An Introduction to QR Code Technology

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An Introduction To QR Code Technology

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***Abstract*— QR i.e. "Quick Response" code is a 2D matrix code that is designed by keeping two points under consideration, i.e. it must store large amount of data as compared to 1D barcodes and it must be decoded at high speed using any handheld device like phones. QR code provides high data storage capacity, fast scanning, omnidirectional readability, and many other advantages including, error-correction (so that damaged code can also be read successfully) and different type of versions. Different varieties of QR code symbols like logo QR code, encrypted QR code, iQR Code are also available so that user can choose among them according to their need.**

Now these days, a QR code is applied in different application streams related to marketing, security, academics etc. and gain popularity at a really high pace. Day by day more people are getting aware of this technology and use it accordingly. The popularity of QR code grows rapidly with the growth of smartphone users and thus the QR code is rapidly arriving at high levels of acceptance worldwide.

Keywords— QR code; Quick Response code; QR code structure; QR Code Encoding; QR Code Decoding.

I. INTRODUCTION

A QR code is a type of matrix bar code or two-dimensional code that can store data information and designed to be read by smartphones. QR stands for "Quick Response" indicating that the code contents should be decoded very quickly at high speed. The code consists of black modules arranged in a square pattern on a white background. The information encoded may be text, a URL or other data [1] [2]. The QR code was designed to allow its contents to be decoded at high speed. The popularity of QR codes is growing rapidly all around the world. Nowadays, mobile phones with built-in camera are widely used to recognize the QR Codes.

QR Codes are created by the Toyota subsidiary Denso Wave in 1994, and was initially used for tracking inventory in vehicle parts manufacturing.

The idea behind the development of the QR code is the limitation of the barcode information capacity (can only hold 20 alphanumeric characters).

While they are developed for tracking parts in vehicle manufacturing, QR codes now are used in many other fields, from commercial tracking to entertainment, in-store product labeling, and in those applications that are aimed at smartphone users. Users may open URL; receive text after scanning QR codes. By using QR code generating sites or apps, users can generate and print their own QR codes for others to scan and use.

The QR code system consists of a QR code encoder and decoder. The encoder is responsible for encoding data and generation of the QR Code, while the decoder decodes the data from the QR code.

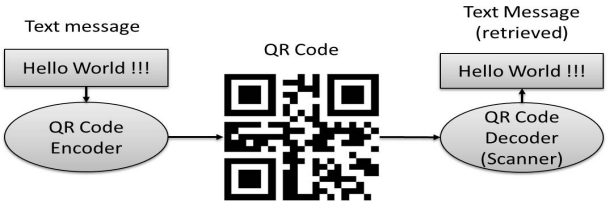

Fig. 1 Working (overview) of QR Code

Figure 1 shows the overview of the QR code working. The plain text, URL, or other data are given to the QR code encoder, and it generates the required QR code and when we want to access the data of the QR code, QR code is decoded via QR Code decoder (scanner) which retrieves the data of QR code [1] [3].

II. INFORMATION CAPACITY AND VERSIONS OF THE QR CODE

The symbol versions of the QR Code range from Version 1 to Version 40 [4]. 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.)

"Module configuration" refers to the number of modules contained in a symbol, commencing with Version 1 (21 × 21 modules) up to Version 40 (177 × 177 modules). Figure 2 shows the module configuration of the basic QR codes.

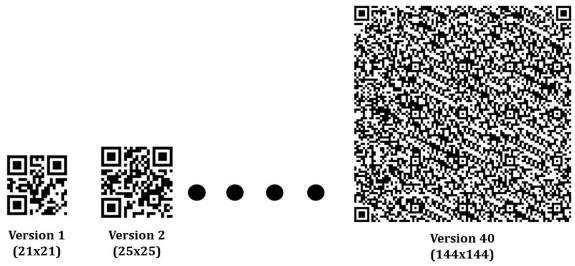

Fig. 2 Version module configuration of the QR Codes

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TABLE I. DATA CAPACITY OF QR CODE VERSION 40

