DEVELOPMENT OF COLOR QR CODE FOR INCREASING CAPACITY

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***Abstract*—Barcodes have been widely popular. Their popularity has encouraged an ongoing invention of decoding methods. Barcodes can be categorized into 2 main groups, namely one-dimension (1D) barcodes at which information is stored horizontally and two-dimension (2D) barcodes which contain information in both vertical and horizontal direction, promising a higher storage capacity compared to 1D barcodes. Despite high data density, an amount of information obtained in 2D barcodes still limited to some extent. This study selected QR Code (Quick Response Code) is a type of 2D barcode because firstly, it can handle a variety of information. Secondly, decoding is reasonably straightforward. Finally, the structure of QR code is specified clearly by its developer. This research aimed to increase QR Code capacity by proposing a color Quick Response Code (color QR code) encoding concept which can hold a larger amount of information than that of the traditional black and white QR Code regarding their physical size. A two-color (black and white) QR Code can store 1 bit in each module only, whereas a module of a color QR code with sixteen different colors can contain 4-bit data. In order to decode a color QR code, this study used a code reader equipped with at least an 8-megapixel camera and a decoding application was developed on Android (Android application on mobile phone) and Java (Java application on PC) platform.**

Keywords-QR code: Two-dimensional barcode, QR Code, Color QR Code, Quick Response Code, HSV color model.

I. INTRODUCTION

The QR Code is a 2D barcode which was invented by DENSO WAVE INCORPORATED in 1994. It is a type of data matrix codes. QR Code can handle a range of data, not only alphabetic characters but also numbers. Since QR code stores information both horizontally and vertically, it is capable to contain alphabetic characters over 100 times the amount of data hold by a traditional 1D barcode. In addition, QR code possesses many benefits such as fast reading speed, high accuracy, and considerable small physical size. Due to its advantages, QR code has been universally recognized and gained more popularity. It is currently more accessible because of the availability of decoding software on portable devices such as mobile phones and the opportunity for users to create a code through QR Code generator websites. Various types of information can be converted to QR code, for instance, Kanji Characters, Kana Characters, Hiragana Characters, Symbols and Control Code. Nevertheless, a tendency for codes capable of holding more information is rising. QR Code information capacity depends on versions, ranging from version 1 (21 x 21 modules) to version 40 (177 x 177 modules). Each version has a different number of modules. Each of them has different maximum data capacity according to the amount of data and character types. In other words, as the amount of data increases, more modules are required to comprise QR Code, resulting in larger QR Code symbols. So that, this research intended to present a notion of color QR code encoding in order to further information space compared with the traditional black and white QR Code at the same physical size.

Important principles need to be considered includes knowledge of QR Code technology and digital image processing technique. The details are as follows.

II. QR CODE AND COLOR MODEL

QR Code is an image-based data encoding formation which possesses a capability of storing different kinds of information, high decoding speed, and damage and distortion resistant. Features of QR Code and the structure of QR Code are described below.

A. *Features of QR Code*

- High capacity encoding of data.
- High-speed reading.
- Variety of type of data can be encoding capability.
- Readable from any direction from 360 degree.

B. *Structure of QR Code*

QR Code can be generated in 40 different versions. Each higher version has 4 additional modules per side (16 additional modules per version). Whilst version 1 contains 21x21 modules, version 40 comprises 177x177 modules. Figure 1 illustrates a structure of 2D barcodes.

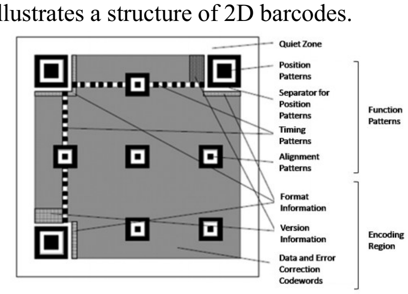


Figure 1. Structure of QR Code

The structure is composed of the following components:

978-1-4673-9721-6/15 $31.00 © 2015 IEEE
DOI 10.1109/SITIS.2015.42

1) Function Patterns are used to provide an exact position and shape of the code to a scanner. The patterns are composed of the elements described below.
    a) Finder Pattern consists of 3 identical square blocks called Position Detection Patterns which are arranged at the upper left upper right and lower left corners of the symbol. These allow the code to be scanned from any direction within a full 360 degrees with high reading speed.
    b) Timing Pattern is presented by black and white cells arranged alternatively. Timing Pattern is actually used for locating the code. The pattern is placed between the Position Detection Patterns.
    c) Alignment Pattern was introduced in version 2 of the QR Code and it is positioned approximately at the lower right corner. It is used for correcting the distortion of the symbol when it is curved. A number of Alignment Pattern is increased in higher versions.

