The Evolution of Nonimpact Print — Impact on Image Quality

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Abstract

In recent years, various color imaging systems have been developed and the quality of those obtained images has improved. In this paper, our approaches to improve color reproduction in hardcopy is presented and the quality of present hardcopy imaging is comapred with the conventional offset printing. Then the capabilities to direct proof in printing of hardcopy is also described.

Introduction

Many kinds of hardcopy imaging systems have been developed, and the image quality of these images has improved greatly. Therefore, various kinds of usages in hardcopy imaging systems are considered such as HDTV printing, Photo CD and the proof press.

It is necessary to measure and evaluate the quality of the hardcopy image in order to apply it for various fields and purposes. We then undertook a first try to evaluate the quality of images obtained by 16 kinds of representative digital hardcopy imaging systems including laser printers, sublimation printers, silver halide printers, on-demand type thermal printers and inkjet printers. The resulting print qualities were compared with the conventional offset printing. Table 1 shows the printing systems used in the experiment.

Two standard color images with test charts were reproduced using these printers. Color reproduction, resolution, tone reproduction and granularity of these images were measured and analyzed. The images were then rated by 18 designers and engineers from the printing industry. In what follows, the problems of present hardcopy systems for usage as the proof press in printing are discussed.

One of the purpose of this paper is to describe the capabilities of direct proof in present hardcopy. Other purpose is to introduce the new method to improve color reproduction of present hardcopy.

Images Used in the Experiment for Direct Proof

Quality of hardcopy image is mainly determined by tone reproduction, sharpness, graininess, color reproduction, and distortion. Many metric for evaluation of these image quality criteria in hardcopy images have been proposed. In this experiment, we used two images including several test patterns as shown in Figs. 1 and 2 as the standard image for evaluation of hardcopy image.

File images with five resolutions; 180 dpi, 190 dpi, 284 dpi, 300 dpi, and 400 dpi were produced for each of the hardcopy system. These images were recorded onto the CMT or MOD in the format of a CMYK raster file writen by Adobe Photo Shop 2.1J.

On the other hand, Test chart 2 shown in Fig. 2 was used as an example of design in printing. Therefore it includes both characters and pictures. The WINE BOTTLE consistes of 4 different dot densities; 330 dpi, 220 dpi, 150 dpi and 72 dpi written by raster file. These 1/4 inch CMT or 5.25 inch MOD files were sent to the companies with the offset print to make hardcopies. While the color transformation methods were arbitrary in making the hardcopies, we requested that the copies be reproduced with the same overall color reproduction as the offset printing. 17 images of Test chart 1 and 16 images in Test chart 2 including the offset printing were obtained in coorporation with the many companies.

Table 1. Printers used in the experiment.

Printer type	Symbol
Laser	A
Sublimation	B,E, G, H, M, N, O, P
Silver Halide	C
On-demand Thermal	F, I, K, L, Q
On-demand Inkjet	J
Continuous Inkjet	D

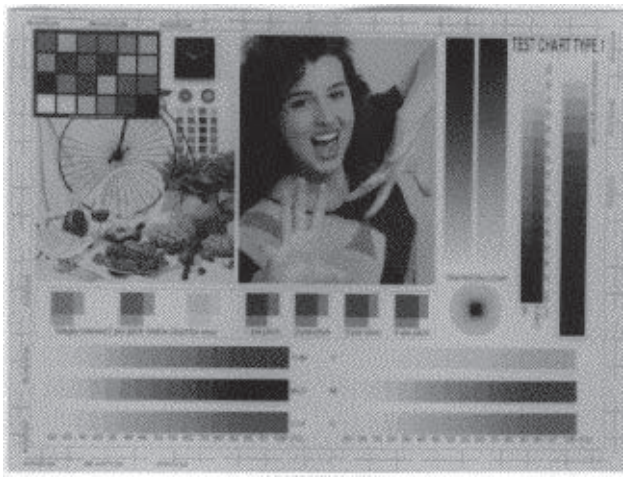


Figure 1. Standard color imge (NO.1) with various charts used in the experiment

Evaluation of Hardcopy

Color reproduction

Fig. 3 shows the chromaticity points of 6 test stimuli (c, m, y, r, g, b) of the images obtained by 17 kinds of printers (include offset print) in the CIE 1976 (a*, b*) chromaticity diagram. Resulting color gamuts are approximately same.

