Four-Directional Edge-Effect Method of Measuring in Laser-Printers

D. G. Ko, S. H. Song, Y. S. Bang, K. M. Kang and S. W. Han
Imaging Lab, Samsung Electronics
130, Samsung-ro, Yeongtong-gu, Suwon-si, Gyeonggi-do, Republic of Korea
E-mail: { dg.ko, suhan.song. yousun.bang, kimin.kang, seongwook.han } @samsung.com

Abstract: Edge-Effect is printing optical density fading phenomenon which is white-gapping between solid and halftone of black area. In this paper, we propose a new method for measuring Edge-Effect based on psychophysical experiments and data analysis method. Our approach is to extract two components both Edge-Effect's P_A and P_B. Edge-Effect is computed by the weighted sum of P_A and P_B, where two parameters are determined by psychophysical experiments. By conducting psychophysical validation experiments, the strong correlation is obtained between the proposed measuring method and the perceived scales. The correlation coefficient r is 0.95.

Keywords-- **white-gapping, optical density fading, print image quality assessment**

1. Introduction

Print image quality analysis has been carried out for both monochrome and color print images obtained by a calibrated scanner. There are many factors affecting the perception of image quality in laser-printer.

The definition and measuring method of print image quality introduced by ISO 13660 [1] and ISO 24790 [2], improved by JBMIA report [3]. Edge-Effect is printing optical density fading phenomenon which is white-gapping between solid and halftone of black area [Fig. 2]. The notion of Edge-Effect is described in the paper by D. G. Ko *et al* [4]. In the paper, the correlation coefficient of quantified metric *r* is 0.97 at black area. However, this metric was measured mainly paper feeding direction as shown in Fig. 1. Thus, it cannot effectively assess on the opposite side.

In this paper, we propose effective four-directional Edge-Effect measuring method (up, down, left and right) at black area [Fig. 2]. Four-directional Edge-Effect will be denoted as EE in this measuring method.

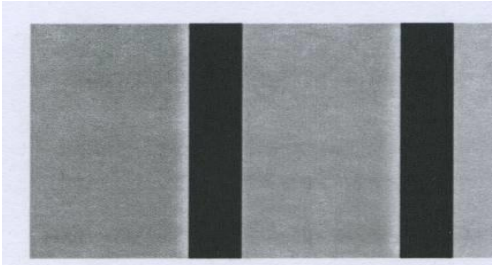

Figure 1. The defect of Edge-Effect

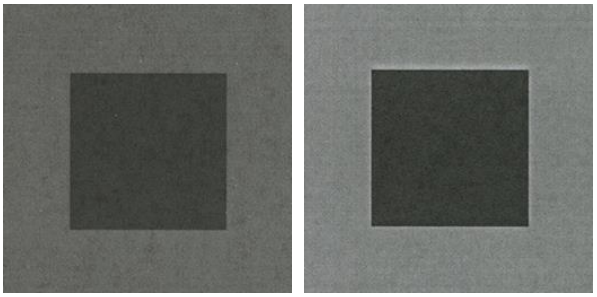

Figure 2. Scanned EE samples are shown with excellent EE (left) and poor EE (right)

Our method is structured as shown in Fig. 3. In the next section we provide both EE test pattern and EE method for measuring. In section 3, we will show that strong correlation coefficient is obtained between the proposed method and psychophysical experiments. In section 4, we derive a conclusion about EE.

2. EE method

Our approach is summarized in the block diagram as shown in Fig. 3 and test chart as shown in Fig. 4. The procedure for EE Process A is as follows:

1. Scanning: color scanning a test chart at 300 dpi. Epson Expressin 10000XL used as scan device.
2. Pre-processing: converting color space from scanned RGB to CIELAB L* using a calibratied scanner.
3. Blocking by black area:splitting into up, down, left and right direction, repectively.
4. Smoothing and projection: applying smooth filter and 1-D projection.
5. Get score: computing EE's integral and white-distance scores.
6. Re-scaling for P_B: P_B re-scaling for improving on EE measuring method.

The final EE score [Eq. (1)] computed by weighting parameter P_A and P_B, where the weights are determined by the psychophysical experiments [5, 6] as in Process B.

In the next subsection, Process A will be described in detail. By using the psychophysical experiments it will be explained how subjective scores are converted to the weighting parameters.

