Robust Digital Image Watermarking Scheme Based on DWT and ICA

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***Abstract*-In recent years, access to multimedia data has become much easier due to rapid growth of the internet. While this is usually considered an improvement of everyday life, it also makes unauthorized copying and distributing of multimedia data much easier, therefore presenting a field of watermarking.Many literatures have reported about Discrete Wavelet Transform (DWT) based watermarking for data security since they are found to be robust against image processing attacks when compared with spatial domain. In this paper, an attempt is made to develop a watermarking scheme based on DWT and extraction using Independent Component Analysis (ICA).FastICA is proposed and implemented for extraction. In this work, proposed DWT with Fast ICA is compared with DWT based Self Reference with Non ICA technique. Simulation results show that proposed technique produces better PSNR and similarity measure. The robustness of the proposed scheme is evaluated against various image-processing attacks.**

Keywords- Authentication, data hiding, digital watermarking, self-reference, wavelet transform.

I. Introduction

Recently, the tremendous growth of the internet has increased multimedia services, such as electronic commerce, pay-per-view, video–on-demand, electronic newspapers and peer to peer media sharing. As a result, multimedia data can be obtained quickly over high-speed network connections. However, authors, publishers, owners and providers of multimedia data are reluctant to grant the distribution of their documents in a networked environment because the ease of intercepting, copying and redistributing electrical data in their exact original form encourages copyright violation. Therefore, it is crucial for the future development of networked multimedia systems that robust methods are developed to protect the intellectual property right of data owners against unauthorized copying and redistribution of the material made available on the network. Furthermore, it is an important issue to develop a robust watermarking scheme with a better tradeoff between robustness and imperceptibility.

Watermarking techniques [2],[5] can be broadly classified into two categories: Embedding watermarks in the spatial Domain or in the frequency (transform) domain.Many literatures have reported about watermarking based on _ spatial domain with different conventional extractiontechniques [6].It has been found that these techniques produce poor robustness and less PSNR. Transform domain watermarking techniques are more robust, this is due to thefact that when image is inverse wavelet transformed, watermark is distributed irregularly over the image, making the attacker difficult to read or modify. Among the transform domains DWT, based watermarking techniques are gaining more popularity because of superior modeling of Human Visual System (HVS). Recently many literatures have reported that the watermarking schemes based on Discrete Wavelet Transform (DWT) [4],[5]. In Joo et al self-reference image scheme, the extraction process depends on the embedding location *idx,* as well as original image. The above said feature does not provide robust [1] and thus the watermark can be removed easily. Hence, ICA based extraction of watermark found to be better alternate when compared with Non ICA extraction techniques.To overcome the above said problem, an attempt is made in this paper, to develop and implement watermarking scheme based on Discrete Wavelet Transform and extraction of watermark by a blind Independent Component Analysis (ICA) algorithms for digital images. The novelty of the proposed method is that it does not require original image and embedding parameters such as watermark location and strength.Simulation results are presented for various attacks and it is found that proposed method(DWT with Fast ICA) produces high similarity measure and robust to various image processing attacks like jpeg compression, Gaussian noise, cropping, Rotation and Translation.This paper is organized as follows: Section II reviews the Watermark embedding and extraction, Section III discusses the self reference scheme, Section IV presents the Proposed work, In Section V Simulation Results are presented and conclusions are drawn in Section VI.

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II. WATERMARK EMBEDDING AND EXTRACTION

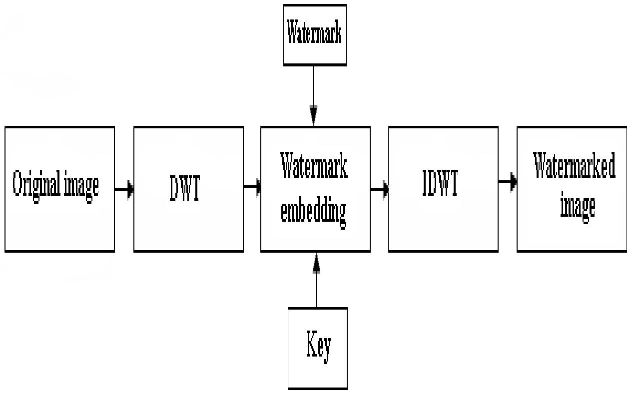


Fig. 1. Watermark embedding

In general, watermark embedding requires an original image and a watermark. In Fig.1 Original image is decomposed to two level using DWT and the watermark is embedded in the HL2 sub-band along with a private key, which is used to hide the watermark. Then IDWT is done to obtain the watermarked image.

