A Hybrid Digital Watermarking Method using Sectioning and DWT Technique in Chrominance Channel

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Abstract
In this research, we proposed a hybrid method to improve performance of extraction process of the digital watermarking by applying the multiple sections embedding technique and DWT digital watermarking method in the embedding process. The YC_bC_r colour space was selected for embedding and extracting a watermark signal. Also, a new pixel prediction method is presented for improving the accuracy of extraction process by using adaptive filter depended on pixel variance of the prediction area. A set of experiments is created to support the proposed concepts including image under attacked conditions and non-attacked condition. The results of the experiments show the improvement of the extraction performance in terms of normal correlation (NC). Also, the improvements in terms of robustness against various types of attack e.g. JPEG compression attack, blurring attack, brightness adjustment attack, etc. are significantly increased. Especially in cropping attacks and compression attacks, the results strongly improve in terms of NC value compared to previous proposed algorithm.

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Introduction

The copyright protection of digital media data becomes an important issue and attracts many researchers to solve this problem. Digital watermarking is a kind of standard technology to maintain access control for the documents. Good introduction on digital watermarking including its essential requirements can be found on [1].

Currently, many image watermarking methods have been proposed and proved to be robust against various kinds of noises and attacks. Such methods can be classified into frequency and/or spatial domain based watermarking. In the frequency domain, the watermark embedding can be accomplished by modifying the image coefficients from its transformed domain. For instance, Patra et al. [2] presented a based Chinese Remainder Theorem (CRT)-based Discrete Cosine Transform (DCT) domain. In addition, [3] and [4] are also proposed the watermarking schemes in frequency domain recently. They presented the method based on applying DCT and DWT to embed and retrieve the watermark signal. They also claimed that the proposed schemes are strongly robust again compression attack. However, many researches demonstrated that the frequency domain based approach was not robust enough against geometrical attack, e.g. cropping. It can survive most image compression standards e.g. JPEG compression standard, though. In contrary, for the spatial domain based approach, it is obvious that the processes of watermark embedding and extraction are simple to perform by modifying the image pixels directly.

For example, M. Kutter et al. [5] presented a method to embed a watermark signal into an image by modifying the pixel using either additive or subtractive depending on the watermark bit, and proportional to the luminance of the embedding pixel. According to their method, the blue colour channel was selected to carry the watermark bit since it is the one that human eye is least sensitive to.

Later, T. Amornraksa et al. [6] proposed some techniques to enhance its watermark retrieval performance by balancing the watermark bits around the embedding pixels, tuning the strength of embedding watermark in according with the nearby luminance, and reducing the bias in the prediction of the original image pixel from the surrounding watermarked image pixels. However, all the methods mentioned above encountered a deficiency when implemented with an image having a large number of high frequency components.

Our approach develop a new method based on the previous proposed in [6] by implementing a hybrid method. The descriptions of the proposed method are given in the next section. Section 3 describes the experimental results. The conclusion is finally drawn in section 4.

Spatial Domain Digital Watermarking

The watermark pixels are first converted from $\{0,1\}$ to $\{1,-1\}$ by changing the value of the zero bits to be the one bits. Then, the watermark balance and security are improved by using the XOR operation to permute the watermark bits with a pseudo-random bit-stream generated from a key-based stream cipher. The scaling factor s is used to adjust and control the watermark strength of the output previous process outputs. Then, the embedding process is started by modifying the image pixel in the blue channel $B_{(i,j)}$, in a line scan fashion. The result $B'_{(i,j)}$ are either additive or subtractive, depending on $w_{(i,j)}$, and proportional to the modification of the luminance of the embedding pixel $L_{(i,j)}$. In addition, the modification of luminance $L'_{(i,j)}$ is calculated from a Gaussian pixel weighting mask. The representation of the watermark embedding process can be expressed by

$$B'_{(i,j)} = B_{(i,j)} + w_{(i,j)} s L'_{(i,j)} \tag{1}$$

To extract the watermark signal, the following steps are used to estimate the embedded watermark bit at (i,j). Firstly, each original image pixel in the chosen channel is predicted from its neighboring watermarked image pixels in the same embedding channel. Each original image pixel in the chosen channel is predicted from its neighboring watermarked image pixels in the same channel. The predicted original image pixel $B''_{(i,j)}$ is determined by

