

Evaluation of Legibility for Color Texts

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Abstract

This paper describes an investigation on the legibility of color texts. We concentrate on line reproduction quality and modulation transfer function (MTF) of Y data in CIE XYZ color space of original images, and study the correlation between legibility and each of these two characteristics in order to develop an objective evaluation method. We begin by preparing samples of test targets of various colors. Then the line reproduction quality and MTF are measured and the legibility is evaluated subjectively for comparison. As a result, we have found that we can predict the legibility of color texts even on color background by the use of these two characteristics.

Introduction

Text quality is as important as ever, and has an influence upon total image quality as most documents still contain texts. Further, users have required higher color-text quality for copiers or printers in recent years (Figure 1). Therefore, a color-text quality evaluation technique is necessary for developing high quality copiers or printers. However, while a large number of studies have been made on text quality evaluation techniques, there are few objective methods for practical purpose, particularly for color texts. To evaluate text quality is very difficult, because text quality has two aspects, legibility and appearance.[1] It is necessary to understand text quality in order to investigate both of them. Therefore, the study of an evaluation technique for them is vitally important in understanding text quality well.

We began our study by considering legibility and previously reported the quantitative evaluation method for Kanji character reproduction quality.[2, 3] To be more precise, we reported that line reproduction quality and MTF could represent Kanji character reproduction quality. This paper is intended as an application of the objective quantitative method to outputs containing color text on color background from color printers.

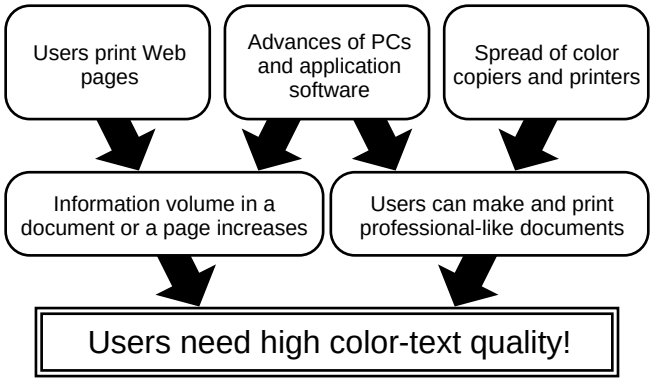

Figure 1. Background of our study

Experimental

Print samples of test targets are prepared as described in the sub-section on "**Test target**" below. These samples are evaluated subjectively, and the line reproduction quality and MTF are measured to investigate the validity of the objective method. The important point to note is that the objective measurement method is only effective in the case that text and test targets are printed with the same halftoning. For example, in some printers, test target is halftoned with the dither as a graphic image, and texts are halftoned with another pattern as a font. It is obviously meaningless to evaluate such images. A detailed explanation of the objective method is given below. The detail of the subjective method is given in the paper presented at PICS '99.[3]

Line Reproduction Quality

Line reproduction quality is an objective parameter we use to show whether or not a line is reproduced well enough. Here "well enough" means no visible breaks in the line when viewed at a predetermined distance. The simple algorithm for measuring the line reproduction quality we have proposed is shown in Figure 2. The line reproduction quality is calculated according to this algorithm. The measurement consists of 5 steps;

1. RGB data of original image are sampled with a drum-scanning type microdensitometer and converted into XYZ image data in CIE color space.
2. With Fast Fourier Transform (FFT), the Y data in the XYZ color space are transformed into the spatial frequency space.
3. The frequency space data are filtered by the transfer function of the visual system (VTF). The VTF is calculated at a viewing distance of 200 mm as expressed by equation (1)[4] in consideration of critical viewing.

$$VTF = 5.05\exp(-0.482u)\{1-\exp(-0.349u)\} \quad (1)$$

   where : u = spatial frequency in cycles per mm
4. With inverse FFT, the filtered data are transformed into the real space again.

5. The transformed data are binarized by a threshold.

In this method, two-dimensional FFT and inverse FFT are used.

For the measurements, we have chosen 200 color lines, excluding lines that are clearly broken or clearly not broken. One half of them are positive lines and the rest are negative lines. The results measured with various threshold values are compared with the results of subjective evaluation. The threshold Y_m is defined by equation (2),

$$Y_m = \frac{m}{100} \cdot Y_{min} + \frac{100 - m}{100} \cdot Y_{max} \qquad (2)$$

For the positive lines, using a threshold of Y_{40}, we have found agreements in 92 out of 100 lines. Similarly, for the negative lines, agreements are obtained for 84 out of 100 lines with a threshold of Y_{45}.

The difference in the thresholds for positive lines and negative lines may be caused by the difference in the visibility between positive images and negative images.[5] However, further studies are needed for a complete understanding of the difference. In the present investigation, different values of thresholds are used for positive and negative lines.

