VISIBLE GRAPHIC QR CODE WITH EMBEDDED INVISIBLE QR CODE TO ENHANCE ANTI-COUNTERFEITING FEATURES

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Abstract - QR code is a popular interface to deliver information between reality andvirtual world. It also plays an important role in marketing advertisement and transactional payment.However, it is sometimes misappropriated and forged by fraudulent users. Therefore, the security of QR code still needs to be strengthened. On the other hand, QR code is not recognizable by human vision because it consists of black and white modules. By the techniques of digital halftoning and data hiding, a graphic QR code embedded with an invisible QR code is developed to enhance the security features. Its explicit QR code can be normally interpreted by a QR code reader, and the message of the implicit QR code can be decoded by inputting the correct key. The research reaches the goal of graphic QR code to be both aesthetically pleasing and strengthening the anti-counterfeiting features.

Keywords - QR code, Halftoning, Data hiding, Security

I.INTRODUCTION

1.1 Background and Related Works

With the widespread of the internet and mobile devices, the application of QR code (Quick Response Code)is more and more adopted by many fields. It connects the physical worldand the internet, and QR code is one of the most common two-dimensional barcodes. Nowadays, QR code plays an important role in daily lives, such as marketing advertisement and transactional payment. With the convenience of QR code, some unscrupulous vendors try to steal personal information from others to heist and scam to commit the crime, which makes the purpose of building up the security feature of QR code more important of all. Besides, with the rise of frequently using QR code, vendors from different businesses gradually start to take the appearance of code into consideration. However, the appearance of the QR code previously is not designed for human eyes to perceive. People cannot tell the difference of barcodes from their eyes. Limited by itself construction, barcode cannot be easy to change its appearance. Hence, there are lots of studies try to beautify QR code [2,3,6,8,9,10]. Most of the works focus on hiding QR code in a grayscale or color image. Garateguyet al. (2014) [6] embed QR code in color image with full frame coverage by optimization technique. Chen et al. (2016) [2]provide a color PiCode that adjusts the intensity of embedded sub-images based on the data (0 or 1). However, it needs special interpretive program. Much less works have been devoted in QR code hidden in a halftone image. Chu et al. (2013)[3]segment the module of QR code into 3x3 sub-modules. The sub-module in the center hides the information of QR code, and other eight sub-modules based on the similarity of the gradation of cover image. Qiaoet al. (2015) [11] further finetuned the method by dividing the QR code module into finer sub-modules and obtained high resolution halftone QR code with both similarity and readability. With their approaches, the aesthetically pleasing and recognizable halftoning QR codes can be obtained, however, the high computational complexity still needs to be improved.

1.2Halftoning and Halftone-based Data Hiding

As for the research, it is a halftoning-based image hiding technology for QR code calculation. Halftoning is a traditional printing process. Because the output device can only control the inking or non-inking to output the image, it has to convert the continuous tone image into a halftone image before output. With the development of modern digital technology, traditional halftoning has been changed to computerized simulation. Digital halftoning is an image processing method which converts the continuous tone image into bi-level image using halftoning algorithm with the goal of meeting the characteristics of output equipment. Digital halftoning can be divided into two major categories. The first is Ordered Dithering, also known as Amplitude Modulation (AM). The AM dots are formed as the same distance with each other but different in size to indicate the tone; the second is Error Diffusion, also known as Frequency Modulation (FM), with the same size of dots but with dot density to indicate the tone of the image.

In the halftoning-based information hiding literature [1,5,7,12], Fu & Au's method [5] has been popularly used. They proposed the Data Hiding Error Diffusion (DHED), which is based on the error diffusion and the neighboring pixels undertake the error between the inserted data and original grayscale value.

1.3 Our Contribution

This study modifies the Data Hiding Error Diffusion (DHED) (Fu & Au, 2002) [5] to produce the graphic QR code with both explicit and implicit QR code information (shown in Figure 1). The key ideas are listed as following:

1. The explicit image can visually identify as meaningful images (e.g. Logo of various businesses) and can be scanned by a regular QR code scanner.
2. It is able to hide another QR code which can not be recognized by the public. However, the second layer of hidden information can be decoded with a specific key.
3. The proposed graphic QR code is aesthetically pleasing and it enhances the anti-counterfeiting features.

