

# Fast Restoration of Warped Document Image based on Text Rectangle Area Segmentation

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**Abstract**—The warp problems usually make the documents being hardly recognized. Specifically, when we copy a page of a thick book or bound document by digital photocopier, the resulted image is usually warped because of the thickness of the document. We focus on this problem and propose a fast method to restore the warped document image in this paper. The text rectangle area of the document is one of the features of a document. The morphological operation is utilized for text rectangle area segmentation. The DLT method is used to compute the mapping relations between the warped document and the non-warped document. In experimental results, the proposed method works on high resolution image very quickly. The warping text and the figures in documents have been restored by the proposed method successfully. This method is efficiency and fast for implementing on the module of digital photocopier.

**Index Terms**—warped document; image process; DLT method; text rectangle area segmentation.

## I. INTRODUCTION

The first photocopier (or copier) is invented by Carlson (American) in 1938. The first commercial copier “Xerox 914” is developed by Xerox in 1959. The Xerox 914 can copy 7 documents per second. The photocopier can copy the large numbers of texts and images from documents to papers quickly. Even in this era of highly computerized, the photocopier is still commonly used in offices, schools, or libraries. The main process of photocopier are “charge”, “exposure”, “development”, “transfer” and “fusing”. In recent years, the traditional photocopier is replaced by the digital photocopier, gradually. The process of digital photocopier is almost the same with the traditional photocopier. The process of

digital photocopier just adds the “digitalization” after “exposure”. In other word, the Organic Photo-Conductor Drum (OPC Drum) of digital photocopier can capture the digital signals of documents.

When we copy a page of a thick book or a bound document, the resulted image is usually warped because of the thickness of the document. Therefore, our objective is to design a fast algorithm for restoring the warped document image for a digital photocopier. The method should be developed on embedded systems of digital photocopier. We hope that the copied documents are non-warped and the copy speed is unchanged.

The warp makes the text not only difficult to read but also being hardly recognized by Optical Character Recognition (OCR). Many researchers have been worked on the warp problem. We are interested in three major types of approach about them. The first type is the model based de-warping method. Such as [1], the plane transform model is established in advance for restoring the warping from camera captured image. Zhang and Tan [2][3] proposed the model of books from the shading and physical analysis. Brown and Brent [4] presented a framework for acquiring and restoring images of warped documents. The second type is segmentation based recovery method. This kind of methods are usually segmenting the characters and detecting the text lines. Based on the text lines, the documents can be restored. Gatos and Pratikakis [5] achieved binary image de-warping based on word rotation and translation according to upper and lower word baselines. Moreover, [6] [7] and [8] are using the similar approaches for warped document restoring. The last is the 3D acquisition method. Such as [9] and [10], a lot of control points are acquired for establishing the surface of document. However, this method is the slowest one of the three approaches.

For our applications, the 3D acquisition method is out of our consideration because of its time-consuming. The model based approach needs the parameters of digital

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photocopier or book. However, these parameters are not easy to obtain from photocopier manufacturing companies practically. Thus we will propose a fast method similar to segmentation based approach for warped documents restoring in this paper. However, a lot of computation is inevitable for detecting the characters and the base line of text. In contrast to former methods, the text area is much easier to segment by our method. The DLT algorithm is used to compute the mapping relations between the warped document and non-warped document. Therefore, the process could restore the document quickly and effectively.

Some cases of the warped document restored by the method will be shown in this paper. From the experimental results, it is demonstrated that the method can work for texts, equations and figures. Moreover, the computing time of high resolution document image is under 0.1 sec. In our survey, few literatures about this topic consider the computing time. Therefore, we strongly believe that the method could be realized in embedded system of digital photocopier.

II. WARPED DOCUMENT IMAGE RESTORATION METHOD

There are three parts in the process. The proposed method is shown in Figure 1. The major steps are image pre-processing, text rectangle area segmentation and document image restoration.

More details will be discussed in the following.

