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RESEARCH ARTICLE

Recognition of 2D Barcode Images Using Edge Detection and Morphological Operation

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Abstract--Bar code recognition has been widely used for several years in many commercial applications. Each symbol which comes into barcode category mainly contains information about the product to which it is attached. 2D barcodes store more information in both vertically and horizontally directions. Common types of 2D barcodes include Aztec, Data Matrix and QR Code. While they all look similar in appearance, each one is encoded in a different formats. The availability of cell phones with digital camera facility provides users a mobile platform for decoding bar code rather than the use of the conventional scanner which is lack of mobility. The motive of this paper is to provide a novel technique for recognition of barcode images captured by mobile phones with the help of image processing techniques. In this proposed work MATLAB platform is used for all processing operations. The performance shows satisfactory results.

Keywords— *Barcodes, QR Code, Edge Detection, Morphological Operations, Connected Component*

I. INTRODUCTION

A barcode is an optical machine-readable representation of data relating to the object to which it is attached. Barcode can be defined as symbology that automates the storage and retrieval of data without any involvement of human. Barcode technology is considered as one of the most important part of Automatic Identification and Data Capture (AIDC) [1]. The two dimensional (2D) barcodes have been developed to enhance the capability of the traditional one dimensional (1D) barcode, especially in data capacity. In the Two-dimensional (2D) symbols, data are encoded in both the height and width of the symbol, and the amount of data that can be contained in a single symbol is significantly greater than that stored in a one dimensional symbol. Over thousands alphanumeric characters can potentially be placed in a single symbol the size of a large postage stamp [2]. Obviously, the main advantage of using 2D bar codes is that possibly a large amount of easily- and accurately-read data can "ride" with the item to which it is attached. There are new applications being created for 2D bar code technology every day. More than thirty different 2D-barcodes are currently in use. Common examples of 2D symbologies include DataMatrix, PDF417, Aztec Code, Codeblock, MaxiCode, QR Code (Quick Response Code), Datastrip 2D, etc. shown in figure1.

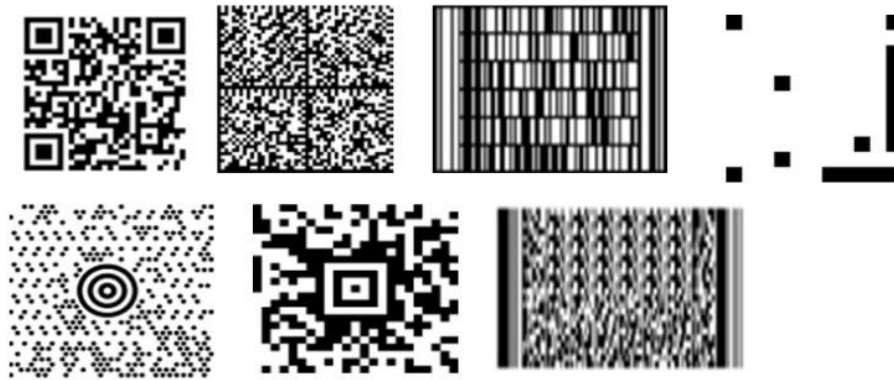


Figure 1: 2D barcode patterns; QR code, Data matrices code, Codebar, EZ barcode, Maxicode, Aztec code, PDF 417 barcode.[2]

A huge number of methods have been proposed for detecting different types of 1D and 2D barcodes within different conditions. Ouaviani *et al.* [3] extracts the boundary of the code in order to evaluate the gray intensity and the co-ordinates of each point of the mesh composing the symbol. Jancke *et al.* [4] introduced a new technique in 2d barcode localization and segmentation, by using a process of thresholding, orientation prediction and then corner localization. Tan *et al.* [5] develop a recognition algorithm which first finds the location of the finder patterns. Then search for the L-shape guide bar(part of the 2d barcode), and Performing projective mapping to correct symbol distortion to localize the barcode region. Huaqiao *et al.*[6], localize the barcode region using texture direction analysis and hough transform. Some morphological operations are also applied [7, 8] to localize and segment barcode region from an image efficiently. Gaur *et al.* [9] proposed a barcode segmentation technique which is based on curvelet transform and neural network. The aim of this proposed work is to suggest an efficient method for recognition of 2-d barcode images.

