Research Status and Development Trend of Two-Dimensional Code

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Abstract: With the development of automatic identification technology and the popularity of smart phones carrying high-definition cameras among the public, application of two-dimensional code has developed rapidly. In this paper, we will expound the research status of two-dimensional code detection methods, including binarization method, Inspection area polarization method and distortion correction method, and summarize the research status of large-capacity two-dimensional code and the development trend of color two-dimensional code technology.

1. Introduction

With the rapid development of intelligent machine technology, automatic identification technology is getting more and more attention. Automatic identification technology allows machines acquire information quickly, correctly, and efficiently in different scenarios, then process information intelligently based on information category. Bar code recognition technology such as one-dimensional code and two-dimensional code commonly used in our life work is an important application of automatic recognition technology.

In the 1980s, China began to introduce bar code recognition technology, mainly applied in the field of resource management such as book management, postal code and material management. However, the automatic identification technology at that time was relatively backward, so the development of bar code technology in the early stage was relatively slow. With the development of automatic identification technology and the popularity of smart phones carrying high-definition cameras among the public, the two-dimensional code has developed rapidly. Now, you can see the two-dimensional code in a variety of advertisements, train tickets, attraction tickets, product packaging, and store payments. Moreover, as the application of two-dimensional codes increases and various types of two-dimensional codes appear, bar codes have developed into a huge industry.

Generally, the two-dimensional code is composed of small modules of two color square with black and white arranged in sequence on the two perpendicular sides of the two-dimensional plane. In the process of compiling the two-dimensional code. The black square module in the bar code represents the low level “0” of the internal logic of the computer, and the white square module represents the high level “1”. Therefore, a series of black and white modules in the barcode image can represent the binary stream of the computer. Because the two-dimensional code often only has two elements of the black and white module, it can automatically acquire the image through the image input device such as mobile phone, computer, etc., and then automatically recognize the two-dimensional code therein.

2. Research of two-dimensional code detection method

The detection and recognition process of the two-dimensional code is to convert the “0” and “1” data expressed by the black and white module in the two-dimensional code picture into the original data before encoding. These include image graying, image filtering, image binarization, two-dimensional code positioning, two-dimensional code correction, and data error correction and decoding steps. Next, we will introduce binarization, region localization and distortion correction methods of two-dimensional code.

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2.1 Research on Two-Dimensional Code Binarization Method

Generally, pictures acquired by the current image acquisition device are color images in RGB format. In order to facilitate image storage and reduce the amount of calculation, the first step in decoding the two-dimensional code is to convert the image containing the RGB three primary colors into a grayscale image. Since only black and white “0” and “1” modules in the two-dimensional code are valid data, the image binarization processing is required immediately after the two-dimensional code image is acquired.

Image binarization can be used as a preprocessing step for digital image processing methods, such as edge extraction, target recognition, image segmentation, etc., which need to be binarized and then processed[1-2].

Considering the situation of illumination imbalance in Two-dimensional code binarization is necessary. At present, there are several common enhancement processing methods: grayscale transformation, homomorphic filtering [3], and Retinex enhancement method [4]. At present, the research direction of image binarization algorithm mainly focuses on searching threshold reasonable and fatly, while the threshold calculation is divided into two categories: global threshold method and local threshold method [5-7]. Common local binarization algorithms are Bernsen [8], Niblack, etc. Although such methods can effectively perform binarization, there are still inevitably problems such as false targets or broken targets.

Madhuri et al. [9] optimized Bernsen's method, proposed to filter the original image with Gaussian filtering, and then use the Bernsen’s method to weight the two thresholds obtained by the original image and the Gaussian filtered image respectively to get the final threshold.

Abutaleb A. S. [l0] uses the entropy of describing distribution density of image grayscale, and then solves a certain threshold so that the entropy sum of the target and the background is maximum.

The method proposed by Brink A. D. [11] is also based on image entropy. The method finds a threshold that maximizes the smaller value of the target and background image thresholds. However, the calculation of this method is more complicated.

Lu Yang [12] et al. improved the homomorphic filtering algorithm, eliminating the influence of illumination inhomogeneity in QR image, and then using the OSTU method to binarize the image.

Wen Sanhu [13] et al. proposed that divide the image into blocks, then calculate the gray value of each part bases on dividing, set gray value of each block with bilinear interpolation algorithm as estimated value, finally obtain a corrected image according detecting the background with original image. This algorithm overcomes the influence of uneven illumination on the threshold selection in the image, but only applies to the binarization of simple background images.

Qu Weifeng [14] divided image into blocks and then used the OSTU binarization algorithm to binarize each image blocks. However, the result of this algorithm is greatly affected by the image block size.

