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High Performance Digital Image Watermarking Scheme Using DCT-DWT-SVD

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Abstract: **In this paper a high performance hybrid watermarking scheme is proposed using Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), and Singular Value Transform (SVD), which satisfies both imperceptibility and robustness requirements. We have used singular values of Wavelet Transformation's sub bands to embed watermark. This algorithm has been proposed to provide copyright protection of digital images, as there is a growing problem of unauthorized access and reproduction of digital multimedia data. Digital watermarking is a technique in which a piece of digital information is embedded into an image and extracted later. Watermarking can be done either in Frequency Domain or in Spatial Domain. Frequency Domain is better than Spatial Domain because working in this domain produces more robust and imperceptible watermarking. Experimental results shows, that by combining the advantages of these transforms, a very high data hiding capacity can be achieved. The Experimental results (quality of the watermarked image and extracted watermark) are shown in the form of Peak Signal to Noise Ratio (PSNR). It is observed that the quality of the watermarked image is maintained with the value of 36dB. Algorithm is tested for various attacks including rotation through some angles, JPEG compression, Salt & Pepper attacks, Gaussian noise, Speckle Noise, High Pass Filter, Low Pass Filter, Hist Equalize, Best Contrast etc.**

Keywords: **Digital Image Watermarking, Hybrid Transform, Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Singular Value Decomposition (SVD), Peak Signal To Noise Ratio (PSNR), Robustness, Imperceptibility**

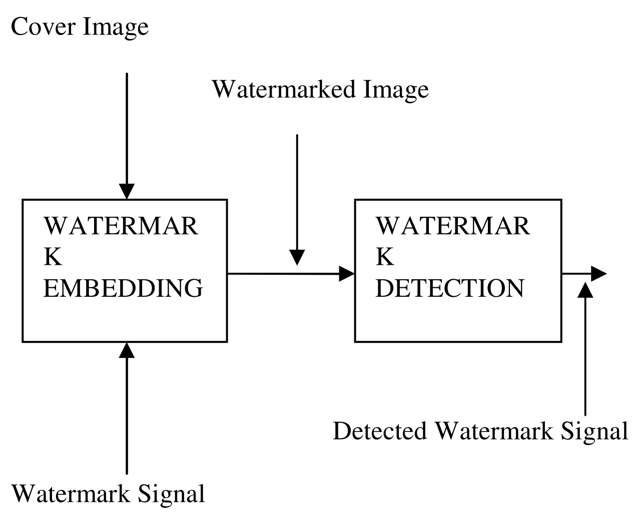
1. INTRODUCTION

In today's world, the availability of The Internet and the amount of applications using digital multimedia technologies opens up a greater possibility of downloading an image from Internet and manipulating it without authorization. A watermarking algorithm is used to accomplish these issues, as it can be used for verification and authorization. Watermarking is the process of embedding data into a multimedia element such as an image, in such a way that it is imperceptible to a human, but can be easily detected by computer. There are various domains in which Digital Image Watermarking can be done, which are categorized as,

1. Spatial Domain based watermarking technique..

2. Frequency domain based watermarking technique.

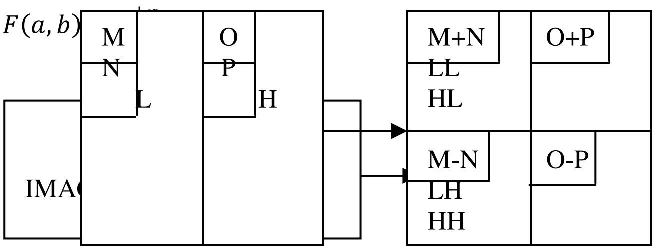
Now, a day's frequency domain watermarking is being used as it produces a robust and imperceptible watermark. While using spatial domain, watermark produced can be easily accessed, modified and destroyed by the attackers. There are various other techniques also like FFT (Fast Fourier Transform), SVD (Singular Value Decomposition), DFT (Discrete Fourier Transform), DCT (Discrete Cosine Transform), but these cannot produce a watermark which can withstand the various types of attacks, along with a less robust, less imperceptible watermark. So, in this algorithm I have a proposed a Hybrid Watermarking Technique (using DCT-DWT-SVD) to overcome all the above stated limitations. There is always a conflict between the robustness and transparency in any of the watermarking algorithm. As, if the watermark is embedded in perceptually most insignificant components, the scheme would be robust to attacks but the watermark may be difficult to hide but if the watermark is embedded in the perceptually insignificant components, it would be easier to hide the watermark but the scheme would be less resilient to attacks.