Fig. 4 shows a* b* chromaticity diagram of flesh color (color of a cheek in chart 1) using 17 hardcopy images. We calculated the color difference ΔE*ab between 16 hardcopy images and offset print and compared it with the observer rating value, the result is described later.

Observer Rating Experiments

The obtained images were rated by 18 observers who are designers and engineers in the area of printing industry. For the practical scaling experiment, those images were viewed at arbitrary distance under lighting condition of about 1000 lux and daylight type fluorescence lamp. Those images were rated from eight point of views: (1) total quality, (2) tone reproduction, (3) color reproduction, (4) as the usage of thumbnail or sketch paper, (5) quality of the logotype or illustration, (6) quality as a proof of phototype setting and block copy, (7) quality as a reproduction proof, and (8) quality of characters. Each observer was asked to place hardcopy images into one of the following calegories: unusable, poor, acceptable, good, and excellent from the above mentioned view points. Then the subjective evaluation values were calculated.

Figure 5 shows the relationship between the color difference and observer rating value (total quality). It corresponds to the average color difference of seven colors (C, M, Y, R, G, B, and CMY black). Where, (●) is by the continuous tone printers, (**O**) shows the values by on-demand type printers.

The color differences are well correlated to the observer rating values for the images using continuous tone printers, however for the on-demand printer there are no correlations. Fig. 6 shows the rating results for the capability of the printers to act as a reproduction proof This experimental result shows that many problems must be resolved to be used the current printers as reproduction proofers in place of the proof by a conventional press.

Figure 2. Standard image (NO.2) with both character and picture

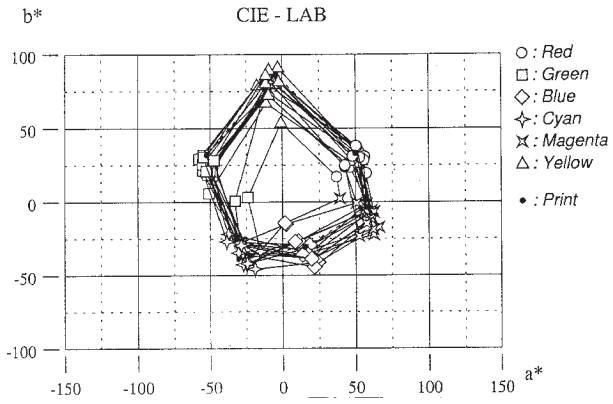


Figure 3. Chromaticities of 6 text stimuli (C, M, Y, R, G, B) by 17 kinds of hardcopies

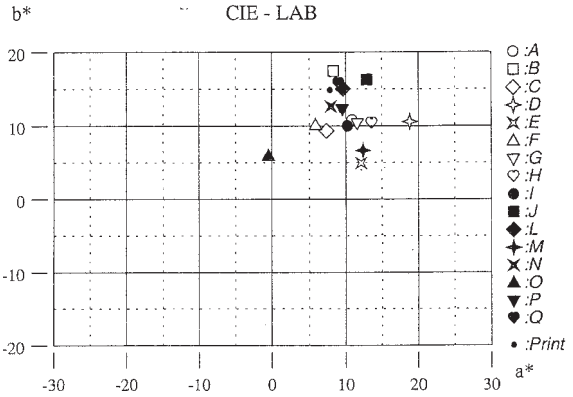


Figure 4. Chromaticities of fresh color (skin color of a check)

