Measurement and Analysis of Sharpness of Printed Image on Silk Fabric by Ink Jet Printer

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Abstract

The sharpness of ink jet image depends on many factors such as resolution of printer, ink drop volume and dot gain. In this paper the printed sheets on silk fabric had been studied using scanner to measure the reflectance of a group of printed test chart. It consists of bar chart with different frequency and dot area coverage chart. Four types of silk fabric, each with different structures, were printed by an ink jet printer. Line width and blurriness were measured from the line patches and the contrast transfer functions measured from bar charts were analyzed and compared. The apparent dot gains were measured and compared. It was found that the sharpness of printed image varied with the silk fabric structure. The dot gain measurement shows the similar results. The frequency of silk fabric influenced to the perceiving contrast of printed images and the contrast of line image could not be observed when its frequency was over 2 lp/mm.

Introduction

Print Quality of an ink jet printing is usually determined by its sharpness, tone reproduction, color reproduction and noise. The printed image quality especially sharpness is significantly dependent on printer resolution and dot volume and size. When an ink drop strikes on the surface of substrate, the interaction between those two parties plays a vital role. If the substrate has the ability to hold the ink dot and maintains its dot shape better, the sharpness will be also better. As a consequence, most of ink jet substrates are coated for minimizing ink spreading and maintaining good image quality. The degree of ink dot increasing from what is expected is well recognized as the mechanical dot gain.

Not only ink spreading plays an vital role for image quality but also the light scattering within the substrate. This phenomenon is well known as Yule-Nielsen effect or the optical dot gain [1]. The optical dot gain has been studied extensively for years and found that printing model based on ink spreading and point spread function of the substrate can be well estimated by the reflectance of halftone printed images[2-4].

The recent printing model is assumed that the substrate has a flat surface and behaves as an isotropic turbid medium which is quite agree well for high quality ink jet papers. However for silk fabric is not the case. Silk fabric is a shift variant substrate therefore ink drop will distribute and spread differently according to its surface and location. The variation of silk fabric surface comes from the yarn size and the fabric structure.

In this paper, the sharpness of line quality and contrast transfer function on four different types of silk fabrics had been measured, analyzed and compared.

Measurement of print sharpness

There are many methods to measure the print sharpness [5-6]. The line width and blurriness are common figures of merit to evaluate the sharpness of line and text quality. Since we see printed image in a normal viewing distance, the contrast transfer function of print is a quite well representation of overall sharpness. The QEA test target provides very useful many patterns for evaluating the printed sheet. It is in PDF format and can be printed by any printer. For the sharpness evaluation, line quality can be measured from a series of lines in horizontal and vertical directions. The test images of this study are shown in Figure 1.

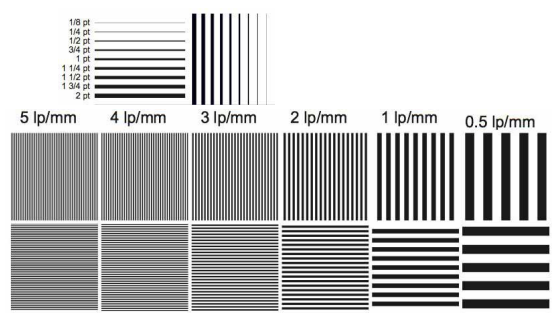

***Figure 1**. The original test images.*

The contrast transfer function (CTF) can be calculated from the Eq. (1)

$$CTF = \frac{C(\omega)}{C(0)}, \tag{1}$$

where $C(\omega)$ and $C(0)$ denote the contrast of the printed square wave at ω and 0 frequency respectively. The contrast of each frequency can be obtain by

$$C(\omega) = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}, \tag{2}$$

where I_{max} and I_{min} are the relative reflectance from the printed image.

Line width

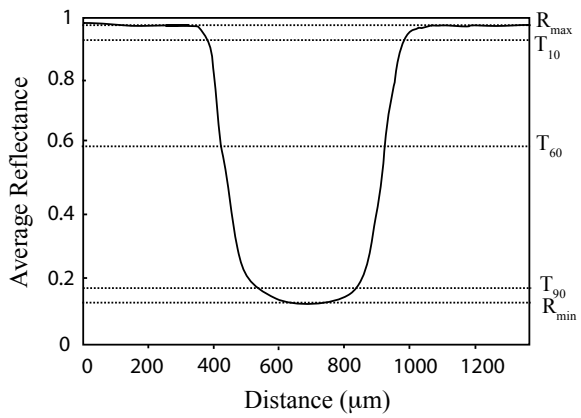

Figure 2. *A typical printed line profile.*

The line width or stroke width is a physical distance between T_{60} boundaries on either size of the line. The definitions of metrics used in this measurement are as follow:

