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A NOVEL DIGITAL IMAGE WATERMARKING SCHEME USING BIORTHOGONAL WAVELETS

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Abstract

Copyright protection is considered as an issue of vital significance owing to the escalating utilization of internet and effortless copying, tampering and distribution of digital images. Digital watermarking methodologies are looked upon as a competent tool for safeguarding the digital images from copyright infringements issues. A number of researches in existence deal with copyright protection with the aid of watermarking. Recently, wavelet domain based watermarking approaches are gaining popularity in watermarking researches. In this paper we have proposed a novel watermarking scheme for copyright protection in digital images. The watermarking is performed in wavelet domain using bi-orthogonal wavelet transform. As the proposed approach is non-blind, it requires original image for extracting the watermark. The watermark image is a binary image. The watermark image is embedded in the HH sub-band of the wavelet transformed original image. A Good quality of watermarked image is assured through the proposed scheme from the higher PSNR values which is evident from experimental result.

Keywords:

Digital Watermarking, Copyright Protection, Non-Blind, Discrete Wavelet Transform, Bi-Orthogonal

1. INTRODUCTION

A variety of invisible watermarking schemes have been reported in recent years which can be broadly classified in two categories: spatial domain and transform-domain based. Spatial domain watermarking slightly modifies the pixels of one or two randomly selected subsets of an image. Modifications might include flipping the low-order bit of each pixel. The inserted information may be easily detected using computer analysis. As for transform domain which is also called frequency domain, values of certain frequencies are altered from their original. The watermark is inserted into the coefficients of a transformed image, for example using the discrete Fourier transform, discrete cosine transform and discrete wavelet transform. In general, transform domain techniques outperform in terms of visibility and security, since they exploit perceptual properties in order to increase robustness without compromising imperceptibility [1]. Based on the fact that small modifications in the wavelet coefficients do not change the image significantly, while minor changes in the image alter the coefficients locally, but noticeably, embedding watermark using wavelet transform is proposed as a method of embedding watermark in this paper. This characteristic is a good premise for watermark invisibility and fragility. The wavelet domain has also attracted the most attention among all the transform domains used as it has been shown to yield the highest degree of robustness to simple image processing operations. The embedding and extracting of watermark can be processed in one or several sub-bands due to multi-resolution feature and hierarchical structure of the Discrete Wavelet Transformation (DWT). Secondly, DWT transformation is designed to incorporate the visual feature of the human visual system (HVS). Thirdly, the main advantage of wavelets over Fourier and DCT analysis is that they allow for combination of spatial and frequency resolutions. Based on its good spatial-frequency characteristics, the ability of characterizing and located attacking is stronger. Relative to DCT, the computing amount of DWT is smaller. So the DWT domain improves the robustness of the watermark and speed up the computation. Moreover, the availability of numerous mother wavelets gives flexibility to the analysis and allows it to be truly adaptive to a particular application. Bi-orthogonal wavelets offer sufficient robustness and security to particular watermark attacks [2]. The technique in [3] uses bi-orthogonal wavelets in watermarking which were robust against numerous attacks.

2. NOVEL ROBUST AND NON-BLIND WATERMARKING SCHEME

The novel watermarking scheme proposed for the copyright protection of images is presented in this section. The proposed watermarking scheme is robust and non-blind, as it is resilient to attacks and necessitates the presence of original image in the extraction process. The watermark embedding and extraction are performed in the wavelet domain using bi-orthogonal wavelet transform. It is necessary that the size of the original image be dyadic (2^n x 2^n) and the watermark image be a binary image.

2.1 WATERMARK EMBEDDING

The embedding of watermark image into the original image is detailed in this subsection. In our scheme, the size of original image is dyadic (2^nx2^n) and the watermark image is a binary image. The embedding is performed in wavelet domain using bi-orthogonal wavelet transform. Initially, the original image is decomposed into four sub-bands such as LL, LH, HL and HH using bi-orthogonal wavelet transform followed by the choice of HH sub-band for embedding the watermark image. The HH sub-band contains diagonal detail coefficients. For every 2x2 non-overlapping block of HH sub-band, a pixel of watermark image is embedded.

Embedding a watermark image pixel into a 2x2 non-overlapping block involves the following: The 2x2 block is initially converted into a vector. Afterwards the mean, maximum and minimum value of the vector is calculated. Subsequently, two vectors are formed based on the calculated mean value. The values, greater than the mean value, are grouped as one vector and the remaining values are grouped into another.

