Phase Watermarking Algorithm using Hybrid Multi-Polarity Hadamard Transform

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Abstract

In this paper, a robust phase watermarking algorithm for still images is presented where the watermark information is conveyed in the phase spectrum in the transform domain. Phase watermarking algorithm that uses multi-polarity Walsh-Hadamard and Complex Hadamard transform is developed. The robustness of presented algorithm is investigated by its uniqueness, JPEG encoding, image resizing, dithering noise distortions, sharpening, cropping and successive watermarking.

Keyword's- Unified complex Hadamard transform ·Multi-polarity complex Hadamard transform ·Multi-polarity Walsh-Hadamard transform ·Phase watermarking · Spectral techniques

I. Introduction:

With the explosive growth of the Internet, the use of digital images is becoming more widespread as digital images are easily transmitted over networked systems. However, this has also heightened the problem of copyright protection. The owners of digital images are reluctant to allow the distribution of their works in a networked environment as exact copies can be obtained easily. Although encryption can be applied to limit access to only valid key-holders, there is no way to trace the reproduction or retransmission of the decrypted images. A digital watermark is intended to complement cryptographic processes. It is an imperceptible identification code that is permanently embedded in the image and remains within the image after the decryption process. The owner and intended recipients of the image can be identified through the decoding of the embedded copyrights information in the image. The characteristics of an effective image watermark are as follows.

(a) It should be perceptually invisible and should not result in artifacts that are different from those that may be seen in the original image.

(b) It should be robust to common signal processing operations such as sharpening, resizing, lossy compression, etc since operations that damage the watermarked images also damage the embedded data. Pirates may also attempt to remove the embedded watermark through other modifications to the watermarked images.

A novel hybrid watermarking technique for grey scale images based on the modified multi-resolution multi-polarity Walsh-Hadamard and Complex Hadamard transforms has been proposed and implemented in the C language. A series of tests to gauge the robustness of the watermark is performed and the experimental results are also presented. The new watermarking technique based on multi-polarity Walsh- Hadamard and Complex Hadamard transforms can also be used in digital and color image processing.

II. Complex Hadamard Transform:

An orthogonal transform known as the unified Complex Hadamard Transform (CHT) has recently been considered as the tool in spectral approach to logic design and in various applications in digital signal processing and communications .The detailed properties and performance of this transform in the above areas is available in . To better suit applications in logic design similarly to multi-polarity Walsh-Hadamard transform the CHT transform has been generalized to multi-polarity transform in . This latter version of the CHT transform is used in this article to convey the watermark information. Some necessary information about basic properties of multi polarity CHT is given below.

Let $C = \{c_{jk}\} = \{a_{jk} + ib_{jk}\}$ of order N be an $N \times N$ square matrix. The Hermitian conjugate (or transpose, complex conjugate) of C is denoted as $C^* = \{\overline{c_{jk}}\} = \{a_{jk} - ib_{jk}\}$, where $i = \sqrt{-1}$, and $0 \le j, k \le N$.

III. Novel Hybrid Technique for Watermarking:

The design and implementation of a novel hybrid transform domain based watermarking technique for grey scale images is described in this section. Figure 1 illustrates the stages involved in the insertion of watermark. It should be noticed that the secret key could be added easily in our watermarking scheme. The insertion of the watermark consists of the following steps:

(a) The raw pixels are extracted from the BMP image and stored in a two-dimensional array. The dimensions of the image are adjusted to the next higher multiple of 8 to handle images of different sizes. For example, the original dimensions of an image are 500 × 300 pixels. The dimensions of the image are adjusted to 504 × 304 pixels, where the additional pixels are filled with 0.