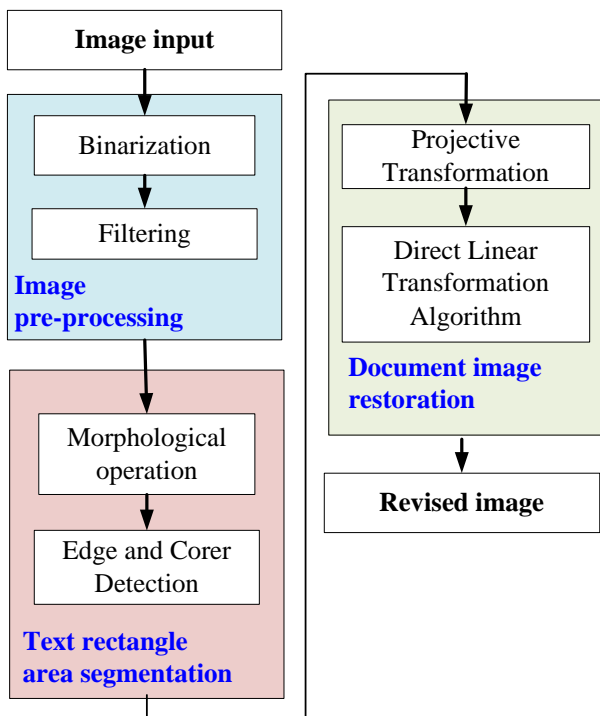


Figure 1. Warped document image restoration method.

A. Text Rectangle Area Segmentation

We found that the text areas in a general document are usually in rectangle. But the area will often be warped in the copied image. Three steps are proposed for segmenting the text rectangle area. In [11] and [12], some

useful image segmentation algorithms have been proposed. However, the processes of the methods are complicated for our application. Therefore, the fast algorithm, Niblack algorithm [13], is utilized for segmenting the document into binary image. Next, filtering and the morphology operation [14] are used for computing the text rectangle area.

1) Niblack Algorithm

The Niblack algorithm is the method for computing local threshold.

$$I(x, y) = m(x, y) \left[ 1 + k \left( 1 - \frac{\rho(x, y)}{L} \right) \right] \tag{1}$$

where  $m(x, y)$  is the mean of the area image,  $\rho(x, y)$  is the standard deviation.  $k$  and  $L$  are constants depending on practical applications. For the cases discussed in this paper,  $k = 0.25$  and  $L=136$ . Niblack algorithm can remove the shadow and salt-and-pepper noise preliminarily.

Figure 2 shows a result of Niblack algorithm. The shadow area in Figure 2(a) is almost removed in Figure 2(b) by Niblack algorithm. The resulting image is clear enough for the next process.

2) Text Rectangle Area Segmentation

In here, the dilation and erosion is utilized to determine the text area. Erosion and dilation are commonly used operations of morphological image processing. The related introductions are described in the following.

An image  $A$  eroded by a matrix  $B$ , denoted by  $A \odot B$ , is defined as:

$$A \odot B = \{A(i, j) | \min(A(i, j) \cap B(k, l))\} \tag{2}$$

where  $B$  is a square mask, and the size of erosion range depends on  $B$ . Similarly, an image  $A$  via dilation operation by a matrix  $B$  is denoted by  $A \oplus B$ . The relation is described as:

$$A \oplus B = \{x | (\hat{B})_x \cap A \neq \phi\} \tag{3}$$

where  $\phi$  is the empty set and  $x$  is a point on the image.

Figure 3(a) is the result from Figure 2(b) by inversion. Figure 3(b) is the result of 3 times erosion by a 13x13 mask. The text parts become some rectangular areas. Next, we dilated Figure 3(b) 4 times by a 16x16 mask. In Figure 3(c), 5 text areas are segmented.

3) Feature Points and Corresponding Control Points Detection

From Figure 3(c), the text areas are warped rectangles. The features of the text areas are the corners and edges. Harris corner detector [15] is used for detecting the corners. The corner points and the mapping of the corresponding control points are illustrated in figure 4. Figure 4(b) is the default page and control points. The areas in figure 4(b) are defined from text rectangle area of original image.

B. Document Image Restoration

The document image restoration is a 2D to 2D projective transformation. In this paper, direct linear transformation (DLT) algorithm is used for recovering the documents.

