A Modified Blind Image Watermarking Scheme Based on DWT, DCT and SVD domain Using GA to Optimize Robustness

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***Abstract*— A modified blind image watermarking algorithm using discrete wavelet transform (DWT), discrete cosine transform (DCT) and singular value decomposition (SVD) is proposed in this paper. One level DWT operation is performed on original host image using Haar wavelet and approximation (LL) sub-band is selected to split it into two sub images. DCT and SVD operations are performed in both sub images using 8x8 block size. Based on pixels values of binary watermark image, singular value of first sub image is modified referring singular value of second sub image to embed watermark. Genetic algorithm (GA) technique is adopted to optimize visual quality and robustness of watermarked image. Peak Signal to Noise Ratio (PSNR) and Normalized Cross correlation (NCC) are computed to evaluate imperceptibility and robustness of the watermarked image. Experimental results obtained confirm that the proposed method is efficient and more robust against different attacks, viz. noise insertion, filtering, JPEG compression, histogram equalization, gamma correction, bit plane removal, image sharpening and cropping attacks.**

Keywords— Digital image watermarking, Robustness, Genetic Algorithm, Imperceptibility, Discrete Cosine Transfer, Singular Value Decomposition, Discrete Wavelet Transform.

I. INTRODUCTION

These days, digital data distribution becomes one of the fastest growing activities due to the development of digital technology along with high speed connecting networks. Hostile persons make use of this opportunity to copy and redistribute valuable digital properties of others breaching copyright rule. In order to mitigate the crisis, content owner should use different techniques which can persistently protect content from unauthorized access and manipulation. Digital image watermarking technique enables content owners and providers to protect their copyright by inserting digital signature called watermark, into the original image. Therefore, Digital image watermarking can be defined as the process of embedding or inserting a digital watermark into original elements that the embedded watermark can be extracted later time to identify copyright owner [1].

Digital watermarking can be classified into spatial and transformed domain watermarking based on embedding domain of host image. In spatial domain watermarking techniques, watermark is inserted simply by modifying the pixel value of host image and the method is usually computationally simple compared to transform domain techniques. Hiding watermark on least significant bits (LSB) of cover image is one of the spatial domain watermarking technique that embed watermark data by replacing least significant bits data with binary watermark bits [2]. The drawback of spatial domain watermarking technique is watermarked image is less robust to different attacks and vulnerable to temper by unauthorized person. As a result, spatial domain watermarking techniques are not chosen for robust watermarking system. However, transformed domain watermarking scheme provides a more robust and secured watermarked image. In transform domain techniques, watermark image is embedded in transformed coefficients of host image and usually transformation is performed using Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT), and Discrete Wavelets Transform (DWT) [3]. Authors in [4] proposed watermarking algorithm using DCT. In [5], DWT based image watermarking algorithm is used for digital image watermarking. SVD [6] based watermarking methods are also available in literatures.

Furthermore, digital watermarking can be categorized into non-blind, semi-blind and blind based on requirement of data for watermark extraction. In blind watermarking scheme original cover image is not needed for extraction process. However, non-blind watermarking scheme requires original un-watermarked cover image during watermark extraction process. In some other watermarking scheme, extraction process may require access to published watermarked image and such type of schemes are known as semi-blind watermarking schemes [7].

Since watermark embedding process inserts additional data to cover image, consequently the visual quality of the image degrade a lot. However, high level of degradation caused by watermark insertion does not satisfy the requirements of

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transparency. This degradation level can be measured using PSNR. Designing optimal watermarking system always involve trade-off between transparency and robustness. So, obtaining optimum value for transparency and robustness requires optimization tools like genetic algorithm. GA is applied to find best scaling factor for watermark coefficient modification. In paper [8], GA based robust watermarking scheme is proposed to optimize the performance of the system.

In this paper, modified blind image watermarking algorithm using DWT, DCT and SVD domain is proposed and Genetic algorithm is used to optimize the transparency and robustness.

