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Research Article

Robust Digital Watermarking using DWT-DCT-SVD Algorithms for Color Image

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Abstract

Digital image watermarking is a method of embedding piece of information into digital content (i.e. images, audio, video and text) and also provides authenticity to digital content. This paper describes the robust digital image watermarking for color image based on algorithms discrete wavelet transform (DWT), discrete cosine transform (DCT) and singular value decomposition (SVD). Performance analysis of the proposed algorithm is carried out by evaluating the performance metrics like MSE, PSNR and NCC values to check effectiveness and imperceptibility of the watermarked image with different attacks like resizing, rotation, salt and pepper noise etc. The main aim of our paper is to provide robustness, security and authenticity to the image.

Keywords: *dwt, dct, svd, embedding, extraction, watermarking.*

1. Introduction

Now-a-days ever growing digital multimedia and internet as a means of communication, lot of embedding techniques used to transmit the digital content through internet. In the current globalization, the accessibility of the internet and different image processing tools opens up profoundly, the possibility of downloading an image from the internet, manipulating it without the permission of specified owner. Copyright protections of transmitted multimedia content have become very important issues. Because of this, many people worked and found different techniques to protect multimedia content from illegal manipulation.

1.1 Digital Watermarking Requirements

Quality of watermarking mainly depends on the three requirements of digital watermarking (C. Rey, *et all*, 2002)- (G. Voyatzis, *et all*, 1998):

Transparency and Fidelity

Transparency and fidelity defines the similarities between the original and watermarked content. After insertion of watermark into the original image there is no distortion in the watermarked image means transparency is high.

Robustness

Robustness is related to different attacks. If removal of watermark is difficult to different attacks like cropping, compression, rotation etc., then the watermarking method is said to be more robust. Robustness of the watermarking techniques is determined by using normalized cross correlation between the original and extracted watermark image.

Capacity or Data payload

Capacity or data payload describes the how much data can be embedded as a watermark to recover the watermark successfully during extraction process. Capacity high means one can hide more information into the original content and is comparatively high for color images than the gray scale images.

1.2 Digital Watermarking classification

Watermarking systems can be classified on the basis of their requirements. According to domain of watermark insertions there are two methods in watermarking techniques, which are spatial domain and frequency or transform domain method.

Spatial domain method

In spatial domain method embedding of watermark into original cover image is directly done. Best example for this method is LSB scheme is, it carries less

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information and low-order bits of original image is modified with watermark. Due to the lower bits embedding, complexity is less and is easy to implement but security is less. In this method extraction of watermark from watermarked image is very easy. Because of this disadvantage now-a-days most researchers refer to transform domain method.

Frequency or Transform domain method

There are three types in transform method i.e. discrete cosine transform, discrete wavelet transform and singular value decomposition.

Discrete Wavelet Transform (DWT): For the purpose of multi-resolution, DWT is used as a mathematical tool. DWT is a method of decomposing an image into set of bands and gather together to get back original image with no error. DWT decomposes into approximation image (LL) and with three directions, i.e. horizontal (HL), vertical (LH) and diagonal (HH). The figure.1 shows a 2-level decomposition of the image (Vaishali S. Jabade, *et all*, 2011).

Low band (LL) has high magnitude compared to the other bands i.e. LH, HL and HH. LL band is more significant one for embedding and extraction process but as we increase the resolution of LL band, it has less number of frequency components, so it computationally effective for detection of watermark.

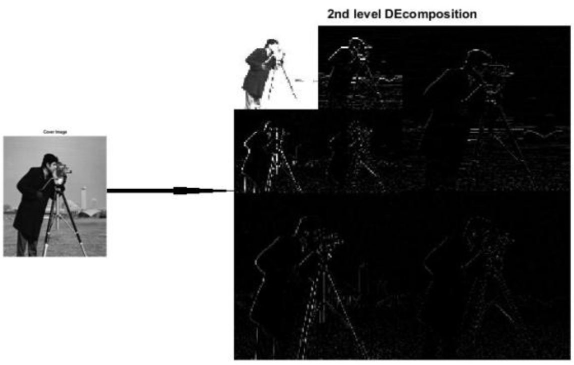


Fig.1 Two Levels DWT Decomposition

Discrete cosine transform (DCT): Discrete Cosine Transform is one method for transforming signal into frequency component. In **Global DCT,** it is applying to all part of the image, with respect to their energy, spectral regions are separating. In **Block based DCT,** the image is first divided into a set of non overlapping blocks and then apply DCT to all these blocks to select coefficients to form a matrix. In DCT two types of coefficients are available for embedding and extraction purpose, left top corner of the matrix represents the DC coefficients and bottom most corner represents the AC coefficients. DC coefficients are more significant because it represents lowest frequency coefficients and AC coefficients are less significant because it represents highest frequency coefficients.

