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A Survey on QR Codes: in context of Research and Application

Kinjal H. Pandya[1], Hiren J. Galiyawala[2]
[1,2] C.G.P.I.T, Gujarat, India

***Abstract*— QR code is the type of matrix barcode, which was first designed for the automotive industry by Denso Wave in Japan. The QR Code system has become admired outside the automotive industry due to its fast readability and greater storage capacity compared to standard UPC barcodes. This paper take account of QR codes basics, its real time application in day to day life and research areas associated. With the technology of mobile phones constantly emerging, especially in the area of mobile internet access, QR codes seem to be an adequate tool to quickly and efficiently converse URLs to users. This also allows offline media such as magazines, newspapers, business cards, public transport vehicles, signs, t-shirts and any other medium that can embrace the print of a QR code to be used as carriers for advertisements for online products. QR code being so versatile because of its structural flexibility that it leads to so many diverse field for research such as increasing data capacity, security applications such as different kinds of watermarking and steganography as well. Some experiments have also been done for better recognition of the QR code image that includes scratch removal techniques. Thus, this paper is an attempt to highlight some of possible research areas while considering QR codes.**

***Keywords*— QR code, Universal Product Code (UPC), watermarking, security, data capacity, scratch removal.**

I. INTRODUCTION

A barcode is an optical machine-readable exemplification of data relating to the object to which it is committed. Primitively barcodes represented data by varying the widths and spacings of parallel lines, and may be referred to as linear or one-dimensional. Later they evolved into rectangles, dots, hexagons and other geometric patterns in two dimensions. Albeit 2D systems use a variety of symbols, they are in general referred to as barcodes as well.

QR code stands for Quick Response Code, Which is the trademark for the type of matrix barcode which was invented by the Japanese corporation Denso Wave. QR code has a number of features such as large capacity data encoding, dirt and damage resistant, high speed reading, small print out size, 360 degree reading and structural flexibility of application.

This paper includes the basic understanding of QR code in the next section. Section III shows the comparison between one dimensional and two dimensional barcodes. Section IV includes the various examples of the use of QR codes. In section V, all different techniques of diverse fields that have been proposed by using QR code for the research is mentioned. Section VI is the conclusion.

II. UNDERSTANDING QR CODE

QR codes have already overtaken the popularity of classical barcode in many areas because of several advantages like increase in capacity, reduced size, etc. Combined with the diversity and extendibility offered, it makes the use of QR code more appealing than that of the barcodes. Statistically, QR codes are capable of symbolizing same amount of data in approximately one tenth the space of a traditional barcode. Information such as URL, SMS, contact information and plain text can be embedded into the two dimensional matrix. Moreover, with the explosive increment of the trend to use smartphones has also played an important role in the popularity of QR codes.

A. Architecture and Encoding

QR code is a two dimensional i.e. matrix type symbol with a cell architecture arranged in a square. Figure 1 shows the QR code architecture. QR codes consist of different areas that are reserved for specific purposes. Finder, separator, timing patterns and alignment patterns comprised function patterns. Function patterns shall not be used for the encoding data. The finder patterns located at three corners of the symbol intended to assist in easy location of its position, size and inclination.

The encode procedure of QR Code include following steps. Firstly input data is encoded in according to most efficient mode and formed bit stream. The bit streams are divided into codewords.

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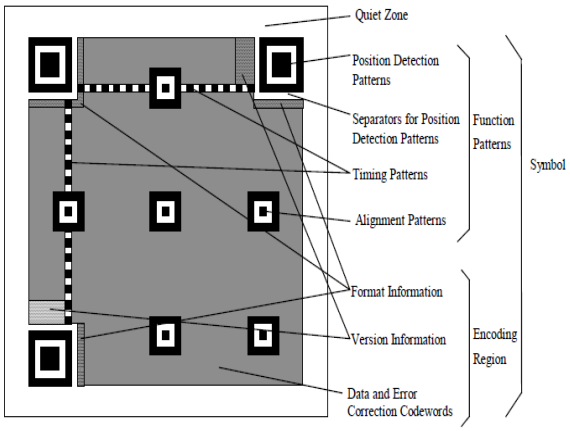

Figure 1: QR Code Architecture *[1]*

Then codewords are divided into blocks, and add error correction codewords to each block. All these codewords are put into a matrix and are masked with mask pattern. Finally function patterns are added into the QR symbol. A QR Code symbol is formed [1].

B. Basic characteristics

1) Encodable character set:

1.	Numeric data (Digits 0-9)
2.	Alphanumeric data (Digits 0 - 9; upper case letters A -Z; nine other characters: space, $ % * + - . / :)
3.	8-bit byte data
4.	Kanji characters

2) *Representation of data:* A dark module is a binary one and a light module is a binary zero.

3) *Symbol size (not including quiet zone):* 21×21 modules to 177×177 modules. Versions 1 to 40, increasing in steps of 4 modules per side.