The paper is organized as follow: section II discus about basics of DWT, DCT, SVD and GA. In section III detail of proposed algorithm is presented. Experimental results are shown in section IV. Finally conclusion is given in section V.

II. Fundamentals of DWT,DCT,SVD and GA

A. Discrete wavelet based image multi resolution decomposing

Wavelet transform is one of the most powerful multiresolution signals analyzing method which has been applied to variety of image processing. The transform is based on small waves, called wavelets which have varying frequency and limited duration. DWT decomposes the signal into different frequency bands. It has excellent space frequency localization property and it can best model human visual system. Since images are two dimensional discrete signals, discrete wavelet transforms (DWT) splits it into four non overlapping images in different space and frequency sub-bands, also known as approximation (LL), horizontal detail (HL), vertical detail (LH) and diagonal detail (HH) sub-bands [9]. A 2-D DWT can be seen as a 1-D wavelet scheme which transforms along the rows and then a 1-D wavelet transform along the columns. Any one sub-band of a given decomposition level can be processed further to get next level coefficients and the decomposition process continues until some desire scale is attained [10]. In Fig.1, block diagram of two level DWT is given.

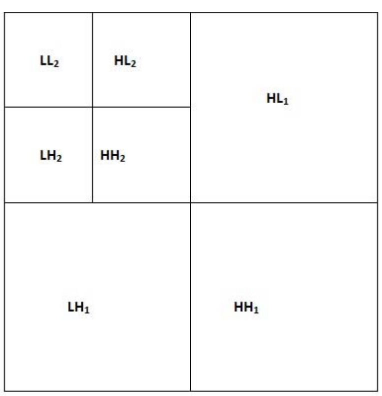

Fig.1. Two levels DWT

B. Discrete cosine transform

Discrete cosine transform (DCT) is popular transform technique which transforms a signal from spatial domain to frequency domain and it has excellent energy compaction property. Let 2D image defined as F= { g (x,y), x, y=0,1,…, M-1}, the formulae for forward DCT and inverse DCT transform is given in Equation 1 and Equation 2 respectively. Discrete Cosine Transformed image has DC and AC components as shown Fig.2. Most times medium frequency (MF) and higher frequency (HF) coefficients are selected for watermark bit insertion [11].

$$G(u,v)=\sigma(u)\,\sigma(v)\sum_{x=0}^{M-1}\sum_{y=0}^{M-1} g(x,y)\cos\left[\frac{(2x+1)u\pi}{2M}\right]\cos\left[\frac{(2y+1)v\pi}{2M}\right] \quad (1)$$

$$g(x,y)=\sigma(u)\,\sigma(v)\sum_{u=0}^{M-1}\sum_{v=0}^{M-1} G(u,v)\cos\left[\frac{(2x+1)u\pi}{2M}\right]\cos\left[\frac{(2y+1)v\pi}{2M}\right] \quad (2)$$

Where,

$$\sigma(u)=\begin{cases}\frac{1}{\sqrt{2}} & \text{for } u=0\\ 1 & \text{for } u=1,2,\ldots,M-1\end{cases} \qquad \sigma(v)=\begin{cases}\frac{1}{\sqrt{2}} & \text{for } v=0\\ 1 & \text{for } v=1,2\ldots M-1\end{cases}$$

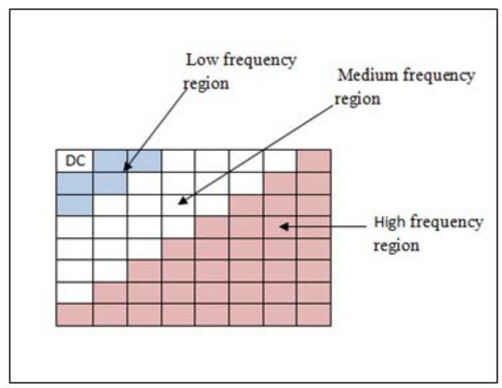

Fig.2. Frequency regions of DCT coefficients

C. Singular Value Decomposition

In linear algebra, the singular value decomposition (SVD) is technique which uses to factorize real or complex rectangular matrix in to three unique matrices. Since digital images can be viewed as a matrix of non-negative scalar entries, linear algebra operation like singular value decomposition can be performed on it. Let M is image matrix of size kxp, SVD operation factorize it into three unique matrices U, S and V such that M can be given as,

