Evaluation of digital color proof

Masao Inui*, Yoshihiko Azuma* and Masahiko Ogino**
**** : Tokyo Polytechnic University, Color Image Laboratory, 1583 Iiyama, Atsugi, Kanagawa 243-0297 Japan***
***** : Mizukami Printing Co. Ltd., 5-14-3 Nishi-Shinjuku, Shinjuku, Tokyo 160-0023 Japan***

Abstract

Digital color prints are being used as color proof to graphic arts print. Many factors affect quality of proof. We attempted to extract significant factors affecting color similarity of color proof. Sixteen digital color proofs, which were printed with inkjet printers, sublimation printers, electro-photographic printers and DDCPs (direct digital color proofers), were used to the study. We printed two kind of digital color proofs, pictorial images and color patches, per a printer. Pictorial images of the proofs were compared to the offset print, and subjective evaluation values on similarity between the proofs and the offset print were obtained. On the other hand colors of patches in the offset print and the sixteen proofs were measured, color differences of the proofs to the offset print were calculated. We analyzed the relationship between subjective evaluation values for color similarity and color differences of digital color proofs. As the color differences decrease, the subjective evaluation values of color similarity became high. Value of correlation coefficient of the relationship was 0.92. There were some proofs which were far from the regression line derived from the relationship. These distances were large in comparison with error. We thought that the differences were caused some other factors, such as paper and ink. We applied a technique of multiple regression to the relationship between the subjective evaluation values and not only color differences but also gross of paper and ink, color of paper, resolution, moire, and spectral density of inks. Consequently, color differences and gloss of paper were extracted as significant factors, and correlation coefficient was 0.97 for the multiple regression.

Introduction

In the field of graphic arts, proof is very important. As DDCP (direct digital color proofers) is so expensive, digital color prints are being used as color proof to offset print recently. We analyzed the relationship between the subjective evaluation values for color similarity and color differences for the offset print and digital color proofs[1)]. The correlation coefficient 0.90 was obtained. However, there were some proofs which were far from the regression line derived from the relationship. These distances were large in comparison with error. We thought that the differences were caused some other factors, such as paper and ink. In this study the factors, which affect color similarity of proof, are extracted by using multiple regression analysis.

Charts, offset prints and digital proofs

Charts used in this study are shown in Fig. 1. The left chart (a), which is MIC-chart developed by Mizukami Printing Co. Ltd., was used for subjective evaluation. The right chart (b), which is defined in ISO 12642[2)], was used for measurements of colorimetric values, gross, etc.

These charts had been lithographically printed with offset printing. Then the chart files, the ICC profiles and the offset prints had been sent to eight manufacturers to print digital color proofs. Proofs had been printed by manufacturers and were used to this study. Manufacturer and type of printer for the proofs are shown in Table 1.

(a) Pictorial chart, MIC-chart ***(b) Color patch chart, ISO 12642 chart***

Figure 1*. Charts used in this study*

Table 1 Number, manufacturer and type of printer for digital color proofs

Proof No.	Manuf.	Type of printer	Proof No.	Manuf.	Type of printer
1	A	IJ-P	9	D	DDCP
2	A	IJ-D	10	E	EP
3	B	EP	11	E	EP
4	B	EP	12	E	EP
5	A	IJ-P	13	F	EP
6	C	DDCP	14	B	EP
7	C	DDCP	15	G	EP
8	D	DDCP	16	H	EP

IJ-P: Inkjet printer with pigment colorant
IJ-D: Inkjet printer with dye colorant
EP: Electrophotography
DDCP: Direct digital color proofer

Table 2 Elements and subjective evaluation points of Fig.1 (a)

Element	Items of evaluation
Notes	Color of background, clarity of characters
Characters	Resolution and contrast of characters
Gray scale arrangement	Reproduction of gray
Bar graph	Color of bar graph and gradation of background
Resolution charts	Resolution of pattern
Map	Reproduction of thin lines and characters, color of map
Color bars	Color of patches, gradation of color
A lady	Color of skin and hair, feel of material on dress, color of background, color of still lives
Two girls	Color of skin, hair, clothes and background, feel of material on sweater, moiré in stitches of sweater
Metallic and classical objects	Color of and feel of material on metallic objects

