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Watermarking Embedding Algorithm for Color QR code Based on Image Normalization and Contourlet Transform

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Abstract:

In this paper, an algorithm that embed watermarking into color QR code based on image normalization and contourlet transform is proposed, which is based on image normalization and invariant centroid theory. For the purpose of enhancing the invisibility and resistance to geometric attack of watermarking, we first encrypt the watermarking with chaotic method before information embedding, and then eliminate the effect of geometric change by utilizing image normalization. Based on the matrix singular value decomposition in contourlet domain, suggests an adaptive watermarking scheme that watermarks are embedded into the above resulted images. Corresponding, we perform inverse transform to the QR code which is attacked by geometric transformation and non geometric transformation including blurring, JPEG compression, noise addition, sharpening, scaling, rotation, and cropping before extracting the watermarking. Thus, we can prove the truth of the attacked QR code by the extracted watermarking which is recognizable.

Keywords: color QR code; digital watermarking; image normalization; contourlet transform; attacks

Introduction

Digital watermark is a pattern of bits inserted into a digital image, audio or video that identifies the copyright and authenticate information. In recent years, some researchers have proposed the adoption of watermark techniques. T.Sridevi[2]implemented a BNA(Blind Normalization Algorithm) watermarking algorithm resistant to geometrical distortions (rotation, scaling and aspect ratio). This algorithm uses a normalized image based on the image moments. A CDMA scheme is used to embed a 256-bit random watermark in the discrete cosine transform domain of the normalized image. Applying statistical inference theory, the watermark detection problem can be transformed as the dual supposition examination question.

2 Related knowledge

2.1 Image Normalization based on geometric moments

Firstly, the concept of image geometric moments is proposed.

Definition 1: the size of digital image $f(x,y)$ is $M \times N$. Let m_{pq} and u_{pq} p,q=0,1,2,...be the geometric and central moments of image, respectively.

$$m_{pq} = \sum_{x=1}^{M}\sum_{y=1}^{N} x^p y^q f(x,y)$$

and

$$u_{pq} = \sum_{x=1}^{M}\sum_{y=1}^{N} (x-\bar{x})^p (y-\bar{y})^q f(x,y)$$

Among, $\bar{x} = \frac{m_{10}}{m_{00}}$ $\bar{y} = \frac{m_{01}}{m_{00}}$ The translation is eliminated by setting the center of the image $f(x,y)$ at point $(\bar{x},\bar{y})$.

Then the normalization steps are as follows:

(1)Centralization: to eliminate the impact of translation transform for normalization process. The resulting image is denoted by $f_1(x,y)$.

(2)Shearing transform: Apply a shearing transform to $f_1(x,y)$ in the x direction with matrix $A = \begin{pmatrix} 1 & \beta \\ 0 & 1 \end{pmatrix}$. The parameter β is set in a way that the resulting image, denoted by $f_2(x,y)$ achieves $\beta = \frac{u_{11}^c}{u_{02}^c}$. Apply a shearing transform to $f_2(x,y)$ in the y direction with matrix $A = \begin{pmatrix} 1 & 0 \\ \gamma & 1 \end{pmatrix}$. The parameter γ is set in a way that the resulting image, denoted by $f_3(x,y)$ achieves $\gamma = \frac{u_{11}^c}{u_{20}^c}$, where u^c is the central moment of the image after centralization.

(3)Scaling normalization: Scale $f_3(x,y)$ in both x and y directions with $A = \begin{pmatrix} \partial & 0 \\ 0 & \xi \end{pmatrix}$ and d=0. The parameters ∂ and ξ are determined in a way that the resulting image denoted by $f_4(x,y)$ achieves a determined standard size $\partial = 8\sqrt{\frac{u_{02}^{sh}}{\left(u_{20}^{sh}\right)^3}}$ and $\xi = 8\sqrt{\frac{u_{20}^{sh}}{\left(u_{02}^{sh}\right)^3}}$, its moments become $u_{50}^{sc} > 0$ and $u_{05}^{sc} > 0$. Where u^{sh} is the central moment of the image after shearing transform.

