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Secure Color QR Codes

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ABSTRACT:*Barcodes are well known and useful in area product identification. Arrival of 2D barcodes improved the condition. QR codes, the most popular 2D barcodes are widely used for the purposes other than product identifications. The higher data capacity provided by the QR codes can still be enhanced by the use of colors. Even then insecure QR codes make its applications narrow. QR codes made available in public Wi-Fi and LAN networks can be an issue in user privacy.Encoding the data in printing color-Cyan, Magenta, Yellow and combining it together can result in Colored QR codes with black and white Position Detection Patterns. Enhancing QR codes using colors not only improve the aesthetic look but also improves the data capacity by the factor of three. This advantage but too arises challenges in perfect decoding. The decoding challenges can be met with different image processing techniques. But still the security of the code is a question. The paper provides a QR code system which is password protected. This enhances the security even though the security issues still pop up. The paper also discusses why we go for password protection rather than classical encryptions.*

Keywords: *Color QR codes, Encryption, Interference Cancellation, QR codes.*

I. INTRODUCTION

Barcodes enable automated work processes without human intervention, and are widely deployed because they are fast and accurate, eliminate many errors and often save time and money. As in [1-6] Barcodes are capable of representing the data clearly and effectively which are optical machine-readable representations of data. Due to their reading speed, accuracy, and functional characteristics, barcodes have become ubiquitous in many applications, including their usage in department stores and retail chains to price goods, to track items and to identify customers through membership cards; in tracking item shipment and movement, such as express mail, rental cars, airline luggage; in patient identification in hospitals; in document management systems; in ticketing for sports events, cinemas, theatres and transportation. Barcodes in broad has two dimensions. The first one referred to as one-dimensional (1D) barcodes; represent data by varying the widths and spacings of parallel lines. The amount of digital information stored in 1D barcodes is limited and these bars are less error-free. Data rate could be simply increased by increasing the number of barcode digits or by laying out multiple barcodes. This approach has many negative effects, however, such as enlarged barcode areas, more complex reading operations, and increased printing costs. Again if one or bars in the code is lost whole barcode becomes unreadable. For this reason, the barcode technology has been deploying geometric patterns in two dimensions: such barcodes are referred to as bi-dimensional (2D) codes. Note that 2D codes increase the data space available by storing information in two dimensions, whereas 1D code contains data in one dimension only.

Figure 1 shows examples of 1D and 2D barcodes. Available 2D codes span from repeating a single 1D barcode over multiple rows to exploiting bi- dimensional shapes inorder to represent data. Figure 2 illustrates the evolution of 2Dbarcode technology. In particular, Figure 2 (a) shows a multiple barcode layout: in which there is the need of multiple scans inorder to get all the information contained in the barcode. Figure 2 (b) illustrates a stacked barcode layout: in this case one single scan is enough to obtain the stored information but the scanning equipment must be carefully aligned with the barcode orientation. Both the above forms an issue and hence in Figure 2 (c) a matrix barcode layout is presented: this layout enables to acquire information with one single scan and does not require the accurate alignment of the scanning equipment.

Fig. 1.Examples of 1D and 2D barcodes

Fig. 2. Evolution of barcodes: (a) multiple barcode layout, (b) stacked barcode layout, and (c) matrix barcode layout.

Now we will have a brief literature review of this research. Then the Secure Color QR codes will be proposed and the results will be discussed.

II. LITERATURE REVIEW

2.1 The 2D Barcodes

2D barcodes improve the working of single dimensional barcode by providing better data rate. Here the data is encoded in both height and width of barcode. Almost 30 different types of barcodes are known. Of these some are commonly used like data matrix code, Shot code, Visual code etc. The 2D barcodes can be widely divided into two categories: Index-based barcodes and Database 2D Barcodes. The type index-based 2D barcodes take into account the reading limitations of these built-in cameras. The Visual Code, Shot Code, and ColorCode belonging to this have a much lower data capacity than database 2D barcodes, but they offer robust and reliable barcode reading. The database 2D barcodes—QR Code, VSCode, and Data Matrix—were initially invented to improve data capacity for industrial applications. However, when integrated into mobile phones with built-in cameras that can scan and decode data, these 2D barcodes can operate as portable databases, letting users access information anytime, anywhere, regardless of network connectivity. Now let us move to important and popular 2D barcodes-QR codes.