$$M=USV^T \quad (3)$$

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Where, U and V are orthogonal matrices of size kxk and pxp respectively. The column of U and V are called left and right singular values of M which specify the geometry detail of the image. S is a kxp non-negative singular value of M arranged in decreasing order diagonally such that $S_n > S_{n+1}$. Singular values do have good stability and its values are rotationally invariant. These properties make SVD operation to have great application on digital image watermarking. Moreover, small changes in singular values do not cause significant degradation of image quality [8] [12].

D. Genetic algorithm

Genetic algorithm (GA) is a heuristic searching algorithm based on natural selection techniques which is used to search best solution to optimization problem. Watermarking process can be viewed as an optimization problem and GA is used to optimize the performance of watermarking scheme. Genetic algorithm process begins with randomly generated initial solution called population and an individual in the population is known as a chromosome. Each chromosome consists of finite length binary strings. The quality of each chromosome in the population is measured using fitness function [13]. The two characteristic parameters PSNR and NCC are used to formulate fitness function which is given in Equation 4. PSNR value indicates distortion level of original image due to watermark insertion and NCC specifies the degree of similarity between the original watermark and extracted watermark [14]. Overall genetic algorithm operation flow chart is shown in Fig.3.

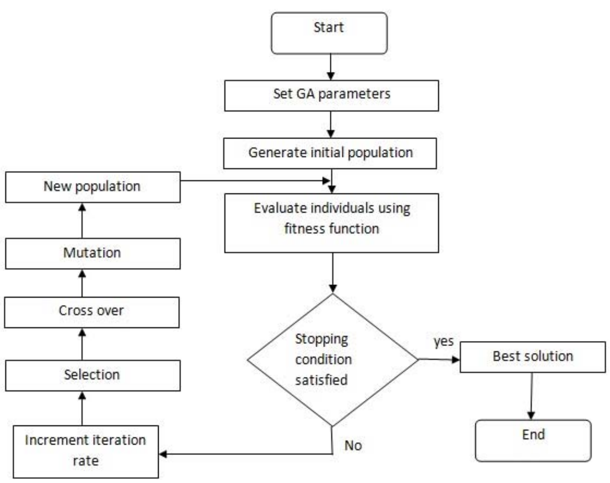

Fig.3. Genetic algorithm flow chart

$$fit\_fun = PSNR + \beta NCC \quad (4)$$

Where, formulae for PSNR and NCC are given in Equation 5 and Equation 6 respectively.

$$PSNR = \left[\frac{255^2}{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(Gw(i,j)-(G(i,j))^2}\right] \quad (5)$$

$$NCC = \left[\frac{\sum_i^k \sum_j^L W(i,j)WE(i,j)}{\sqrt{\sum_{i=1}^{k}\sum_{j=1}^{L}W(i,j)^2 \sum_{i=1}^{k}\sum_{j=1}^{L}WE(i,j)^2}}\right] \quad (6)$$

Those individuals which have the best fitness value are selected to produce a next generation. Selection, crossover and mutation operation are used to produce next generation and the operations continue looping by varying GA parameters, Viz. population size, selection rate, mutation rate and iteration rate until the best solution for the optimization problems is obtained. In this paper, GA optimizes robustness and imperceptibility by searching best scaling factor (α).

