Dual Digital Water Marking Using Wavelet Transform

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ABSTRACT

Image watermarking has become an important tool for intellectual property protection and authentication. Digital watermark is the technique in which visible / invisible signal is embedded in a multimedia document for copyright protection. Dual watermarking is a combination of visible watermark and an invisible watermark. In this paper, we propose watermarking scheme called dual watermarking that incorporates two invisible watermarks in the host image for improved protection and robustness. A watermark, in form of a PN sequence (secondary watermark), is embedded in the wavelet domain of a primary watermark before being embedded in the wavelet domain of host image. The discrete wavelet transformation algorithm is proposed for embedding invisible watermark. The results obtained are shown and their detecting strategy for authentication is also discussed in this paper.

Keywords : Digital watermark, wavelet transform primary watermark, secondary watermark and authentication.

1. INTRODUCTION

Digital watermarking is the technique in which visible/ invisible watermark is embedded in a multimedia content for copyright protection. For any invisible watermarking technique to be valid, it must satisfy three important requirements namely perceptual invisibility, robustness against various image processing attacks, as well as security. Recently many watermarking algorithms have been proposed in the literature [1], [2]. Some of them works either in the frequency domain using the DCT [3], [4], DFT [5] or DWT [6]-[10]. In this paper, the combination of invisible watermarking algorithm in the DWT domain has been proposed and implemented. Here, the original image and primary watermark image are taken. The secondary watermark assumed is Pseudo-random noise sequence. Images are decomposed into two resolution levels before being embedded. Watermarked primary watermark is embedded in DWT domain.

Two invisible watermarks are embedded in the host image. For any kind of attacks secondary watermark is easy to detect even when the primary one is severely distorted. This is the main advantage with two level watermarking and it provides improved protection and robustness.

2. DISCRETE WAVELET TRANSFORM

The procedure[11] to find the DWT coefficients of a discrete signal given by X[n], starts with passing the signal (sequence) through a half band digital low pass filter with impulse response h[n] and the initial frequency of the signal. Filtering a signal corresponds to the mathematical operation of convolution of the signal with the impulse response of the filter. The convolution operation in discrete time is defined by (1).

$$x[n]*h[n] = \sum_{k=-\alpha}^{\infty} x[k].h[n-k] \qquad (1)$$

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A half band low pass filter removes all frequencies that are above half of the highest frequency in the signal. Simply discarding every other sample will subsample the signal by two, and the signal will then have half the number of points. The scale of the signal is now doubled. This procedure can mathematically be expressed by (2).

$$y[n] = \sum_{k=-\infty}^{\infty} h[k].x[2n-k] \quad (2)$$

The decomposition of the signal into different frequency bands is simply obtained by successive high pass and low pass filtering of the time domain signal. The original signal x[n] is first passed through a half band high pass filter g[n] and a low pass filter h[n]. After the filtering, half of the samples can be eliminated according to the Nyquist's rule, since the signal now has a highest frequency of 'p/2' radians instead of 'p' radians. The signal can therefore be subsampled by 2, simply by discarding every other sample. This constitutes one level of decomposition and can mathematically be expressed by (3) and (4) respectively.

$$y_{high}[k] = \sum_n x[n].g[2k-n] \quad (3)$$
$$y_{low}[k] = \sum_n x[n].h[2k-n] \quad (4)$$

Where y_{high} [k] and y_{low} [k] are the outputs of the high pass and low pass filters, respectively, after subsampling by 2.

3. Discrete Wavelet Transform Of An Image

An image I of size 64 x 64 pixels has been considered for the analysis of DWT decomposition. The decomposed image after first and second levels is shown in Fig.1 & Fig.2. After one level DWT decomposition, the image is decomposed into four parts. They are,

A1 = Level-I Approximation (Low frequency) coefficients of size 32 x 32 pixels,

H1 = Level-I Horizontal coefficients of size 32 x 32 pixels,

V1 = Level-I Vertical coefficients of size 32 x 32 pixels,

D1 = Level-I Detail (High frequency) coefficients of size 32 x 32 pixels.

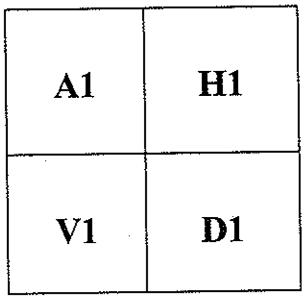

Figure 1 : Image After One Level Decomposition

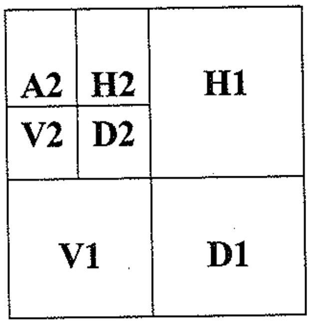

Figure 2 : Image After One Level Decomposition

After the second level DWT decomposition approximation coefficient (A1) is further decomposed into four components. They are,

A2 = Level-II Approximation (Low frequency) coefficients of size 16 x 16 pixels,

H2 = Level-II Horizontal coefficients of size 16 x 16 pixels,

V2 = Level-II Vertical coefficients of size 16 x 16 pixels,

D2 = Level-II Detail (High frequency) coefficients of size 16 x 16 pixels.

Thus DWT of an image dissolves the approximation coefficients successively as the level increases. The main feature to be noted here is that the approximation coefficients contain most of the energy of the original image I.

4. Embedding Algorithm

The original gray-scale 256*256 image (host image) and the gray-scale 128*128 primary watermark image are decomposed into 2 resolution levels using Daubechies-1 filter as shown in Fig.3. The Magnitude of DWT coefficient is large in the lowest bands (LL) at each level of decomposition and is smaller for other bands (HH,LH,HL). Pseudo Random noise codes are only added to the large coefficients of the high and middle frequency of the DWT transferred image.

