Colorimetric Characteristics of Process Color Prints Produced under the *Japan Color* Conditions

Conversion Trials from L*a*b* Values to CMY Dot Percent Values

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Abstract

A part of the work in our laboratory is to analyze the colorimetric characteristics of process color prints produced under various printing conditions. This paper explains at first that the certified proofs available for the preparation of the colorimetric characterization data were made in order to meet the requirements of the Japan Color Conditions.

Values of printed color patches on the proof for which dot values were specified in ISO 12642 "Graphic technology—Prepress digital data exchange—Input data for characterization of 4-colour process printing" are computed with CIE LAB color coordinates.

For halftone proofs, a conventional square dot screen of 70 cm-1 screen ruling and stochastic screens having minimum dots of 16 µm and 21 µm are specified.

By using the measured results, the reproduction gamuts of certified proofs made under the Japan Color Conditions are investigated and the color coordinate conversion between L*a*b* values and CMY percent values with the projective transformation method are studied.

The approximation is evaluated as follows: First is comparing the specified dot values and predicted CMY percent values and second is by color difference ΔE between measured values and L*a*b* values predicted from the specified CMY dot values. Also a subjective investigation has been performed with prints made by using Pictrography 3000.

Consequently, it has been confirmed that the proposed conversion method is useful and provides an easier color reproduction technique.

Introduction

The introduction of electronics into the graphic arts has allowed printing to become a much more open process. This has led to an increased dependence on more analytically-based processes including digital proofing and imaging technologies. Such processes impose increasingly stringent requirements for consistency and predictability in the printing process. In order to meet these requirements, the relationship between the printed color and the associated input CMY(K) data has to be characterized.

These efforts have been made in ISO /TC130 (Graphic Technology) over 6 years and as a result, printing tests to specify either the reflection density or the tristimilus values of a solid printed ink film and to specify tolerances of colorimetric values at which various halftone dot values should been reproduced have performed in the USA. Japan and Europe by using the specification of ISO 12642 "Graphic technology-Prepress digital data exchange-Input data for characterization of 4-colour process printing".

As the specifications for the process control elements, SWOP in the USA and FIPP in Europe are widely recognized standards. In 1990, Japan National Committee for TC130 (JNC) had specified the similar standard "Japan Color Conditions" in which standard Ink SF-90, standard paper, standard color values and standard color samples are included.

The JNC experts group, working in conjunction with industrial groups, undertook the development of the standardization of printing conditions and the creation of characterization data for material printed in accordance with the Japan Color Conditions.

This paper shows the color gamut of printed materials made by our laboratory, studies about the relationship between CMY dot values and L*a*b* values and how to get the relationship of both values shown by the projective transformation formula.

By using the formula, it is possible to predict the L*a*b* values of CMY dot percent values. The CIE LAB color difference Δ E are calculated for each color patches and values are depicted.

A comparison of both prints having the specified CMY dot values and prints having the CMY values predicted from the L*a*b* values obtained by measurement of patches of the specified CMY dot values was performed and the grade of approximation of the transformation formula was confirmed subjectively.

Measurement Protocol

Process Model

Figure 1 shows the color reproduction model in which the exchange of device independent digital color data is supported between scanner and reproduction system. To implement a system like the process model, three conversion steps should be used for device independency.

At Conversion 1, RGB color separation values should be converted to the device independent data like as CIELAB or CIELUV to make possible the exchange of data. The function of Conversion 2 is to convert the color gamut of the original data to the gamut of the reproduction system in the uniform color space.

The hardcopy reproduction must use the CMY(K) color materials and then the conversion from the uniform color space to the CMY(K) color space is performed in Conversion 3.

Our studies reported on in this paper are primarily related to the Conversion 3 process. The Conversion 3 process installed in usual reproduction devices is implemented by using the look up tables (LUT) combined with interpolation techniques.

If the conversion is possible by using transformation formula, the conversion algorithm will become easier than LUT techniques.