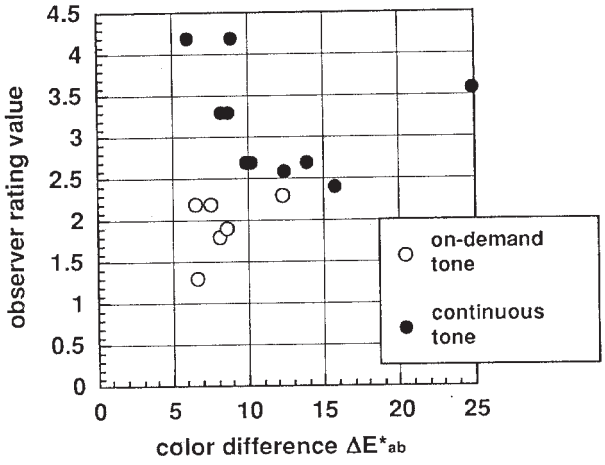


Figure 5. Relationship between observer rating value and color difference (average of C, M, Y, R, G, B and CMY black)

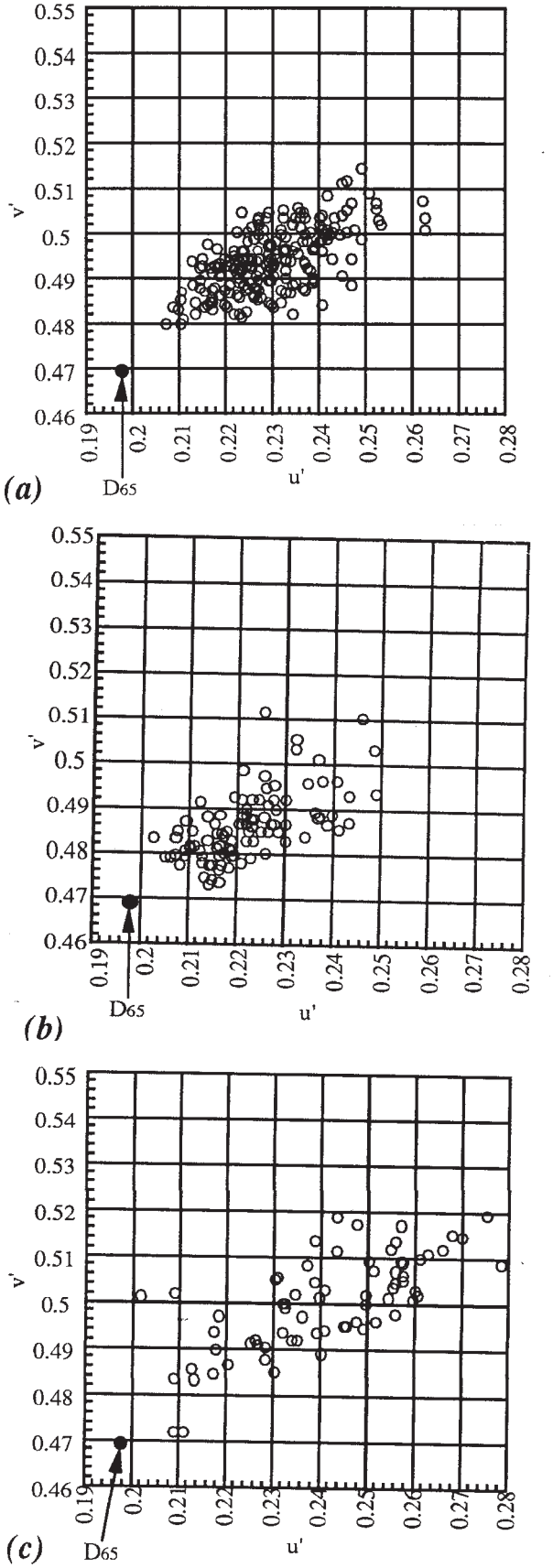


Figure 6. u'v' chromaticity plots of skin color. (a) 216 Mongorian skin colors measured from Japanese magazines. (b) 101 Caucasian skin colors measured from American magazines. (c) 70 Negro and Negroid skin colors measured from American Magazines