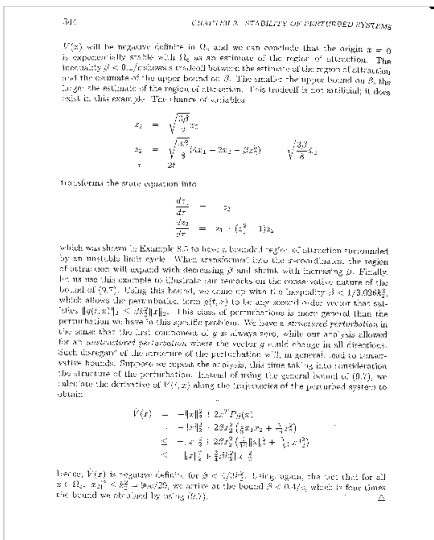
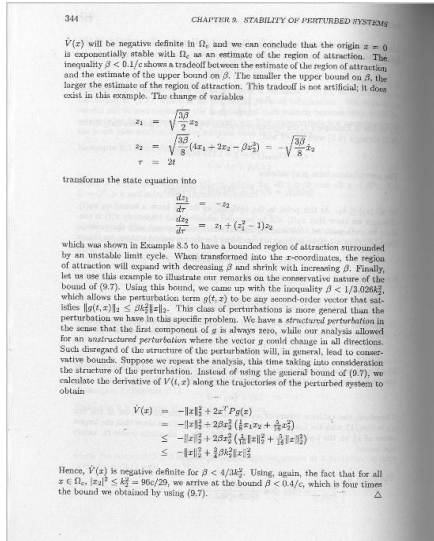


Figure 2. The binarization of document image. (a) Original image. (b) The result of Niblack algorithm.

1) Projective transformation

The projective transformation matrix [16] from the warped document to the original document can be given by

$$\begin{pmatrix} x'_1 \\ x'_2 \\ x'_3 \end{pmatrix} = \begin{pmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} \quad (4)$$

or  $X'=HX$ . Let the inhomogeneous coordinates  $X$  and in plane  $A$  and be  $(x, y)$  and  $(x', y')$ , respectively. The projective transformation of equation (4) will be written as

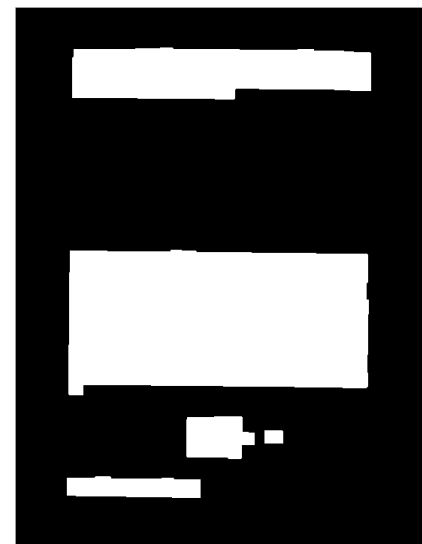
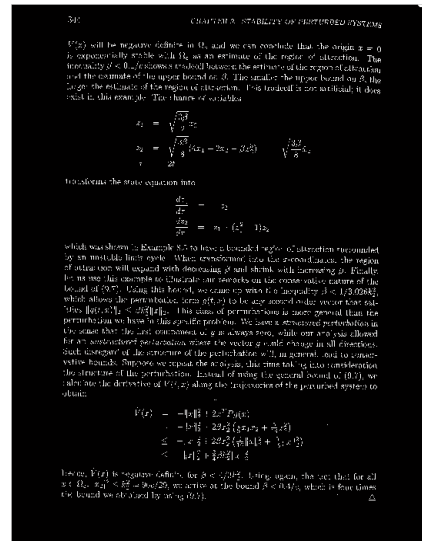


Figure 3. (a) The highlight of binarization document image. (b) The result of erosion operation. (c) The result of dilation operation.

