Measurement of Reading Characteristics of Multiplexed Image in QR Code

Damri SAMRETWIT
Graduate School of Engineering
Fukuoka Institute of Technology
3-30-1 Wajiro-Higashi, Higashi-Ku, Fukuoka 811-0295
Japan
E-mail: airetam_@hotmail.com, mgm11007@bene.fit.ac.jp

Toshihiko WAKAHARA
Dept. of Information and Communication Engineering
Fukuoka Institute of Technology
3-30-1 Wajiro-Higashi, Higashi-Ku, Fukuoka 811-0295
Japan
E-mail: wakahara@fit.ac.jp

Abstract—**With the growth of the Internet in recent years, two-dimensional codes, such as a QR code has been widely used in the world. However, as this QR code is just a collective symbol of black and white dots, it does not have a good visual display. To improve this problem, an image or picture is superimposed to this two-dimensional code. This code can still be read without error, but this image is considered to be noisy, which reduces the reading ability. In order to avoid the reduction of the ability for reading the two-dimensional arrangement of code data, the location characteristics of the superimposed image should be studied. In this paper, taking into account the parameters of the error correction, the reading characteristics for different positions of the superimposed image are measured and the best position for it has been studied.**

Keyword: QR codes; two-dimensional barcode; superimposed images; error correction codes; Reed Solomon code.

I. INTRODUCTION

In recent years, with the development of Internet technology and LSI technology, various barcode symbols have been developed. Especially one-dimensional barcodes are widely used when making immediate purchases in supermarkets and convenience stores. But as a barcode usually includes a Japanese Article Number (JAN) code, which is limited to 13 digits or 10 digits for numbers, two symbols are used to indicate the ISBN (International Standard Book Number) and prices of the book. A QR code (abbreviated from Quick Response code) is a type of matrix barcode (or two-dimensional code) and is at first designed for the automotive industry. More recently, this QR code has become very popular due to its fast readability and comparatively large storage capacity. The code consists of black and white modules arranged in a square pattern on a white background. The information encoded can be made up of four kinds of data (i.e. Numeric mode, Alphanumeric mode, 8-bit byte mode or Kanji and Kana character mode). After created by Toyota subsidiary Denso Wave in 1994*, the QR code [1] has become one of the most popular types of two-dimensional codes [2]. The QR code is designed to be decoded at high speed. The technology is frequently used in Japan and Asian countries [3]. Recently, multimedia such as music or still pictures for cellular phones includes QR codes. The application of these QR codes has been increasing during recent years.

This paper presents the reading characteristics of the superimposed images or other objects on a QR code without reading errors. Experimental results show good characteristics of multiplexing pictures on a QR code.

The paper is organized as follows. In Section II, an outline of QR codes is given. In Section III, we discuss the related work. In Section IV, we will explain how to create superimposed image on a QR code. In Section V, experimental results are reported. Finally, we present in Section VI our conclusions.

II. QR CODE OUTLINE

A. QR Code Configuration

The symbol version of QR code is defined in the range from 1 to 40 corresponding to the size of the encoded information. Each version has a different module configuration or number of modules (the module refers to the black and white dots that make up QR Code). The minimum number of modules contained in a symbol is 21 × 21 modules (Version 1) and the maximum number is 177 × 177 modules (Version 40). If the version number is incremented by 1, the modules increase 4 X 4 modules.

Figure 1 shows an example of version 3 QR code that is arranged in a grid pattern of black and white squares. The QR Code has three Finder patterns for showing the positions of the symbol arranged in the three corners (the upper left corner, bottom left and top right corner) to enable high-speed reading in all directions (360°). Timing patterns are placed between each of these position detection patterns. An alignment pattern is a pattern for correcting the distortion of the QR Code. It is highly effective for correcting nonlinear distortions. The variance between the center position of the alignment pattern estimated from the outer shape of the symbol and the actual center position of the alignment pattern will be calculated to have the mappings (for identifying the center position of each cell) corrected. The encoded data will be placed into the data code words. Then the calculated Reed Solomon error correction codes are placed into the remaining positions.

