Image Embedding in QR Code

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Abstract: ***Quick Response (QR) code is a two dimensional barcode widely used in many applications such as manufacturing, advertising, retailing etc. QR code looks like a noisy structure. The appearance of QR code can be improved by embedding an image into the code. This work proposed a method where the appearance of QR code is composed of visually meaningful patterns selected by users. This work makes QR code from machine read only to a personalized form with human visual pleasing appearance. The image embedding in the QR code is not an easy task because embedded result should be decodable by standard decoding applications and can be applied to any color image with full area coverage. In this work QR code pixels are selected by genetic algorithm, then the selected pixels are encoded with the luminance values of the image.***

Keywords: Image Embedding, QR Code**.**

1. Introduction

The QR (Quick Response) code is a two-dimensional barcode developed by the Japanese company Denso-Wave in 1994, and was approved as an ISO International Standard and Chinese National Standard in 2000. The QR code has been widely used due to its good features such as large data capacity, high speed scan, and small printout size. Increase in number of smart phones is the reason behind popularity of QR code. Smart phones are capable of decoding and accessing on line resources as well as it has high storage capacity and high speed of decoding. QR codes are used in a various applications, such as accessing websites, initiate phone calls, reproduce videos or open text documents and data storing purposes.

An important problem of QR codes is its noisy looks. To improve the appearance of QR code and to reduce noisy black and white random texture has generated great interest for algorithms capable of embedding QR codes into images without losing decoding robustness. There have been many efforts to improve the appearance of such embeddings. The main challenge of any embedding method is the embedded result should be decodable by standard applications. The embedding introduces changes in the luminance of the code, distorting the binarization thresholds and thus increasing the probability of detection error. The second challenge is the problem of using the entire area of the code in which the image or logo is to be embedded. This cannot be done by simply replacing information modules with the desired image. A good embedding method should decrease the number of corrupted modules and uses the utmost area. The proposed method is based on the selection of a set of pixels using genetic algorithm. The concentration of pixels and its corresponding luminance are optimized to minimize a visual distortion. Distortion metric is subject to a constraint in the probability of error.

There have been a lot of efforts to improve the appearance of QR code. The recently proposed method [1] is one of the best method to embed the color image into the QR code. Section II presents the structural characteristics of QR code. Section III gives the existing embedding methods. Our approach is presented in section IV. Comparative analysis on the QR images is given in section V.

2. QR Code Outline

QR code consists of black and white square blocks called as modules of a QR code. Each module is assigned a single bit value. Information is encoded into the QR modules. A dark module is binary one and a light module is binary zero. A codeword contains 8 bits of information. There are 40 versions of QR code. A QR code with version V have (17 + 4V) × (17 + 4V) number of modules. Therefore version 1 has 21 × 21 modules whereas version 40 corresponds to 177 × 177 modules.

Fig. 1 shows the structure of a QR code. Finder pattern contains three identical square shape located at the three corners of QR code. Finder pattern is the most important pattern which enables the detection of QR code. Alignment patterns are also essential to locate, rotate and aligning the QR code. Finder pattern, timing pattern and alignment pattern are collectively known as function pattern region of QR code. Alignment patterns are observed with version number 2 and onwards however version number 1 does not have any alignment pattern. Encoding region within the green color consists of data and error correction codewords. Data codewords are of two types i.e. information codewords which stores the actual information and the second is padding codewords. Encoding region stores the data, parity modules and decoding information in the form of a codewords. A codeword consist of a block of 8 modules. Quite Zone is the guard region of QR code. QR code utilizes RS (Reed Solomon) codes for error correction. A QR code contains multiple RS codes where one RS code is sufficient to store the message. The remaining RS codes are usually used to store non meaningful messages [2]. There are 4 types of error correction level i.e. L, M, Q and H which can recover 7%, 15%, 25% and 30% of errors in the codewords respectively.