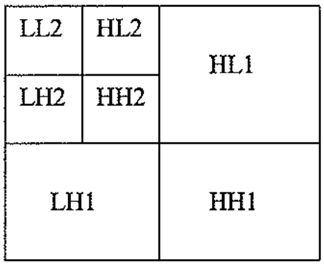

Figure 3 : Decomposition into 2 Resolution Levels Using DWT

A Pseudo Random Noise (PN) Sequence w2(i,j) (secondary watermark) having a length of 1024 bits and zero mean is generated and added to the horizontal coefficients (HL2) of the decomposed primary watermark image according to (5).

$$w_1(i,j) = I_2(i,j) + w_2(i,j) \qquad (5)$$

with $I_2(i,j)$ and $w_1(i,j)$ representing the DWT coefficients of the primary watermark and the watermarked primary watermark respectively. The resulting $w_1(i,j)$ coefficients are then added to the horizontal, vertical and diagonal DWT coefficients (HL2, LH2, HH2) of the original image according to (6).

$$I'(i,j) = I_1(i,j) + \alpha\, w_1(i,j) \qquad (6)$$

In which $I_1(i,j)$ is representing the DWT coefficients of the original image, $I'(i,j)$ is the watermarked DWT coefficients of the original image and a is a scaling factor that is usually used to adjust the invisibility of the watermark, here is set to 0.0001. Finally, applying the IDWT to $w_1(i,j)$ and $I'(i,j)$ we can get the watermarked primary watermark image and the dual watermarked image.

A pseudo random noise is a sequence of numbers comprising 1 and -1 which has watermark with zero mean and one variation. Such watermarks are used for objective detection using a correlation measure.

5. Implementation And Results

Here the original image taken is "THERESA" image shown in Fig.4. The primary watermark taken is "SUNFLOWER" image shown in Fig.5. Here the secondary watermark assumed is Pseudo-random noise sequence. Images are decomposed into 2 resolution levels before being embedded. Watermarking is done in DWT domain. The watermarked primary watermark and the dual watermarked image are shown in Fig. 6 & Fig. 7 respectively.

Figure 4 : Original "THERESA" Image

Figure 5 : Primary Watermark

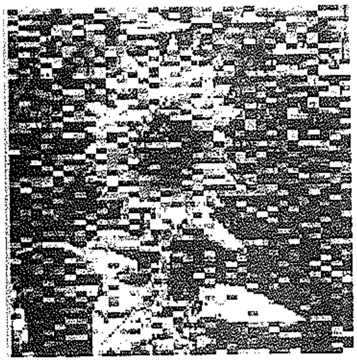

Figure 6 : Watermarked Primary Watermark

Figure 7 : Dual Watermarked "THERESA" Image

A. The Detecting Strategy

To detect the PN sequence, a 2 level DWT is applied to the dual watermarked image to obtain I'(i,j). Knowing the key and the 2 levels DWT transformed original image $I_1(i,j)$, the DWT coefficients of watermarked primary watermark can be extracted using (7).

$$w_1(i,j) = (I'_{(i,j)} - I_{1(i,j)})/\alpha \qquad (7)$$

From the obtained primary watermark the original primary watermark is compared and the resulting values are the generated PN sequence. Plotting the original PN sequence with the generated PN sequence, the secondary watermark can be detected. Fig.8 shows the detected secondary watermark from the dual watermarked image.

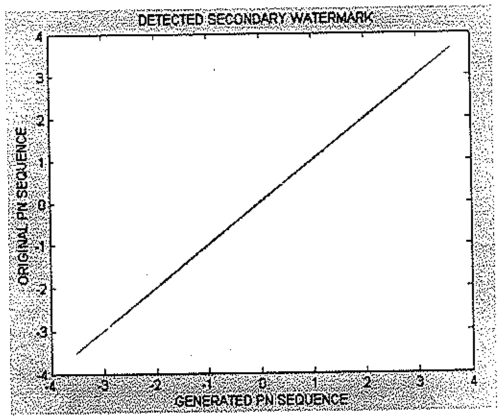

Figure 8 : Plot between Original PN Sequence with Generated PN sequence

B. Attacks on Watermarks

To judge the performance of the proposed technique it has been extensively applied to various standard images and watermarked image was exposed to various types of attacks namely, Bidirectional change in intensity (Fig.9 & Fig.10), Rotation (Fig.11) , JPEG Compression (Fig.12), Salt and Pepper Noise (Fig. 13) and Median Filtering (Fig.14). In all cases the secondary watermark is easy to detect even when the primary one is severely distorted.

Figure 9 : Lightened Watermarked Image

Figure 10 : Brightened Watermarked Image

Figure 11 : 90 Degree Rotation of Watermarked Image

Figure 12 : Compressed Watermarked Image

Figure 13 : Salt and Pepper Noise Added to Watermarked Image

Figure 14 : Median Filtered Watermarked Image

6. Conclusion

The invisible/invisible watermarking algorithm in the Discrete Wavelet Domain algorithm is coded in Mat Lab and implemented. Also the results obtained are shown and their detecting strategy for authentication is also discussed. With the above results, we conclude that the two watermarks in a host image provide improved protection and robustness. The algorithm satisfy important requirements namely, perceptual invisibility and robustness. The watermarked image is tested with various attacks such as Bi-directional change in intensity, rotation, JPEG compression, salt and pepper noise, and Median filtering. For all the above attacks applied to the watermarked image, the embedded watermark is perceptually invisible and the secondary watermark is still detectable. This shows that the proposed technique is robust against lossy compression, geometric distortions and common signal processing operations. In future, the technique can be enhanced using two different watermarking algorithms and to embed the watermarks in the text documents and video.

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