II. OUR APPROACH

This paper proposes a novel method for recognition of 2D QR Barcode images. Firstly, pre-processing is performed on input image. Then edge detection followed by some morphological operation is applied to improve the connected properties of QR barcode. At last, one of the popular techniques of image processing, connected component is used to finally localize the barcode region. The flow chart of proposed work is shown in Figure 2. The various barcode decoders is not the focus of this paper, thus is not discussed.

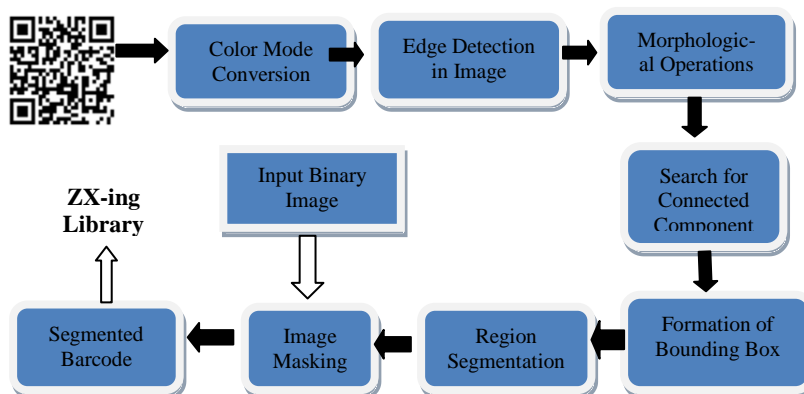


Figure 2. Block diagram of proposed methodology.

III. BARCODE SEGMENTATION

The purpose of barcode segmentation is to find a minimal rectangle which covers the barcode area efficiently. Some of the image processing techniques are explained below which are used in this paper to fulfil the purpose of barcode segmentation:

A. Gray Conversion

Captured barcode image is generally a colorful image. Normally Barcode symbol is a set of dark and light pixels. It is needless to deal with color information and the gray image calculated quickly with little space, so gray conversion is needed to do firstly.

B. Edge Detection

Edges represent the important features which are present in any digital image. In an image if there is an intensity change or sharp variation at or around the pixel value then that variation corresponds to presence of an edge. There are various types of edge detection operators available which can be used to find out the edges in an image [10-12]. Here, in this proposed work canny edge detection technique is used to detect the edges of 2d QR code. The procedure used by canny edge detector follow some steps which are as follows:

1) To eliminate the noise from input image first smoothing operation is performed. For this purpose input image is convolved with the gaussian smoothing filter. The convolution is done by :

$$F [i, j] = G [i, j, \sigma] \times I [i, j] \tag{1}$$

Where i, j corresponds to row and column value respectively. G is Gaussian smoothing filter and σ represents the degree which controls the level of smoothing. I and F represents the input and output images respectively.

2) Now the partial derivatives are calculated with the help of smoothed image F. The equations 2 and equation 3 is used for this operation:

$$M [i, j] = (F [i, j+1] - F [i, j] + F [i+1, j+1] - F [i+1, j])/2 \tag{2}$$

$$N [i, j] = (F [i, j] - F [i+1, j] + F [i, j+1] - F [i+1, j+1])/2 \tag{3}$$

3) After calculation of partial derivative, the magnitude and the orientation of gradient can be calculated by equation 4 and equation 5 respectively. The magnitude is basically used to suppress non maxima pixels which ended up the ridges of the edge pixel. Where, Z is the magnitude, θ is the orientation of gradient and arctan is a function that takes two input arguments and generates angle.

$$Z[i, j] = \sqrt{M [i, j]^2 + N [i, j]^2} \tag{4}$$

$$\theta[i, j] = \arctan(N[i, j], M[i, j]) \tag{5}$$

4) To remove the ridges of the edge pixel two thresholds T1 and T2 (high and low respectively) are used. These two thresholds are applied at each edge pixel for comparison. Any pixel in the image that has a greater value than T1 is considered as edge pixel. Pixel value that that is greater than T2 and connected to the pixel which is considered as edge pixel previously, also marked as edge pixel. All the pixel having the value less than T2 are rejected for consideration as edge pixel.

C. Morphological Operations

Mathematical morphology is the set of various operations that process the image based on shapes [13]. The digital image components which are used in representation and description of region shape like boundaries, skeleton etc can be extracted by morphological operations. All the processing performed by the morphological operation is depends on the one structuring element. The structuring element is moved across every pixel in the original image to give a pixel in a new processed image. This structure elements can be of different size and shapes depends on neighbourhood. It is basically a binary matrix with origin. Example of one structure element is shown in figure 3 which have 5 neighbours. The basic fundamental morphological operations are Dilation, Erosion, Opening and closing. Operations which are used in this proposed work are Dilation and Erosion.

