Proceeding of IC-ITS 2018 e-ISBN:978-967-2122-64-7
4th International Conference on Information Technology & Society
October 30th-31st, 2018, Selangor, MALAYSIA

Fuzzy Encoder for Four Layers Color QR Code

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Abstract. In this paper we proposed four layers QR code encoder utilizing fuzzy technique. The framework extended the If maximum capacity for current color QR code by 25%. The fuzzy encoder will select the best fit color QR code in aspect of the number of colors according to the file side and the space on the paper. Then, the encoder will divide the file into maximum of four layers of QR code and give each layer a specific color by multiplexing those QR code. We produced color QR code with maximum capacity of four times larger than black and white QR code. The encoder also proposed color reference on the locater pattern in the QR code to easily identify the number of colors used in the generated color QR code.

Keywords: fuzzy, QR code, QR code version, color QR code, encoder, color reference.

INTRODUCTION

2D barcodes is visible images that help to transfer information using mobile camera. QR code is a popular type of 2D barcode. It gains its popularity for many features like, higher data capacity, 360 degrees of reading, error correction, fast encoding and decoding. Because of these features now we can see QR code anywhere, for example in name card, bus ticket, security tags, store front, etc. However, until now we can see the usage for QR code only for small data for example in text file website link and contact information. This limited usage is due to the size limitation for current QR code. Since the maximum data size for black and white (B/W) QR code is 10208 bits [1, 4, 5]. B/W QR code is unable to encode simple files like PDF files, Word documents and PowerPoint slide show. Having QR code with larger capacity will facilitate encoding more types of data and extend the popularity for QR code. This paper consists of six sections. Section 2 is about QR code. Section 3 reviews the related research works. Section 4 proposed our fuzzy QR code encoder, section 5 discusses on the experiments and finally section 7 is the conclusion and future works.

QR CODE

B/W QR Code

B/W QR code consists of 8 sections [4, 6, 8]. Figure 1 shows the QR code and its sections.

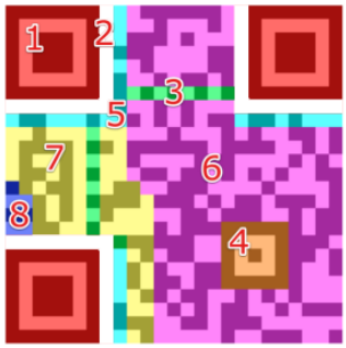

FIGURE 1. QR Code Sections.

Each of these sections has a specific rule as follows:

1. Finder Pattern: The finder pattern consists of three identical structures that are located in all corners of the QR Code except the bottom right corner. Each pattern is based on a 3x3 matrix of black modules surrounded by white modules that are again surrounded by black modules. The Finder Patterns enable the decoder software to recognize the QR Code and determine the correct orientation.
2. Separators: The white separators have a width of one pixel and improve the recognisability of the Finder Patters as they separate them from the actual data. They are generally always white
3. Timing Pattern: Alternating black and white modules in the Timing Pattern enable the decoder software to determine the width of a single module.
4. Alignment Patterns: support the decoder software in compensating for moderate image distortions. Version 1 QR Codes do not have Alignment Patterns. With growing size of the code, more Alignment Patterns are added.
5. Format Information: section consists of 15 bits next to the separators and stores information about the error correction level of the QR Code and the chosen masking pattern.
6. Data: Data is converted into a bit stream and then stored in 8 bits parts (called code words) in the data section.
7. Error Correction: Similar to the data section, error correction codes are stored in 8 bits long code- words in the error correction section.
8. Remainder Bits: This section consists of empty bits of data and error correction bits cannot be divided into 8 bits code words.

B/W QR code has different version, form version 1 to 40. The data size that each version can encode depends on the data type and error correction level. There are four types of error corrections, each level can fix certain percentage of damage [1, 2] as follows:

[L] - Low up to 7% damage
[M] - Medium up to 15% damage
[Q] - Quality - up to 25% damage
[H] - High - up to 30% damage

Error correction comes with a cost, the higher the error corrections, the lower data to be encoded. Table 1 show the data size that can hold QR code from version 1 until version 3.

TABLE (1). QR Code Version and Its Data Size.