1) Decomposition By DWT

Wavelet transform allows the decomposition of the signal in narrow frequency bands while keeping the basis signals space limited. Fig. 2 shows a two level DWT decomposition tree using low pass and high pass analysis filter banks $h(-m)$ and $g(-m)$ respectively [8]. If the level of decomposition is increased, the approximate image will be more stable. However, the complexity increases and the amount of information that can be embedded will be decreased. As a compromised way, the original image is decomposed into two levels. In wavelet analysis, an original image can be decomposed into an approximate image LL1 and three detail images LH1, HL1 and HH1 as shown in Fig. 2. Using wavelet analysis on the approximate image LL1 again, four lower-resolution sub-band images LL2 and three detail images LH2, HL2 and HH2 will be obtained and the approximate image holds the most information of the original image. Others contain some high-frequency information such as the edge details and these detail images can be affected easily by the noise, some common image processing, etc, so they are not stable enough to hide information in them. However, the watermark can be embedded into the approximation coefficient. Thus, the degree of robustness will be improved and integrity of the details which improve the imperceptibility. The main drawback of not embedding the watermark in the LL2 will lead to serious degradation of image quality. Hence, the watermark can be embedded either in HL2 or LH2. In this paper, HL2 sub-band is chosen to embed the watermark.

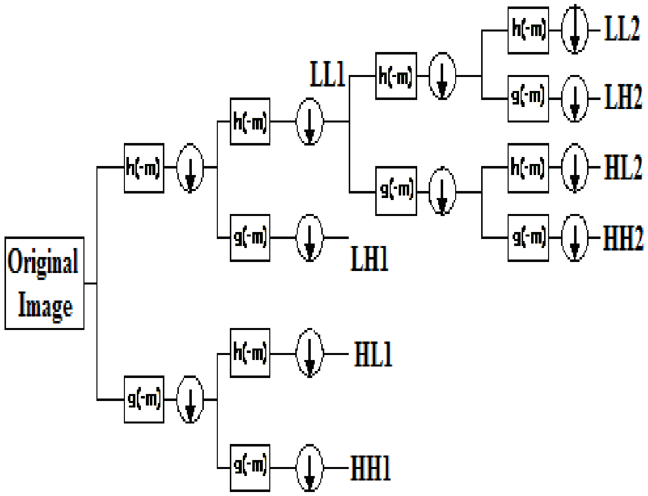


Fig. 2. Two level 2D DWT analysis filter banks

2) Embedding

The watermark embedding procedure is to embed a watermark into the original image in HL2 sub-band obtained from DWT as shown in Fig. 2. The watermark can be perceptible or imperceptible in the watermarked image depending on the applications. For applications, requiring the original image not being distorted, imperceptible watermark is desired. For some other applications, which require displaying the embedded image, a perceptible watermark is preferred. In this paper, imperceptible watermark is obtained.

3) Extraction

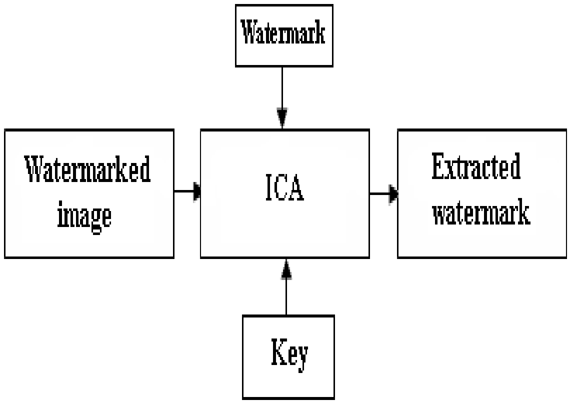


Fig. 3. Watermark extraction

Watermark extraction is used to retrieve the embedded watermark from the watermarked image as shown in Fig. 3. For watermark extraction, a secret key, which is the same used during embedding, is used together with the watermarked image to retrieve the embedded watermark. In this paper, FastICA is proposed to extract the watermark.