Improvement of Color Reproduction

Segmentation and Local Color Correction

Color transformation and correction methods in above mentioned hardcopy systems are based on the colorimetric color reproduction by using the LUT or transformation matrix. As shown in Fig. 3, color gamuts of the printers are approximately same. This means that the color reproduction of the image depends chiefly on the color correction method. Namely, it is necessary to correct color more precisely for a special use of hardcopy such as reproduction proof.

In color reproduction of image, the color of the sky, green grass and skin is most important since these colors are familiar in daily living. Therefore, local color correction technique is significant for those regions. In this purpose, it is necessary to classify the pattern into each region.

In a previous paper, we introduced a method to detect facial pattern from negative color film or television picture, and local color correction technique of this region was successfully applied to the improvement of color print and newspaper printing from television picture.[2, 3]

Furthermore, we modified the method, namely picture is classified into five calegories: skin region, gray, red, green and blue regions, used color information, and color transformation matrix in each region is calculated based on colorimetric color reproduction. Then each image is synthesized and printed with a thermal printer.

This method was significant to transforming the color from CRT to hardcopy.[4] Therefore, we consider that the method is also useful to color correction for reproduction proof.

Preferred Color Reproduction

As well known, Dr. Hunt proposed six different types of approach for color reproduction: spectral, colorimetric, equivalent, exact, corresponding, and preferred color reproductions.[5]

In the present hardcopy imaging, colorimetric color reproduction has been usually used, however, it will be necessary to introduce the characteristics of human visual systems such as color appearance and adaptation for advanced color reproduction and transformation between the different imaging systems. Therefore we considered the preferred color reproduction in hardcopy.

Dr. Hunt defined the preferred color reproduction as follow:

the colors depart from equality of appearance to those in the original, either absolutely or relative to white, in order to give a more pleasing result to the viewer.

Since the preferrence is ambiguous and influenced by many factors, it is difficult to determine and define it precisely, namely it would be impossible to attain preferred color reproduction of all object.

As our first approach, we considered to attain the preferred color reproduction of the skin color, particularly, facial pattern of portrait picture.[6]

It is considered that the preferred color is well corresponding to the memory color, then we measured the chromaticities of skin color in many portrait pictures