R_{max} refers to the maximum reflectance value averaged from the non printing area of the substrate

R_{min} refers to the minimum reflectance value averaged from the solid area of the printed line

T_{pp} refers to a specific reflectance value calculated as :

$$T_{pp} = R_{max} - \frac{pp}{100}\left(R_{max} - R_{min}\right), \quad (3)$$

Blurriness

Blurriness is the sharpness of the transition from substrate to colorant, and vice-versa. It is measured as the mean physical distance between the T_{10} and T_{90} boundaries of the edge profile, measured on both sizes of the line.

Dot Gain

Apparent dot gain or total dot gain is the dot gain that includes both mechanical and optical dot gain. Ideally, the reflectance of a halftone image can be obtained by Murray-Davies equation as follow

$$R = aR_s + (1-a)R_w, \quad (4)$$

where R_S is the reflectance from print solid, R_W is the reflectance from bare substrate, a is the fractional dot area on digital halftone image. However, the practical reflectance from the printed tint always less that that calculated from Murry-Davies equation. The differences of measured reflectance and calculated reflectance usually report in percentage of its ideal dot area.

Experimental

The silk fabrics used in this study were obtained from Thai Silk Company Limited. Four degummed and unbleached silk fabrics were washed with soap solutions (Sunlight), then cleansed with water and dried at ambient atmosphere. The description of them is presented in Table 1. They are all plain style silk fabrics except B, a twill style.

Table 1 Description of silk fabrics

Silk	Type Style	Yarn (Denier, warp x weft)	Number of yarn per unit length (warp x weft)*
A	plain	104 x 87**	130 x 51
B	twill	102 x 66	140 x 51
C	plain	79 x 67	130 x 70
D	plain	98 x 84	130 x 51

* Count of yarns per inch, ** Represents the number of yarns

These fabrics were printed by Canon BJF 8500 ink jet printer and the printed test targets were scanned with Genius View Pro, the flatbed scanner, at 600 dpi. The results were 8 bits RGB image which were converted to gray scale with MATLAB program.

Results and Discussion

The images captured by the scanner are shown in Figure 3-4.

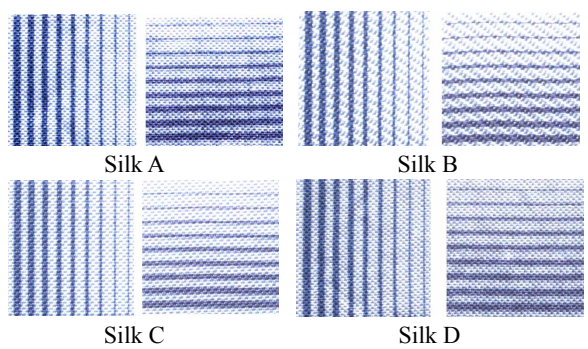

Figure 3*. Printed line for measurement of line quality from Silk fabric A, B, C and D*