Singular value decomposition (SVD): Singular Value Decomposition is an algebraic representation of an image. It converts single matrix into three matrices with the same size as the original matrix. Consider a matrix A= U*S*V', here U and V are orthogonal matrices and S is a diagonal matrix. SVD is used to increase the transparency of the watermarked image. Singular values of watermark are modified with singular values of original image to form a watermarked image. To get back original watermark inverse process is applied using U and V matrices.

2. Related work

The following works were carried out by specific persons in the area of digital watermarking search

Authors proposed non-blind watermarking using DWT-DCT-SVD algorithms. Applied 2-level DWT decomposition of LL-HH band followed by DCT and SVD to improve imperceptibility and robustness of the watermarked image (Nidhi Divecha *et al*, 2013). DWT is used to take middle frequency bands LH and HL then divided into 8*8 square blocks. DCT is applied to these bands to select DC coefficients and then SVD is applied. Proposed method achieved robustness against common image processing attacks (MdSaiful Islam *et al, 2014*). Take principle component of the watermark for embedding with the DCT of DWT decomposition of horizontal sub bands of the cover image. Recovered watermark has reliability in the quality as well as better imperceptibility. It reduces the diagonal line problem and is proved by recovered watermark (N. J. Harish, *et all*, 2013). Used Arnold transform to get scrambled version of watermark. Watermarking embedding and extraction is done in DWT high frequency domain so small modification is not observed by human then watermark detection not depends on original image (blind scheme). Image quality depends on the evaluation of parameters PSNR and SR (Dasu Vaman, *et all*, 2013). Proposed method improves transparency of the watermarked image with the help of combination of discrete cosine transform and 3-level discrete wavelet transform. Watermarking uses random interval keys to embed watermark. It improves performances parameters peak signal to noise ratio and normalized correlation and reduced computational time (Reena Anju, *et all*,2013). Cover image is modified (zigzag) and divided to number of blocks of size n*n. To form reference image find the spatial frequency of each block and kept a threshold on this spatial frequency. Then applied DCT to HF band of DWT and modified the singular values of watermark and reference image to hide the watermark (Satyanarayana Murty, *et all*, 2012). Original image is rearranged using zigzag sequence then apply DCT and SVD on all high bands LH, HL and HH of DWT. Watermark is then embedded by modifying the singular values of these bands to achieve robustness against different attacks (Md. Maklachur Rahman, *et* *all*, 2013). Proposed method used 2-level DWT decomposition to get middle bands LH2 and HL2 then it is divided into 8*8 square blocks and apply DCT to all blocks to get middle frequency coefficients. Watermark is converted into strings 1's and 0's and is embedded into these coefficients (R. Eswaraiah, *et all,* 2012). The proposed method increases the capacity of watermarking techniques and provides robustness against intentional and signal processing attacks. Embedding and extraction process is done for all bands of DWT and compare the metrics values (V. Santhi, *et all*, 2011).

By observing all the paper s, we proposed a new robust digital watermarking technique for color image as cover and watermark using advantages of three algorithms discrete wavelet transform, discrete cosine transform and singular value decomposition. To achieve robustness against different attacks watermark is embedded in lower band and modification is done singular values to get good transparency.

3. Proposed work for embedding and extraction

In the proposed scheme, the 'watermark and cover images' are color images. Read cover image then 1st level DWT is applied, LL band is selected to achieve imperceptibility of the image. Then apply 2-level DWT on LL band to select HH2 band to improve robustness. Then it is divided into 4*4 square blocks using block based DCT transform to select DC coefficients to form the matrix. Then SVD is applied to this matrix to get singular values and orthogonal matrices. Then read watermark image apply single level DWT and select HH band, then divided into 4*4 square blocks using block based DCT to select DC coefficients to form matrix, then apply SVD. Modified singular values of watermark with cover image to get watermarked image. Inverse process is applied to extract watermark image from watermarked image.

3.1 Embedding process

The procedure for embedding process, hide watermark (of size 256*256) into cover image (of size 512*512) to get watermarked image.

