Suitable Printer Color Reproduction for Office Environment (1)

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Abstract

One of the most important aspects in office color printer is to enable a naive user to reproduce a good color reproduction without any extra efforts. Another important aspect, especially in office, is to get the same color reproduction regardless of which printer model they use. Unfortunately, printer manufacturers tried to please a customer by improving color image processing algorithm with their own goal, and this act as an obstacle to the bi-collateral of above two customer requirements.

One way to resolve this conflict is to establish common color reproduction mode. Two approaches are implemented, one is to use a common GMA (Gamut mapping algorithm) and another is to use a common printed color and intermediate color space conversion.

Office color printer GMA was evaluated, using CIE TC8-03 guideline[1] with the CRT to print workflow. 4 types of GMAs, 10 office color printer models, 4 test images and 30 raters to perform rating test. As a result, the effect of "printer model" and "printer model x test image" were stronger than GMA. Also further analysis indicated that to get a printed color and intermediate color space relationship, which provides a good rating score, requires more efforts.

Introduction – Issues in Office Color Printer Color Management

As the world of multimedia including photography, graphic arts and motion picture is growing and digitalizing rapidly, naive users encounter an opportunity to access color information more and more. Internet global information exchange makes color information widely spread around the world, and home and office use documents "color matching" demand increases in its level and variety. Color management concept, which can coordinate various color-related devices from input to output, gained its importance among both software and hardware manufacturers.

In office color printer, reproduction of a good color by a naive user is one of the most important aspects. But there is competition among printer manufacturers to please a customer so as to get the best selling position and it acts as an obstacle. There are many activities to resolve this conflict. Interconnection color management standards of various color devices were developed by manufacturers collaboration efforts.

In multimedia equipments and systems, applicable color management-related standards such as sRGB,[2] ICC profile,[3] etc. are now available. sRGB is a color space with RGB, and 1931 CIE XYZ[4] relationships are defined as a set of formula. ICC profile is a standard format, which describe various color devices input and output characteristics and it defines conversions between device dependent color space and device independent color space, so called PCS (Profile Connection Space).

ICC profile, as a comparison with sRGB, can describe color devices input and output characteristics more in detail flexibly. sRGB is convenient means and requires no detailed prior arrangements.

After sRGB is standardized, color management issues and number of complaints decreased in color devices interconnections such as digital camera and color printer. So many manufacturers practically adopt color devices ICC profile when it is known, and when it is unknown, use input color space as sRGB color space.

Some people are beginning to feel that the current available color management-related standards are not sufficient to office color printer as represented by electro photography and inkjet. One of the biggest reasons is a huge variety (about 30 degree) of primary color hue angle difference. This variety is not only a difference of marking technology, but also an intellectual property blocks use of the same colorant.

Other color management-related attributes are; color matching objective, difference of viewing condition between profile making environment (D50) and office consumer environment (around 4000K), original scene or document type, adopted color space, gamut mapping algorithm, accuracy of color matching system, gamut volume, media and color measurement backing material, fluorescence in media and colorant, color instability and non uniformity in one page.

Office color printer customer desires are, for example,

1. The same color reproduction both in their office, and at a copy shop. Many copies of documents are hard to carry, so customers want to print it at the place they need.
2. The same color reproduction of multiple color printers at a copy shop. It takes a time to print many copies of color documents and usually using multiple color printers to accelerate print job.

Color difference of printer-to-printer is eye-catching, and improvement is highly desirable in the current office color printer market.

So far, color printers with reflective prints and RGB inputs input-output color characterization method is standardized as IEC61966-7-1: 2001,[5] and GMA evaluation guideline is reported as CIE 156:2003.[1]

The next step is to characterize printer models to find a way to achieve the same color reproduction. Two approaches are being implemented, one is to use a common GMA (Gamut mapping algorithm) and another is to use a common printed color and intermediate color space conversion.

This paper is to report GMA evaluation test result (CRT to print) and future plan.