Version	Modules	ECC Level	Data Bits (mixed)	Numeric	Alpha-numeric	Binary	Kanji
40	177x177	L	23,648	7,089	4,296	2,953	1,817
		M	18,672	5,596	3,391	2,331	1,435
		Q	13,328	3,993	2,420	1,663	1,024
		H	10,208	3,057	1,852	1,273	784

Each QR Code symbol version has the maximum data capacity, according to the amount of data, character type and error correction level. In other words, as the amount of data increases, more modules are required to comprise QR Code, resulting in larger QR Code symbols. Table 1 show the data capacity of version 40 for different type of data.

III. QR CODE ERROR CORRECTION

QR Code employs error correction to generate a series of error correction codewords which are added to the data codeword sequence which enable symbol to be read even if it is dirty or damaged. The QR code achieves powerful error-correction capability by using Reed-Solomon codes, a widely used mathematical error-correction method. Four levels of error correction are available, higher level has high capability of recovery. Table 2 shows error-correction levels and their approximate ability of error correction.

When selecting the level of error correction, environmental conditions as well as the desired size of the QR Code symbol need to be taken under consideration.

TABLE II. ERROR CORRECTION LEVELS AND % OF CORRECTION

S No.	Error-Correction Level	Approximate Amount of Correction
1.	L	7%
2.	M	15%
3.	Q	25%
4.	H	30%

For example, Level Q (25% error correction) or H (30%) may be required for factories or other applications where the QR Code is likely to become dirty or damaged. For clean environments and codes containing a large amount of data, Level L (7%) may be selected. In general, Level M (15%) is most frequently used [3] [4].

IV. STRUCTURE OF A QR CODE

Each QR Code symbol shall be built of square modules arranged in a regular square array and shall consist of function patterns and encoding region. And the whole symbol shall be surrounded on all four sides by a quiet zone border [4] [5].

Function patterns are the shapes that must be placed in specific areas of the QR code to ensure that QR code scanners can correctly identify and orient the code for decoding. There are 4 types of function patterns; they are finder pattern, separator, timing patterns, and alignment patterns.

Encoding region contains data, which represents version information, format information, data and error correction codewords. Fig 3 illustrates the structure of a QR Code symbol.

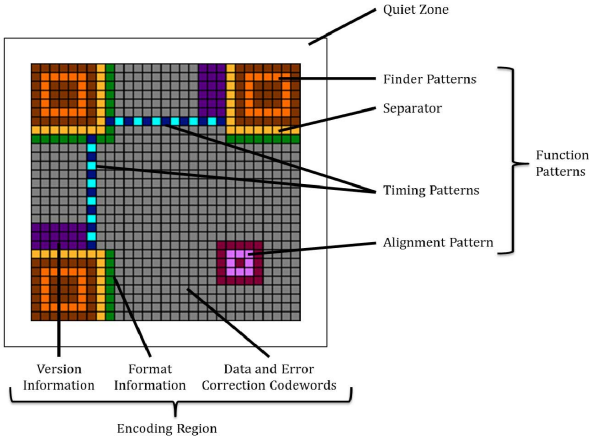

Fig. 3 Structure of a QR Code symbol

- *Finder Pattern*: Finder patterns are the special position-detection patterns located in three corners (upper left, upper right, and lower left) of each symbol.

  It consists of an outer dark square that is 7 × 7 modules, an inner light square that is 5 × 5 modules, and a solid dark square in the center that is 3 × 3 modules. The ratio of module widths in each position detection pattern is 1:1:3:1:1, as shown in fig. 4.

  The finder pattern is designed to be a pattern that is unlikely to appear within the other sections of

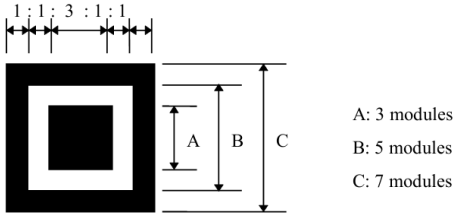

Fig. 4 Finder Pattern

the QR code so that QR code scanners can search for this ratio of light to dark modules to detect the finder patterns and correctly orient the QR code for decoding.

