IMPROVING PERFORMANCE OF THE DECODER FOR TWO-DIMENSIONAL BARCODE SYMBOLOGY PDF417

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Keywords: Two-dimensional barcode, Segmentation, Error correction code, Warping

Abstract: In this paper we introduce a method to extract the bar-space patterns directly from the gray-level two-dimensional barcode images, which employs the location and the distance between extreme points of profiles scanned from the barcode image. This algorithm proves to be very robust from the high convolutional distortion environments such as defocussing and warping, even under badly illuminating condition. The proposed algorithm shows excellent performance and is implemented in real-time.

1 INTRODUCTION

Linear barcodes have been used globally in the various fields such as supermarkets and other stores for several decades. Usually, they do not have detailed information but just carry a key to database, because they can hold only several bytes of information. The need to increase the amount of data in a symbol brought the introduction of a new form of barcodes with much higher density called the two-dimensional (2-D) barcodes. They have been introduced since 1990's. While conventional or one-dimensional barcodes usually function as keys to databases, the new or two-dimensional barcodes meet a need to encode significantly more data than the conventional codes and would act as a portable data file because the information could be retrieved without access to a database. They have additional features such as error correction and the ability to encode in various languages like English, Korean and Chinese, etc., besides their increased capacity. Thus, the traditional concept of barcode as a key to a database is changing towards a "portable data file" in which all the relevant information accompanies the item without access to a database.

There are two types of 2-D symbologies - stacked and matrix-type symbologies. The stacked barcodes, to which Code49, PDF417, etc. belong, have the structure of rectangular block comprising numbers of rows, each of which is like 1-D symbology. The matrix-type barcodes are essentially a form of binary encoding in which a black or white cell can represent either binary 1 or 0. These cells are arranged in an array structured on a grid of rectangular block. DataMatrix, Maxicode, and QR code, etc. are representative of Matrix-type symbology (Pavlidis, 1992).

In this paper, we focuss only on PDF417 (AIM USA, 1994), known as the most widely used 2-D stacked symbology. PDF417 is a multi-row, variable-length symbology offering high data capacity and error-correction capability. A PDF417 symbol is capable of encoding more than 1,100 bytes, 1,800 ASCII characters, or 2,700 digits, depending on the selected data compaction mode. Every PDF417 symbol is composed of a stack of rows, from a minimum of 3 to a maximum of 90 rows. Each PDF417 row contains start and stop patterns, left and right row indicators. Fig. 1 shows the high-density scanned barcode image of PDF417 code.

We explain about our barcode decoder and propose a novel method of extracting codewords directly from gray-level barcode image by analyzing their profiles instead of binarizing the image.

2 LOCALIZING THE DATA REGION

The data region is localized to extract the bar-space patterns and to detect the codewords, in the following way. Firstly, the start pattern or stop pattern, or both are searched by scanning horizontally and vertically. The start pattern is 81111113 and the stop pattern is 711311121, both beginning with bar. Fig. 2 shows the segments

Hahn H. and Jung J. (2004).
IMPROVING PERFORMANCE OF THE DECODER FOR TWO-DIMENSIONAL BARCODE SYMBOLOGY PDF417.
In *Proceedings of the First International Conference on Informatics in Control, Automation and Robotics*, pages 130-134
DOI: 10.5220/0001139101300134

corresponding to the start patterns, which are extracted from the clear barcode image and the highly blurred, high-density one respectively, together with their profiles. Although the start patterns shown in Fig. 2-(a) can be easily identified, it might not be easy to detect them in case of Fig. 2-(b) because the width of one module is less than 1.5 pixels and the dynamic range of the profile at the region corresponding to narrow bar or space is severely reduced due to convolution with the point spread function of the camera. After the start pattern and/or stop pattern are detected, line equations corresponding to them are estimated through line fitting to localize left and/or right row indicators. Secondly, the header information such as the number of rows and columns, error correction level, row number, error correction level and the width of module, etc. are obtained by extracting and decoding the left and/or right row indicators (Hahn, 2002).

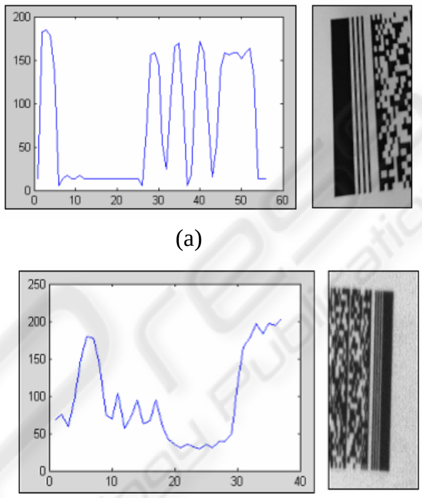
Figure 1: The scanned PDF-417 barcode image

Finally, four vertices of the data region are detected by scanning in the directions perpendicular to the start pattern line and the stop pattern line. To ensure the vertices obtained are correct, row numbers are checked by decoding the left or right row indicators around the vertices. If the row numbers corresponding to the detected four vertices are not the first row or the last row, the true four vertices are predicted by considering the proportion of the row number to the number of row, as depicted in Fig. 3. Since barcode image is usually scanned using a digital camera, it should be warped due to the nonlinearity of lens and the viewing angle of the camera. In this paper, Affine transform is adopted to warp the data region of the scanned image (Gonzalez, 1993). Fig. 4 shows the warped result of the data region inside the barcode in Fig. 1.