The Outline of GMA Evaluation

Major specification of Gamut mapping algorithm evaluation test is shown in Table 1.

Table 1: GMA Evaluation Test Conditions

Attributes	Contents	
Workflow	CRT to print	
CRT	Nanao EIZO T566 17inch	White luminance 85 cd/m2 white chromaticity D65 ambient illumination 32lx Surround N2 grey
Printer	10 printer models	Illuminant 500 lx D50/F11 Luminance of paper white 100cd/m2 Surround N5 grey Recommended media
GMA	4 GMAs	GMA1: HPMINDE in CIELAB HPMINDE is “Hue-angle preserving minimum ΔE*ab clipping”
		GMA2: SGCK in CIELAB (SGCK is “Chroma-dependent sigmoidal lightness mapping and cusp knee scaling”)
		GMA3: SGCK in CIECAM02
		GMAX: Manufacturer’s choice
Test images	4 images	Ski (sRGB), SCID N7, Weather2, Disk4
Raters	30 raters	Age 23-54, male and female, researcher & engineers, image quality non & professionals
Characterization error	CRT	CIELAB delta E = 0.54 (Macbeth 24 colors)
	Printers	CIELAB delta E ave. = 3.21, min.=2.04, max.=4.90 (IEC61966-7-1 test chart, 10 printers average.)

Test Images

In office color printer market, most of all the customers create easy-to-make, simple-contents business graphics as compared to graphic arts industries. They use sophisticated application software for complicated graphics. On the other hand, because of its simplicity, a large part of mid tone gray area tends to color, smooth gradation gets false contours, and these documents are fairly difficult originals. So, the simple business graphics originals were intentionally created and add as a test images. Two photographic scenes and two simple business graphics were selected as the test images as shown in Fig. 1.

Test Image Preparation Workflow

For CRT to print sample preparation, test image is processed with the workflow as shown in Fig. 2.

Figure 1. Test images

The XYZ values were transformed to the gamut mapping color space by using CAT + CIELAB and CIECAM02, and the color value were mapped to the printer gamut. CAT02 matrix was used for Chromatic adaptation from CRT white to D50. CIELAB and CIECAM02 were adopted as gamut mapping color space in order to estimate the effect of the hue uniformity of these two color spaces. The combination of mapping color space and GMA was shown in Table 1.

The mapped colors were transformed to the XYZ value by using CIELAB + CAT and CIECAM02, and the printer dependent colors by the each individual printer characterization model prepared by manufacturer. The error of the printer characterization model is shown in Table 1.

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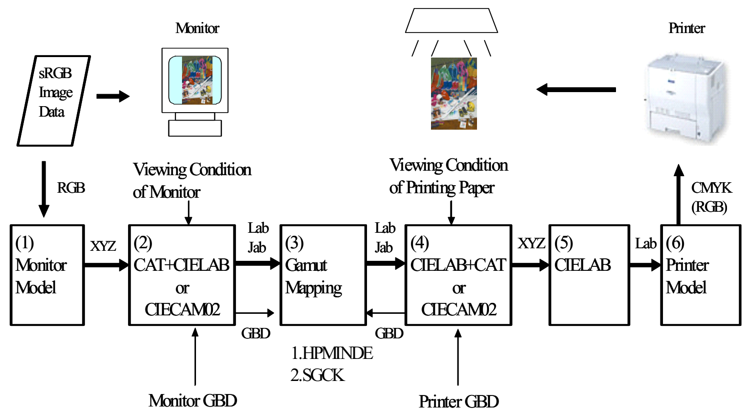
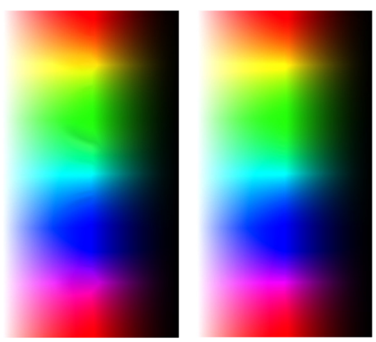


Figure 2. Workflow

Rendering Issue

As previously expected, false contour occurred with 16 segments GBD (Gamut Boundary Descriptor), which was in the sample program provided at CIE TC8-03 web site.[6] After several iterations, 72 segments were selected as a result of compromise between a magnitude of false contour and calculation time. A numbers of gamut boundary data were also evaluated and selected an appropriate number. Figure 3 shows an example of false contour level (HPMINDE)to be used in the test.