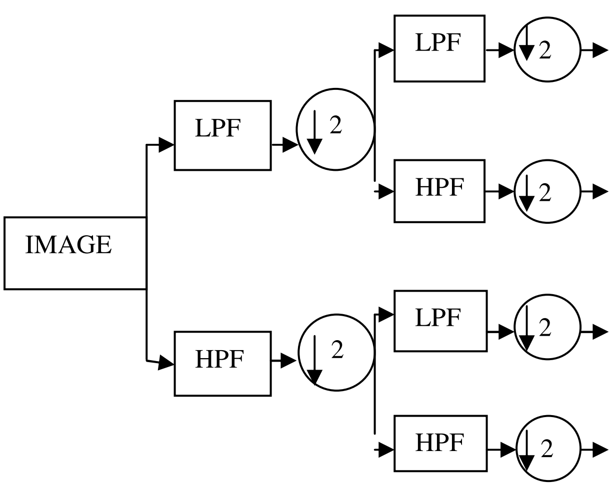
2. DISCRETE WAVELET TRANSFORM (DWT)

Wavelet refers to small waves. DWT is a wavelet transform for which the wavelets are sampled discretely. It can capture both frequency and time. DWT is similar to the Windowed Fourier Transform. The main difference is Fourier Transform decomposes the signal into sines and cosines i.e., the functions localized in Fourier Space while the Wavelet Transform uses functions that are localized in both Real and Fourier Space. That's the property which makes it superior than Fourier transform. It can analyze the signal at different frequency bands with different resolutions by decomposing it in a multiple of 2^n, in such a way that one dimensional signal is divided in two parts one is high frequency part and another is low frequency part. Then, the low frequency part is split in two parts and the process will continue until desired level is reached. Generally, the wavelet transform can be expressed by the following equation,

$F(a, b)$



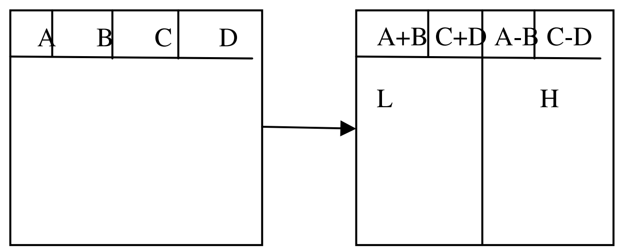
Original image has been decomposed into three high frequency parts (HL, LH and HH, named detail sub-images) and one low frequency part (LL, named approximate sub-image). Fringe information has been contained in the detail sub-images and the convergence strength of the original image has been contained in the approximate sub-image. To achieve better robustness watermark is embedded in approximate sub-image because majority of image energy concentrates here and hence, this part is more stable also.



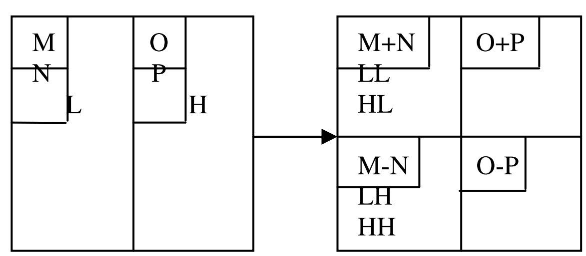
2.1 Haar Wavelet Transform

The first DWT was invented by the Hungarian mathematician Alfred Haar. For an input represented by 2^n numbers, the Haar wavelet transform may be considered to simply pair up input values, storing the difference and passing the sum. This process is repeated recursively, pairing up the sums to provide the next scale: finally resulting in 2^n-1 differences and one final sum. A 2-Dimensional Haar-DWT consists of two operations: One is horizontal operation and the other is the vertical one.

Step 1: At first scan the pixels from left to right in horizontal direction. Then, perform the addition and subtraction operations on neighboring pixels. Store the sum on the left and the difference on the right as illustrated in Figure. Repeat this operation until all the rows are processed. The pixel sums represent the low frequency part (denoted as symbol L) while the pixel differences represent the high frequency part of the original image (denoted as symbol H).



Step 2: Secondly, scan the pixels from top to bottom in vertical direction. Perform the addition and subtraction operations on neighboring pixels and then store the sum on the top and the difference on the bottom as illustrated in Figure. Repeat this operation until all the columns are processed. Finally we will obtain 4 sub-bands denoted as LL, HL, LH, and HH respectively. The LL sub-band is the low frequency portion and hence looks very similar to the original image.