Defects of target false and fracture for regional block binarization algorithm, Zhang Jieyu [15] proposed to first divide the image, then judge whether the gray level change in the block window is intense with a larger local window, thus binarizing.

2.2 Research on the method of two-dimensional code region localization

After the two-dimensional code is binarized, it is necessary to locate the two-dimensional code region in the image. If a suspected two-dimensional code area is not detected in an image, the recognition process will terminate and the image will no longer be recognized. Therefore, two-dimensional code positioning is a prerequisite for decoding.

Yuan Renjie [16] used Hough transform and Sobel edge detection operator to process the image to locate the two-dimensional code vertex.

Ohbuchi et al [17] preliminarily locate the features of the QR code based on the features of the QR code on the preprocessed image, and then use extract the two-dimensional code region with inverse perspective transform metro.

Ojala et al. [18] used the texture features of the image to perform preliminary location detection

on the two-dimensional code.

Belussi et al. [19] used the Haar feature and the joint weak classifier to train and identify the positioning pattern of the QR code, then use the geometric relationship to determine whether the found positioning pattern is a legal two-dimensional code.

Szentandr et al. [20] first detected the straight line by Hough transform, and then used the perpendicularity of the lines in the two-dimensional code region to detect the HOG feature of the line, so as to quickly locate the two-dimensional code region in the high pixel picture.

Dubsk et al. [21] performed edge detection on the image, and found the vanishing point of the line in the corresponding Hough space to locate the area of the two-dimensional code.

Wang Jingzhong [22] proposed using feature of QR code internal module is a square, first use Rough transform to detect approximate square area, then combine the detected square areas, and finally adjust the area to obtain the QR code area.

Lingling et al. [23] first calculated the LBP feature for the image, then analyzed it to obtain the preliminary region of the QR code, and then accurately located the QR code area based on the ratio of the number of black and white modules in the QR code image close to 1:1.

2.3 Research on Distortion Correction Method of Two-Dimensional Code

After the position in the image where the two-dimensional code is located, decoding cannot be performed immediately. In the application process of the two-dimensional code, distortion is often caused by various reasons, such as lens distortion of the image acquisition device, tilting of the shooting angle, and two-dimensional code sticking on the twisted surface. Direct reading of the distorted QR code data will cause data errors, so correction processing is required.

Vijayan [24] proposed a correction method of relational mapping, which uses the mapping relationship of polynomial to describe the mapping relationship between the distorted two-dimensional code image and the standard two-dimensional code image, and then finds the pixel corresponding to the standard two-dimensional code on the distorted two-dimensional code. The point coordinates are used to find the mapping relationship, and the distorted two-dimensional code is mapped to the undistorted two-dimensional code accordingly.

Si Guodong et al. [25] divides the differently distorted areas along the axis of the cylinder and then corrects each part according to the curvature of the cylinder according to the distortion of the midline region, the distortion of the left and right edge regions will become larger and larger. This algorithm works well when the aspect ratio of the cylindrical two-dimensional image is greater than 0.7, but the correction effect is not ideal when the curvature of the cylinder is relatively large.

Ai Qionglong et al [26] used a matching algorithm to correct the distorted two-dimensional code. The algorithm firstly uses the arc surface fitting algorithm to segment the image, then uses the Hough transform-based linear detection algorithm and a method for utilizing the mapping relationship between undistorted and distorted key points on a two-dimensional code to correct distorted two-dimensional code.

Liu Fengjie [27] first added an auxiliary square outside the outline of the standard QR code, and then corrected the auxiliary square from the warped two-dimensional code to a square to achieve the effect of correcting the two-dimensional code.

Yang Xu [28] first used the method of bridging to improve the detecting accuracy of key points in the edge contour of the two-dimensional code, and then used the least square method to fit the key points on the edge into a curve, and calculated the coordinate position of the corresponding point on the edge of the two-dimensional code by curve integral, and finally achieve the purpose of correction through the mapping relationship.

Wang Kena et al. [29] proposed using BP neural network to learn the relationship between standard two-dimensional code and distorted two-dimensional code for correction. This method requires a large number of learning samples and a large amount of learning time, and the time taken in the calibration process is long, and the correction efficiency for different twisted two-dimensional codes is not good.

3. Research Status of Large Capacity two-dimensional Code Technology

Although the research work on bar code technology worldwide has been going on for more than 60 years and has made great progress.

Although the capacity of QR codes is larger than other types of two-dimensional codes, with the explosive growth of information in modern society, how can we increase the capacity of information with limited space in today's efficient social environment, make transmission and acquisition of information more secure fast and convenient, this makes a higher requirements on the most popular information carrier --- QR code.

The research on increasing the QR code information capacity abroad is also relatively early in China.