As the watermark image is a binary image, the value of its pixels will be either '0' or '1'. Thus the embedding of watermark involves two cases: embedding pixel value '1' and embedding pixel value '0'. The steps involved in the embedding of both the pixel values are described detailed later in this subsection. The aforesaid steps are repeated until all the watermark pixels are embedded. Later, the watermark embedded HH sub-band is replaced in its original position and inverse bi-orthogonal wavelet transform is applied to obtain the watermarked image.

Watermark Embedding Steps:

1. The original Image I_O is decomposed into four sub bands LL, LH, HL and HH using bi-orthogonal wavelet transform. From the four sub-bands, HH sub-band (I_{OH}) is chosen for embedding the watermark image.
2. A 2 x 2 non overlapping block is extracted from I_{OH} and converted into a vector C.
3. The mean, maximum and minimum value of the vector C($\overline{C}$, max(C) and min(C)) is calculated.
4. The two vectors C_l and C_h based on the calculated mean value $\overline{C}$. The values, greater than the mean $\overline{C}$, are grouped as one vector C_h and the remaining values are grouped as another vector C_l.
5. Calculate the mean value for the vector C_l.
6. If the vector C_h is not empty, calculate the mean value of it otherwise assign the mean value of C_l to mean value of C_h.
7. The two cases for embedding the watermark image pixels are as follows:

   Case 1: For embedding pixel value '1'

   The elements of the vector C are compared against the mean value $\overline{C_h}$ and modified as follows: If the value in vector C is greater than $\overline{C_h}$, it is replaced with the maximum value of the same vector C and if it is greater than or equal to $\overline{C_l}$ and less than the mean $\overline{C}$, it is replaced with the mean value $\overline{C}$. If the aforesaid conditions are not satisfied then the scaling factor α is added to the current element of C.

   Case 2: For embedding pixel value '0'

   The elements of the vector C are compared against the element of the vector C_l and altered as described consequently: If the value in vector C is less than $\overline{C_l}$, it is replaced with the minimum value of the same vector C and if it is greater than or equal to $\overline{C}$ and less than the mean $\overline{C_h}$, it is replaced with the mean value $\overline{C}$. If the aforesaid conditions are not satisfied then the scaling factor α is subtracted from the current element of C.
8. The steps 2 to 7 for all the blocks are repeated until all the watermark pixels are embedded.
9. The modified HH sub-band is mapped back to its original position and inverse bi-Orthogonal wavelet transforms is applied to obtain the watermarked image I_W^*.

In the above mentioned steps, N represents the size of vector and equals to 4 and NB represents the number of blocks in the HH sub-band. For instance, if the size of HH sub-band is (n x n) then it comprises of (n/2 * n/2) number of blocks.

2.2 WATERMARK EXTRACTION

The extraction of watermark image from the watermarked image is detailed in this subsection. The present watermarking scheme is non-blind, it requires the original image along with the watermarked image and size of watermark image for extraction. The watermarked image and original image are decomposed using bi-orthogonal wavelet transform. From the HH sub-bands of wavelet transformed original and watermarked images, the watermark image is extracted. Initially, 2x2 non overlapping blocks are extracted from both the HH sub-bands.

The extraction of a watermark image pixel from two blocks involves the following: A block from the HH sub-band of wavelet transformed original image and its corresponding block from the HH sub-band of wavelet transformed watermarked image are taken and converted into vectors followed by the computation of the sum of both the blocks. If the sum value of watermarked image's block is greater than the sum value of original image's block the extracted pixel value is '1' otherwise '0'. The above described process is repeated for the size of watermark image to extract watermark image.

Watermark Extraction Steps:

1. The watermarked Image (I_W^*) and the original Image (I_O) is decomposed using bi- orthogonal wavelet transform and choose the HH sub-bands I_{OH} and I_{WH}^* for watermark image pixels extraction.
2. The 2 x 2 non overlapping block from I_{OH} and I_{WH}^* is extracted and converted into vectors C_o and C_w respectively.
3. Calculate the sum value for both the vectors C_o and C_w. Subsequently, compare the sum value of C_o against the sum value of C_w for extraction of watermark image pixels. If the sum value of C_w is greater than the sum value of C_o then the extracted watermark image pixel value is '1' otherwise the value is '0'.
4. The steps 2 and 3 are repeated until all the watermark image pixels are extracted.
5. A matrix with size of watermark image is formed and the extracted pixel values are placed in it in order to obtain the watermark image (I_W).

In the above mentioned steps, N represents the size of vector and equals to 4.