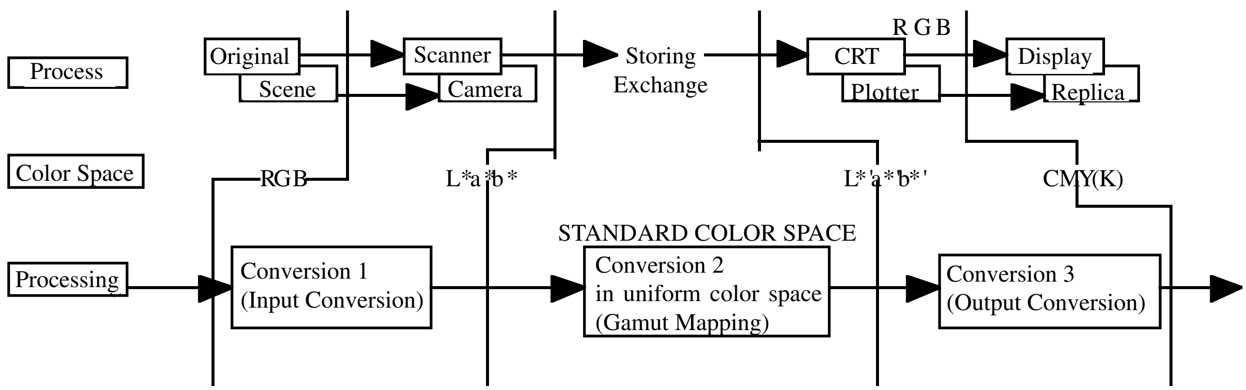


Figure 1. Process model of color reproduction system.

Japan Color Conditions

The suggested values of process parameters required for halftone offset prints are specified in the International Standard ISO 12647/1,2, and the Japan Color Conditions are specified on the basis of this standard as follows:

1. Color Separation Film
   - Transmission density of dot • • • • • at least 2.5
   - Film base plus fog • • • • • • • • less than 0.06
2. Screen ruling
   - 70cm^{-1} for commercial/specialty printing
3. Screen angle
   Normal screen separation for cyan, magenta and black shall be 30º with the yellow separated by 15º from an other color.
4. Substrate

Type 1. (gloss-coated 115 ± 15 g/m^2) for proof prints *

L*	a*	b*	gloss	brightness
93 ± 2	0 ± 2	-3 ± 2	40 ± 2%	85 ± 2%

The JNC designates 2 brands “Tokubishi-art” and “OK-art” as the standard paper on the basis of the specifications shown in the ISO 12647/2.

5. Ink set colors as printed
   Recommended data is shown in Table 1.

Table 1. CIE LAB Coordinates of Colors for the Color Sequence Cyan-Magenta-Yellow; Black Backing, Illumination D50. (1993)

	L*	a*	b*	(1)	D(4)	(2)	(3)
Black	12.5	0.7	1.2	6	1.83	4	2
Cyan	53.9	-35.9	-50.4	6	1.48	5	2.5
Magenta	46.3	74.4	-4.8	6	1.53	8	4
Yellow	86.5	-6.6	91.1	6	1.04	6	3
Red	48.0	65.5	48.0	6	—	—	—
Green	48.9	-70.1	27.1	6	—	—	—
Blue	23.1	20.4	-52.1	6	—	—	—
White	93.0	0.5	0.4	6	—	—	—

(1) ΔE allowable in Japan Color Conditions,
(2) Deviation tolerance,
(3) Variation tolerance
Both (2) and (3) are defined in the ISO 12647/2 standard.
(4) Aim density

* errata shown in shaded box; original manuscript read **115g/m^2**

Samples and Measurement Procedure

Prior to producing the test prints, the following activities were performed in our laboratory.

1. Three halftone images as shown in Figure 2 were prepared.

❶ 70 cm^{-1} screen ruling, square dot screen
❷ 21 µm minimum dot size, stochastic screen (Randot: Dainippon Screen)
❸ 16 µm minimum dot size, stochastic screen (Randot: Dainippon Screen)

