FUZZY ENCODER FRAMEWORK FOR FOUR LAYERS COLOR QR CODE

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ABSTRACT

QR code is a popular type of two-dimension barcode due to high demand of QR code which makes it an active research area specifically to overcome QR code limitation. One of QR code limitation is encoding data size limitation. In this paper, we proposed four layers QR code encoder utilizing fuzzy technique to overcome size limitation. The framework extended the maximum capacity for three layers color QR code by 25%. The fuzzy encoder will select the best-fit color QR code in the aspect of the number of colors according to the file size and the space on paper. Then, the encoder will divide the file into a maximum of four layers of a black and white QR code and give each layer a specific color by color multiplexing for those QR codes. We produced a color QR code with a maximum capacity of four times larger than existing black and white QR code. The encoder also proposed color reference on the locator pattern in the QR code to easily identify the number of colors used in the generated color QR code.

Keywords: Fuzzy, QR code, Framework, Color QR code, Encoder, Color reference

1.0 INTRODUCTION

Two-dimensional barcode is a visible image that helps to transfer information using devices such as scanners and mobile camera. QR code is a popular type of two-dimensional barcode. It gains its popularity because of many features like higher data capacity, 360 degrees of reading, error correction, fast encoding and decoding. Due to these features, we can see QR code anywhere, for example in name card, bus ticket, security tags, storefront, etc. However, until now we can see the usage for QR code only for small data for example in small text file website link and contact information. This limited usage is due to the size limitation in 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 of QR code. Many research works address the size limitation and proposed three layers color QR code [26, 19, 6, 8, 9, 5]. These researches focused to extend the size of B/W QR code, without considering the extra empty space of small file encoded using color QR code. In addition, the encoder will encode color QR code with a static number of color because there is no way for the decoder to determine how many and what colors are used in the encoder.

The aim of this research work is to propose four layers dynamic color QR code to extend the maximum size limitation of current QR code. The proposed encoder utilized fuzzy logic to determine the number of layers needed based on the file size and color reference to tell the decoder what colors are used in the encoder. In this paper, the data is encoded, as a preparation for the QR code to be readable by the decoder.

This paper consists of seven sections. Section 2 explains about QR code. Section 3 reviews the related research works. Section 4 methodology, Section 5 proposed our fuzzy QR code encoder, section 6 discusses the experiments and finally, section 7 is the conclusion and future works.

2.0 QR CODE

2.1 B/W QR Code

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

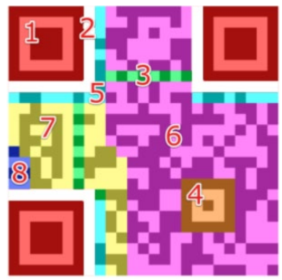

Fig. 1: QR Code Sections

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. QR Code decoder uses the finder patterns to locate the QR Code and rotate to the right position.

2 - Separators: it is the white area next to finder pattern the main function for this pattern to separate the finder pattern and data pattern.

3 - Timing Pattern: is consist of two lines horizontal and vertical. These lines are consist of black and white modules this pattern tells the decoder the exact size for the data model

4 - Alignment Patterns: is a black square like the finder pattern but with smaller size. the main function for this pattern is for geometric correction, and rotation, therefore we can see more alignments pattern with large QR Codes.

5 - Format Information: is the first section after the separators, it contains information about datatype and error correction level.

6 - Data: is the largest part of QR Code, and it contains the actual file that data.

7 - Error Correction: is the information that Reed-Solomon algorithm need to correct the error in the data section.

8 - Remainder Bits: this pattern tells the decoder what is the last data model that content data.

There are 40 versions for Black and white QR Code, each version has 4 models, each model is for error correction level. since QR Code can encode different data type, the data size that black and white QR code can encode is base in data size and error correction model [1,2]. the percentage for each error correction model is as follow:

[L] - Low 7% error correction
[M] - Medium 15% error correction
[Q] - Quality 25% error correction
[H] - High 30% error correction

Table 1 shows the data size for QR Code version 1, 2, and 3 bases on data size and error correction level.