**** QR code is a trademark of Denso Corporation.***

Table 1 shows the main specifications of the QR code. There are four modes available: (1) Numeric mode, (2) Alphanumeric mode, (3) 8-bit byte mode and (4) Kanji and kana characters mode. Combinations of these modes are also possible. The QR code has four different error correction levels (7%, 15%, 25%, and 30% per symbol). By this error correction functionality, the code can be read correctly even when it is smudged or damaged up to the error correction level.

Table 1. Main QR code specifications.

Item	Specifications	
Error Correction Code	RS code	Data Information
	BCH code	Format Information
		Version Information
Modes	Numeric	10 bit coding per 3 number digits
	Alphanumeric	11 bit coding per 2 characters
	8-bit byte	8 bit coding
	Kanji and Kana	13 bit coding per 2 characters
Version	1	21 x 21 cells (modules)
	2	25 x 25 cells (modules)
	40	177 x 177 cells (modules)
Error Correction Level	L	about 7 %
	M	about 15%
	Q	about 25%
	H	about 30 %
Finder Pattern	1:1:3:1:1	3 concentric squares 7x7, 5x5, 3x3 modules
Alignment Pattern	1:1:1:1:1	3 concentric squares Higher version>=2 5x5, 3x3, 1x1 modules

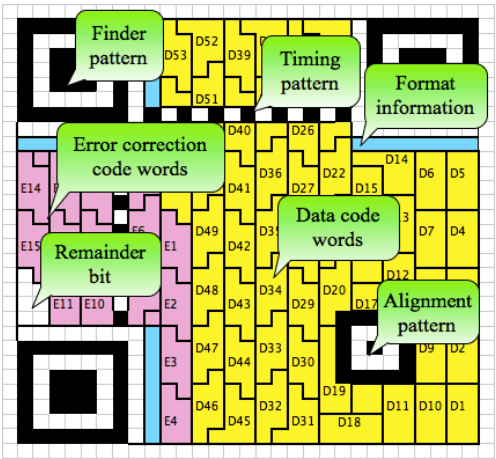


Figure 1. Example of QR code (version 3-L).

B. QR Coding Method

The QR encoding method is as follows.

(1) Considering the total of coding capability of the data information, the smallest number is chosen for information accommodation to select the version of QR code and error correction level.

(2) Maximum numbers of coding characters in each mode are as follows.

I. Numeric mode: 7089 characters

II. Alphanumeric mode: 4296 characters

III. 8-bit byte mode: 2953 characters

IV. Kanji and kana character mode: 1817 characters

(3) Encoding the data by using RS (Reed Solomon coding) code algorithm and creating the QR code.

RS code parameters are shown in parentheses (code length, information symbol length, number of error correction).

For example, for a 3-L type (version 3, error correction level: L) QR code, as represented in Figure 1, (70, 55, 7) RS codes are used as 55 data code words (D1-D55) and 15 error correction code words (E1-E15). In this case, seven pieces of data can be corrected. The arrangement of words is as follows: each code is placed in a row starting from the bottom right sequence of words for each code (76543210) to D1, D2, D3,...,D7 arranged in two columns from the bottom-up and the error correction code is placed in the left sequence in two columns. So when there is a small amount of data to be encoded in the QR code, the free space for coding becomes large and the middle part or the end part of the symbol is usually vacant as remainder bits.

III. Related Works

In recent years, new types of advanced 2D code (the specification of QR code is not in compliance) have been developed. The QRForest [4] is the 2D code which users can change position shape, data area shape, alignment shape and superimposed image by their will as shown in Figure 2.

There are other works which are related to new types of 2D code. For example, multimedia QR code which can save melodies and images, a multiplexing QR code, QR-JAM [5] and DesignQR [6], which are shown in Figures 3 and 4.

