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Imperceptible and Robust Digital Image Watermarking Techniques in Frequency Domain

Aparna S. Kulkarni, Sunita S. Lokhande

Abstract: - The digital watermarking provides the protection against the digital data copying, proceeding distributing among the unauthorized users using easily available software. This paper gives the comparative analysis of digital image watermarking in frequency domain. The parameters used to test the robustness and transparency of the watermarking algorithm are Normalized cross- correlation coefficient (ρ) and Peak Signal to Noise Ratio (PSNR). Also, Robustness of watermarking algorithm is tested for various attacks including salt and pepper noise and Gaussian noise, sharpened and contrast adjustment. The experimental results show that the frequency domain method is more robust against different kinds of attacks and the watermarked image has good transparency.

I. INTRODUCTION

The watermarking is hiding the information in digital media like images, music, and video. The digital watermarking is the process of embedding the given watermark into the protective information and picking the watermark from the protective information. The digital watermarking is technique to protect the digital contents from illegal copying and manipulation. The digital content (watermark) is an unnoticeable signal and added to digital data (protective information). The digital watermarking can be divided into two categories by the embedding position first is spatial domain, which is easier to implement but is limited in robustness, while the transform domain technique embed the watermark into host's transform domain which gives better robustness compare to spatial domain.l In order for digital watermarking to be effective it should be imperceptible and robust to comman image manipulations like compression, filtering, rotation, scaling cropping, collusion attacks. The idea of applying two transform is based on the fact that combined transforms could compensate for the drawbacks of each order, resulting in effective watermarking.This paper introduces the digital watermarking algorithm based on DCT, DWT and combined DCT-DWT transform.

II. METHODOLOGY

The image is considered to be a sampled-digitized data of an analog signal. The analog signal can be obtained by various transforms like the DCT (Discrete Cosine Transform), DFT (Discrete Fourier Transform), FFT (Fast Fourier Transform) etc. and hence represented as a series of signals of increasing frequencies. The watermark can now be embedded in the coefficients of the various frequency components. The watermark is not embedded in the high frequency components, as they are usually lost on compression or scaling. Frequency domain watermarking disperses the watermark over the whole image thus rendering it less visible (or detectable) than spatial domain watermarking. However, it is more difficult to decode a watermark applied in the frequency domain. Another novel method is to embed the watermark in the phase component of the DFT. It has been demonstrated quite conclusively that the phase is more important than the magnitude of the DFT values, so a watermark embedded in the phase will be robust to tampering as any noise deliberately introduced will have to be sufficiently large to destroy the watermark thus damaging the image. It has also been shown that angle modulation possesses superior noise immunity when compared to amplitude modulation. Also, a phase-based watermark is robust to changes in image contrast. Frequency-domain watermarking embeds the watermark into the transformed image. It is complicated but has the merits which the former approach lacks.[6]

A. Discrete Cosine Transform

With an input image,x, the DCT coefficients for the transformed output image, y, are computed according to Equation.1 shown below. In the equation, x, is the input image having N xM size, x (m, n) is the intensity of the pixel in row m and column n of the image, and y (u, v) is the DCT coefficient in row u and column v of the DCT matrix. [3]

$$Y(u,v)=\sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}\,\alpha_u\alpha_v\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}A \qquad (1)$$

$$A=\left\{x(m,n)\cos\frac{(2m+1)u\pi}{2M}\cos\frac{(2N+1)u\pi}{2N}\right\}$$

$$\alpha_u=\begin{cases}\frac{1}{\sqrt{2}} & for\ u=0\\ 1 & for\ u=1,2,\dots\dots,M-1\end{cases} \qquad (2)$$

$$\alpha_v=\begin{cases}\frac{1}{\sqrt{2}} & for\ v=0\\ 1 & for\ v=1,2,\dots\dots,M-1\end{cases} \qquad (3)$$

The image is reconstructed by applying inverse DCT

$$X(m,n)=\sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}\,\alpha_u\alpha_v\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}B \qquad (4)$$

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$$B = \left\{ y(u,v) \cos\frac{(2m+1)u\pi}{2M} \cos\frac{(2N+1)u\pi}{2N} \right\}$$

The DCT is the technique for converting the signal into frequency components. It represents an image as a sum of sinusoids of varying magnitudes and frequency. The image is first divided into square block of size 8*8. Apply DCT to each block and use block selection criteria and coefficient selection criteria. After that embed the digital watermark by modyfing the selected coefficients. The popular block based DCT transform segments an image into non-overlapping blocks and apply DCT to each block. This will gives the three frequency sub-bands: low frequency sub-band, mid-frequency sub-band, and high frequency sub-band. The DCT based digital watermarking is based on two facts. First is that much of signal energy lies at low frequencies sub-band which contain the most important visual part of the image. the second fact is that high frequency components of image are usually removed through compression and noise attacks. Hence the watermark is embed into the middle frequency sub-band so that the visibility of image will not be affected and the watermark will not be removed by compression and noise attacks.[4]

B. Discrete Wavelet Transform

The wavelet transform is identical to a hierarchical sub-band system,where sub-bands are

