Label Restoration Using Biquadratic Transformation

Huy Phat Le , Toan Dinh Nguyen, GueeSang Lee
Department of Electronics and Computer Engineering
Chonnam National University, Gwangju, 500-757, Korea

ABSTRACT

Recently, there has been research to use portable digital camera to recognize objects in natural scene images, including labels or marks on a cylindrical surface. In many cases, text or logo in a label can be distorted by a structural movement of the object on which the label resides. Since the distortion in the label can degrade the performance of object recognition, the label should be rectified or restored from deformations. In this paper, a new method for label detection and restoration in digital images is presented. In the detection phase, the Hough transform is employed to detect two vertical boundaries of the label, and a horizontal edge profile is analyzed to detect upper-side and lower-side boundaries of the label. Then, the biquadratic transformation is used to restore the rectangular shape of the label. The proposed algorithm performs restoration of 3D objects in a 2D space, and it requires neither an auxiliary hardware such as 3D camera to construct 3D models nor a multi-camera to capture objects in different views. Experimental results demonstrate the effectiveness of the proposed method.

***Keywords**: label restoration, biquadratic transformation, Hough transform*

1. INTRODUCTION

In data acquisition phase of an intelligent system, image shape distortion is regularly produced. It makes some difficulties to generate the input data for an intelligent system. It has a great variety of forms according to the specific acquisition system.

Image distortion, especially non-linear distortion, is one of above forms. An obvious example of nonlinear distortion can be found in a photograph taken by a camera at an oblique angle. If the angle between the plane which contains the object to be acquired and direction of camera is perpendicular, a standard digitized image is produced as shown in Fig. 1 (b). Since this condition is not always guaranteed, nonlinear distortion is caused as illustrated in Fig. 1 (c).

In our application, which is depicted in Fig. 2, users use a portable camera to capture a rectangular label wrapped around a cylindrical object. When the camera's optical axis is not perpendicular to the label plane, the label image is distorted. The general shape of this distorted image contains four boundary segments: two vertical boundaries, one upper-side boundary and one lower-side boundary. Due to the distortion of the label image, the objects residing inside such as text, company logo are deformed accordingly. For this reason, it is important to restore the distorted label to the original one in order to the recognition module can recognize objects correctly.

There are two basic phases to deal with the restoration problem. They are the identifying types of the restoration and restoration method. In the first phase, there have been several researches for the restoration related-problem. In [1], the text content resides on a rectangular board. So, instead of restoring text directly, the authors find the bounding box of rectangular board and then apply a restoration method for that bounding box. In the end, the text inside the rectangular board is also restored accordingly. In [2], the type of the restoration is classified into two main classifiers. The first one is horizontal slant which can be restored by a rotation method. The last classifier is the vertical slant which can be restored by a shearing method.

In the restoration method, many researchers have progressively been working on this area. Image shape restoration based on shape transformation is a successful approach to nonlinear distortions. Some significant studies on it can be found in references [3-7]. A key problem of the image shape restoration based on shape transformation is to find an appropriate mathematical formula, known as shape transformation, to model the distortion function. However, it needs a priori knowledge of the distortion function already applied to original images. Unfortunately, the distortion function is often unknown or unclear. Even in the case of that when the function is known, it remains difficult to compute or estimate the parameters necessary for the restoration. Consequently, we should consider a more practical situation where we will manage distorted images directly without any knowledge of the distortion function.

In this paper, we propose an algorithm to detect and restore the distorted label. The proposed algorithm has two major steps. First, the Hough transform is applied to detect two vertical boundaries. The upper-side and lower-side boundaries are then detected by analyzing the edge profile. Secondly, based on the

* Corresponding author. E-mail : gslee@jnu.ac.kr
Manuscript received Sep. 01, 2009 ; accepted Feb. 17, 2010

detected boundaries of the label in the previous step, reference points that are used as input parameters of the biquadratic algorithm are extracted. The experimental results attained in test images show the effectiveness of our algorithm.