A new non-systematic way of encoding the error correction RS code has been developed and the images are multiplexed on the QR code [7] as shown in Figure 5. The animated QR code is also designed by using the optimization algorithm [8] as shown in Figure 6.

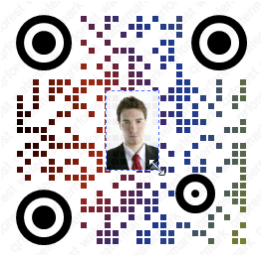


Figure 2. QRForest with superimposed image.

Figure 3. QR-JAM.

4. DesignQR.

Figure 5. Image displayable DesignQR code.

Figure 6. Animated QR code.

IV. SUPERIMPOSED IMAGE ON QRCODE

A. *Superimposed Image Using Error Correction Code*

QR Code can display a monochrome dot by prescribed Reed-Solomon encoding data. However, as QR codes are monotone and are difficult to be distinguished from each other, the method of superimposing image on the QR code using the redundancy of RS code is considered [9]. QR Code has been defined as four levels of error correction, level L (7%), level M (15%), level Q (20%) and level H (30%). However, as the relations between these error correction levels and the size or position of the superimposed image can be estimated roughly, the details are not clear. Therefore, the effects of the degraded reading characteristics by changing the size and location of superimposed image need to be obtained by the experiments.

B. *Superimposed Image Procedure*

There are several ways to superimpose image in QR code by using picture editor program by using the abovementioned condition.

(1) The size of a superimposed image in QR code is counted by the overlapped cell area.

(2) The size of a superimposed image that lowers the error correction capability (L, M, Q and H) can be readable or unreadable.

(3) The superimposed image that overlapped in any pattern can introduce some problem such as unreadable codes.

By using the Editor software, the superimposed image on QR code and any overlapped cells are counted as noise in reading algorithm

In Figure 7 is shown an example of superimposed image (15x11 cells) that overlapped in QR code cell, center position of red areas, which must be recovered by error correction code algorithm later. The pink areas are error correction code cells and yellow areas are data code cells that are overlapped by superimposed image.

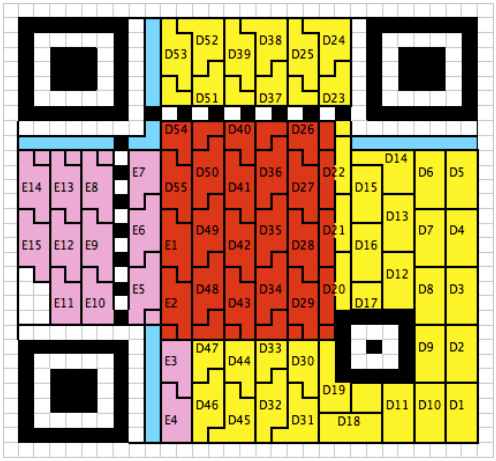


Figure 7. Size of 15x11 cells superimposed image.

V. EXPERIMENTS AND THEIR RESULTS

A. *QR Code Reading Experiments Outline*

Experiments were conducted as follows. It was examined whether QR code with a superimposed image can be read or not. A cellular phone was used as a QR code reader for reading a QR code shown on a notebook computer's LCD display. The experiments were carried out under the normal room brightness environments. Table 2 shows the main experimental conditions.

Table 2. Experimental conditions.

Items		Specifications
QR Code	Encoded Data	15 English Characters
	Version	3
	EC Level	4 Levels: H, Q, M, L
Display Tool		MacBook Air (11ince)
Lighting		Usual Room Brightness
Display Brightness		80% Brightness
Cellular Phone		iPhone 4
Editor Software		Gimp 2.6.7[10]

Reading Software	i-nigma[11]

B. *Image Multiplexing Method*

In this study, combinations of eight different sizes and four different positions of still images are superimposed on the QR code as shown in Figure 8 and Figure 9. The used QR code is version 3 (29x29 cells). Eight size of the images are 5x4 cells, 7x5 cells, 9x6 cells, 10x8 cells, 12x9 cells, 15x11 cells and 15x13 cells as shown in Figure 8.

