Digital Watermarking-A Combined Approach by DWT, Chirp-Z and Fast Walsh-Hadamard Transform

Dr. Dayanand.G.Savakar
Department of Computer Science, Rani Channamma University, Belagavi-591156, Karnataka, India.
e-mail: dgsavakar@gmail.com.

Anand Ghuli
Department of Computer Applications(M.CA) B.L.D.E.A’s V.P.Dr.P.G.Halakatti College of Engineering and Technology., Bijapur-586103, Karnataka, India.
e-mail: anandghuli@yahoo.co.in

Abstract

Digital Image Watermarking is one of the ways to protect intellectual property right and copyright of the information owner. Fidelity, Capacity and Robustness are the important requirements of digital watermarking techniques, but these requirements compete with each other; if one is improved the other two are affected. This paper presents a combined approach of DWT, Chirp-Z and Fast Walsh-Hadamard Transforms for digital image watermarking to minimize the gap between robustness and fidelity with limited capacity. The DWT is used for locating the suitable area in the cover image for watermark embedding. The chirp z-transform is the z-transform of input signal along a spiral contour defined by a scalar. The output of Chirp Z-transform is given to Fast discrete Walsh–Hadamard transform that returns the coefficients of the input. Then watermark is embedded depending on pseudo random sequence into predefined mid-band components of the block of cover image.

1. Introduction

Digital image watermarking is considered as one of the major research field in image processing and security. It can strengthen the ownership of the original image and also can completely recover the original image from the watermarked image. Several watermarking schemes and techniques are used for wide range of applications. (Bhupendra Ram, 2013) has proposed digital image watermarking technique using discrete wavelet transform and discrete cosine transform and shown improved resistance to attacks on the watermark and demonstrated that this proposed technique is robust to most of the signal processing techniques and geometric distortions [1]. (K. Chaitanya et.al., 2013) have developed the digital color image watermarking scheme using DWT-DCT coefficients in RGB Planes [2]. (Pratibha Sharma and Shanti Swami 2013) have devised a digital image watermarking technique using 3 level discrete wavelet transform and demonstrated that quality is dependent on scaling factors [3]. (D.Phani Kumar et.al., 2013) presented a contrast based color watermarking scheme using Lagrange Polynomials Interpolation in Wavelet Domain [4]. (Abdelhamid Benhoucine et.al., 2013) have proposed new image watermarking scheme based on singular value decomposition [5]. (Huming Gao et.al., 2013) have presented digital watermarking algorithm for color image based on DWT [6]. (Hongshou Yan and Weimin Yang2013) proposed a watermarking algorithm based on wavelet and Hadamard transform for color image [7]. (Aris Marjuni et.al., 2013) have presented an improved DCT-Based image watermarking scheme using Fast Walsh Hadamard Transform [8]. (Rama Seshagiri Rao Channapragada et.al., 2012) proposed digital watermarking algorithm based on CCC - FWHT technique [9]. (Franklin Rajkumar.V et.al., 2011) presented an entropy based robust watermarking scheme using Hadamard transformation technique [10]. (Liu Ping Feng et.al., 2010) have proposed a DWT-DCT based blind watermarking algorithm for copyright protection [11]. (Ali Al-Haj, 2007) has proposed combined DWT-DCT digital image watermarking scheme [12].

From the literature it is observed that, still there is a scope to examine and determine the suitability of a watermarking scheme with respect to properties like; fidelity, capacity and robustness. The requirements are application-dependent, but some of them are common to most practical applications.

2. The Watermark Insertion Methodology

For the effective watermarking it is evident to find suitable area x to insert watermark, this can be done by embedding the watermark in the middle frequency sub-
hands using Haar wavelets [12]. Set the gain factor $k$ and block size as 4. The chirp $z$-transform is applied to input signal $x$ along a spiral contour defined by a scalar that specifies (i) The length of the transform (ii) Ratio between the points along the $z$-plane spiral contour of interest (iii) A scalar, the complex starting point on that contour. The chirp $z$-transform computes the $z$-transform on a contour of the form $z_k = AW^{-k}$ where $A$ and $W$ are arbitrary complex numbers. This path describes a spiral, starting at an arbitrary point $A$ and curving in or outwards depending on the value of $W$. The transform can be broken into three parts: i) Construct a signal $y_n = x_nA^{-n}W^{n^2/2}$. ii) Circularly convolve the signal with $v_n = W^{-n^2/2}$. iii) Weigh the result by $W^{k^2/2}$. The Fast Walsh–Hadamard transform is applied to $czt$ signal, performing an orthogonal, symmetric, involutional linear operation on $2^n$ complex numbers yielding walsh functions. This transformation has no multipliers and is real because the amplitude of Walsh (or Hadamard) functions has only two values, +1 or -1. The Hadamard transform $H_m$ is a $2^n \times 2^n$ matrix, the Hadamard matrix (scaled by a normalization factor), that transforms $2^n$ complex numbers $x_n$ into $2^n$ real numbers $X_m$. We define $H_m$ for $m > 0$ by: $H_m = \begin{pmatrix} H_{m-1} & H_{m-1} \\ H_{m-1} & -H_{m-1} \end{pmatrix}$ where the $1/\sqrt{2}$ is a normalization that is sometimes omitted. Thus, other than this normalization factor, the Hadamard matrices are made up entirely of 1 and -1. The watermark embedding process discussed so far is depicted in Fig.1 and procedure in Algorithm 1.

**Algorithm 1: Watermark Embedding**

Input : i. Cover image  
ii. Watermark image

Output : Watermarked image

**Start**

**Step.1:** Decompose the cover host image into four non-overlapping multi-resolution sub-bands: LL1, LH1, HL1, and HH1 using DWT.