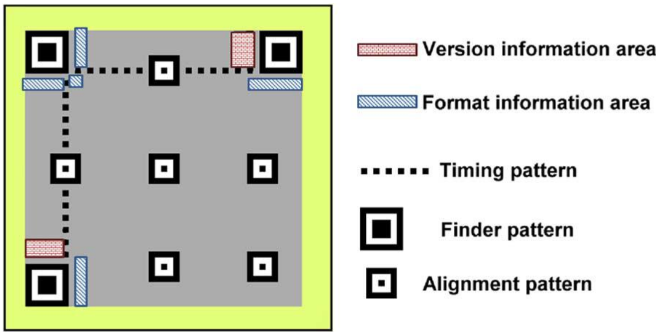

Figure 1: Structure of a QR Code

3. Related Work

There have been a lot of efforts to improve the appearance of QR code. The base strategy of such work is to find the best group of QR modules to substitute by the image or logo in the QR code. The method presented in [3] proposed that, there are three areas to replace the QR module by the image or logo. These areas include data codewords, padding codewords and the error correcting codewords. Depending on the error correction level of QR code, pad characters have been changed. The size of the embedding image in the QR code is identified and then the image is implanted in the identified region of QR code. The size of the image which is to be embedded is increased and tested the readability of QR embedding to find largest size of which the image could be embedded except the finder pattern of QR code. Author concludes that if the numbers of characters in the QR code is decreased then the larger image can be embedded.

The second approach [12] of embedding is based on the modification of the pixel's luminance. The luminance of central pixels is modified since this is the area usually sampled by the decoder. This approach uses the entire area of the code for embedding except the finder and alignment pattern. The approach in [10] performs the blending which combines the color image C and the QR code Q based on the luminance of color image and the binary value of QR code. The blending of C and Q to produce an output B is accomplished by replacing pixels of Q with those of C. Author assumes that pixels of Q are normalized so that white pixels have a luminance of 1, and black pixels have a luminance of 0. This algorithm ensures that the blended output image preserves the bright part of color image when the pixel value of the QR code equals to 1, and dark part of the color image when pixel value is 0.

Cox proposed a complicated algorithm [19] to embed a binary image into a QR code during the data encoding stage of generating the code. He carefully investigated the internal structure of QR code and the logic behind data encoding, and designed an algorithm to encode image content as redundant numeric strings appended to the original data. However this technique works only for URL type data string and the quality of embedded image is limited by the length of encoded URL.

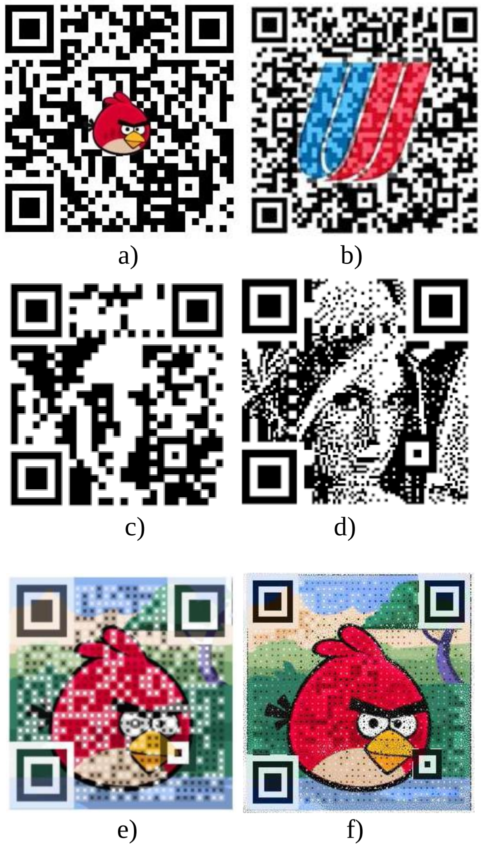

Figure 2: (a) Substitutions of QR modules by a logo, (b) image blended in a QR code [10], (c) QArt Code [19], (d) halftone QR code [14], (e) luminance modification algorithm [12], (f) luminance modification and halftoning algorithm [1].

The method presented in [14] first generates a QR code using a data encoding library. A key component in generating halftone QR code is a representation model that minimally binds to the original module, and yet is flexible to adapt target halftone image.

In [1], QR code values are encoded into the luminance values of the image in such a way that average luminance is increased for light regions in the code and decreased for dark regions. The first is the use of halftoning techniques for the selection of modified pixels allows breaking and reducing of the coarse square structure of the code. The second component is the modification of the luminance levels to minimize the image distortion. Central pixels of QR modules are sampled for correct decoding. Due to errors in the estimation of the sampling grid, adjacent pixels plays an important role in the decoding process. A center of size da × da is always selected by the user for the modification and remaining pixels are selected using a halftone mask.