The difference between the proposed approach of information hiding by error diffusion in QR code and the approach proposed by Fu & Au, in 2002 [5], is the former provide both fixed information position and a random information position. The fixed information position allows the extraction of explicit QR code which is compatible to general QR code reader in mobile device and can be directly interpreted.The random information position is using the pseudo-random number generated by the key tohide the information. Besides, both fixed information point and random information point do not interfere with each other, which can substantially expand the flexibility and scope of original technology.

II. PROPOSED METHOD

Our method is based on the modification Fu & Au's DHED for the QR code application. Some of the hidden messages can be interpreted by a QR code reader, while others need a key to solve them. First, enter a gray levels image and two QR codes (one for the explicit QR code A, the other for the implicit QR code B) to form a graphic QR code. Second, scan with a phone to solve the QR code A, corresponding to a web site or other digital message. The implicit QR code B can be solved by inputting the correct key from another program. The flow chart of producing the graphic QR code image is shown in Figure 1.

The approach of hiding the information in the graphic QR code is as follows: Enter a grayscale image which is a picture/logo and two QR codes. The approach is to segment each module of QR code into 3x3 sub-modules. The information of QR code A is put in the center of the module (as shown in Table 1). The other eight around can use error diffusion to calculate the dots with the tone of explicit image. If there is a second QR code B information, the key is used to generate a pseudo-random number at the same time to calculate the location of hidden QR code B information. The hidden QR code information is added into the corresponding position of the 3x3 sub-modules. The coding sequence length generated by the pseudo-random number is 1,681 (we use QR version 6, 41x41,and error correction level H as a calculation basis.There are 172 codewords, which include 60 codewords for data, 112 for error correction), so the hidden second QR code information is not necessarily hidden in the same place for each 3x3 blocks. And then error diffusion is carried out to calculate the dots, which forms the hidden QR code in the graphic QR code.The detailed description of data encryption and decryption will be shown in the following sections.

2.1. Error Diffusion Encryption

Error diffusion data hiding is used to make the graphic QR code to hide the second QR code information, so error diffusion and error diffusion data hiding will be introduced first. The error diffusion algorithm was first proposed by Floyd & Steinberg in 1976 [4]. It diffuses the quantization error during the biniarization process of a specific pixel in a gray-scale image into the neighboring un-binarized pixels. The binarization process continues in the order with the calculation in a serpentine manner until completing the calculation of the entire image.The binary image with FM halftone dots can be obtained.

Table1: The illustration of the location of hidden information in the graphic QR code.

QR code	The location of hidden information
Explicit QR code A	○ ○ ○ / ○ √ ○ / ○ ○ ○ — √ : e information of QR code A is hidden in the center.
Implicit QR code B	○ : information of QR code B is hidden in one of the other eight sub-modules by pseudorandom number.

It can also impose the data of 0 or 1 on the selected positions and then spread the error to the

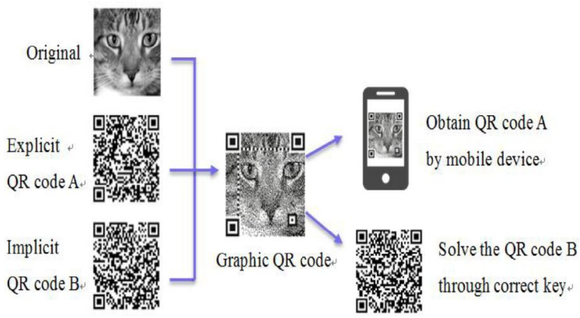


Fig.1. The graphic QR code image with both the explicit and implicit QR codes.