Version	Modules	ECC Level	Data bits (mixed)	Numeric	Alphanumeric	Binary	Kanji
1	21x21	L	152	41	25	17	10
		M	128	34	20	14	8
		Q	104	27	16	11	7
		H	72	17	10	7	4
2	25x25	L	272	77	47	32	20
		M	224	63	38	26	16
		Q	176	48	29	20	12
		H	128	34	20	14	8
3	29x29	L	440	127	77	53	32
		M	352	101	61	42	26
		Q	272	77	47	32	20
		H	208	58	35	24	15

Color QR Code

To overcome the size limitation for B/W QR code, we add layer a color, which means the color QR code data size is equal to the number of layered color QR code. The number of color used for color QR code is equal to the number of QR code layers multiply by B/W QR code data size. The data size is calculated using the following formula:

Color QR-Code data size= log2N [2] * D
Where, N is the number of colors, and D is the data size of B/W QR code.

Figure 2 shows an example of color QR code.

FIGURE 2. Color QR Code.

RELATED RESEARCH WORKS

We will describe in detail three systems that we are using as our benchmarks in our research work:

Research Work Zhibo Yang, 2016

They proposed a fast decoder for high density color QR code. The sender will split the user file into three equal chucks, each chuck represents a monochrome QR code then red, green, blue colors will be assigned to each black and white QR code. Using color multiplexing, color QR code is produced. Figure 3 shows the encoder process.

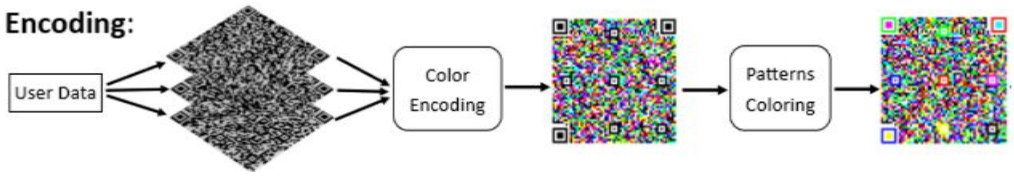

FIGURE 3. Encoder by Zhibo Yang, 2016.

From our review, this research provides good data capacity with acceptable success rate. However, the data capacity could be enhanced by adding more colors.

Research work by Blasinski, Henryk, 2013

They proposed a color barcode framework by exploiting the spectral diversity afforded by the cyan (C), magenta (M), and yellow (Y) print color channels commonly used for color printing. The receiver captures data from the printed paper and uses Color Interference Cancellation based on Kubelka-Munk theory (Diffuse reflection) to get the color values.

From the sender, the text file is split into three chucks. Then three monochrome QR code (Cyan, Magenta, Yellow) are generated. Using color multiplexing between the three QR codes, QR code with eight colors are produced.

From our review, this system provides good data capacity with excellent success rate for printed QR code. However, their algorithm cannot work for the QR code from computer screens, and the data size can be enhanced by adding more colors.

Research Work by Thilo Fath, Falk Schubert, and Harald Haas, 2014

Authors have proposed data transmission within an aircraft cabin. The data is transferred by stream of QR code. The QR codes are captured from a built-in camera of passenger's mobile phone and are decoded to reconstruct the transmitted data.

From the sender, first, the file, for instance text documents or images, is compressed to reduce the amount of data. Second, the encoded data is segmented into several packets. Each of these packets is visually encoded by a visual code resulting in a sequence of several visual codes. Fourth, this visual code sequence is displayed in a continuous loop on the inflight entertainment (IFE) screen like a common video film.

The sending and receiving process is shown in Figure 4. From our review, this system provides good data capacity. However, the success rate can be enhanced by adding colors in the QR code detection. In addition, the data size can also be increased.