3. PERFORMANCE EVALUATION METRICS

To investigate the performance of the technique, it is essential to subjectively or objectively evaluate the quality of the image after the embedding process.

3.1 PERCEPTUAL QUALITY EVALUATION METRICS

Objective image quality measures are based on image features, a functional of which, should correlate well with subjective judgment.

Peak Signal to Noise Ratio (PSNR)

A widely adopted assumption is that the loss of perceptual quality is directly related to the visibility of the error signal (watermark). The simplest implementation of this form is the PSNR, which quantifies the strength of the error signal. It is a widely used fidelity measure. The objective evaluation of image quality is performed by the PSNR value.

Correlation Coefficient

To measure the similarity between the extracted watermark and the embedded watermark, normalized correlation coefficient is calculated.

4. EXPERIMENTAL RESULTS AND ANALYSIS

The performance of the proposed technique to various types of image distortions are evaluated and discussed with simulation results.

4.1 EFFECT OF GAIN FACTOR (A)

Different gain factors are being used during embedding to see the effect on the visual quality of the watermarked image and the extracted watermark. PSNR and correlation as defined earlier are used as the performance indicator. Simulations are carried out on 512 x 512 host image and a 128 x 128 binary watermark as shown in Fig.1(a) and (b).Table.1 below shows the PSNR and Correlation values for different gain factors.

(a) (b)

Fig.1. (a) Host Image and (b) Watermarking Image

Table.1. Effect of gain factor α on visual quality and extracted watermark

α	PSNR	Correlation
0.1	56.13	1
0.5	56.13	1
1.0	56.03	1
1.5	51.84	1
2.0	51.84	1
2.5	51.84	1
3.0	51.73	1
4.0	47.23	0.99

From the above table, it can be seen that the decrease in gain factor increase the PSNR value. However, it does not affect the correlation value. So, gain factor can be chosen as small as possible so that it will give a high PSNR which means that the visual quality of the watermarked image is good.

4.2 EMBEDDING TIME EVALUATIONS

Using the watermark embedding and detection procedures explained in Section 2 a set of five common images were tested with a standard dimension of 512x512 pixels. The images are illustrated in Fig.2.

Fig.2. Set of Original Images

By applying the embedding steps, binary watermark pattern shown in Fig.1 (b) is embedded into the high pass band. Computational costs are compared by measuring the embedding time taken by each of the embedding with a HVS model [4]. The HVS model has the highest amount of computation because the weight function calculation involves many summation/convolution operations. Table.2 shows the embedding time for the images processed.

Table.2. Embedding Time of the two Embedding Techniques

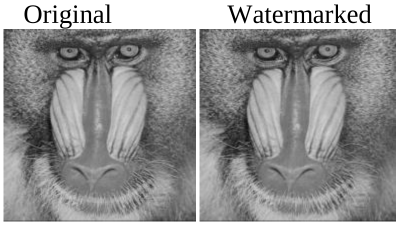
IMAGE	EMBEDDING TIME (SECONDS)	
	HVS	PROPOSED
Lena	61.209	1.912
Fishing boat	61.209	1.913
Camera man	61.398	2.142
Baboon	62.370	2.161
Pepper	61.089	2.509

4.3 IMPERCEPTIBILITY EVALUATIONS

The watermarked images produced by the proposed technique are measured by PSNR value and it is tested in five images with a size of 512 x 512 pixels is shown in Fig. 3.The performance measures are the invisibility of the inserted watermark. It is obvious that the watermarked copy is undistinguishable from the original image.