16 segments GBD 72 segments GBD

Figure 3. False contour

Office Color Printer Unique Conditions

There are test conditions specified in CIE TC8-03 guideline. All obligatory conditions were adopted, but some of the recommended conditions were modified to represent real office color printer market. Those are;

Paper size: Letter (8x11) / A4 (210x297)
Border: 5mm in all sides
Display ambient: not dark (ordinary office environment)

Regarding viewing conditions, adopted illuminant for print samples rating test were D50 and F11. F11 represents typical office viewing conditions. This paper only covers D50 results, and F11 results will be reported at another opportunity.

Rating Procedure

7 levels Category rating method (7 is the best and 1 is the worst) used in rating test. 30 raters, range of age 23-54, male and female, researcher & engineers, image quality non-professionals & professionals participated in the rating test. Raters were asked to rate 160 samples (4 test images x 10 printer models x 4 GMAs). Raters were also asked not to take other image quality attributes, such as defects, into account for the rating score, and only focused on color accuracy between CRT to print, prior to the rating test.

Results

The contribution ratio (Normalization data) of each attribute is shown in Fig 4. The GMA and its Rating score are shown in Fig. 5. By Fig. 5, the best GMA is GMA1 in average. But by Fig. 4, "printer models" and "printer models x test images" contribution ratio are significantly bigger than GMA.

Table 2 shows the effectiveness of GMA. The CIELAB delta E of GMAX is the worst in all test images, but it is the best in the business graphics rating score. In Table 2, the CIELAB delta E is the average delta E of 10 printer models. The comparison of GMA1 and GMAX in CIELAB color coordinate is shown in Fig. 6. According to Fig. 6, GMA1 has smaller printer model variation.

Printer model vs. rating score is shown in Fig. 7. Printer model has the strong dependency in the test image type.

