2010 3rd International Conference on Computer and Electrical Engineering (ICCEE 2010)
IPCSIT vol. 53 (2012) © (2012) IACSIT Press, Singapore
DOI: 10.7763/IPCSIT.2012.V53.No.1.11

Research on Segmentation Algorithm of 2D Color Barcode Based on Mobile Phone

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Abstract. Aiming at the 2D color barcode images captured by mobile phone camera under complex environment, this paper presents a novel segmentation algorithm of 2D color barcode image based on gradient features. Firstly, the gradient image can be obtained by extracting gradient features from the image captured. Then the DCT transformation algorithm is used to partition the gradient image and the enhanced coefficient of each block is calculated. The enhanced coefficient will be used to distinguish the barcode region and non-barcode region. Finally, the barcode region can be segmented accurately by using morphology and convex hull algorithm. The experimental results show that this approach has a good performance on segmentation. It can segment the barcode region from the 2D color barcode image captured by camera under different environments.

Keywords: 2D color barcode, segmentation, gradient feature, DCT, morphology;

1. Introduction

At present, the black-and-white two-dimensional bar code technology has been applied in various fields. American National Standards Institute (ANSI) developed the international standards of two-dimensional bar code, including Data Matrix, PDF417, QR codes[3][4]. However, with the increase of information, as well as expanding the field of bar code applications, bar code needs to be stored more information. The current black-and-white two-dimensional bar code can only use two colors to describe the information and this limits the increase of the information capacity of bar code in a larger extent. Under this background, the color bar code opens a new research field. Microsoft Research Institute proposed a full-color two-dimensional bar code. There are two kinds of versions with four-color barcode and eight-color barcode. The smallest recognition unit is a triangle. As opposed to black-and-white two-dimensional bar code, this color bar code can raise approximately 2-3 times data density [5]. The company of ColorZip in South Korean is also promoting the value-added business based on color bar. The current prevalent two-dimensional bar codes, including Microsoft Research Institute, are mainly developed for English char and digital number. For the Chinese characters coding, the Chinese character internal code are used in those standards. This coding method has low efficiency because all Chinese characters are coded in the same coding length. So referring to the Data Matrix standards, we have designed and implemented a color two-dimensional bar code with high compression ratio for Chinese characters [5]. This kind of color two-dimensional bar code is decoded according the using frequency of Chinese characters and the length of bar code is changing with the using frequency. The higher frequency the Chinese character uses, the shorter length of the bar code is. It is showed in Fig.1.

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Figure 1. The 2D color bar code proposed here

Unlike the previous bar code scanning with a bar code scanner, here the color bar code is taken by a mobile phone. In practice, bar code image taken by mobile phone is inevitable to be affected by light, complicated background and other factors. It will make a difficulty for segmenting the bar code image from the background. At present, there are a lot of segmentation methods in this field, such as a recognition method based on the projection algorithm, a method of measurements for parallel margin, a method of by calculating the margin strength to segment the boundary of the bar code, a method using morphology to segment bar code[1][2][6]. These algorithms are mainly suitable for the traditional black and white barcode to be identified and segmented from background. Here, we propose a segmentation algorithm based on the gradient feature under complex environment for 2D color bar code.

2. Color Bar Code Segmentation Algorithm Based on the Gradient Feature

Generally, the 2D color bar code photographed by a mobile phone camera will always contain much background information. It is showed in Fig. 2. Comparing to other parts in the picture, we can find that the color bar code region has a very clear texture contrast. That means the color bar code region will have large gradient value. So we can use gradient features to enhance the bar code region. It will help to segment the color bar code from the complex environment.

In this paper, the segmentation algorithm is proposed and this method includes the following five steps: (1) preprocessing image; (2) extracting gradient feature; (3) enhancing bar code region with DCT; (4) extracting bar code region; (5) positioning and segmenting the bar code.

2.1 Image preprocessing

In practice, because of the defacement of 2D color bar code image, or the limitation of the camera mobile phone, there are some inevitable noise points on the photographed image. So the images should be preprocessed firstly in order to eliminate noise points. The filtering method is mainly used to solve this problem. The commonly used filtering algorithms include mean filtering, median filtering, Gaussian filtering. Different filter algorithms are suitable for different environments. In this paper, the Gaussian filter is applied.