4) Independent Component Analysis

ICA is a statistical technique for obtaining independent sources S from their linear mixtures X, when neither the original sources nor the actual mixing A are known. Thisis achieved by exploiting higher order signal statistics and optimization techniques. The result of the separation process is a demixing matrix W, which can be used to obtain the estimated unknown sources, $\overline{S}$ from their mixtures. This process is described by

$$X = AS \rightarrow \overline{S} = WX \quad (1)$$

FastICA algorithm applied in this work for watermark extraction is discussed below:

Aapo Hyvarinen and Erkki Oja have proposed an Fast ICA algorithm and it is based on a fixed-point iteration scheme [7]. The operation of Fast ICA algorithm is outlined as follows:

The mean of the mixed signal X is subtracted so as to make X as a zero mean signal as

$$X = X - E[X] \quad (2)$$

Where $E[X]$ is the mean of the signal?

ii) Then covariance matrix is

$$R = E[XX^T] \quad (3)$$

is obtained and eigenvalue decomposition is performed on it, where E is the orthonormal matrix of eigenvalues of R and D is the diagonal matrix of eigenvalues. Find the whitening matrix, P which transforms the covariance matrix into an identity matrix is given by

$$P = Inv\left(sqrt(D) \times E^T\right) \quad (4)$$

iii) Choose an initial weight vector W, such that the projection $W^T X$ maximizes non-gaussianity as

$$W^+ = E\{X * g(W^T X)\} - E\{g'(W^T)\}W \quad (5)$$

Where g is the derivative of the nonquadratric function. The variance of $W^{+T} X$ must be made unity. Since X is already whitened it is sufficient to constrain the norm of W^+ to be unity.

$$W = \frac{W^+}{\|W^+\|} \quad (6)$$

If W not converges means go back to step (iv).

iv) The demixing matrix is given by

$$W = W^T \times P \quad (7)$$

and independent components are obtained by

$$\overline{S} = W \times X \quad (8)$$

III. Self Reference Scheme

Watermark embedding by Liu et al [1] is shown in Fig. 4. In this scheme, three sub-bands (LH_2, HL_2 and HH_2) are set to zero except LL_2 as stated by Joo et al. After performing inverse wavelet transform, its reference sub-band LL_2' is obtained. The information *idx* of embedding location in the watermark embedding process is obtained by sorting $|LL_2 - LL_2'|$ .Finally, the watermark information isembedded into the sub-band $LL_2 = LL_2' \pm k \times w(idx(j))$, where $j = 1$ to 1000, k is a factor for controlling embedding intensity and w is a pseudo-random binary sequence with the length of 1000 bits generated by using a seed, w belongs to [1, -1] and idx is the key. In watermarking extraction process, the original image is required for obtaining the watermark embedding location. According to the embedding location, the watermark can be extracted by comparing the two sub-bands LL_2 and LL_2' . Finally, the extracted watermark is compared with the original watermark by similarity measure. However, the above embedding process is quite time – consuming. Besides, the original image is required in the watermark extraction process, which is impractical in real applications. The two schemes discussed by Joo & Liu, embed the watermark by zeroing of high frequency sub-bands. Hence, the above scheme does not provide robustness as stated by Ting et al [9] and the reason is embedded space where the watermark location can be recovered easily, thus the watermark can be removed or replaced.