(b) The modified multi-resolution integer-valued multi polarity WHT is applied to decompose the image into a pyramid structure with various bands such as the low frequency band, low-high frequency band, high frequency band etc. The modified multi-resolution integer-valued multi-polarity WHT is implemented in two steps and applied three times. The decomposition is performed as follows:

$$T_1[:, x] = \left\lfloor \frac{I[:, 2x] + I[:, 2x+1]}{2} \right\rfloor,$$

$$T_1\left[:, \frac{\text{width}}{2} + x\right] = I[:, 2x] - I[:, 2x+1],$$

$$T_2[y, :] = \left\lfloor \frac{T_1[2y, :] + T_1[2y+1, :]}{2} \right\rfloor,$$

$$T_2\left[\frac{\text{height}}{2} + y, :\right] = T_1[2y, :] - T_1[2y+1, :]$$

Where $I[y,x]$, $T1[y,x]$ and $T2[y,x]$ refer to pixels in The original, temporary and transformed images, respectively. The symbol ":" on the left hand side of The comma refers to the rows of the image. When the Symbol ":" appears after the comma, it refers to the Columns. *Width* and *height* denote the dimensions of the *ll* quadrant and _· represents the downward truncation. *y* and *x* denote the rows and columns of the images, respectively. The two-dimensional transformation is performed by applying the transformation on the rows of the image. The *ll* quadrant in Fig. 2 forms another image with half the resolution. The same transformation is applied to this reduced resolution image twice to form the pyramid structure.

(c) The lowest frequency band (LFB) is segmented into *n* 8×8 blocks.

(d) The two-dimensional multi-polarity CHT is performed on the segmented 8 × 8 blocks by applying the one dimensional multi-polarity CHT on the rows followed by the columns. The CHT coefficients of a real image are complex-valued which leads to a magnitude and phase representation for the transformed image.

Fig.1 Insertion of watermark

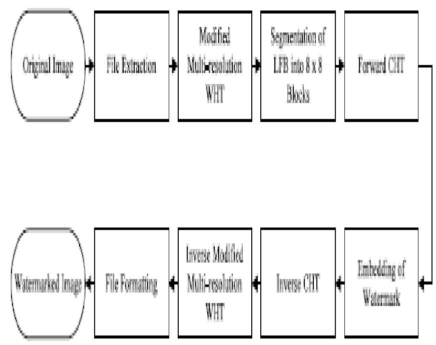
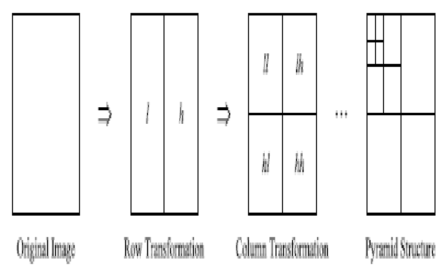
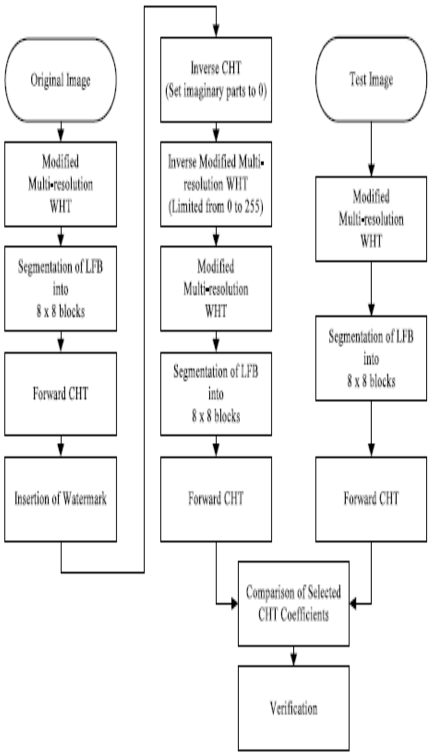


Fig.2 Multi-resolution decomposition of an image



(e) After altering selected CHT coefficients, an inverse two-dimensional multi-polarity CHT is applied by performing the one-dimensional multi-polarity CHT on the columns followed by the rows.