Gaussian filter is a kind of linear smoothing filter that the right value is selected according to the shape of Gaussian function. In Gauss filter, the value of each pixel is replaced by the weighted average of neighborhood pixel gray value, which is determined by filter mask. The pixels in the mask center position of power will have larger weights, and the pixels far from the mask center will have smaller weights. So using Gaussian filter, the boundary effect can be eliminated and the edge blurring in the smoothing process will be reduced. Because the Gaussian smoothing filter has good filtering performance, flexible filter adjustment scale and high filter efficiency, it has been widely used in image processing. Two-dimensional Gaussian function can be expressed as:

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2} \tag{1}$$

In formula (1), the σ is the smoothing factor. The greater the value is, the more obvious smoothing effect is. Here, the σ is set to 0.2 and the filter window is 3x3. Using formula (1), the R, G, B three color channels in 2D color barcode images is filtered and the noise points are eliminated. The image preprocessed is shown in Fig.2.

Figure 2. The 2D color bar code preprocessed

2.2 Extracting gradient feature

Gradient is corresponding to the first derivative of information and it can be generally obtained by gradient operator in image processing. The commonly used gradient operator include: Roberts operator, Prewitt operator, Soble operator, Laplaican operator and Canny operator and so on. In this paper, Soble operator is used to extract the gradient features in 2D color barcode image.

The Soble operator is used to calculate the R, G, B three- channel gradient in 2D color barcode image separately and they are marked as $Grad_r$, $Grad_g$, $Grad_b$. Here the gradient of a color pixel (x, y) on 2D bar code image is defined as below:

$$Grad(x,y) = \max\{Grad_r(x,y), Grad_g(x,y), Grad_b(x,y)\} \tag{2}$$

Each point in the 2D color bar code is scanned and the gradient range [Glow, Ghigh] can be determined. In formula (3), the scope of the image gradient can be mapped to the range [0,255] through linear transformation. Then the gradient image I of the 2D color bar code can be gotten.

$$I(x,y) = \frac{255}{Ghigh - Glow} \times Grad(x,y) \tag{3}$$

The gradient image transformed is shown in Fig.3 below.

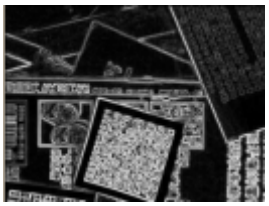


Figure 3. The Gradient Image Transformed

2.3 Enhancing the bar code region with DCT

DCT is a kind of transformation in real number field. The transform kernel is the cosine function of a real number. The distribution of coefficients transformed is concentrated. Because the main information in image is the low frequency information, the main image information transformed by DCT is concentrated at the low frequency domain. It is widely used in image data compression. The 2D 8x8 DCT is defined as follows:

$$F(u,v) = C(u)C(v)\sum_{x=0}^{7}\sum_{y=0}^{7} f(x,y)\cos\frac{(2x+1)u\pi}{16} \bullet \cos\frac{(2y+1)v\pi}{16} \tag{4}$$

$$C(s) = \begin{cases} 1/\sqrt{2} & s = 0 \\ 1 & s \neq 0 \end{cases} \tag{5}$$

In which $0 \le u, v < 8$.

Restructuring the DCT coefficients, the directional and multi-resolution features can be obtained in the frequency domain. It is showed in Tab. 1 below.

Table 1 The 8x8 DCT block coefficients Restructured

$A0_0$	$A1_0$	$A4_0$	$A4_1$	$A7_0$	$A7_1$	$A7_2$	$A7_3$
$A2_0$	$A3_0$	$A4_2$	$A4_3$	$A7_4$	$A7_5$	$A7_6$	$A7_7$
$A5_0$	$A5_1$	$A6_0$	$A6_1$	$A7_8$	$A7_9$	$A7_{10}$	$A7_{11}$
$A5_2$	$A5_3$	$A6_2$	$A6_3$	$A7_{12}$	$A7_{13}$	$A7_{14}$	$A7_{15}$
$A8_0$	$A8_1$	$A8_2$	$A8_3$	$A9_0$	$A9_1$	$A9_2$	$A9_3$
$A8_4$	$A8_5$	$A8_6$	$A8_7$	$A9_4$	$A9_5$	$A9_6$	$A9_7$
$A8_8$	$A8_9$	$A8_{10}$	$A8_{11}$	$A9_8$	$A9_9$	$A9_{10}$	$A9_{11}$
$A8_{12}$	$A8_{13}$	$A8_{14}$	$A8_{15}$	$A9_{12}$	$A9_{13}$	$A9_{14}$	$A9_{15}$

In which A0 is the approximation of the low frequency region in the image. A1, A4, and A7 represent the horizontal frequency changes on the different bands. A2, A5, and A8 represent the vertical frequency changes on the different bands. A3, A6, and A9 represent the diagonal frequency changes on the different bands. Region A7, A8, A9 mainly represents the details of original image. Region A0, A1, A2, A3, A4, A5, A6 reflects the main information of the original image and they are the important regions for extracting image features. The edge, contour, and texture of original image on the horizontal direction, vertical direction, and diagonal direction are represented by coefficient amplitudes of the larger frequencies. That means if there are obvious edge features on the horizontal direction, vertical direction, and diagonal direction, the region A4, A5, and A6 will have larger amplitudes. So the edge, contour, and texture of image can be extracted according to larger frequency amplitude value on the same place.