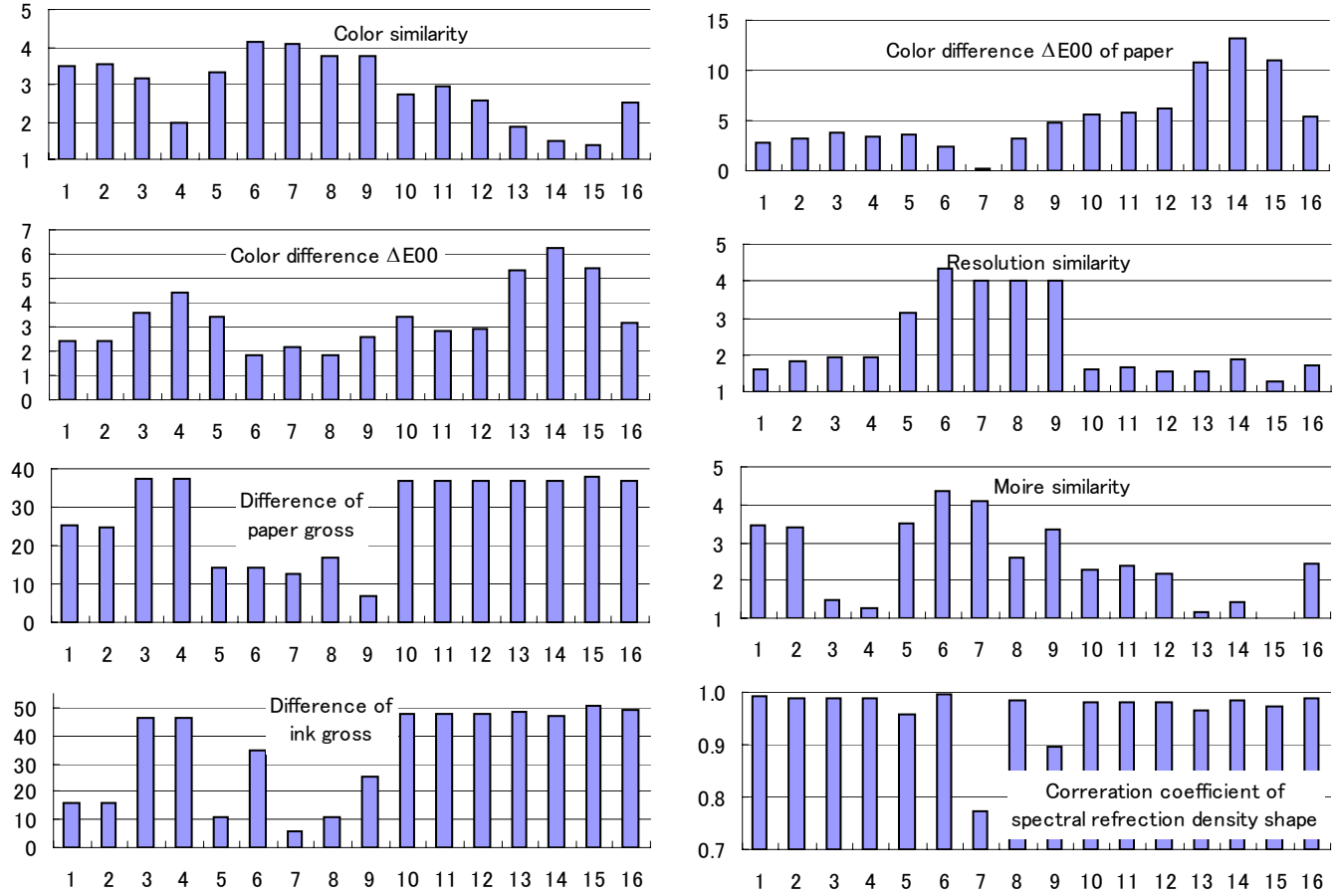

***Figure 2**. Subjective and objective evaluation values for sixteen proofs*

Table 3 Correlation coefficients between subjective evaluation value for color similarity (y) and seven factors (x)