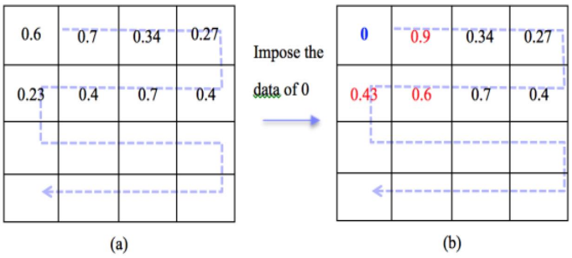


Fig.2. The illustration for information hiding calculation: (a) The gray scale value of the original image. (b) error diffusion while hiding the "0" information.

$$\begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} a_0 & a_1 & a_2 & a_3 & a_4 & a_5 \\ b_0 & b_1 & b_2 & b_3 & b_4 & b_5 \end{bmatrix} \begin{bmatrix} 1 \\ x \\ y \\ x^2 \\ xy \\ y^2 \end{bmatrix} \quad (1)$$

$$U = AX \quad (2)$$

surrounding non-binarization positions.Information hiding is first to segment each module in the QR code into 3x3 sub-modules.The QR code A information is put in the center position of 3x3 sub-modules, and the QR code B information is hidden in one of the adjacent eight sub-modules which is determined using a secret key (as shown in Table 1). To illustrate the difference from the regular error diffusion, assuming that the hidden information value is 0, the pixel in the upper left corner directly diffuses the error value 0.6 to nearby pixels (as shown in Figure 2). So that it can continue the information hiding in the process in a serpentine manner.

2.2. Decrypttwo hidden QR code information

The QR code reader on the mobile device can interpret the QR code A (corresponding to digital

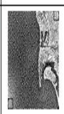
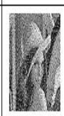
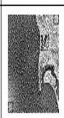
data or website) in the graphic QR code (as shown in Figure 1). In Figure 3, it needs the correct key to receive the implicit QR code B while solving the second QR code hidden in the graphic QR code. Moreover, it also needs to be interpreted to the correct corresponding website by inputting correct key. On the contrary, while inputting the wrong key, the generated QR code cannot be interpreted by the QR code reader and connect to the correct website.

Figure 4 is the flowchart that illustrates the process of solving the hidden QR code in the graphic QR code. First of all, the QR code image is obtained under the process of print-and-scan both by 600dpi. The finder patterns of QR code are usedtobe the control points. And then, the geometrical transformation is adopted to retrieve the correct control point position of the graphic QR code. The transformation matrix is represented as Equation (1). (x, y) is the coordinate of the original QR code image (represented as X). (u, v) is the coordinate of the print-and-scan image after geometric transformation (represented as U). The coefficient of transformation matrix are $a_i$and b_i (i = 0, 1, ..., 5) (represented as A).The matrix X and U are coordinate matrices of known control points. A is unknown. Equation 1 can be abbreviated as shown in Equation (2). And matrix A can be obtained by linear algebra as Equation (3).
First,the transformation matrix is used to automatically locate the sampling points. Second, the sampled image intensity isconverted into bi-level image. And then, result of detected 123×123 graphic QR code is obtained, which makes comparison of data in the original graphic QR code. By doing so, it shows the difference between the two. And finally, the correct key is input through the program.It can solve the detected 41x41 hidden QR code. And, thecorrect recognition rate is obtained by comparing with the content of the original 41x41 QR code B (as shown in Figure 4).

III. RESULTS AND DISCUSSION

In order to explore the image quality of multiple encrypted QR codes in this research, Peak Signal to Noise Ratio (PSNR) was used. The comparison of the original image, graphic QR code and double-hidden QR code can be a judgment of image quality assessment, as depicted in Table 2. It can be seen from Table 2 that the PSNR of the images are between 28.6 to 29.5dB after transformed into the graphic QR code. The PSNR of hiding two QR codes in the images are between 27.0 to 28.4dB. The PSNR values of four images are obviously decreased, indicating that it reduces the image quality after hiding the second QR code information to the image. It also reduces the similarity with the original image.From this result, the more QR code information it hides, the poorer image quality is.PSNR is getting lower and lower. However, the explicit image can still be identified as a meaningful pattern by the naked eye.

Table 2: The comparison of PSNR in each image（123x123）.

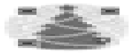
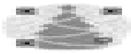
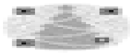
	 Lena	 boat	 pepper	 harbor
Hidden QR code A	 29.36 dB	 29.19 dB	 28.66 dB	 29.45 dB
Hidden QR code A&B	 28.33 dB	 28.13 dB	 27.02 dB	 28.27 dB

$$A = UX^T(XX^T)^{-1} \quad (3)$$

Follow the approach above to hide two QR codes in the graphic QR code, the explicit image can indicate the meaningful halftone image. It can be interpreted by the QR code reader in mobile device. Implicit QR code information may not be known to the public to achieve the function of hidden secret message. Through the scanned image, the correct key is input to solve the data in the hidden QR code. The recognition errorrate of both detected QR code B of the image and the original QR code B can be calculated by geometric transformation and binarization processes.

