Study on two-dimensional code recognition algorithm in non-uniform illumination based on digital images processing technology

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Abstract. It is possible that the shaded area was mistakenly identified based on digital images processing technology with non-uniform illumination. The binarization algorithm of two-dimensional code was optimized to this problem. The local area threshold of the image and the pixel-by-pixel sliding calculation are used to eliminate the influence of the illumination on the image, thereby improving the recognition rate of the two-dimensional code image which contains the shadow. Experimental result indicate that the method has a stronger adaptability to images with shaded areas, especially for unilateral shadows which are less ideal for block resolution. Compared with the classical global Ostu algorithm, the recognition rate of the image is increased by about 3 times.

1. Introduction
With the rapid development of modern science and technology, the application of bar code recognition technology is more and more broad. Bar code can be seen everywhere in our daily life, and it has become more and more common in industry. When one bar code is scanned, there are two main types: photoelectric scanning technology and images processing technology [1]. In recognition process, photoelectric scanning technology transmitted light signals are converted to electrical digital signals via bar code scanners. This technology is influenced by non-uniform illumination a lot, and scanning barcodes is generally low successful rate. The images processing technology capture images based on devices, then the images are pre-processed and identified. However, in the actual industry application is not so. Because of restriction by the light conditions and equipment environments, which make the degree of shade with the identifying image may be non-uniform and causes many problems for the identification with two-dimensional code image. To meet constantly improve demand of reading two-dimensional code information. The method to eliminate the non-uniform illumination needs to be identified, which eliminated the disturbance of non-uniform illumination with two-dimensional code image.

The images captured by the image acquisition are RGB format in most common cases. For the convenience of image storage and reduce calculation amount, the first step of two-dimensional code recognition is that RGB image was converted to grayscale image. Because of unit module with black and white were only valid data in the two-dimensional code image, the next was binary image processing. The unbalance of illumination must take into account in binary image processing. But for now, the research of binary image processing focuses on how to find the threshold reasonably and quickly, and the threshold algorithm divided into global threshold method and local threshold method [2-4].
The most common local threshold includes Bernsen [5] and Niblack. This kind of methods were effectively to attain binary image, but it's inevitably existed the false targets or the target object fracture. Madhuri L.M. [6] optimized the performance of the local threshold with Bernsen. Firstly, the original image was processed by Gaussian filter. Then utilizes Bernsen to determine the threshold value of original image and filtered image by Gaussian, respectively, and the final threshold was obtained via weighting processing. Abutaleb A.S. [7] and Brink A.D. [8] used the distribution density of image grey scale to describe image entropy so as to maximize the sum of entropy with target and background through calculating some threshold. Gao Huimin [9] optimized the algorithm of homomorphic filtering, which can eliminates the effect on non-uniform illumination in the two-dimensional code image. Yan Sanhu [10] divided original image into blocks, each sub-graph for calculating its gray value, and then gain the final corrected image based on bilinear interpolation algorithm. The algorithm overcame the effect of threshold selection on non-uniform illumination of two-dimensional code image, but it only applies to binary image processing with simple background.

The domain decomposition method of two-dimensional code image also exist the false targets or the target object fracture. In allusion to these problems, Zhang Jieyu [11] taked a more image windows to judge whether tremendous change of the grayscale values with each sub-graph, and thus image binarization treatment. Because the strategy of using segmented two-dimensional code image was effective, so an improved binarization algorithm method of Ostu was developed in this article. Firstly, the original image was divided into blocks. Then, binary image with two-dimensional code was attained by the method of the improvement Ostu algorithm.

2. Materials and methods

2.1. Binarization theory of illumination unbalance
The most common was image segmentation algorithm, which can be used for binary image processing with grayscale images. And its advantage was due to its simple arithmetic and aims clear in the image. The object region was region of interest (ROI) in processing image, and redundant portion was background region. For ROI and background region a method was proposed, which was used the threshold to recognize them. The binary image processing was aimed at no information was lost and rejecting redundant information with background region. Therefore, the key of image binarization was to find an effective threshold [12].

The essence of threshold segmentation was to select a threshold T in all pixels with the images, and each pixel will be judged to belong to ROI or background region according to the threshold T. The computation process of T is shown as formula (1)

\[
b(i, j) = \begin{cases} 
1 & f(i, j) > T \\
0 & f(i, j) \leq T 
\end{cases}
\]

where T represents the selected threshold, f(i, j) represents the pixels in processing image, and b(i, j) represents output pixel value after binary image processing.

