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Embedding QR Code in the Wavelet Domain of Image for Metadata Hiding

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Abstract

Background/Objectives: The most image watermarking techniques has nearly always been implemented in red, green and blue color space. This paper provides a method for inserting the QR code in the CIEXYZ color space to store metadata information. **Methods/Statistical Analysis:** This paper provides new QR code watermarking technique that is included in the low-frequency sub-bands through the haar wavelet transformation to CIE XYZ color space of the color image. Independent Component Analysis was applied to the watermark signal and to insert the QR code to the low frequency band of the host image. In the QR code extraction process, QR code was to be detected even without the image. **Findings**: The results of several experiments indicate that the proposed method provides unambiguous detection, imperceptibility, security, and robustness against JPEG compression, median filtering, different noise and image cropping attacks. **Application/Improvements**: This method can be utilized to insert the metadata into the digital content. The proposed method will be developed to be more robust to various attacks in the future.

Keywords: Data Hiding, Metadata, QR Code, Watermark, Watermarking, Wavelet

1. Introduction

Rapid growth of information and communication technique, many business companies uses a network to efficiently transfer digital data products for benefit. As can be readily copy and distribute the digital data, unauthorized copying with a copyright, it has emerged as the most important social problem in the smart media industry. Digital watermarking technology is getting considerable attention in order to solve the problem of copyright protection, it has been developed for decades[1-6]. The watermark can only rightful owner can display the logo or the binary sequence. Since the watermark technology, used to detect or protect that displays the copyright of digital content. Characteristic required in the watermarking technique is robustness and imperceptibility.

The purpose of this paper, we aim to hide metadata by embedding it in the color image via an image watermark technology. Firstly, the metadata information converted to a binary QR code image. The QR code image embed into an original image and then transmitted it over public network by any unauthorized user.

In order to ensure the confidentiality, the host color image and a QR code image is not known in advance. Therefore, by utilizing the oblivious watermarking technique is to satisfy these requirements. In this paper, oblivious watermarking scheme that contains the text information to the CIE XYZ color space of the color image

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that is applied to the low-frequency wavelet domain using the saturation component. Color watermarking system was studies in the previous gray scale method was utilized in the color space using the brightness of the host image[7]. Ahmidi et al.[8] proposed a non-blind scheme based on discrete cosine transform to insert the watermark in the color middle-frequency band of the host image. Kutter et al. watermarked[9] to the blue channel of an RGB color space. Recently, more approaches use human visual system characteristics and the essential properties of color. Chang et al.[10] using the characteristics of the HIS color space and the discrete cosine transform introduces a multiple of watermark system. However, these previous techniques are focuses on digital copyright protection using the embedded watermark logo. Volume of the watermark insertion is relatively small than that of the host image.

Independent Component Analysis is a signal processing technique for calculating a set of statistical random variable to a linear combination of independent component[11]. Recently, several Independent Component Analysis[12] techniques on the basis of the original image, the linear combination of the watermark in the spatial domain and the key images are used to perform the watermark detection[13,14]. Most of the ICA methods are used to blind separate the host image[15-18]. In[19], a watermark was inserted based on the discrete wavelet transform and Independent Component Analysis. In[18], mixed ICA and watermark has been inserted into the original image. These watermarking technique of the watermark extraction process by using independent component analysis to separate the watermark and the original image. In[14], Yu et al. through the wavelet transform approach, they propose a watermarking method that includes information extracted by adopting ICA technique, and Hien et al.[19] Hien etc. introduced a similar detection method which is based on a Redundant DWT method. Both methods require a key, the watermarked image and the original image from the watermark extraction process. Therefore, these algorithms are susceptible to attack on the network. In order to solve this problem, it requires a key for the metadata extracted by the watermarked image with fast ICA[11], which is a simple and efficient configuration of the generalized fixed point method. Using the characteristics of the human eye is less sensitive to changes in the saturation component and insert the watermark to the luminance portion region. Therefore, we propose a new watermarking techniques which is insert the QR code into an image of the saturation component of the color image over the Haar discrete wavelet transform using these characteristics.

In this paper, we propose a digital watermarking method based on Haar DWT and fast ICA. The simulation results prove invisibility, clearly, and robustness.

This paper is organized as follows. Chapter 2 introduces simplified previous work. Chapter 3 describes the proposed watermarking technology. Section 4 shows the experimental results. In Section 5 the conclusions are presented.

2. Previous Works

2.1 Independent Component Analysis

In recent years, ICA of research and applications, has been attracting attention in the areas of digital signal processing. Independent Component Analysis is a particular linear decomposes the vector of interest as far as possible, is to find conversion can be independently as it components. ICA, which has come from the blind source separation and blind signal separation, and now, especially in blind extraction watermark, it has been widely used in digital watermarking. In this paper, fast ICA is not only used in the inserting, but also in the detecting.

