Robust Watermarking Scheme Based on Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) for Copyright Protection of Digital Images

Vijaya K. Ahire†, Vivek Kshirsagar††

†MGM's Jawaharlal Nehru Engineering college , Dr B.A.M University, Aurangabad,Maharashtra India
††Government Engineering college , Dr B.A.M University, Aurangabad,Maharashtra India

Summary
In this paper robustness of image watermarking algorithm in transform domain using combined DWT-DCT is evaluated. Host image is decomposed up to 3-levels using discrete wavelet transform. DCT transform of selected DWT sub band coefficients blocks are computed. Binary Watermark is embedded in the DCT transform of each selected DWT sub-band. For embedding watermark bits corresponding random number sequence is added in the middle frequency coefficients of the DCT block. To extract the watermark same procedures as the embedding process is used. Correlation between mid-band coefficients and random-sequences is calculated to determine watermarked bits. The implementation of algorithm shows good imperceptibility and higher robustness against common signal processing attacks.

Keywords
Watermarking, Robustness. , imperceptibility, Blind watermarking, Spatial Domain, Transform Domain, Discrete Wavelet Transform, (DWT) Discrete Cosine transform (DCT), Arnold cat map Peek signal to noise ratio. Normalized correlation.

1. Introduction

Copyright protection for multimedia data has become an important issue due to the increasing use of internet and easy copying, tempering and distribution of digital data.[6] A solution to this kind of problem is a digital watermarking. Digital watermarking is a digital media protection measures .It is a technology which is used to identify the creator, owner, distributor of a given video or image by embedding copyright marks into the digital content, hence digital watermarking is a powerful tool used to check the copy right violation. [6]A digital watermark is an invisible signature embedded inside an image to show authenticity and ownership.
Using digital watermarking copyright information is embed into a digital signal in a way that is difficult to remove.[7][5] The watermarks are coded, interleaved, and then Embedded into the image. Watermarking techniques are i) visible, ii) invisible fragile, iii) invisible robust. Digital Image Watermarking domains are spatial domain and frequency(Transform) domain. The spatial domain algorithms are so simple to implement but the problems are Low watermark information hiding capacity Less PSNR, Less Correlation between original and extracted watermark and less security and the watermark can be damaged easily.LSB Least Significant Bit insertion is an example of spatial domain watermarking. The frequency domain algorithm can resist attacks such as common image processing operations i.e. watermark information can't be damaged easily The transform domain algorithm mainly includes DWT, DFT, DCT and SVD,WHT etc.
Quality of watermarking scheme is commonly determined by the four factors robustness, imperceptibility, capacity, and blindness. Good quality watermarking scheme should have maximum PSNR, ideally Correlation Factor equals to 1 and should have maximum watermark information hiding capacity. Watermark must be highly robust to distortion introduced during either normal use (unintentional attack), or a deliberate attempt to disable or remove the watermark present (intentional, or malicious attack). Unintentional attacks involve transforms that are commonly applied to images during normal use, such as addition of noise, cropping, resizing, contrast enhancement, filtering.etc. In order to be successful, the watermark should be invisible and Robust to premeditated or spontaneous modification of the image.
Among the transform domain method, the Discrete cosine Transform (DCT) technique is important because DCT is used in many image process and compression standards such as JPEG. This makes the DCT domain watermarking schemes have the ability to survive the digital image compression method, such as JPEG. DC values are adapted to embed watermarking in transparence.
DWT is used frequently in digital image watermarking due to its Multi-resolution property i.e. time (space)/frequency decomposition characteristics, which resemble to the theoretical models of the human visual system [3]
In this paper, a blind watermarking algorithm based on DCT-DWT that embeds a binary image into the gray images is presented.

Manuscript received August 5, 2011
Manuscript revised August 20, 2011

2. Methodologies

2.1 Discrete Cosine Transform (DCT):

A transformation function, which transforms the representation of data from space domain to frequency domain. The two- dimensional DCT of an M-by-N image A is defined as follows

$$B_{pq} = \alpha_p \alpha_q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} A_{mn} \cos\frac{\pi(2m+1)p}{2M} \cos\frac{\pi(2n+1)q}{2N}, \quad \begin{matrix} 0 \le p \le M-1 \\ 0 \le q \le N-1 \end{matrix}$$

$$\alpha_p = \begin{cases} 1/\sqrt{M}, & p=0 \\ \sqrt{2/M}, & 1 \le p \le M-1 \end{cases} \quad \alpha_q = \begin{cases} 1/\sqrt{N}, & q=0 \\ \sqrt{2/N}, & 1 \le q \le N-1 \end{cases}$$

