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High-Capacity Color QR Code Based on Grayscale Design

Xinxin Zhao[1], Peng Cao[1]
[1]*Beijing Institute of Graphic Communication, China*

Abstract: QR code capacity and anti-counterfeiting is an important problem that needs to be solved. Based on the application requirements of large-capacity and anti-counterfeiting 2D codes, this study generates large-capacity color 2D codes by using primary and mixed colors multiplexed into the 2D codes, based on the RGB triple color equation, encoded by grayscale encoder, and realizing multi-code composite information modulation. The proposed color two-dimensional code can be read directly by the reading device, and through the computer color filtering software color filtering processing, the composite implanted secret two-dimensional code can be read separately, so as to realize the high-capacity integration and anti-counterfeiting function.
Keywords: storage capacity; Anti counterfeiting traceability; Color QR code; Multi channel; QR code

I. INTRODUCTION

QR codes are popular two-dimensional barcodes that are widely used in a variety of fields due to their fault tolerance, wide encoding range and fast response to scanning. For example, it is used in commercial, diplomatic and military fields. However, the current existing 2D barcodes are seriously hindered in their applicability due to limited data capacity and lack of information security strategies. To address this issue, researchers have proposed color QR codes, which are designed to contain more information in the same version, and the introduction of color can provide some additional functions. In terms of the current state of research on color QR codes, the technology is still in its infancy, not only because it relies on specialized scanning tools, but also because it is limited by the size of the color gamut, which leads to the research on color QR codes falling into a rut.

The essence of color 2D code is to extend from two-dimensional plane to three-dimensional stereo, so as to realize the multi-dimensional bearing of data information. However, for the practical application of color two-dimensional code, in view of the current research status of color two-dimensional code, has not been widely used. The reasons for this are: there is no uniform standard for color 2D code, which is not compatible with ordinary 2D code technology; the generation authority of color 2D barcode is not open to the users, which leads to the user's demand cannot be met in time.

Based on previous research, this study designs a new type of color QR code by using primary and mixed color color modules. This type of color 2D code is to use one 2D code as the plain code and the other two as the dark code, using the RGB triple base color grayscale equation ,the color and grayscale encoding of the plain code image as the carrier and the two dark codes of the information modulation $Y = 0.3R + 0.59G + 0.11B$, so as to make them compound into one.

II. CORRELATION THEORY

From the perspective of color QR code reading, most of the researchers proposed color QR code reading by decoding the black and white QR code in the color channel by proprietary decoder on the basis of the black and white QR code decoding process. On the one hand, most of the current color QR codes only use the color as a carrier or a lookup table for decoding, on the other hand, these color QR codes pay more attention to the selection of shades when choosing the different color modules and neglect to differentiate between them in grayscale, so that color QR codes need to be decoded by a specific algorithm to read them.

In this paper, color QR codes are generated using primary colors and mixed colors, the mix of primary colors is shown in Table 1:

Table 1: Primary color mixing results

Color1	Color2	Color3	Results4
R	G		Yellow
G	B		Cyan
R	B		Magenta
R	G	B	White

Based on the RGB three-color grayscale equation: $Y = 0.3R + 0.59G + 0.11B$ (1) Y is the calculated grayscale value and R, G, and B correspond to the normalized values of the red, green, and blue channels of the color QR code respectively.

In black and white QR code data is represented by black and white pixels and color QR code is represented by pixels of selected color module. After the color filtering process, the color modules that represent the plain code are filtered out of the corresponding color to get the new grayscale, i.e., after the color QR code is decoded, a color image is converted into a grayscale image corresponding to the original color QR code before the color is flipped. That is: under the red channel only allows red to pass, filtering out blue, that is, G, B set to 0, green channel, blue channel under the same reason [1]. Specifically, as shown in Table 2 Table 3 Table 4 below based on the color flip under different channels, the black and white pixels are represented by 0 and 1 respectively:

Table 2: Red channel color flip

Original color	Original pixel point	Pixel point after flip
R+G+B	1	1
R+G	1	0
G+B	1	1
G	1	0
R+B	0	1
R	0	0
B	0	1
R+G+B	0	0

Table 3: G channel color flip

Original color	Original pixel point	Pixel point after flip
R+G+B	1	1
R+G	1	1
G+B	1	1
G	1	1
R+B	0	0
R	0	0
B	0	0
R+G+B	0	0

Table 4: B channel color flip

Original color	Original pixel point	Pixel point after flip
R+G+B	1	1
R+G	1	1
G+B	1	0
G	1	0
R+B	0	1

R	0	1
B	0	0
R+G+B	0	0

III. ALGORITHM DESIGN

We use the color coding technique to composite the plain code and the secret code to get the color QR code based on keeping the complete structure of the traditional black-and-white QR code. Before the composite are the same version number of the two-dimensional code, the purpose of doing so is to maximize the data capacity at the same time to maintain the traditional black and white two-dimensional code of strong robustness and strong error correction. The following is a schematic diagram of the color QR code structure as shown in Figure 1:

Fig1 Schematic structure of color QR code

3.1 Color QR code generation method

Step 1: Generation of plain code and dark code image of 2D code.