- *Separators*: Separators are the one-module wide areas of whitespace between each finder pattern and encoding region.
- *Timing Patterns*: There are 2 timing patterns, i.e. horizontal timing pattern and vertical timing pattern. They are consisting of alternating dark and light modules. The horizontal timing pattern is placed in the 6th row of the QR code between the separators. The vertical timing pattern is located in the 6th column of the QR code between the separators. These patterns are helpful in determining the symbol density, module coordinates and version information area.
- *Alignment Patterns*: An alignment pattern is constructed of 5 × 5 dark modules, 3 × 3 light modules and a single dark module in the center. QR codes that are version 2 and larger must have alignment patterns and the number of alignment patterns depends on the symbol version.
- *Encoding Region*: Encoding region contains format information, version information, data and error correction codes. For format information, one-module array must be reserved near the top-left, top-right, bottom-left finder pattern and version information, an area of a 6 × 3 block above the bottom-left finder pattern and a 3 × 6 block to the left of the top-right finder pattern is reserved.
- *Quiet Zone*: It is a 4-module wide area containing no data, and it used to ensure that the surrounding text or markings should not misguide the QR code data.

V. Encoding and Decoding Of A QR Code

A. Procedure for the generation/encoding of a QR Code

In order to convert input data into a QR code symbol, we'll go through some step [4] [5] [6]; figure 5 shows an overview of the encoding process.

- *Data Analysis*: A QR code encodes a string of text. The QR standard has four modes for encoding text: numeric, alphanumeric, byte, and Kanji. Each mode encodes the text as a string of bits (1s and 0s), but each mode uses a different method for converting the text into bits, and each encoding method is optimized to encode the data with the shortest possible string of bits.

  Therefore, first step should be to perform data analysis to determine whether text can be encoded in numeric, alphanumeric, byte, or Kanji mode, and then select the most optimal mode for your text.

- *Data Encoding*: Next step is to encode text. The result of this step is a string of bits that is split up into data codewords that are each 8 bits long.

  The mode used for encoding is identified by the Mode Indicator, which is a string of 4 bits. Encoded data must start with the appropriate mode indicator which is used for encoding.

  The number of characters that are being encoded is represented by the string of bits known as Character Count Indicator. Character Count Indicator is placed after the mode indicator and its length is version dependent.

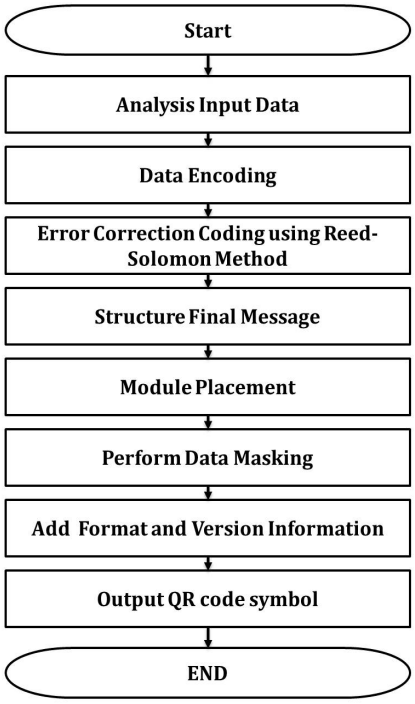

Fig.5 QR code encoding

- *Error Correction Coding*: QR codes use error correction. This means that the string of data bits that represent our text, we must then use those bits to generate error correction codewords using a process called Reed-Solomon error correction.

  QR scanners read both the data codewords and the error correction codewords. By comparing the two, the scanner can determine that it reads the data correctly or not, and if it did not read the data correctly it can correct errors.

- *Structure Final Message*: The data and error correction codewords generated in the previous steps must now be arranged in the proper order. For large QR codes, the data and error correction codewords are generated in blocks, and these blocks must be interleaved according to the QR code specification.
- *Module Placement in Matrix*: After generating the data codewords and error correction codewords and arranging them in the correct order, you must place the bits in the QR code matrix. The codewords are arranged in the matrix in a specific way.