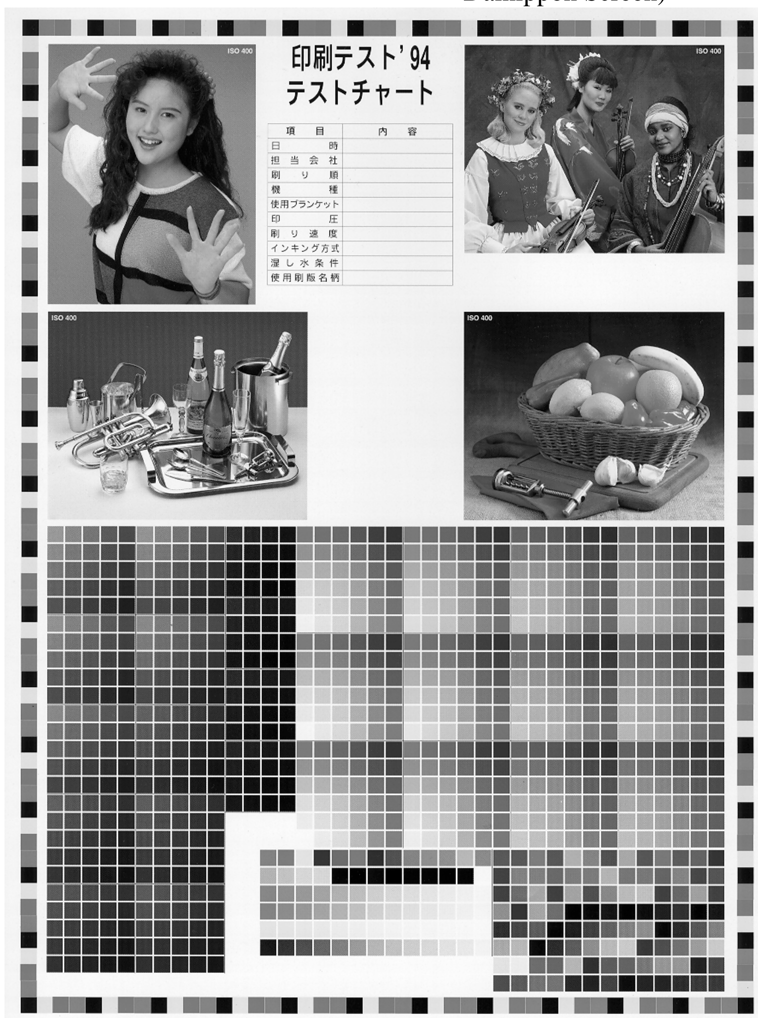


Figure 2.

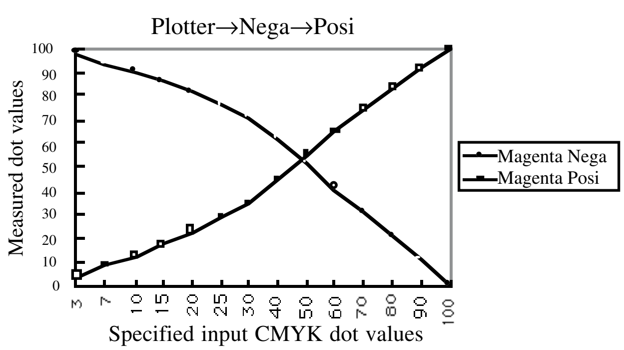


Figure 3. Comparison between measured dot percent values and specified values

2. Dot gain values are measured in square dots. (Figure 3)
3. By using these films, the plates used were produced with adequate exposure time which was controlled so as to remain 8 µm lines in the Bruner Chart.
4. A proof printing machine was used to make samples.

The densities of the solid portions defined by the JNC were measured for every print. (Refer to Table 1.)
The following materials were used to produce sample prints.

① Paper: Tokubishi-art 128g/m^2
② Ink: Japan Color SF-90
③ Proofing Machine: KF-123-GL (Dainippon Screen)
④ Blanket: Barcan New 278
⑤ Plate: FPP-J (Fuji film)
⑥ Color sequence: Cyan→Magenta→Yellow →Black

5. All measurements were made in accordance with the procedures of ISO standards. That is, the measurement geometry was 45º/0º or 0º/45º and a black backing was used. The calculation of the CIE tristimulus values, XYZ, and the subsequent CIELAB values used the weighting functions which are based on the 1931 CIE 2º observer and the D50 illuminant. The actual operations were performed by using the X-Rite 938 spectrodensitometer.
6. Color patches specified in ISO 12640 (SCID) or 12642 (Output Targets) are consisted of 928 patches for which

combinations of dot percent values are defined. Colorimetric data were measured for all patches and data analysis was implemented for 216 patches excluding black values to get the transformation formula from CMY to L*a*b* or vice versa.

The combinations of dot values for 216 patches are as follows;

Cyan	0	10	20	40	70	100%
Magenta	0	10	20	40	70	100%
Yellow	0	10	20	40	70	100%

Results

Gamut of Process Print

Figure 4, Figure 5-1, 5-2, and 5-3 are gamuts of proof prints we produced under the Japan Color Conditions.