In the fast fixed-point algorithm for ICA, if the n value is mutually exclusive statistically independent elements, it is represented by the vector $S=[s_1, s_2, \ldots, s_n]^T$. Thereafter, the vector of the linearly observations $X=[x_1, x_2, \ldots, x_n]^T$ is blended A, i.e. $X = AS$. Therefore, linear analysis processing, such as matrix W, is to find that $Y = WX$. And it will probably recover the permutations and re-scaling independent component S, column A corresponds to the line of W.

In this paper, we used the independent component analysis technique presented in[11], it provides an efficient decomposition satisfying results. The proposed algorithm is performed to the next step. First, principal component analysis is used to process pre-whitening of the observed vector X or pre-spherical, all of the unit has a variance and elements x_i are not correlated. Second, this can be simply calculated by the matrix w obtained by using the equation (1).

$$w(k) = E\left\{x\left(w(k-1)^T x\right)^3\right\} - 3w(k-1) \quad (1)$$

2.2 Haar Discrete Wavelet Transform

It is an optimal edge matching filter for mathematical that the Haar wavelet can be used to extract information from a variety of different types of data[20].

and therefore f^2_{LL} is chosen for inserting of QR code image in this paper.

2.3 CIE XYZ Color Space

Lab color space, a color counterpart dimension lightness is a dimension space L and color counterpart of A and B, for the dimensions of the color party, on the basis of the nonlinear compression coordinates. It is derived from the three-dimensional color space of Hunter 1948 in the term L, a, and b[21,22]. Nevertheless, Lab has been more frequently used as an informal abbreviation for the expression of the CIELAB. Hunter CIE color coordinates of the original difference is that adjusts the Hunter CIE coordinates while based on the square root transformation, which is based on the cube root conversion of the color data.

The L*a*b* Color space, contains all of the perceived color that it is such as for the independence of the device, is used as communicate between different device types. Color space is a real-time three-dimensional space that includes a representation of the infinite number of colors. Practically, the practice area is generally mapped to

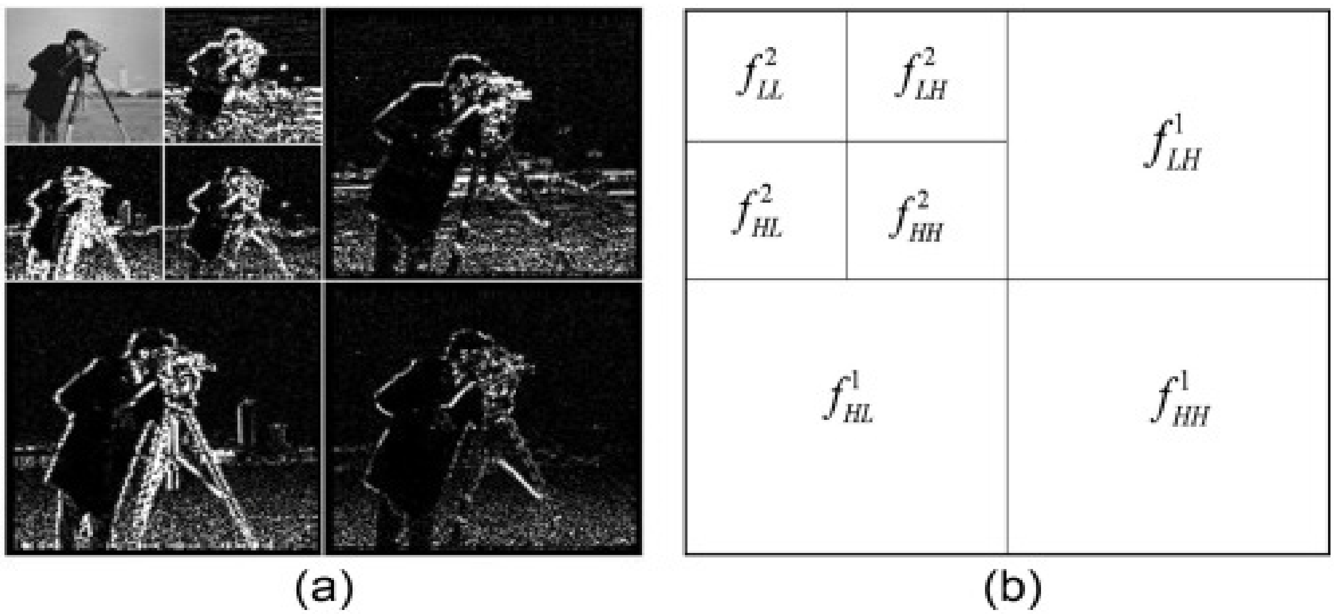


Figure 1. Haar wavelet decomposition of an image (a), and its sub-band area (b).