(4)Rotation normalization: Apply a rotation transform to $f_4(x,y)$ with matrix $A = \begin{pmatrix} \cos\phi & \sin\phi \\ -\sin\phi & \cos\phi \end{pmatrix}$ and d=0. The parameter ϕ is determined in a way that the resulting image denoted by $f_5(x,y)$ achieves

$$u_{30}^{r} + u_{12}^{r} = 2\left(u_{30}^{sc} + u_{12}^{sc}\right)\cos\phi + 2\left(u_{03}^{sc} + u_{21}^{sc}\right)\sin\phi = 0$$

and $u_{03}^{r} + u_{21}^{r} < 0$, where u^{sc} is the central moment of the image after scaling normalization.

You can get a normalized standard image after more than four steps, the order of the matrix can not be changed. Anti-normalization process can be obtained by multiplying A^{-1} step by step. Fig.1 illustrates the normalization procedure.

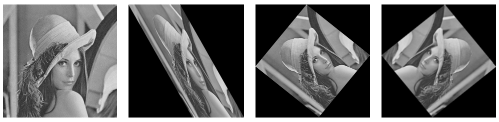

Fig. 1. (a) Original image Lena. (b) and (c) The Lena image after shearing distortion in x and y directions, respectively. (d) Normalized image.

The original image "Lena" is shown in Fig. 2(a). Also, this image after x-shearing transform is shown in Fig. 2(b). the image after y-shearing transform is shown in Fig. 2(c). Both of these images yield the same normalized image, illustrated in Fig. 2 (d), when the above normalization procedure is applied.

2.2 contourlet transform

The contourlet transform is a novel image processing scheme that is flexible multiresolution, local positioning and directional image decomposition, as introduced by Minh Do and Martin Vetterli. For using efficient two-dimensional multiscale and directional filter bank, the contourlet transform not only possesses the characteristics of the multiscale and time-frequency localization but also offers a high degree of directionality and anisotropy in contrast to traditional image processing using wavelet transform.

3 The proposed method

A watermarking method consists of two phases: the watermarking embedding procedure and the watermark verification procedure. In the first phase some binary features are extracted from the color QR code. Then image normalization and contourlet transform are applied on the binary map image and a binary logo to generate the verification map. Finally, the verification map that is a kind of signature is sent to a trusted authority. The second phase consists of retrieving the binary logo and authenticating the copyright of the image.

3.1 watermarking embedding procedure

Let the original image I be color QR code image of size $M_i \times N_i$ and the digital logo W be a binary image of size $M_w \times N_w$. The original image I and the binary logo W are defined as follows:

$$I = \{I_{ij}, I_{ij} \in \{0,1\}, 0 \le i \le M_i, 0 \le j \le N_i$$

$$W = \{w_{ij}, w_{ij} \in \{0,1\}, 0 \le i \le M_w, 0 \le j \le N_w$$

Step 1)The information is encoded into color QR code and watermark QR code. The color QR code has a backdrop of green as the original image.

Step 2)Take distortion compensation for watermark QR code. $W'(\omega) = \partial \times W(\omega) \times \frac{1}{P(\omega)}$ where $W'(\omega)$ is watermark frequency response after pre-distortion, $W(\omega)$ is original watermark frequency response, ∂ is compensation coefficient, $P(\omega)$ is impulse response of printing and scanning model.

Step 3)Scrambling watermark sequence by chaos transform to get new sequence,

$$W'' = W_1', W_2', \ldots, W_{m\times n}' ;$$

Step 4) Convert color space from RGB to Lab for backdrop，then extract the luminance component L；

Step 5) Normalization: The normalization procedure which has been described in section 2.2 is applied on the luminance component L to obtain the normalized image. Then extract an important region of the normalized image which has been described in section 2.3 to get a district Z.

Step 6) Contourlet transform of the area Z: The important area Z is decomposed by using t level contourlet transformation to obtain the low frequency subband LL_t.

Step 7) Decompose optimized coefficient matrix LL_t by SVD to obtain singular values S_I. The first singular values are stayed for they are much larger and more stable than others. The watermark is embedded into singular values S_I from the second values by $S_{I-W} = S_I + \partial W_W$. ∂ is embedding strength, W_W is a matrix which contains watermark information.

