A Method of Restoring the Shadow Distortion in a Bounded Book Scanned Image by Using Non-Edge Segment

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Abstract

When a thick bounded book is scanned on a flatbed scanner, the folding areas adjacent to the left page and right page would not be contacted on the glass. Therefore, the folding areas are darkened because the light reflected from the folding areas is weakened. In order to restore the shadow distortion in the folding areas, distortion profile should be firstly estimated. This paper proposes a method for estimating shadow distortion from the bounded book scanned image itself and for restoring the shadow distortion. The estimation of the shadow distortion can be done by analyzing the information of the non-edge segment which consists of non-edge pixels. The analysis of the change of the average luminance in the non-edge segments can estimate the characteristics of the shadow distortion.

Introduction

When a thick bounded book is scanned on a flatbed scanner, two types of distortion happen, photometric degradation and geometric distortion. Photometric degradation indicates the darkened thick borders and shadowing folding area. The typical geometric distortion is skew and warping. Figure 1 shows the luminance degradation and geometric distortion. This paper explains the proposed method for compensating shadow degradation.

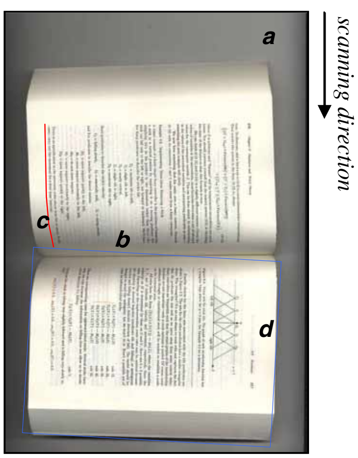

Figure 1. *Distortion in a Bounded Book Scanned Image: darkened thick borders(a), shadowing folding area(b), warping(c) and skew (d)*

Shadow Distortion

Shadow distortion is typically caused in the folding area where left page and right page are separated because the folding area would not be contact with the glass plate of the scanner. If the paper does not contact with the glass plate, the amount of the light reflected from the surface of a paper is weakened. Figure 2 shows the brief relationship between the distance from the glass plate to the paper surface and the luminance value digitized from CCD sensor.

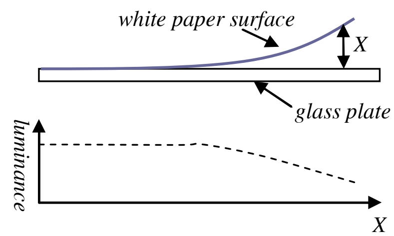

Figure 2. *Relationship between Luminance and Amount of Paper's Contacting on Glass Plate*

To solve the shadow distortion, a method calculating the variable *X* shown in Figure 2 by sensing the external sensor mounded on the glass plated was proposed[1]. However, the external sensor can be hardly implemented in the real scanner or MFP. An image contents based method was proposed that estimates the variable *X* by calculating the amount of skew in the scanned image[2]. Also, the relationship between the variable *X* and the trajectory of the book boundary has been used to estimate the warping and shadow distortion[3].

The proposed algorithm estimates the luminance change of the shadow from the background region through 4 steps. In the first step, the *Minimum Boundary Rectangle* is founded. In the second step, the *Book Boundary Curvature* is extracted by using the binary edge map and *Minimum Boundary Rectangle*. Whether a pixel in the scanned image belongs to the book area can be decided by using *Book Boundary Curvature*. In the third step, the background is extracted by using the *Non-Edge Segment* and the profile of the shadow is calculated. Finally, the shadow degradation is corrected by using the shadow profile.

Shadow Correction

Minimum Boundary Rectangle

Minimum Boundary Rectangle is the smallest rectangle containing the book area. To find the *Minimum Boundary Rectangle*, *Laplician* filter is applied to the scanned image so that the binary edge map is extracted. Figure 3 shows the binary edge map that is acquired by applying *3x3 Laplacian* filter to the luminance channel. For the binary edge map, *X_histogram(m)* and *Y_histogram(n)* is calculated, where *m* and *n* mean the column and row respectively. *X_histogram(m)* and *Y_histogram(n)* indicate the sum of the number of the edge pixel for the column *m* and the row *n* respectively as shown in Figure 3. The (*x,y*) point of the four vertices in the *Minimum Boundary Rectangle* selects m and n where the first peak and the last peak occurs in *X_histogram* and *Y_histogram*. An extreme peaks greater than a threshold value are considered as a noise that is excluded to calculated *Minimum Boundary Rectangle*.