3. DISCRETE COSINE TRANSFORM (DCT)

Discrete Cosine Transform (DCT) is a technique which transforms signal from spatial domain to frequency domain. DCT expresses a sequence of finitely many data points in terms of a sum of cosine functions oscillating at different frequencies. The frequency components are represented by set coefficients. Applying DCT to any image breaks it to three frequency sub-bands: low-frequency, mid-frequency and high-frequency. The mid-frequencies are chosen because they avoid the low-frequency band where the most important visual data are present as well as the high frequency band which can be easily removed by compression or noise attacks.

The most common variant of discrete cosine transform is the type-II DCT, which is often called simply "the DCT"; its inverse, the type-III DCT, is correspondingly often called simply "the inverse DCT" or "the IDCT".

The DCT and Inverse-DCT equations for any image of size M x N is given by

$$C(u,v) = \propto(u) \propto(v) \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y)\, X \cos\left[\frac{\prod(2x+1)\,u}{2M}\right] \cos\left[\frac{\prod(2y+1)\,v}{2N}\right]$$

And, inverse transform is defined as,

$$f(x,y) = \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} \propto(u) \propto v C u,v X \cos 2x+1u 2M \cos 2y+1v 2N$$

Where,

$$\propto(u) = \begin{cases} \frac{1}{\sqrt{M}}, u = 0 \\ \sqrt{\frac{2}{M}}, u = 1,2 \ldots. M-1 \end{cases}$$

$$\propto(v) = \begin{cases} \frac{1}{\sqrt{N}}, v = 0 \\ \sqrt{\frac{2}{N}}, v = 1,2 \ldots. N-1 \end{cases}$$

4. SINGULAR VALUE DECOMPOSITION (SVD)

Any image can be considered as a square matrix without loss of generality. The Singular Value Decomposition (SVD) is a linear algebra transform technique in which factorization of real or complex matrix. It comprises of three vectors of which one vector consists of diagonal matrix and two vectors consist of orthogonal matrices. The responsibility of diagonal matrix is for the image luminance while that of orthogonal matrices is tor the geometry of the image.

$$M = U \sum V *$$

The SVD of a matrix M is typically computed by a two step procedure. In the first step. The matrix is reduced to a bidiagonal matrix. This takes O (mn^2) floating-point operations (flops), assuming that $m \geq n$ (this formulation uses the big O notation). The second step is to compute the SVD of the bidiagonal matrix. This step can only be done with an iterative method (as with Eigen value algorithms).

5. ALGORITHMS FOR PROPOSED METHOD

5.1 Watermark Embedding

1. Apply one-level Haar DWT to decompose the host image A into four sub-bands i.e., A_{LL}, A_{HL}, A_{LH} and A_{HH}.
2. Consider A_{HL} and perform 2D DCT and using zigzag sequence, map the DCT coefficients of A_{HL} into four quadrants viz. B1, B2, B3 and B4.
3. Apply SVD to all four quadrants, $B_k = U^k S^k V^{kT}$, where k=1,2,3 and 4.
4. Apply the SVD on the watermark image and calculate the principle component of the watermark.
5. $W = U_W S_W V_W^T$, $P = U_W * S_W$
6. Divide the principle component P into four quadrants viz. P1, P2, P3 and P4.
7. Modify the singular values oif the DCT coefficients of the cover image with the principal component of watermark image i.e.,
8. $S^{Wk} = S^k + \Phi. P_k$, k=1, 2, 3 and 4.
9. Perform, $B_W^k = U^k S^{wk} V^{kT}$, where k=1, 2, 3 and 4.
10. Map the coefficients of B_W^k back to their original positions and apply DCT to produce the modified HL band, A_{HL}^W.
11. Perform the inverse DWT by using modified and non-modified coefficients to get the watermarked image, A_W.

5.2 Watermark Extraction

Apply one-level Haar DWT to decompose the watermarked (possibly attacked) image A_W into four sub-bands: A_{LL}*, A_{HL}*, A_{LH}* and A_{HH}*.

Apply DCT on A_{HL}* and using zigzag scan arrange the DCT coefficients of A_{HL}* into four quadrants B_1*, B_2*, B_3* and B_4*.

Subtract each quadrant with the original transformed quadrants: $C_k = B_k^* - B_k$, where k=1, 2, 3 and 4.

