

A 2D Barcode Inspection Using Template Matching

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Abstract—In this paper we demonstrate the use template matching in printed 2D barcode inspection. The inspected area is focused to the finder pattern of the data matrix code since the pattern does not depend on the information carried by the barcode. There are 4 templates used in the matching process. The resulted lowest score obtained from these 4 matching case, is collected for decision making. We found that this technique work well in most condition that the smudge does not appear in the data cell.

Keywords- 2D Barcode; Normalized Cross-correlation (NCC); Template Matching.

I. INTRODUCTION

The wildly used data matrix 2D barcode is sometime suffering from its printing quality. Poor printing qualities can fail the barcode reading procedure according to the incomplete information conveyed. In most practical case smudge occurs. Therefore the imperfectness of the barcode can be the crucial cause of the product reworking. Eye observing inspection is very time consuming, task. It also needs operator experiences. Of long working hours, human can be tired and the productivity declines. Toward this argument, machine inspection is desirable. There are several possible ways to do inspection. However according to flexibility and cost effectiveness, cheap webcam and a PC-based software seem to be a solution. A classical template matching technique can be efficiently employed for barcode printing quality inspection.

Template matching is the process of finding the location of a source image, called a template, inside an input image or source image. Once a number of corresponding pattern are found, their corresponding scores can be recorded. The basic template matching algorithm consists in calculating at each position of the image under examination the degree of similarity between the template and the image. Then, the minimum distortion, or maximum correlation, position is taken to locate the template into the examined image. However, as far as template matching is concerned, Normalized Cross Correlation (NCC) is often the adopted for similarity measure due to its better robustness [1, 2, 3].

In this paper we propose a series of sequence for printed barcode quality inspection where a template matching technique is employed. The rest of this paper is organized as follows. A data matrix 2D barcode is given in brief in section II. The template matching is shortly reviewed in section III. In section IV we elaborate the application of template matching

for barcode inspection. In section V, we show the experiment results where classification (grouping), effect of source rotation, and a case of imperfectness that the algorithm fails, are considered. Finally the paper is concluded in section VI.

II. MATRIX BARCODE

A. 2D Barcode

2D barcode is the development over 1D barcode. It contains information that referred to in both vertical and horizontal direction. Allows information contained approximately 4,000 characters or approximately 200 times, compared to the 1D barcode. Most products of industries begin with detecting 2D barcodes attached to them, storing data, then comparing these to database and categorizing these products for tracing and/or packaging. The previous processes mentioned above show some errors caused by image capture factors such as orientation and distance inconsistency of the objects. However in many cases, the imperfection of the images is also introduced by the low clarity and/or the poor quality of the barcode itself.

The aim of the 2D barcode development was to provide that can perform ultra-fast reading, handling not only stationary objects but also moving targets on a conveyor belt for industrial usage. 2D barcode symbol is used for detecting a moving target such as luggage on the conveyor belt. A bigger and more distinctive finder pattern should be required to be robustly detected and tracked. On the other hand, a smaller and less distinctive finder pattern may be sufficient for 2D barcode whose position is known or can be easily assumed. That is, the application where a 2D-barcode is used is an important determinant of the properties of its finder pattern [4, 5].

B. Data Matrix 2-D Barcode

Data Matrix Barcode was introduced by RVSI Acuity ciMatrix company, USA in 1989. It meets ISO/IEC 16022 and ANSI/AIM BC11-ISS-DATA Matrix standard. The shape of this barcode appears in both rectangle and square. This type of barcode has the maximum storage capacity of 3,116 numeric data or 2,355 characters. These capacities are varied by types of database, for example, 1,556 bytes for binary numbers and 778 for Japanese characters. The Data Matrix comprises two parts. The data cell is surrounded by a specific pattern called finder pattern. The data matrix barcode is often required for a very limited area on an object and a small barcode is needed [6].



Figure 1. Data matrix barcode structure example:
(a),(d) Finder pattern (b) Whole barcode, and (c) Data cell

III. TEMPLATE MATCHING USING NORMALIZED CROSS CORRELATION (NCC)

Correlation is a statistical technique which can show how strongly pairs of variables are related. Correlation coefficients range from -1.0 to +1.0. The closer range of +1, the more closely one variable is related to the other. The correlation between two signals (cross-correlation) is a standard approach to find out how the two signals are related. It has shown its good applications in pattern recognition and cryptanalysis. Other than template matching and image registration, normalized cross correlation (NCC) has also been used extensively in machine vision for industrial inspection including defect detection in complicated images.