The remainder of this paper is organized as follows. In section 2, we will explain the method to detect two vertical boundaries of the label. In section 3, the upper-side and lower-side boundaries detection is presented. The restoration method is discussed in section 4. Experimental results are illustrated and discussed in section 5. Finally, some our concluding remarks are given in section 6.

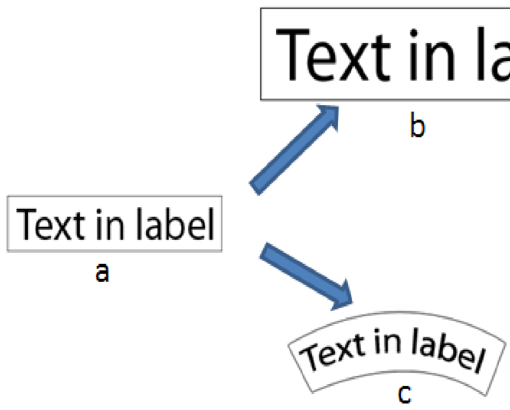


Fig. 1.a) original shape, b) up-scaling transformation – linear, c)Biquadratic transformation – none linear.

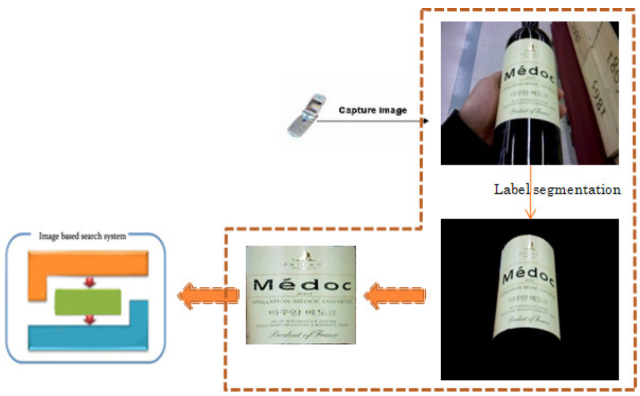


Fig. 2. Image based search system.

2. VERTICAL BOUNDARIES DETECTION

In our application, the rectangular label is wrapped around the cylindrical object. The obtained label in a 2D image includes two vertical boundaries that are straight lines. In this section, the method of detecting interest region of the label which is between the two vertical lines is presented.

2.1 The Hough Transform

The Hough transform (HT) is an approach for detecting straight lines in an image. In [8], the author explored the fact that any line in the *xy* plane, shown in Fig. 3, could be represented by the following equation.

$$\rho = x\cos\theta + y\sin\theta, \quad (1)$$

where ρ is the normal distance and θ is the normal angle of a straight line. Applying Hough transform for each point will produce a sinusoidal curve in the ρ-θ space, namely parameter space shown in Fig. 4. In the parameter space, curves of points lying on a same straight line will intersect at one point which presents the normal distance and normal angle in the *xy* plane and has the highest energy in parameter space.

2.2 Straight Line Detection in the Image

In our application, the HT method is used to detect two vertical boundaries that are almost parallel together in geometric relation. The overall of detecting two vertical boundaries of a bottle label is shown in Fig. 5. First, the binarized edge map shown in Fig. 5 (b) is achieved by applying the vertical Sobel operator C.10 [9] to the original image in Fig. 5 (a) for detecting vertical edges. HT is used to convert all pixels of edges to the Hough space. In the HT space, some peak points that have very high energy compared to that of other points will be identified as in Fig. 5 (c). Straight lines with ρ and θ parameters that are calculated from corresponding peak points are shown in Fig.5 (d). Detected lines contain not only two vertical boundaries of the label but also other edges due to the complex background and light reflection. Thus, redundant lines must be removed. First, we remove the middle-lines, redundant lines in the middle of label generated due to the light reflection, by using the difference among intensity values of points lying on their two opposite sides. Whereas the intensity values of pixels on the two opposite sides of a middle-line are almost similar, those of other lines are much different. For this reason, those lines having small differences between two sides are removed. In the next section, the method of removing straight lines in non-interest region is explained.

2.3 Detection of Vertical Lines

Denote M as a centre point of the picture. We can categorize remaining lines into two groups. The left group and the right group contain all lines on the left and right of M, respectively. For example, in Fig. 6, the d_2 and d_3 are on the right of centre point M, whereas the d_1 is on the left.