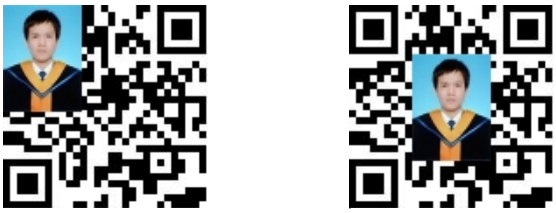
Changing of the superimposed position may affect the results of reading performance. For this reason, we measured the characteristics of reading performance. The superimposed positions of the QR code are four: top-left, center, center-left and bottom-right as shown in Figure 9.

(a) 5x4 cells b) 7x5 cells (c) 9x6 cells

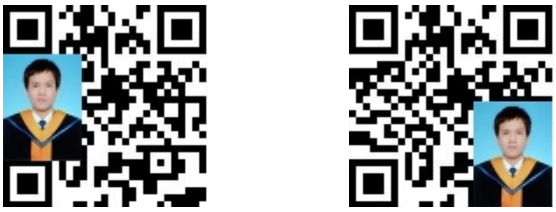
(d) 10x8 cells (e) 12x9 cells (f) 14x10 cells

(g) 15x11 (h) 15x13 cells

Figure 8. The size of the image to be superimposed.



(a) top-left (b) center



(c) center-left (d) bottom-right

Figure 9. Superimposed positions.

C. *Reading Characteristics*

Table 3, Table 4, Table 5 show the results of QR code reading experiments of a superimposed image: ○ shows a success reading and x shows a failure reading. In addition, if superimposing any image on the top-left position of QR code (Finder pattern), this QR code will become unreadable (so remainder total cells are 694 cells).

The results are shown in Table 3, Table 4, Table 5 and Figure 10. The image area ratio in the superimposed image QR code level H in the center is about 20.1%, the center-left is about 28.1% and the bottom-right is about 15.6%. The image area ratio in the superimposed image QR code level Q in the center is about 15.6%, the center-left is about 23.4% and the bottom-right is about 15.6%. The image area ratio in the superimposed image QR code level M in the center is about 11.9%, the center-left is about 20.1% and the bottom-right is about 15.6%. The image area ratio in the superimposed image QR code level L in the center is about 5.0%, the center-left is about 7.8% and the bottom-right is about 7.8%. It should be noted that in the above calculation of area ratio (the quite zone), the Finder pattern area is ignored.

Table 3. The result of the image superimposed in the center position.

	5x4	7x5	9x6	10x8	12x9	14x10	15x11	15x13
H	o	o	o	o	o	o	x	x
Q	o	o	o	o	o	x	x	x
M	o	o	o	o	x	x	x	x
L	o	o	x	x	x	x	x	x

Table 4. The result of the image superimposed in the center-left position.

	5x4	7x5	9x6	10x8	12x9	14x10	15x11	15x13
H	o	o	o	o	o	o	o	o
Q	o	o	o	o	o	o	o	x
M	o	o	o	o	o	o	x	x
L	o	o	o	x	x	x	x	x

Table 5. The result of the image superimposed in the lower-right position.