The DCT Inverse transform is given by

$$A_{mn} = \sum_{p=0}^{M-1} \sum_{q=0}^{N-1} \alpha_p \alpha_q B_{pq} \cos\frac{\pi(2m+1)p}{2M} \cos\frac{\pi(2n+1)q}{2N}, \quad \begin{matrix} 0 \le m \le M-1 \\ 0 \le n \le N-1 \end{matrix}$$

$$\alpha_p = \begin{cases} 1/\sqrt{M}, & p=0 \\ \sqrt{2/M}, & 1 \le p \le M-1 \end{cases} \quad \alpha_q = \begin{cases} 1/\sqrt{N}, & q=0 \\ \sqrt{2/N}, & 1 \le q \le N-1 \end{cases}$$

In general, watermarking scheme adopting the 8×8 block-based DCT showed superiority to the whole image-based DCT in the sense of robustness except for the resizing. The block-based DCT transform divides image into non-overlapping blocks and applies DCT to each block. An image divided into 8×8 blocks. Each of these 8×8 blocks of the original image is mapped to the frequency domain. This results in giving three frequency coefficient sets: low frequency sub-band, mid-frequency-sub-band and high frequency sub-band. DCT-based watermarking is based on two facts. The first fact is that much of the signal energy lies at low-frequencies sub-band which contains the most important visual parts of the image.[2] The second fact is that high frequency components of the image are usually removed through compression and noise attacks. The watermark is therefore embedded by modifying the coefficients of the middle frequency sub-band so that the visibility of the image will not be affected and the watermark will not be removed by compression [2]

2.2 Discrete Wavelet Transform (DWT)

Wavelet transform is a multi-scale signal analysis method, which overcomes the weakness of fixed resolution in Fourier transform (DFT). In the wavelet transform domain the general features and the details of a signal can be analyzed[4]

DWT is a hierarchical sub-band system. Wavelet transform decomposes an image into a set of band limited components which can be reassembled to reconstruct the original image without error. Since the bandwidth of the resulting coefficient sets is smaller than that of the original image, the coefficient sets can be down sampled without loss of information.[4] Reconstruction of the original signal is accomplished by up sampling, filtering and summing the individual sub bands. For 2-D images, applying DWT corresponds to processing the image by 2-D filters in each dimension. The filters divide the input image into four non-overlapping multi-resolution coefficient sets, a lower resolution approximation image (LL) as well as horizontal (HL), vertical (LH) and diagonal (HH) detail components. The sub-band LL represents the coarse-scale DWT coefficients while the coefficient sets LH, HL and HH represent the fine-scale of DWT coefficients. To obtain the next scale of wavelet coefficients, the sub-bands are further processed until some final scale N is reached.

Fig 1.First level decomposition on lenna image

Due to its excellent spatial-frequency localization properties, the DWT is very suitable to identify the areas in the host image where a watermark can be embedded effectively.[1,2] In particular, this property allows the exploitation of the masking effect of the human visual system such that if a DWT coefficient is modified, only the region corresponding to that coefficient will be modified. In general most of the image energy is concentrated at the lower frequency coefficient sets LL and therefore embedding watermarks in these coefficient sets may degrade the image significantly. Embedding in the low frequency coefficient sets, however, could increase robustness significantly.[4,1] On the other hand, the high frequency coefficient sets HH include the edges and textures of the image and the human eye is not generally sensitive to changes in such coefficient sets. This allows the watermark to be embedded without being perceived by the human eye[3]. The agreement adopted by many DWT-based watermarking methods, is to embed the watermark in the middle frequency coefficient sets HL and

LH is better in perspective of imperceptibility and robustness

3. Combined DWT-DCT Method

Transform domain watermarking schemes based on the discrete cosine transform (DCT) the discrete wavelet transform (DWT) provide higher image imperceptibility and are much more robust to image manipulations. The DCT domain watermarking schemes have the ability to sustain the digital image compression method, such as JPEG. [3]
The wavelet transform has several advantages : The DWT is a multi-resolution description of an image: the decoding can be processed sequentially from low resolution to higher resolutions. The DWT is closer to human visual system than DCT. Hence, the artifacts introduced by wavelet domain coding with high compression ratio are less annoying than those introduced at the same bit rate by DCT.
In the DWT-DCT method, the most proper sub-bands are selected to take these benefit of DWT in case of robustness and imperceptibility. Then, the block based DCT is applied on these selected band to embed watermark in middle frequencies of each block to improve further robustness of watermarked image against different attacks. [2]By combing the two common frequency domain methods, we could take the advantageous of both two algorithms to increase robustness and imperceptibility.
Improvement in the performance in DWT-based digital image watermarking algorithms could be achieved by combing DWT with DCT[3]. Two transforms are combined to make up for the disadvantages of each other, so as to increase the effectiveness of watermarking algorithm.