Step 8) Decompose singular values S_{I-W} by SVD to get the watermarked diagonal matrix and left singular matrix U and right singular matrix V. Perform singular value reconstruction and inverse contourlet transform and anti-normalization to obtain the luminance component $L^{'}$.

Step 9) Convert color space from Lab to RGB for $L^{'}$ to get the watermarked color backdrop. Combine backdrop and QR code in the Photo shop. Print out watermarked color QR code in 600DPI by digital printing.

3.2 watermark verification procedure

Step 1)Scan the printed color QR code in 600DPI resolution and eight-level Grey. Take the image processing operations such as edge detection, and adjust its size;

Step 2)Convert color space from RGB to Lab for color QR code, then extract the luminance component L_w;

Step 3)Normalization: Normalize L_w by applying the indicated normalization procedure.

Step 4)Contourlet transform: The normalized image is decomposed by performing t-level contourlet transform to obtain the subband LL_{wt}.

Step 5)Decompose LL_{wt} matrix by SVD to obtain singular values S_2, perform singular value reconstruction to get the S_3.

Step 6) Get information bits W=$(S_3 - S_1)/\alpha$.

Watermark information obtained by chaotic system transforming, decode the standard QR code image to get the original information.

4 Experimental results and analysis

We conducted some experiments to demonstrate the robustness of our copyright proving scheme against signal processing and geometric attacks.

4.1 experimental results

In this essay, Peak signal-to-noise ratio (PSNR) is used to measure the difference between original color image and watermarked color image. The normalized correlation coefficient (NC) is used to analyze similarity between the extracted watermark and the original watermark.

In this study, we used color scale QR code as our host image, and the gray QR code for watermark image. In our experiments, we used the scaling factor α =10. Fig. 2 shows cover image, original QR code and watermark. Fig. 3 shows watermarked image, combined image and the extracted watermark.

(a) background (b) QR code (c) watermark

Fig2. Cover images and watermark

(d)watermarked image (e)recovered watermark

Fig3. watermarked image and extracted watermark

In no attack case, the experimental results are that PSNR is 32.3893dB, NC is 0.9632, embedding time is t1=7.9063, extracting time is t2=9.4219. This show that the watermarked image has good invisibility, and we can extract watermark with less distortion.

4.2 Applying attacks to the watermarked image

Attack methods is defined as any kind of distortions that can be applied on the watermarked image in order to disturb the procedure of binary feature extraction in watermark verification phase. Different signal processing and geometric attacks were applied on the test image and the Normalized cross correlation between the retrieved watermark and the original watermark is computed. In addition the related method [5] has been implemented and the results of our proposed method are compared with it.

Tables 1 and 2 show the NC of the proposed method for color QR code under the non-geometric and geometric attacks. As shown in these two Tables the average NC between the retrieved watermark and the original logo is 0.8765. Also, according to the retrieved watermark in Table 1 and 2, the proposed scheme can retrieve clear and recognizable information from the attacked images.

Table 1. The performance of the proposed method by calculating the NC value and the retrieved watermarked under mentioned non geometric attacks in section 4.2.

Attacked Image PSNR(dB)	Blurring	Sharpening	JPEG	Gaussian Noise	Low-pass Filtering
	21.5920	24.8388	21.1761	22.5164	20.5033
Extracted Watermark NC	0.8653	0.8495	0.8737	0.8839	0.8062

Table 2. The performance of the proposed method by calculating the NC value and the retrieved watermark under mentioned geometric attacks in section 4.2.

Attacked Image PSNR(dB)	Cropping	Cropping	Shear X	Printing Scanning	Rotation
	6.0996	6.3599	7.6281	8.6556	7.7507
Extracted Watermark NC	0.9270	0.9323	0.8228	0.8525	0.8514

5 Conclusion

This paper presents a robust watermarking algorithm based on color two-dimensional code. Combining the encode techniques of color two-dimensional code, watermark pre-distortion processing techniques, chaotic system encryption technique, color space conversion techniques, image normalization, contourlet transform. With the encoded watermark information is embedded into backdrop of color QR code, it not only without affecting the fast reading of two-dimensional code but also improves digital watermark embedding capacity and robustness. Experimental results demonstrate that the proposed scheme has high performance against common geometric attacks and sufficient robustness under non geometric attacks.

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