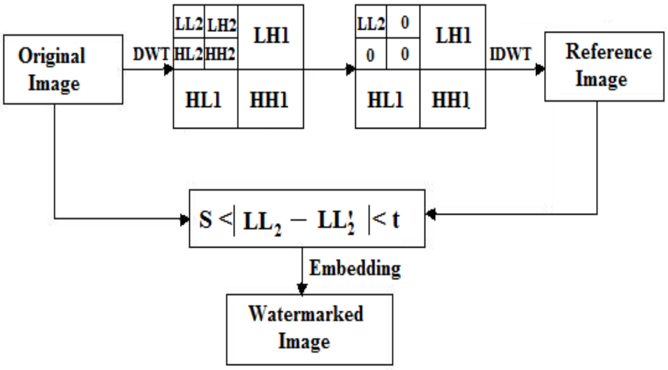


Fig. 4. Watermark embedding process using self reference scheme

IV. Proposed Work

To overcome the above said problems, this paper proposes a watermarking scheme based on DWT and extraction of watermark by blind ICA techniques. This proposed scheme is compared with the existing self-referencenon-ICA extraction technique to evaluate the performance. The novelty of this method is that it does not require original image and embedding parameter such as watermark location and strengthThe watermark embedding process is shown in

Fig. 1. The original image is decomposed into two levels using DWT analysis as shown in Fig. 2. Between the two middle subbands HL_2 is chosen in this work to embed watermark as it provides high PSNR values, also this HL_2 subband provides high robustness and imperceptibility when compared to LH_2. A stochastic model of the cover image is applied to an adaptive watermark by computing NVF with non-stationary Gaussian model [10]. In this case, NVF can be expressed by

$$NVF(i,j) = \frac{1}{1+\sigma_x^2(i,j)} \qquad (9)$$

Where $\sigma_x^2(i,j)$ denotes variance of the cover image in a window centered on the pixel with spatial coordinates (i,j). A masking function named Noise Visibility Function (NVF) is applied to characterize the local image properties, identifying the textured and edge regions where the information can be more strongly embedded. Such high-activity regions are generally highly insensitive to distortion. With the visual mask, the watermark strength can be reasonably increased without visually degrading the image quality.By applying NVF; the watermark in texture and edges becomes stronger than in flat areas. The watermark is embedded using the following equations:

$$I'HL_2(i,j) = HL_2(i,j) + E(HL_2)\alpha\,(1-NVF(i,j))W(i,j) + \frac{E(HL_2)}{10}.\alpha\ .NVF(i,j).W(i,j) \qquad (10)$$

Where $I'HL_2(i,j)$ are watermarked coefficients, $E(HL_2)$ and $\frac{E(HL_2)}{10}$ denotes the watermark strengths of texture and edge regions, respectively. α is the smoothing factor and E denotes the mean and $W(i,j)$ is the watermark. Then, perform the inverse DWT to retrieve the watermarked image. For watermark extraction, a random key is used together with the watermarked image to retrieve the embedded watermark.

$$X_1 = a_{11}I' + a_{12}W + a_{13}K \qquad (11)$$

$$X_2 = a_{21}I' + a_{22}W + a_{23}K \qquad (12)$$

$$X_3 = a_{31}I' + a_{32}W + a_{33}K \qquad (13)$$

Where$a$ is a mixing matrix, I' is the watermarked image, W is the watermark and K is a random key in the embedding process. Applying the above mentioned ICA algorithms to those mixtures, watermark W is extracted. The watermark is extracted from the watermarked image as shown in Fig. 3.

V. SIMULATION RESULTS

A gray scale of size 256x256 is considered as original image (Flower image) as shown in Fig. 5. Simulations are carried out using MATLAB software. The original image is decomposed using discrete wavelet transform for two level. The watermark is embedded in the second level middle frequency subband (HL_2) using the embedding equation (10). A binary image of size 64 x 64 is considered as the watermark image (Robust) as shown in Fig. 6. The watermarked image is obtained using two level IDWT. To justify the results, various images are taken and watermark is embedded using DWT to obtain watermarked image and it is shown in Fig. 7(a-e). The Peak Signal to Noise Ratio (PSNR) is calculated between original and watermarked image using the formula (14). PSNR values for various test images are shown in Table 1. From the results, it is observed that the wavelet transform reconstructs the image better when compared to the self reference technique.The quality of the watermarked image is evaluated by calculating the Peak Signal to Noise Ratio (PSNR) betweenoriginal and watermarked image using the formula

$$PSNR = 10\log_{10}\frac{255^2}{MSE}(dB) \qquad (14)$$

Where MSE is the Mean Square Error. The PSNR values calculated for the existing self- reference technique as well as the DWT technique for Flower image is 33.4104 and 41.6662, respectively.