For lines categorized in the left group, the line whose distance to M is the least is assumed as the left vertical boundary of the label. Similarly, the right vertical boundary of label is selected as a line of right group that has the least distance to M.

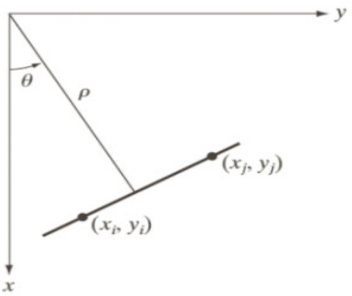


Fig. 3. Representation of straight line by ρ and θ parameters.

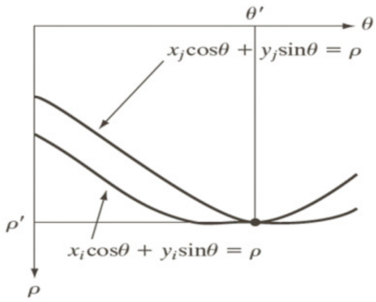
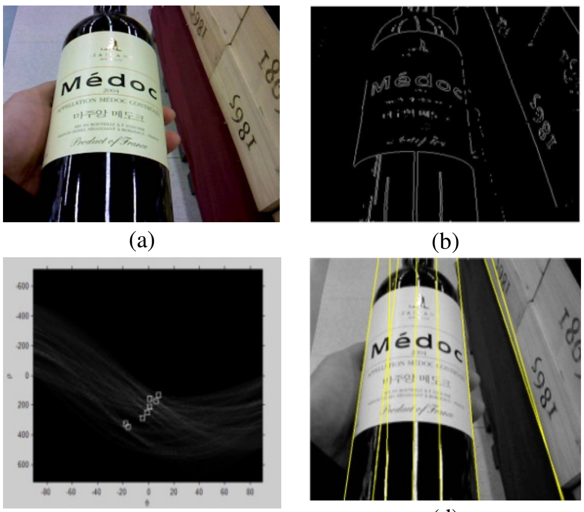


Fig.4. The result of applying Hough Transform for (x_i, y_i) and (x_j, y_j) points.



(a) (b) (c) (d)

Fig.5.
a) The original image,
b)edge map of a, c)Hough space of b, d) line detected based on c.

Fig.6. The distance from centre point to each straight line.

3. UPPER-SIDE AND LOWER-SIDE BOUNDARIES DETECTION

To detect the upper-side and lower-side boundaries, first, the horizontal Sobel operator is employed to get horizontal edge information. Then, we analyse the edge profile to gain information of upper-side and lower-side boundaries.

3.1 Edge Profile Extraction

The colour image of the interest region is converted to a 256-level grayscale image as in Fig.7 (a). We perform some pre-processing steps to enhance the upper-side and lower-side boundaries. The grayscale image is applied 3 by 3 median filter to blur the background before generating edge image shown in Fig.7 (b). This step will blur the texts and small objects in the interest region whereas the edges of the upper-side and lower-side curves are still remained.

Since the upper-side and lower-side boundaries are usually aligned in horizontal direction, we will calculate the horizontal edge profile in the edge image to detect them. Before calculating the horizontal edge profile, we convert the grayscale image to edge image with Sobel horizontal edge-emphasizing method with convolution matrix of

$$\begin{vmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{vmatrix}$$

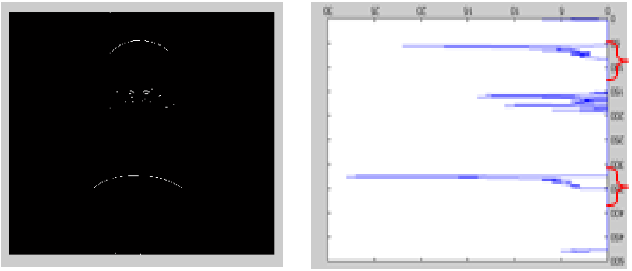
The Fig. 8 (a) shows the edge map when the Sobel horizontal edge-emphasizing method is applied on the image in Fig. 7 (b). And the Fig. 8 (b) illustrates the horizontal edge profile of the image in Fig. 8 (a). Each value of the profile is the total number of pixels of corresponding row of the edge image.