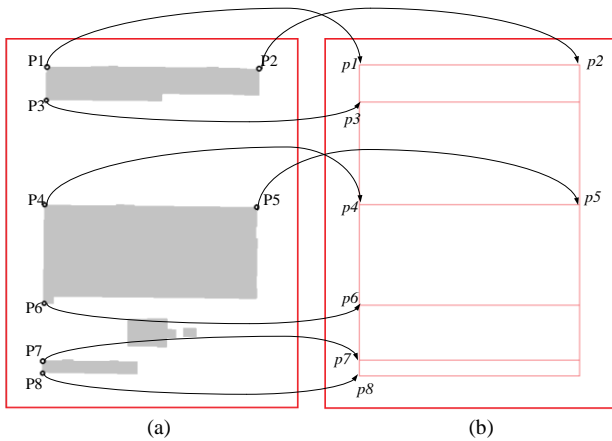


Figure 4. The control points mapping relation. (a) The feature points of text areas. (b) The default page and control points.

$$\begin{aligned} x' &= \frac{h_{11}x + h_{12}y + h_{13}}{h_{31}x + h_{32}y + h_{33}} \\ y' &= \frac{h_{21}x + h_{22}y + h_{23}}{h_{31}x + h_{32}y + h_{33}} \end{aligned} \quad (5)$$

Re-arrange equation (5) and we will have

$$\begin{aligned} h_{11}x + h_{12}y + h_{13} - x'h_{31} - x'h_{32}y - x'h_{33} &= 0 \\ h_{21}x + h_{22}y + h_{23} - y'h_{31} - y'h_{32}y - y'h_{33} &= 0 \end{aligned} \quad (6)$$

Equation (6) is an over-determined system, the DLT algorithm [14] is utilized for solving the system.

2) Direct Linear Transformation Algorithm

Rewrite equation (6), the linear system can be expressed in matrix form:

$$\hat{A}\hat{H} = \hat{x} \quad (7)$$

where  $\hat{x} = [x'_1 \ y'_1 \ x'_2 \ y'_2 \ \dots \ x'_i \ y'_i]^T$ ,

$\hat{H} = [h_{11} \ h_{12} \ \dots \ h_{33}]^T$ , and

$$\mathbf{A} = \begin{bmatrix} x_1 & y_1 & 1 & 0 & 0 & 0 & -x'_1x_1 & -x'_1y_1 & -x'_1 \\ 0 & 0 & 0 & x_1 & y_1 & 1 & -y'_1x_1 & -y'_1y_1 & -y'_1 \\ x_2 & y_2 & 1 & 0 & 0 & 0 & -x'_2x_2 & -x'_2y_2 & -x'_2 \\ 0 & 0 & 0 & x_2 & y_2 & 1 & -y'_2x_2 & -y'_2y_2 & -y'_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_i & y_i & 1 & 0 & 0 & 0 & -x'_ix_i & -x'_iy_i & -x'_i \\ 0 & 0 & 0 & x_i & y_i & 1 & -y'_ix_i & -y'_iy_i & -y'_i \end{bmatrix} \quad (8)$$

The algorithm is illustrated as follows:

- STEP 1 For each corresponding point, compute the matrix  $\mathbf{A}$ . ( $i \geq 4$ )
- STEP 2 Obtain the SVD (Singular value decomposition) of  $\mathbf{A}$ .
- STEP 3 If  $\mathbf{A} = \mathbf{U}\mathbf{D}\mathbf{V}^T$ . The last column of vector  $\mathbf{V}$  corresponding to the smallest singular value of  $\mathbf{A}$  are the elements of the vector  $H$ .

III. EXPERIMENTAL RESULTS AND ANALYSIS

In this section, we demonstrated the warped document image restoration by our method. The sizes of the left and right page images are both 2550x1755 pixels. They are large image files. The test images are scanned from a 750-page book. The thickness of the book will cause the warp in copying or scanning.

Figure 5(a) is the left (odd-numbered) page image. Figure 5(b) is the de-warped result by the proposed method. Figure 6(a) is the right (even-numbered) page image. The image is warped seriously. This image has rotation and warping. Moreover, there are not only texts but also figures in this image. In Figure 6(b), the text and figures in the image are restored successfully by our method.