2.2 QR Codes

QR-Quick Response codes are one among the most powerful 2D barcodes. Although it was initially developed for ship tracking by Denso-Wave company, now they are widely useful in most of applications like product tracking, person identification, online urls etc. This was made possible by the features of QR code like readable from 360^0, linking functionality, masking, data restoration functionality, small size, high speed reading etc. The code could handle Japanese and Chinese characters as well.

Going to the structure of QR codes the standard QR code consists of a Function region, Data Region and a Quiet Zone that separates QR code from other regions. QR codes adopt an arrangement of black and white squares for all the required functions. In particular, each module represents a single bit following a simple rule: black squares store 0 and white squares store 1(fig 3).

The finder patterns, alignment patterns and the timing patterns make QR codes easily detectable as well as decodable. Once the special patterns are set the information to be encoded is then included in the other parts. The encoding type is first identified for the given data and then encoding is done based on that. To make the code more safe and hence securely usable error resistant functionality should be invoked. Inorder to be resistant to errors and distortion up to a certain level, error correction code words corresponding to encoded words is made based on Reed-Solomon error correction. Now this codewords and error correction codewords are combined together and are placed within qr code. The binarised data is then given level color, black or white, and placed in a zigzag manner. The reverse process is done in decoding to get the data back.

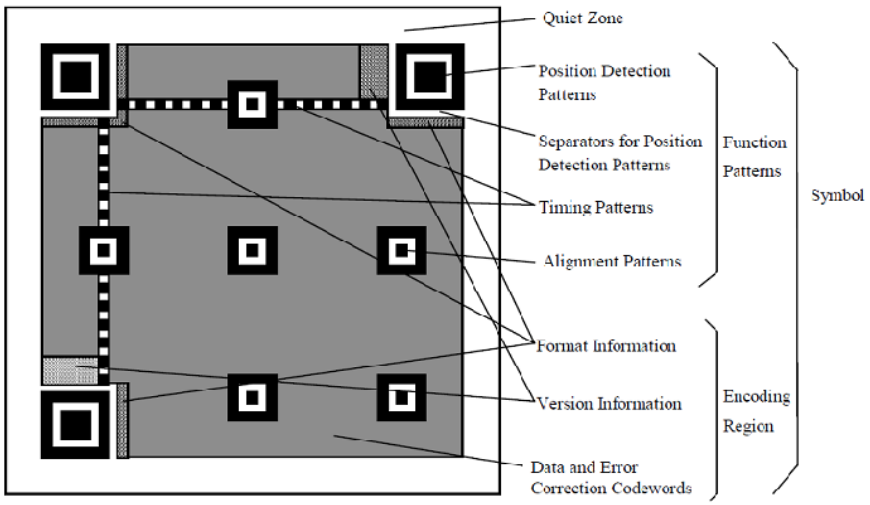

Fig. 3. Structure of QR Codes

QR code thus created can be enhanced by the application of color. The issues of which how colors should be selected and the color of border begin used is discussed in [7-8] .Data encoding is same as per the standards while instead of black and white we go for using the colors. This is also handled in [9-12].The use of colors in QR codes enhances its functionality now. The data rate which is high among the 2D barcodes can be further enhanced with the use of colors. But the same can cause a set of issues too.

The image of QR code is taken by a simple cell-phone camera can suffer from all the imaging issues and hence is to be carefully handled. The use of colors adds more issues. The correct color has to be identified for correct decoding. The interference between colored layers make it more complicated. The issues can be handled in better processing of images.