The ranges of reproduced colorimetric values for these proofs having the three type of dot shapes are tabulated in Table 2.

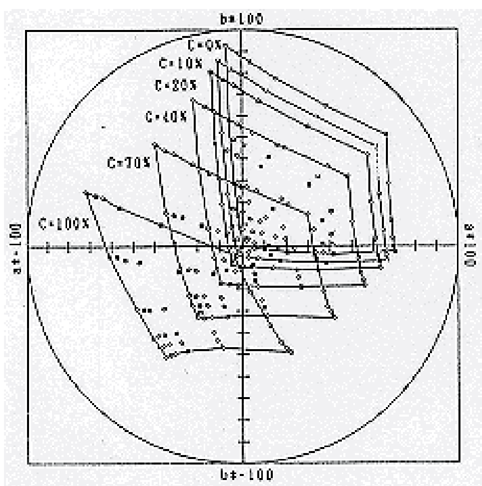


Figure 4. Gamut reproduced by using 3 process color inks Data of C = constant locate almost on a flat plane

Table 2. The Range of Reproduced Color Values

	Square Dot (70cm^{-1})	21µm min. dot	16µm min. dot
L*	2.9 ~ 92.7	2.6 ~ 92.4	2.8 ~ 92.5
a*	-72.6 ~ 70.6	-73.0 ~ 70.9	-70.9 ~ 70.4
b*	-51.2 ~ 93.9	-52.1 ~ 92.0	-50.6 ~ 93.2

The ranges of L*a*b* values shown in Table 2 are almost same. However, the distribution of measured values indicates variations among different shapes.

Conversion between Colorimetric Values and Dot Values

When observing the distribution of measured colorimetric values, we can find out that the measured data for C = constant are almost on the flat plane in the L*a*b* coordinates. For M and Y, the same phenomena can be observed from Figure 10(a) and Figure 11(a). The plane which the group of data for C = constant are located on is represented as Equation 1.

$$L^* = \alpha(C) + \beta(C)a^* + \gamma(C)b^* \cdots \quad (1)$$

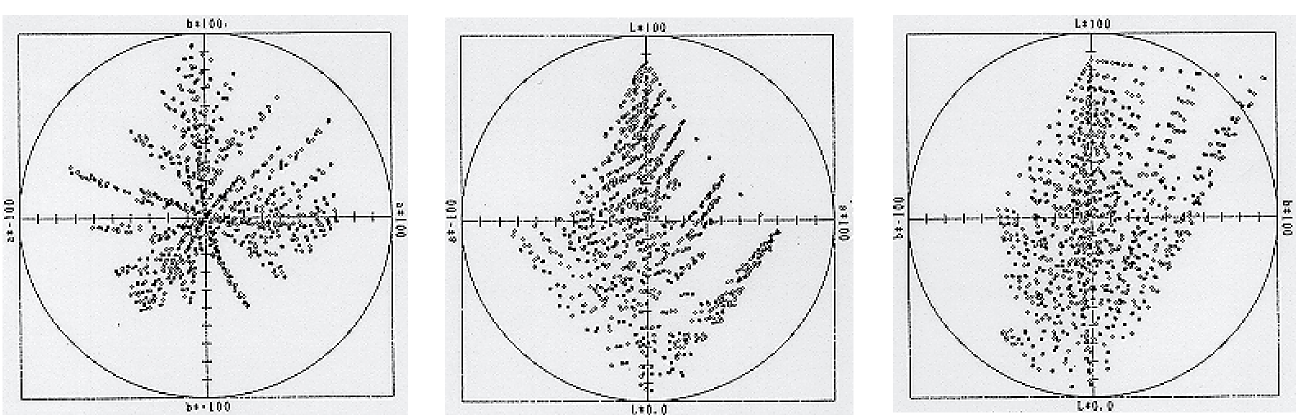
Figure 6 shows examples of α (C), β (C) and γ (C) as the function of C values.

If α (C), β (C) and γ (C) are expressed as a function of C values, then C values are related to L*a*b* values from Equation (1). The equation like (1) for M = constant and Y = constant can be obtained from the measured data.