3.2 Upper-side and Lower-side Boundaries Extraction

We extracted the upper-side and lower-side boundaries based on the edge profile extracted in the previous section. As mentioned before, the curves are usually aligned in horizontal direction. Therefore, after applying Sobel operator, almost pixels belonging to a curve will be detected as an edge. And in Fig. 8 (b), they will form a range which is non-zero value in the horizontal direction. Furthermore, almost white pixels come from the curves. For this reason, the two highest values in horizontal direction of Fig. 8 (b) belong to two ranges of upper-side and lower-side curves as shown in Fig. 9.

a) b)

Fig.7. a)The interest region of label, b)the blured version of a.



a b

Fig.8
a) Edge map of Fig. 7(b)
b) histogram of a.

3.3 Upper-side and Lower-side Boundaries Approximation

Bezier curve is a basic one for any curve representation. B-spline curve is a generalization of the Bezier curve. In our algorithm, we used B-spline of degree 2 to define a curve.

For curve pixels detected in section 3.2, we will use B-spline representation method to approximate the curves of upper-side and lower-side boundaries, named C_1, C_2 repectively. Fig. 9 shows the result of the two curves.

Until this stage, four boundaries segments are successfully detected. Those information will be used to represent the shape of distorted label before applying biquadratic method to do restoration. In restoration phase, the most difficult work is to indentify reference points of the distorted image. The more exactly reference points are indentified, the more accurate the result is. Next section will explain this step in more details.

4. LABEL RESTORATION

Shape distortion always happens in the data acquisition phase. Shape distortion can be divided into two categories: linear and nonlinear. Linear shape distortion such as rotation, scaling, translation and reflection has been successfully solved in [10]. But correction of nonlinear shape distortions remains as the most challenging topic [11]. Many distortion models have been reported such as bilinear, biquadratic and bicubic transformation models [7]. In this paper, biquadratic transformation model is used to restore distorted label image.

4.1 Nonlinear Transformation

In nonlinear distortion, several approaches have been given. Image shape restoration based on shape transformation is a successful approach to nonlinear distortion. Some studies regarding to it can be found in [4,11]. The main idea of them can be described as follows.

- First, the nonlinear distortion image is modelled by a shape transformation function. This shape function is used to transform the original image to distorted one.
- Finally, for every shape transformation, they will find a corresponding inverse function which is used to transform back to the original image.

To solve the shape function, presented by a mathematical formula, we need to know the original shape and some corresponding points between the original image and distorted image. In our application, we assume that the original shape is a rectangle.

Fig.9. An example of B-spline curve representation.

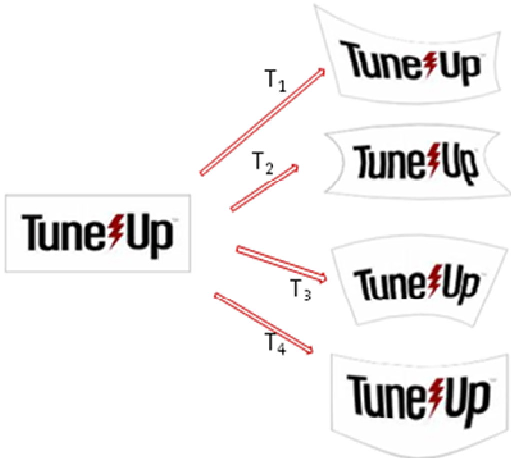


Fig.10. Patterns of Biquadratic transformation.

4.2 Biquadratic Transformation

Biquadratic transformation is one kind of nonlinear transformation [8]. The Fig. 10 shows show some patterns of distorted images from a rectangular shape. With different parameters of the shape function we will have different results of distortion. If T_2 and T_3 are applied to the original image, upper-side of the rectangle is bended up. Otherwise, upper-side is bended down if T_1 and T_4 shape functions are used.