At first the image should be preprocessed to remove any blur or noise and make it suitable for color estimation. A lot of methods have been proposed in this area [13-22]. The attained image can be filtered using median or any deblurring filters to correct the image. Once the image is corrected the image is then examined for the function patterns. The most important function pattern-Position Detection Pattern are encoded for this easy detection. PTD consists of concentric squares with ratio of Black: White: Black: White: Black as 1:1:3:1:1. The image is searched for the same pattern [13-18]. Once this is found we are with three sides of QR code. The detection of fourth corner and hence the total QR code is also discussed in [13-18].

The localized image may be tilted or flipped while image acquisition. Thus the image should be geometrically corrected so as to decode correctly. This is also discussed in [13-18].

Now the image is processed for color detection. Here the color detection can be by either using simple probabilistic methods or by specific methods similar to ones used in High Capacity Color Barcodes [9-11]. But again probabilistic methods are always between true or false and hence the accuracy will be less. But if the data is critical such as passport or hospital data then the incorrect reading can't be afforded. While considering the case of reference colors the quality of camera the paper on which its printed ink used for printing etc is to be considered. The cost of the resources makes it infeasible. Hence we can't rely on such methods faithfully. Once color is detected then decoding can be done as per standards. Now let us go to Secure Color QR codes.

III. SECURE COLOR QR CODES

The secure color QR codes being proposed here ensures secure decoding of important data.

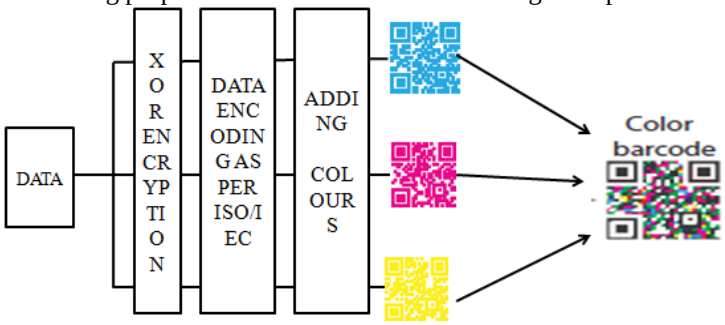

Fig. 4. Block Diagram(Encoding)

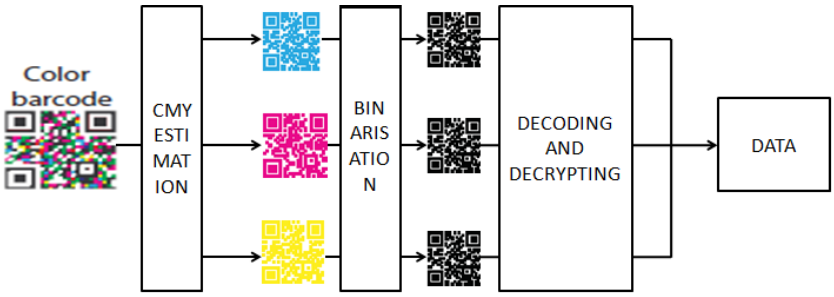

Fig. 5. Block Diagram(Decoding)

3.1 Encoding Region: As shown in Fig 4 the data to be encoded into color QR code is first of all encrypted by xor encryption with key as password. Then the data is encoded.

3.1.1 Encryption: The data is encrypted here before encoding. Although classical and powerful encryption techniques are available we have to stick on simple xor encryption here. The topic will be discussed later. The data is divided into three parts for unity in encoding. The first character is placed on first QR code 2^{nd} on 2^{nd} QR code and so on. Thus the data is diffused even before encrypting. Now this data is xored with the encryption stream created by password. Encryption stream is created by random generator within the range of value of password.

3.1.2 Encoding: Now with three encrypted data we go for encoding to form QR codes. Three Black and White QR codes are created as per ISO/IEC standards. Now in each QR code Black is respectively replaced with Cyan, Magenta and Yellow. The resultant color QR codes are added together to form a color QR code. It can be seen that due to the structure the position detection patterns of the Color QR codes will be Black and White still. This also now increases the data rate by a factor of three along with improved security.