3 DECODING CODEWORDS FROM BAR-SPACE PATTERNS

After the data region is localized and warped as mentioned above, bar-space patterns are extracted from the data region and are decoded to obtain the corresponding codewords. The problem is how we get bar-space pattern from the barcode data region.

Usually, image thresholding is employed for this goal. Many researchers developed the image thresholding algorithms, most of which reported to date are based on edge information or histogram analysis using information-



(a)

(b)

Figure 2: Profiles and segments corresponding to the start patterns of the scanned barcode, which are excerpted from (a) clear image and (b) highly blurred, high-density image.

theoretic approaches (Parker, 1991). The selection of optimal thresholds has remained a challenge over decades. However, they can not be applied to decode the barcode images, because the widths of bars or spaces can be 2 pixels or even less in case of high-density barcode images and even slight variation of threshold can cause severe errors (Eugene, 1991).

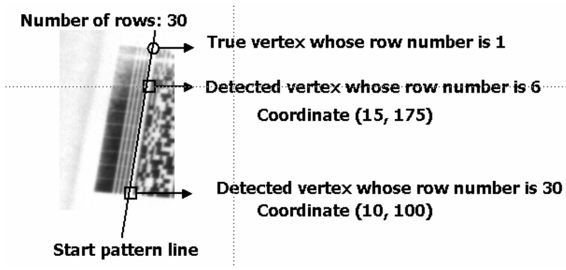


Figure 3: Locating true vertices by checking row numbers.

Fig. 5 shows the segmented bar-space patterns and their corresponding profiles obtained from the focussed clean image and the outfocussed image. Although the widths of bars and spaces of Fig. 5-(a) can be easily measured, it might not be a simple matter to measure them in case of Fig. 5-(b) and the obvious thing is single global threshold can not even discriminate them. Fig. 6 shows the intensity profile of the codeword (824 : 1, 5, 1, 2, 1, 1, 1, 5) comprised of four bars and four spaces, together with their widths and classification results.

As shown in Fig. 6-(a), it is impossible to select the single optimal threshold for detecting the widths of four bars and four spaces because the pixel values change dynamically according to the widths of bars and spaces.

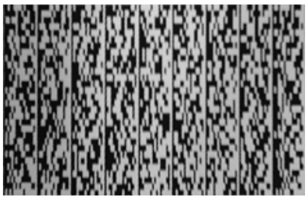


Figure 4: Warping the data region of Fig. 2 using Affine transform.

The widths and peaks of narrow bars or spaces corresponding to 1 or 2 module values get smaller compared to the wide ones even under the same illumination, due to convolution with the point spread function. The proposed algorithm employs the high curvature points and local extreme points to extract four bars and four spaces from the warped barcode image. The points of high curvature on the waveform represent the midpoints of the bar or space, whereas the local extreme points are estimates of their centers.

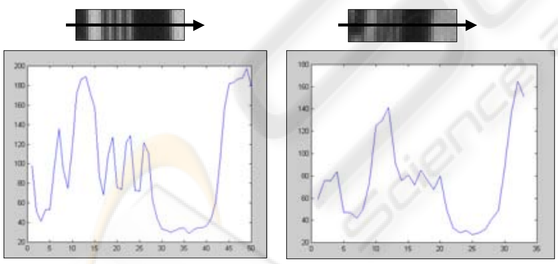


Figure 5: Segmented bar-space patterns and their corresponding profiles obtained from (a) the focussed image, (b) the outfocussed image.

At first, our algorithm localizes four local minimum points and four local maximum points by scanning the profile of each bar-space pattern, as shown in Fig. 6-(b). The local minimum point whose value is large compared to the other minimum points or the maximum point smaller than the adjacent ones are compensated to increase their dynamic range as depicted in Fig. 6-(c). Then, the break regions are detected between the compensated extreme points, where the break region means the region whose profile is horizontal. The regions marked as rectangular box in Fig. 6-(d) represent the break regions. Finally, the break regions are partitioned according to the following rules. Usually, the edges between bars and spaces lie in the break regions. In Fig. 7, we define Δa = x2 – x1 and Δb = x3 – x2. If Δa is greater than Δb, the more part of the break region belongs to the space region, vice versa. The ratios are obtained by experimenting with several hundreds of bar-space patterns, extracted from the various barcode images scanned under varying conditions. Thus, the widths of bars and spaces are represented as real values rather than integer ones to measure the bar-space patterns as correctly as possible.