1) Read original color image (Iorg) of size N*N (here N=512) and separate the color components R G and B for example, R = Iorg(:, :, 1), G= Iorg(:, :, 2), B= Iorg(:, :, 3)
2) Select R component and apply DWT to get four sub bands LLR, LHR, HLR and HHR with size N/2*N/2
3) Select LLR band and apply 2-level DWT to decompose it into N/4*N/4 sub bands LL2, LH2, HL2, and HH2
4) Select HH2 band, apply DCT 4*4 block process to select dc coefficients from each block to form matrix B
5) Then apply SVD to B, B= UR*SR*VR', where UR and VR orthogonal matrixes and SR is diagonal matrix are called singular values
6) Read secrete or watermark color image (Iw) of size N/2*N/2 then separate the color components rw = Iw(:, :, 1), gw =Iw(:, :, 2), bw = (:, :, 3)
7) Select rw component and apply DWT decomposition to get sub bands LLr, LHr, HLr and HHr
8) Select HHr band divided into 4*4 square blocks using block based DCT techniques to select DC coefficients and form a matrix Br
9) Apply SVD to Br, Br= Ur*Sr*Vr', and obtain Ur, Sr and Vr
10) Modify SR with Sr using tuned factor alpha
    i. S1= SR + (alpha * Sr)
11) Getting Dct_val1w= UR*S1*VR' i.e. nothing but inverse SVD and place these values into positions of Br
12) Apply inverse DCT (IDCT), to get LL_HH_R band
13) Apply inverse DWT (IDWT) to LL2, LH2, HL2 and LL_HH_R to get LL1 sub band
14) Apply inverse DWT to LL1, LHR, HLR and HHR to get watermarked image of R component nothing but we have embedded r component of watermark into R component of original image
15) Above steps repeated for G and B component
16) Finally concatenate all R G B component to get watermarked image

3.2 Extraction process

The procedure for extraction process to extract watermark and original cover image explained bellow

1) Select watermarked R image and apply DWT to get llr, lhr, hlr and hhr.
2) Then apply DWT on llr band to get ll2r, lh2r, hl2r and hh2r
3) Then select hh2r band and apply DCT 4*4 square block process to select dc coefficients from each block to form matrix Cr
4) Apply SVD to Cr, Cr= u*ss*v', and obtain u, ss and v
5) To get back watermark, take temp = (ss-SR)/alpha, EWr = Ur*temp*Vr'
6) Then apply inverse DCT to get high frequency ll_hhr band
7) Then apply inverse DWT to LLr, LHr, HLr, ll_hhr to recover watermark r component
8) To get back original cover R image, take temp1= ss-alpha*Sr,
    a. EWR = UR*temp1*VR'
9) Then apply inverse DCT to EWR to get LL_HHR
10) Apply inverse DWT to LL2, LH2, HL2 and LL_HHR to get LL_R
11) Apply inverse DWT to LL_R, LHR, HLR and HHR to recover original R component
12) Above steps repeated for other components
13) Finally concatenate all color components to recover watermark and cover image

4. Parameter metrics

4.1 PSNR (Peak Signal-to-Noise Ratio)

The PSNR value computes the peak signal-to-noise ratio, in decibels, between two images this ratio is used to measure quality of the image between the original cover and watermarked image. Higher the PSNR, the better is the quality of watermarked or recovered watermark image.

4.1 MSE (Mean Square Error)

Mean square error represents error between the watermarked and original cover image, whereas PSNR represents a measure of the peak error. Lower the MSE value means error is less.

To compute PSNR first we calculate the MSE using the following equations:
For color image:

$$MSE = \frac{\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}(|originalcoverimage - watermarkedimage|)^2}{3*m*n} \quad (1)$$

$$PSNR = 10\log_{10}\left[\frac{R^2}{MSE}\right] \quad (2)$$

Here m and n are the size of original cover and watermarked image and R is the maximum fluctuation in the input data.

4.3 NCC (Normalized Cross Correlation)

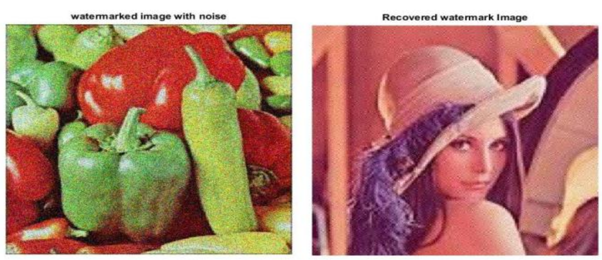
Normalized cross correlation is calculated to know the robustness of the image. NCC value is 1 (ideal) is said to be more robust. NCC value is calculated using original watermark image (Iow) and extracted watermark image (Iew), equation given as:

$$NCC = \frac{\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}(Iow*Iew)}{\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}(Iow*Iow)} \quad (3)$$

5. Results and tabulation

5.1 Results

We used the software tool MATLAB to get results. Applied different attacks on watermarked image and recovered watermark with respect to these attacks. The results show clear idea about embedding and extraction of watermarking with the attacks and calculate MSE, PSNR and NCC values to evaluate performance of the image to achieve robustness of the image.