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

Fig.1 mid Band Coefficients Of 4x4 DCT Blocks

logarithmically spaced in frequency. The basic idea of DWT watermarking is , an image is first decomposed into four parts of frequencies by critically sub-sampling horizontal and verticalchannels using subband filters. The filters divide the input image into four nonoverlapping multiresolution sub-bands LL1,LH1,HL1,and HH1. The sub-band LL1 represents the coarse-scale DWT coefficients and sub-bands LH1, HL1, and HH1 represents the fine-scale of DWT coefficients. The DWT separate the image into a lower resolution approximation image(LL) as well as horizontal (HL), vertical (LH) and diagonal (HH) components. The process can be repeated to compose the multiple scale wavelet decomposition. Due to its excellent spatio-frequency localization properties, the DWT is very suitable to identify the areas where the watermark can be embedded effectively. Generally the watermark is embedded into the middle frequency sub-bands LH and HL where acceptable performance of imperceptibility and robustness could be achieved.[3]

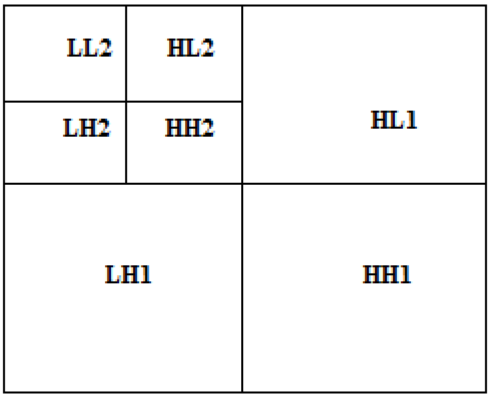

Fig.2 Two-level Decomposition

C. Combined DCT-DWT

In this algorithm, we use DCT and DWT both the transforms for embedding and extraction of watermark. 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.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.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. Two transforms are combined to make up for the disadvantages of each other, so as to increase the effectiveness of watermarking algorithm.[3]

III.PERFORMANCE EVALUATION RESULT

For the testing of the proposed algorithm following measures are used for assessment of quality of image and watermark.

A. Imperceptibility

Imperceptibility means that the perceived quality of the host image should not be distorted by the presence of the watermark. The watermark should be imperceptible to human observation while the host image is embedded

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with secret data. In this paper we employee the PSNR to indicate the transparency degree. The PSNR describe below Where x i,j and $\hat{x}_{i,j}$ i,j are the gray-scale values of host and watermarked images and N x N is the size of image respectively.[5]

$$\text{PSNR} = 10\log_{10}\frac{255^2}{\frac{1}{N\times N}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}(x_{i,j}-\hat{x}_{i,j})^2} \quad (5)$$

PSNR is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range,PSNR is usually expressed in terms of the logarithmic decibel scale.[2]

B. Robustness

Robustness is a measure of the immunity of the watermark against attempts to remove or degrade it, internationally or unintentionally, by different types of digital signal processing attacks. We measured the similarity between the original watermark and the watermark extracted from image using Normalized Cross-Correlation (NC) as given below Where N is the number of pixels in watermark, w and wˆ are the original and extracted watermarks respectively. The correlation factor may take values between 0 (random relationship) to 1 (perfect linear relationship). In general, a correlation coefficient of about 0.75 or above is considered acceptable.[5]

$$\text{Normalized cross correlation} = \frac{\sum_{i=1}^{N} w_i \tilde{w}_i}{\sqrt{\sum_{i=1}^{N} w_i^2}\sqrt{\sum_{i=1}^{N} \tilde{w}_i^2}} \quad (6)$$

The 32x32 is taken as watermark image information in fig. 6.1 and 256x256 is taken as the source image shown in fig.

(a) (b)

Fig. 3 (a) Original image (b) Watermark

TABLE I [1]
RESULTS AFTER ATTACKS PSNR (in db)

Category	DCT	DWT	DCT-DWT
Watermarked Image	34.45	36.38	41.40
Salt Paper	20.02	21.33	22.05
Enhancement	30.41	32.65	37.41
Rotation	14.91	15.57	17.61
Gaussian Noise	16.23	17.11	21.34

TABLE II [2]
RESULTS AFTER ATTACKS NC (in db)

Category	DCT	DWT	DCT-DWT
Watermarked Image	1	1	1
Salt Paper	0.991	0.996	0.998
Enhancement	0.983	1	1
Rotation	0.952	0.963	0.982
Gaussian Noise	0.964	0.972	0.985

The watermarking algorithms are usually evaluated with respect to imperceptibility and robustness. imperceptibility means that the perceived quality of original image should not be degraded by the presence of watermark. Robustness is a measure of the immunity of the watermark against attempts to remove or degrade it,by different types of digital signal processing attacks.The performance result for imperceptibility of combined DCT-DWT watermarking algorithm will be better as compare to individual transform. The improvement in imperceptibility is due to applying DCT on the DWT coefficients. The robustness performance result will also gives better result for Combined DCT-DWT watermarking algorithm.

III. CONCLUSION

This paper shows how the combined transforms improve the performance result of watermarking algorithm against the individual transform. The results will show the comparative study of frequency domain techniques. The DWT/DCT combined technique provides better imperceptibility and higher robustness against attacks the evaluation results show that DWT is somewhat better than DCT but, combination of these two gives much better results than individual one. The capability of watermarking algorithm is robust to salt & pepper, enhancement but somewhat weaker to rotate and Gaussian noise.

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