ImageCode: Using Any Image as 2D Visual Code

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Abstract. Today, many people are familiar with getting information from 2D barcodes by scanning them with their mobile phones. However, the current 2D barcodes have very limited design customizability to be used for advertisement or marketing. We developed a new type of 2D visual code called ImageCode that generates an index key from an image and connects it to user-specified information such as a URL. A comparative evaluation with QR Code and ColorCode shows that, although recognition robustness needs improvement, its high customizability, retention over time, and code/content awareness make it highly effective for advertisement purposes.

Keywords: Mobile interaction, 2D barcode, ImageCode

1 Introduction

The proliferation of smartphones has brought users new ways of obtaining information and interacting with the real world. One example of technologies supporting such interactions is the visual marker recognition techniques such as QR Code reader applications. These days, many companies and organizations are using 2D barcodes for advertising purposes because the codes can connect people to relevant information with a simple interaction (i.e., aiming phone at the codes).

QR Code (Fig. 1. (a)), developed by Denso-Wave in 1994, is the most widely used 2D barcodes. It employs features such as finder patterns, alignment pattern, and Reed-Solomon(R-S) error correction [4] to enhance its recognition performance. However, it has one weakness; the barcode symbol itself is just a machine-readable code that does not carry any meaning to human. Also, the black-and-white square-shaped symbol is hard to catch people's eyes. This is a big problem for barcodes to be used in advertisements and marketing where it is important to attract people's attention to make people remember the brand, product, or service. To address this problem, 2nd generation of 2D barcodes, also called 2D visual codes, have been developed.

ColorCode (Fig. 1. (b)) developed by Cheong et al. [1] in 2000 is the first color-patterned 2D visual code that uses combination of 4 colors (red, green, blue, black) in 5x5 cells. In addition to the use of colors, ColorCode gives designers more design flexibility by allowing 60% of each cell in a ColorCode symbol to be freely designable. Such a 2D visual code satisfies the need for customizable design to some extent. But they are still too restricted in their format and style to be easily designed.

Fig. 1. 2D Visual Codes

We propose a new type of 2D visual code called ImageCode, which allows people to use any user-selected image with special patterns on its border as a 2D visual code. For example, a company can make an ImageCode with the company's logo and connect it to the company's website. People can create ImageCodes with their own photos and make a link to their homepage or blog. With ImageCode, users can make their own unique meaningful 2D visual codes easily and quickly.

2 ImageCode

We will explain the overall structure of ImageCode and how it encodes/decodes data.

2.1 Overall Structure

ImageCode is an index-based visual code [2] that encodes and decodes an index key to fetch data from a database server. When a user provides an image and its associated data such as a URL, ImageCode encoder generates an index key from the image and stores the data into database with the generated index key.

The minimum unit of ImageCode recognition is a module. Compared to other 2D barcodes which always have square shape, an ImageCode symbol is composed of 50x50, 50x42, 50x34, or 50x26 modules. Modules construct finder patterns, an alignment pattern, error correction patterns, and data blocks (Fig. 2). Finder patterns and alignment pattern are adopted from QR Code. The shape of a finder pattern and an alignment pattern has a unique property that any straight line passing through its center always go through the black and white sections with the constant ratio of 1:1:4:1:1 and 1:1:2:1:1 respectively (B:W:B:W:B). These patterns make an ImageCode symbol quickly detectable by its reader and are used to correct a distortion of a symbol. Besides the finder patterns and alignment pattern, there are 4 error correction patterns attached to each side of a symbol.

The center and most part of the symbol is data area where a source image is placed. The data area is divided into 8x8 equal-sized square data blocks. Each data block represents one data byte. From the data blocks, an index key is generated. In summary, an ImageCode symbol is an image surrounded by special patterns.

2.2 Encoding and Decoding

To make an index key from a source image, ImageCode uses the image's shape and color. First, shape information is encoded into 4 bits in each data byte (Fig. 2). Before

encoding the shape information, we convert the original image to a binary image using Otsu's method [3] to avoid shape obscurity. Because the shape is less vulnerable to change than color, we divide a data block into 4 4x4 sub data blocks. Each sub data block is mapped to one bit in a data byte to encode shape information.