0	1	0
1	1	1
0	1	0

Figure 3: Example of the structuring element with five neighbours (colored pixel is the origin).

1) *Dilation*: Dilation operation used to grow or expand the objects present in binary image. All the processing is controlled by the structuring element. The dilation operation can be defined as:

$$A \oplus B = \{z|\{B\}_z \cap A \neq \emptyset\}$$
 (6)

Where, A is the input binary image and B is structuring element. The equation shows that the dilation of A by B is the set consisting of all the structuring element origin locations where the reflected and translated B overlaps at least some portion of A.

2) *Erosion*: Erosion operation used to shrink the objects present in binary image. In erosion also structuring element used to control shrinking of objects. The erosion of A by B is the set of all structuring element origin locations where the translated and reflected B has no overlap with the background of A. Equation represents the Erosion operation.

$$A \ominus B = \{z|\{B\}_z \cap A^c \neq \emptyset\}$$
 (7)

D. Connected Component:

Connected component can be defined in terms of connectivity which presents between the neighborhoods of a pixel. With this connectivity a path can be formed which depends on adjacency [13].

1) *Adjacency and Connectivity*: Let V: a set of intensity values used to define adjacency and connectivity. In a binary image, $V = \{1\}$, if we are referring to adjacency of pixels with value 1. There are three type of adjacency are defined :

- i) *4-adjacency*: Two pixels p and q with values from V are 4-adjacent if q is in the set $N_4(p)$.
- ii) *8-adjacency*: Two pixels p and q with values from V are 8-adjacent if q is in the set $N_8(p)$.
- iii) *m-adjacency (mixed)*: Two pixels p and q with values from V are m-adjacent if: q is in $N_4(p)$ or q is in $N_D(p)$ and the set $N_4(p) \cap N_4(q)$ has no pixel whose values are from V (no intersection)

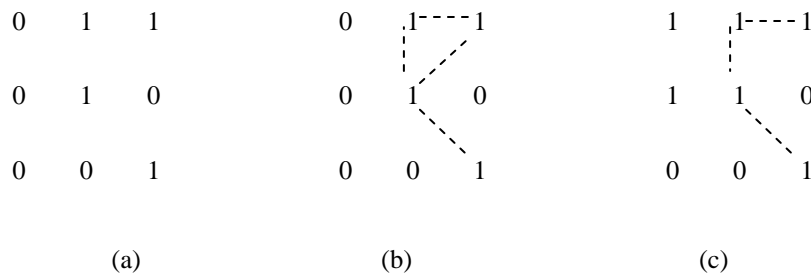


Figure 4: Adjacency representation ;(a) Arrangement of pixels (b) Pixels that are 8-adjacent(shown by dashed line) to the centre point; (c) m-adjacency.

In the example shown in figure 4, we can note that to connect between two pixels (finding a path between two pixels): In 8-adjacency way, we can find multiple paths between two pixels, While, in m-adjacency we can find only one path between two pixels. So, m-adjacency has eliminated the multiple path connection that has been generated by the 8-adjacency. The set of connected components partition an image into segments. For example, if S is a subset of pixels in an image, two pixels p and q are said to be connected in S if there is a path between them consisting entirely of pixels in S. For any p in S, the set of pixels that are connected to it in S is called a connected component of S. if it only has one connected component, then set S is called a connected set.

IV. IMPLEMENTATION

Implementation of proposed work is carried out in the following steps:

Step 1: The gray scale conversion operation is performed on the input colored 2d barcode image. Result of the gray conversion is shown by the figure 5 b.

Step 2: Now to highlight the important features of gray image, edge detection is performed using canny edge detection. Result of edge detection is shown in figure 5 c.

Step 3: After edge detection ,it is shown that the edges of barcode are still broken at some places. To connect the broken edges of the QR code after edge detection, morphological operation dilation is performed. We use a square shaped structure element for dilation whose size is defined as an [11, 11] matrix. Nevertheless, this dilation may also thicken and merge unwanted non-barcode locations as well. To cope with this problem, we also use the erosion operation. The result is shown in the figure 5 d:

Step 4: For the further procedure we take advantage of the structure of the 2d QR code which is a biggest connected component in the image. We analyze the entire image using a horizontal scan .After scanning, there are many small connected components which satisfy the criteria but are not barcode regions. These false regions are eliminated in this step using an area threshold. We set the threshold to half the size of the largest component. A too high threshold value could remove small barcodes from high-resolution images; therefore in this step we only remove the smaller false regions. A bounding box is formed around that found biggest connected component. Of course, there may still be false-positive objects which are removed in the last step on the basis of their size and proportions. Figure 5(e, f) shows the result of area thresholds and connected component.