**Step.2:** Apply DWT again to sub-band HL1 to get four smaller sub-bands and choose the HL2 sub-band.

**Step.3:** Divide the sub-band HL2 into 4 x 4 blocks.

**Step.4:** Apply Chirp-Z transform to each block in the chosen sub-band (HL2).

**Step.5:** Apply Fast Walsh-Hadamard transform which performs an orthogonal, symmetric, involutional linear operation on $2^n$ numbers (real or complex).

**Step.7:** Re-formulate the grey-scale watermark image into a vector of zeros and ones.

**Step.8:** Generate two uncorrelated pseudorandom sequences. One sequence is used to embed the watermark bit 0 and the other sequence is sued to embed the watermark bit 1.

**Step.9:** Embed the two pseudorandom sequences; sequence 0 and sequence 1, with a gain factor some $k$ in the FWH-CZT transformed 4x4 blocks of the selected DWT sub-bands of the host image.

If the watermark bit is 0 then $X = X + k *$ pseudorandom sequence for 0 otherwise, $X = X + k *$ pseudorandom sequence for 1 [Where $X^*$ represents the pseudorandom sequence embedded block. X denote the matrix of the midband coefficients of the FWH-CZT transformed block.]

**Step.10:** Apply CZT to each block after its mid-band coefficients have been modified to embed the watermark bits as described in the previous step, then inverse FWH transform to it.

**Step.11:** Apply the inverse DWT (IDWT) on the DWT transformed image, including the modified sub-band, to produce the watermarked host image.

**Stop**

**Fig.2- Input and Output of the Algorithm 1**

**3. The Watermark Extraction Methodology**

Locate middle frequency sub-bands using Haar wavelets in watermarked image. With gain factor $k$ and
block size 4 compute pseudorandom sequence and apply FWHT block wise then extract middle band coefficients. Calculate the correlation of the middle band sequence to pseudorandom sequence and move to next block to get watermark. The watermark extraction process discussed so far is depicted in Fig.3 and procedure in Algorithm 2.

Algorithm 2: Watermark Extraction
Input : Watermarked image.
Output : Watermark.

Start
Step.1: Decompose the watermarked image into four non-overlapping multi-resolution subbands: LL1, HL1, LH1, and HH1 using DWT.
Step.2: Apply DWT to HL1 to get four smaller subbands, and choose the sub-band HL2.
Step.3: Divide the sub-band HL2 into 4X4 blocks.
Step.4: Apply CZT to each block in the chosen sub-band (HL2), and extract the mid-band coefficients of each CZT transformed block.
Step.5: Regenerate the two pseudorandom sequences for 0 and 1 using the same seed used in the watermark embedding procedure.
Step.6: For each block in the sub-band HL2, calculate the correlation between the mid-band coefficients and the two generated pseudorandom sequences for 0 and 1. If the correlation with the pseudorandom sequence 0 was higher than the correlation with pseudorandom sequence 1, then the extracted watermark bit is considered 0. Otherwise the extracted watermark is considered 1.
Step.7: Reconstruct the watermark using the extracted watermark bits, and compute the similarity between the original and extracted watermarks.
Stop.

4. Evaluation of performance and results

The evaluation of proposed scheme is done with respect to robustness and fidelity. Matlab 2009a programming tool and the bitmap cover image Lena of size 225 X 225, binary watermark bitmap image containing text ‘ANAND’ of size 50 X 20 are used for the purpose. The imperceptibility by the presence of watermark is measured as 35.2584 dB as shown in Fig.5.1 and Fig.5.2. Better robustness is achieved and demonstrated with addition of Gaussian noise with different mean values, variances shown in Fig.6; and also by adding multiple noise like, “Gaussian noise and Poisson noise”, “Gaussian noise, Poisson noise and salt & pepper noise” as shown in Fig.5.3 to Fig.5.8. Other image processing attacks like jpeg compression gives PSNR 33.61 dB as shown in Fig 5.9, and retrieval of watermark from cropped watermarked image is also better as shown in Fig 5.10. The correlation for the Gaussian noise are shown in Fig.6 and correlation for other said attacks shown in Table 1.

The charts in Fig.6 represent the behavior of the algorithm with respect to Gaussian noise with different mean and respective variances. It is clearly observed that when mean and variance are increased the correlation slowly decreases. The algorithm is best suitable for Gaussian noise with mean 0.4. It is also observed that the algorithm behavior is feasible with multiple noise, compression and cropping as depicted in Table 1.

<table>
<thead>
<tr>
<th>Noise</th>
<th>Correlation</th>
</tr>
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<tbody>
<tr>
<td>Gaussian noise and Poisson noise</td>
<td>0.9083</td>
</tr>
<tr>
<td>Gaussian noise, Poisson noise and salt &amp; pepper noise</td>
<td>0.7320</td>
</tr>
<tr>
<td>jpeg compression</td>
<td>0.8287</td>
</tr>
<tr>
<td>cropped watermarked image</td>
<td>0.9266</td>
</tr>
</tbody>
</table>

Table 1- Correlation for different attacks
5. Conclusion

The DWT, Chirp-Z and Fast Walsh-Hadamard Transforms are used successfully for digital watermarking. The experimental results reveal that, this combined approach gives acceptable psnr value 35.2584 dB and correlation of retrieved watermark with original is 1. It is observed that the correlation decreases as mean and variance increased in case of Gaussian noise attack. The algorithm yields better result for different noise attacks, multiple noise attack, compression and cropping as observed in Table 1. This type of combination is feasible for reducing the gap between robustness and fidelity with limited capacity.
6. References