III. Proposed algorithm

The proposed algorithm comprises of two main components; watermark insertion and watermark detection. Detail of each part is given in the subsequent sections.

a. Watermark insertion

The steps involved in the watermark embedding are given as follows:

Input: original host image (G) and binary watermark image (W)

Output: Watermarked image (G_W)

1. Read an original gray image(W) of size MxN and binary watermark image (W) of size KxP
2. Decompose G into four sub bands using DWT
[LL, LH, HL, HH]=DWT (G)
3. Take approximation coefficients (LL) of size $\frac{M}{2}$x$\frac{N}{2}$ and Split it into two sub images (G1 and G2) taking alternatively pixel value along rows and columns.
4. Perform DCT and SVD on both G_1 and G_2 using block of size 8x8.
5. Modify G_{1S} based on pixel value of watermark by adding the product of G_{2S} and α. then perform inverse DCT and SVD.

for q=1 to number of blocks, do
G_{1DCT}=DCT (G_1)
G_{2DCT}=DCT (G_2)
[G_{1U}, G_{1S}, G_{1V}]=SVD (G_{1DCT})
[G_{2U}, G_{2S}, G_{2V}]=SVD (G_{2DCT})
For i=1 to k
For j=1 to p
If W (i, j) =1
$G_{1S}(1, 1) = G_{1S}(1, 1) + \alpha\, G_{2S}(1, 1)$
else
$G_{1S}(1, 1) = G_{1S}(1, 1) - \alpha\, G_{2S}(1, 1)$
end if
Inv_G_{1S} = G_{1U} *G_{1S}*G_{1V}^T
Inv_ G_{1DCT} = IDCT (Inv_G_{1S})
G_{1m}= combination of (Inv_ G_{1DCT}) blocks

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end

6. Combine the two sub-images G_{1m} and G2 to obtain modified LL_m sub band.

$$LL_m = G_{1m} + G_2$$

7. Finally, perform inverse DWT to obtain watermarked image G_W.

$$G_W = IDWT\ (LL_M, LH, HL, HH)$$

b. Watermark Detection

Since proposed watermarking algorithm is blind, neither original image nor watermark image is required for watermark extraction purpose. Watermark detection procedure is presented as follows.

Input: Attacked watermarked image (G_W^*)

Output: Extracted watermark image (W_E)

1. Read watermarked image G_W^*
2. Perform DWT decomposition on G_w^* and take approximation coefficient.

$$[LL_E, LH_E, HL_E, HH_E]=DWT\ (G_w^*)$$

3. Split LL_E into two sub images G_{1Ew} and G_{2E}
4. Perform block based DCT and SVD on both sub images

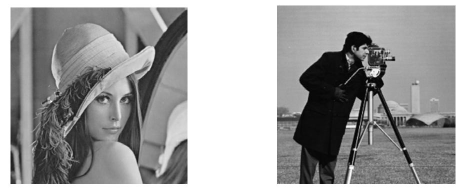
for y=1 to number of blocks, do
$G_{1EW\text{-}DCT}$=DCT (G_{1EW})
$G_{2E\text{-}DCT}$=DCT (G_{2E})
[G_{1EU}, G_{1ES}, G_{1EV}]=SVD ($G_{1EW\text{-}DCT}$)
[G_{2EU}, G_{2ES}, G_{2EV}]=SVD ($G_{2E\text{-}DCT}$)
For i=1 to k
For j=1 to p
If
$G_{1ES}(1, 1) >= G_{2ES}(1, 1)$
$W_E(i, j) = 1$
Else
$W_E(i, j) = 0$
end

IV. Experimental results

The proposed algorithm is programmed in Matlab (Matlab R2014a). Watermark images of size 64x64 and test images of Lena and cameraman of size 512x512 are used to test the algorithm. In Fig.4 the two test images and watermark image are shown.