4) *Data characters per symbol:* Maximum allowable data capacity for maximum symbol size version 40 and minimum error correcting level L:

1.	Numeric data	7,089 characters
2.	Alphanumeric data	4,296 characters
3.	8-bit byte data	2,953 characters
4.	Kanji data	1,817 characters

5) *Selectable Error correction level:* Four levels of error correction allowing recovery of:

L	7%
M	15%
Q	25%
H	30%

III. 1D V/S 2D BARCODES

Some features that describe how QR code is better in comparison with conventional barcodes have been listed out in Table 1.

TABLE I
FEATURES OF QR CODES COMPARED TO BARCODES

Feature of QR	QR code	Barcode
High capacity	Upto 7089 numeric digits	10-20 digits
Durability against soil and damage	Reading is possible (upto 30% damaged)	Reading is impossible
Reduced space	40 digits Numeric (approx 5 mm × 5 mm)	10 digits numeric (approx.50 mm × 20 mm)
360° reading	Supports 360° reading	Horizontal reading
Language supported	Numeric, Alphanumeric, Kanji, Kana	Numeric, Alphanumeric

IV. WHERE THEY ARE USED

Without a machine, it's impossible for human to manually decode QR Codes but they are easily processed by smart phones. Users photograph QR Codes and the software integrated into their phones decodes the messages and displays, manipulates, or stores the information on their mobile devices.

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Depending on the type of data recognized and the nature of the application, alternative actions can follow the decoding stage: a phone number can be automatically dialed, a short text message can be sent, a web page corresponding to the decoded URL (Uniform Resource Locator) can be displayed in a mobile browser, or a definite application can be executed. QR Codes are part of daily life in Japan, Korea, Taiwan, Hong Kong and China.

Some of the examples are enlisted below:

- McDonalds uses QR codes to its packages. By scanning which it inform users about the nutritious value of its burger or may be in some case, recipe of food also.
- Apple advertised the new i-Pod on billboards with QR codes. QR Codes used in a Nike advertising campaign allows direct access to a dedicated mobile site.
- Daimler AG, the parent company of Mercedes-Benz, has announced that it will be placing two QR codes on new Mercedes-Benz vehicles. To help emergency workers view rescue sheets, The QR codes will be there, which show the best way to get occupants out of a crashed vehicle safely.
- QR codes now appear in magazines, advertisements, product wrappings, T-shirts, passports, business cards and on subway billboards in Japan.

V. Diversity In Research Areas While Considering QR Code

There are different areas in which researchers have experimented with QR codes. Some of these are mentioned below.

A. Improving Data Capacity: Color Barcodes

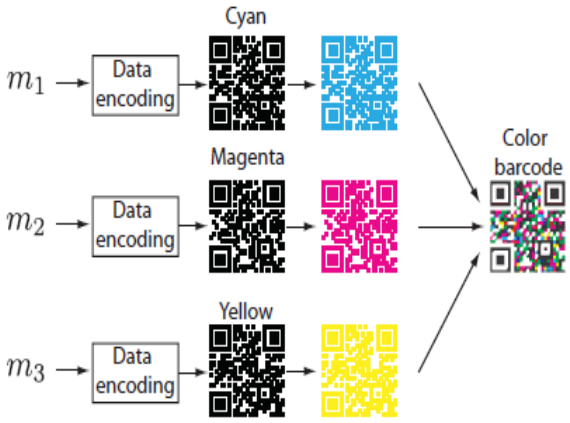

Figure 2: Per channel based data encoding *[3]*

The paper proposed by Henryk Blasinski postulates a new framework for color barcode construction that enables extension of existing monochrome barcodes to color [3]. Data is independently encoded in three monochrome barcodes which are then combined as the cyan (C), magenta (M), and yellow (Y) colorant channels within a single print leading to a three-fold increase in data rate compared with the corresponding monochrome barcode. Figure 2 shows the encoding part.

They ended up concluding that this paper [3] provides an effective method for extending monochrome barcodes to color. Color QR code constructions offer three times the data rates of their monochrome counterparts with low bit-error rates that are readily handled by the error correction coding options available in the QR code.

B. Use of multiplexing to increase information

The approach to multiplex data in order to increase the information in QR Code is presented by Sartid Vongpradhip [12]. The technique presented by him can increase the amount of data, as the original information in QR Code, keeping secret information as well (as illustrated in Figure 3).