Compute the distorted principle component parts

$$E_{PC}^{k} = (U^{k} * C_{k} * V^{kT}) / \Phi$$

Construct the distorted principle component from their parts i.e.,

$$E_{pc} = \begin{pmatrix} E_{pc}^{1} & E_{pc}^{2} \\ E_{pc}^{3} & E_{pc}^{4} \end{pmatrix}$$

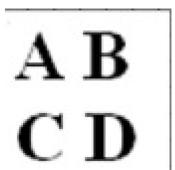
Obtain the extracted watermark.

$$E_{W} = E_{pc} * V_{W}^{T}$$

6. EXPERIMENTAL RESULTS

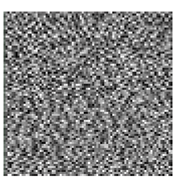
HH sub-band has minimum value for original image while the HH sub-band has maximum difference when compared to other two sub-bands in the "singular values of original and noisy image". Thus, as discussed above HL and LH sub-bands does not affect the image quality, when watermarking is done in these sub-bands.

A

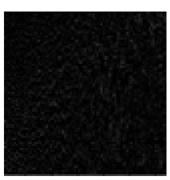


B

C



D

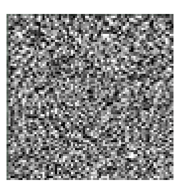


E

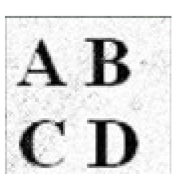
F

G

H



I



J

A–The Cover image
B–The Watermark image
C–LL Band image after performing DWT on Cover image
D-Image after performing DCT on LL Band Cover image
E-Image after performing SVD on LL Band DCT cover image
F-Image after performing watermarking on Cover image with Watermark image
G-Image after performing Gaussian noise attack on watermarked image
H-LL Band image after performing DWT on attacked watermarked image
I-Image after performing DCT on LL Band of attacked watermarked image.
J-Extracted watermark image after extraction on attacked watermarked image.

6.1 Performance Evaluation

For the evaluation of the performance of any watermarking scheme, the common measure of visual quality is PSNR. It is used to measure the difference between two images. It is basically used to calculate the deviation of the watermarked and the attacked frames from the original image frames. It can be defined as

$$PSNR = 10 \log_{10} 255/MSE$$

$$MSE = 1/MN \sum_{i=1}^{M} \sum_{j=1}^{N} [I(i,j) - I'(i,j)]^{2}$$

MSE- Mean Square Error

A higher, PSNR would normally indicate that the reconstruction is of higher quality

Lena

House

Girl

Image	PSNR (in dB)	MSE
Lena	46.0068	1.6308
House	45.7364	1.6416
Girl	45.9573	1.6495
Boat	45.9804	1.6407

TYPE OF ATTACK	NC (Normalized Correlation Coefficient)	CC (Correlation Coefficient)
Histogram Equalize	0.949	0.918
Speckle Noise	0.982	0.989

Gaussian Noise	0.961	0.969
Rotate by +45°	0.992	0.998
Best Contrast	0.94	0.918
Salt n Pepper Noise	0.946	0.894
Poisson Noise	0.944	0.939
Jpeg Compression	0.987	0.993
Low Pass Filter	0.982	0.991
High Pass Filter	0.982	0.991

7. FUTURE DEVELOPMENT

Watermarking technology has powered us to verify and authenticate digital multimedia content in this era of increasing cyber theft. A number of watermarking algorithms are available, which can be used as per our needs. In this paper, DWT-DCT-SVD based technique has been discussed which can be used for Copyright protection, Source Tracking (different recipients get differently watermarked content). Television news often contains watermarked video from international agencies (Broadcast Monitoring) and Covert communications.

8. ACKNOWLEDGEMENT

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9. CONCLUSION

The proposed watermarking algorithm using DWT, DCT and SVD has been suggested. The DWT-DCT-SVD algorithm has a good performance on imperceptibility and robustness as compared to DCT-SVD or DWT-SVD. The algorithm DCT-SVD is very time consuming, yet it offers better capacity and imperceptibility. DWT-SVD algorithm is also similar to DCT-SVD algorithm except that the process is fast. The new hybrid algorithm using DCT-DWT-SVD techniques is chosen as it satisfies all the requisites of digital image watermarking scheme which are robustness, imperceptibility and good capacity. Experimental results show that this method is very robust against different attacks like Gaussian Noise, Filtering and Rotation. Therefore this algorithm is a good method for authentication and verification of image materials.

Correlation values are also computed here for finding the relation between. The maximum correlation exists for an image with no attack whose value is 0.99984 while minimum correlation exists for Gaussian noise attack whose value is 0.20238.

In the above proposed DWT-DCT-SVD algorithm, the value of PSNR of the watermarked images is always greater than 40 dB and it can be used to resist JPEG compression and low-pass filtering attacks.

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