hard copy systems.

More extensive study will be necessary to understand in detail the colorimetric behavior of process ink and other color materials when Black is included. However, the phenomenon regarding the distribution of colorimetric data seems to be a essential law of color materials. We hope to further discuss for modeling these behavior of color materials.

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Reference

1. M. Kaji, et. al., "Colorimetric Characteristics of Process Color Prints Produced under the JAPAN COLOR Conditions" *IS&T NIP 12 Conference 1996*; (see page 62, this publication).
2. ISO 12647-2 "Graphic technology-Process control for the manufactures of half-tone colour separations, proofs and production prints-Offset processes".
3. ISO 12642 "Graphic technology—Prepress data exchange—Input data for characterization of 4-colour process printing targets".

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