Let image s be a source image and we want to seek any similarity of image f which is considered as a template image. A simple method for measuring similarity or mismatch measure is by taking the absolute difference between template image f and given source image s over a specific region [7].

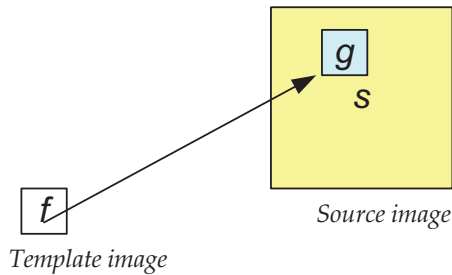


Figure 2. Template matching, $f \ll s$

The maximum value of absolute difference will give the similarity measure. Generally f is very small compared to source image s . If we take the sum of difference square between template f and given image g over a region A , then for an image having 2 dimensions we can get

$$\sum_{i,j \in A} (f(i,j) - s(i,j))^2 \quad (1)$$

The above equation (1) can be expanded to,

$$\iint_A (f-s)^2 = \iint_A f^2 + \iint_A s^2 - \iint_A 2fs \quad (2)$$

For given template the term $\iint_A f^2$ is fixed and for given image the term $\iint_A s^2$ is also fixed. The term $\iint_A (f-s)^2$ will give the degree of mismatch. If this both terms are constant

then remaining term $\iint_A (2fs)$ is a measure of similarity between template f and image s [1, 2, 3].

The above equation gives the normalized cross correlation. The maximum value of above ratio will give the measure of similarity in the given image s . The Normalized Cross-covariance is the linear correlation coefficient of statistics and is equivalent to the normalized cross correlation of the zero means equivalents of f and s [8, 9]. It is given by

$$C(f,s) = \frac{n \sum fs - \sum f \sum s}{\sqrt{(n \sum f^2 - (\sum f)^2)(n \sum g^2 - (\sum g)^2)}} \quad (3)$$

Where

- n = number of pixels in the template
- f = Template image
- g = Image part (in the source image) under the template
- s = Source image

The procedure for template matching is summarized here:

- i) Load the source image and template image.
- ii) The image on all the sides with zeros so that the center of the template falls on the very first pixel of the main image when kept on the top-left corner as shown in Fig. 3
- iii) Calculate the size of the template image.
- iv) Image rows of zeros on the top and bottom of main image. The number of rows is equal to the size of template in y-direction.
- v) Image columns of zeros on the left and right side of the above image with number of columns equal to the size of template in z-direction and the length of columns being main image size in y-direction plus size of template in y-direction.
- vi) Move the mask over the entire image and simultaneously calculate the values of summation of template padded image under the template and store it in an array.
- vii) Also calculate the values of image under the templates and sum all the values. Take of the obtained value and store it in an array.
- viii) Find the position where the maximum value in the above result falls. The coordinates so obtained will give the best match of the template and calculate maximum cross correlation coefficient.
- ix) Inspect the template from the source image using the above obtained co-ordinates and the size of template.

IV. 2D BARCODE INSPECTION VIA TEMPLATE MATCHING

A template matching technique described in the above section is employed for inspection of printing quality of a 2D barcode. In most cases, the low quality barcode are generated with smudge or incomplete black portion, especially in the area

of finder pattern. In rare case those imperfectness can be found in the barcode cell only. The barcode cell pattern is varied with the information it carries while the finder pattern are fixed pattern as demonstrated in Fig. 1 a) and d). Of its fixed pattern, we hence can make use of the pattern quality for a whole printing quality inspection.

In our experiment, the barcode adhered to a piece of product fed on a conveyor is captured. The pre-determined ROI captured images are at the size of 640×480 pixels. This is the source image. As an example it is shown in Figure 3 below. The barcode area is 400×400 pixels. The information pallet is 20×20 pixels. With such knowing barcode size we can design the templates correspondingly. There are 4 templates. Each is for each side of the barcode; top, right, bottom, and left. The dimension of a template is basically pixel unit. However, we did extend the white area with the width of 5 pixels to ease the matching process. This is helpful for the pattern to be matched precisely. Detailed designs of the templates are shown in Figure 4 below.