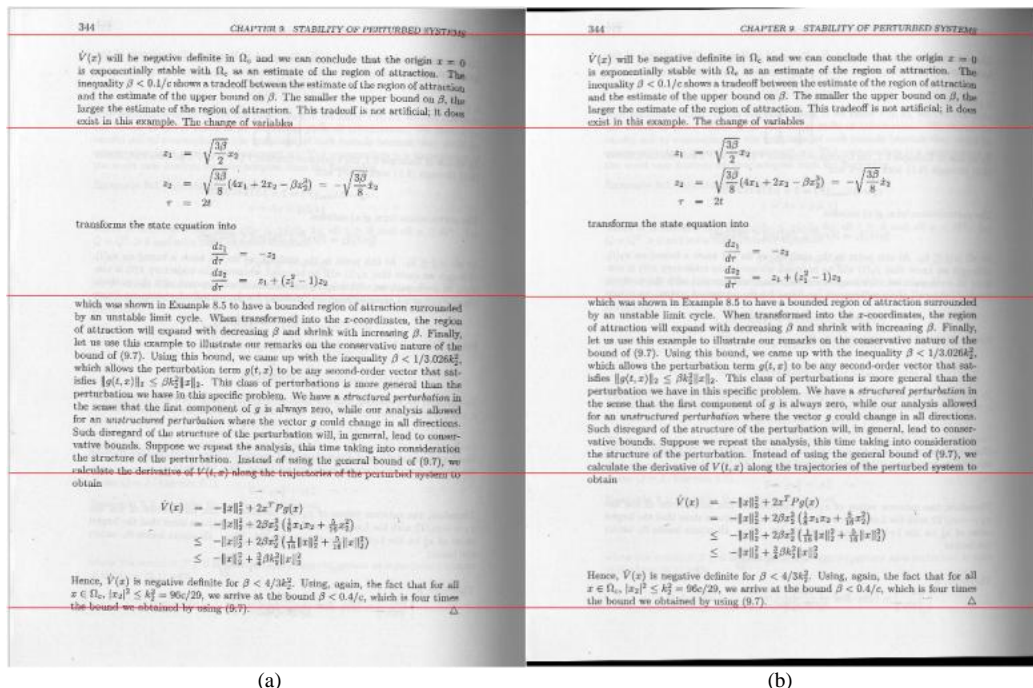


Figure 5. Case 1: Left page document image restoration. (a) Original image. (b) The result of the restoration.

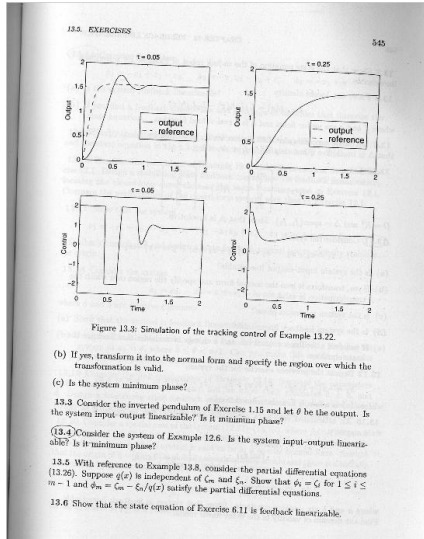


Figure 13.3: Simulation of the tracking control of Example 13.22.

(b) If yes, transform it into the normal form and specify the region over which the transformation is valid.  
 (c) Is the system minimum phase?  
 13.3 Consider the inverted pendulum of Exercise 1.15 and let  $\theta$  be the output. Is the system input-output linearizable? Is it minimum phase?  
 (13.4) Consider the system of Example 12.6. Is the system input-output linearizable? Is it minimum phase?  
 13.5 With reference to Example 13.3, consider the partial differential equations (13.26). Suppose  $g(x)$  is independent of  $c_1$  and  $c_2$ . Show that  $\phi_1 = G$  for  $1 \leq i \leq m-1$  and  $\phi_m = c_m - \xi_m/g(x)$  satisfy the partial differential equations.  
 13.6 Show that the state equation of Exercise 6.11 is feedback linearizable.