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

2.2 Color QR Code

Color QR Code is consists of multiple color layers of monochrome QR Code, thus the data size for color QR Code is equal to the number of layers multiply by the size of black and white QR Code. and the number of colors is equal to 2^n. the following formula to calculate the size for color QR Code.

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.

Fig. 2 shows an example of a color QR code.

Fig. 2: Color QR Code

2.3 Current Color QR Generator Framework

Current Color QR Code Generator following general standard since all color QR Code generators use multiple black and white QR Code layers to generate color QR Code, this standard may be different in some generators in terms of sub-steps. The general steps for Color QR Code generator are shown in fig. 3.

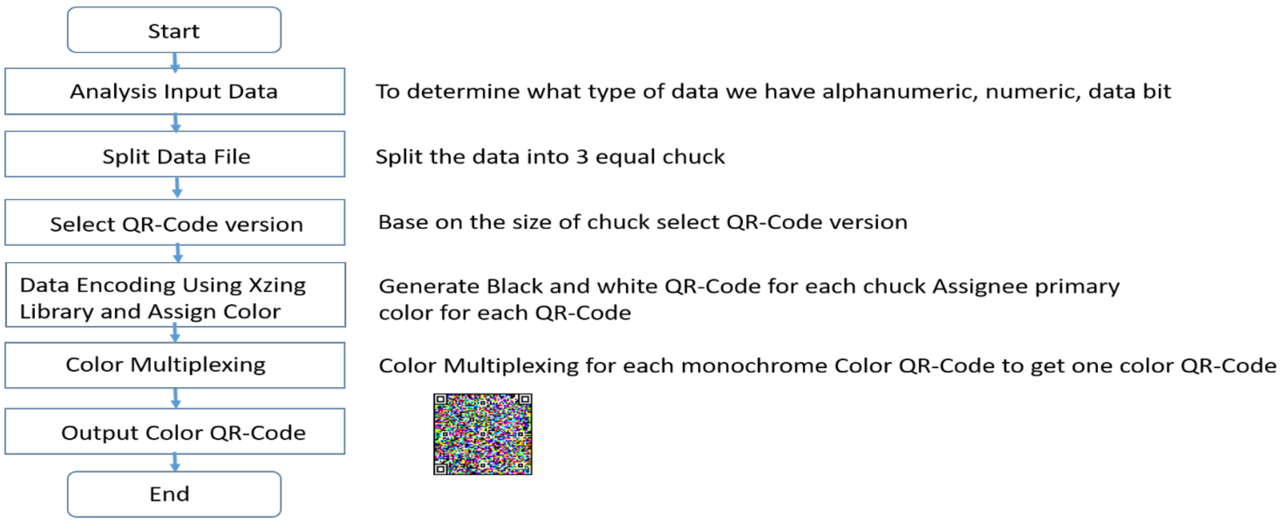

Fig. 3: Current Color QR Code Framework

3.0 RELATED RESEARCH WORKS

We will describe in detail five systems that we are using as our benchmarks in our research work then we will show a comparison table for those systems and our proposed encoder as follows:

3.1 Research Work by Zhibo Yang, 2018

They proposed a fast decoder for high-density color QR code.

The encoder will split the user file into three equal chunks, each chunk represents a black and white QR code then, color encoding primary colors (red, green, blue) will be assigned to each black and white QR code. Using color multiplexing, color QR code is produced, finally, pattern coloring will assign the color used to the locator. Fig. 4 shows the encoder process.

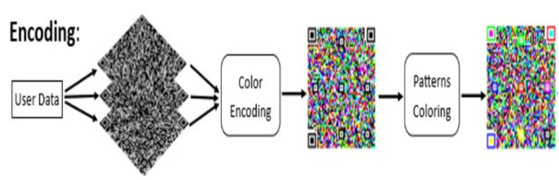

Fig. 4: Encoder by Zhibo Yang, 2016

From our review, this research provides color QR code encoder with a maximum of 3 layers. This limitation is due to the usage for only primary colors for RGB color model. Moreover, the encoder does not provide any algorithm to find the best fit for QR code resulting extra empty data for small files encoded using this encoder.