2) Encoding Region is used for data encoding purposes. The area includes the following parts.
    a) Format Information section obtains Error Correction and Mask code. This is the first part to be read in a decoding process.
    b) Version Information section stores the version of a QR Code which is represented by 2 rectangular patches - one is placed to left of the top-right-corner Position Detection Patter and the other is located on the top of the bottom-left-corner Position Detection Pattern.
    c) Data and Error Correction Codewords area consists of both data and error correction Codewords. Both are stored into row and column array. Data Codewords are firstly encoded and placed into data space, and then the correction Codewords will be stored consecutively.

C. Color model

Color QR code design need a suitable color model that effect on decoding accuracy. This research use HSV color model to encode color QR code because HSV (Hue, Saturation and Value) color model is one of many color model that good at separate color.

- Hue is expressed as a number from 0° to 360° representing hues of red (starts at 0°), yellow (starts at 60°), green (starts at 120°), cyan (starts at 180°), blue (starts at 240°), and magenta (starts at 300°).
- Saturation is the amount of gray (0% to 100%) in the color.
- Value works in conjunction with saturation and describes the brightness of the color from 0% to 100%.

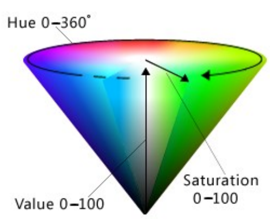


Figure 2. HSV color model

HSV describes color in terms of shade and brightness. So, for low values of Saturation, a color can be approximated by a gray value specified by the Intensity level while for higher Saturation, the color can be approximated by its Hue.

III. RELATED WORKS

A. CQR CODES: COLORED QUICK-RESPONSE CODES

By Max E. Vizcarra Melgar, Alexandre Zaghetto, Bruno Macchiavello, Aderson C.A.Nascimento, 2012

This study proposed a concept of QR Code encoding by adding more colors (green, yellow and red) along with black and white. After decoding 15 different snapshots among 120 of 1.3 cm x 1.3 cm printed photos, the result is presented in Table I.

CQR Code	Correctly decoded	Average symbol error (%)
1	15	0.97
2	15	0.53
3	14	5.49
4	15	8.79
5	15	8.24
6	13	14.8
7	15	7.25
8	15	3.04

Table I. The decoding result of 15 snapshots

B. The Use of Alignment Cells in MMCC Barcodes

By Siong Khai*, Douglas Chai and Alexander Rassau, 2010

This research focused on correcting the error in color code decoding while being scanned with a cell phone camera. The cause of error was expected to be distorted surface of the code. The experiments were to decode the color code without alignment while scanning and decode the color code with alignment while scanning.


Figure 3. Color code without alignment while scanning


Figure 4. Color code with alignment while scanning

The experiment investigated the decoding process by employing Visaul Studio .NET Compact Framework environment with C# on HTC Touch Diamond phone and Windows Mobile 6.1 phone. Both were equipped with a 3.2 mega pixel camera. The researchers found that the alignment of color code enhanced the quality of a decoding process. Furthermore, data density was increased when decoding process was improved.

IV. THE PROPOSE METHODOLOGY

QR Code are not only capable of handling a variety of data types, but also possesses larger data storage than some other types of 2D barcodes. However, their maximum data volume may be inadequate for a demand for more data space. Therefore, this research aims to propose a design concept for color QR code through the following encoding algorithm.

A. Color QR Code Encoding

QR Code symbol consists of an encoding region and function patterns, as shown in figure. 1. Finder, separator, timing patterns and alignment patterns comprised function patterns. Function patterns shall not be used for the encoding data. The finder patterns located at three corners of the symbol intended to assist in easy location of its position, size and inclination, the encode procedure of QR Code including follows steps. Firstly input data is encoded in according to most efficient mode and formed bit stream, the bit streams are divided into Codewords. Then Codewords are divided into blocks. All these Codewords are put into a matrix. Finally function patterns are added into the QR symbol. A QR Code symbol is formed. Encoding input data for color QR code is described below.

Define sixteen different colors for encoding color QR code.

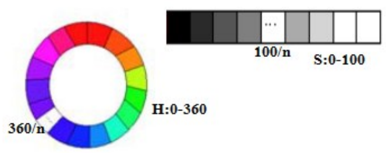


Figure 5. Circular representation of hue and linear representation of gray values

White modules configure to S=0, V=100, black modules V=0, gray modules H=0, S=0 and Value as a center of range of value calculated by subtracting the lowest (0) from the highest value (100) divide number of gray color (n). In Figure 5. show calculated range of value, this research use 2 shade of gray and color modules S=100, V=100 and Hue as a center of range of hue calculated by subtracting the lowest (0) from the highest Hue value (360) divide number of color (n). In Figure. 5, show calculated range of Hue. In figure 6, show convert binary input data to hexadecimal.

