High Capacity Multi Colored Code System

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***Abstract*—This project describes the development of multi colored code. The main objective is to develop a code which has a higher data capacity than the current QR code system. This paper describes the layout design of the proposed multi colored code. The multi colored code employs Hamming data error correction technique and color multiplexing using 8 types of colors. These colors are namely red, green, blue, cyan, magenta, yellow, white and black. A decoder application is also designed in order to process and decode the captured multi colored code. From result, it shows that the decoder is able to decode the multi colored code with low decode error rate within the range of 6cm to 13cm. The first prototype of the proposed color code is having approximately same number of module as QR code Version 10. As result, the proposed color code is able to store almost double of the data capacity compared to the QR code Version 10.**

Keywords—Color; Code; High; Capacity

I. Introduction

The barcode is a single dimensional (1D) optical data representation that is invented by Bernard Silver and Norman Joseph Woodland since 1948 [1]. The barcode represents information systematically by varying the widths and spacing of parallel lines. Before the emerging of the smartphones, the barcode is decoded by using barcode reader which also known as optical scanner. Now, the mobile software applications are available for the smartphones to decode the information of the barcode by using the camera on the smartphones.

However, as technology advances, the required size for the data storage increases as well. Thus, the maximum size of barcode which is able to store 48 alphanumeric character is no longer sufficient. The single dimensional (1D) barcode eventually improvised into two dimensional (2D) barcode. The Quick Response (QR) code is the most common standard among the 2D barcodes.

The Quick Response (QR) code is a standard for a type of 2D barcode that is invented by a development team led by Masahiro Hara of Denso Wave Incorporated, Japan in 1994 [2]. The layout of QR Code is monochrome, which is constructed by black squares on the white background [3]. The layout of QR code is composed by two main components. They are known as function patterns and encoding region. The function patterns such as finder pattern, timing pattern and alignment pattern are used to assist the decoder to locate the exact position of QR code. The encoding region consists of format information, version information, data and error correction codewords. These are the information that encoded in the QR code which can only be retrieved by using the decoder [4].

There are few features that make the QR code unique from the barcode and previous matrix barcode. First, its high capacity of encoding data can achieve 100 times capacity of the 1D barcode. Secondly, QR code is able to encode various type of data type such as numerical, alphanumerical, binary data and Japanese words (Kanji) as well. Another feature is known as 360 degree of readability, which means the QR code does not have to be read exactly on straight upward direction. Lastly and the most exclusive feature of QR code is the error correction capability. The error correction algorithm utilized is known as Reed-Solomon error correction. The current QR code is able to achieve the error correction capability up to 30%.

The usage of QR code is extremely wide. In the beginning, the invention of QR code is only to replace barcode in inventory tracking. However, as technology advances, the QR code is widely used for other purposes such as ticketing, entertainment, commercial tracking, and product marketing. Due to its capability to encrypt data such as website URL, many actions such as browse web, bookmark webpage, initiate call, send short message, send emails, connect to WIFI networks, access information and purchase items can be performed by just single scanning on the QR code. Besides, QR code are also used in education to increase the efficiency in teaching [5][6].Thus, QR code is able to increase the efficiency of various task of our daily life.

The maximum data storage capability which can be achieved by the latest version (Version 40) of QR code is approximately 3 kilobytes [7]. As the technology advances, the expectation on the QR code is arisen as well. People may expect that the QR code is able to store an image, a short video or even a document in it. However, this current capability of the QR code is not sufficient to allow the QR code to store these data.

In this project, the main objective is to develop a code that is able to store twice as much data than QR code. To achieve this aim, this paper proposes the multicolor data encryption code which encrypts the information into square block with various colors and store onto a rectangular code layout. Since the QR code consists of the feature of data error correction, the proposed QR code is also designed by considering Hamming Error Correction Code as error correction algorithm. For the first prototype, the color code is designed according to the number of module consisted in QR Code Version 10. Then, the data capacity of the developed color code is assessed by comparing with data capacity of QR Code Version 10. Besides, another objective of this project is to develop a decoder application in order to decode the proposed color code.

II. Design And Implementation

A. Layout Design

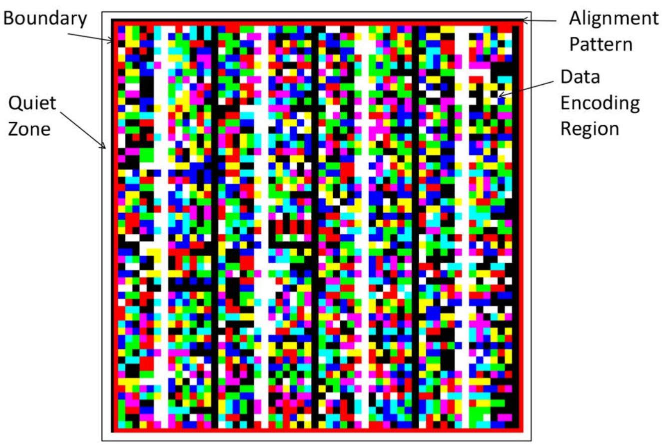

Fig. 1: Multi Color Code Layout

Fig. 1 shows the designed layout of the Multi Color Code.The function of each component of the Multi Color Code layout is explained in detail as shown in TABLE I.