Step 5: Now after the rough localization of barcode region, the entire boundary value of bounding box is extracted and used for precise barcode region segmentation. Now this segmented image used as a mask for input binary 2d barcode image for barcode extraction shown in figure 5(g, h).

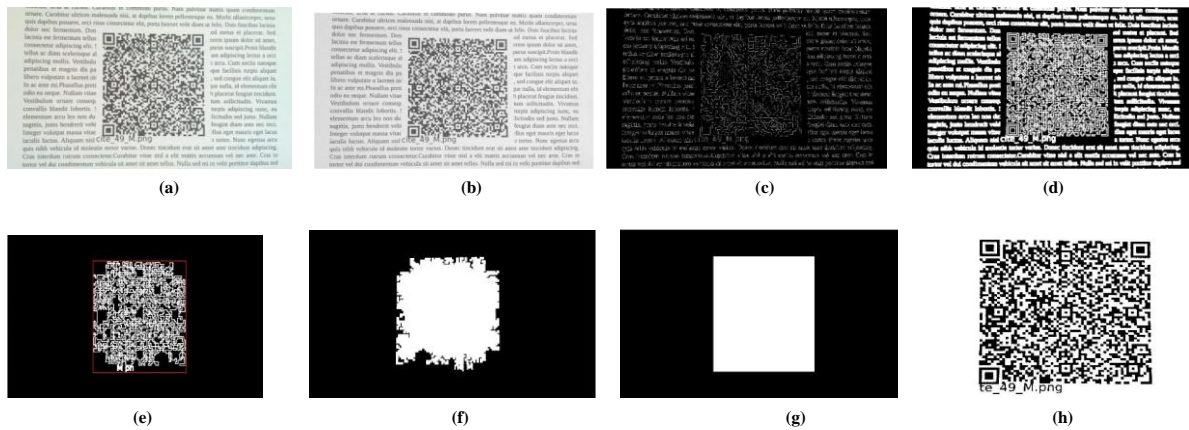


Figure 5. Implementation results (a) Original image; (b) Gray image; (c) resultant image after canny edge detector; (d) result of dilation operation; (e) bounding box formation around largest connected component (f)rough region segmentation (g)precise region segmentation(h)Extracted barcode.

V. EXPERIMENT RESULTS

For the experiment a dataset [14] of 2d barcode images is used. The images in the dataset were taken both with a cell-phone camera and a professional high-definition camera. The resolution of the images scales from 1MPix to 15MPix. The images in the dataset contain several different QR codes.

To evaluate the performance 50 barcode images from dataset are selected. We also evaluate performance for blurred images. Gaussian blur is introduced with standard deviation in the range 0.1 to 0.6 in selected barcode images. The final result is concluded in the table 1 and table 2.

Table 1: Segmentation results for selected samples.

Images	Barcode without blur	Barcodes with blur	Deformed Barcodes
Detection rate	98%	96%	86.66%

For the 50 images without blur, our method can detect almost all of them with the detection rate 98%, and detection rate is 96% for the images with blur. For the 30 images with deformed barcode, our method also did very well, with detection rate achieving 86.66%.

Table 2: Recognition results for selected samples.

Images	Barcode without blur	Barcodes with blur	Deformed Barcodes
Detection rate	98%	92%	73.33%

For the decoding of the barcodes, open source library ZX-ing [15] is used. ZXing or zebra processing is an open-source library. This library is implemented in Java. ZXing supports the generation and decoding of 1D and 2D barcodes images. According to ZXing decoder recognition rate of selected barcode samples is calculated as shown in Table 2. For the 50 images without noise, except for the one detection failure, Zxing library can decode correctly all of them. For the images with noise 92% recognition rate is achieved. Recorded recognition rate for the detected deformed barcode images is 73.33%.

VI. CONCLUSION

Strong edge connectivity exists on most of the 2D barcodes. Based on this feature, this paper proposes a new 2d QR barcode recognition method which includes: gray conversion, edge detection, morphological operations, barcode segmentation using connected component and area threshold. The segmented barcode then applied to Zxing decoder for recognition. The proposed method provides effective performance for segmentation and recognition of 2d qr barcode.

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