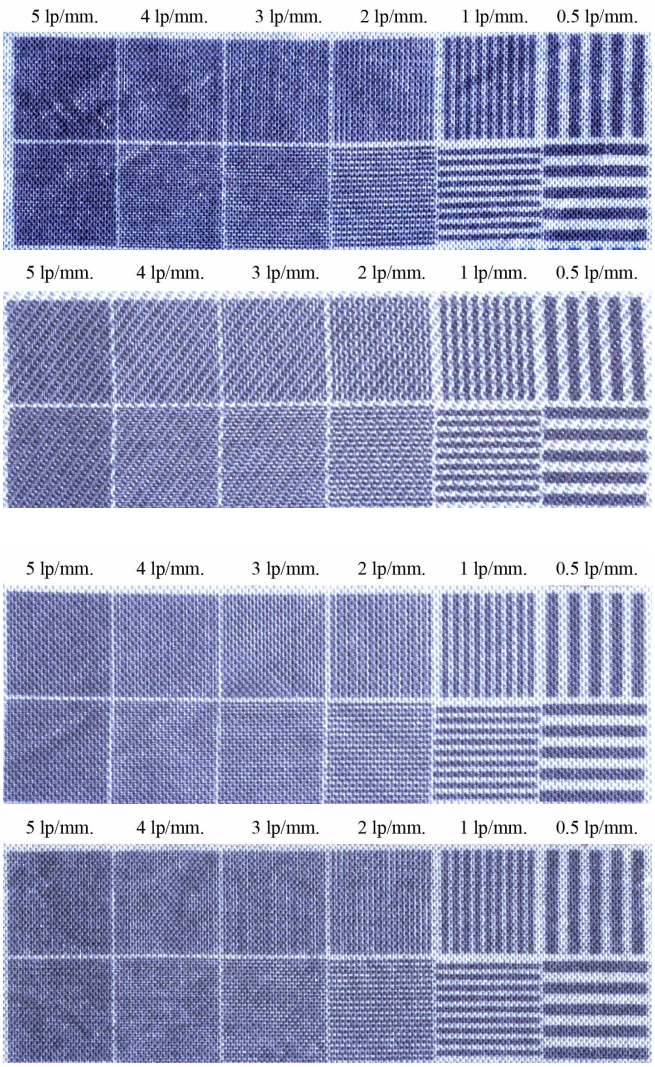

***Figure 4**. Printed for evaluate the contrast transfer function of Silk fabric A, B, C and D*

The stroke width was measured from 1 point line. The images in Figure 4 were processed through the MATLAB in order to obtain contrast transfer function. Since the silk fabric patterns were included in the one dimension scanned data therefore their frequencies were canceled out using filtering in Fourier domain. Figure 5 shows a sample of the data before and after filtering.

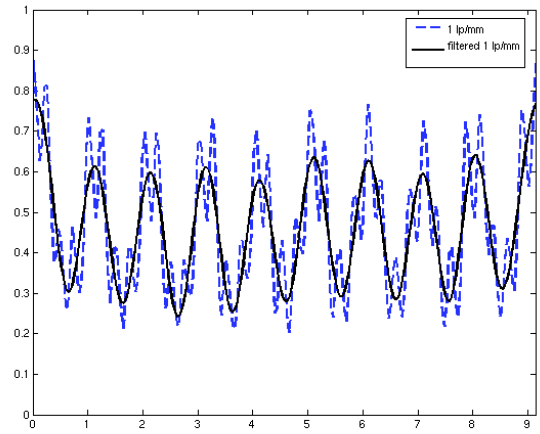

***Figure 5**. One dimensional scanned data of 1 lp/mm from silk fabric A*

All four types of silk were measured and the results of stroke width and blurriness are shown in Table 2.

Table 2 The stroke width and blurriness of 1 lp/mm line.

Silk	Stroke Width (mm)		Blurriness (mm)	
	Horizontal	Vertical	Horizontal	Vertical
A	0.423	0.423	0.317	0.254
B	0.381	0.381	0.296	0.213
C	0.423	0.402	0.296	0.233
D	0.444	0.423	0.403	0.275

We can see from the results that silk B has the less stroke width and blurriness. This indicates that its edge profile has the highest transition and therefore produces the best text and line quality among the test fabrics.

The contrast transfer functions of each type of silk were calculated from Equations (1) and (2). Since the zero frequency is not available therefore the contrast at 0.5 lp/mm is assumed the same as the contrast of zero frequency because it has the highest contrast in the test chart. All four types of silk were measured and the results are shown in Figures 6 and 7.

