MVA2011 IAPR Conference on Machine Vision Applications, June 13-15, 2011, Nara, JAPAN

Color Recognition by Extended Color Space Method for 64-color 2-D Barcode

Takuma Shimizu, Mariko Isami, Kenji Terada,
Wataru Ohyama, Tetsushi Wakabayashi and Fumitaka Kimura
Graduate School of Engineering, Mie University
1577 Kurimamachiya-cho, Tsu-shi, Mie, 5148507, Japan
{*ohyama,waka*}*@hi.info.mie-u.ac.jp*

Abstract

Colorizing two–dimensional (2-D) barcodes is a promising modality for improvement on design and data capacity. The number of colors employed in recent 2-D color barcodes is limited less than 8. To increase the number of recognizable colors, we propose a color recognition method which classifies 64 colors, using an extended color space and pattern recognition techniques. The proposed method employs 4 seed colors embedded within 64-color code to prevent influences from environment illumination. In the proposed method, we extend the color representation for each code color in 2-D barcode from three components to higher number component. And a classifier is trained using the extended colors captured from several environmental lighting conditions. The classifier is selectable. In this paper, artificial neural network (ANN), support vector machine (SVM) and nearest neighbor (NN) are employed as the classifier. The experimental results shows that the proposed method achieves MSER less than 3.0%. Comparing the number of seed colors, 4 seed color is comparable to that using 8 seed color. SVM achieves the best recognition performance of 1.17% SER. These results suggest that 64-color recognition is possible by the proposed method.

1 Introduction

With the drastic permeation of low cost camera such as camera phones or webcams, two–dimensional barcodes (2-D barcode) are getting popular on consumer market. The QR code [1], which is one of the most successful 2-D barcode, can contain not only text data but binary data like images and voices. The QR code can carry up to several hundred times the amount of data carried by an ordinary one–dimensional bar codes. Many of the existing 2-D barcodes are based on monochromatic and single color printing.

However, such monochromatic (binary) 2-D barcodes have problems on both their data capacity and design. The main usage of the QR code with camera phones is limited to carry only short text data like an URL or an e–mail address, so far. This is because that the data capacity of the binary QR code is still insufficient for carrying rich data. And its uncouth appearance also makes the 2-D barcode itself difficult for using in combination with colorful visual design.

Colorizing 2-D barcodes is recognized as a promising modality to provide further improvement of data amount per unit area. Introducing colors to each block of 2-D barcode pattern is equivalent to adding a third dimension (depth) to the 2-D patterns. By stacking 2-D pattern using the depth axis, we can create a new 2-D barcode that has more capacity than that the binary 2-D barcodes have. Some related researches [2–6] has been proposed in the literature of colorizing 2-D barcodes. The 2-D barcode captured by low–cost camera system receives several degradations, i.e. noise, optical burring, geometric disturbances and color change by environmental illumination. Most of these researches proficiently combine algorithms developed in computer vision research to address of the variety of image degradations.

The main problem of the methods is that the number of colors employed in 2-D color barcodes is limited less than 8. The reason is that the color classification used in the methods rely on the unsupervised classification scenario. The unsupervised classifier does not have enough availability for distinguishing colors which is spreading in the RGB color space. This problem of small number of colors in 2-D barcodes results a significant barrier for permeation of this technology.

In order to resolve these problems of capacity and design in a higher dimension, increasing the number of colors used in 2-D barcodes is necessary. In this paper, we propose a new color recognition method to increase the number of colors in 2-D barcodes. The proposed color classification method can classify 64 ($= 2^6$) colors using the extended color space and pattern recognition techniques. The basic concept of our method is that 4 or 8 seed colors are printed with 64-color 2-D barcode. These seed colors is used for prevent influences from environment illumination. In the method, the classifier is selectable. In this report, Artificial Neural Network (ANN), Support Vector Machine (SVM) and Nearest Neighbor classifier (NN) are compared for the performance of color classification.

The rest of this paper is organized as follows. Section 2 introduces our approach to the color recognition using the extended color space, followed by description about training and classification scheme for a classifier. In Section 3 we give details the experiments for performance evaluation of the proposed method. We created a prototype of actual color 2-D barcode. Section 5 gives introduction of our prototype. Finally, the conclusions and future direction of the research are given in Section 5.