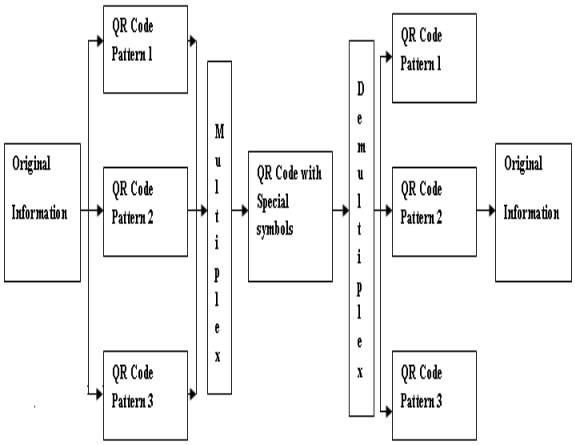

Figure 3: Overview of multiplexing and demultiplexing method *[12]*

The original data that is needed to be encoded is divided into smaller parts. A QR Code pattern is generated for each part in its standard form. Each pattern multiplexed and represented each module in QR Code with black and white special symbols. At the receiving end, this QR Code with special symbols (multiplexed ones) is decoded to give back the same number of QR Code patterns that was multiplexed. These decoded QR Code pattern can be read by the general QR Code reader of the smart phones and the data can be concatenated back to form its original information.

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C. Scratch removal technique

This study introduces an advance technique on removing scratch or damage that exists on QR-code [4]. The QR-code decoding algorithm is unable to decode if the scratch that applies on the QR-code is more than Error Correcting Level threshold of current QR-code or the damage applies on some curtain area, which consider as information area of the QR code. The scratch removal technique consists of several processes. In order to extract scratch from damage QR-code, simulate HSV (Hue, Saturation and Value) is applied and scratch on damage QR-code becomes more distinctive. Next, Morphological Image processing technique is apply by start with Dilation process that change the image structure and allow scratch become even more obvious. At this point scratch should be obvious enough and able to remove. To increase efficiency of decoding, Median filter is applied by transform image to Binary image to removing noise. The algorithm used in paper [4] is as shown in Figure 4.

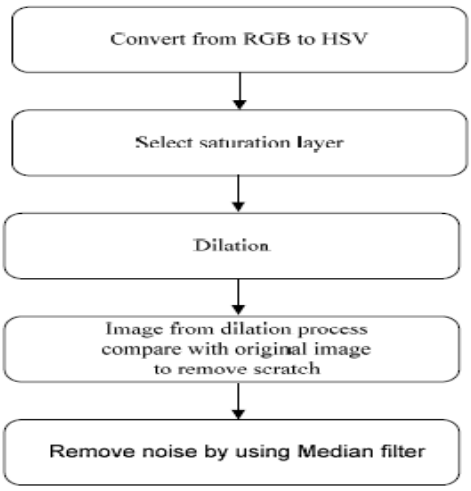

Fig. 4: The process of Separating scratches from QR code [4]

As the result of their experiment, image that been optimizing with the image processing technique is able to be decode with standard cell phone QR code software without any information lost. The image processing technique and procedure is efficiency enough to be used as Pre-processing of QR code. However, if the scratch color intercity is close to black or threshold level is not well adjusted; the significant value could be increase.

D. Data hiding techniques

Nowadays, commercial activities on internet and media are greatly exploding. The 2D Barcode with a digital watermark is a widely interesting research in security field.

Suppat Rungraungsilp et. Al. in [6] proposes QR Code embedded technique for invisible watermarking by using Discrete-Cosine-transform (DCT) compare with Discrete-Fourier-Transform (DFT). Their result shows comparison between mid-band coefficients and low-band coefficients. DWT-based watermarking was proposed by Shanjun Zhang and Kazuyoshi Yoshino [8].Geometric invariant watermarking technique have been explained and enlisted by Lakshmi Chetana Vemuri at. Al. [9].

Many approaches towards information hiding have been proposed for different attributes, such as undetectability, robustness, capacity, imperceptibility and reversibility. These are used for various applications like secret communication, copyright protection, image tampering detection [10], and other human-centered approaches. Even though traditional data hiding techniques have been proficient to make secret data imperceptible to attackers, alterations of cover media, caused by the hiding process have often been inevitable and irreversible. According to developed reversible data hiding methods, four main technologies have been widely applied: the compression based technology, the difference-expansion-based technology [7], the histogram-based technology [7] and visible watermarking.

The combined technique of visual cryptography and steganography is used in QR code and in banking as case applications. The combined technique of cryptography and steganography gives multi-level security. This multi-level security can be applied in future for similar parallel applications as illustrated in [11].

VI. Conclusion

This paper concludes that there are so many possibilities for QR code's use in different areas that is yet to be explored. The technology has a firm ground for research aspects. More and more experiments are done with QR codes in different aspects like enhancing the security, better recognition, reducing redundancy in order to save space, possibility of encoding different kind of data like audio, etc. As QR code provides the structural flexibility, it opens up the huge platform for researchers to explore the possibilities to enhance the performance of QR code or to merge QR code with different technologies, like -

- Experiments can be done to improve data capacity of QR codes.
- To find out the possibility of the use of coding techniques other than RS coding.
- Use encryption to encode data first, and then encode it to QR code for better security solutions.

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