Taking Table 3 as an example, different concentrations of halftone dots in the graphic QR code are carried out with the print-and-scan process. The calculation of all automatically sampled positionsis done by geometrical transformation. And then, the detected grayscale image is converted into a bi-level image to extract the 0 or 1 data of the graphic QR code. The difference between the detected information in the print-and-scan graphic QR code and the original one is also shown in Figure 4.

Table 3:The recognition error rate for different concentrations of halftone dots in print &scan image.

image					
QR physical size 21mm	Recognition error rate (123x123 sub-modules)	0.2% (30)	0.1% (15)	0.2% (30)	0.6% (90)
	Recognition error rate (41x41 modules)	0.1% (2)	0.1% (2)	0.1% (2)	0.3% (5)
	Codeword error rate (Explicit QR code)	1.1% (2)	0.5% (1)	1.1% (2)	2.9% (5)
	Codeword error rate (Implicit QR code)	1.7% (3)	0.5% (1)	1.1% (2)	2.3% (4)
QR physical size 10.5mm	Recognition error rate (123x123 sub-modules)	8.4% (1271)	9.4% (1422)	1.6% (242)	3.0% (454)
	Recognition error rate (41x41 modules)	7.0% (117)	8.3% (140)	0.7% (12)	1.5% (25)
	Codeword error rate (Explicit QR code)	40.1% (69)	40.7% (70)	18.0% (31)	12.2% (21)
	Codeword error rate (Implicit QR code)	41.3% (71)	45.3% (78)	16.8% (29)	11.0% (19)

In Table 3, the four varied densities of graphic QR codes have been resized into 330x330 pixels and 660x660 pixels, respectively, and the two images of different sizes are printed at 600 dpi. (The physical sizesare 10.5mm and 21.0 mm, respectively.) During QR code decoding, they are scanned at 1200 and 600 dpi, respectively. We also test the QR code with physical size of 42 mmand the total error rate is0%.So we don't show the result here. More specifically, the recognition errors of two kinds of QR code, explicit QR code and implicit QR code, are listed in Table 3. It is observed that the recognition error rates QR code with physical size at 21 mm are

Fig.3.The illustration for the hidden QR code in the graphic QR code solved by different keys.

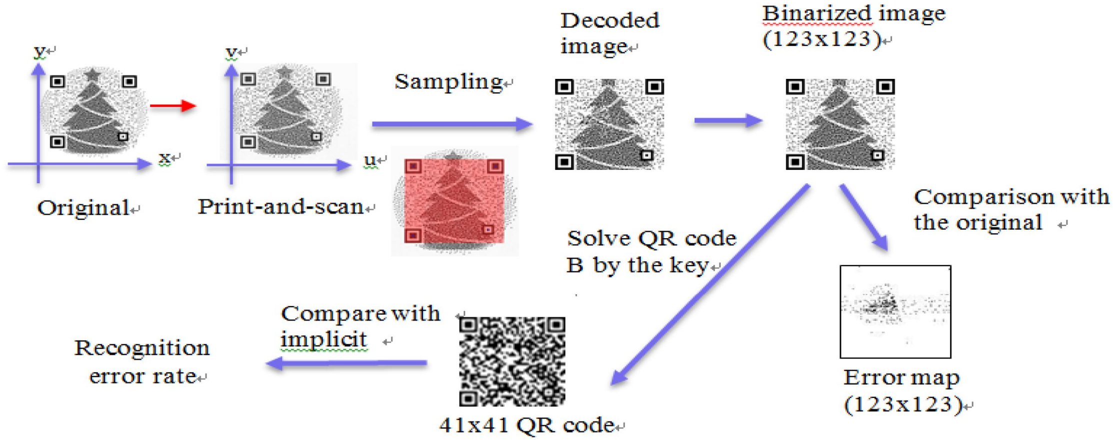


Fig.4.The flowchart for solving the implicit QR code with secret key.

within 1% for both explicit QR code and implicit QR code. Similarly, the recognition error rates QR code with physical size at 10.5 mm are within 10% for both explicit QR code and implicit QR code, which are based on 123x123 sub-modules or 41x41 modules. The recognition errors of higher density of image are approximately between 40% to 46% based on codewords, which cannot be interpreted. On the other hand, the lower density ones are within 18%, which, however, can be interpreted. The error correction level of the original QR code is set to 30% (in 172 codewords). Because the recognition error ratesare more than 30%, they cannot be interpreted completely.