4. Proposed Work

QR code and source image is optimized by changing the luminance value. To take advantage of local correlations between the luminance of the image and the values of the QR code, the optimization of the transformation parameters is performed. Optimization of source image makes it possible to specify regions of the image which require higher visual quality or higher decoding robustness. The masking process is employed which is based on the user specified range for masking of the pixels of source image.

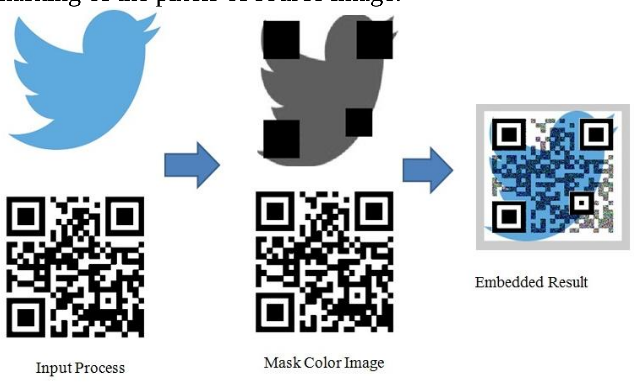

Figure 3: Overview of the embedding procedure

Genetic algorithm is implemented to select the pixel of QR code. The genetic algorithm is a powerful search algorithm that performs an exploration of the search space that evolves in analogy to the evolution in nature. It uses probabilistic transition rules instead of deterministic rules, and handles a population of candidate solutions that evolves iteratively. The first generation of this process operates on a population of randomly generated individuals. From there on, the genetic operations, in concert with the fitness measure, operate to improve the population. The evolution of the species is simulated through a fitness function and some genetic operators such as crossover and mutation. The fittest individuals will survive generation after generation while also reproducing and generating offspring's that might be stronger and stronger. At the same time, the weakest individuals disappear from each generation. In each cycle of genetic evolution, a subsequent generation is created from the chromosomes in the current population. The cycle of evolution is repeated until a termination criterion is reached. The pixel regions within the particular range are identified as the selected pixels using genetic algorithm. The selected pixels are encoded into the luminance of the color image to obtain the QR embedding.

5. Discussion and Conclusion

In this paper we present a method of the image embedding in QR code, where the visual appearance of QR code is composed of visually meaningful patterns selected by users. The modification of QR codes to improve their visual appearance is widely spread. All of these methods either deliberately use the error correcting capability of the code or these methods are based on heuristics without any analysis of the modification's effect on error. The main concern is that the embedded QR code should be decodable by standard applications. To retain the decoding capability of embedded QR code, the ratio of color image to the code area should be approximately proportional to the correction capacity of code. It was noted that the overlapping images over finder or alignment pattern severally decrease the probability of correct decoding. We expect that such decorated code can extend the usage in manufacturing sector as well as various mobile multimedia applications.

The method which finds the best group of QR modules to be replaced with the image generates the embedded QR code. The embedded QR code is decodable by a standard decoding application. The use of tiny part of QR code which is replaced by the image is the limitation of such method. The method used in [12] generates the embedded QR code with the decoding robustness but result shows the visual distortion. However it uses the entire area of code to produce the visual QR code. In [10], author gives the visually significant QR code by blending the color image into the QR code. This technique is also compatible with the existing decoders. The technique presented in [1] is based on modification of luminance values and halftoning method for the selection of modified pixel which generates the more visual pleasant result. This method always reduces the robustness of the code however it can be controlled by changing the value of maximum acceptable probability of error and the size of center region in pixels. Our approach embeds the source image into the QR code with full area of the code. This work gives the more visual pleasant result than the most of the previous results. The only issue is that the decoding robustness of embedded QR code is reduced.

Pixels of the embedded code are a mixture of pixels from the image and the QR code. This mixture distorts the binarization thresholds with respect to the black and white QR code, and in general increases the probability of binarization error. The probability of binarization error is the error of sampling the incorrect binary value at any pixel in the QR module. This probability is subjective by different factors such as the local distribution of luminance values in the image, the distribution of pixels in the QR code and the parameters of the luminance transformation. The problem can be minimized by optimizing the luminance parameters, but this presents a tradeoff between decoding robustness and image quality. The future work is to reduce the probability of binarization and sampling error by constructing probability of error modules.

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