Implementation of PiCode Embedded 2D Barcode System

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ABSTRACT

In 21st century, 2D barcodes are used very commercial. It has been mostly used to product advertisement contents and many other purposes. However, it can appears a 2D barcode pattern is often too obtrusive for integrating into an aesthetically designed advertisement. In this way, before the barcode is decoded, no human readable information is provided. This paper proposes a new picture-embedding 2D barcode, called PiCode, which overcome these two limitations by equipping a scannable 2D barcode with a picturesque appearance. PiCode is designed with mannerly both the perceptual quality of the embedded image and the decoding robustness of the encoded message. It Compared with the existing beautified 2D barcodes show that PiCode achieves one of the best perceptual qualities for the embedded image, and maintains a better tradeoff between image quality and decoding robustness in various application conditions. PiCode has been implemented in the Android based on a system and some key building blocks have also been provided to Android and iOS platforms. Its practicality for real-world applications has been successfully demonstrated.

Index Terms—2D Barcode Detection, 2D barcode, decoding robustness, embedded picture, perceptual quality.

1. INTRODUCTION

A **barcode** is an optical, machine-readable, representation of data; the data describes about the object that carries the barcode. Originally barcodes systematically represented data by varying the widths and spacings of parallel lines. Barcodes originally were scanned by special optical scanners called barcode readers. In the 21st century, many artists have started using barcodes in art, such as Scott Blake's Barcode. Barcode verifiers are primarily used by businesses that print and use barcodes. Any trading partner in the supply chain can test barcode quality. It is important to verify a barcode to ensure that any reader in the supply chain can successfully interpret a barcode with a low error rate.

QR Code is a graphical representation of data in a vertical & horizontal position over a fixed space. The pro for this method is that maintains the same robustness & error correction of the QR Code. The two-dimensional (2D) barcodes are widely used in the advertisement business as a bridge to link the offline and online contents. In such a application, a 2D barcode encoding a product promotion web link is often attached to an advertisement to engage customers and the mobile phone with ever increasing computational power and imaging capability is employed as a 2D barcode capturing and decoding device [3]. Potential customers can conveniently retrieve further information about an advertisement by scanning the barcode with their mobile phones.

(a) (c) (e)

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(b) (d) (f)

Fig. 1. The low and high capacity versions of the conventional2D barcodes and the proposed PiCode listed in the top and bottom rows, respectively. (a)-(b) QR codes; (c)-(d) Data Matrix codes; (e)-(f) PiCodes embedding the HKUST Academic Building image.

This process simply involves initiating sutaible barcode scanning mobile software & pointing the phone camera to words the barcode. More human oriented applications of 2D barcodes can be found in [4]–[6]. However, the traditional 2D barcodes, such as QR code and Data Matrix code shown in Fig. 1 (a)-(d), are not originally designed for mobile barcode applications. A recent report shows that the scanning volume of a picture-embedding QR code is three times more than that of the traditional QR code [8]. Therefore, designing a superior picture-embedding 2D barcode for the customer engaging applications is a problem of practical significance. In this paper, a novel picture-embedding 2D barcode, called PiCode . Unlike QR code and Data Matrix code in Fig. 1 (b) and (d), in the case of high capacity versions, no fixed pattern is inserted in the interior area of a PiCode so as to avoid the obtrusive pattern which degrades the appearance of the embedded image.

2. LITERATURE REVIEW OF BEAUTIFIED QR CODE

To facilitate our further on the proposed PiCode system , some background on the conventional 2D barcode system are needed. This section gives a review of the convention QR code and some existing beautified QR code, some of which are currently in practical usage. The goal of our research is to recognize products in supermarket or shops using 2D videos analysis. Most sighted people use three kind of clues to recognize products. The global appearance or shape of the packaging (especially for branded products), the text written on the packaging, and sometime the pictures or see-through windows to the package content. Sadly, using a single of these clues might not always be sufficient to recognize the product[4]. This is a classic problem for sighted people traveling abroad: the packaging might not have pictures, the brand is unknown and the alphabet unreadable. Appearance-based recognition of products is an exciting approach but relies on up-to-date exhaustive appearance databases that do not exist. An alternative machine-friendly way of recognizing the product is to simply read its barcode. The inconvenience of barcodes is that they are small and very often at the back of the packaging. This means that the user has to find the barcode first. This is not difficult for sighted people but very difficult for visually impaired individuals, especially totally blind people.