The aforementioned results indicate that the higher the density of image is, the higher the recognition error rate is. In other words, the recognition error rate is decreased when the density is lower. Among different sizes of the same graphic QR code, 21mm is suggested for future applications because of the fact that 42mm is too big for product applications and

10.5mm might bring high recognitionerror rate. It is observed that only the lower densityimage can be suitable for the size of 10.5 mm.

CONCLUSIONS

In this paper, we present a method based on error diffusion and data hiding to successfully combine boththe explicit and implicit QR codes to produce an aesthetically pleasing and recognizable graphic QR code.

1. In the future, it is suggested to move towards assessing the correct percentage of color QR code. Halftone dots in color QR code are complex, while it can be quantified recognizing data. In order to further enhance the security of QR, a hidden infrared (IR) QR code is suggested to withstand the unauthorized duplication [13].

2. In addition, if the mobile phone can scan the graphic QR code and allow users to input thecorrect key to solve the implicit QR code, it will further improve the QR code security in the future.

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REFERENCES

[1] A.V. Alasia, U. S. Patent 3,937,565, Process of coding indicia and product produced thereby, 1976.

[2] C. Chen, W. Huang, B. Zhou, C. Liu and W. H. Mow, “PiCode: a new picture-embedding 2D barcode,” IEEE Transactions on Image Processing, vol.25, no.8, pp. 3444-3458, August 2016.

[3] H.K. Chu, C.S. Chang, R.R. Lee, and N.J. Mitra, “Halftone QR codes,” ACM Transactions on Grapics, New York, vol.32, no.6, pp. 1-8, July 2013.

[4] R.W. Floyd, and L. Steinberg, “An adaptive algorithm for spatial gray-scale,” Proceedings of Society for Information Display, vol.17, no.2, pp. 75-77, 1976.

[5] M.S. Fu and O.C. Au, “Data hiding watermarking for halftone images,” IEEE Trans. Image Process, vol.11, no.4, pp. 477-484, April 2002.

[6] G.J. Garateguy, G.R. Arce, D.L. Lau and O.P. Villarreal, “QR images: optimized image embedding in QR codes,” IEEE Transactions on Image Processing, vol.23, no.7, pp. 2842-2853, 2014.

[7] D.L. Hecht, “Printed embedded data graphical user interfaces,” IEEE Computer, vol.34, no.3, pp. 47-55, 2001.

[8] P.C. Huang, C.C. Chang, Y.H. Li and Y.J. Liu, “Efficient access control system based on aesthetic QR code,” Personal and Ubiquitous Computing, Vol. 22, no. 1, pp 81–91, November 2017.

[9] S. S. Lin, M.C. Hu, C.H. Lee and T.Y. Lee, “Efficient QR code beautfication with high quality visual content,” IEEE Transactions on Multimedia, vol.17, no.9, pp. 1515-1524, September 2015.

[10] L. Lin, S. Wu, S. Liu, J. Bo, “Interactive QR code beautification with full background image embedding,” Second International Workshop on Pattern Recognition, SPIE vol.10443, May 2017.

[11] S. Qiao, X. Fang, B. Sheng, W. Wu, E. Wu, Structure-aware QR code abstraction,. Vis. Comput. Vol. 31, pp. 1123-1133, 2015.
[12] H.C. Wang, P.C. Hsiao and C.M. Lien, Method of watermark with hybrid halftone dots. U.S. Patent 7,554,699, 2009.
[13]Y.M. Wang, C.T. Sun, P.C. Kuan, C.S. Lu, & H.C. Wang. Secured graphic QR code with infrared watermark. IEEE International Conference on Applied System Innovation. Chiba, Tokyo, Japan. 2018.

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