3.2 Research work by Blasinski, Henryk, 2013

Their proposed color QR Code is base in CMYK color format. the research is aim to take the advantages of spectral diversity of CMYK color format and use it to get good decoding success rate
From the encoder, the text file is split into three chunks. Then three monochrome QR code (Cyan, Magenta, Yellow) are generated. Using color multiplexing between the three QR codes, color QR code with eight colors are produced.

From our review, this system provides color QR code generator using CMYK color model, the proposed encoder can generate color QR code with maximum of 8 colors. This due to the using of only primary color for CMYK color model, furthermore the system does not provide any algorithm to all the encoder to determine the number of colors based on the file size which results in generating extra empty space for small files.

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

their research is aimed to use Color QR code as a simple way to transfer data in a place that doesn't allow to use wireless communication. the research proposed to show color QR Codes as video stream, and the reserve will user his mobile camera to get the data

From the encoder, first, the file, for instance, text documents, 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 Fig. 5.

From our review, this system provides a new way to overcome the size limitation of QR code. However, this solution needs video streaming to show the QR code which is not available on printed paper.

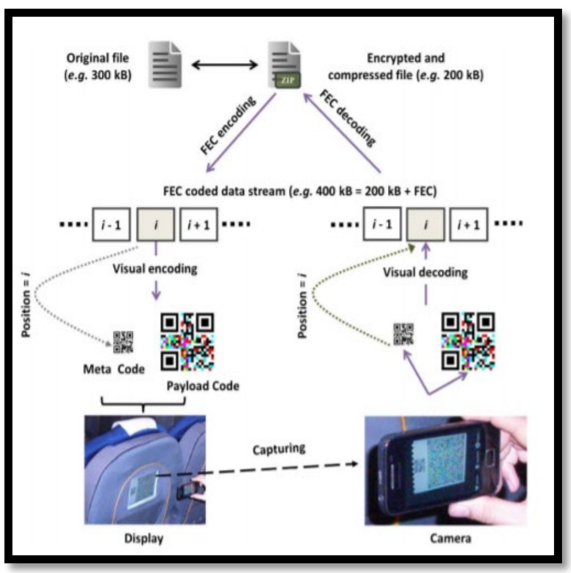

Fig. 5: IFE Screen Encoding and Decoding Process by Fath, Falk Schubert and Harald Haas, 2014

3.4 Research Work by Sin Rong Toh, Weihan Goh and Chai Kiat Yeo, 2016

They proposed a QR code encoder and decoder using color multiplexing.

The encoder will split the file into 3 equal chunks each chunk represents black and white QR code consisting of red, green, blue color which will be assigned to each black and white QR code. With color multiplexing from those QR codes they produced a color QR code.

The sending and receiving process is shown in Fig. 6

From our review, this research provides color QR code using RGB color model which limit the number of layer to maximum 3 layers, in addition to the encoder doesn't support encoding for small files

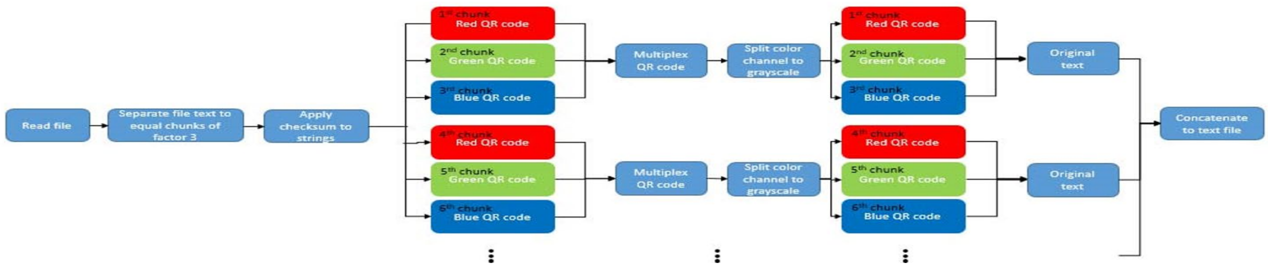

Fig. 6: Thilo Fath, Falk Schubert, and Harald Haas, 2014 encoding and decoding process

3.5 Research Work by Tian Hao, Ruogu Zhou and Guoliang Xing 2012

They have proposed colored barcode to increase the capacity of QR code.