The shape function of the biquadratic transformation is described as following equation.

$$\begin{bmatrix} X \\ Y \end{bmatrix} = \begin{bmatrix} X_{P_1} & Y_{P_1} \\ X_{P_2} & Y_{P_2} \\ X_{P_3} & Y_{P_3} \\ X_{P_4} & Y_{P_4} \\ X_{P_{12}} & Y_{P_{12}} \\ X_{P_{23}} & Y_{P_{23}} \\ X_{P_{34}} & Y_{P_{34}} \\ X_{P_{41}} & Y_{P_{41}} \end{bmatrix}^T \begin{bmatrix} (1-\xi)(1-\eta)(1-2\xi-2\eta) \\ \xi(1-\eta)(2\xi-2\eta-1) \\ \xi\eta(2\xi+2\eta-3) \\ \eta(1-\xi)(2\eta-2\xi-1) \\ 4\xi(1-\xi)(1-\eta) \\ 4\xi\eta(1-\eta) \\ 4\xi\eta(1-\xi) \\ 4\eta(1-\xi)(1-\eta) \end{bmatrix} \quad (3)$$

where (ξ, η) is coordinate representing the normalized image. (X, Y) is coordinate representing the distorted image. P_1, P_2, P_3, and P_4 are four vertices of the rectangle in a distorted image. P_{12} is midpoint of line between P_1 and P_2. Similarly, midpoints P_{23}, P_{34}, P_{41} correspond to lines P_2P_3, P_3P_4, P_4P_1. The Fig. 11 shows the correspondence in shape between the original image and distorted one.

Based on the above formula, the condition to apply biquadratic transformation is that eight reference points of the distorted image must be identified. We will show how to get those reference points in next section.

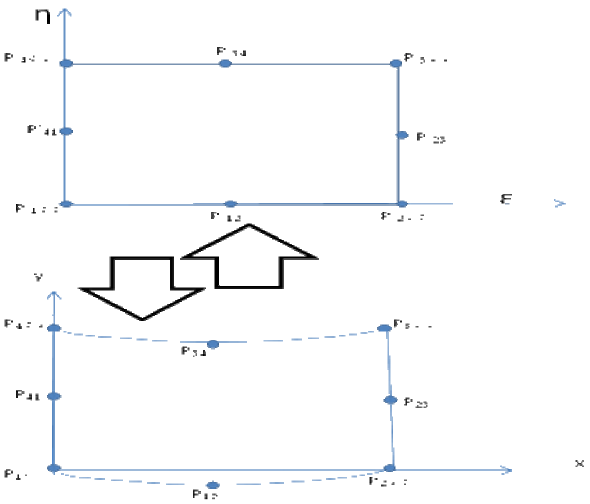


Fig.11. the reference points in distorted model and original model.

4.3 Choosing Reference Points in Distorted Label Images

Before applying biquadratic algorithm [8], we need to know the eight reference points P_1, P_2, P_3, P_4, P_{12}, P_{23}, P_{34}, and P_{41} in the distorted image. In section 3, we already got the upper-side and lower-side curves information. For the lower curve, we assign the most left pixel as P_1 and the most right pixel as P_2. Denote P(x) is a value of point P in x direction and P(y) is value of point P in y direction. $P_{12}(x)$ is calculated by averaging value of $P_1(x)$ and $P_2(x)$. And $P_{12}(y)$ is got from B-spline lower-side curve C_2 in section 3.3. Similarly, as for the upper-side curve, we will assign the most left pixel as P_4 and the most right pixel as P_3. The way of calculating P_{34} based on B-spline upper-side curve C_1 is similar with the way of calculating P_{12} based on C_2. P_{23} is midpoint of P_2P_3 and P_{41} is midpoint of P_4P_1. By this procedure, we can identify eight reference points in the distorted image.

5. EXPERIMENTAL RESULTS

Our database that contains many images captured by camera under various conditions is used to evaluate the proposed algorithm. The experimental results in Fig. 12 show that the proposed algorithm can successfully restore distorted labels.

a b

Fig.12.
a) original images, b)restoration images

6. CONCLUSIONS

In this paper, we propose an effective algorithm for restoring labels containing text and objects in non-linear distorted images. The Hough transform is applied to detect two vertical boundaries of the bottle label image. Then, upper-side and lower-side boundaries of the label are detected by analyzing horizontal edge profile. Finally, biquadratic transformation algorithm is employed to restore the distorted image to the original one. The experimental results shows that we can achieve good images from distorted ones by our method.