TABLE I: Function of Elements in Color Code

Component Name	Function
Quiet Zone	Margin around the code. This margin is free from any markings and indicates the boundary of the code.
Boundary	Red color region enclosing the Data Encoding Region. The Boundary is used to locate the position of the code.
Alignment Pattern	L-Shape in black color outside of the boundary. Alignment Pattern is the feature of the code to perform positioning of the code. This pattern is used to rotate the code for decoding when the code is misaligned.
Data Encoding Region	Area where both data and error correction codewords are encoded into color blocks. The information is stored into row and column array of the code.

B. Hamming Error Correction Code

Quick Response (QR) code employ Reed-Solomon error correction algorithm. However, due to the complexity of the Reed Solomon error correction algorithm, the decoding application requires long computational time in order to handle multi number of colors [2].

Thus, the Hamming Error Correction Code that currently used in error correction for random access memory (RAM) is employed in this Multi Color Code for data correction algorithm [9]. This feature allows the decoder application to auto correct the error bits once the error is detected.

The type of Hamming Code employed in the Multi Color Code is known as the Binary Hamming (7,4) code. This code is using 7 bits to encode data where 4 bits are data bits and 3 bits are parity bits. The parity bits are used to detect the error and determine the location of the error bits.

In this implementation, the Multi Color Code is aimed to encode the 255 data from the ASCII table. Thus, by referring to the ASCII table, the data in character form will be converted into binary form. Thus, the 255 data requires 8-bit binary number to represent a single character.

Since the Binary Hamming (7,4) code encodes only 4 data bits in 7-bits form, two Binary Hamming (7,4) code is required to encode a single character. The 8-bit binary number that used to represent the single character is divided into 4 most significant bits (MSB) and 4 least significant bits (LSB). Thus, both separated 4-bits data are encoded by using two Binary Hamming (7,4) code.

Consider the four data bits arranged as $d_4 d_3 d_2 d_1$. The equations used to determine the parity bits are shown in (1), (2) and (3).

$$p_1 = d_1 \oplus d_2 \oplus d_4 \quad (1)$$

$$p_2 = d_1 \oplus d_3 \oplus d_4 \quad (2)$$

$$p_4 = d_2 \oplus d_3 \oplus d_4 \quad (3)$$

Then, the parity bits will be encoded with the data bits and formed the 7-bits encoded data with sequence of $d_4 d_3 p_4 d_2 d_1 p_2 p_1$.

C. Color Multiplexing

Every bit of the data is represented by using black and white square block according to the value of bit. Bit with value '1' is represented by white square block while bit with value '0' is represented by black square block.

These blocks are stored into three layers. Then, these three layers of data are converted into color blocks by using color multiplexing technique.

The color multiplexing technique is implemented by employing additive color model [10][11]. The additive color model utilized in this approach is the primary color known as Red, Green and Blue.

Each layer is represented by different colors. The first layer is represented by red color, second layer is represented by green color and third layer is represented by blue color.

By mixing the primary colors of different layer, it results in secondary colors which known as Yellow, Magenta and Cyan. Besides, if three primary colors exist in all three layers, it will eventually form white color. If there is no any color exists in all three layers, the resulting color will remain black color. The layer multiplexing technique is shown in TABLE II.

TABLE 2: Layer Color Multiplexing

First Layer (Red)	Second Layer (Green)	Third Layer (Blue)	Resulting Color
0	0	0	Black
0	0	1	Blue
0	1	0	Green
0	1	1	Cyan
1	0	0	Red
1	0	1	Magenta
1	1	0	Yellow
1	1	1	White

In this way, this method is able to create a multi color code which involves diversity of 8 colors, which are white, black, cyan, magenta, yellow, red, green and blue). Fig. 2 (a), (b) and (c) shows the data that encodes in black and white of each layer: layer 1, layer 2 and layer 3. Fig. 2(d) shows the color multiplexed code.

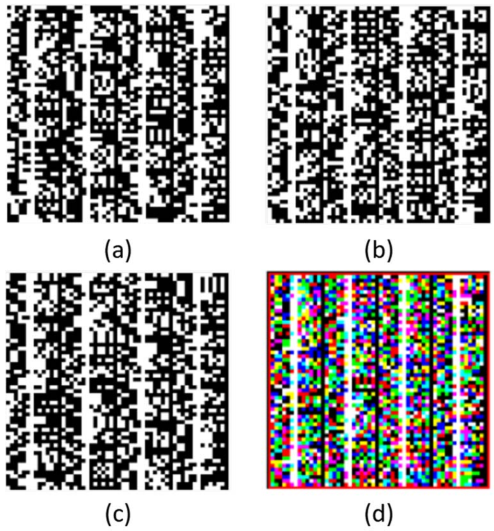

Fig. 2: (a) Layer 1 (b) Layer 2 (c) Layer 3 (d) Multiplexed Color Code

D. Decoding Algorithm

A decoder application is implemented to process and decode the captured image that consists of the multi color code.