- *Data Masking*: Certain patterns in the QR code matrix can make it difficult for QR code scanners to correctly read the code. To counteract this, the QR code specification defines eight mask patterns, each of which alters the QR code according to a particular pattern.
- *Format and Version Information*: The last step is to add format and (if necessary) version information to the QR code by adding pixels in particular areas of the code that were left blank in previous steps. The format pixels identify the error correction level and mask pattern being used in this QR code. The version pixels encode the size of the QR matrix and are only used in larger QR codes [4].

B. Procedure for decoding a QR Code

Decoding data from the QR code is the reverse of the encoding procedure. Figure 6 shows an overview of the decoding process [5] [6].

- *Recognizing Modules*: Recognize dark and light modules as an array of "0" and "1" bits by locating and getting an image of the symbol.
- *Extract Format Information*: Decode the format information and release the masking pattern and apply error correction on the format information modules as necessary. Also obtain a mask pattern reference.
- *Determine Version Information*: If version information is applicable then decode it from the version information area and then determine the version of the QR code symbol.
- *Release Masking*: In order to release the masking, XOR the encoding region bit pattern with the Mask Pattern whose reference has been extracted from the format information.
- *Restore Data and Error Correction Codewords*: Restore the data and error correction codewords of the message by reading the symbol characters (according to the placement rules for the model).
- *Error Detection and Correction*: By utilizing the error correction codewords, identify errors and if any error is detected, correct it.
- *Decode Data Codewords*: Divide the data codewords into segments according to the Mode Indicators and Character Count Indicators. And finally, decode the data characters according to the mode(s) in use and output the decoded text as result.

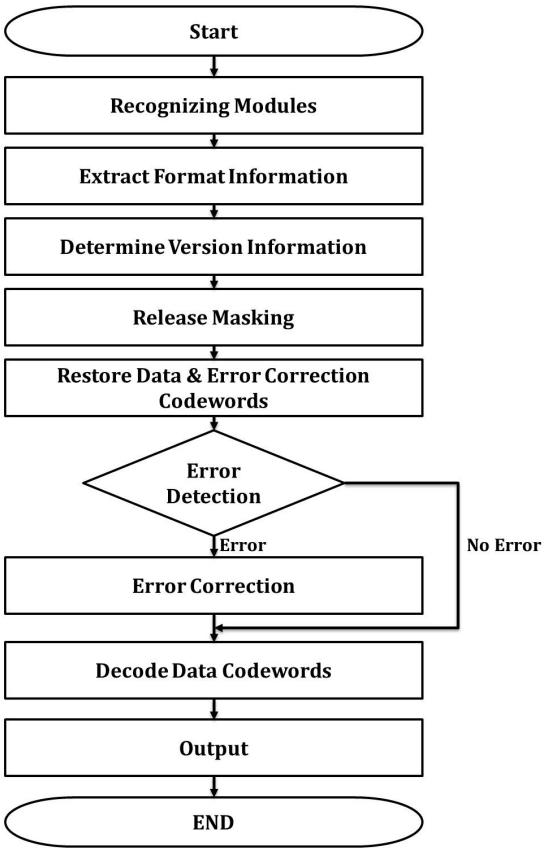

Fig.6 QR code decoding

VI. Type Of QR Codes

QR Codes are categorized into five broad categories [6].

A. QR Code Model 1 & 2

The original QR Code is QR Code Model 1, a code capable of coding 1,167 numerals with its maximum version being 14 (73 x 73 modules).

QR Code created by improving Model 1 so that this code can be read smoothly even if it is distorted in some way.

QR Codes that are printed on a curved surface or whose reading images are distorted due to the reading angle can be read efficiently by referring to an alignment pattern embedded in them.

This code can encode up to 7,089 numerals with its maximum version being 40 (177 x 177 modules).

