High density QR code with multi-view scheme

Jen-Shiun Chiang, Chih-Hsien Hsia and Hsin-Ting Li

Since the data storage capacity per unit area of a QR code is very limited, it is restricted in various QR code applications. An approach is proposed based on visual skew to improve the data capacity of the QR code. The proposed method can enhance the capacity of the QR code per unit area by using different angle views to combine several QR codes together. The storage capacity of the proposed mechanism can be increased 1.5 times per unit area more than that of the normal QR code.

Introduction: A QR code is a two-dimensional code developed by Denso Corporation of Japan in September 1994. The advantages of a QR code are not only high reliability, but also strong confidential security. In addition, it can be expressed to contain varieties of text and image information. In Japan, the QR code is used in various areas of daily life, such as magazines, guidebooks, store information, posters, web pages, product packaging, passports, visas and customs [1, 2]. There are also many applications of QR codes in public affairs, such as the identity of bus stops and tickets of high-speed rail, flights and navigation systems.

The use of QR codes is becoming more popular in real life. However, the limited QR code data storage capacity per unit area restricts the range of applications. In this Letter, we propose a method based on visual skew to increase the data capacity of the QR code. To enhance the capacity per unit area of the QR code, we use different angle views of QR codes to combine several QR codes together to increase the storage capacity. By our approach the storage per unit area of the QR code increases significantly. The proposed mechanism can extend the applications of the QR code to those applications that need higher data storage.

Multi-view QR code: To increase the storage capacity per unit area in the QR code, we propose a multi-view mechanism and the structure of the proposed multi-view QR code system is shown in Fig. 1. The proposed multi-view QR code system consists of three QR codes. In the multi-view QR code system, the front view is a normal QR code; in order to save area, the top view and side view comprise two skewed QR codes. By this arrangement, the area does not increase much, but the storage capacity per unit area can increase significantly. The details of encoding and decoding of the proposed multi-view QR code system are illustrated in the following sub-sections.

Fig. 1 *Structure of multi-view QR code*

A. Encoding: As shown in Fig. 2*a*, first, we convert all the data into three QR codes, and the data storage sequences are followed in the order of front view, top view and side view, respectively. The front view is in a normal QR code structure. The other two views of the QR codes must be skewed. To find a good resolving rate, here we use an affine transform [3] to produce the skewed QR codes. Finally, the three-view QR codes are combined to form the multi-view QR code shown in Fig. 1. The details of the affine transform are described later in this Section.

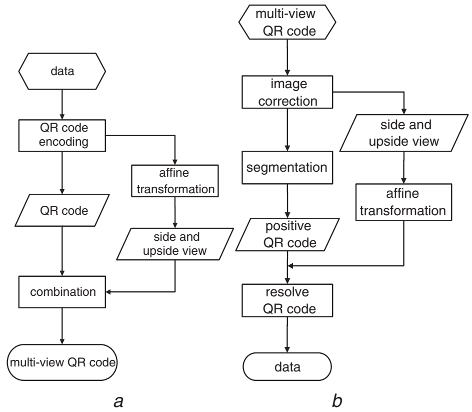

Fig. 2 *Flowchart of multi-view QR code*
a Encoding
b Decoding

B. Decoding: The multi-view QR code consists of front view, top view and side view QR codes. Fig. 2*b* shows the flow to resolve the multi-view QR codes. First, like the normal QR code decoding, the feature point, finder pattern, of the QR code is utilised to confine the block area of the QR code [4]. It then uses the finder pattern of the front view QR code as the reference feature and the known skewed angle to calculate the locations of the top view and side view QR codes to separate the top view and side view QR codes from the multi-view QR code. The separated skewed QR codes are then converted to the normal QR codes by the algorithms of affine transform [3] together with the compensation of cubic interpolation [5, 6]. The affine transform can adjust the skewed QR code back to a normal QR code for further QR code resolving.

C. Affine transform: The affine transform can preserve the co-linearity and ratios of distance of an image object. The general form is

$$Y = Ax + b \tag{1}$$

The affine transform contains a rotation and scaling process. Matrix $\boldsymbol{A}$ can be S, R_x, R_y or R_z, and they are represented as follows:

$$\boldsymbol{S} = \begin{bmatrix} S_x & 0 & 0 & 0 \\ 0 & S_y & 0 & 0 \\ 0 & 0 & S_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad \boldsymbol{R}_x = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & \sin\theta & 0 \\ 0 & -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{2}$$

$$\boldsymbol{R}_y = \begin{bmatrix} \cos\theta & 0 & -\sin\theta & 0 \\ 0 & 1 & 0 & 0 \\ \sin\theta & 0 & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad \boldsymbol{R}_z = \begin{bmatrix} \cos\theta & \sin\theta & 0 & 0 \\ -\sin\theta & \cos\theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3}$$

where $\boldsymbol{S}$ is the matrix of scaling, $\boldsymbol{R}_x$ the rotating matrix of the X-axis, $\boldsymbol{R}_y$ the rotating matrix of the Y-axis and $\boldsymbol{R}_z$ the rotating matrix of the Z-axis. Table 1 records the recognition rates of different rotation angles of a QR code by affine transformation. According to Table 1, the largest rotation angle where the QR code still preserves perfect recognition is 45°. Therefore, we skew the top view and side view QR codes by 45° in this Letter.

Table 1: Relationship between rotational angle and QR code recognition rate

Rotation angle	30	35	40	45	50	55
Recognition rate (%)	100	100	100	100	95	85

Experimental results: In this Letter, the specification of the computer for simulation is an Intel Core i7-3770 CUP with 3.40 GHz working frequency and 4G RAM. We implemented our method by using Microsoft Visual Studio 2008 in the Windows platform.

A. QR code skewed angle and recognition rate: To test the recognition rates of a QR code under various skewed angles, we use the 100-byte QR code with 20 different contents, and the results are shown in Table 1. According to the results of Table 1, we find the maximum rotation angle where the QR code still preserves perfect recognition accuracy is 45°.

B. Scaling of top view and side view QR codes: For the scaling test of the top view and side view QR codes, we used five kinds of QR codes, 100, 200, 300, 400 and 500-byte QR codes, each with 20 different contents. Fig. 3 shows the recognition rates with various scaling ratios of the five types of QR codes. In the experiment, without loss of generality, let us take the 100-byte and 200-byte QR codes as the example. It needs three 100-byte QR codes to compose a multi-view QR code; the total contents of the multi-view QR codes are 300 bytes, and it takes 67 240 pixels. However, for the normal 200-byte QR code, it takes 70 255 pixels. The multi-view QR code (300 bytes in content) takes less area, but has more data content (1.5 times) than those of the normal 200-byte QR code. Fig. 3 can help us decide the scaling rate of the QR code for composing a multi-view QR code.

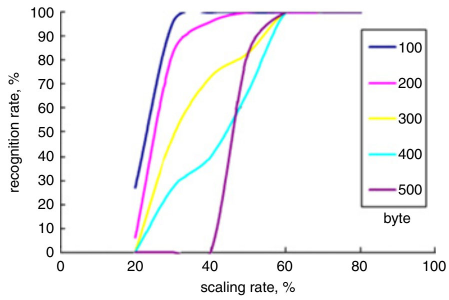

Fig. 3 *Scaling and recognition rates of multi-view QR code*

Conclusion: The QR code is widely used in daily life. However, the application is limited by the data storage capacity per unit area. In this Letter, we proposed a high density QR code approach with a multi-view scheme to improve the capacity of the QR code. Our multi-view QR code can not only enhance the capacity of information stored per unit area, but also increase the applications of QR codes.

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