Form the sender, the bitstream of data are obtained, then convert each of the bit into color for example red, green, blue and white colors which represent 00, 01, 10 and 11 respectively On a typical 4-inch phone screen with 800×480 resolution, a single color barcode with 6-pixel block size contains 18.8K bits.

The proposed barcode is shown in Fig. 7

From our review, this system introduced a new color code. The proposed code encodes only 2 bit per color while other researchers have enhanced the capacity to 3 bits per color.

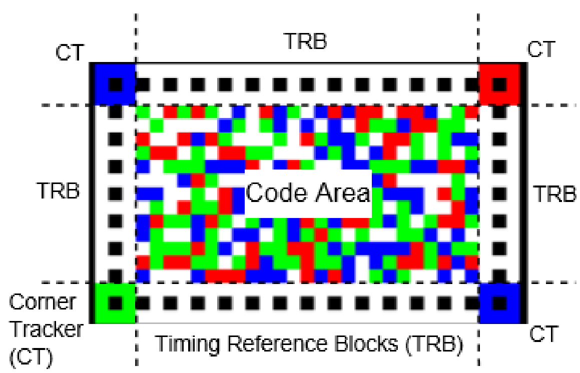

Fig. 7 Tian Hao, Ruogu Zhou, Guoliang Xing 2012

3.7 Comparison with Existing Systems

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

Table 2. Comparison Table

Research Works	Generator	Max data size byte	Number of color	Algorithm used	Color Selection
(Zhibo Yang , 2018) [26]	8 Color	8868	8	Color reference	Static
(Blasinski, Henryk,2013) [18]	8 Color	8868	8	Diffuse reflection	Static
(Thilo Fath, Falk Schubert,and Harald Haas, 2014) [6]	B/W or 8 Color	1158	8	Color multiplexing	Static
(Sin Rong Toh, Weihan Goh, and Chai Kiat Yeo, 2016) [8]	8 Color	8868	8	Color multiplexing	Static
(Tian Hao, Ruogu Zhou, Guoliang Xing 2012) [9]	5 Color	2350	5	Bit encoding	Static

From Table 2, it can be summarized that the maximum data capacity for existing work can hold 8868 byte per barcode for 8 colors QR code.

4.0 Methodology for Proposed Color QR Code

Figure 8 shows the methodology of the proposed dynamic four layers color QR code, consisting of eight steps. First, the user needs to insert data file and the available size on paper. Second, the fuzzy system will select the number of layers. Third, the file is split into chunks which is equal to the number of layers. Fourth, the black and white QR codes are generated. Fifth, monochrome color is assigned to the generated black and white QR code. Sixth, color multiplexing is utilized to get one color QR code. Seventh, color reference is added to the encoder and lastly, the proposed color QR code is produced.

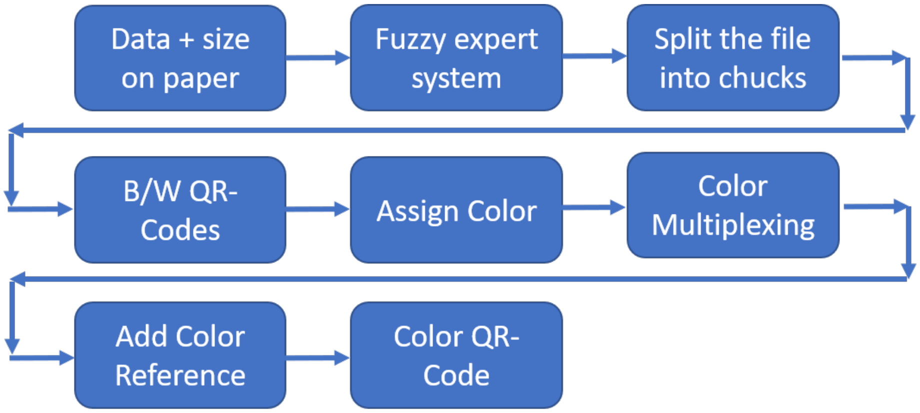

Fig. 8 Methodology for the Proposed Four Layers Color QR Code

5.0 Proposed Color QR Code Encoder

The steps for QR Code generator algorithm is shown as follows:

i. First, we need to insert available size on screen and data file.
ii. Find the correct B/W QR code for the selected space utilizing fuzzy technology.
iii. We calculate the number of layers by divide the data size to the size of the selected B/W QR Code that we get from step ii.
iv. We calculate the number of colors needed which is equal to $2^{\text{number of chunks}}$.
v. For each data layer, we generate monochrome QR Code.
vi. Color multiplexing for the monochromes QR code that we get from step v, to get one colored QR Code.
vii. Add color reference to identification pattern.