Foreign scholars Sartid Vongpradhip, Hiren J. Galiyawala and Masanori KIKUCHI et al. proposed to use a multiplexing technique to obtain a composite QR code, thereby increasing the information capacity of the QR code [30-32], and dividing the information to be encoded into multiple segments, then encode Each segments, generate multiple QR coded, and multiplex these QR codes to generate a composite QR code.

Ferreira et al. proposed to increase the information capacity of the QR code using multi-color coding technology [33-34], they use red, green, blue and white four colors to represent the binary 00, 01, 10 and 11 respectively, and obtain compatibilized QR code.

In the research of using multi-color coding to expand the storage capacity of QR codes, Microsoft Research Institute's self-developed 2D high capacity color barcodes are available in 4 colors and 8 colors [35].

A color two-dimensional bar code service launched by Color Zip in South Korea, through the embedded index information, using the reader or mobile phone to send index information to the server, and then converted into URL information, and finally jump to the corresponding web page to read the content, currently in Countries such as Japan and South Korea have already had relatively mature market applications [36]

Yuan Yuansong designed a color two-dimensional bar code with high compression ratio Chinese character encoding ability [37], add red, green, blue and yellow colors on the basis of black and white color of the ordinary two-dimensional code, then build encoding library according to the using frequency of Chinese characters, so that the Chinese character frequency is inversely proportional to the encoding length, make this color two-dimensional barcode has the characteristics of large information capacity and high compression ratio of Chinese characters.

Later, scholar Li Zhaohui [38] added red, green and blue colors to the black and white color of the QR code, making the original binary coding rule into hexadecimal corresponds to five colors of black, white, red, green and blue to increase the capacity to obtain a color QR code.

Scholar Liu Tie [39] Zheng Herong [40], Niu Wanhong [41] and so on have also proposed several color QR code technology scheme similar to Li Zhaohui, and developed color QR code with its own intellectual property rights.

Scholars Zou Min, Wang Xiao et al. [42] proposed an improved Huffman coding technique to expand the information capacity of QR codes. First, they use Hill algorithm to sort the data to be encoded, then construct Huffman tree to obtain the code, encoding obtained data to QR code, expand the capacity of the QR code by data compression.

4. Development trend of two-dimensional Code

To increase the amount of QR code information in limited space, color two-dimensional code came into being. Color two-dimensional code is actually a three-dimensional code, which is based on the two-dimensional plane coordinates of the two-dimensional code, and the color dimension is added to represent the information, thereby extending into three-dimensional space. The study of color two-dimensional codes has the following advantages:

(1) Color two-dimensional code adds a color dimension on the basis of the traditional two-dimensional code, and replaces the multi-bit information of the traditional two-dimensional

code by corresponding multi-bit binary data streams by different colors. Color two-dimensional code has greater information storage capability in the QR code picture of the same specification.

(2) Comparing the traditional two-dimensional code and the color two-dimensional code of the same area, in the case of storing the same information content, the traditional two-dimensional code block distribution is denser and the resolution requirement is higher, the color block distribution of the color two-dimensional code is relatively sparse, and the color block division is easier than the traditional two-dimensional code when identifying.

Compare with traditional two-dimensional code, color two-dimensional code has larger amount of information storage capacity, which makes it easier to realize mass storage and recognition of characters, Chinese characters, sounds and pictures. However, the discovery of color two-dimensional codes during the research process also has certain limitations. For the limitations of color two-dimensional codes, the improvement will be further discussed and designed below.

(3) Color two-dimensional code stores information in different colors and is relatively susceptible to interference from the external environment. If the obtained color two-dimensional code is the original picture, the influence of external interference during transmission is weak, and the information carried by the information can be accurately identified. If the obtained color two-dimensional code is a picture taken by the camera, the color deviation may cause problems such as color deviation. Therefore, when designing a color two-dimensional code structure, a white reference frame is added to deal with the color cast problem. When recognizing, the obtained white reference frame is compared with the built-in standard white background for RGB values, and the RGB color space of the image is normalized, thereby reducing the influence of illumination and shadow, and improving the accuracy of color recognition.

(4) The using of color equipment for color two-dimensional codes may increase the cost. If the color code is added to the original black-and-white printing, the printing cost may increase. If the black and white hardware that originally recognizes the traditional two-dimensional code is changed to the hardware that recognizes the color two-dimensional code, the hardware overhead may increase. Intelligent terminals such as mobile phones are changed from identifying traditional two-dimensional codes to recognizing color two-dimensional codes, which may increase software overhead. However, color printing is now very popular, printing costs are gradually reduced, and with the development of technology, the cost of color recognition equipment will gradually decrease, reaching a range accepTable to users.

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