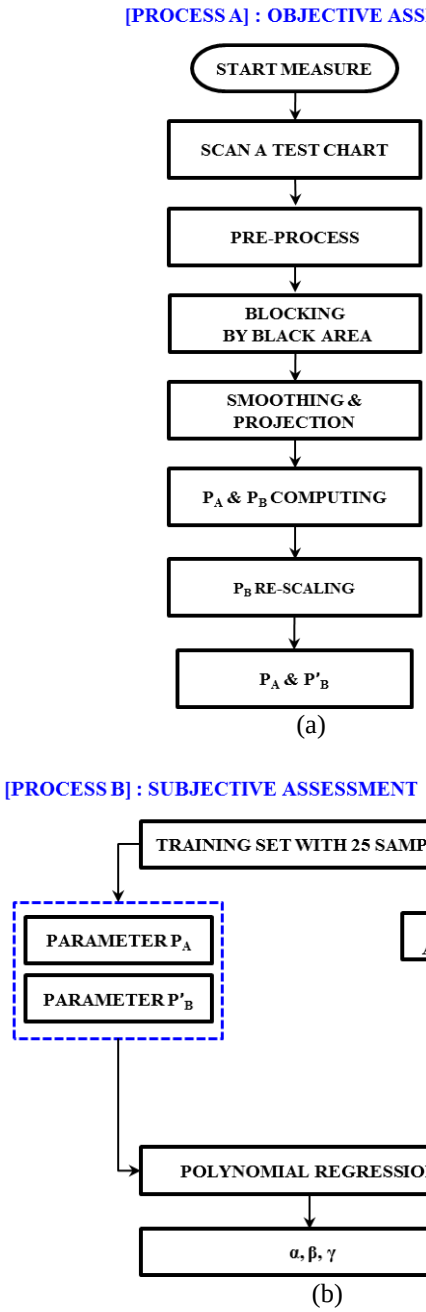

Figure 3. EE flow chart:
(a) Objective assessment, (b) Subjective assessment

$$\mathbf{EE} = \boldsymbol{\alpha} \times \boldsymbol{P_A} + \boldsymbol{\beta} \times \boldsymbol{P'_B}^2 + \boldsymbol{\gamma} \quad (1)$$

Figure 4. Test chart for EE

2. 1 Objective Assessment

In this paper, we propose EE measuring method using Edge-Effect's P_A and P_B. It can be computing as follows:

1. Projection: four-direction profiling [Fig. 5]
2. Computing P_W [Eq. (2)] and P_A [Eq. (3)]
3. Get a P_B and re-scaling for P_B: since white-distance strongly affect the EE [Eq. (4)]
4. Computing $Grade_{Edge\text{-}Effect}$ [Eq. (1)]

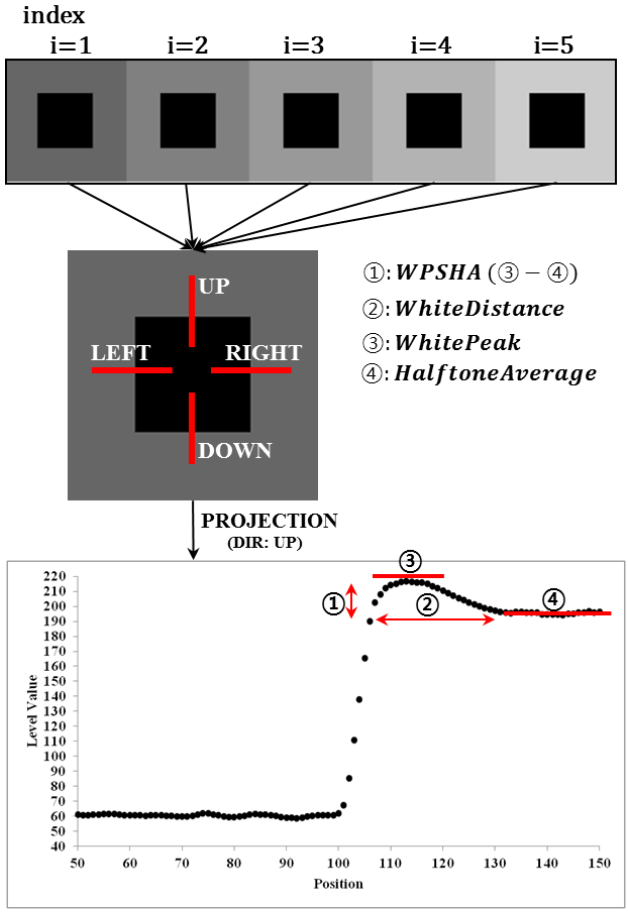

Figure 5. EE's Projection

$$\boldsymbol{P_W} = \boldsymbol{argmax}[\boldsymbol{UP}, \boldsymbol{DOWN}, \boldsymbol{LEFT}, \boldsymbol{RIGHT}]\left(\frac{\sum_{i=1}^{5} \boldsymbol{WhiteDistance}}{6}\right) \quad (2)$$