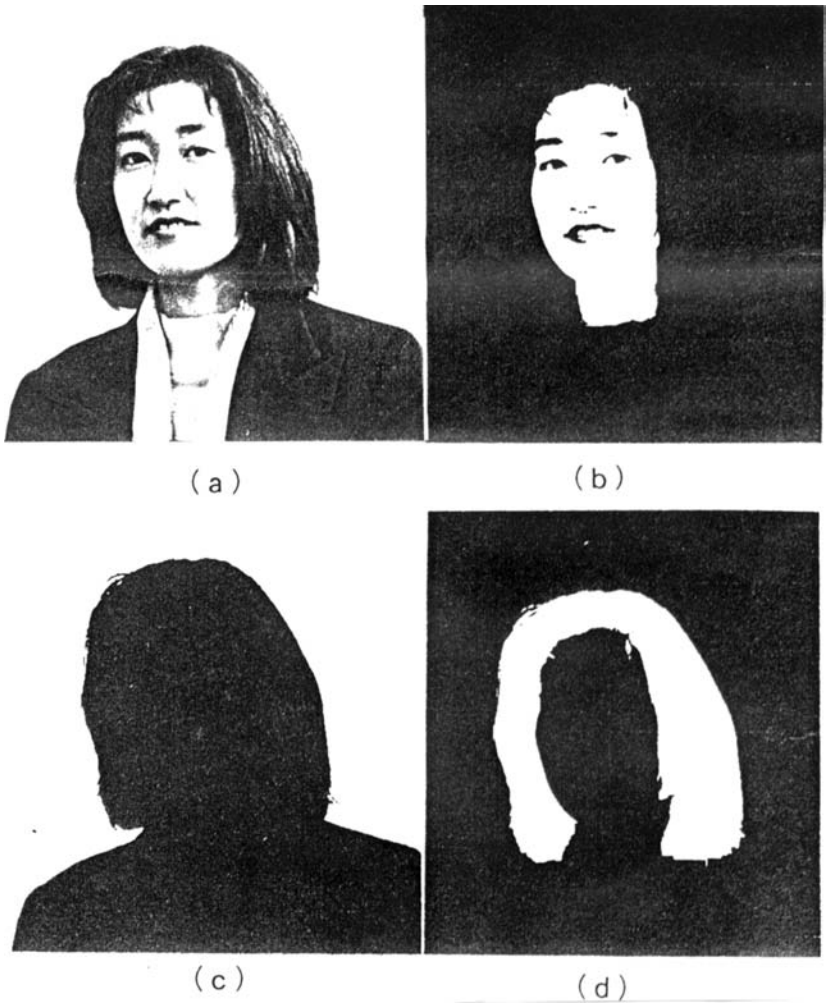


Figure 7. (a) Picture used in the experiment for preferred color reproduction, (b) Detection of facial pattern, (c) Detection of background, (d) Detection of hair region.

printed by offset printing. Figure 7 shows the u'v' chromaticities of (a) 216 Mongorian skin colors, (b) 101 Caucasian skin colors and, (c) 70 Negro and Negroid skin colors. These measured chromaticities are useful to reproduce the preferred facial colors in hardcopies.

Preferred color of facial pattern, however, is dependent on many factors such as observer, color and luminance of background, viewing conditions, pattern size and others.

In our experiment, preferred color reproduction of mongorian skin color (Japanese young ladies) was studied under the condition as follows:

(1) observers five students of our laboratory), (2) viewing condition (two light sources, D65 approximation fluorescent light and a tungsten lamp), (3) back ground color and luminance (color of the background was changed to red, green, blue, white and black), (4) size of face (two different sizes were used, the area of face is 9.6% and 2.0% of the frame)

Figure 8 shows the portrait picture used in the experiment (a), and extracted facial pattern (b), extracted background (c), and hair region (d).