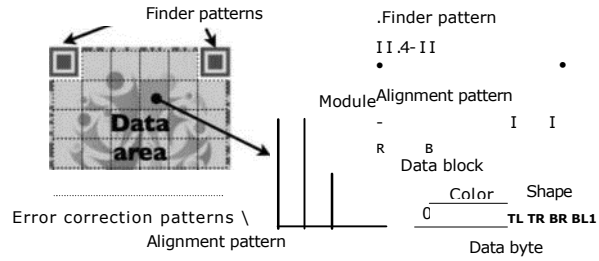

Fig. 2. Structure of ImageCode Symbol

When capturing an image, several factors including camera setting and lighting conditions can affect color values. For robust color recognition, two procedures are required. The first is color correction using reference black and white. Inside each finder patterns and alignment pattern, there are black and white areas which are considered to have pure black and white colors. Using these areas as reference, all the colors in a symbol is normalized. This color correction process makes ImageCode resistant to global color shifting mostly caused by different color temperatures of light.

The second procedure is color categorization. We categorize the color of each module into 8 colors — black, white, red, cyan, green, magenta, blue, and yellow. We threshold each RGB channel using Otsu's method. Data blocks are also categorized into 8 colors by aggregating colors of 64 modules in each data block. Hence 3 bits are used for encoding color information. (Fig. 2)

ImageCode utilizes R-S error correction coding which is highly effective for burst errors. The error correction code is encoded into error correction patterns and it is used to restore data blocks that might be damaged due to smudge of symbol, reflection of light, shadow on symbol, and etc. In 50x50 symbol, there are 32 data blocks and 16 error correction blocks. This generates 32 data bytes and 16 error correction bytes, which can correct 8 erroneous data bytes by R-S error correction. Therefore, 50x50 ImageCode symbol has 25% error correction capability. By the same calculation, 50x42, 50x34, 50x26 symbols can be restored from up to 23%, 20%, 28% symbol damage respectively.

3 Evaluation

Previous 2D visual codes comparisons mainly focused on data compaction and recognition performance of the codes. We believe that different evaluation criteria are needed to take into account the effectiveness of 2D visual codes in terms of serving the advertisement and marketing purposes. Thus, we propose new evaluation criteria for 2D visual codes to fill the gap (see Table 1), and then we evaluate ImageCode according to the new criteria in comparison with QR Code and ColorCode.

Table **1.** Comparison of 2D Visual Codes

	QR Code	**ColorCode**	**ImageCode**
Type	Database/Index	Index	Index
Base Shape	Square only	4 rectangles	4 rectangles
Base Color	2 colors	4 colors	Any colors
Data Capacity	119271 bytes (ver. 10)	1114 bytes	1432 bytes
Error Correction Level	7-30%	Less than 10%	2028%
Recognition Robustness	High	High	Medium
Customizability	Low	Medium	High
Retention Over Time	Low	Medium	High
Content Awareness	Low	Medium	High
Code Awareness	High	High	High

3.1 General Characteristics

ColorCode and ImageCode are index-based type, which need an external database server to fetch data, whereas QR Code is database type that stores data in itself. Since wireless connections are almost always available in smartphone environments, requiring a network connection for data retrieval is no longer a limitation.

The base shape of QR Code is limited to square. On the contrary, ColorCode and ImageCode basically support four different aspect ratios. In terms of base colors, ImageCode has clear superiority over both QR Code and ColorCode because any colors in a source image are used in ImageCode symbol intactly.

Maximum data capacity of QR Code is 2,953 bytes. However, QR Codes of version 10 or less which have a smaller data capacity are used for mobile devices due to the limited camera resolution. Data capacity of ColorCode and ImageCode is lower than that of QR Code. But as they are index-based type, it is not a disadvantage.