(a)

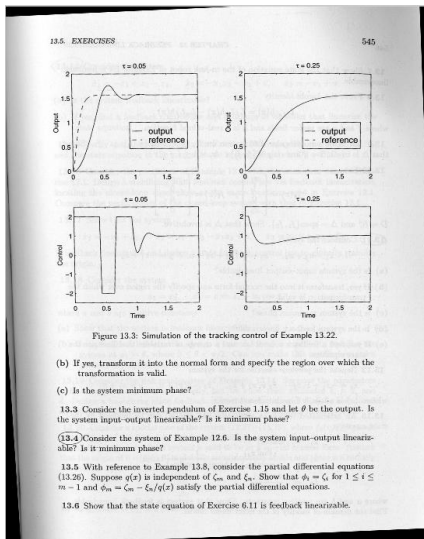


Figure 13.3: Simulation of the tracking control of Example 13.22.

(b) If yes, transform it into the normal form and specify the region over which the transformation is valid.  
 (c) Is the system minimum phase?  
 13.3 Consider the inverted pendulum of Exercise 1.15 and let  $\theta$  be the output. Is the system input-output linearizable? Is it minimum phase?  
 (13.4) Consider the system of Example 12.6. Is the system input-output linearizable? Is it minimum phase?  
 13.5 With reference to Example 13.3, consider the partial differential equations (13.26). Suppose  $g(x)$  is independent of  $c_1$  and  $c_2$ . Show that  $\phi_1 = G$  for  $1 \leq i \leq m-1$  and  $\phi_m = c_m - \xi_m/g(x)$  satisfy the partial differential equations.  
 13.6 Show that the state equation of Exercise 6.11 is feedback linearizable.

(b)

Figure 6. Case 2: Right page document image restoration. (a) Original image. (b) The result of the restoration.

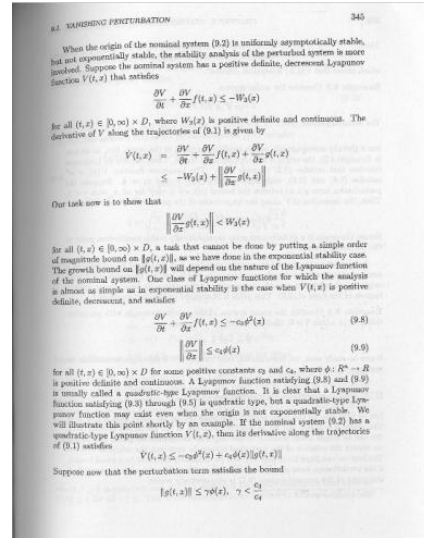
The last case is shown in Figure 7. This is a common situation when we copying or scanning a thick books. Figure 7(a) is also the right page image. The warp in upper right corner is severer than other parts of the document. By our method, the text area in the image is restored. The computation time of case 1, case 2, and case 3 are 0.0863 sec, 0.0926 sec and 0.0736 sec, respectively.

IV. CONCLUSION

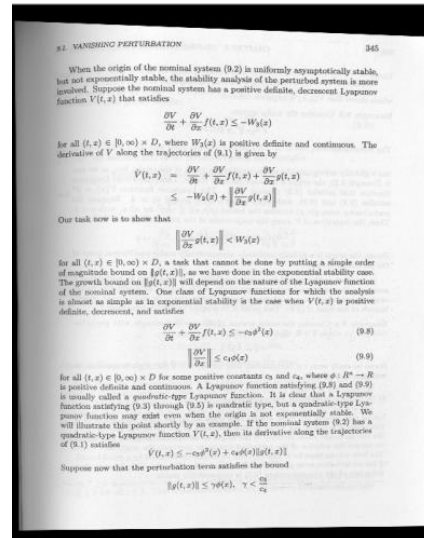
In this paper, the text rectangle area segmentation and direct linear transformation (DLT) algorithm are used for restoring the warped document image. The complex text areas are segmented by expansion and erosion. The simple rectangles and corners are used for computing the mapping relation between the warped document and non-warped document by DLT algorithm. In the experimental results, three high resolution images are restored quickly and successfully. Not only the warped text but also the figures in documents can be restored by the proposed method. This method is easy to implement on the

embedded systems of digital copier.

In some case, such as figure 7, the restored text area has a little trapezoidal deformation. That needs further works to improve it in the future.



(a)



(b)

Figure 7. Case 3: Another right page document image restoration. (a) Original image. (b) The result of the restoration.

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