DICTA2002: Digital Image Computing Techniques and Applications, 21—22 January 2002, Melbourne, Australia.

DIGITAL WATERMARKING FOR GRAY-LEVEL WATERMARKS

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Abstract

Digital watermarking has recently emerged as an important area of research to protect the copyright of multimedia and internet data. Most of other literatures focus on the algorithms of embedding one-dimensional watermarks or two-dimensional binary digital watermarks. In this work, a robust method of embedding a gray-level digital watermark into an image is proposed. A gray-level digital watermark is decomposed into a series of binary digital images for implementing multiple watermark. This watermark is self-extractable.

1. Introduction

A digitally watermarked image is obtained by invisibly hiding a signature information into the host image. The signature is recovered using an appropriate decoding process. The challenge is to ensure that the watermarked image is perceptually indistinguishable from the original and that the signature be recoverable even when the watermarked image has been compressed or transformed by standard image processing operations.

Many other works have been presented for the one-dimensional watermarks [1][2] and two-dimensional watermarks [3][4]. A one-dimensional watermark is a set of ID numbers which has less perception and information of copyright ownership when compared to two-dimensional watermark.

This paper describes a novel gray-level digital watermark embedding algorithm that provides more perceptual information compared with a binary digital watermark. A gray-level digital watermark will first be decomposed into a series a binary digital images for implementing multiple watermarking. The multiple watermarks can be inserted into any region of an original image. The discrete cosine transform (DCT) coding is one of the common algorithms used in watermarking based on one-dimensional watermarks or two-dimensional binary digital watermarks. The multiple watermarks will then be inserted into the DCT transform of the original images.

Binary bits of watermark are embedded directly into the Least Significant Bit (LSB) [5][6] of DCT coefficients in an image. By using the duplication of copies of watermark, it can further robust the attacks of signal processing techniques. To extract the watermark, we can take the LSB out and replace by watermark bit streams. This method is self-extractable.

Section II describes the decomposition techniques of gray-level digital images, Section III gives a brief description about the watermarking procedures. Section IV and V give the experimental result and conclusion respectively.

2. The bit decomposition of gray-level digital images

The bit decomposition algorithm is described as follows:

Let $X(m,n)$ be a 2^L gray image of size MxN and $X_p(m,n)$ be a pixel value of the image

$$x_p(m,n) = \begin{cases} 1 \rightarrow if\ (Integer[x_p(m,n)/2^l]) \bmod_2 = 1 \\ 0 \rightarrow if\ (Integer[x_p(m,n)/2^l]) \bmod_2 = 0 \end{cases}$$

(*I*= *m*= *M*, *I*= *N*= *N*). Then the bit decomposition of the images is described as:

$x^l(m,n) = B^l(X_p(m,n))$

where B^l *(.)* represents the operator of the bit decomposition, and x^l *(m,n)* *Î {0,1}*. Also, the composition of the $x^l(m,n)$ is:

$$X(m,n) = \sum_{l=0}^{L-1} x^l(m,n) \times 2^l$$

Figure 1 shows an example of how the bit decomposition can be applied to an 8 bit gray-level image of 2 x 2 size image. We can apply this decomposition techniques into a 256 gray-level watermarked images with size *M x N*.

3. The embedding and extraction of Gray-level digital watermarking

a. Embedding digital watermark procedure

According to section II figure 1 , a gray-level digital watermark is decomposed into a series of binary bit planes by bit decomposition. The 8-bit gray-level image has been divided into 8 planes (b7, b6, b5, b4, b3, b2, b1 and b0), each binary bit plane of the watermark can implement multiple watermarking. In figure 2, the embedding procedure first segments the eight original images (I_1, I_2, I_3, I_4, …I_8) into 8 x 8 pixels blocks and each block is DCT transformed independently. The eight planes decomposed gray-level digital watermark will be embedded into the eight host transformed images. The output eight images from multiple watermarks embedding process will have the inverse DCT transform. The output eight images (I_1', I_2', I_3', I_4', …I_8') are the watermarked images.

The embedding procedure is as follow:

1. Eight images (I_1, I_2, I_3,….I_8) will be divided into 8x8 blocks and have the DCT transform independently.
2. Eight bits gray-level watermark is divided into 8 planes (b7, b6, b5,…b0).
3. The LSB of each modified DCT coefficients is replaced by the watermark bit streams in each block.
4. The output images from step 3 will have IDCT transform.
5. The output images from step 4 are the watermarked images (I_1', I_2', I_3', … I_8').