3.2 Error Correction Level and Recognition Robustness

Recognition robustness represents how well the code symbol is recognized and decoded by its readers under different conditions and environments. We redefined the original First Read Rate (FRR) [2] as follows to utilize the processing power of current smartphones which can recognize a code from preview video in real-time.

$$\text{First Read Rate (FRR)} = \frac{\text{Number of Successful reads in is}}{\text{N umber of attempted reads}} \quad (1)$$

We evaluated the recognition robustness using this FRR measure under various conditions of symbol size, distance and angle between symbol and camera, lighting conditions, and printed medium (paper or screen). Normally, FRR of each code has no significant difference. But when the code symbol is damaged due to shadow, reflection, or discoloration, FRRs of ImageCode and ColorCode dropped sharply.

ColorCode recognition is relatively robust to global color shifts but it is weak to local hue changes. The weakness in local color distortion is due to its low error

correction level. ImageCode is strong for local discoloration than ColorCode. However, because ImageCode categorizes all colors in a source image into 8 colors, the errors caused by wrong color categorization are more frequent than ColorCode. This makes overall ImageCode recognition less robust compared to the others.

3.3 Customizability and Retention Over Time

The most important advantage of ImageCode is its high customizability in design. Data area which takes up more than 75% of ImageCode symbol is freely designable. So code designers can make an eye-catching or well-suited ImageCode symbol without detriment their original intentions. Also, ordinary people with no design skills can create their own unique ImageCodes with any images they want within a few minutes. This high design customizability makes it possible to create code symbols that people can retain in their memory for a long time.

In contrast, QR Code and ColorCode have very limited customizability. In QR Code, only a few colors which have high enough contrast to its background color can be used. ColorCode has more design flexibility than QR Code as it allows 4 colors in encoding data and only 40% area of each cell is required to correctly recognize the code. Designers can utilize the remaining 60% space to add some design elements. One restriction is that the cell's centroid area must be preserved to prevent its recognition reliability from degrading. This restriction makes ColorCode much less flexible in design than ImageCode.

In QR Code and ColorCode, designers can add design elements to its symbol but they cannot be bigger than the area the code's error correction level can cover. Also, error correction capability decreases as the designed area grows because adding design elements on the code damages the original data. In ImageCode, on the other hand, data are generated from any images in their data area. Therefore, the error correction capability is maintained constantly regardless of its design.

3.3 Code and Content Awareness

Code awareness is a criterion to evaluate how easily people can aware that an image is a 2D visual code. If people cannot aware the code and do not even try to scan it, the code is of no use at all. Conversely, if the code has too fixed format and shape, its flexibility in design decreases.

QR Codes and ColorCodes have typical format and shape so that people who have seen any QR Codes or ColorCodes before can recognize them as a visual code at a glance. But when designed extensively, they could lose their identities as QR Code or ColorCode. In ImageCode, the patterns around a symbol give a hint to people that it is scannable like QR Code because the patterns are adopted from QR Code. However, if the patterns are designed in a way that harmonious with its content image, it becomes hard to distinguish the symbol from other images or logos. The trade-off between human awarability and harmonious code symbol design is controllable by its designer.

Along with the code awareness, ImageCode has high content awareness that gives a chance for people to be aware of what information the symbol contains before

scanning it Presenting some information beforehand helps drawing people's attention to it. With QR Code and ColorCode, it is impossible to figure out the contents before they are scanned by code scanners because they represent nothing visually.

4 Discussion

ImageCode works as a physical hyperlink that connects a physical image to an online resource. Since any image can be used, the recognition of ImageCodes look similar to computer vision based object recognition systems like Google Goggles and CHoG [5]. However, because of limitations of current computer vision technologies, they cannot differentiate subtle distinction among similar objects or images. Also their recognition speed and accuracy are low compared to those of visual marker systems including ImageCode and QR Code. Since objects themselves don't have any hints that they can be scanned, people do not know what to scan. Thus, these object recognition systems are not suitable to be used for advertisement purposes in terms of code awarability.

5 Conclusion

We presented a new type of 2D visual code called ImageCode. ImageCode uses any images to encode/decode an index key and makes a link to information that the creator assigned. From the comparative evaluation, we confirmed that ImageCode can be effectively used in advertisement and marketing with its high customizability, retention over time, and code/content awareness. However, recognition robustness, especially color recognition, should be improved to make it more useful.

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