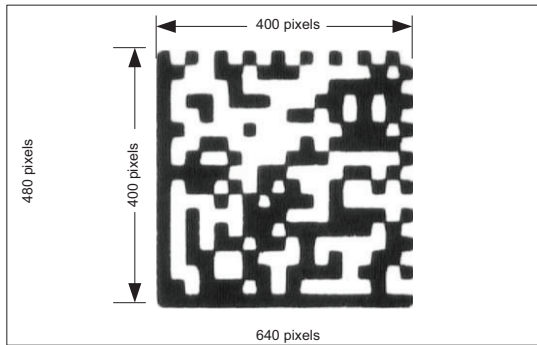


Figure 3. Source image of a Data matrix 2D barcode

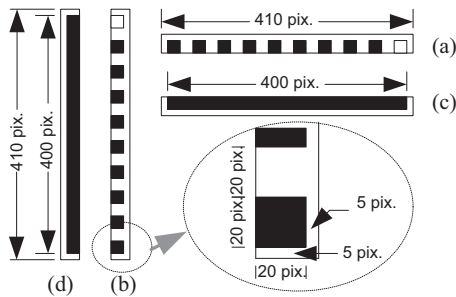


Figure 4. Input Templates (a) Template #1 (b) Template #2 (c) Template #3 (d) Template #4

Once the source image is acquired, the matching process starts. The templates are used in sequence; template #1, template #2, template #3, and template #4, respectively. As shown in Fig. 5, the highest matching score can be obtained when the template is perfectly matched with the source portion.

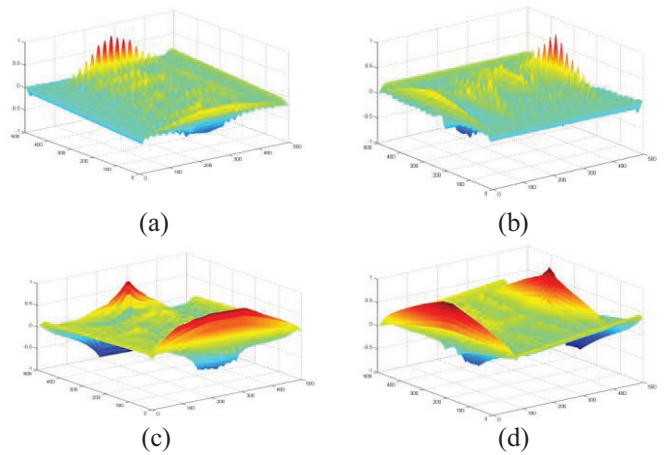


Figure 5. Normalized cross correlation plot (a) Template #1 (b) Template #2 (c) Template#3 (d) Template #4

V. EXPERIMENTAL RESULTS

To carry out the quantitative results of applying the idea to the real barcodes, we randomly picked 20 pass samples and 20 rejected samples. They were eye-classified by operators in a production line. We did pattern matching and scored out. The lowest score among those 4 templates is collected for each sample. For all 40 samples, the result is shown in Fig. 6 below.

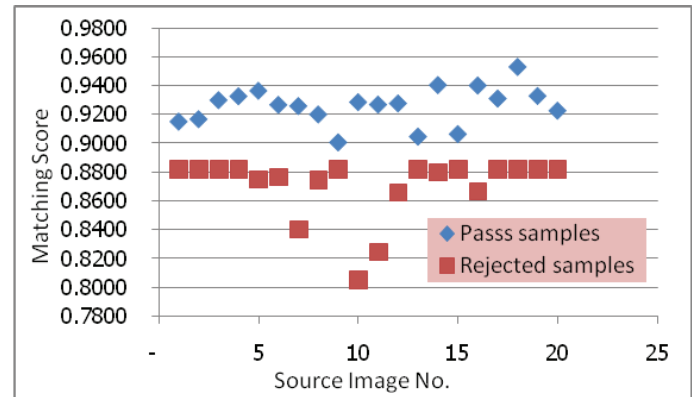


Figure 6. Matching scores of pass and rejected samples

It is fairly obvious that the obtained matching scores can be grouped. Each can represent the pass or rejected samples. Those samples with the score less than 0.890 fall into the rejected group. If we want to draw a line for a machine inspection, perhaps the score of 0.890, which is roughly between 0.900 and 0.980, can be the decision line.