2 Method

2.1 Overview

The basic concept of the proposed method is that a 2-D color pattern and reference colors are printed together and matched to each other so that the influence

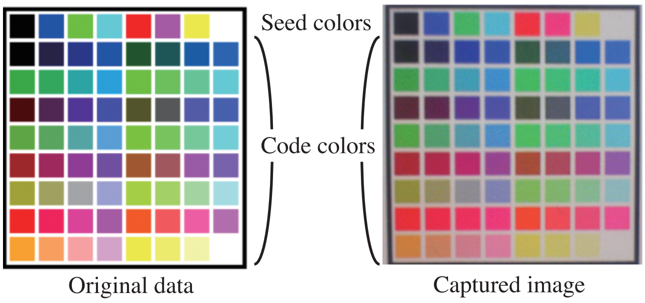


Figure 1. Prototype of 64-color 2-D barcode. The seed color is placed on the top row of the 2-D color pattern.

on color appearance from environmental illumination variety is prevented. For instance, when the system is required to handle 64 colors, if 64 reference colors are printed with 2-D color barcode pattern, the reference colors and 2-D color pattern should be influenced similarly because the affection from the environmental illumination change is similar.

However, printing many reference colors with the 2-D color barcode is not proper solution for the problem. The many reference colors not only degrade the design of 2-D barcodes but decrease data capacity par unit area. We take an other strategy where the smaller number of reference colors, called **seed colors**, are employed and the system generates the reference colors in virtual from the seed colors.

2.2 Seed colors and extended color space

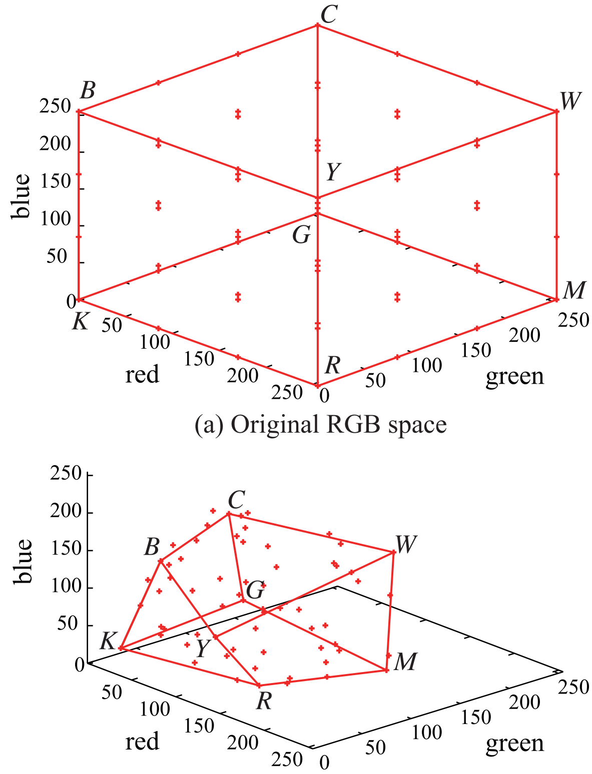
We define the 64 code colors as that they are arrayed with equal intervals within the color cube on the RGB color space. Let us denote a code color c_i by,

$$c_i = (r_i, g_i, b_i), \tag{1}$$

where, $r_i, g_i, b_i \in [0, 85, 170, 255]$ denote red, green and blue component, respectively, of the code color. Note that we assume 24-bit RGB representation (8-bit for each component).

The seed color pattern is a color pattern consists of small number (4 or 8) of colors and is located beside a 2-D color barcode pattern (Figure 1). In this research the seed color pattern consists of Red ($R = (255,0,0)$), Green ($G = (0,255,0)$), Blue ($B = (0,0,255)$), Cyan ($C = (0,255,255)$), Magenta ($M = (255,0,255)$), Yellow ($Y = (255,255,0)$), White ($W = (255,255,255)$) and Black ($K = (0,0,0)$) color blocks as the each vertex of color cube. Therefore, the 64 reference colors can be reconstructed by linear interpolation.