$$B''_{(i,j)} = \frac{1}{8}\left(\sum_{m=-1}^{1}\sum_{n=-1}^{1} B'_{(i+m,j+n)} - B'_{(m\_\max,N\_\max)}\right) \tag{2}$$

where $B'_{(m\_max,\ n\_max)}$ is a neighbouring pixel around (i,j) that most differs from $B'_{(i,j)}$. Then, the embedded watermark bit $w'_{(i,j)}$ at a given coordinate (i,j) can then be determined by the following equation

$$w'_{(i,j)} = B'_{(i,j)} - B''_{(i,j)} \tag{3}$$

where $w'_{(i,j)}$ is the estimation of the embedded watermark w around (i,j). Since $w_{(i,j)}$ can be either 1 and -1, the value of $w'_{(i,j)} = 0$ is set as a threshold, and its sign is used to estimate the value of $w_{(i,j)}$. That is, if $w'_{(i,j)}$ is positive (or negative), $w_{(i,j)}$ is 1 (or -1, respectively). Notice that the magnitude of $w'_{(i,j)}$ reflects a confident level of estimating $w_{(i,j)}$.

Frequency Domain Digital Watermarking

The host image is processed with the following steps;

Step 1: The blue channel of the host image is decomposed into n levels using discrete wavelet transform. The HL_n of LL_{n-1} transformed sub-band is selected for watermarking embedding.

$$\left[a_n, q_n, b_n, r_n\right] = dwt\left(LL_{n-1}\right) \tag{4}$$

where a_n, q_n, b_n, r_n is wavelet coefficient value of LL_n ,HL_n LH_n and HH_n sub-band, respectively.

Step 2: Watermark pixels are converted from {0,1} to {1,-1} by switching the value of the zero bits to the one bits.

Step 3: The watermark balance and security are improved by using the XOR operation to permute the watermark bits with a pseudo-random bit-stream generated from a key-based stream cipher.

Step 4: The embedding process is started by modifying the dwt coefficient values in the HL_n sub-band $q'_{(i,j)}$, in a line scan fashion. The result $q''_{(i,j)}$ are either additive or subtractive, depending on $w_{(i,j)}$, the result is then adjusted by a scaling factor s to control the strength of watermark for the entire HL_n sub-band. The representation of watermark embedding process can be expressed by

$$q''_{n(i,j)} = q'_{n(i,j)} + w_{(i,j)}s \tag{5}$$

Then, the final embedding process is applied by using inversed DWT, set *n* equal to decomposition level at the first place.

$$LL_{n-1}' = idwt[a_n, q''_n, b_n, r_n] \tag{6}$$

The watermarked image can be extracted by with the following steps;

Step 1: The watermark image *I'* is decomposed into *n* levels using discrete wavelet transform.
Step 2: Each original transformed image pixel in the chosen sub-band is predicted from its surrounding scaled coefficient values. The predicted original image pixel $q'''_{(i,j)}$ is calculated by

$$q'''_{(i,j)} = \frac{1}{9}\left(\sum_{m=-1}^{i} \sum_{n=-1}^{j} q''_{(i+m,j+n)}\right) \tag{7}$$

Step 3: The embedded watermark bit *w' (i,j)* at a given coordinate (i,j) can then be determined by the following equation

$$w'_{(i,j)} = q''_{(i,j)} - q'''_{(i,j)} \tag{8}$$

where $w'_{(i,j)}$ is the estimation of the embedded watermark *w* around *(i,j)*.
Step 4: Since $w_{(i,j)}$ can be either 1 and -1, the value of $w'_{(i,j)} = 0$ is set as a threshold, and its sign is used to estimate the value of $w_{(i,j)}$ as follows:

$$w'_{(i,j)} = \begin{cases} 0 & , q'' - q''' < 0 \\ 1 & , q'' - q''' \geq 0 \end{cases} \tag{9}$$

Experimental Results

In the following experiments, two standard colour images, namely '*Lena'* and '*Bird'* with the size of 256×256 pixels were used as the original images. We also used the 32x32 pixels black & white image containing a logo '*ICT'*. In addition, '*Haar'* wavelet filter were selected and used in discrete wavelet transform. The level of wavelet decomposition (*n*) and was set to 3. We used both previous algorithms in our method those are the spatial domain embedding and the frequency domain embedding using DWT.