4. Watermarking Algorithm

The watermark is a m x m binary image. We arrange the binary image to 0-1 watermark vector WT. The length of WT is m 2. Key is obtained by applying Arnold cat map on the Image. For any image the iteration when original image is obtained is fixed so this number is the key. The Cover image is a NxN gray image. The subbands LL, HL, LH, and HH are referred as shown in the figure 2.

LL→A,HL→H, LH→V and HH→D

A (Approximation sub band) H(Horizontal sub band),V(Vertical sub band) and D(Diagonal sub band)

LL: Approximate Subband	HL: Horizontal Subband
LH: Vertical Subband	HH : Diagonal Subband

Fig.2 Four subbands

4.1 Watermark Embedding Algorithm

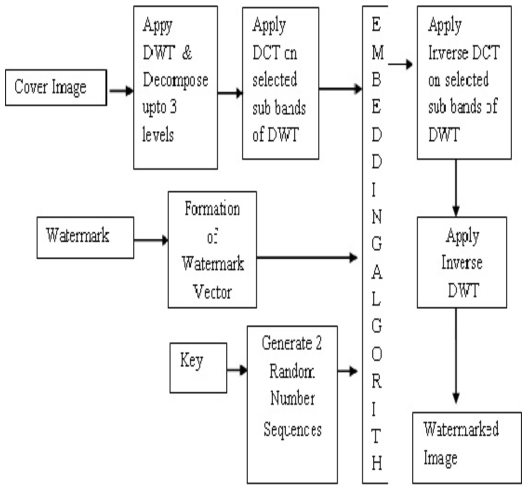


Fig.3 Block Diagram of Watermark Embedding Algorithm

The watermark Embedding procedure is shown in figure 3 and described in details in the following steps.

Step 1 :- Apply DWT to the cover image of size NxN to get four sub bands [A1 ,H1, V1, D1] of size N/2xN/2 at first level decomposition . Middle frequency sub-bands HL(H1) and LH(V1) are selected for better imperceptibility and robustness.
Step 2:- Apply DWT on H1 to get four sub bands [H1A2, H1H2 ,H1V2, H1D2] of size N/4xN/4 at second level of decomposition. Similarly apply DWT on V1 to get four sub bands [V1A2, V1H2 ,V1V2, V1D2] of size N/4xN/4.
Step3 :- Select four sub band H1H2 ,H1V2 and V1H2 ,V1V2 .apply DWT on them to get 16 sub bands of size N/8xN/8 at third level of decomposition . Select 4 sub bands H1H2H3, H1V2H3, V1H2H3, and V1V2H3 for next processing. They are shown as B1, B2, B3, B4
Step :-4 This step is block processing where each selected sub band is divided into block of 4 x 4. DCT is applied to each 4x4 block .This way one sub band of size N/8xN/8 is divided into N/32xN/32 blocks. Selected 4 sub bands creates 4/32) blocks. *(N/32xN/32)

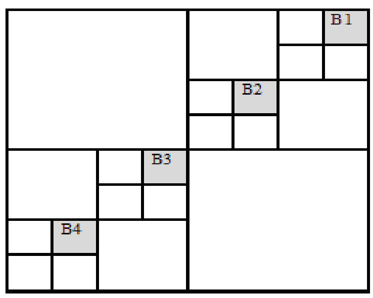


Fig. 4 four selected multiresolution DWT sub bands of the cover Image at level 3.

Step 5 :- Here watermark vector is to be embedded in the middle coefficient of the DCT blocks. Following are the sub steps

Step 5.1 :-Generate two uncorrelated pseudorandom sequences by a key. One sequence is used to embed the watermark bit 0 (RNS0) and the other sequence is used to embed the watermark bit 1 (RNS1). Number of elements in each of the two pseudorandom sequences equals to the number of mid-band elements of the DCT-blocks

Step 5.2 :- The mid-band elements of the 4 x 4 DCT-are shown in the figure

L	L	M	M
L	M	M	H
M	M	H	H
M	H	H	H

Fig.5 mid band coefficients of 4x4 DCT blocks.