In Figure 1 (a), the wavelet transform sub-bands is equal to the logarithmic frequency separation layer sub-band system. When applying the wavelet transform to the image is decomposed into a high frequency, middle frequency, and low frequency regions (i.e., $f^1_{LL}, f^1_{HL}, f^1_{LH}, f^1_{HH}$) by subsampling vertical and horizontal channels as (1). Marked sub-bands $f^1_{HL}, f^1_{LH,}$ and f^1_{HH} represents the wavelet coefficients that are no longer decomposed as shown in Figure 1 (b). In order to obtain the two level wavelet decomposition, decompose the f^1_{LL} sub-band again. The watermark is embedded into f^2_{LL} of the low-frequency domain. For discrete haar wavelet transform, the LL band includes a source image with the most watermark energy included in a low frequency component resistant to attack operation of a general digital signal processing[16],

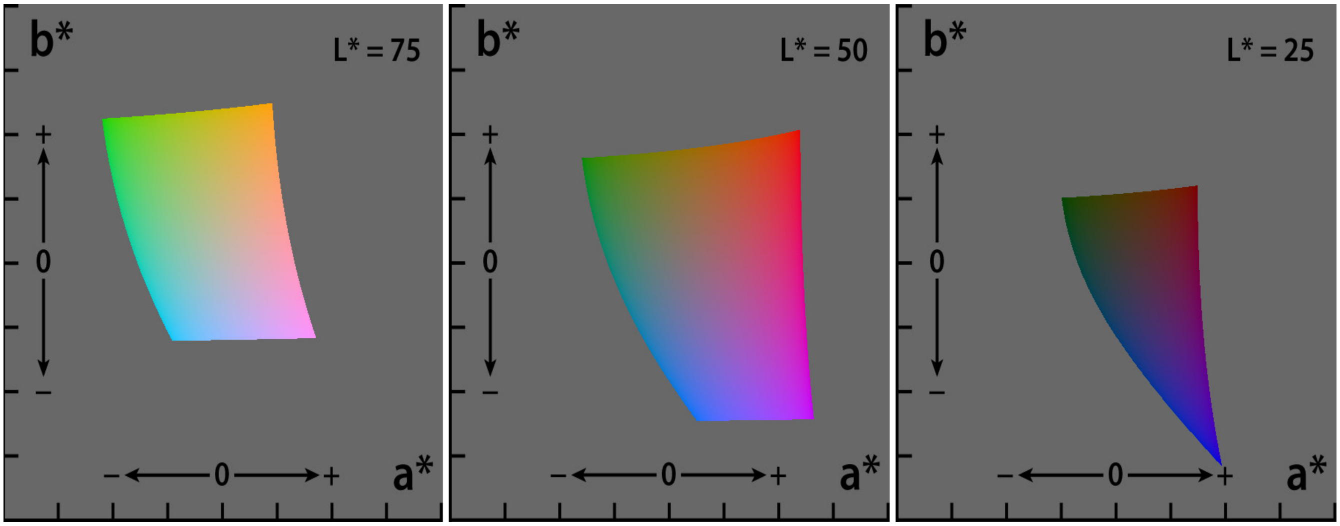


Figure 2. The CIE 1976 (L*, a*, b*) color space.

the three-dimensional integer space to represent device independent.

Although both hunter and CIE1976 space was originated from CIE1931 XYZ. The intention of "Lab" color space of both, has been calculated through a simple equation of the XYZ space, a space may be a perceptually uniform than XYZ it is to create. The same amount of change in the perceptually uniform color value means that it results in a changes equal visual emphasis. For saving the color values of the limited accuracy, it can enhance the reproducibility of the tone. As long as the white point is not specified, the lab value does not define the absolute color. Brightness correlation in CIELAB is calculated by using the relative luminance cube root.

The CIE1976 may be displayed on a common monitor screen because they belong to the color gamut of sRGB as shown in Figure 2.