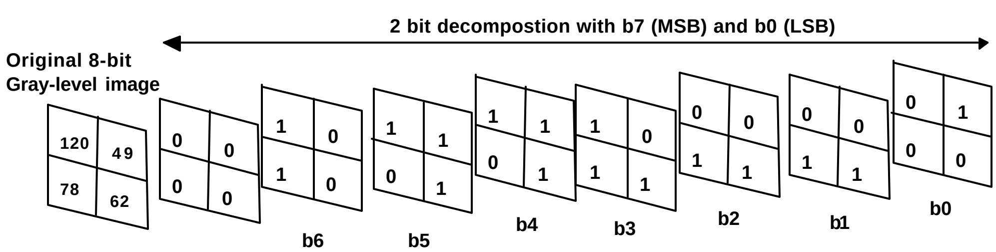

Figure 1 Two bit decomposition of an 8-bit gray level image

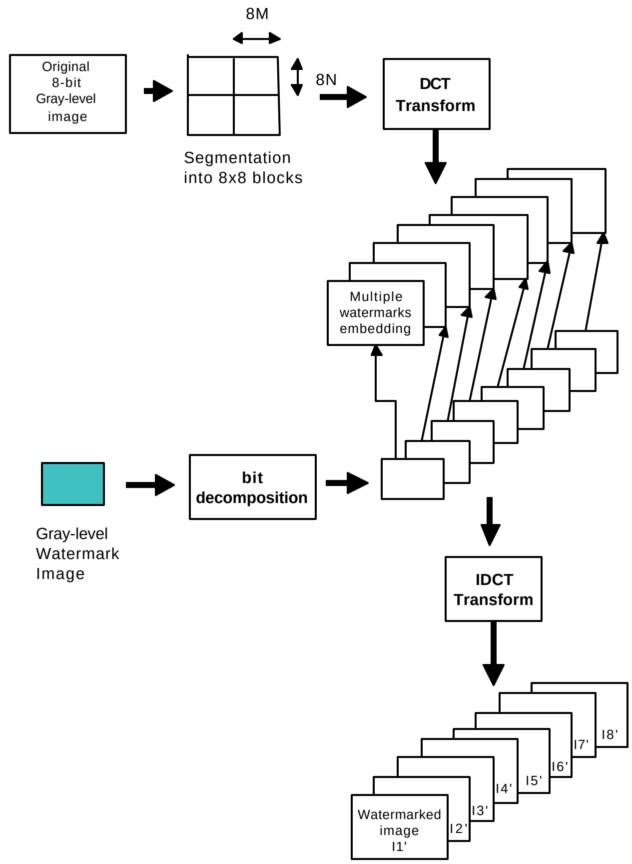

Figure 2 Data embedding scheme for gray level digital watermark

During multiple watermark process in figure 2, we first decide the embedding position. The watermark block is embedded into its corresponding block by replacing the least significant (LSB) of DCT coefficient. Figure 3 shows the detail of how the LSB can be replaced by the watermark information. We have done some testing on replacing second LSB, third LSB, forth LSB, fifth LSB or sixth LSB. Table 1 and table 2 in section IV show the result of replacing different bits instead of LSB.

b. Extracting digital watermark procedure

The algorithm can extract the watermark in self-extractable way. The extracting method is as follows:

1. Eight images (I_1', I_2', I_3',….I_8') will be divided into 8x8 blocks and have the DCT transform independently.
2. Copy the LSB of each modified DCT coefficients in each transformed image from step1.
3. The 8 bits watermark data from step 2 will be combined together to form a gray level watermark image output.
4. The host images (I_1, I_2, I_3, … I_8) can be obtained after the IDCT transform process.

Figure 4 is the block diagram of the watermark extraction. The eight watermarked images from part (a) (embedding digital watermark) output will first be segmented into 8 x 8 block size. After the DCT transform, the multiple watermarks are extracted and the gray-level watermark is composed from each block of the eight images.

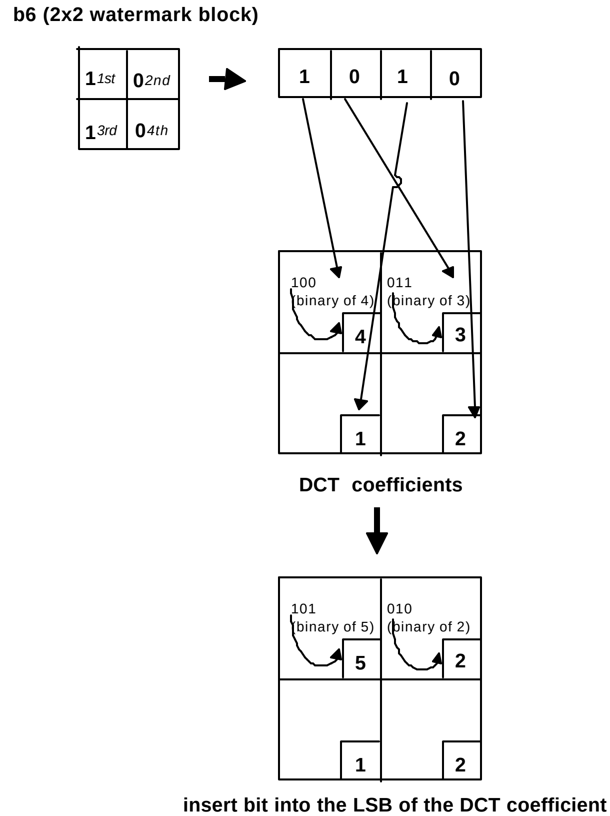

Figure 3 The detailed embedding process for b6 (2nd MSB plane)