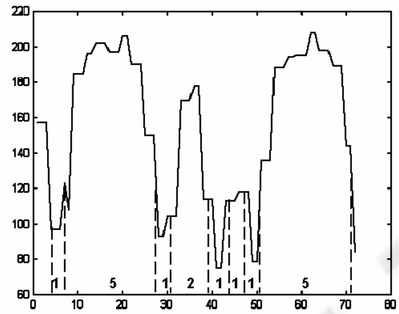
4 EXPERIMENTAL RESULTS

The "edge to similar edge" estimation method is employed to check whether the detected bar-space pattern is correct. The detected bar-space patterns can be converted to the encoded codewords by using the lookup table specified in (AIM USA, 1994). The codewords are checked whether there are any errors through Reed-Solomon error correction coding algorithm. Given the error-corrected codewords, they are decoded in the manner as specified in (AIM USA, 1994), to get the message.

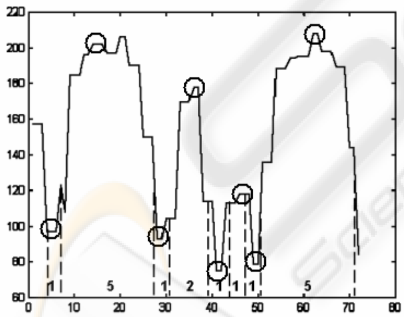
In order to verify our algorithm , we benchmark-tested our decoder with the test barcode images. Our database is composed of 153 barcode images, which were taken under various conditions. In other words, they are rotated, outfocussed, warped or even severely damaged by cutting off some region, as shown in Fig. 8. Almost of them are taken under badly illuminated conditions. At first, 2,000 pieces of profiles corresponding to the bar-space patterns are extracted from our database. Each profile is tested to extract the bar-space pattern and decode the corresponding codeword. Among them, 1,466 profiles are detected correctly. As an example, the image of Fig. 8-(a) is obtained by hardcopying the barcode image several times, whose upper part is severely degraded. When it is applied to our decoder, 42 erasures and 32 errors are detected among total 329 codewords, which can be decoded correctly through Reed-Solomon error correction algorithm. Fig. 8-(b) is an image reassembled but aligned incorrectly after tearing it into two parts. Fig. 8-(c) is obtained from Fig. 8-(a) by cutting off the right part of it and Fig. 8-(d) are taken outfocussed under too bright illuminating condition. Our algorithm decoded 138 images correctly among total 153 images. This result is expected to be good for manufacturing purpose although there might be no public images for benchmarking test.

5 CONCLUSION

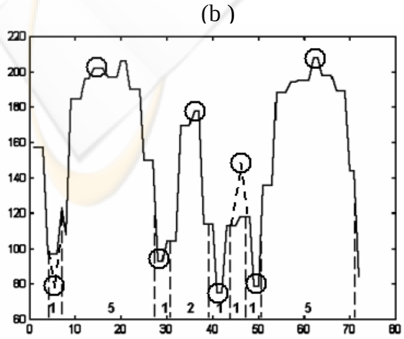
We have proposed algorithms to decode two-dimensional barcode symbology PDF417 and implemented a barcode reader in real-time using ARM core. Our decoder employs a method to extract the bar-space patterns directly from the profiles of the gray-level barcode image. Our algorithm shows performance improved further than the method of extracting the bar-space patterns after binarizing the barcode image, when we experiment with the test images of variable resolution and error correction levels. In order to improve the performance further, it is needed to extract bar-space patterns more accurately from the barcode image, which might be defocused or taken under badly illuminating conditions.



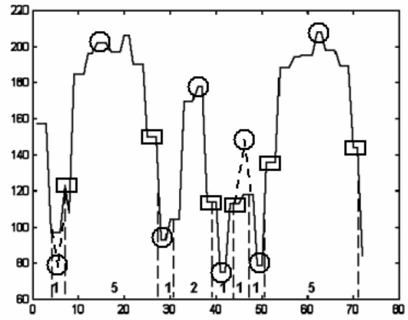
(a)



(b)



(c)



(d)

Figure 6: The intensity profiles of the codeword comprised of four bars and four spaces

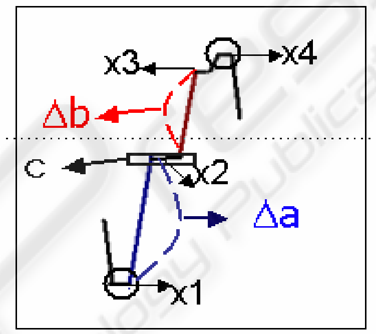
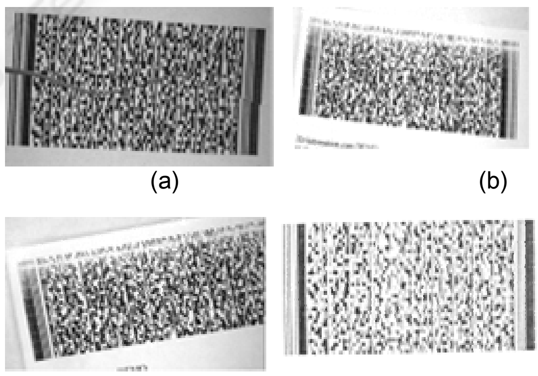


Figure 7: Partition of break region according to the ratio of Δa to Δb



(a) (b)

(c) (d)

Figure 8: Sample images for measuring the performance of our decoder.

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