The encoder for the QR code generator algorithm is shown in Fig. 9.

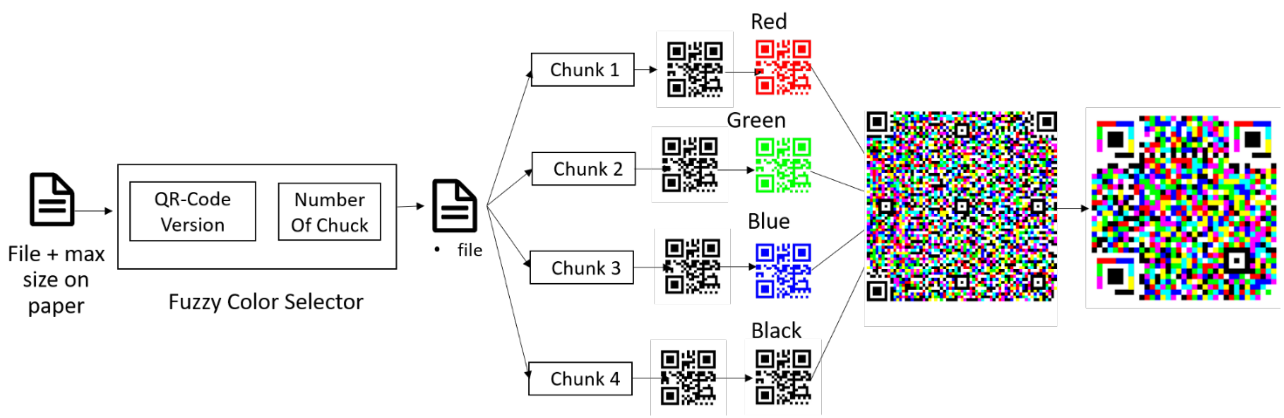

Fig. 9: Proposed approaches and experiment

5.1 Proposed Color QR Code Encoder Pseudocode

The proposed color QR code encoder pseudocode is as follows:

```
f = get file size();
s = size on paper;
v = best-fit QR code version(s);
v += cv+1;
while (f/v>4)
{
        v=v+;
        v += v+1;
}
r = f mod v
if (r <=0.5) then
        version = v
        number of chunk = selected value + 1-r value;
else version = v+
        number of chunk = selected value-r value;
```

5.2 Fuzzy QR Code Version Selection

The proposed system has two input file size and the size on the paper. The size on the paper is the preferred size for the generated QR code in pixels.

5.2.1 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 section 4.2.2. The maximum value will be the color value.

5.2.2 Membership Function

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

Fig. 10 shows the membership function. X axis represent the fuzzified input (file size/ qrcode size), y axis represent the output for the membership functions. V represent B/W QR code form the preferred version, V+ represent B/W QR code form the preferred version + 1.

The membership functions consist of:

i. Input Minimum: 1.
ii. Input Maximum: 4.
iii. Output Values (v+, 2v, 2v+, 3v, 3v+, 4v).

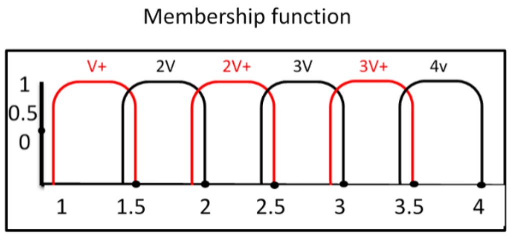

Fig. 10: Membership Function for the Proposed QR Code Generator

5.2.3 Fuzzy Rules

For the QR code generator, fuzzy rules are used to select the number of chunks plus the QR code version. For the defuzzification process, we take the selected version and the resulting number and we consider it as the number of chunks.