3.2 Decoding Region: The barcode scanning is mostly done by images. The image of QR codes can be taken by help of simple camera phones. As the quality of phone varies the quality of image also varies. Again if the phone camera is good as well the lighting conditions, background lights etc can affect the image. The case becomes more complicated while the QR codes are colored. The intensity value of the combination of different colors has to be correctly detected. This has to be perfectly detected for perfect decoding (Fig 5).

3.2.1 CMY Estimation: Camera images taken for the processing will be mostly in jpeg format, i.e., its already compressed. The data is lost there itself. Now again different combinations of C, M and Y happen during creating and have to be decoded from the blurred image. For this the image should be processed and then passed through the method of color estimation.

a) **Pre-processing:** The pre-processing methods work on captured image so as to make the QR codes decidable. The processes can be classified under two major steps:

b) **Localisation and Geometry Correction:** The methods for localising the QR code from image and correcting the orientation strictly follows the previous methods that are being discussed in literature review. The position detection patterns are found and the fourth corner is detected using Hough transform. Once the QR code is found then its geometrically corrected using simple angle rotation.

c) **Filtering the Image:** Here the camera image may be blurred or affected with noise. This can be suppressed by using the well known median filter. The median filter is a non linear filter in which every pixel is replaced by a median value. This is best among filters in noise suppression.

d) **Color Image Processing:** In this we detect the color from the image. For this the filtered image is taken and divided into R G and B bands. An experimental threshold is set which can be adjusted by least mean square method and is used for detection.

e) The color value is set to that pixel position if it's greater than the threshold. This is iteratively done and adjusted so as to get the image. The corrected image will now contain almost corrected color values.

3.2.2 Binarization: Once we are with color corrected QR codes we have to binarize it. Binarization results in black and white QR code only in which decoding can be done.

3.2.3 Decoding and Decrypting:

a) Decoding*:* Once C,M,Y are estimated using the threshold then the image is processed inorder to get the three QR codes in Cyan, Magenta, Yellow. Now this is binarised to form three black and white QR codes. The QR codes are then decoded as per the ISO/IEC standards. Any missing data can be retrieved using the Reed-Solomon Error Correction technique that is implemented for the encoding.

b) Decrypting*:* Decoding results in encrypted data. This has to be decrypted for the information retrieval. For this XOR decryption is used which just the reverse of encryption. Combining the three data result in our valuable data.

IV. RESULTS AND ANALYSIS

The QR codes for private applications was developed using the above algorithm and was successfully decoded with 95% results. The coding was done in matlab environment and with the help of Google zxing package for QR code operations. This package helps in easy implementation of encoding and decoding Black and White QR codes. The private data cannot be decoded without the password that enhances the security. The different steps in encoding and decoding can be drawn as following images:

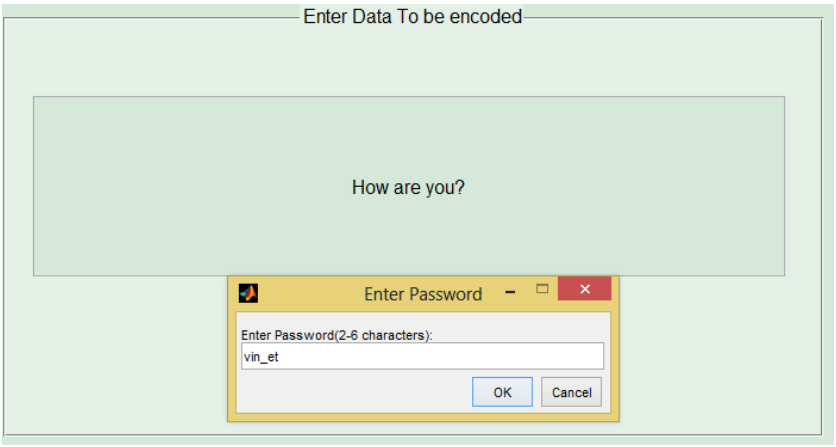

Fig. 6. Encryption of Data

Fig. 7. Creating Color QR Code

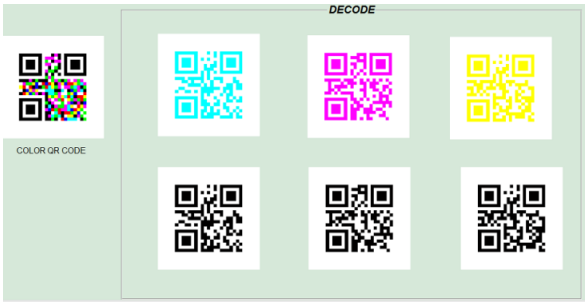

Fig. 8. Color Estimation

Fig. 9. Decryption Of Data

Fig.10. Decoding Of Data.

Fig. 11. Image Pre-processing a) Camera Image b)Filtered Image c) Color Estimation Of Cyan and Magenta

4.1 Encryption Strength:

The use of Xor encryption can be simply questioned because of its crackability. Accepting the fact that password protection is not safe we hereby bring to lights the problem of implementing the powerful encryption algorithms.

As an experiment we tried the well known and powerful encryption algorithm Advanced Encryption standard. The 16 byte input is encrypted to form a 16 byte output. But this results in a set of English special characters too. This result in next problem that these characters are not added into the character set of QR code standards. Thus the simple decoding of exact code will be also erroneous.
The following table gives an idea about this:

Table 1. Problem With AES

Padding Character	Characters Successfully Decoded	Characters Not Decoded
~	a,e,f,g,h,i,l,s	b,c,d,j,k,m,n,o,p, r,t,u,v,w,x,y,z.
!	b,d,h,l,m,n,q,r	a,c,e,f,g,i,j,k,o,p, s,t,u,v,w,x,y,z.
`	b,f,l,x	a,c,d,e,g,h,i,j,k,m,n,o,p, q,r,s,t,u,v,w,y,z.
{	b,f,g,h,k,q,r,s	a,c,d,e,i,j,l,m,n,o,p,t,u,v, w,x,y,z

The above table shows a list of characters that can be successfully decoded when they are given. For example when 'a' is encoded with padding character its decoded but not in any other case. The case is just opposite in the 'b'.This is because of the above English special characters being formed after encryption. No encoding method is found for them. They are not even entered into symbol set for encoding in the QR code format. Thus the this characters occupy the reserved space of JIS character set and the encoding and decoding become unknown and hence erroneous. This makes clear how AES fails the encryption here. The similar results can be found in DES too. Thus such encryption methods fail and hence we go for password protection.

The experimental and analytical results give 95% success rate for the above password protection method. A number of images where taken using different phones of Nokia, LG, Sony and the results remained the same. Estimation from Yellow image is a challenge in the case of low light conditions as well as strong illumination that reduced the success rate from 100.

V. CONCLUSIONS AND FUTURE WORK

Quick Response codes have become the efficient 2D barcode by its features. The comparative study of available 2D barcode proves this. The data rate of QR codes can be enhanced by using the colors. Replacing the black and white by Cyan-White; Magenta-White; Yellow-White enhances the data rate by a factor of three. Now the security can be enhanced by the use of password protection. The password protection is enhanced by xor encryption. This results in Secure Color QR codes.

This secure color QR codes can be decoded back to encrypted data by the simple color estimation methods and decoding specified in ISO/IEC standards. Then the encrypted data is decrypted by XOR decryption with the password given as key. Once the correct password is given the data is retrieved back. Although, bit error rates and therefore information capacities vary across the three resulting channels, the error rates are in ranges that are readily handled by the error correction coding options available for monochrome barcodes.

As Future expansion we can think of elaborating the Character set of encoding in QR codes. Along with this a small change in QR codes can be proposed so as to distinguish between both private and public data there by enabling a single QR code scanner for decoding the data which can be private or public. The working of password encryption can be enhanced by using the One Time Password systems.

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