Since the seed colors are placed just close to the color pattern to classify, the seed colors and color pattern are expected to receive similar disturbance to each other. Consequently, we can expect that the generated 64 reference colors have similar distributions in RGB color space. From this expectation, we generated 64 reference colors using linear interpolation on RGB color space. However the classification accuracy was insufficient for color 2-D barcode. This suggests that the code colors receive nonlinear transformation from environmental disturbance.



(a) Original RGB space

(b) RGB space after nonlinear transform

Figure 2. An example of nonlinear affection on the color codes in RGB color space

Even though the original code colors are defined having equal intervals to each other, they receive significant disturbance during print and capture process. Figure 2 shows an example of this affection on the color codes shown by Figure 1 in RGB color space. In the figure, (a) illustrates distribution of 64 original code colors in RGB space. As described above, the seed colors are located on the vertex of color cube and each color distributes with same interval. (b) illustrates the distribution of 64 code colors contained by the capture image shown by Figure 1(b). It is obvious observed that printing and capturing process affects the each code color. This mentions that estimation and recovery of this transformation in RGB color space are quite difficult, while this transformation is expected to be written as a nonlinear transformation function.

Instead of estimating this nonlinear affection in RGB color space, we propose a new color recognition algorithm, named by the extended color space method, to handle this problem. In the proposed method, we extend the color representation for each code color in 2-D barcode from three components (r_i, g_i, b_i) to higher number components. A classifier is trained using the extended colors captured from several environmental lighting conditions.

The extension of color representation is defined as follows. Instead of representing a code color as an isolated vector of size 3 $c_i = (r_i, g_i, b_i)$, we represent the color as a higher dimensional vector combining the color itself and seed colors. When we employ 4 seed colors, each code color is represented by a vector of size 15 consisting of original RGB components and them of

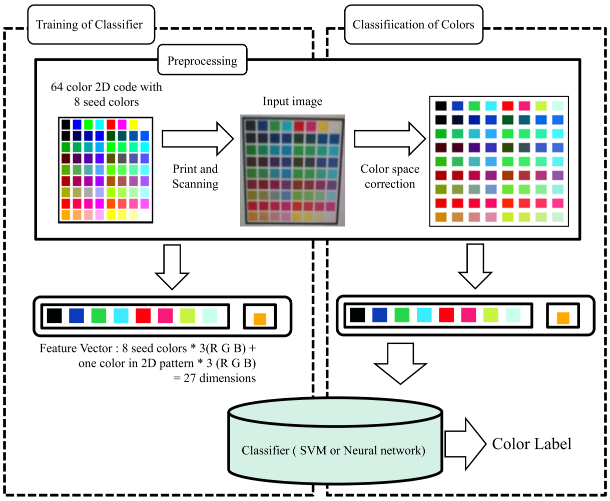


Figure 3. Process flow of the extended color space method

seed colors,

$$c_i^{(4)} = (c_i, R, G, B, W). \tag{2}$$

Where, the notation of a seed color $R = (r^{(R)}, g^{(R)}, b^{(R)})$ means the seed color after the print–capture process[1](displayed in Figure 2 (b)).

2.3 Color recognition

Figure 3 illustrates the process flow of the method. This method consists of two main stages, i.e. the training of classifier and the classification of colors. At first, the classifier is trained using training data set captured in a variety of environmental illumination. The color pattern employed as training data set is shown in Figure.1. The seed color is printed on upper area of color pattern and the 64–color blocks are aligned the bottom. Since the alignment of 64 color blocks are known, extracting one color block, we can determine the color label of the block. In the training stage, we placed this color pattern printed on high–quality papers in various environmental illumination and captured them using a CMOS digital camera.

Each color block in the color pattern is extracted from detected location of the four corners of color pattern. Input feature vectors consists of color components of an extracted color block and the seed color (4 or 8).

In the classification stage, each color block in the 2-D color code is combined with the 4 or 8 seed colors and input to the classifier. The classifier trained using the seed colors and code color captured on a variety of environment prevents the disturbance which changes the color appearance.