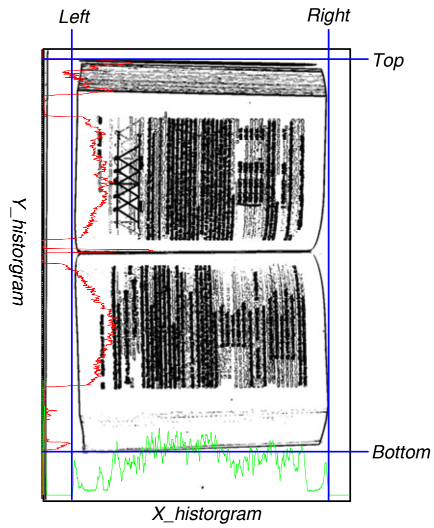

Figure 3. *Edge Histogram and MBR*

Book Boundary Curvature

Book Boundary Curvature is the real boundary of the book. The coordinates, (*x,y*), forming *Book Boundary Curvature* is defined as the edge pixel nearest to the side of *Minimum Boundary Rectangle*. Each coordinate of *Book Boundary Curvature* is in the inside of *Minimum Boundary Rectangle*.

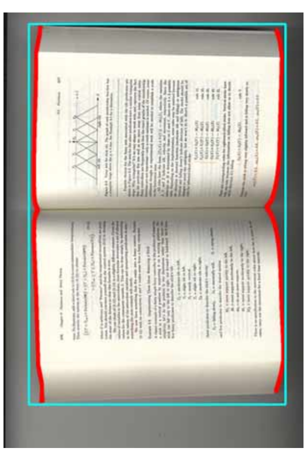

Figure 4*. Book Boundary Curvature*

Non-Edge Segment & Shadow Profile

Non-Edge Segment is a set of pixels which do not belong to the edge. Non-Edge Segment is defined in each row.

$$NonEdgeSeg(\,x_i, x_j, y_k, L_i^j\,) \tag{1}$$

In Equation 1, *x* and *y* indicate the horizontal and the vertical direction respectively. Only if the offset from *i* to *j* is larger than T_{offset}, pixels from (x_i, y_k) to (x_j, y_k) are registered as *Non-Edge Segment* In Equation 1, L_i^j means the average luminance of the pixels from (x_i, y_k) to (x_j, y_k). Each row can have the different number of *Non-Edge Segment* according to the edge map.

Shadow profile describing the luminance variation shown in Figure 4 can be estimated by tracing L_i^j in Equation 1.If {x_i, x_j}s in each row, k, are same, the variation curve of L_i^j is the shadow profile. However, {x_i, x_j}s in each row are not same because the edges are not evenly distributed. Therefore, the proposed method applies the simple estimation of the shadow profile as the following steps.

1. Non-Edge Segment described in Equation is extracted for all of rows by using the edge map
2. For each row, search the nearest *Non-Edge Segment* from the *Book Boundary Curvature*. Two *Non-Edge Segment*s are found in each row.
3. The connection of *Non-Edge Segment* nearest to the left side of *Book Boundary Curvature* is defined as the left-most shadow profile.
4. The luminance variation of the pixels between the left-most shadow profile and the right-most shadow profile can be calculated by the linear interpolation with two shadow profile in each row.

Figure 5 shows the example of the shadow profile. The solid line indicates the left-most shadow profile and the dashed line indicates the right-most shadow profile. The horizontal axis indicates the row.