	5x4	7x5	9x6	10x8	12x9	14x10	15x11	15x13
H	o	o	o	o	o	x	x	x
Q	o	o	o	o	o	x	x	x
M	o	o	o	o	o	x	x	x
L	o	o	o	x	x	x	x	x

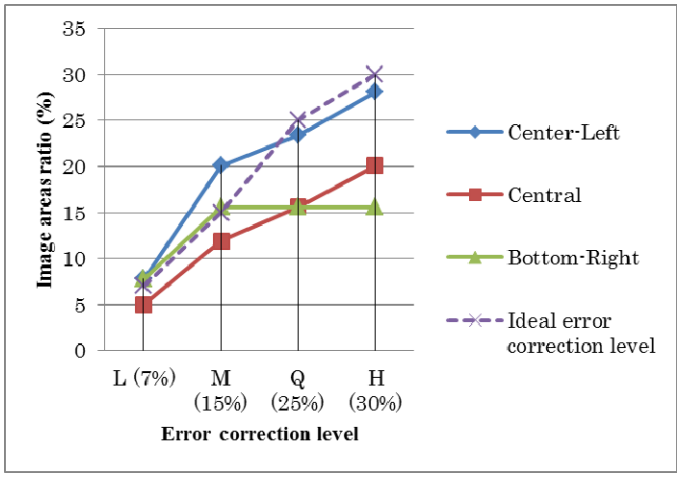


Figure 10. Image area ratio in each error correction level.

In this experiment, the center-left position shows the highest reading capability characteristic and this position is the best position for superimposing among all positions as shown in Figure 10. Especially, the image area ratio in QR code level M is 20.1% and this value is higher than the normal error correction level M (15%).

As the result, superimposing image in various positions will cause different outcomes.

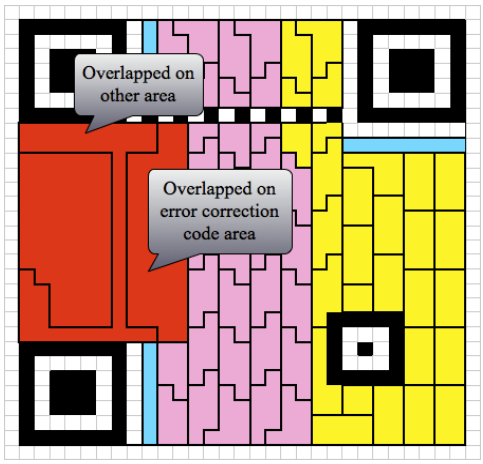


Figure 11. Superimposed image on the center-left position.

Figure 11 shows superimposed image on the center-left position of QR code (red area). This position is usually overlapped only on the error correction code word, the remainder bits, a Timing pattern and the Format information.

(1) This position is influenced by the remainder bits, a Timing pattern and the Format information but this image areas ratio is the highest characteristic in all experiments.

(2) The remainder bits, Timing pattern and Format Information has not a bit influence to recovery algorithm and their cells may be recovered by another BCH error correction algorithm.

(3) Due to (2), the image area ratio is higher than normal error correction in level M.

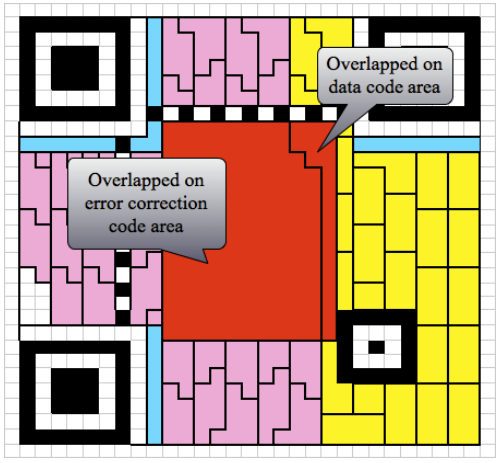


Figure 12. Superimposed image on the center position.

Figure 12 shows the superimposed image on the center position of QR code (red area). This position is usually overlapped only on the error correction code word and data code word.

(1) As the information of the center position consists of error correction code word and data code word, this position has not a bit influence comparing with any pattern of QR code but this image area ratio in Level L and M is the lowest in all experiments.

(2) Due to the influence by any pattern cells, every cell in this area is used in recovery algorithm.