The smaller number of seed color is the better for both data capacity and design of 2-D barcode. We evaluate the performance of system in the both case, using 4 and 8 seed colors. The 8 seed colors consists of *RGBCMYWK*. The 4 seed colors consists of only *RGB* and *W*.

While the proposed method is developed for handling nonlinear affection in RGB color space, the scale correction in RGB color space is employed as preprocessing.

[1]Other seed colors *GBCMYWK* are denoted by the same manner.

2.4 Classifier

In the proposed method, the classifier is selectable. In this paper, artificial neural network (ANN), support vector machine (SVM) and nearest neighbor (NN) are employed as the classifier.

The structure of ANN is three–layer of which neuron number on input and output layers are 15[2] and 64, respectively. The neuron number on the input layer corresponds to the dimensionality of feature vector for one color block. Each neuron on the output layer corresponds to a color number (1 to 64). When the ANN is on training, 1 and -1 are given for corresponding color and others, respectively. The training of ANN is driven by the back propagation algorithm.

The SVM is also employed in the proposed method. The input feature vector, which is equal to for ANN, consists of 15 dimensionality for 4 seed color. The system constructs 64–class SVM.

In the NN classifier, Euclidean distance between the input code color and each reference color is employed to determine the nearest color.

3 Experiments

Figure 1 shows an example of 2-D color pattern used for the experiment. 64 colors are generated by assigning two bits (four level) on each of R, G and B. The created color code is printed using a ink–jet printer (EPSON PM3300–C) on dedicated premium presentation papers. The camera phone used for capturing the printed color code is a CMOS digital camera (about 3 mega–pixel, built in TOSHIBA auW54T). 150 2-D barcode patterns (50 par day, thee days) are captured in a variety of environmental illumination conditions.

For the ANN, the neuron number on the hidden layer are set 90 from the best performance on our preliminary experimental results. For the SVM, RBF kernel is employed. The experiments are conducted using 3–fold cross validation. The performance of color recognition is evaluated using Mean Signal Error Rate (MSER) defined as the following.

$$\mathrm{MSER} = \frac{1}{M}\sum_{i=i}^{M} r_i = \frac{1}{MN}\sum_{i=1}^{M} e_i. \tag{3}$$

Where e_i and $r_i = e_i/N$ are the number of incorrect recognition and signal error rate, respectively, on i-th code image. $M = 150$ and $N = 64$ are the total number of code images and the number of color block per one code image, respectively.

3.1 Results

Figure 4 shows the experimental results comparing the MSER among the classifiers and the number of seed colors.

[2]The 15 neurons on the input layer is for 4 seed colors. When the system employs 8 seed colors, 27 neurons on the input layer are used.

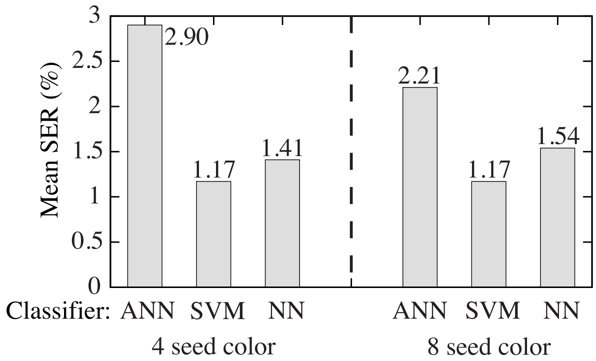


Figure 4. Comparison of mean signal error rate among classifiers and number of seed colors

Totally, the proposed method achieves MSER less than 3.0 %. In this experiment, the number of signal (data size) is 64 which is equal to the number of code color. This means that at most 2 colors are mis–recognized per one sample color code pattern.

Comparing the number of seed colors, 4 seed color is comparable to that using 8 seed color. Only when using ANN, 8 seed colors provides better performance than 4 seed colors. However, using SVM and NN, significant difference on MSER is not observed. Comparing classifiers, the SVM achieves the best recognition performance. These results suggest that 64–color recognition is possible with 4 seed color.

4 Prototyping of multicolor 2-D barcode

To evaluate the implementation feasibility, we prototype a multi–color 2-D barcode employing color recognition by the proposed extended color space method.