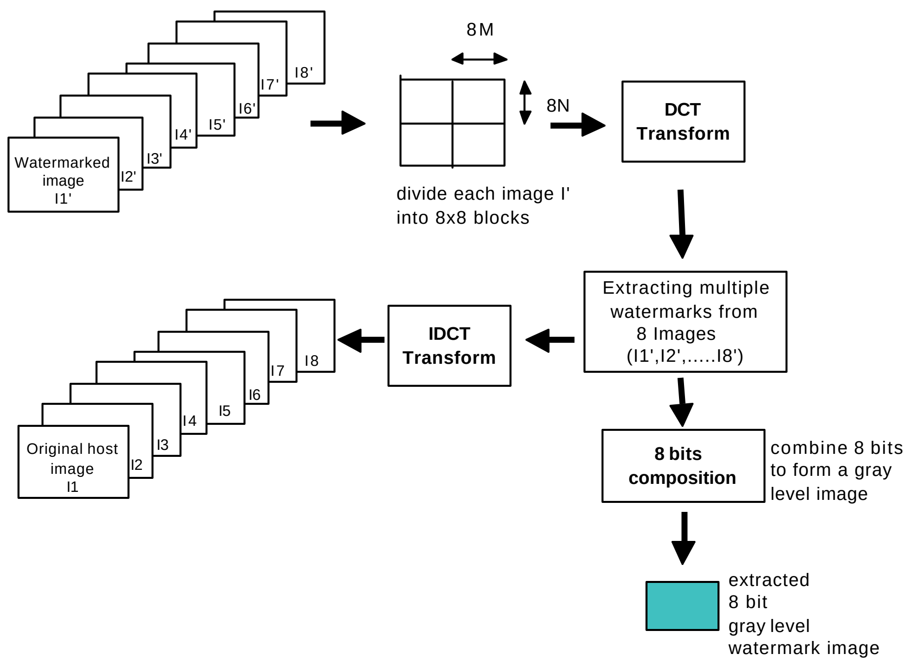

Figure 4. Data extraction scheme for gray-level digital watermark

4. Results and discussion

The Peak Signal to Noise Ratios (PSNR) is used to measure the distortion of watermarked image.

$$PSNR = 10\log_{10}\left[\frac{255^2}{\frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N}(x_{i,j} - x_{i,j}^{'})^2}\right]$$

Where $x_{i,j}$ and x_{ij}' denote the pixels of the original and reproduced images and the images are the size M x N.

Table 1 and table 2 show the result of replacing different bits (2nd lsb, 3rd lsb, 4th lsb, 5th lsb and 6th lsb) in host image by watermark information. Table 1 shows the result for recovered host image and table 2 shows the result for the extracted watermark image. Figure 5a shows the original image Elaine of size 512 x 512 with 256 gray levels, and figure 5b is the watermark image Lenna of size 64 x 64 with 256 gray levels. The PSNR of watermarked image Lenna with 8 bit planes is 44.06dB and the PSNR of recovered host image Elaine with 45.834dB. Figure 6a shows the recovered host image Elaine, figure 6b shows the extracted watermarked image Lenna.

In order to test and verify the robustness of our watermarking algorithm, the JPEG compression and other signal processing attacks will be further tested.

Position	***PSNR*** (in dB)	***RMSE*** Root Mean Square Error	***MSE*** Mean Square Error	***NMSE*** Normalized Mean Square Error
2nd lsb	54.518	0.479	0.230	0.0109
3rd lsb	50.855	0.730	0.534	0.0252
4th lsb	45.834	1.300	1.689	0.0796
5th lsb	40.165	2.500	6.260	0.2950
6th lsb	34.245	4.946	24.46	1.1530

Table 1 The recovered host image with different bit replacement

Position	***PSNR*** (in dB)	***RMSE*** Root Mean Square Error	***MSE*** Mean Square Error	***NMSE*** Normalized Mean Square Error
2nd lsb	24.345	15.460	239.11	10.517
3rd lsb	34.383	4.869	23.703	1.043
4th lsb	44.060	1.598	2.553	0.112
5th lsb	34.610	4.740	22.50	0.989
6th lsb	51.839	0.653	0.426	0.0187

Table 2 The extracted watermark image with different bit replacement

5. Conslusion

In this paper, we have presented a novel digital watermarking technique which can embed the gray level image. In our proposed method, the digital watermark is decomposed into a series of binary digital images for implementing multiple watermarks. The decomposed watermark image is embedded into the DCT domain by modifying DCT coefficient values. Section IV shows the result of embedding watermarked image into different bits. The recovered images Elaine and Lenna have high PSNR value and good visual quality. We will further test our watermark algorithm with JPEG compression and other signal processing attacks.

6. Acknowledge

This research is supported by the VPAC (Victorian Partnership for Advanced Computing Expertise Program) Grants Scheme.

7. References

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Figure 5a Original host image Elaine with 512 x 512 pixels

Figure 5b Original watermark image Lenna with 64 x 64 pixels

Figure 6a Recovered host image Elaine after DCT watermark with 45.834dB (PSNR) Replacing 4th lsb in table 1

Figure 6b Extracted watermark image Lenna with 44.06db (PSNR) Replacing 4th lsb in table 2