Fig.4. (a) Host images (b) Watermark image

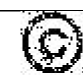
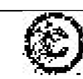
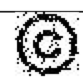
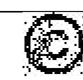
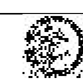
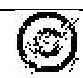
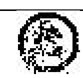
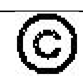
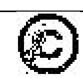
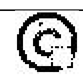
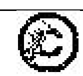
DCT and SVD operation is performed on LL sub-band using block size of 8x8. Genetic algorithm parameters: Mutation rate of 0.01, iteration rate of 20, 50 and 100 are used in this paper. Experimental result which is obtained proves that proposed algorithm insert and detect watermark efficiently. In Fig.5, watermarked images are shown with their respective PSNR value. The robustness of proposed algorithm is evaluated by performing different image processing attacks: Gaussian noise addition (GN), salt& pepper noise (GP), Histogram Equalization (HE), Gamma Correction (GC), Cropping (CR), Rotation (RT), Bit plane Removal (BP), Image Sharpening (IS),Camera Motion (CM), Gaussian filtering (GF), Median filtering (MF), Average filtering (AF) and JPEG compression (JC). In Table1 recovered watermark images and their respective NCC values are given. In addition scaling factors α obtained are included in Table1. In Fig.6 a plot of best NCC versus different attacks are given.



PSNR=44.5866 PSNR= 44.5218

Fig.5. Watermarked images

Table1. Extracted watermark images and respective NCC value.

Types of attack	Results for Lena Image			Results for Cameraman Image		
	extracted Image	NCC	α	extracted Image	NCC	α
Gaussian noise intensity 0.001		0.9454	0.0214		0.9159	0.0265
Salt& pepper noise of D= 0.002		0.9290	0.1328		0.9188	0.0152
Median filtering (3x3)		0.8284	0.0193		0.8393	0.0144
Histogram equalization		0.9378	0.0144		0.9023	0.0193
Gamma correction (gamma=0.9)		0.9919	0.0066		0.9565	0.0080
Cropping		0.9814	0.005		0.9506	0.0052

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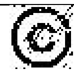
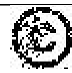
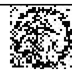
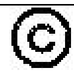
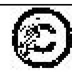
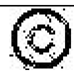
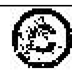
Rotation 15^0		0.5192	0.0015		0.4150	0.0214
JPEG compression (QF=60%)		0.8578	0.0306		0.8362	0.0306
Average filtering (3x3)		0.7447	0.0177		0.7404	0.0011
Gaussian filter (3x3)		0.9539	0.0199		0.9106	0.0199
Linear motion of camera (9 pixel, zero degree)		0.7756	0.0183		0.7454	0.0183
Bit plane removal (LSB)		0.9918	0.0068		0.9476	0.0072
Image sharpening		0.9536	0.0136		0.9442	0.0191

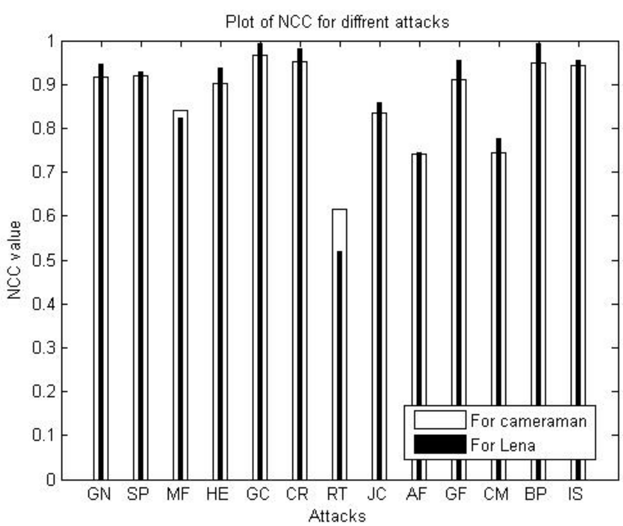


Fig.6. plot of NCC value for different attacks

V. Conclusion

Optimized blind gray image watermarking algorithm based on DWT, DCT and SVD domain is proposed in this paper. Best scaling factor which gives good imperceptibility and robustness is obtained using genetic algorithm. Experimental results which obtained from simulation show that proposed method yields robust watermarked image. PSNR values which are obtained indicate that the visual quality of watermarked is less degraded due to inserted watermark. NCC values between original and extracted watermark are good enough which shows that watermarked image is robust against all attacks performed, except rotational attack for which NCC value is small compared to the rest.

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