Figure. 5 illustrates the outline of the prototyping. We created the multi-color 2-D barcode by stacking three equivalent size QR codes. Three QR codes were assigned to *RGB* bit plane so that the 2-D barcode consists of eight colors. The number of signal contained in 2-D barcode is 249. Three of four seed colors *RGB* are placed on the position detection patterns and the white can be obtained from blank space of the code.

We printed and captured the generated 2-D color barcode using the same printer and cell–phone camera as above experiments. The color of each data block in the captured color barcode was recognized by SVM which achieved the highest performance in the experiments described above. We decomposed the original three QR codes by the results of color recognition.

The total SER of the example in Figure.5 was 14.9%. Error rates of each bit plane are 0.0%,12.4% and 2.4% for Red, Green and Blue, respectively. The error rate of Green bit plane was higher than that of others, however, this level of BER is lower than the error correction capability of QR code.

5 Conclusions

In this paper, we proposed new color recognition method for 64–color 2-D barcode. While the proposed method requires seed color to be printed with the color code, the recognition performance is promising to achieve multi color 2-D barcode. The experimental results suggests that the proposed method can classify 64 colors using only 4 seed color.

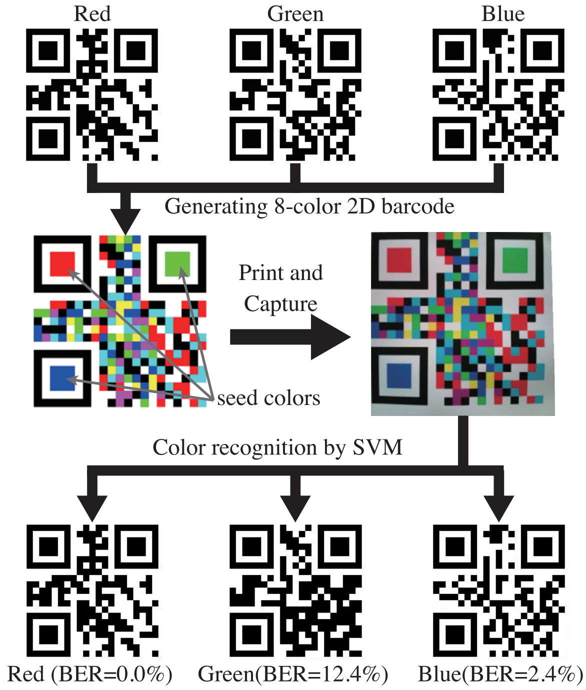


Figure 5. Prototype of multicolor 2D barcode recognition system employing the proposed extended color space method

The future research topic contains the follows: (1) experiments using other camera devices, (2) introduce of other color space, (3) increasing the number of recognizable colors and (4) designing of total system which consists from encoding of information into color code to decoding from captured color code.

References

[1] DENSO WAVE INCORPORATED. QRcode.com. [Online] [Cited: Aug. 27, 2010] http://www.denso-wave.com/qrcode/index-e.html

[2] J. Mayer, J.C.M. Bermudez, A.P. Legg et.al., "Design of high capacity 3D print codes aiming for robustness to the ps channel and external distortions," Proc. of 16th IEEE International Conference on Image Processing (ICIP), pp.105–108, 2009

[3] D.Parikh and G. Jancke, "Localization and segmentation of a 2D high capacity color barcode," Proc. of IEEE workshop on applications of computer vision, pp 1–6, 2008

[4] K.A.H. Nurwono and R. Kosala, "Color quick response code for mobile content distribution," Proc. of the 7th International Conference on Advances in Moblile Computing and Multimedia, pp.267–271, 2009

[5] R.Villán, S.Voloshynovskiy, O.Koval and T.Pun, "Multilevel 2–D Bar Codes: Toward High–capacity Storage Modules for Multimedia Security and Management," IEEE Trans. on Information Forensics and Security, Vol.1 No.4, 2006

[6] O.Bulan, V.Monga and G.Sharma, "High Capacity Color Barcodes Using Dot Orientation and Color Separability," Proc. of SPIE–IS&T Electronic Imaging, SPIE Vol.7254 pp.725417-1–725417-7, 2009