(a) (b)

Fig. 2 (a) Watermarked color image with AWGN noise (b) Recovered color watermark image with AWGN noise

(c) (d)

Fig. 3 (c) Watermarked color image with JPEG compression 50% (d) Recovered color watermark image with JPEG compression 50%

(e) (f)

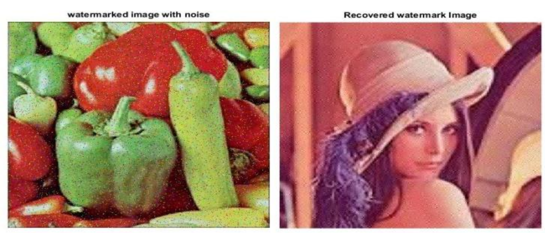
Fig. 4 (e) Watermarked color image with Median filter (f) Recovered color watermark image with Median filter

(g) (h)

Fig. 5 (g) Watermarked color image with Wiener filter (h) Recovered color watermark image with Wiener filter

(i) (j)

Fig. 6 (i) Watermarked color image with Gaussian filter (j) Recovered color watermark image with Gaussian filter

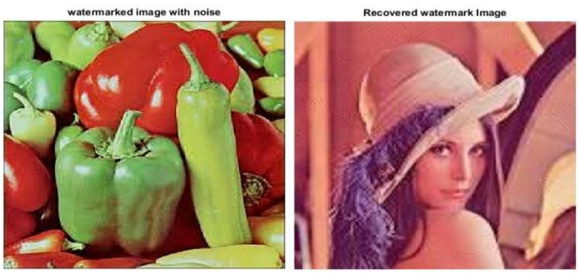


(k) (l)

Fig. 7 (k) Watermarked color image with salt and pepper noise (l) Recovered color watermark image with salt and pepper noise

Table 1: Results for embedding and extraction of color image with MSE, PSNR and NCC for different attacks

		MSE			PSNR			NCC
		R	G	B	R	G	B	
Without attack		0.5287	0.5161	0.4671	56.9537	57.0582	57.4913	1
AWGN noise		33.4529	31.0320	30.4611	38.9411	39.2673	39.3480	0.9983
Jpeg 50% compression		2.4355	1.4121	2.3158	50.3196	52.6868	50.5384	0.9999
Median filter		0.7370	0.7089	0.7380	55.5108	55.6797	55.5473	0.9999
Wiener filter		0.7042	0.6736	0.6215	55.7086	55.9014	56.2507	0.9999
Gaussian filter		0.7788	0.6955	0.5223	55.2710	55.7623	57.0059	1
Salt and pepper noise		2.6196	2.4517	2.3771	50.0031	50.2906	50.4249	0.9990
Sharpen image		7.2204	6.4646	5.7722	45.5998	46.0800	46.5720	1
Image replacing		0.4426	0.5161	0.4671	57.7256	57.0582	57.4913	1
Image rotation	45^0	43.8544	46.1086	43.7775	37.7653	37.5476	37.7729	0.9997
	90^0	39.6375	39.6803	36.8270	38.2043	38.1996	38.5237	0.9999
Image resize		0.8561	0.8308	0.7731	54.8600	54.9903	55.3031	0.9999



(m) (n)

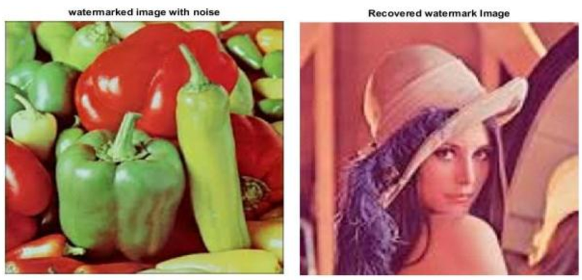
Fig. 8 (m) Watermarked color image with sharpening (n) Recovered color watermark image with sharpening

(o) (p)

Fig. 9 (o) Watermarked color image rows and columns replacement (p) Recovered color watermark image with rows and columns replacement

(q) (r)

Fig. 10 (q) Watermarked color image with rotation 45^0 (r) Recovered color watermark image with rotation 45^0



(s) (t)

Fig. 11 (s) Watermarked color image with resizing (t) Recovered color watermark image with image resizing

5.2 Tabulation

The tabulation results show the parameter values of PSNR, MSE and NCC values with different attacks. As we can see in the table 1, it gives idle NCC value for no attack. It gives good parameter values for all most all common image processing attacks. We can see all values in the tables to check the robustness of the image.

Conclusion

In this paper, proposed watermarking method gives NCC value 1 for no attacks with good PSNR and MSE values. It gives good parameter values for all most all common image processing attacks. It provides transparency by using SVD-values, reduces compression attack by using discrete cosine transform and provides the robustness to the watermarked image by using discrete wavelet transform. Capacity high for color images so it can hide more information.

In future work, we extend this work with neural network to increase robustness and security of the image by generating random sequences.

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