The watermark bits are embedded as

if(WT(k)= =0)
mid_coeff= mid_coeff + RNS0
elseif(WT(k)= =1)
mid_coeff= mid_coeff + RNS1

where k=1,2…(N/32xN/32) for one (N/32xN/32) blocks.

The process is repeated for all other blocks. Random numbers may be multiplied with constant gain factor.

Step 6:- Perform inverse DCT (IDCT) on each block after its mid-band coefficients have been modified

Step 7 :- Perform the inverse DWT (IDWT) on the including the modified coefficient sets, to produce the watermarked image.

4.2 Watermark Extraction Algorithm

The joint DWT-DCT algorithm is a blind watermarking algorithm, and thus the original host image is not required to extract the watermark. The watermark extraction procedure is shown in Figure 5, and described in details in the following steps

Step 1: Perform DWT on the watermarked image to decompose it into four non overlapping multi-resolution coefficient sets: [RA1 ,RH1, RV1, RD1]

Step 2: Perform DWT again on two sub-bands RH1, RV1 to get eight smaller sub-bands and choose four coefficient sets: [RV1A2, RV1H2 ,RV1V2,RV1D2]

Step 4: Perform DWT again on four sub-bands to get sixteen smaller subbands and choose four coefficient sets: RH1H2H3, RH1V2H3,RV1H2H3,RV1V2H3

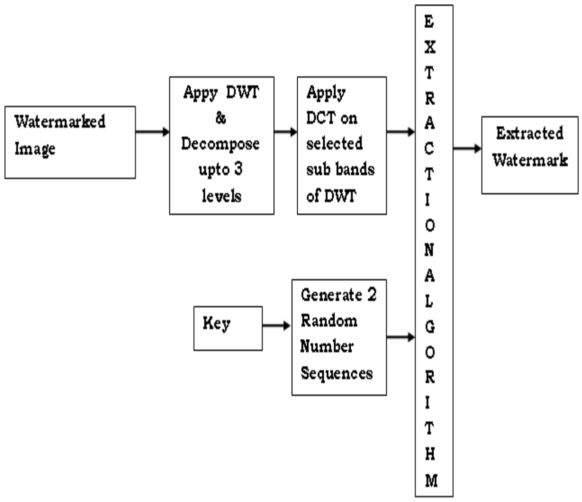


Fig.6 Block Diagram of Watermark Extraction Algorithm

Step 5: Divide these four coefficient sets into 4 x 4 blocks.

Step 6: Perform DCT on each block in the chosen coefficient sets

Step 7: Regenerate the two pseudorandom sequences (RNS0 and RNS1) using the same key which used in the watermark embedding procedure.

Step 8: For generating the watermark vector correlation between the mid-band coefficients and the two generated pseudorandom sequences(RNS0 and RNS1) is calculated for each block in the coefficient sets: RH1H2H3, RH1V2H3,RV1H2H3,RV1V2H3.If correlation with the RNS0 is higher than the correlation with RNS1, then the extracted watermark bit is considered 0, otherwise the extracted watermark is considered 1.

Step 9: The watermark image is reconstructed by converting watermark vector into Watermark image

5. Implementation and Results

The DWT-DCT Based watermarking algorithm is applied to number of input cover images and different Binary Watermarks. In this paper, 512 x512 Lena image and 32×32 binary image is selected as the cover image ie original image and watermark image respectively . By using a row-major algorithm watermark image is transformed into a binary sequence of length 1024. Original image is decomposed up to three levels using ‘Haar’ Wavelet transform. At this level four selected 64×64 DWT sub-band is divided into 4×4 blocks giving a total of 1024 blocks. 1024 bits of Watermark vector can be embedded in these blocks .

The performance evaluation of the this methods is done by measuring their imperceptibility ie transparency and robustness. Here we use the normalized correlation (NC) to measure the similarity between original image and the watermarked image. Peek Signal-to-Noise Ratio

(PSNR) measures the fidelity between the original image and the watermarked image. A larger PSNR indicates that the watermarked image more closely resembles the original image meaning that the watermarking method makes the watermark more imperceptible. Generally, if PSNR value is greater than 35dB the watermarked image is within acceptable degradation levels, i.e. the watermarked is almost invisible to human visual system. PSNR and NC values are calculated for Original watermark and extracted watermark .