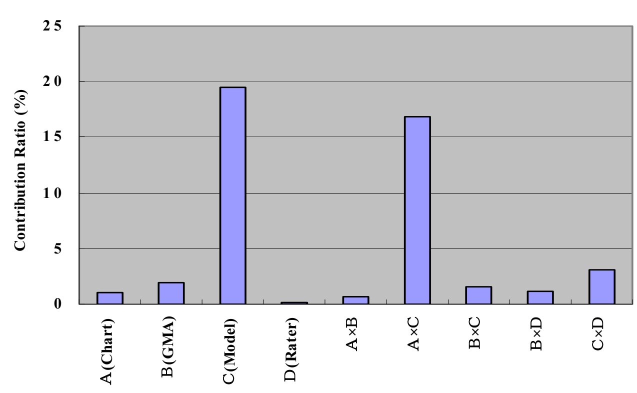


Figure 4. Contribution ratio

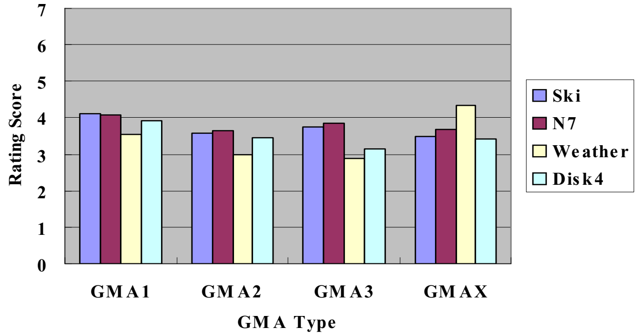


Figure 5. Type of GMA and Rating Score

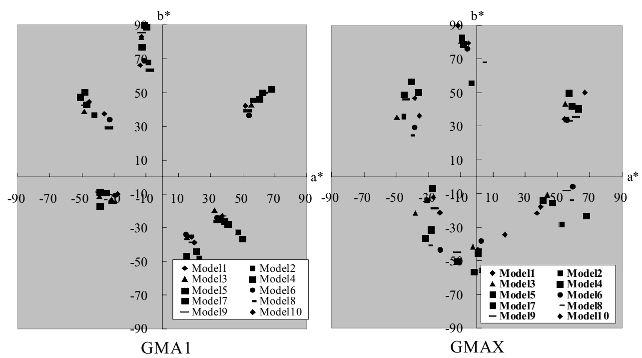


Figure 6. Comparison of GMA1 and GMAX (CIELAB)

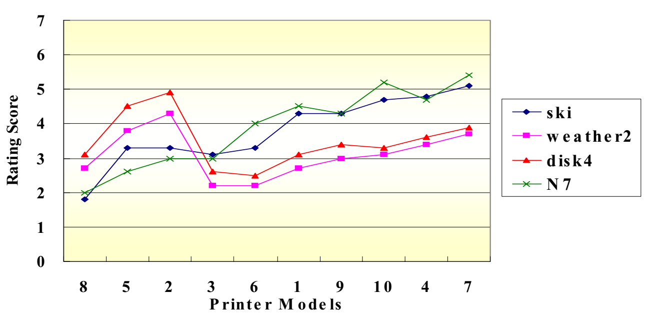


Figure 7. Models and test images

Table 2: Outlook of GMA Effectiveness

Image	Attributes	GMAX	GMA1	GMA2	GMA3
Ski	CIELAB delta E	11.7	8.3	9.8	9.3
	Rating Score	3.5	4.1	3.6	3.7
Weather	CIELAB delta E	12.0	8.8	8.2	7.6
	Rating Score	4.2	3.3	3.0	3.0

Discussion

There were several new findings; The best GMA is GMA1 (HPMINDE) in average; "printer models" and "printer models x test images" contribution ratio are significantly bigger than GMA, so more efforts are required to achieve optimum input and output color relationship; The business graphics look like more difficult than the photographic scenes; Observers felt that they made judgment not by looking at all the colors in the sample, but looking at some elements, which gives special attention to them. Those should be reflecting to the data analysis.

Conclusion

Office color printer GMAs were evaluated, using CIE TC8-03 guideline.[1] 4 types of GMAs, 10 office color printer models, 4 test images and 30 raters to perform rating test. As a result, the effect of "printer model" and "printer model x test image" were stronger than GMA. Also further analysis indicated that to get a printed color and intermediate color space relationship, which provides a good rating score, requires more efforts.

Future plan is to study printed color and intermediate color space conversion, which gives a good rating score. For that, the categorical color mapping method will be used including other office environmental attributes such as office illuminant condition. CRT to print and print to print rating difference will be evaluated as well.

Acknowledgements

The authors would like to acknowledge the contributions of JBMIA (Japan Business Machine and Information System Industries Association) members such as Ricoh Co. Ltd., CASIO Computer Ltd., Toshiba TEC Corporation, Sharp Corporation and Brother Industries Ltd., in provide print sample, JCIE TC8-03 members and Chiba University students in prepare and participate in rating tests.

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Author Biography

Fumio Nakaya received his B.S degree in Mechanical engineering from Keio University in Japan in 1976. Since 1976 he has worked in research and development divisions at Fuji Xerox Co., Ltd in Kanagawa, Japan. His work has primarily focused on image quality and image quality design, including microscopic image structure for high quality color image using dry toner, color management in multimedia equipment and systems. He is a member of the IS&T and the Institute of Image Information and Television Engineers.

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