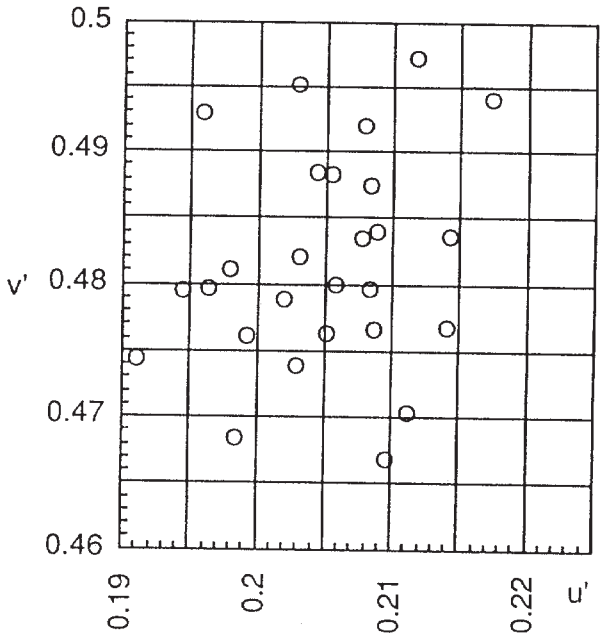


Figure 8. Average u'v' chromaticities of facial pattern

used in observer rating experiment

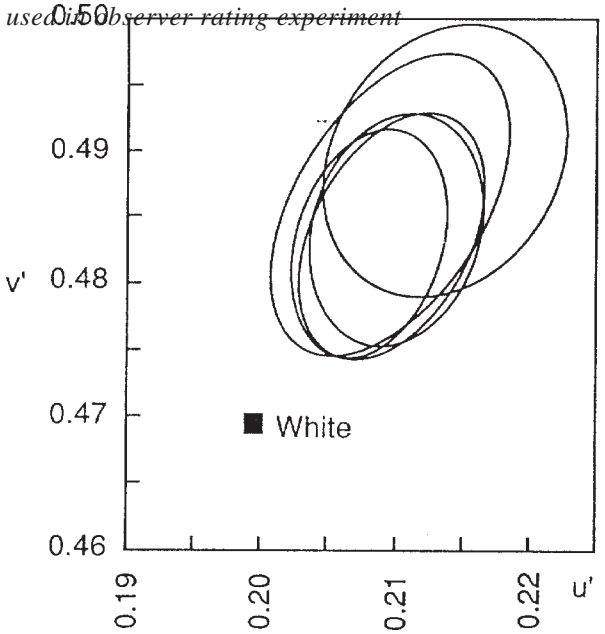
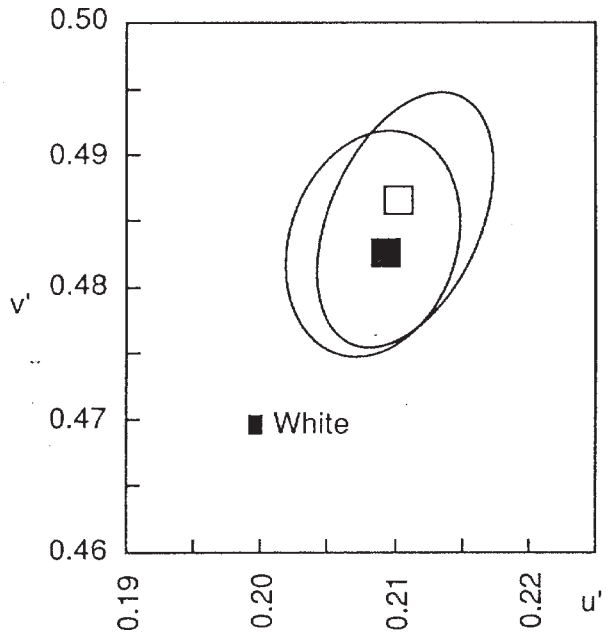


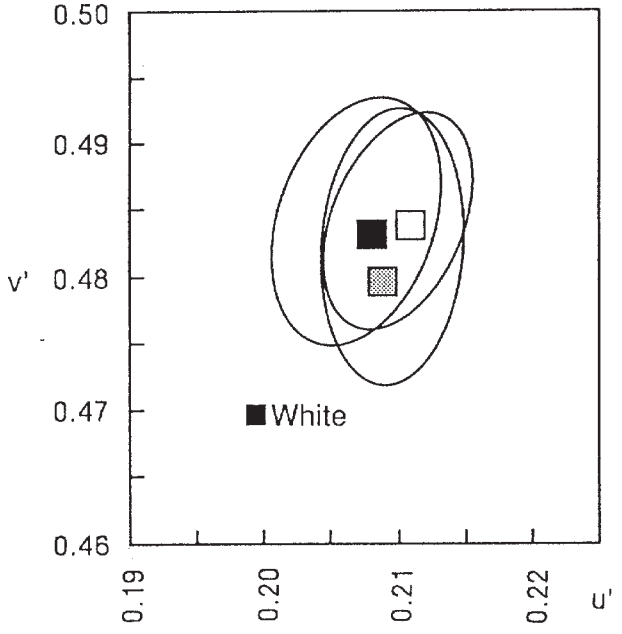
Figure 9. Distribution of the preferred color by five observers. (ellipse of a score 3.5)

Table 2. a* b* chromaticities of background.