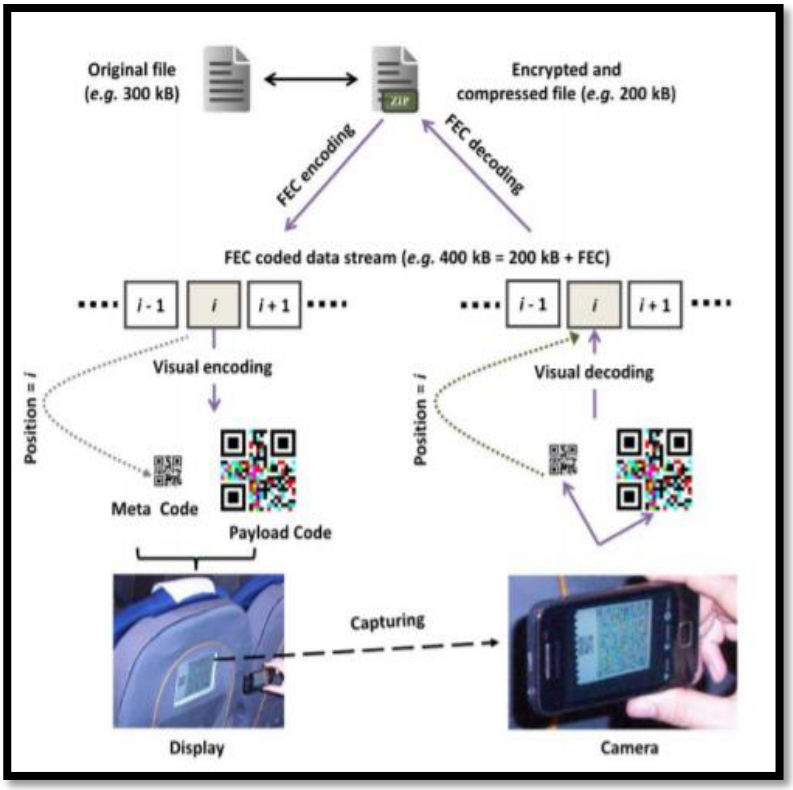

FIGURE 4. IFE Screen Fath, Falk Schubert and Harald Haas, 2014.

Comparison with Existing Systems

We compare the systems in four aspects consisting of: (a) the QR code generator, (b) maximum data size, (c) number of color, and (d) algorithm used as shown in Table 2.

TABLE (2). Research Work by Thilo Fath, Falk Schubert and Harald Haas, 2014.

Research Works	Generator	Max data size	Number of colors	Algorithm used
(Zhibo Yang , 2016)[22]	based on user choice	8900 byte	8	Color reference
(Blasinski, Henryk,2013)[19]	8 Color	3 Times > B/W QR code	8	Diffuse reflection
(Thilo Fath, Falk Schubert,and Harald Haas, 2014)[6]	B/W or 8 Color	9264 bit	8	Color multiplexing
Proposed system	Dynamic based on file size	4 time > original QR code	16	Fuzzy

From Table 2, it can be summarized that the maximum data capacity for existing work which can be hold per barcode = 3*23684= 71052 bit 8 colors.

QR Code Encoder

The encoder QR code generator algorithm is as follows:

- First the user inserts the max size in paper and its data to encode.
- Our framework will check the max size on paper and select the best fit black and white QR code for that space using fuzzy technique.
- Select the number of chucks = data size / max size for the selected QR code.
- Number of color = 2^ number of chunks.
- Generate black and white QR code for each data chunk and give each chunk a specific color.
- Merge all generated QR code into one color QR code.
- Replace the identification pattern with color reference identification pattern.

The encoder QR code generator algorithm is shown in Figure 5.

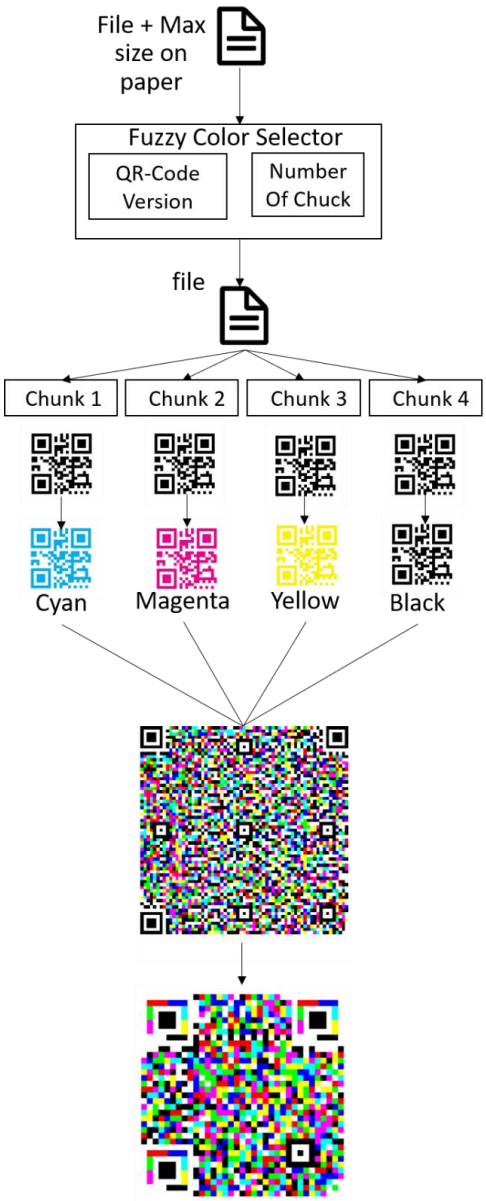

FIGURE 5. QR Code Generator Algorithm.