ACKNOWLEDGEMENT

This research was supported by the MKE(The Ministry of Knowledge Economy), Korea, under the ITRC(Information Technology Research Center) support program supervised by the NIPA(National IT Industry Promotion Agency) (NIPA-2010-C1090-1011-0008)

REFERENCES

[1] Qixiang Ye, Jianbin Jiao, Jun Huang, Hua Yu, "Text detection and restoration in natural scene images", *Journal of Visual Communication and Image Representation, vol.18, no.6*, Dec. 2007, pp.504-513.

[2] Wu Guo-Ping, Ao Min-Si, Cheng Shi, Lei Hui, "Slant correction of Vehicle License Plate Image", *International Conference of Image Analysis and Processing*, 2005, pp.919-922.

[3] Q. L Gu, C. Y. Suen, T. D. Bui and Z. C. Li, "Mathematical methods for font generation and shape design of characters", *Proc. Int. Conf. Comput. Process. Chinese Oriental Languages*, 1991, pp. 1-14.

[4] Z. C. Li, T. D. Bui, C. Y. Suen, Y. Y. Tang and Q. L. Gu, "Splitting-integrating method for normalizing images by inverse transformations", *IEEE Trans. Pattern Anal. Mach. Intell. vol.16, no.6* , 1992, pp. 678-686 .

[5] Z.C. Li, Q. L. Gu, C. Y. Suen and T. D. Bui, "A comparative study of nonlinear shape models for digital processing and pattern recognition, *IEEE Trans. Syst. Man. Cybernet. vol.20, no.4,* 1990, pp. 858-871 .

[6] Y.Y. Tang, Z. C. Li, C. Y. Suen and T. D. Bui, "Conversion of Chinese characters by transformation models", *Proc. Int. Conf. Comput. Process. Chinese Oriental Languages*, 1988, pp. 293-297.

[7] Y. Y. Tang and C. Y. Suen, "Nonlinear shape restoration by transformation models", *Int. Conf. Pattern Recognition*, 1990, pp. 14-19.

[8] R. Duda and P. Hart. "Use of the Hough transform to detect lines and curves in pictures", *Communications of the ACM*, Jan. 1972, pp.11-15

[9] Rafael C. Gonzalez Richard E. Woods. *Digital Image Processing, Pearson, New Jersey*, 2010

[10] James D. Foley et. al, *Computer Graphics Principles and Practices in C, 2nd Edition , Addison Wesley*, 1997

[11] Y.Y. Tang and C.Y. Suen, "Image transformation approach to nonlinear shape restoration", *IEEE Trans. Syst. Man Cybernet. Vol.23, no.1*, 1993, pp. 155–172.

Huy Phat Le
He received the B.S degree in Information Technology from University of Science, Ho Chi Minh City, Vietnam in 2006. He is currently a MS student in Computer Science department of Chonnam National University, Korea. His interesting researches are Image processing, especially document analysis, and computer vision.

Toan Dinh Nguyen
He received the B.S. degree in Information Technology from Vietnam National University – Ho Chi Minh City, University of Natural Sciences and the M.S. degree in Computer Science from Chonnam National University, Korea in September 2005 and February 2008, respectively. Currently, he is pursuing Ph.D. degree in Computer Science at Chonnam National University, Korea. His main research interests include H.264 video standard, distributed video coding (DVC), text image processing, tensor voting, and mobile applications.

Gueesang Lee
He received the B.S. degree in Electrical Engineering and the M.S. degree in Computer Engineering from Seoul National University, Korea in 1980 and 1982, respectively. He received the Ph.D. degree in Computer Science from Pennsylvania State University in 1991. He is currently a professor of the Department of Electronics and Computer Engineering in Chonnam National University, Korea. His research interests are mainly in the field of image processing, computer vision and video technology.