Baboon

Original Watermarked



51.84

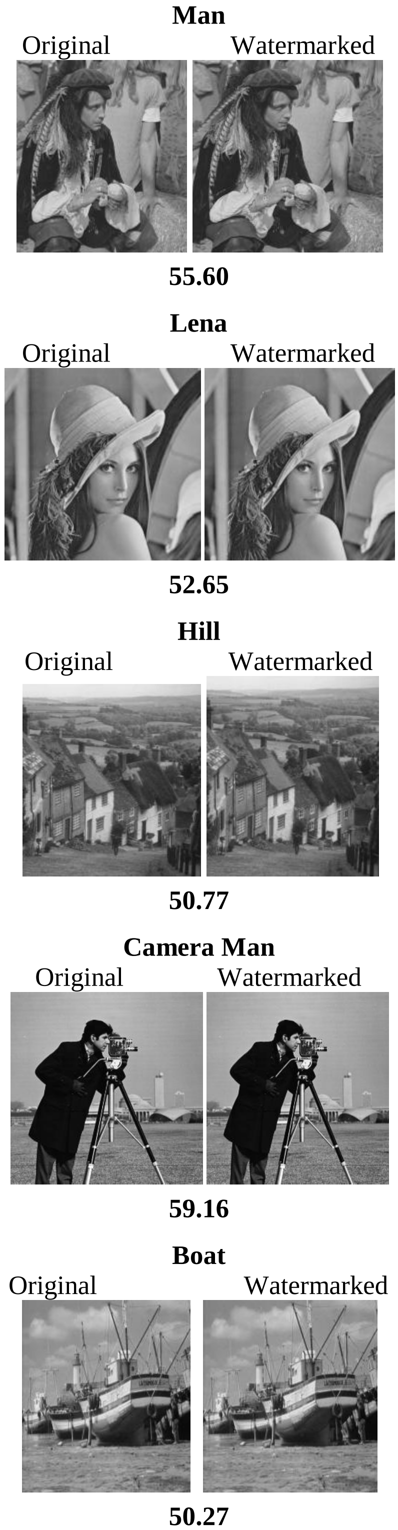


Fig.3. Set of Images Embedding Results with their PSNR

5. COMPARISON WITH OTHER DOMAINS

To compare the visual quality of watermarked image by the proposed scheme with DCT and LSB Replacement, which uses (512x512) host image with (64x64) watermarking image, is shown in Fig.4(a) and (b). The Results are tabulated in Table3.The image quality of the proposed method is good than those of LSB and DCT method [5].

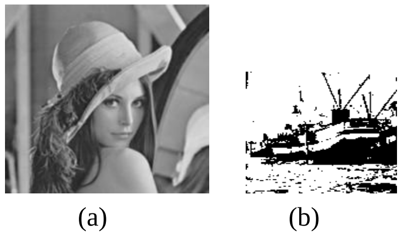


Fig.4. (a) Host Image (512x512); (b) Watermarking Image (64x64)

Table.3. Image Quality (PSNR) of the proposed method / DCT / LSB Replacement

Algorithm	Proposed Scheme	DCT	LSB Replacement
PSNR	52.62	46.19	27.89

6. PERFORMANCE OF THE PROPOSED METHOD WITH EXISTING DWT TECHNIQUE

The proposed method achieves the high level of Imperceptibility especially for cameraman and man image. The proposed method for digital watermarking is based on wavelet transform. This is unlike most previous work done by Xia *et al*. and Kim *et al.* which is used a random number as a watermark and where the watermarking can only be detected by comparing an experimental threshold value to determine whether a sequence of random signals is the watermark [6] and [7]. The proposed approach embeds a watermark with visual recognizable patterns such as binary image by modifying the frequency part of the images. In the proposed approach, an original image is decomposed into wavelet coefficients. The performance of the Current Proposed method is compared with the algorithms described by Xia, Kim have been re-implemented by[8] and Tao [9] .These methods are based non–blind watermark detection .The PSNR of the watermarked images are given in Table.4.

Table.4.

Algorithm	Xia	Kim	Tao	Proposed
PSNR	38.71	38.57	42.4	51.84

7. PERFORMANCE OF THE PROPOSED METHOD WITH EXISTING BI-ORTHOGONALWAVELET TECHNIQUE

Our Proposed method is compared with another bi-orthogonal wavelet technique proposed by S. Hajjara *et al.* [10]. The results are shown in Table.5. For the comparison a gain factor of 3 is chosen for embedding.

Table.5. First Level Decomposition with a gain factor α = 3

	S. Hajjara	Proposed Method
PSNR	2.70	51.73
Correlation co-efficient	0.99	1

The results of the proposed method are done in HH sub-band is comparatively better to the results executed in HL band [10]. The Robustness is achieved in the proposed work by the different attack analysis [11].

8. CONCLUSION

A novel watermarking scheme based on bi-orthogonal wavelet transform is presented in this paper. The proposed scheme has been used to protect the copyright of digital images. As the watermarking is performed in wavelet domain, the proposed novel watermarking scheme is resilient to attacks and yields a good quality watermarked image. The binary watermark image pixels are embedded in the HH sub-band of the wavelet transformed original image. Subsequently, the watermark image is extracted from the HH sub-bands of wavelet transformed original image and watermarked image. Since, the high frequency data are noisy, embedding watermark in the HH sub-band yields good quality watermarked image. The experimental results demonstrate that the watermark with the proposed algorithm satisfied imperceptibility. Future research includes the development of a robust watermarking algorithm without using the original image.

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