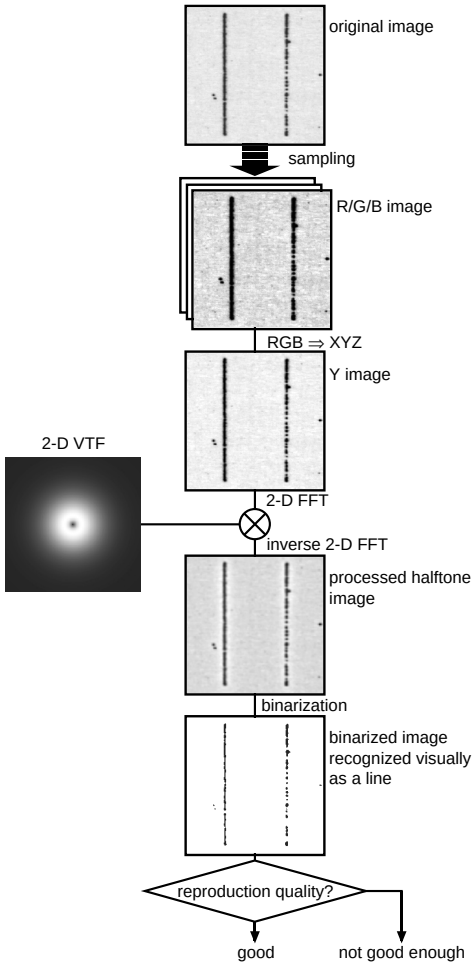

Figure 2. Proposed method to measure line reproduction quality

MTF

We have used rectangular-waves as the input waveforms. The MTF can be obtained as the amplitude divided by the central value of the Y data in XYZ color space of the output waveform. The amplitude is obtained from the Fourier transformed outputs. The central value is the average value of maximum and minimum of the output waveform. For small values of the ratio: (line width) / (line pitch) = 0.1 to 0.4, the measured values of MTF have been corrected for errors due to the small duty of waveform.

Test Target

We have prepared different test targets for measurements of line reproduction quality and MTF. Both targets are described in PostScript. Therefore, we can investigate any PostScript printers independent of their print resolutions.

The test target for line reproduction quality consists of six blocks. Each block has two vertical lines and two horizontal lines. In each of these blocks the line width is different, corresponding to Kanji character size (Table 1). Figure 3 shows one block of the test target.

Table 1. Relationship between Kanji character size and line width

Character size [pts]	Line width [μm]
21	250
14	167
10.5	125
7	83
5.25	63
3.5	42

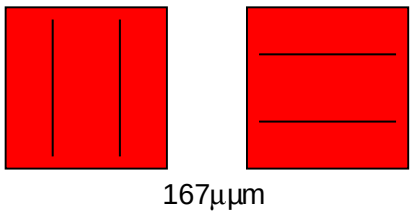

Figure 3. One block of test target for line reproduction quality

The test target for MTF consists of two blocks. One contains vertical rectangular-waveforms, and the other contains horizontal rectangular-waveforms. Each block has six parts, including rectangular-waveforms. The line width of the waveforms differs in each part, as in the test target for line reproduction quality. Each of the six parts contains four

patterns with different (line width) / (line pitch) ratios. The latter correspond to different Kanji character strokes as shown in Table 2. Figure 4 shows a part of the test target for MTF.

Table 2. Relationship between Kanji character strokes and line width / line pitch

Line width / Line pitch	Strokes
0.1	3
0.2	9
0.3	15
0.4	21

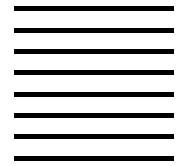

Figure 4. A part of test target for MTF

The test targets are prepared in various colors. Table 3 shows the color combinations we have chosen in this experiment. They are the basic colors we can obtain from the text color palette in a typical word processor, MS-Word.

Table 3. Color combinations of texts and background

Background	Text
White	Black
	Red
	Dark red
	Yellow
	Dark yellow
	Bright green
	Green
	Turquoise
	Teal
	Blue
	Dark blue
	Pink
	Violet
Yellow	Turquoise
Turquoise	Yellow

Results and Discussion

We have investigated the validity of the objective method for evaluating color-text legibility. Print samples of test targets are evaluated subjectively and compared with the results of measurements by the objective method mentioned above.

The results of two typical measurements (sample A and B) are shown in Figure 5. Sample A is a print of test target in which the patterns are blue and the background is white. Sample B is a print in which the patterns are yellow and the background is turquoise. The diagrams on the left are the measurement results for vertical lines, and the diagrams on the right are the results for horizontal lines. The symbol "○" indicates the limits of Kanji character reproduction quality by subjective evaluation. The diagrams in sample A indicate that a characters in 10.5 to 21 points reproduce to 21 strokes and character in 7 points reproduces to 15 strokes. The shaded area indicates the area where lines are reproduced or the value of MTF is more than 0.2.

In the case of sample A, as the diagrams indicate, the limit of subjective judgement corresponds well with that of the common area where lines are reproduced and the value of MTF is more than 0.2. The same result is obtained for sample B. These results lead to the conclusion that the idea of the objective method is effective for the evaluation of legibility in the case of color texts on color background. However, this objective method is only effective in the case that texts and test targets are printed with the same halftoning, as mentioned above. It is an unsettled issue. When we evaluate text using this method we must pay attention to this issue.