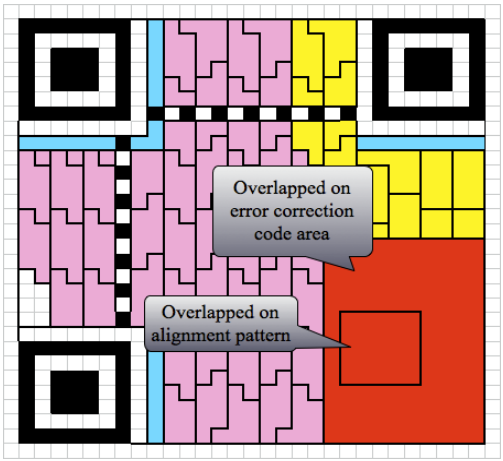


Figure 13. Superimposed image on the bottom-right position.

Figure 13 shows superimposed image on the center-left position of QR code (red area). This position is usually overlapped only on the error correction code word and the Alignment pattern.

(1) This position is influenced by the Alignment pattern and this image area ratio in level L and M is higher than the center position image area ratio, but for some reasons it is stopped at 15.6% in level Q and H.

(2) Recovery performance may be decreased by the Alignment pattern influence.

(3) Despite the influence of the Alignment pattern, QR code is still readable.

VI. CONCLUSIONS

In this paper, we measured the reading characteristics of the two-dimensional QR code with a superimposed image by the experiments. The reading capability uses the error correction code and the characteristics are different by the error correction level. Experimental results show that the center-left position has the highest reading capability because of the superimposing images overlapping on the remainder bits, a Timing pattern and the Format information. In fact, the position of the superimpose image should be center because this area consists mainly of error correction code cells and data code cells and the influence may be small.

This paper presented how to superimpose an image on the ordinary QR code and showed the best locations of the superimposed image in QR code and best size of superimposed image by the reading characteristics of experiments.

The main results are as follows.

(1) The position of the Finder pattern is not adequate for superimposing any image. Any image superimposed on the Finder pattern may be unreadable.

(2) The area that can be superimposed as a data code area and error correction code area. Then any image may be not superimposed on the function pattern area.

(3) The superimposable image area ratio to the total area of the symbol, which is counted as cell x cell of the area, has similar value to the correction error level.

(4) Superimposing image in the alignment pattern may decrease the recovery performance.

(5) A superimposed image which is overlapped on the remainder bits, a timing pattern and the Format information, may be recovered by the BCH code.

REFERENCES

[1] Japanese Industrial Standards, “Two Dimensional Symbol-QR-Code-Basic Specification”, JIS X 0510, October 2004.

[2] ISO/IEC 18004:2000 Information Technology: Automatic Identification and Data Capture Techniques (Barcode Symbology) QR Code (MOD), June 2000.

[3] T. J. Soo, “QR Code”, Synthesis Journal, pp. 59–78, 2008.

[4] QRForest, http://qrforest.com/.

[5] QR-JAM, http://staff.aist.go.jp/hagiwara.hagiwara/qrjam/index.html.

[6] DesignQR, http://d-qr.net/index.htm.

[7] K. Fujita, M. Kuribayashi and M. Morii, “Study of Image Displayable Design QR Code”, IEICE Technical Report, LOIS2010-51 pp. 39–44, January 2011.

[8] S. Ono, K. Morinaga and S. Nakayama, “Animated Two-Dimensional Barcode Generation Using Optimization Algorithms-Redesign on Formulation, Operator, and Quality Evaluation”, Journal of Advanced Computational Intelligence and Intelligent Informatics, Vol. 13, No. 3, pp. 245–254, 2009.

[9] T. Wakahara, N. Yamamoto, H. Ochi, “Image Processing of Dotted Picture in QR Code of Cellular Phones”, IEICE Technical Report, LOIS2010-65, pp. 1-5, March 2011.

[10] Gimp, http://www.gimp.org/.

[11] i-nigma, http://www.i-nigma.com/i-nigmahp.html.