3. Proposed Method

3.1 QRcode Embedding

3.1.1 Watermark Embedding in CIEXYZ color spaces

The sub image component CIEXYZ with the $M \times N$ matrix of the host image is converted into binary to insert the QR code. The first of the proposed algorithm will convert between RGB and CIE XYZ. If not considering the limitation of the color of the display device, the color obtained as a result of the algorithm of the CIE XYZ is not correctly displayed in any display[7,8]. The principle of color space conversion shows that the change in the color coordinate transformation matrix[9]. In accordance with the principles of transformation, we obtain transformation matrices between XYZ and RGB.

$$T = \begin{pmatrix} 0.46494 & 0.32275 & 0.1871 \\ 0.23563 & 0.65348 & 0.11088 \\ 0.043925 & 0.1171 & 0.97655 \end{pmatrix} \tag{2}$$

We define the color saturation of the display system according to the transformation matrix between the RGB color space to CIE XYZ color space is calculated given in equation (3).

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = T \begin{pmatrix} R \\ G \\ B \end{pmatrix} \tag{3}$$

The size of QR code image is a quarter of the original image. We used the QR code watermark of the same size as the CIE XYZ, and the binary QR code watermark is mixed according to the pseudo-random number generator. The pseudorandom key K_{kl} is used to generate a

Figure 3. (a) color Lena image, (b) converted Lena, (c) decomposed Lena, (d) Binary QR code watermark.

mixed signal. The pseudo-random number is a sequence of one-dimensional of the length $M \times N$, the watermark is converted before applying the scramble of the image in the order of the 2-D. The host image (a) and the QR code (d) are shown in Figure 3.

In Figure 3 (c), it is a wavelet decomposition of the original image and the low frequency band and the same size shown QR code. The low sub-band *LL*, includes an original image and a watermark, most of the energy in the low-frequency component that can withstand the attack of the signal processing. The *LL* sub-band contains most energy of the original image and watermark embedded in the low-frequency components can resist attack operations of general image processing[16], and therefore, in this paper, insert a secret code to the LL2 sub-band.

3.1.2 Purmutation QR code

In data hiding, the low sub-band of CIEXYZ space is chosen. In order to satisfy perceptual invisibility, watermark dispersing the spatial relationship is allowed based on the properties of the cover image to increase transparency. This sequence is applied to QR_{k2}, depending on the sort order of the sub-band *LL2*. Using the pseudo-random sequence was performed permutation.

3.1.3 Embedding the QR code into LL2 sub-band

Embedding watermark into *LL2* sub-band of *CIEXYZ* space is shown as follows

$$CIEXYZ_{LL2}'' = sf \cdot QR_{k2} + CIEXYZ_{LL2} \quad (4)$$

where *sf* is the strength of watermark. As shown in Figure 4, the watermarked image *CIEXYZ'* is generated by the inverse wavelet transform by equation (5).

$$CIEXYZ' = CIEXYZ + K_{k2}(K_{k1}(sf \cdot QR)) \quad (5)$$

3.2 QRcode Extracting

In order to extract the QR code by using the ICA detector detects the original image and a watermark. QR code detection is performed in CIEXYZ space. The other two transforms DWT and CIEXYZ are applied to the original image, they transform the image from the spatial to the frequency domain, and from RGB to CIEXYZ. Separating the image components from the host CIEXYZ and extracts the QR code. To meet the needs of blind Watermarking, two key is necessary to produce different mixtures K_{k1} and K_{k2}. The recover key of K_{k2}^{-1}, is used to recover the watermarked image and is defined as

$$K_{k2}^{-1}(CIEXYZ') = K_{k2}^{-1}(CIEXYZ + K_{k2}(K_{k1}(sf \cdot QR))) \quad (6)$$

Next, decomposing the sub-images into a two-level DWT to the receiving low frequency band $CIEXYZ'_{LL2}$. The third mixture is created by a modified recovery key using a fast ICA[14], denoted as K_{k3}^{-1} obtained by

(a) (b)

Figure 4. (a) Convertied images, (b) Watermarked images.

$$K_{k3}^{-1}(CIEXYZ') = K_{k3}^{-1}(CIEXYZ + K_{k2}(K_{k1}(sf \cdot QR))) \quad (7)$$

And then, Fast ICA detector is adopted by the three design linear mixture, as represented

$$X_1 = CIEXYZ + K_{k2}(K_{k1}(sf \cdot QR)))$$
$$X_2 = K_{k2}^{-1}(CIEXYZ') = K_{k2}^{-1}(CIEXYZ + K_{k1}(sf \cdot QR)))$$
$$X_3 = K_{k3}^{-1}(CIEXYZ') \quad (8)$$

As a result of applying fast PCA algorithm of the equation (8), and the mixture is extracted three independent components. Finally, the QR code image W' can be extracted by equation.

$$W' = K_{k1}^{-1}(K_{k1}(QR))) \quad (9)$$

4. Experimental Results

The three types of images were used to test the algorithm. The size of all images in the original host (Lena, Pepper and Baboon) are 256×256 pixels, and QR code watermark is binary images with size 64×64. Cover images are shown in Figure 3 (a) and Figure 5 (a), (b) respectively. The extracted QR code images after quantified are shown in Figure 6.