0000	0001	0010	0011
0100	0101	0110	0111
1000	1001	1010	1011
1100	1101	1110	1111

➡

0	1	2	3
4	5	6	7
8	9	A	B
C	D	E	F

Figure 6. Converting binary input data to hexadecimal

Pair hexadecimal data to color, fill in QR Code module. Show in Figure 7.

0	1	2	3
4	5	6	7
8	9	A	B
C	D	E	F

➡

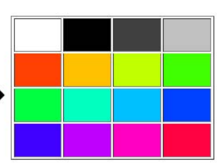


Figure 7. Pair hexadecimal to color code

And encoding function patterns will be the same standard QR code process.

Figure 8. Color QR code

For generating and acquiring color QR code. The color QR code encoder was realized with the help of Zxing, a Java library for encoding data in standard QR code symbols.

B. Color QR Code Decoding

The color QR code decoding process is similar to standards QR code decoding process. However, reading color has difference that is standards QR code transfer image color to grey but color QR code reads image color then transfer to hexadecimal and binary data respectively for decoding (Described in encoding process in previous section) and next step will be the same standard QR code process.

The decoder was built with the help of Zxing, an Opensource Java, Android project for improving the processing of QR code. In our implementation, the decoder tries to detect the color palette. If the color palette is successfully detected, the decoder tries to process a color QR code. The image processing phase ends by returning a matrix representation of the scanned code, in color QR code a Bitmatrix (0,1) is not adequate to represent the chromatic information of the modules. The acquisition process ends with a matrix of vectors that describe the scanned modules according to the color model used by the scanning equipment. Each scanned module is represented as a vector in the color model. Once Bitstream is reconstructed, the decoding process can retrieve the original input. Reading the color QR code is described below.

After the type of barcode is detected which is forwarded for decoding. Acquired image is converted to bitmap. In computer graphics, when the domain is rectangle, a bitmap gives a way to store a binary image. Image consists of pixels 1 bit image consist of 24 bit RGB. The entire Image can be thought of as two dimensional arrays of pixel values. We refer to such array as a bitmap. In next step the bitmap is converted to the RGB value of a pixel is first transformed to the HSV value using a method suggested in [3]. The feature is next extracted from each image pixel. After extraction, the pixel features are clustered using the K-Means clustering algorithm (suggested in [4]) to group them into regions of similar color within QR Code module, then analysis group of pixel compare to original color for match color data to hexadecimal after that convert hexadecimal to binary and next step will be the same standard QR code decoding process.

V. EXPERIMENTAL RESULTS

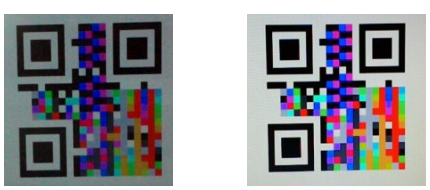
This research developed a prototype that implements the encoding (developed on PC, Java) and decoding (developed on Android and PC, Java) process for color QR code. In particular, we implemented two different applications, the encoder and the decoder, while we executed some performance tests using our prototype.

Experimental environment	Personal computer	Mobile device (Android)
CPU	Intel core i5-4200U CPU 2.30 GHz	Dual core 1.2 GHz
Memory	4 GB	1 GB
OS	Windows 7	Android 4.4 KitKat
Programming language	Java 8	Android
Camera	-	8 mega pixel
Monitor display	12.5 inch HD 1366x768 pixel	14 inch TFT LCD 800x480 pixel

Table II. Experimental environment

Image	Device	Source	Accuracy (%)
	Mobile device (Android)	Camera	75
	Personal computer	File	100
	Mobile device (Android)	Camera	100
	Personal computer	File	100

Table III. Experimental results



(a) (b)

Figure 9. Capturing Color QR code (a) Light is not enough (b) Light is enough

In this section, present encoding and decoding experiments to evaluate the performance. We used the first version of the QR code and the decoding was performed under the environment shown in Table II. Focus on comparing the accuracy between color QR code decoding algorithm and standards QR code. The experiment result shows that color QR code (16 different color) decoding algorithm has worse accuracy (correct 15 from 20 snap short = 75% accuracy) than standards QR code decoding when decoding process execute on mobile device reader equipped with an 8-megapixel camera and a decoding process was developed on Android, but decoding process was developed on java application execute on personal computer found that the experiment result same as standards QR code decoding (100% accuracy) and when we capture it with not enough light for camera decoding has the worst accuracy show in Figure 9(a). In the concluded that the design color QR code with a different color. So the resulting QR code can store much more. But decoded may not be accurate, depending on environmental conditions (light, monitor or printer display color QR code) while decryption and decoding performance of the equipment used.

VI. CONCLUSIONS

This research created a new QR Code (Color QR Code) for increasing capacity of QR codes, so decoding process has difference that is standards QR code, color QR code reads image color then transfer to output data. It was found, variety of color can effect increasing capacity of QR codes and reading accuracy.

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