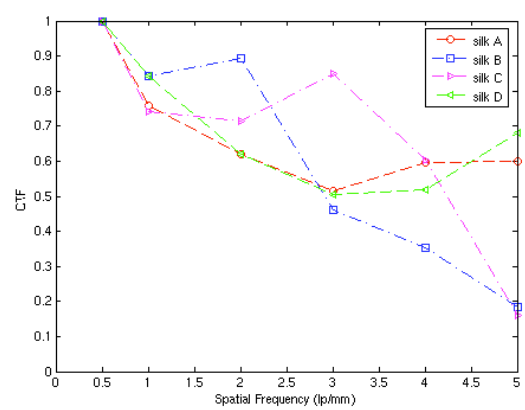

***Figure 6**. The CTF of printed horizontal lines on silk fabric A, B, C and D*

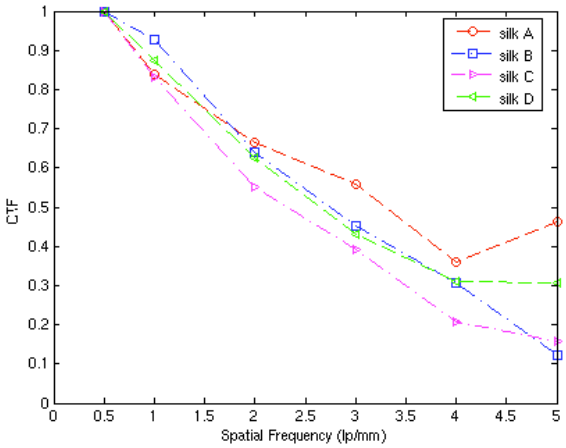

***Figure 7**. The CTF of printed vertical lines on silk fabric A, B, C and D*

When analyzing in the Fourier domain, silk fabric A, C and D had the frequency at 2 lp/mm in the vertical direction. Silk fabric B had the frequency at 3 lp/mm. Ideally, if the line was perfectly printed, the silk fabric would be able to show the 4 lp/mm for silk fabric A, C and D, and 6 lp/mm for silk fabric B according to its Nyquist frequency limited. However, the experiment results showed that visible contrast of the printed image was limited by 2 lp/mm thus the mechanical spread of ink and the optical spread of light within the fabric affect on this observation. It was also observed that at the high frequency, such as 5 lp/mm, the contrast was still quite high especially for silk fabric A and D. The explanation should come from the fact that silk fabric A and D have rougher surface than silk fabric B and C. Therefore, they are more shadower since the light beam for the measurement come from 45/0 degree.

Considering the overall contrast of the silk fabrics, the silk fabric B which has the good contrast on frequency at 1 lp/mm should provide the overall sharpness for printing purpose.

The reflectance of each patch of the halftone step-wedge printed on four types of silk fabric was measured, and calculated the apparent dot gain which the result is shown in Figure 8.

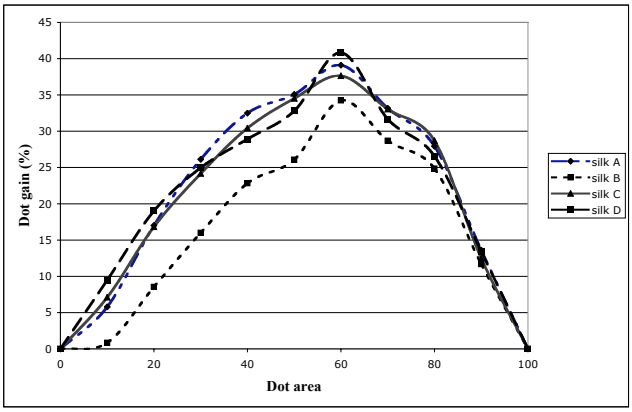

***Figure 8**. Dot gain of silk A, B, C and D*

The dot gain result shows that each type of the fabrics has the maximum dot gain at 60% dot area. The silk fabric B has less dot gain. The silk fabrics A, C and D have similar characteristic, This indicates that silk fabric B has the ability to maintain the dot area better than the other three silk fabrics.

Conclusion

The print sharpness of silk fabrics was measured for line quality, contrast transfer function and dot gain in this paper. The yarn structure shows significant impact on the sharpness of the final print. The results of stroke width and blurriness confirm the shift variant behavior of silk fabrics.

Future works

In order to estimate the printing reflectance each ink dot must be known and modeled. In addition, a bi-directional reflectance model should be combined into the printing model in order to estimate the reflectance of silk fabric if the surface has different depth and under the different illuminations.

References

[1] J. A. C. Yule and W.J. Neilsen, The penetration of light into paper and its effect on halftone reproduction, Proc. TAGA , pg**.** 65(1951)

[2] B. Kruse and M. Wedin, "A new approach to dot gain modeling", Proc. TAGA., pg 329 (1995)

[3] P. Emmel and R. D. Hersch, " A unified model for color prediction of halftone prints", J. Imaging. Sci. and Technol., **44**, pg (2000)

[4] C. Koopipat,; N. Tsumura, and Y. Miyake, Effect of Ink Spread and Optical Dot Gain on the MTF of Ink Jet Image J. Imaging. Sci. and Technol., **46**, pg. 321. (2002)

[5] J. C. Briggs, A. H. Klein and M.K. Tse, Applications of ISO-13660, A New International Standard for Objective Print Quality Evaluation, Proc.,Japan Hard Copy, (1999)

[6] J. Grice, J. P. Allebach, The print quality toolkit: An integrated print quality assessment tool, J. Imaging. Sci. and Technol., **43**, pg. 187. (1999)

Author Biography

Chawan Koopipat received B.Sc (Photographic Science and Printing Tech.) from Chulalongkorn University, Thailand in 1989 and MPhil (Printing Tech.) from West Herts College, UK in 1996. He received Ph.D.(Image Information Processing) from Chiba University, Japan in 2002. He is currently a lecturer at Department of Imaging and Printing Technology, Faculty of Science Chulalongkorn University, Thailand. He researches in the area of printed quality evaluation especially of ink jet printing, ink jet printer model and multi-spectral imaging.

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