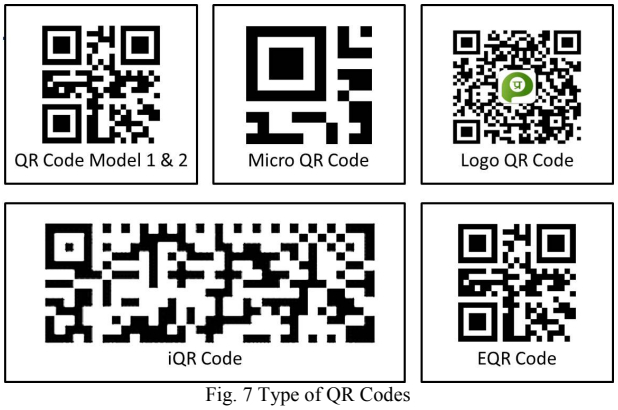

Fig. 7 Type of QR Codes

B. Micro QR Code

This QR Code is only one orientation detecting pattern code so that it can be printed in a smaller space. A major feature of Micro QR Code is it has only one position detection pattern, compared with a regular QR Code that require a certain amount of area because position detection patterns are located at the three corners of a symbol.

Furthermore, QR Code requires at least a four-module wide margin around a symbol, whereas a two-module wide margin is enough for Micro QR Code. This configuration of Micro QR Code allows printing in areas even smaller than QR Code.

C. LogoQ (Logo QR Code)

The Logo QR Code is a novel type of QR Code created to enhance visual recognizing-ability by blending it with letters and pictures in full color.

Since LogoQ is a highly designable type of QR Code, it becomes possible to differentiate LogoQ from the ordinary QR Code.

Since a proprietary logic is used when generating LogoQ codes, it is possible to combine design-ability and readability.

D. iQR Code

iQR Code is a matrix-type 2D code, allowing easy reading of its position and size. This code allows a wide size range of codes from ones smaller than the traditional QR Code and Micro QR Code to large ones that can store more data than these.

This code can be printed as a rectangular code, turned-over code, black-and-white inversion code or dot pattern code (direct part marking) as well, leaving a broad range of applications in various areas.

E. Encrypted QR Code

Encrypted QR Code is a type of QR Code equipped with reading restricting function. This can be used to store private information and to manage a group which is capable of accessing QR Code information. Basically, an encrypted QR Code is a QR Code, which contains encrypted data.

In Encrypted QR Code system, data information is encrypted by using encryption techniques and then the encrypted data is applied to the QR Code encoder (generator) which generates the QR Code. Later this QR Code is first scanned and decoded by the QR Code decoder then data information is retrieved using decryption techniques. Figure 8 show an overview of encrypted QR code mechanism.

VII. Merits and Demerits Of QR Code

A. Merits of the QR Code

- *Omnidirectional and Fast Scanning*: QR code can be read much faster and scanned from any angle within 360 degrees i.e. no need to align the scanner with the code symbol.
- *Small Size*: QR code takes less space. A QR Code can hold the same amount of data contained in a 1-D barcode in only one-tenth the space.
- *Huge Data Storage Capacity*: QR code has high data storage capacity. A single QR Code symbol can contain up to 7,089 numerals (200 times the amount of data storage capacity of the traditional 1-D barcode).
- *Many Types of Data*: The QR Code can handle numerals, alphanumeric characters, Japanese, Chinese or Korean characters and binary data.
- *Error correction*: Error correction technique used in QR codes enables successful decoding of the code symbol even if up to 30% of the data is dirty or damaged.
- *Direct Marking*: The QR Code due to high degree of readability under low-contrast conditions allows printing of a symbol directly onto a part or product.
- *Available for Everyone*: Anyone can make their own QR code according to their need, for example, user can create QR code of the URL of its own website for advertising purpose.
- *Wide Range of Uses*: There are lots of potential uses of QR codes. They can be used to extend the user experience in store, restaurants, websites and more.

B. Demerits of the QR Code

Although QR code has many positive points on its side but, there are some demerits of the QR code too, such as, Need of QR code scanner; to decode the code users must have a QR reader app, which limits the audience; Security issues, before scanning a code, the scanner can never really know where the code is going to lead them; Lack of public awareness, large portion of population is still unaware of this technology.