$$\boldsymbol{P_A} = \boldsymbol{DIR_{max}}\left(\frac{\sum_{i=1}^{5} \boldsymbol{WhiteDistance}}{6}\right) \quad (3)$$

$$\boldsymbol{P_B} = \frac{\boldsymbol{P_A} \times \boldsymbol{P_W}}{2} \quad (4.1)$$

$$\boldsymbol{P'_B} = \boldsymbol{-3E-06} \times \boldsymbol{P_B}^2 + \boldsymbol{0.0061} \times \boldsymbol{P_B} + \boldsymbol{1.368} \quad (4.2)$$

2. 2 Subjective Assessment

For psychophysical experiment, to have different levels of EE, we choose 25 test samples, and two anchor samples are selected: one has minimal defect, and the other has the worst levels of defects.

We explain to observers the definition of EE using two anchor samples. The best anchor sample is assigned to Grade 1, and the worst anchor sample is Grade 4. Observers can be scoring Grade 1 to Grade 5. In addition, observers are composed of print image experts and non-experts. From the psychophysical experiment, the minimum correlation coefficient between a single observer and the average score is 0.87. Lastly, we obtained three weighting factors using this psychophysical experiment, and by linear regression [Table 1].

Table 1. Weighting factor α, β, γ

Weighting factor	α	β	γ
Value	0.09121	0.48098	0.45938

2. 3 Scanner Calibration

Before the EE measuring, we conduct scanner calibration [7] using IT8.7/2-1993 chart [Fig. 6]. It consist of patch of 144 color and 24 level of gray color. We get a polynomial expression by polynomial regression in this step.

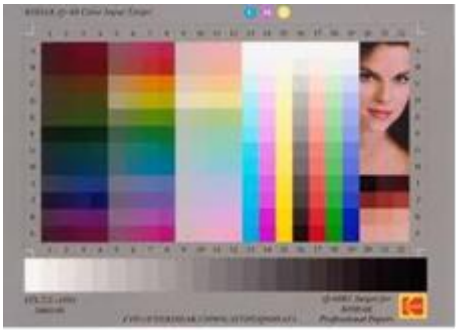

Figure. 6. Scanner Calibration chart: IT8.7/2-1993

3. Experimental result

Our metric is tested with 25 samples that are printed from seven different printing manufacturers and has various Edge-Effect defect at black area. Fig. 7 is a graph of EE correlation about proposed measuring method and psychophysical experiments. The correlation coefficient *r* is 0.95.

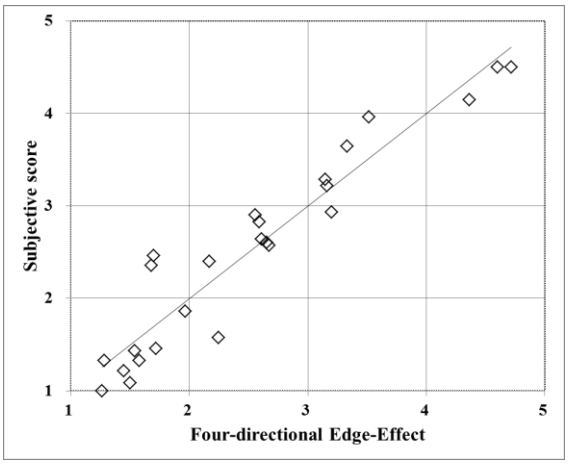

Figure 7. Validation result of EE measurement method. The correlation coefficient *r* is 0.95

4. Conclusion

In this paper, we proposed four directional Edge-Effect measurement method based on psychophysical experiments and test pattern in laser-printers. The EE score is estimated by two parameters P_A and P_B that are determined by psychophysical experiments. The EE measurement method is validated by psychophysical test: the correlation coefficient r is 0.95. Our study can be extended to cyan and magenta color in the future.

References

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