In this paper, we have investigated the document output from color printers. However, it is obvious that the method is also effective for color copiers, too.

We can choose any colors for texts and background in most application software. However, it is impossible to evaluate legibility for all color combinations. Therefore we need further consideration of the suitable color combinations to avoid such a hard work and evaluate legibility efficiently.

There exists misregistration between cyan and yellow according to our observation in sample B. Even for characters in 14 points which are judged to be reproduced well, include green parts, i.e. overlaps of cyan and yellow. The misregistration can be detected, but it does not always cause deterioration of legibility. However, the misregistration certainly causes deterioration in appearance. We must be aware of the importance of further work in the area of appearance including color registration concerning the total evaluation of color texts.

Conclusion

It is concluded that we can predict Kanji character reproduction quality using line reproduction quality and MTF effectively independent of the color of texts and background.

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Biography

Soh Hirota received his B.E. degree in Applied Physics from the University of Electro-Communications at Tokyo in 1991. Since 1991 he has worked in Toyokawa Development Center at Minolta Co., Ltd. His work has primarily focused on the study of image quality evaluation.

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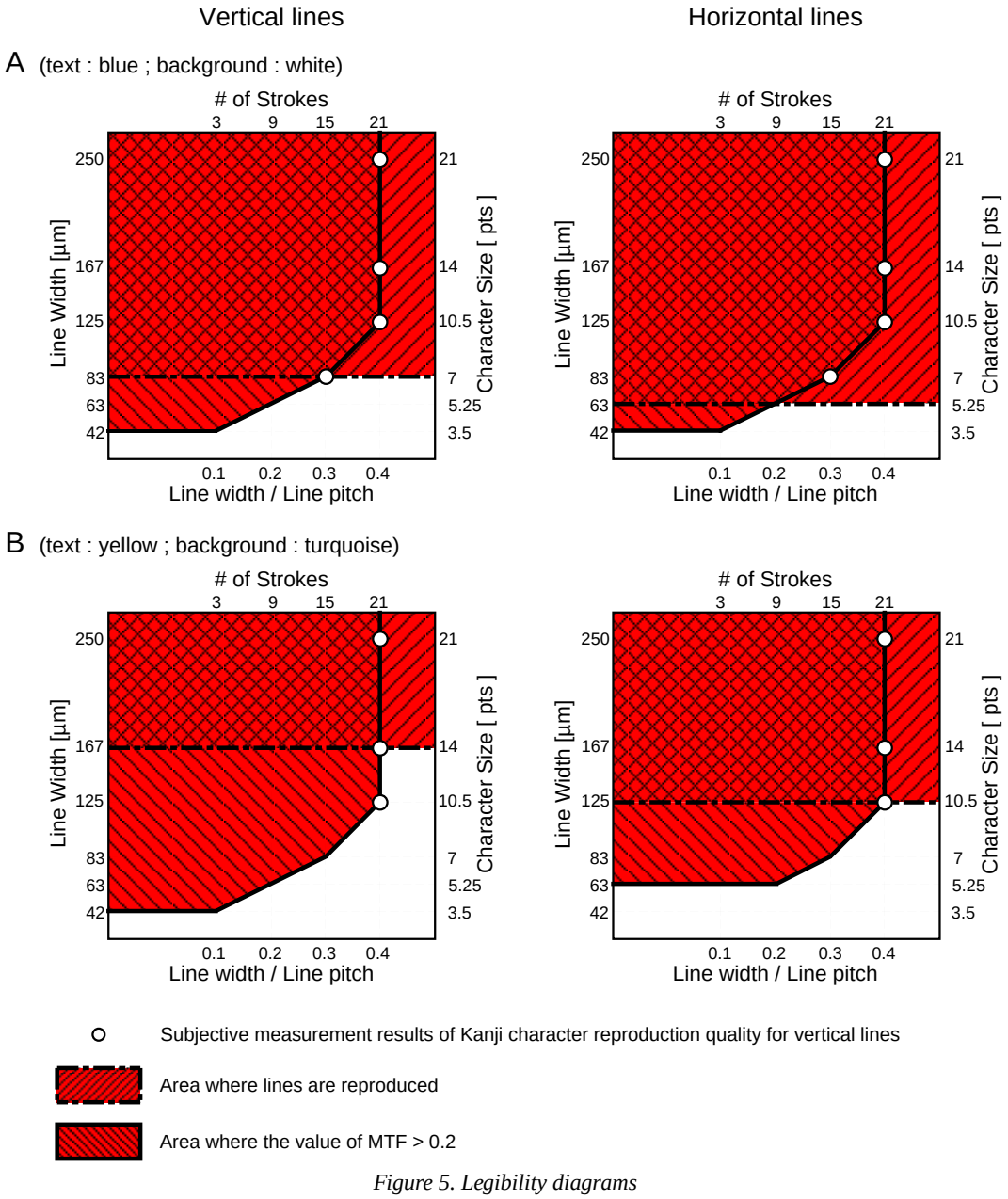

Figure 5. Legibility diagrams