Through analyzing the feature of 8x8 blocks in bar code region and non bar code region in the gradient image of 2D color bar code, it will be found that there are obvious edge features on the bar code region relative to the non bar code region. So according to this feature, firstly, the gradient image of the 2D color barcode is divided by N-8x8 sub-blocks and the DCT coefficients of these blocks are calculated. Then the larger value of the frequency coefficient at the same place from the DCT coefficients reorganized is found and is regarded as the gradient features of sub-blocks. Finally, the gradient features of sub-blocks are used to calculate the strengthening coefficients of sub-blocks.

In each DCT block coefficients, finding the maximum coefficient at the same place in region A4, A5, A6. It is showed below:

$$S_i = \max\{ A4_i, A5_i, A6_i \} \quad (i = 0,..., 3) \tag{6}$$

The strengthening coefficients of the k-th sub-blocks is defined as f_k. It is showed in equation (7):

$$f_k = S_{k0} + S_{k1} + S_{k2} + S_{k3} \quad (k = 1..., N) \tag{7}$$

From the equation (6) and equation (7), we can calculate the strengthening coefficient of each sub-block. In order to highlight the barcode region, we define the adaptive regulation function and make non-linear transformation on strengthening coefficients. It is showed below:

$$f_k' = \left(\frac{f_k}{fMax} \right)^{fAvg/f_k} \quad (k = 1,..., N) \tag{8}$$

$$fMax = \max(f_k) \quad (k = 1,..., N) \tag{9}$$

$$fAvg = \sum_1^N f_i \Big/ N \tag{10}$$

The formula (8) can be used to enhance the contrast degree of strengthening coefficients in each sub-block and map the range of strengthening coefficients to the range of [0,1]. The greater the strengthening coefficient of sub-block is, the more likely the bar code is. The strengthening coefficient of sub-block can be used to enhance the gradient image. It is showed as follow.

$$I'(x, y) = I(x, y) \times f' \tag{11}$$

In which, f' is strengthening coefficient of a sub-block where the pixel (x, y) belongs. The I is the original image and I' is the enhanced gradient image. After calculated through formula (11), the bar code region in the gradient image can be enhanced and non bar code region will be weakened. The previous image is enhanced in this way and it is showed in Fig. 4.

Figure 4. The enhanced gradient image.

2.4 Extracting bar code region

After the bar code region is enhanced, the bar code region of the gradient image can be extracted. It can be divided into the following two steps:

- Gradient binary image

The segmentation algorithm with appropriate threshold should be selected to make gradient binary image. Here, the Otsu algorithm is used and the gradient binary image is gotten. It is showed in Fig.5 below.

Figure 5. The gradient binary image

- Mathematical morphology

Mathematical morphology is a kind of new Interdisciplinary in the field of image processing and pattern recognition, which is developed on the basis of set theory. The basic idea is to use the some structural elements with special patterns to measure and extract the corresponding shape in the image in order to achieve the image analysis and recognition. The most commonly used mathematical morphology includes seven kinds of transformations: dilation, erosion, opening, closing, hit, thinning and thickness. According to the different types of image processed, the mathematical morphology can be divided into binary morphology and gray (more value) morphology. In the gradient binary image segmented through threshold, there are some holes and cracks in the bar code region frequently. It is showed in Fig. 5 above. So the closing operation in binary morphology is used to deal with this problem in the paper. The closing operation can mix the narrow gap and the slender curved gap. It can eliminate small holes and fill in the broken part of the contour.

The operation object in binary morphology is a set. Assuming the set A is for the image set and the set B is for the structural element, the closing operation using the structural element B on the set A is expressed as the Eq (12).

$$A \bullet B = (A \oplus B) \Theta B \tag{12}$$

Using Eq (12), the gradient binary image is processed through closing operation and the holes and gaps are filled. The experimental results show that the structural elements with 3x3 have a good result. The image processed by morphology is shown in Fig. 6 below.