2.2. Non-uniform illumination analysis
The appeared problems of non-uniform illumination phenomenon occur when two-dimensional code image were captured based on handheld devices, and in general the following common phenomenon: 1) overall grayscale value of acquisition images is low when especially in low light or the limitations of the image acquisition devices; 2) partial grayscale value of acquisition images is low when in poor light; 3) the partial shadow appears in the images when partial occlusion; 4) the light intensity is too much in the partial image. The threshold T selected is affected greatly by the phenomena, and the error is inevitable. There are many black piece and the shadow in the partitioned images, which can impact the recognition of two-dimensional code image. The common solution to the problem is to enhance the image contrast and brightness, such as histogram equalization and gray expanding.
These methods require the proportion coefficient and structural elements are reasonably adjusted to realize image enhancement result. And another method obtains threshold by image partition, which does not need to adjust the proportion coefficient of image. The traditional algorithm is time intensive on computation and appears the phenomenon of boundary effect.

2.3. **OSTU algorithm**

The basic purpose of Ostu method [13] was to select a threshold makes infra-class and inter-class variance minimum or maximum, and the pixels in the image are separated into targets and background based on threshold.

The computation process of the total average values with gray density is shown as formula (2), the computation process of infra-class variance is shown as formula (3), and reduced-form-approach is shown as formula (4).

\[
\mu = w_0\mu_0 + w_1\mu_1 \tag{2}
\]

\[
g = w_0(\mu_0 - \mu)^2 + w_1(\mu_1 - \mu)^2 \tag{3}
\]

\[
g = w_0 \times w_1 \times (\mu_0 - \mu_1)^2 \tag{4}
\]

where \(g\) represents infra-class variance, \(w_0\) represents the proportion of target pixels of the whole image pixels, \(\mu_0\) represents the average gray of target pixels; \(w_1\) represents the proportion of background pixels of the whole image pixels, \(\mu_0\) represents the average gray, \(\mu_1\) represents the average gray of background pixels.

The larger the infra-class variance of \(g\) is, the more different the target pixels and background pixels are, and the smaller the risk of dividing error with target pixels and background pixels. Therefore, threshold \(T\) was selected is the optimal segmentation threshold when \(g\) is the maximum.

2.4. **Improved algorithm with Ostu**

The following is its basic process of improved algorithm with Ostu. Step 1: Convert the acquisition image to grey scale one. Step 2: The way of median filter or Gaussian filter is used to denoise underwater images. Step 3: The image was divided into blocks of \(n\) (\(F_1, F_2, \ldots, F_n\)). Step 4: Calculate the threshold value of each subimage. Step 5: Compare the threshold value of each sub-image with that of Ostu algorithm. When the threshold value of sub-image is higher than that of Ostu algorithm, Ostu algorithm is adopted to process sub-image for image binarization, or set the non obvious area to white that is less than that of Ostu algorithm otherwise. Step 6: Then according to different position of shadow, the suitable direction was selected to iterate through the images and finally the optimized images were obtained. The binary image was dealt with by classical Ostu algorithm is shown in Figure 1.
Figure 1 shows the binarization image process of classical Otsu algorithm.

Figure 2 shows the shadows in two different directions, and the result of the binarization is the best when the original image was divided into 4*4 blocks. For the image contain more transition from light to shadow, the effect is better. But the effect is not ideal when the image contain less of that. The reason is that the strategy of using segmented image cannot automatically recognize shadows and it converts the obtrusive part of shadow changes to a black one, which had a huge influence to the identification of the two-dimensional code image.

3. Experiment results and analyses
For verifying the accuracy and effectiveness of the algorithm, 50 images were captured by cellphone cameras. The image size is cutting and resized, and the image size is 300*300 pixels. The test images include 5 images of uniform illumination, 10 images of low light, 10 images of strong light, and 25 images of non-uniform illumination. The experiment compared the recognition rate between Otsu algorithm and improved Otsu algorithm, where translation and recognition of two-dimensional code image based on Matlab. Table 1 shows the recognition rate of uniform illumination and non-uniform illumination.
Table 1. Recognition rate of experimental images

| Image number | Recognition rate of uniform illumination (25) | Recognition rate of non-uniform illumination (25) |
|--------------|-----------------------------------------------|--------------------------------------------------|
| Otsu         | 100%                                          | 36%                                              |
| Improved Otsu| 100%                                          | 99%                                              |

The results from experiments indicate that classical algorithm of global Otsu has good flexibility to uniform illumination, but the effect is bad when the image contain shadow. The improved Otsu algorithm in this article has good flexibility to shadow in the two-dimensional code image, and especially with unilateral shadow that is not very well based on image blocks.

4. Conclusion
Aiming at the problems of two-dimensional code image containing shadow in non-uniform illumination, this paper presented an improved Otsu algorithm to image segmentation method of non-uniform illumination. The experiment results show that this method can effectively segment the target from the background, and it makes for easier identification of the two-dimensional code images based on traversal operators. Compared with classical algorithm of global Otsu, the improved Otsu algorithm in this article has higher recognition rate and solves the distraction of non-uniform illumination in the two-dimensional code image.

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