From coefficients of α (M), β (M), γ (M) for M and α (Y), β (Y), γ (Y) for Y, we can obtain relationships (2) between L*a*b* values and dot values of M and Y respectively.

$$\begin{aligned} Csq &= \frac{230L^* + 146.29a^* + 22.158b^* - 20748.9}{L^* + 0.72979a^* - 0.16366b^* - 191.35} \\ Msq &= \frac{-L^* + 0.7104a^* + 0.05393b^* + 89.084}{0.003178a^* + 0.71760} \\ Ysq &= \frac{-L^* + 0.5788a^* + 1.2130b^* + 91.1336}{-0.004574a^* + 0.00492b^* + 0.73848} \end{aligned} \quad (2)$$

Csq, Msq, Ysq: Dot percent values for square dot halftone.



*(1) a*b* plane* *(2) L*a* plane* *(3) L*b* plane*

Figure 5. Gamut reproduced by using the Japan Color Conditions (175 line/inch)

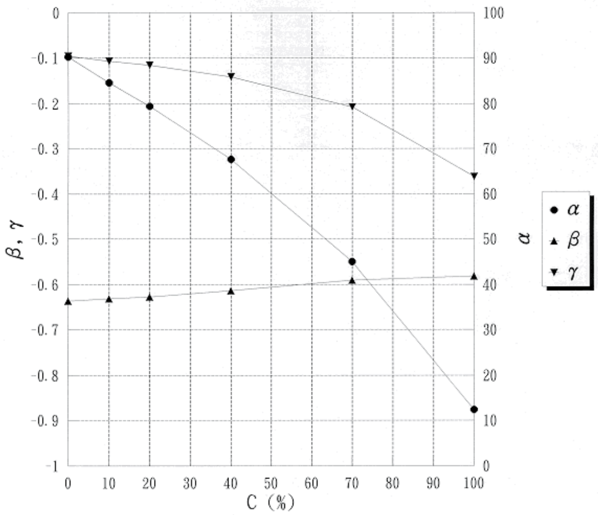


Figure 6. Characteristics of coefficients for cyan ink

From three equations shown in (2) ~ (4), L*a*b* values can be predicted from the CMY dot percent values. (Process 3 in Figure 7).

For two types of stochastic screening halftones the relationships between L*a*b* values and dot percent values are shown in Equation 3 and Equation 4.

$$C21=\frac{-L^*-0.6364a^*-0.0804b^*+94.8891}{0.00057a^*+0.0025b^*+1.7927}$$
$$M21=\frac{-L^*+0.7150a^*+0.0743b^*+94.3101}{0.00320a^*+0.0002b^*+0.7781} \qquad (3)$$
$$Y21=\frac{-L^*-0.5719a^*+1.1817b^*+92.5955}{-0.00470a^*+0.00460b^*+0.7831}$$

C21, M21, Y21: Dot percent values for Randot (DS) screen of 21 µm minimum dot size

$$C16=\frac{-L^*-0.6748a^*-0.09068b^*+96.0899}{-0.000965a^*+0.00248b^*+0.80248}$$
$$M16=\frac{-L^*+0.67174a^*+0.04869b^*+91.2785}{0.00311a^*+0.7688} \qquad (4)$$
$$Y16=\frac{-L^*-0.6542a^*+1.2669b^*+96.2464}{-0.005539a^*+0.00558b^*+0.84913}$$

C16, M16, Y16: Dot percent values for Randot (DS) screen of 16 µm minimum dot size

Evaluation for Approximation

Evaluation algorithm are shown in Figure 7.

Approximation of Dot Percents

By using the Equation (1) ~ (4), the dot percent data corresponding to the measured CIELAD values which are colorimetry data of patchs can be preicted. Figure 8 shows the comparison between input dot percents and C and M values predicted form the measured L*a*b* values when Y (square dot) = 40%. Figure 10(b) and Figure 11(b) show the same characteristics of stochastic screeening halftones (Process 5 in Figure 7).

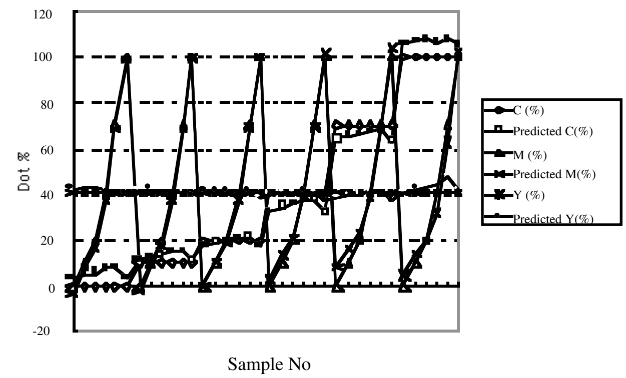


*Figure 8. Comparison between specified dot percent values and predicted dot percent values approximated from the measured L*a*b* values when Y (square dot) = 40%*

Evaluation of Approximation by Δ E

Color difference Δ E is defined by Equation 5.