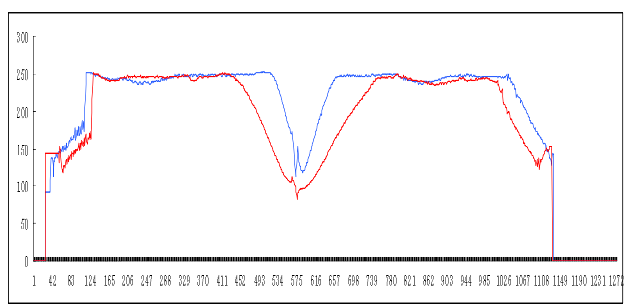

Figure 5. *The Left-Most Shadow Profile and The Right-Most Shadow Profile*

Luminance value in (*m,n*) is calculated by Equation 2.

$$L(\,m,n\,) = L_{left-most}(\,n\,) + \frac{L_{right-most}(\,n\,) - L_{left-most}(\,n\,)}{m_{right-most} - m_{left-most}} \times (m - m_{left-most}\,) \tag{2}$$

where, *m* and *n* indicate the horizontal and the vertical coordinates respectively. Basically, Equation 2 explains the linear interpolation with both of the left-most and the right-most shadow profiles

$$L'(m,n) = L_{max} + \frac{L_{right-most}(n) - L_{min}}{L(m,n) - L_{max}} \times (L(m,n) - L_{max}) \quad (3)$$

Once $L(m,n)$ is calculated, shadow degradation is corrected by Equation (3). In Equation 3, L_{max} and L_{min} are the constant values of the white and the black respectively.

Experimental Results

In order to take the scanned image, EPSON GT-15000 scanner is used. The experimental steps are the followings

1. Take a RGB scanned image with 600 dpi.
2. Convert RGB image into YCC image.
3. Calculate edge map with down-sampled image, Minimum Boundary Rectangle and Book Boundary Curvature.
4. Non-Edge Segment is extracted based on the edge map.
5. Calculated the left-most and the right-most shadow profiles
6. Execute the shadow correction with the shadow profiles based on linear interpolation.

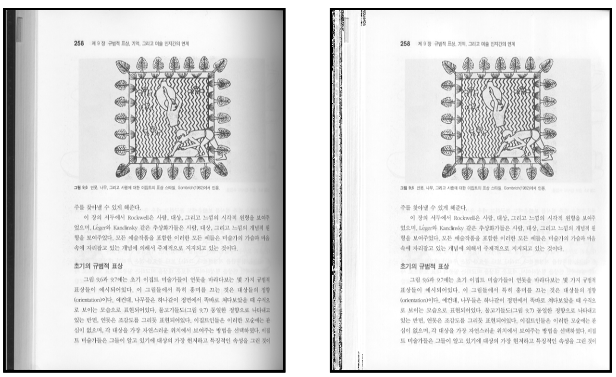

Figure 6. *Experimental Result for Gray Scan*

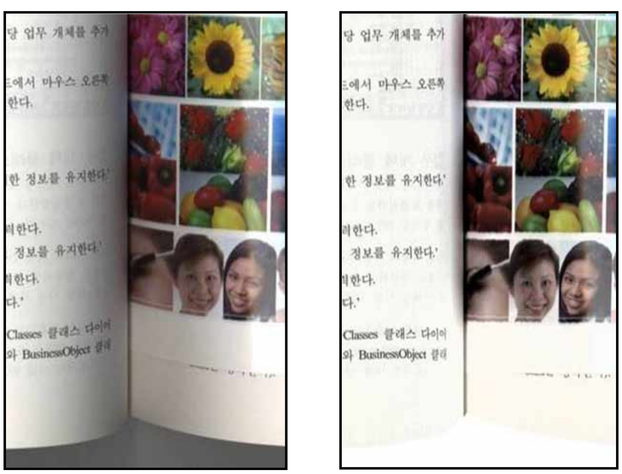

Figure 7. *Experimental Result for Color Scan*

Figure 6 and Figure 7 show the experimental results. Epson GT-15000 is used to acquire the scanned images with 600 dpi. Edge map is calculated with150 dpi through down-sampling. Figure 6 does not suffer from the perspective distortion because book is placed perpendicular to the main scanning direction. However, Figure 7 suffers from the perspective distortion.

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Author Biography

Hyungsoo Ohk received his BS and MS degrees in electronics from Jungahng university, Seoul, Korea, in 2001 ,2003. Since then he has worked in the Advanced R&D lab2 at Digital Printing Division in Samsung Electronics. His Work has focused on the enhancement and compression of document image.