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	y
ΔE00 of all patches (x_1)	1.00							
Gross of paper (x_2)	0.63	1.00						
Gross of inks (x_3)	0.62	0.83	1.00					
ΔE00 of paper (x_4)	0.87	0.58	0.64	1.00				
Resolution (x_5)	-0.57	-0.90	-0.64	-0.54	1.00			
Moire (x_6)	-0.81	-0.83	-0.75	-0.72	0.68	1.00		
Spectral density of inks (x_7)	0.23	0.53	0.48	0.31	-0.50	-0.40	1.00	
Subjective evaluation value for color similarity (y)	-0.92	-0.81	-0.75	-0.85	0.74	0.89	-0.37	1.00

Subjective evaluation

An offset print and sixteen digital color proofs for pictorial chart were used for subjective evaluation. Each proof was observed and compared with the offset print, and observer ranked similarity of the proofs to the print. Twenty four students and two teachers observed the proofs under the condition of color temperature 5000K and illuminance 700 lx. The ranks and corresponding points are the followings.

Completely similar	5 pt.
Similar	4 pt.
Slightly similar	3 pt.
Not similar	2 pt.
Completely not similar	1 pt.

The distance from the print or the proofs and the observer was about 30 cm. Values for color similarities, which are shown in Table 2, are averaged and used as subjective evaluation values. These averaged values are shown in Fig. 2. Resolution and moire are not considered to concern color, but correlation coefficients between the subjective evaluation values for color similarity and values of these two factors were very high as mentioned later, the two factors were used to analyze with other objective factors.

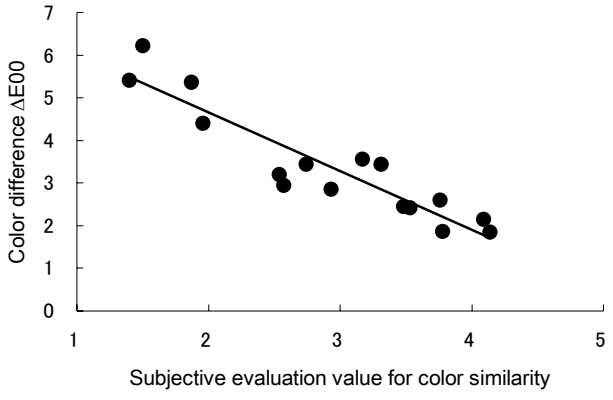

***Figure 3**. Relationship between the subjective evaluation value for color similarity and color difference ΔE00 of all patches (x_1)*

Measurements

Color of all patches of a offset print and sixteen digital color proofs for patch chart were measured with GretagMacbeth Spectrolino with SpectroScan. And CIE color differences ΔE 2000 between the print and the proofs were calculated[3,4]. Then gross of paper and inks were measured with Konica Minolta gross meter Multi Gloss. Also, difference of gross between a offset print and sixteen digital color proofs were calculated. Spectral densities of inks of a offset print and sixteen digital color proofs were also measured with GretagMacbeth SpectroLino with SpectroScan.

Correlation coefficients between spectral densities of a offset print and sixteen digital color proofs were also calculated at the near of peak reflection densities for cyan, magenta and yellow inks. Differences of color and gross, and the correlation coefficient are also shown in Fig. 2.

Table 4 Extraction of significant factors

Step	x_1	x_2	x_3	x_4	x_5	x_6	x_7	y	Correlation coefficient	F ratio
1	A							A	***0.92***	***81***
2	A	A						A	***0.97***	***93***
	A		N					A	0.95	62
	A			N				A	0.93	40
	A				N			A	0.96	73
	A					N		A	0.95	64
	A						N	A	0.94	48
3	A	A	N					A	0.97	58
	A	A		N				A	***0.97***	***62***
	A	A			N			A	0.97	58
	A	A				N		A	0.97	59
	A	A					N	A	0.97	58

Multiple regression and F-test

Correlation coefficients between values of seven factors (x) and the subjective evaluation value for color similarity (y) are shown in Table 3. The correlation coefficient between color difference ΔE00 of all patches (x_1) is the highest absolute value, 0.92. In the case of conventional color difference ΔE^*_{ab}, the absolute value of correlation coefficient 0.90 had been obtained for the same data[1]. The other factors except spectral density of inks (x_7) show relatively high absolute values. The relationship between the subjective evaluation value (y) and color difference ΔE00 of all patches (x_1) is shown in Fig.3. As the color differences decrease, the subjective evaluation values became high. Value of correlation coefficient of the relationship was -0.92. Such results were expected before the experiments. However, there were some proofs which were far from the regression line derived from the relationship. These distances were large in comparison with error. We thought that the differences were caused some other factors, such as paper and ink.