In all experiments, we evaluated the quality of watermarked image by measuring its *PSNR* (Peak Signal-to-Noise Ratio). The following equation defines the PSNR value:

$$PSNR(dB) = 20\log_{10} \frac{255\sqrt{3MN}}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(B'_{(i,j)} - B_{(i,j)})^2}} \tag{10}$$

where M and N are the numbers of row and column of the images; $B_{(i,j)}$ and $B'(i,j)$ are the original host image bit and the retrieved watermark image bit at coordinate (i,j). Note that the higher the *PSNR* value, the better the quality of watermarked image. Furthermore, Normal Correlation (*NC*) value was measured to evaluate the quality of extracted watermark. The calculation of *NC* value can be expressed by:

$$NC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} w_{(i,j)} w'_{(i,j)}}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(w_{(i,j)})^2}\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(w'_{(i,j)})^2}} \tag{11}$$

In this experiment, the performance of the proposed method was evaluated in terms of the quality of watermarked image and extracted watermark. The PSNR of watermarked image was fixed around 40 decibel. Then, the NC value was evaluated. The obtained results are shown in figure 1 and 2.

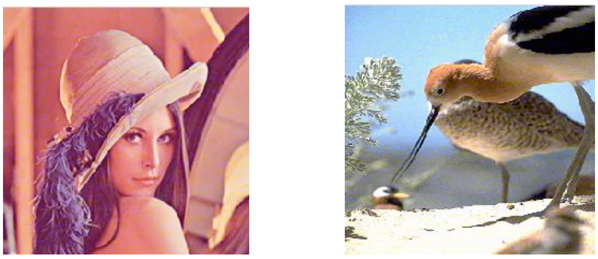

Figure 1. The resultant watermarked image at PSNR = 40 decibel

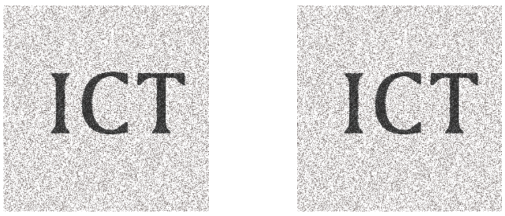

Figure 2. The resultant extracted signal NC = 0.954 and NC = 0.965, respectively

The robustness of our proposed watermarking method was then evaluated by using three different types of attack. The NC values from the attacked images were then computed and compared. A list of the attacks in the experiment consisted of additive Gaussian distributed noise with zero mean at various variances, JPEG compression at various percentage and the salt and pepper noise at various densities. The experimental results are illustrated in table I.

TABLE I. ROBUSTNESS AGAINST VARIOUS ATTACK TYPES

Attack Types	**Lena**	**Birds**
JPEG Image Quality= 90%	0.952	0.963

JPEG Image Quality= 80%	0.912	0.954
JPEG Image Quality= 70%	0.874	0.901
Gaussian distributed noise Variance = 0.001	0.922	0.935
Gaussian distributed noise Variance = 0.005	0.901	0.912
Salt and Pepper Noise density = 0.01	0.950	0.961
Salt and Pepper Noise density = 0.02	0.948	0.952
Salt and Pepper Noise density = 0.05	0.940	0.951

Conclusion

This paper has described a scheme for digital watermarking based on discrete wavelet transform and pixel modification. In the proposed method, the embedded watermark logo can be recovered without accessing to the original image by applying DWT in the chroma blue channel of YC_bC_r color space and editing pixel in the spatial domain directly. In the extraction process, the mean filter is used to recover the watermark bits. The experimental results have shown the strength in every types of attack including the non-attacked cases. Especially in the JPEG compression attack, even though the original image is compressed about 70%, the extracted watermark signal is still clearly readable with a high NC value.

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