Fuzzy QR Code Version Selection

The proposed system has two input file size and the size on the paper. Figure 6 is an overview of the proposed fuzzy technique. The size on the paper is the maximum size for the generated QR code in pixels.

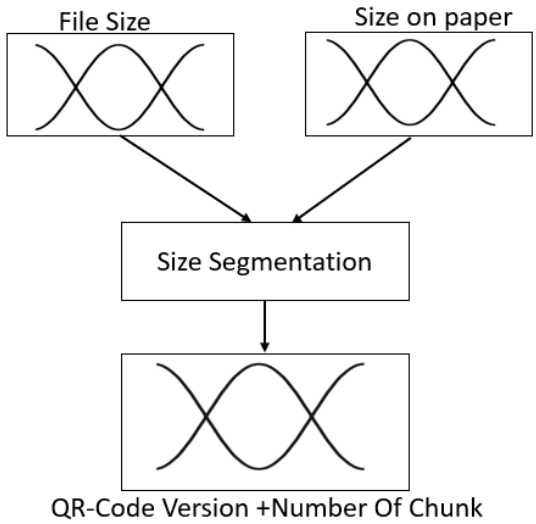

FIGURE 6. Overview of Proposed Fuzzy Generator.

Fuzzification

MAX operator is used to remove the ambiguity between the selected QR code versions, for example, if file size X we will select v, v+ will use the membership functions that will be explained in next section. The maximum value will be the color value.

Membership Function

The character or the membership function number of chuck minimum is 1 and maximum is 4. The output will be the number of chuck with the selected version (1, 2, 3, 4) based on the input or selected bigger version (1+,2+,3+,4+). Figure 7 shows the membership function.

Input membership functions

- Minimum: 0.
- Maximum: 4.
- Values (1, 1+, 2, 2+, 3, 3+, 4).

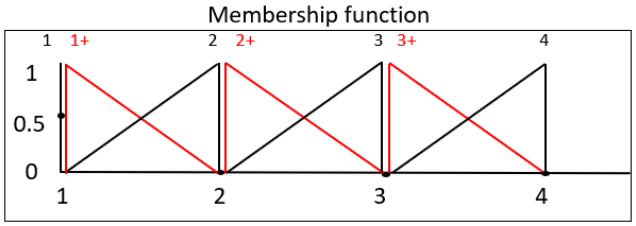

FIGURE 7. Membership Function for QR Code Generator.

Fuzzy Rules

In QR code generator, fuzzy rules are used to select the number of chunk + QR code version. In defuzzification we take the selected version and the resulting number, and we consider it as the number of chuck.

For the generator rules, if (selected value in (1,2,3,4)) then the selected version proceed, else select higher value and go for another round of fuzzy membership function.

Defuzzification

For this function, we obtained the QR code version and number of chuck. For the defuzzification process we obtained the result from the fuzzy rules and we divided the file, based on the number of chunk.

RESULTS AND DISCUSSION

For the generator evaluation, we compare our proposed frame work with existing QR code generator as our proposed system can encode four layers of QR code. We obtained 25% higher capacity than existing color QR code generator. Figure 8 shows the comparison between our generator and existing generator.

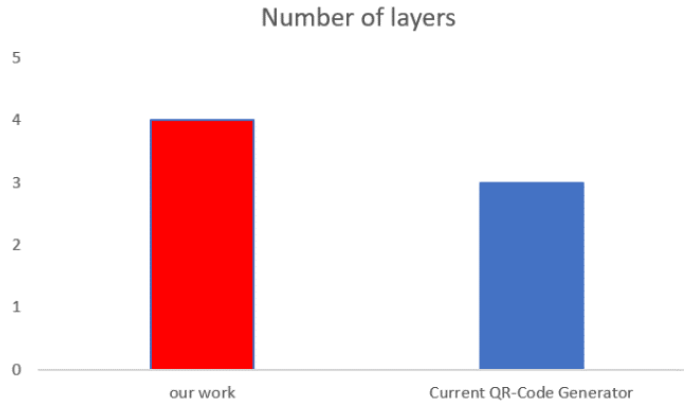

FIGURE 8. Comparison between QR Code Sizes.

CONCLUSION AND FUTURE WORKS

In this paper, we show our proposed four layers color QR code utilizing fuzzy technique and the result show that we can increase the data capacity for the current QR code by 25%.

For future works, the system will be tested for the decoder success rate, on both printed and on computer screen QR code.

ACKNOWLEDGEMENT

We would like to thank Universiti Putra Malaysia for support given under the Putra Grant, project code GP/2018/9621800.

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