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2} \qquad (5)$$

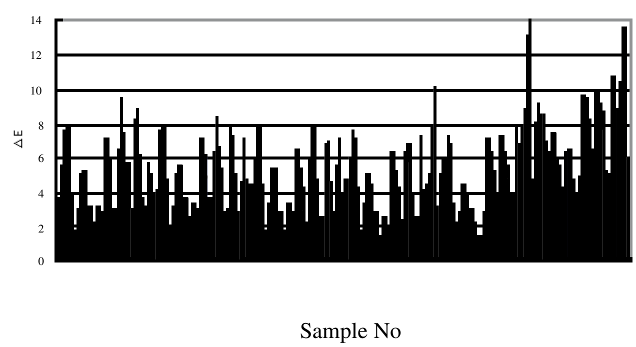


Figure 9. ΔE characteristics of square dot screen print

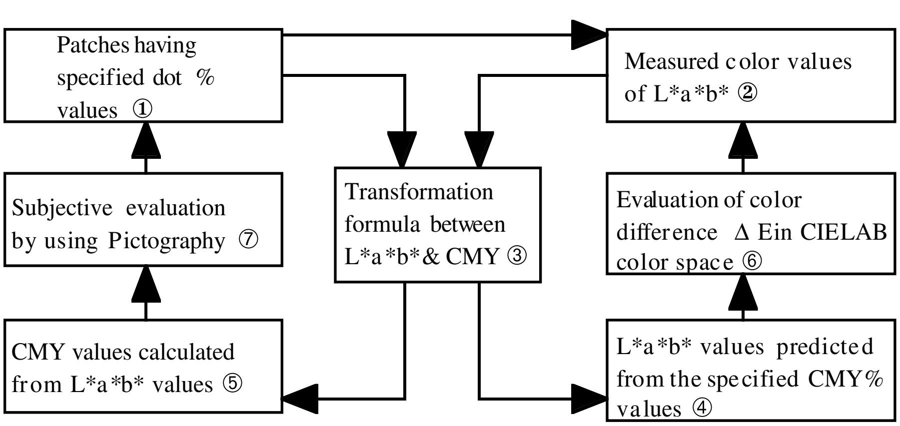
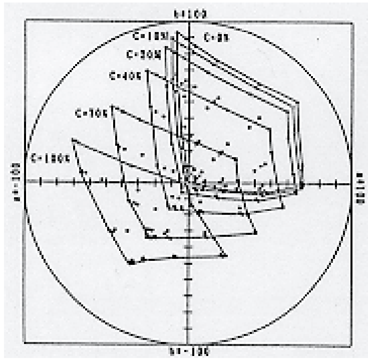
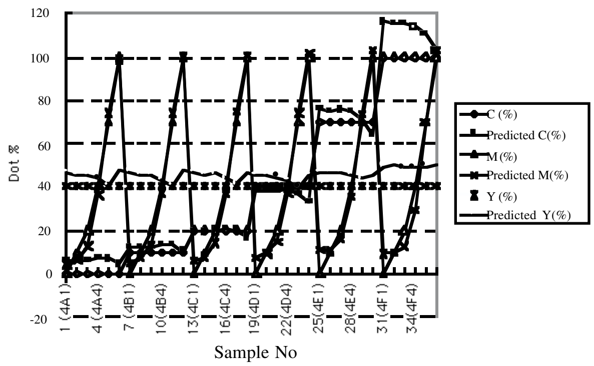


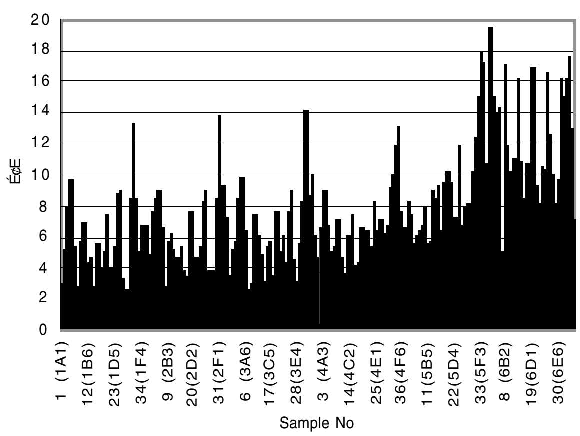
Figure 7. Evaluation algorithm of color reproduction characteristics



(a) Gamut on a *b* plane.