Table 1. PSNR values for various test images

Test Images	Self Reference Technique	Proposed Technique
Flower	33.4104	41.6662
Football	32.8963	39.2112
Peppers	31.1125	36.5659
House	30.4937	34.9548
Moon	35.7625	40.9858

Among the test images, Flower is chosen for simulation. Fig. 8(a-e) show the various image processing attacks like JPEG compression, gaussian noise addition with noise density of 0.5, cropping, Rotation and Translation respectively on Flower image Fig. 9(a–e) shows the extracted watermarks using FastICA from the above mentioned attacks respectively. The similarity measure criteria is calculated between original and extracted watermark using the expression

$$Sim(X,X') = \frac{X.X'}{\sqrt{X'.X'}} \qquad (15)$$

where X is the original watermark and X' is the extracted watermark.

Fig. 5. Original image

Fig. 6. Watermark

(a) Flower

(b) Football

(c) Peppers

(d) House

(e) Moon

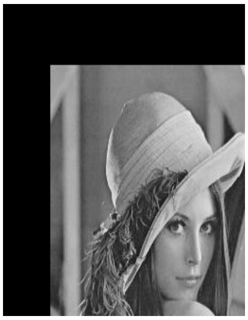
Fig. 7(a-e). Watermarked images

(a)Jpeg compression

(b)Gaussian noise

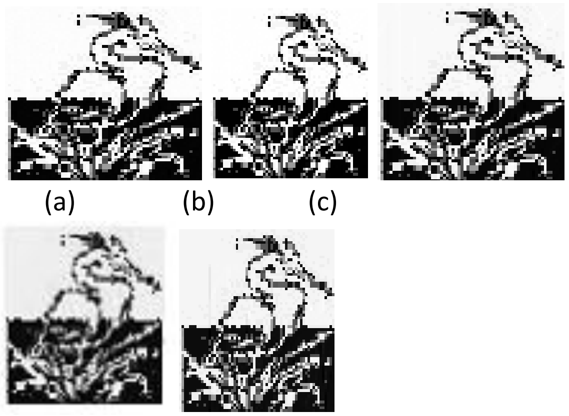
(c) Cropping

(d) Rotation



(e) Translation

Fig. 8(a-e). Various attacks



(a) (b) (c)

(d) (e)

Fig. 9 (a-e). Extracted watermarks

Table 2 compares the performance of PSNR (dB) and Similarity Measure for existing technique (Self Reference with Non ICA) with proposed technique (DWT with Fast ICA) for Flower image. Considerable differences between the two techniques are observed for all type of attacks and it is inferred that DWT with Fast ICA performs better.

Table 2. Performance comparison of existing technique with proposed technique

ATTACKS	PSNR (dB)		SIMILARITY MEASURE	
	Existing Technique	Proposed Technique	Existing Technique	Proposed Technique
JPEG Compression	29.1823	33.3772	0.8916	0.9599
Gaussian Noise	24.8114	25.7510	0.8869	0.9589
Cropping	8.4236	11.4382	0.8824	0.9532
Rotation	13.5321	14.1585	0.8801	0.9538
Translation	22.3428	27.5552	0.8851	0.9571

VI. CONCLUSION

A Robust Watermarking scheme using DWT with FastICA is presented in this paper and their performance against various attacks are obtained. To evaluate the performance of the proposed technique, it is compared with Self Reference Non ICA technique. The simulation results reveal that the proposed scheme (DWT with Fast ICA) is better interms of PSNR values and similarity measure values.

VII. REFERENCES

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