Significant factors were extracted during F-test[5]. At step 1, because of the highest absolute value of correlation coefficient, ΔE00 of all patches (x_1) was extracted. The marks "A" and "N," which mean adopted and not adopted, are written at the corresponding cells in Table 4. At step 2, multiple correlation coefficients and F ratios of residual six factors were calculated. As shown in Table 3, correlation coefficient and F ratio of gross of paper (x_2) were the highest values among the residual six factors. Because the value of F ratio of gross of paper, 93, was higher than the one of step 1, 81, gross of paper was extracted as a significant factor. At step 3, multiple correlation coefficients and F ratios of residual five factors were also calculated. As shown in Table 3, correlation coefficient and F ratio of ΔE00 of paper (x_4) were the highest values among the residual five factors. Because the value of F ratio of ΔE00 of paper, 62, was lower than the one of step 2, 93, ΔE00 of paper was not extracted as a significant factor.

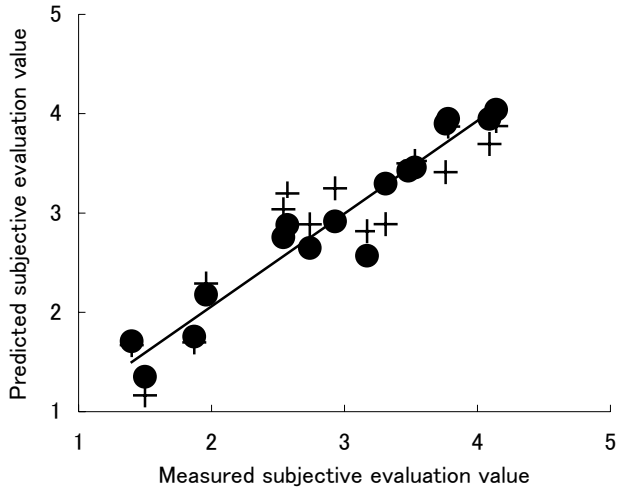

***Figure 4**. Measured and Predicted subjective evaluation values of color similarity. Circles are predicted from ΔE00 of all patches and grosss, crosses from ΔE00 of all patches only.*

Consequently, ΔE00 of all patches (x_1) and gross of paper (x_2) were extracted as the significant factors and an equation of multiple regression line is the following.

$$y = -0.463\,x_1 - 0.0289\,x_2 + 5.30$$

Measured subjective evaluation values for color similarity, predicted ones which are calculated from the above equation, and a regression line are shown in Fig. 4. The crosses show the subjective evaluation values for color similarity predicted from ΔE00 of all patches ($x1$) only, and the circles show those from both ΔE00 of all patches ($x1$) and gross of paper ($x2$).

Summary

We prepared offset prints and digital color proofs, which were printed with inkjet printers, sublimation printers, electro-photographic printers and DDCPs. We analyzed the relationship between subjective evaluation values for color similarity and color differences, gross, resolution, moiré, and spectral density of inks by applying multiple regression analysis. Consequently, color differences and gloss of paper were extracted as significant factors, and correlation coefficient was 0.97 for the multiple regression. It was found that color proof was required to resemble not only color but also gloss of paper.

References

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Author Biography

Masao Inui received his M. Eng. from Chiba University in 1973 and joined the University staff there in the same year. In 1986, he joined Konica Corporation, where he advanced to the position of Chief Research Associate. In 1993, he received his Ph.D. from Chiba University, and in 1998, Dr. Inui took a professorship at Tokyo Polytechnic University. His special interests include image analysis, evaluation, design, and processing. He is a member of the IS&T, The Royal Photographic Society, The Society of Photographic Science and Technology of Japan and The Color Science Association of Japan.