The quality of the watermarked image can measure the signal by Equation (10) using a peak to signal noise ratio (PSNR), where *MSE* is the mean square error between the original image and the watermark image. The watermarked image Lena has PSNR=46.8, Pepper has PSNR=41.22 and Baboon has PSNR=45.58.

$$PSNR = 10\log_{10}\frac{255^2}{MSE} = 10\log_{10}\frac{255^2}{\sum(f(x)-f(x)')^2} \quad (10)$$

The *NC* represents the correlation coefficient is used to determine authentication. It calculates a correlation coefficient by Equation (11).

$$NC = \sum_{x,y} w_{x,y} \cdot w'_{x,y} / \sum_{x,y} w^2_{x,y} = \sum_{x,y}\frac{w \cdot w'}{w^2} \quad (11)$$

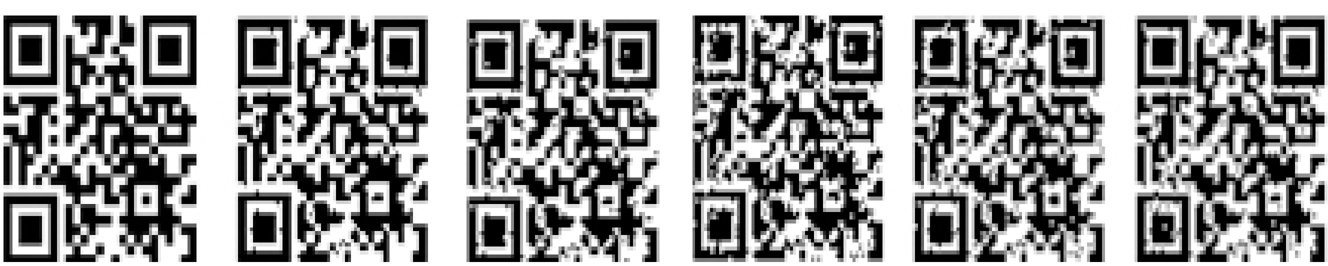
(a) (b)

Figure 5. (a) Pepper image, (b) Baboon image

The proposed method was experimented with JPEG compression, unified noise, cropping and filtering to measuring the robustness of various attacks. Noising is the opposite process to de-noising, namely, the adding of noise to an image. The "Uniform Random Noise" filter in the image editor program can be used with amounts from zero to 100%. Uniform noise can be considered as a signal with excessive high frequency. Therefore, the proposed watermark embedding and extracting method must be robust against uniform noise attack. Our experimental results indicate approximately 50% of the extraction watermarks even if adding the 40% uniform noise attack. Table 1 summarizes the experimental results for the three images.

Table 1. The correlation coefficients under various attacks

Attacks	Lena	Pepper	Baboon
JPEG Quality (100%)	0.982	0.992	0.933
JPEG Quality (90%)	0.967	0.971	0.931
JPEG Quality (70%)	0.845	0.867	0.821
JPEG Quality (50%)	0.774	0.792	0.744
JPEG Quality (30%)	0.642	0.681	0.610
Cropping (25%)	0.997	0.998	0.987
Cropping (50%)	0.987	0.986	0.980
Cropping (75%)	0.974	0.975	0.914
Add uniform noise (30%)	0.725	0.739	0.697
Add uniform noise (40%)	0.603	0.624	0.584
Add uniform noise (50%)	0.386	0.360	0.344
3x3 Median filtering	0.632	0.652	0.540



(a) (b) (c) (d) (e) (f)

Figure 6. Extracted QR code images against attacks (a) 100% quality JPEG, (b) 90% quality JPEG, (c) 70% quality JPEG, (d) 50% quality JPEG, (e) 3x3 Median filtering, (f) add 40% uniform noise.

5. Conclusion

In this paper, we propose a watermarking scheme based on fast ICA to send the QR code information embedded in the CIEXYZ color space. In order to satisfy perceptual invisibility of the watermark image, the cover image was decomposed by haar wavelet transform. This technique is ICA-based on high-speed blind source separation algorithms. ICA was applied to the watermark signal and to insert the QR code to the low frequency band of the host image. In the extraction step, the host image and a QR code has been extracted correctly from watermarked image. Experimental result shows that the QR code image is clearly detected against JPEG compress, filtering, and cropping. This technique has the characteristic of adaptive adjustment, robust, unambiguous detection, secure and blindness extraction without host image.

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