Fig.3 Extraction of watermark



(f) The inverse modified multi-resolution multi-polarity WHT is applied three times. The construction of the watermarked image from the altered transformed image is performed using the following inverse transformation:

$$T_1[2y,:] = T_3[y,:] + \left\lfloor \frac{T_3[\frac{height}{2}+y,:]+1}{2} \right\rfloor,$$

$$T_1[2y+1,:] = T_1[2y,:] - T_3\left[\frac{height}{2}+y,:\right],$$

$$I_1[:,2x] = T_1[:,x] + \left\lfloor \frac{T_1[:,\frac{width}{2}+x]+1}{2} \right\rfloor,$$

$$I_1[:,2x+1] = I_1[:,2x] - T_1\left[:,\frac{width}{2}+x\right]$$

where $I1[y,x]$, $T1[y,x]$ and $T3[y,x]$ refer to pixels in the reconstructed, temporary and altered transformed images, respectively.

(g) BMP file format is applied to create the watermarked copy of the original image.

IV. Extraction of Water mark:

Figure 3 summarizes the stages involved in the extraction of watermark. It should be noticed that the watermark detector does not need the original image when a hash of the original image is used as a watermark. The steps to extract the embedded watermark are performed as follows:

(a) The raw image pixels are extracted from the original and test images in BMP format. The dimensions of the images are adjusted to the next higher multiple of 8 to handle images of different sizes.

(b) The following steps are performed for the original image:

(1) The original image is decomposed into the pyramid structure using the modified multi-resolution multi polarity WHT.

(2) A forward multi-polarity CHT is performed on the segmented 8×8 blocks of the LFB.

(3) The watermark is inserted.

(4) An inverse multi-polarity CHT is performed and all the imaginary parts are set to zero.

(5) An inverse modified multi-resolution multi-polarity WHT is computed and the results of the inverse transformation are limited in the range from 0 to 255.

(6) A modified multi-resolution multi-polarity WHT is performed again followed by the forward multi polarity CHT of the segmented 8 × 8 blocks of the LFB.

(c) A modified multi-resolution multi-polarity WHT is performed on the test image followed by the forward multi polarity CHT of the segmented 8 ×8 blocks of the LFB.

(d) A comparison of selected CHT transform coefficients of both images is performed.

The flow chart for the verification of watermark is given in Fig. 4. $D1$,$D2$ and $D3$ are three predefined thresholds obtained empirically that are equal to 1.25◦ , 0.5n and 17.5, respectively. The number of elements in the watermark sequence is n. If the absolute phase difference (qi) of the respective transform coefficients from the original watermarked (wi) and test (yi) images exceeds $D1$, the particular selected transform coefficient fails the watermark test. The test image is considered to be a watermarked copy of the image if either one of the following conditions is satisfied:

(1) The number of selected transform coefficients r clearing the watermark test is equal to n.

(2) r is greater than $D2$ and the test parameter u is greater than $D3$.

(a) Original (b) Watermarked

Fig.4.Original and watermarked versions of Lena

The above-mentioned test parameters are defined as follows:

$$q_i = |w_i - y_i| \quad \text{for } 1 \leq i \leq n,$$

$$s = \sum_{i=1}^{n} q_i \quad \text{if } q_i < D_1,$$

$$t = \sum_{i=1}^{n} q_i,$$

$$u = \frac{s}{t} \times 100.$$

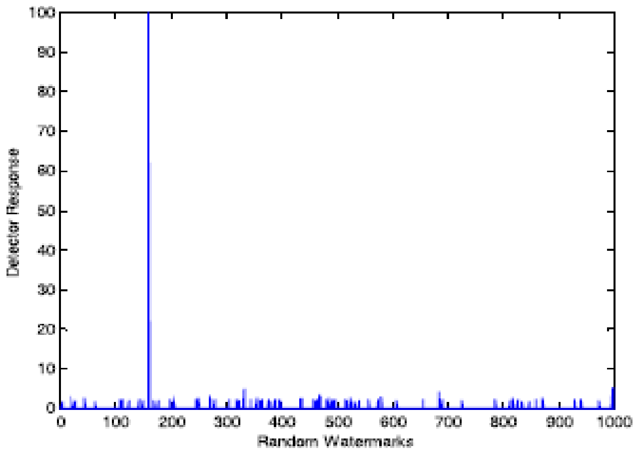


Fig. 5 Watermark detector response (uniqueness of watermark)

Fig. 6 JPEG encoded version of Lena at 10% quality and 0% smoothing.