The decoding algorithm starts to detect the alignment pattern of the multi color code. Then, performs the auto realignment if the multi color code is misaligned to ensure the multi color code is on upright position.

Then, the application detects the boundary of the multi color code and extracts the data encoding region. The data encoding region that consists of the data color block is to enhance with few image enhancing technique. These image enhancing techniques are used to pre process the image to reduce the detection error while decoding the color block into alphanumerical data.

Next, the color is processed to split the code back to three layers which consists of only binary colors (black and white). At last, these codes are decoded back into alphanumerical data according to ASCII table. During this step, the bit error correction is also implemented to correct the error bit using the Hamming Code.

The algorithm is as shown in Fig. 3.

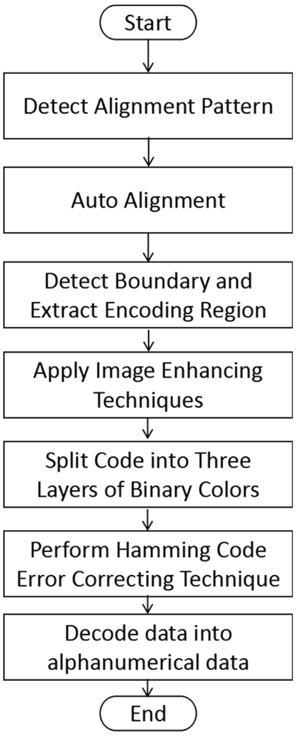

Fig. 3: Decode Application Flowchart

III. Results And Discussion

A. Simulation Setup

For this research project, two prototype softwares are developed for both encoding and decoding purpose. Both software is developed by using Visual Studio C# [8]. The application is run on a personal computer with Windows operating platform. The TABLE III shows the specifications of the personal computer involved.

TABLE III: Specification of Personal Computer Utilized

Operating System	Windows 10 Home
Processor	Intel® Core™ i5-7200CPU @ 2.70GHz
Memory (RAM)	8.00GB
System Type	64-bit Operating System
Programming Platform	Visual Studio C#

For the experimental testing, the printed multi color code is having dimension of 20 mm× 20 mm. The multi color code is printed on a white 80g/m2 density A4 paper.

The testing set is composed by 75 snapshots captured by using the primary camera of the Huawei Mate9 mobile phone. The resolution of the primary camera is 20 megapixels. These images are captured under the condition of indirect daylight illuminance.

B. Average Decode Error vs Captured Distance

The testing images are captured for five images in the specified captured distance. Thus, the average decode rate is calculated by averaging the unsuccessful decoding rate of five captured images. Fig. 4 shows the result of average decode error in the specified captured distance.

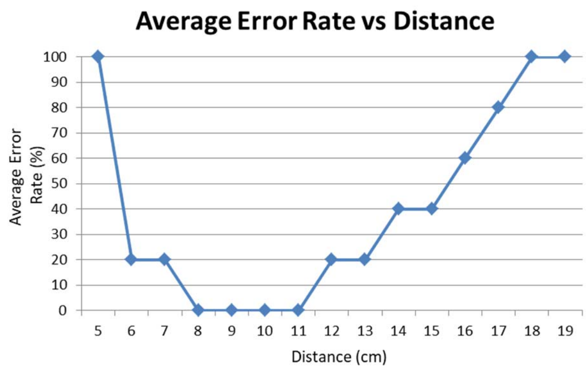

Fig. 4: Average Decoding Error Rate vs Captured Distance

C. Data Capacity vs Module

The data capacity of the multi color code is compared to the existing QR code. In QR code, the data is represented as module which is the small square block that is similar to the color block of the developed multi color code.

The data capacity of the multi color code is compared to the QR code Version 10 which has the approximately same number of module. The comparison is done and shown in TABLE IV.

TABLE IV: Comparison between QR code (Version 10) with Multi Color Code (First Prototype)

Code	Module (Square Block)	Alphanumerical Data Capacity
QR Code (Version 10)	57*57 = 3249	395
Multi Color Code	56*56 = 3136	672

According to the comparison shown in TABLE IV, the Multi Color Code which has approximately same number of module with QR code Version 10, consists of 1.7 times more data capacity compare to QR code. Thus, it almost doubles the data capacity compare to QR code.

IV. Conclusion

The results also show that the color code is only able to be decoded with acceptable error rate within the range 6 cm to 13 cm. The quality of the acquired image is the major contribution. Thus image enhancement and processing techniques have to be improved in order to reduce the average decoding error rate.

In conclusion, a code that utilized multi color to encode data is implemented. The first prototype of the multi color code which has the approximately same number of module (square block) with QR code Version 10 is able to store data approximately double the capacity compare to the QR code. However, the encoding technique still can be improved to increase the capacity in order to store solely alphanumerical data instead of all the elements in ASCII table.

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