Shown in Figure 7 are samples of 2 best scores and 2 worst scores source images. The high score samples (a and b) look good as it should be. The scores given there are the average scores. In contrast, the clear defect can be observed for samples that hold low scores (c and d).

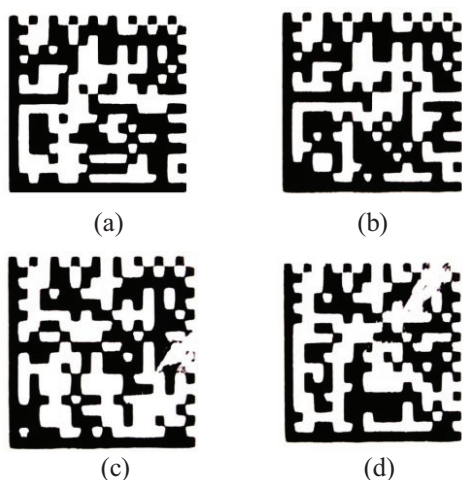


Figure 7. “Pass” inspection(a), (b) and “Rejected” inspection (c), (d)
 (a) 2D barcode image17 score 0.961 (b) 2D barcode image16 score 0.959
 (c) 2D barcode image30 score 0.865 (d) 2D barcode image31 score 0.8926

We also have investigated the matching score of each template that tends to vary according the rotation distortion. We did this by rotating the source image by ± 4 degrees. The matching scores are plotted accordingly as shown in Fig. 8. The score of template #1 and template #2 change quite linearly when the source image is rotated. The rate of change can be estimated to about 10% per degree. The scores of template #3 and template #4 do not reveal much the changes.

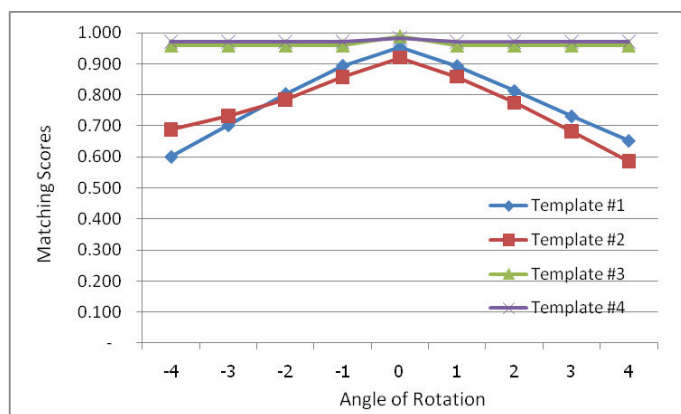


Figure 8. Matching scores versus source rotation angle (Image 17)

Since the inspection algorithm has checked only the score of the finder pattern of data matrix barcode. This algorithm may fail when the finder pattern is perfect but not the data cell itself. The said condition is shown in Fig. 9. The minimum matching score is 0.915 which is actually lies in the pass region. The algorithm then wrongly passes this sample. The way to tackle this failure is under investigation.

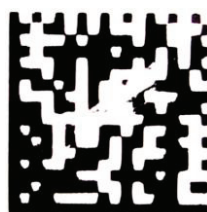


Image No. 45
 #1; Matching score = 0.923
 #2; Matching score = 0.915
 #3; Matching score = 0.946
 #4; Matching score = 0.936

Figure 9. Perfect finder pattern source image but not the data cell

VI. CONCLUSION

In this paper we have proposed a machine barcode printing quality inspection. The main idea is based on a template matching technique which is quite common in image processing area. 4 templates are matched to the source image of which rotation and perspective distortion are not considered. It is also found that the matching scores decrease fairly at a high rate when the image is rotated.

Upon the experiment result, we are convinced that the obtained scores are of benefit in classifying the printed barcode quality. The only one case that the algorithm fails is that the image hold good finder pattern but the imperfectness appears in the data area.

ACKNOWLEDGMENT

The authors appreciate the cooperation and support of Compart Precision (Thailand) Co., Ltd. during this research project. And also be appreciative to NECTEC for giving us the research grant with the contract number HDD 01-51-010M.

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