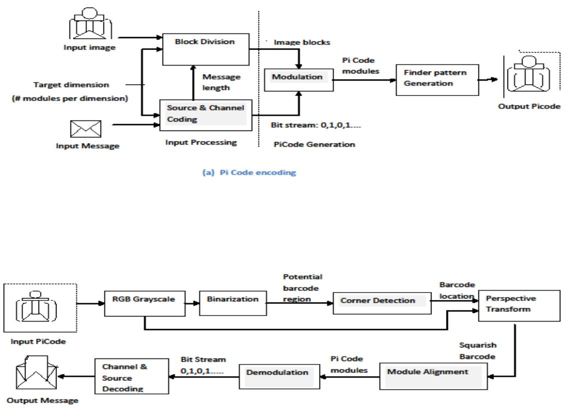
BARCODES have played a great role in facilitating numerous identification processes since their invention in 1952. In fact barcode is a simple and cost-effective method of storing machine readable digital data on paper or product packages. As pressing needs to transfer even more data faster and with high reliability have emerged, there have been many improvements that were made on the original barcode design[4]. Invention of two dimensional (2D) or matrix barcodes open new front forth cost-effective codes and their application in more complex data transfer scenarios like storing contact information, URL same on go there things, in which QR codes have become increasingly popular. A comparison of 2D barcode performance in camera phone applications can be found.

Barcode is a representation of digital data that are encoded in it and can be read using an optical machine. Due to its advantage over human performance in accuracy, speed and so on, barcode technology is used extensively. Once the traditional 1D barcode was developed, people started to think of developing 2D barcodes[5]. 2D barcodes can be formed using simple geometrical shapes such as square, circle, hexagon, triangle and so on, rather than using adjacent parallel lines. Moreover, the need to maximize data capacity of the barcode, led to the development of 2D barcodes such as Quick response (QR) codes and color barcodes. A QR code is a graphical representation of data in vertical and horizontal positions over a fixed space. For example, the Microsoft's High Capacity Color Barcode (HCCB) or the tag barcode. has the data density of 16,000 bits per square inch which is three times larger than data density in QR barcodes[5]. Nowadays, application of QR code can be seen in airport boarding pass, retail shops, company logo and so on.

Color barcodes accessible by mobile devices become popular as an inexpensive computing tool for information encoding. The information density of conventional black and white barcode technologies is limited because only one bit per symbol is possible. Color barcode systems such as HCCB (Microsoft's High Capacity Color Barcode) increase the information density by using more colors (e.g. four or eight colors). Increasing the number of colors to encode information makes barcode decoding a challenging task. This is due to the fact that the observed color patch depends on several factors such as unknown illuminant, viewing parameters, printing device and material, and color fading in addition to other nuisance parameters[12]. A mainstream approach to ensure robust decoding is to use a color palette of barcode colors printed with the barcode. One challenge facing such color clustering methods using a large number of colors is that the color distribution of one class can overlap significantly with color distributions of other classes. The clustering techniques may not work well in case of blur-induced color mixing from neighboring color patches.

3. THE PROPOSED PICODE SYSTEM

In this section the propose PiCode system id described with an emphasis on the novel aspect of the encoding and decoding algorithm .



(a) Pi Code encoding

(b) Pi Code Decoding

Fig.2. The block diagrams of the PiCode encoding and decoding procedures. The contributions of this work are focused on the shaded blocks.

The PiCode samples of both low and high capacities. It should be noted that PiCode also supports various pattern sizes from 29 × 29 modules to 65 × 65 modules with a step size of 4 modules on each dimension. Generally speaking, the finder pattern of PiCode is similar to that of the Data Matrix code and they both have a '_'-shaped pattern of solid lines on the left and bottom sides and a '_'-shaped pattern of broken lines on the top and right sides. (Note that the finder patterns of PiCode and those of the QR code are of very different shapes.) The main differences lie in three aspects. First, PiCode has an odd number of modules on each side while that of the Data Matrix code is even[7]. This is so designed to cater for the proposed fine-corner detection algorithm which can improve the corner detection accuracy.

Second, the high capacity PiCode does not include extra fixed patterns in the interior region of the barcode and hence no additional distortion due to such patterns is incurred to the embedded image, unlike most existing beautified 2D barcodes. Third, a new adaptive modulation scheme that induces less distortion in the embedded image is introduced to replace the binary modulation scheme of existing beautified QR codes.