VIII. Area Of Applications

Although the QR Code was originally designed to track automotive components but, now these days it is rapidly used in many other areas where traditional barcodes are used, such as Manufacturing, Retailing, Healthcare, and Transportation [7]. Also, QR code found useful in some novel application

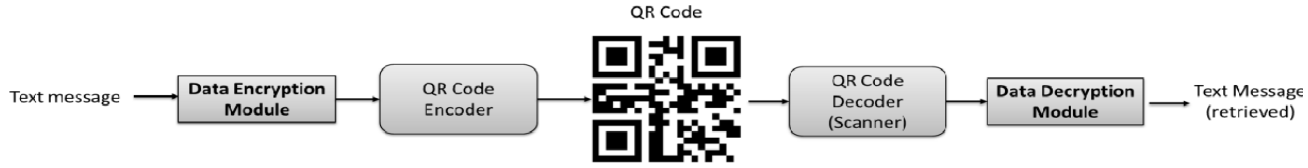

Fig.8 Concept of Encrypted QR Code

fields including mobile marketing, online advertising, electronic ticket/coupon, electronic payment, identification, academics[8], information security, OMR sheet tampering detection [9] etc.

Mobile marketing gains popularity and has recently witnessed rapid growth, where the QR Code increasingly appears in print and online advertising, as well as on signs, hoardings, posters, and other particulars.

By scanning a QR Code with a smartphone, consumers can be connected to a relevant Web page or receive targeted marketing messages such as a special offer, discount coupon, product or store information, etc.

IX. Impact And Growth Of QR Code In Today's Era

QR codes are quickly arriving at high degrees of acceptance. More and more people adopt and use this technology every day. One of the reasons behind the rapid growth of the QR code is that it gains momentum as smartphone users grow across the world and marketers use QR codes to reach mobile consumers.

QR codes first started to appear in marketing campaigns in 2011-2012. Even then, when there was significantly low smartphone and mobile internet penetration, QR codes mark their presence in the market. A study held in 2012 shows that Americans were the most likely to have used the technology. According to the study of 2,000 Americans and 1,000 Europeans undertaken by Pitney Bowes, US consumers frequently scan QR codes across every medium by which the codes were delivered.

In July 2012, comScore reported that there were 5.1 million QR code users in Germany, 3.3 million in the UK and another 3.4 million in Spain.

TABLE IV. Study report by ScanLife

Smartphone Users in the EU-5 Who Scan QR Codes, by Country, July 2012			
COUNTRY	**Millions**	**% of total smartphone owners**	**% change vs. July 2011**
Spain	3.4	16.0%	218%
Germany	5.1	18.6%	128%
Italy	2.8	11.9%	75%
France	2.8	12.5%	71%
UK	3.3	11.4%	43%
EU-5	17.4	14.1%	96%

The use of code scanning has gone up during the past years, as awareness and adoption of QR Codes grow exponentially. QR code stats done by ScanLife shows that, 23 million QR codes are scanned during the first quarter of 2015, which is nearly 10 million more than during the first quarter of 2012, and the first quarter of 2012 had posted a 157 percent increase as compared to the first quarter of 2011 [10].

TABLE III. Study report by ScanLife

Users who scan QR codes in the first quarter of the several years	
Year	**Users**
2011-Q1	7.5 millions
2012-Q1	13.3 millions
2013-Q1	18.2 millions
2014-Q1	21.8 millions
2015-Q1	23.1 millions

X. Conclusion

In this paper, we studied QR code technology, its benefits, application areas, and its impact on marketing and technological world. Initially, QR code are developed and use for inventory tracking stuff but, now these days, they found applications in many new areas like marketing, advertising, secure payment systems, education industries, etc.

Adoption of the QR codes grows rapidly during past years and number of users increases exponentially, due to its features like high data storage capacity, fast scanning, error-correction, direct marking and ease of use.

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