Pseudocode for the generator rules is as follows:

```
 if (selected value in range [1-4]) then
        if (decimal value <= 0.5) then
            version = v
           number of chunk = selected value + 1 decimal value;
       else
           version = v+
           number of chunk = selected value decimal value;
else  // the number of layers exceeds the maximum number of layers which is 4
    v=v+ and v+=v++ (Select higher version of black and white QR Code to fit the data size, and then call the membership function for the new value of V, V+)
```

5.2.4 Defuzzification

For this function, we obtained the QR code version and number of chunks. The defuzzification process result from the fuzzy rules and we divide the file based on the number of chunks.

6.0 RESULTS AND DISCUSSION

We have compared our proposed framework with existing QR code generator research works [26], [19], [8]. These existing works have the same data capacity as they can encode color QR code with three layers. Our proposed system can encode 4 layers of QR code where we succeeded to produce a 25% higher capacity compared to existing color QR code generator. This percentage is obtained by applying the increase percentage calculation as follows:

Increase = Our Generator - Existing Generator
= 11824 – 8868 = 2956

% Increase = Increase ÷ Our Generator × 100
= 2956 ÷ 11824 * 100 = 25%

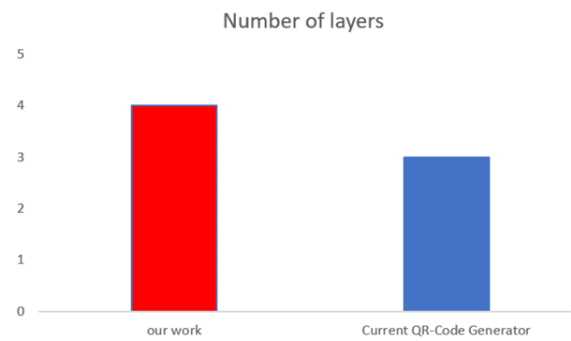

Fig 11. Comparison Between QR Code Sizes

Table 3 shows the comparison of data size (in bytes) for QR code version 1, 10, 20, 30 and 40 with low error correction. The second column refers to other research work by (Zhibo Yang, 2018) [26], (Blasinski, Henryk, 2013) [18] and (Sin Rong Toh, Weihan Goh, and Chai Kiat Yeo, 2016) [8] where they used the same encoding data size for each of the QR code version. For each version presented in Table 3, there is a 25% increase in our proposed generator compared to existing color QR code generator.

Table 3. Data Size Comparison

QR Code Version	B/W QR Code (bytes)	Other Research Work [26], [18], [8] (Color QR Code in bytes)	Our Proposed Generator (Color QR Code in bytes)
1	19	57	76
10	274	822	1096
20	861	2,583	3,444
30	1,735	5,205	6,940
40	2,956	8,868	11,824

Fig. 12 shows the data size (in bytes) comparison between our proposed color QR code generator and existing generator. From Fig. 12, our proposed system produced 25% larger data capacity for all QR code version, compared to existing color QR code generator.

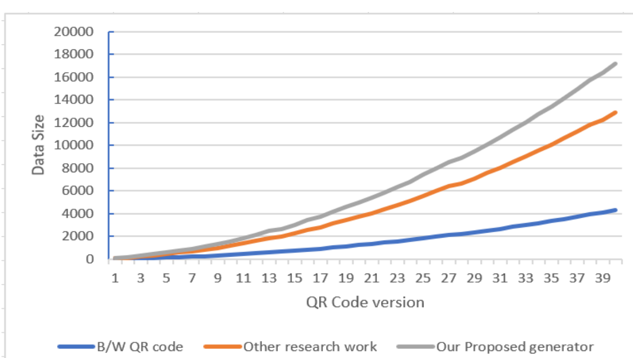

Fig 12: Data Size Comparison

7.0 CONCLUSION AND FUTURE WORKS

We discuss dynamic color QR Code generator which can generate color QR Code up to four-layer, using fuzzy technique allows the encoder to select the best fit QR Code for the available space. the result shows that we can have color QR Code with data capacity 25% more than existing color QR code, by adding one extra color layer.

For future works, we will show decoder for the proposed color QR Code.

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