PiCode Encoding

Fig. 2(a) shows the block diagram of the PiCode encoding procedure. Generally speaking, the PiCode encoding process can be divided into two parts: the input processing and the PiCode generation. In the first part, the input message is converted into a bit stream with source coding and channel coding to improve the efficiency and robustness of the encoded message. The input image is then divided into a 2D grid of image blocks according to the user's input on the number of modules per dimension. Each block consists of $k \times k$ pixels. In the PiCode generation part, the pixels in each image block are modified by the proposed adaptive modulation scheme so that each image block conveys a bit '0' or '1'. Finally, a layer of finder pattern of one module wide is added to the exterior of the modulated 2D grid of image blocks to form the PiCode. In the following, we describe the channel coding and the modulation schemes which are essential in balancing the decoding robustness and perceptual quality[8]. The goal of channel coding is to protect the information bits against errors after the demodulation step. In PiCode, a Reed-Solomon (RS) code over the finite field GF*(*28*)* is adopted. The code rate3 is adaptive to the message length (or the number of information bits). The shorter the input message, the smaller the code rate (and hence the stronger error correction capability), and vice versa. This is designed to maximize the error correction capability under a given pattern size and message length (Unlike QR code has four preset error correction levels to guarantee the robustness under different operation conditions). To ensure decoding robustness, the maximum code rate is set as 5⁄6 which ensures that the code is capable of correcting one erroneous byte out of every 12 bytes. For the modulation scheme, the aim is to represent a message, e.g., bit '0' or '1', by varying some physical parameter (e.g. intensity) of the modulation waveform. In this part, we present a modulation scheme with considerations on the trade-off between decoding robustness and perceptual quality[12]. For the color components of the embedded image, they should be modified with the least perceptual differences when compared with the original colors. We perform the modulation operation in the YUV color space which treats the chrominance and luminance components independently. During color rendering, the two chrominance components, U and V, should be kept the same as the original ones so that the perceptual difference between the original and modulated colors are minimized, while the luminance component (Y) is modified according to the proposed modulation scheme represented by Eq. (1).

Ie(i, j)= {I0(i, j)−(−1)B(i,j)· I, for inner pixels
{ I0(i, j)+(−1)B(i,j)· I R , for outer pixels

PiCode Decoding

Fig. 2. (b) illustrates the steps for PiCode decoding process. First, the captured PiCode image is converted to grayscale and is binarized to facilitate the search for the potential barcode regions which are then checked against the detection criterion. If the check is passed, the four corners are obtained; otherwise, the image will be rejected and the decoding process will be re-initiated with another image frame. Based on the barcode corner locations, the perspective distortion is then estimated and compensated on the gray level image. For the module alignment step, the region for each PiCode module is obtained based on broken line parts of the finder patterns. The following demodulation process is the reverse of the modulation process by inspecting the intensity differences between the inner and outer parts of each module. The modulated bit in each module is retrieved by the demodulation operation. Finally, then message is obtained by applying channel and source decoding to the demodulated bits[6]. In this part, we mainly cover the
corner detection, module alignment and demodulation steps which reflect our major contributions.

- **Coarse-Fine Corner Detection:** The corner detection algorithm locates four extreme corners of the barcode from the captured image. This is a non-trivial task due to various image distortions, such as uneven illumination, perspective distortion, blurriness and complex background structures.

- **Module Alignment***:* The module alignment step slices the barcode region into image blocks with reference to the black and white alternations in the '_'-shape pattern is illustrated . Each block corresponds to one module which is then input to the succeeding demodulation step. The accuracy of the module alignment step is therefore critical to the decoding performance. The slicing operation depends on the broken line'_'-shape pattern, as also used in the Data Matrix code.

- **Demodulation***:* In the demodulation step, each received module resulted from the module alignment step is analyzed to retrieve the data bit. The demodulation scheme is designed according to the modulation scheme described. Before the demodulation operation, each module is first resampled with the bilinear interpolation into 8 × 8 pixels since it is the minimum size required for our demodulation algorithm, luminance change, e.g., a sharp edge and a corner.

4. CONCLUSION

This paper has concluded a 2D barcode, named the PiCode. Comparing with QR codes, it provides one of the best perceptual quality in preserving the aesthetic appearance of the embedded image, while maintains the decoding robustness. It is achieved by the design of barcode pattern and better decoding algorithms. The PiCode is designed with less obtrusive fixed patterns to avoid distortions on the embedded image, and a modulation scheme which represents the data bit value adaptively with the embedded image intensity. On the other hand, some key steps of the decoding process have also been developed to guarantee the decoding robustness including the coarse-fine corner detection, module alignment with barcode structural information and demodulation with information from all pixels in each module. Comparisons with the existing beautified QR codes by experimental results show that PiCode has maintained a better trade-off between the perceptual quality and the decoding robustness. To evaluate its practicality, the PiCode system has been implemented in Android based on a PC, and as mobile application softwares in Android and iOS platforms. The perceptual quality and the decoding robustness of the PiCode system have been successfully demonstrated. In the future, the unobtrusive pilot symbols will be embedded into the PiCode center to serve as center alignment pattern and training symbols for the camera response function. Hopefully, a lower BEP in the demodulation process can be achieved.

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