Background Color	L*	a*	b*
White (Bright)	93.49	-0.36	2.23
Black (Dim)	43.86	-3.45	2.79
Red	52.61	-41.36	21.66
Green	57.41	-32.79	34.11
Blue	58.20	-8.35	-23.37



(a)



(b)

Figure 10. Preferred skin color distributions in five different background colors. (a) White (□) and Black (■), (b) Red (■), Green (□) and Blue (□).

The chromaticities u'v' of facial pattern region were changed to other chromaticities and 30 kinds of picture with different chromaticities at the facial pattern regions were obtained as shown in Fig. 9. Furthermore, background color was also changed in each skin color as shown in Table 2.

A series of 30 images were rated by a panel of five observers. Each observer was asked to place to those images into one of the categories; preferred (excellent), (good), (acceptable), (poor), not preferred (bad), and each category was scored to 5, 4, 3, 2, 1.

Figure 10 shows the ellipse of preferred color (scores over the 3.5) by five observers and this results shows that the preferred color of facial pattern is approximately coincided with each observer, however, distribution of the chromaticities did not agree with those measured chromaticities of prints shown in Fig.7.

Figure 11 shows the preferred skin colors for five different background colors, (a) black and white, (b) red, green and blue. This result also shows that the preferred skin color is not dependent on the background color. On the other hand, Figure 12 shows the preferred skin colors for different pattern size. The distribution is clearly different in each other.

We note here that those generalized conclusions are not warranted since in this investigation, only two portrait pictures were processed and evaluated by five observers. Color correction for preferred color reproduction is very difficult and complex problem, however, we believe that the method proposed here is significant to realize it.

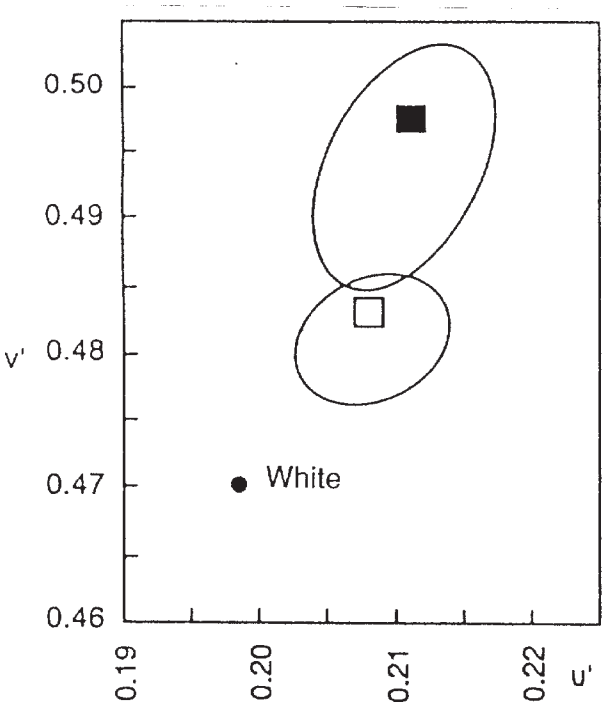


Figure 11. Preferred skin color distributions in two different skin color areas. Large (□), *Small* (■).

Conclusions

Image quality of the hardcopy images obtained by representative 16 printers was evaluated and compared with the conventional offset print both subjectively and objectively. Color difference between hardcopy images and offset prints are well correlated to the observer rating value based on total quality and color reproduction. However, it became clear that almost all designers and engineers in printing industry recognize that the quality of present hardcopy image is not good enough to use as the reproduction color proof.

Therefore, in order to improve color reproduction more precicely, we introduced segmentation and local color correction methods. Furthermore, on the basis of these methods, preferred skin colors in hardcopy was estimated by five observers. By the introduction of those techniques, it will be possible to apply the hardcopy to reproduction proof.

Examples of various hardcopy will be shown at the conference.

Acknowledgements

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