According to the actual application needs, such as article coding and anti-counterfeiting needs, the text information, network connection information, etc. were entered into the visible light can be read directly into the plain code two-dimensional code and in the addition of optical color filtering or computer image color filtering in the dark code two-dimensional code generation software.

Step 2: Gray scale encoding.

Encode the grayscale information presented by the three RGB colors and mixed colors to generate a grayscale encoding table.

Step 3: Multi-code composite modulation based on grayscale lookup table.

The QR codes are ordinary binarized images before composite. Color dark color block with 0 , color light color block with 1, according to this method bright code image and dark code image as a unit of 0 , 1 data array, while in accordance with the way of the look-up table, to complete the traversal of the data, to achieve multi-code composite information modulation.

Step 4: Multi-code composite color anti-counterfeiting two-dimensional code.

The color 2D code in RGB format generated after information modulation.

3.2 Color definition rules for color 2D code

Compared with the traditional black and white 2D code, the color 2D code increases the module color dimension, which easily affects the detection of the 2D code symbol graphics and brings more challenges to the decoding part of the color 2D code. The recognition of black-and-white QR code is to judge the depth of the current module by the normalization of the local gray scale. Therefore, how to select the color modules so that the shades of gray of each module are correctly distinguished is the key to make the color QR code can be correctly decoded.

Based on the RGB color space, in order to increase the anti-jamming tolerance between modules and modules, when choosing color modules, we make the distinction between dark and light color modules as large as possible, so as to improve the accuracy of color 2D code decoding. So, the module color of the color QR code can be selected from the color at the vertex of the RGB color space.

3.3 Gray scale encoding

The bright code, dark code 1 and dark code 2 are used as input variables and RGB is used as the output variable of the coding table to generate the coding table for grayscale coding. Among them, the dark color module is represented by "0" and the light color module is represented by "1". The grayscale coding table is shown in Table 5.

Table 5 Gray scale coding table

clear code	dark code1	dark code2	R	G	B
0	0	0	0	0	0
0	0	1	0	0	1
0	1	0	1	0	0
0	1	1	1	0	1
1	0	0	0	1	0
1	0	1	0	1	1
1	1	0	1	1	0
1	1	1	1	1	1

The color module attribute values and corresponding colors are shown below Table 6 and Figure 2:

Table 6 Color module attribute values

（0，0，0）	（0，0，1）	（1，0，0）	（1，0，1）
（0，1，0）	（0，1，1）	（1，1，0）	（1，1，1）

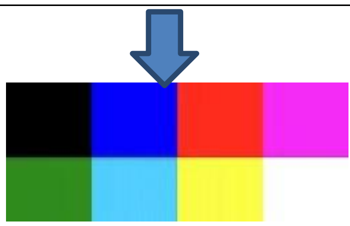


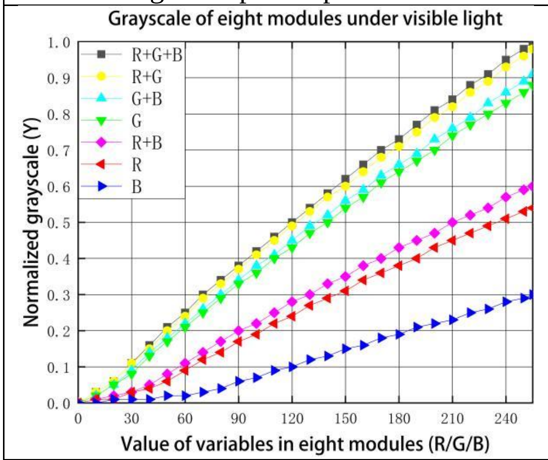
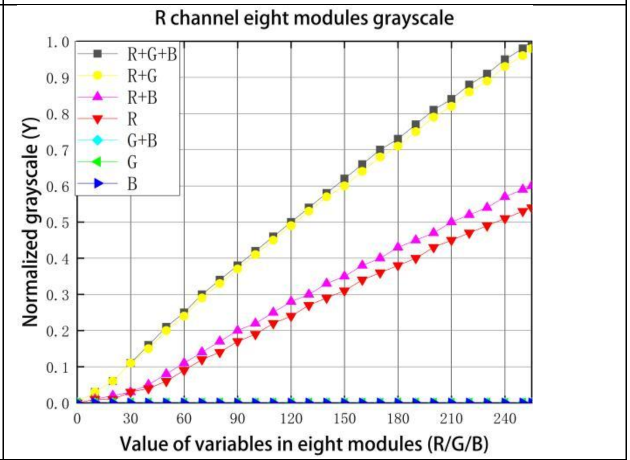
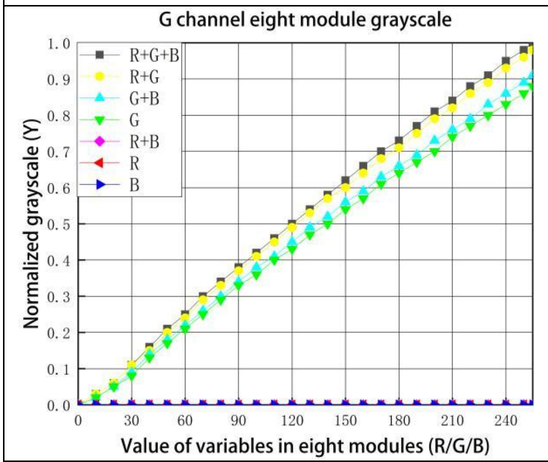
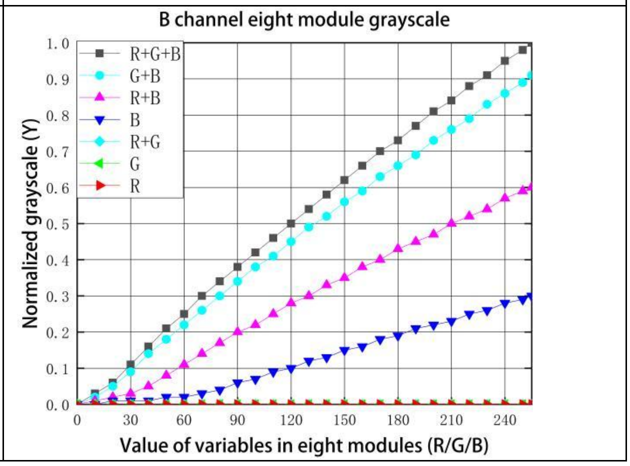
Fig 2 Corresponding Color Module

A QR code with version number 2 and size 750×750 pixels is used as the plain code for the experimental part, a QR code with version number 2 and size 750×750 pixels is used as the secret code 1 for the experimental part, and a QR code with version number 2 and size 750×750 pixels is used as the secret code 2 for the experimental part, i.e., V=2, N=25, and the generated color QR code is saved in the RGB format with the resolution of "600 dpi". Figure 3 shows the plain code, Figure 4 shows the cipher code 1 and Figure 5 shows the cipher code 2:

Fig 3 clear code
Fig 4 dark code1
Fig 5 dark code2

In order to accurately read out the plain code cipher information, the selected modules were tested in gray scale and compared, and the test results are shown in the table7 below:

Table 7 Gray scale comparison of different color modules

<table>
<tr><th>light in optical spectrum</th><th>R channel</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>G channel</th><th>B channel</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

According to the above grayscale test results, it can be seen that it is difficult to identify the cipher code information under the green channel, according to the test results under the red channel, blue channel, choose eight groups of suitable RGB color ratios. Using Matlab software programming, the color QR code is assigned. Use ordinary code scanning software to read the generated color two-dimensional code, and observe whether the bright code is readable; through image processing software (such as Photoshop software) to filter the color processing to get two dark codes. As shown in the figure is in RGB mode, close the G, B channel and R, G channel to simulate the effect of different color filters, the specific results are shown in Table 8:

Table 8 Simulation effect diagram

Clear code	Close the G and B channels	Close the R and G channels

IV. CONCLUSION

Based on previous research, in this paper, we propose a novel color QR code that can read multiple QR codes using spectral multiplexing technique and color coding technique. We further increase the capacity based on the color QR code proposed by the previous researchers and experimentally demonstrate the superiority and innovation of this method over the existing color QR code methods. In the future, we can print the test on paper and combine it with anti-counterfeiting technology and other fields to extend it to any desired application scenario.

V. REFERENCES

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