(b) Comparison between original values and predicted values



(c) Δ E characteristics for color samples
Figure 10.

Figure 9, Figure 10 (c) and Figure 11 (c) show ΔE characteristics of square dot screen print 21μm stochastic screen print and 16 μ m stochastic screen print. Δ E values are calculated by using measured L*a*b* values and values predicted from dot percent data (Process 4 in Figure 7) to compare with each other. (Process 6 in Figure 7).

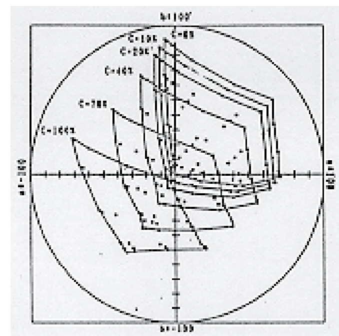
Although most of the ΔE values are less than 10 in highlight and midtone areas, ΔE values in shadow area have a trend to become larger.

Finally we produced the color output of input dot values and that of predicted dot values (Process 5 in Figure 7) with Pictrography 3000, compared subjectively and confirmed that both were indistinguishable. (Process 7 in Figure 7).

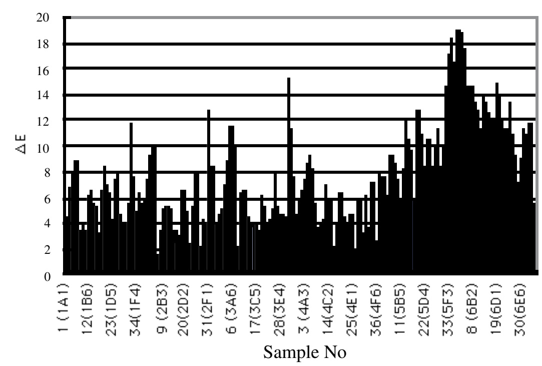
This would make it more convenient to exchange device independent data between color reproduction systems in the DTP field.

The projective transformation method we proposed will provide an easier way to convert the device independent data to CMY values which rely on the characteristics of reproduction devices rather than the lookup table method.

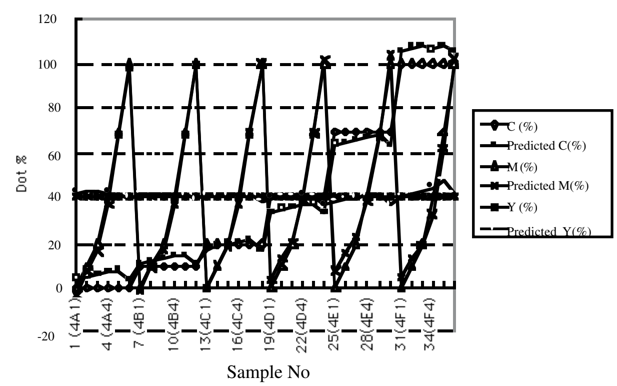
For the approximation of shaded portions, further studies shall be required to reduce ΔE values.



(a) Gamut on a *b* plane.



(b) Comparison between original values and predicted values



(c) ΔE characteristics for color samples
Figure 11. Colorimetric characteristics of 16μm stochastic screen print

Conclusion

An approximation algorithm between dot values and CIE LAB values is presented and results have been depicted when that algorithm is applied to the proof prints produced under the Japan Color Conditions.

Acknowledgments

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Reference

1. ISO 12642"Graphic technology-Prepress data exchange-Input data for characterization of 4-colour process printing targets".
2. ISO 12647-1 "Graphic technology-Process control for the manufactures of half-tone colour separations, proofs and production prints-Parameters and measurement methods".
3. ISO 12647-2 "Graphic technology-Process control for the manufactures of half-tone colour separations, proofs and production prints-Offset processes".
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✰ This paper was previously published in *IS&T's NIP12,* p. 94 (1996).