Figure 6. The image processed through closing operation

- Filtering the bar code region

Through these treatments, most of the background image is filtered and the bar code region can be preserved well. Usually the bar code region in the whole image keeps a large area. So marking the connected areas with regional connectivity symbols firstly, then selecting the bar code according to acreage of bar code region and the geometric characteristics of rectangular bar code, the filtered barcode region is obtained in Fig. 7 below.

Figure 7. The filtered bar code region.

2.5 Positioning and segmentation of the bar code

Sometimes, the bar code is defaced or is over segmented. The bar code region appears incomplete. It can be seen in Fig.7 above. So some processing is needed to separate out the complete bar code. Taking into account the quadrilateral geometry feather, convex hull algorithm can be used firstly to extract the approximate contour of the bar code from the bar code region. Then the contour can be used to fit a quadrilateral. Through this quadrilateral, the bar code can be positioned. Finally, the bar code can be segmented accurately. The result is showed in Fig.8 below.

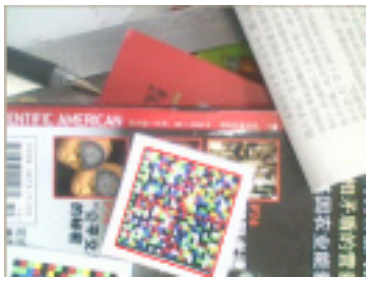
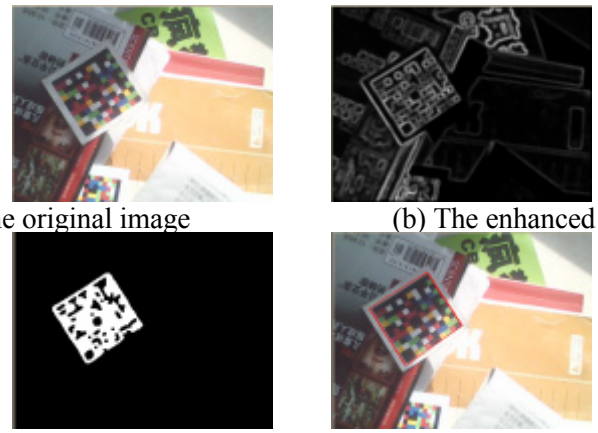


Figure 8. The positioning and segmentation result.

3. Experimental Analysis

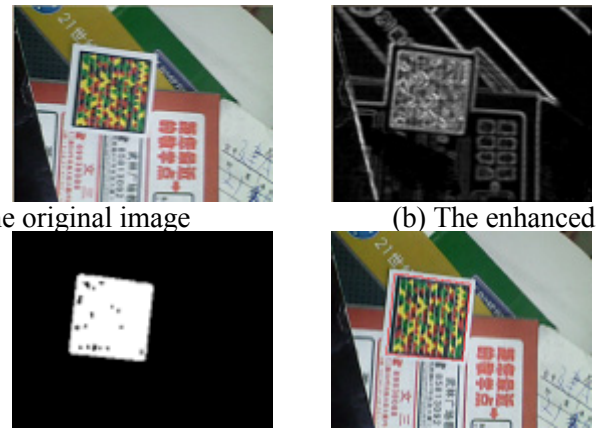
In order to verify the validity and generality of this method proposed in this paper, the two groups of color bar code images taken by mobile phone are used for testing. The first testing group is the color bar code image used in this paper. It is showed in Fig.9 below. The second group comes from the Microsoft. It is showed in Fig.10. Both of these testing images are taken under the complex background and different lights. Here, we use the correct detection rate and error detection rate as the evaluation criteria. It is showed in Tab. 2.



(a) The original image (b) The enhanced image

(c)The extracted image (d) The final image

Figure 9. The result of first testing image



(a) The original image (b) The enhanced image

(c)The extracted image (d) The final image

Figure 10. The result of second testing image

Table 2 The testing results of two groups

Testing groups	Pixels	Number of error detection	Right detection rate (%)	Error detection rate (%)
1	100	5	95	5
2	100	3	97	2

It shows that the segmentation method proposed in this paper is valid and has a good performance.

4. Conclusions

According to the texture feather of 2D color bar code, a kind of segmentation algorithm for bar code region based on gradient feather is presented in this paper. Through extracting the gradient feather of 2D color bar code, the gradient image is gained. In the meantime, the coefficient characteristics of 8x8 DCT block in the gradient image are analyzed. According to DCT coefficients, the gradient image is enhanced and the bar code region can be segmented from the gradient image. Experimental results show that the algorithm has good adaptability and it can effectively segment the 2D color bar code from the image taken by mobile phone. It can meet the requirements from real application.

5. References

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