In order to investigate the robustness of the watermarking scheme, the watermarked image was attacked by various signal processing technique, such as Additive Gaussian noise, Additive salt noise, Median filtering, image enhancement, and cropping

Fig 7(a)

Fig 7(b)

(a) Original Lenna Image (b) Watermarked Image

Fig8(a)

Fig 8(b)

(a) Original Watermark (b) Extracted Watermarked

Table 1. RESULTS OF WATERMARKED IMAGE FOR NO ATTACK

No Attack	PSNR	NC
Lenna Image	39.2654	1
Watermark	65.6811	0.9802

Table 2.RESULTS OF WATERMARKED IMAGE FOR CROPPING ATTACK

Cropping Attack	Extracted Watermark	PSNR	NC
12%		65.2235	0.9936
19%		61.8991	0.9861

Fig9(a)

Fig 9 (b)

(a)19% Cropped Image b)12% Cropped Watermarked Image

Table 3. RESULTS OF WATERMARKED IMAGE FOR JPEG ATTACK

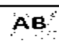
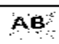
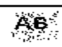
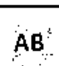
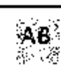
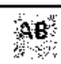
JPEG Attack	Extracted Watermark	PSNR	NC
Quality 75 %		63.9202	0.9698
Quality 50 %		62.0013	0.9609
Quality 35%		57.7806	0.8959

Table 4. RESULTS OF WATERMARKED IMAGE FOR NOISE ATTACK

Noise Attack	Parameter	Extracted Watermark	PSNR	NC
Salt & Pepper Noise Parameter is Noise Density	1%		61.7993	0.9569
	2%		60.0384	0.9378
	3%		58.1478	0.8985
	5%		56.3026	0.8451
	7%		55.0323	0.7926
	10%		54.5977	0.7884
Gaussian Noise Parameter is Variance	0.001		64.6165	0.9749
	0.003		62.6708	0.9623
	0.005		59.4832	0.926
	0.01		57.1958	0.876
	0.02		55.4692	0.8144
speckle Noise Parameter is Variance	0.04		57.2996	0.8819
	0.05		56.7725	0.8609

From the data in Result Tables, we can see that the performance of combined DWT-DCT algorithm has great robustness against the attack from the Salt & Pepper noise Addition ,Gaussian noise addition. Speckle Noise addition, Cropping, JPEG compression. The combined DWT-DCT watermarking algorithm is robust to most of the image processing attacks. Thus the combined DWT-DCT watermarking algorithm can be used for protecting the copyrights of digital images

6. CONCLUSION

The combined DWT-DCT digital image watermarking algorithm is evaluated in this paper. Watermark is embedded in the DCT blocks of the in the selected four middle frequency sub-bands of 3-levels DWT transformed of a cover image. Implementation results show that the imperceptibility of the watermarked image is acceptable. The Results shows that algorithm is robust for most of the common image processing attacks .The algorithm can be applied on color images.

REFERENCES

[1] Mohamed A. Mohamed, Mohy EI-Din A. Abou-Soud\ Mai S. Diab " Fast Digital Watermarking Techniques for Still Images" 2009 IEEE

[2] Wei-Min Yang, Zheng Jin " A Watermarking Algorithm Based on Wavelet and Cosine Transform for Color Images" 2009 First International Workshop on Education Technology and Computer Science

[3] Saied Amirgholipour Kasmani, Ahmadreza Naghsh-Nilchi "A New Robust Digital Image Watermarking Technique Based On Joint DWTDCT Transformation. Third 2008 International Conference on Convergence and Hybrid Information Technology 2008 IEEE computer society.

[4] Jianmin Xie Qin Qin 2010 IEEE "Study of Image Digital Watermarking Algorithm and Robustness Based on the Wavelet Transform Techniques "

[5] Mr.Manjunatha Prasad.R Dr.Shivaprakash Koliwad " A Robust Wavelet-Based Watermarking Scheme for Copyright Protection of Digital Images" 2010 IEEE Second International conference on Computing, Communication

[6] Jiang Xuehua "Digital Watermarking and Its Application in Image Copyright Protection" 2010 International Conference on Technology and Automation

[7] "Digital Watermarking Technique for Protecting Digital Images Munesh Chandra", Shikha Pandel, Rama Chaudharl 2010 IEEE