V. Experimental results:

The proposed watermarking technique has been implemented in the C language. In order to evaluate the proposed technique, the original grey scale image (Lena from [2]) of 256 × 256 pixels shown in Fig. is watermarked using the proposed scheme. The watermarked version is shown in Fig.. The robustness of the watermark depends directly on the embedding strength, which in turn influences the visual degradation of the image. The PSNR of the watermarked image with respect to the original image is 41.34 dB. The watermarked image is subjected to a series of tests to gauge the robustness of the embedded watermark such as:

(a) Uniqueness of Watermark: Fig shows the response of the watermark detector to 1000 randomly generated watermarks of which only one matches the watermark embedded in Fig. . The positive response due to the correct watermark is very much stronger than the response due to incorrect watermark.

(b) JPEG Compression: In this test, the watermarked image is compressed using the standard JPEG encoding . Figure shows a JPEG encoded version of Lena at 10% quality factor and 0% smoothing. The embedded watermark is still detected even though the JPEG encoded image is clearly distorted. Table 1 lists the results for the JPEG compression tests from 10% to 100% quality factor.

Table 1 Results of JPEG compression tests

JPEG coding quality	PSNR (dB)	Detected
100	58.43	Yes
90	40.66	Yes
80	37.31	Yes
70	35.63	Yes
60	34.48	Yes
50	33.67	Yes
40	32.84	Yes
30	31.92	Yes
20	30.66	Yes
10	28.30	Yes

Fig. 7 Image of Lena after five successive watermarking operations

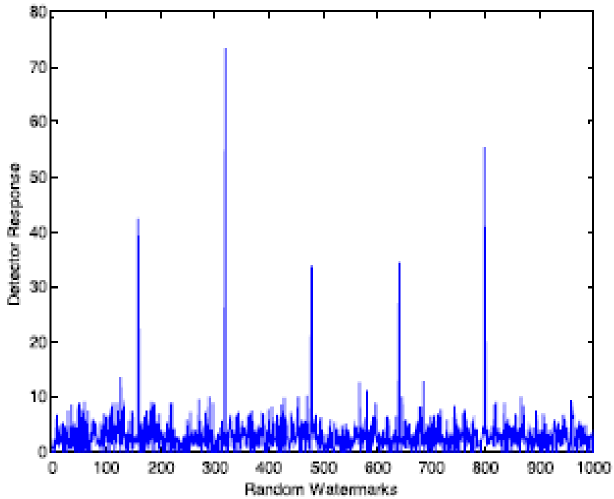


Fig. 8 Watermark detector response (successive watermarking)

(c) Successive watermarking: The original image is watermarked, the watermarked image is then watermarked and so on. This can be considered as another form of attack in which it is clear that significant image degradation eventually occurs as the process is repeated. After five successive watermarking operations, the five watermarks are still detected in the resulting image (PSNR = 31.18 dB) shown in Fig.7. In the response of the watermark detector given in Fig.8, the five spikes clearly indicate the presence of the watermarks and demonstrate that successive watermarking does not remove the embedded watermarks.

VI. Conclusion:

A new hybrid technique for watermarking grey scale images based on the multi-resolution modified multi-polarity WHT and CHT is proposed and developed. The quality of the watermarked image is very good. The proposed technique also exhibits robustness to JPEG compression up to 10% quality factor, successive watermarking, sharpening, dithering distortion (25%), cropping and scaling up to 31.64% of the original image.

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