AN OVERVIEW OF TRANSFORM DOMAIN ROBUST DIGITAL IMAGE WATERMARKING ALGORITHMS

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ABSTRACT

Internet and Multimedia technologies have become our daily needs. Hence it has become a common practice to create copy, transmit and distribute digital data. Obviously, it leads to unauthorized replication problem. Digital image watermarking provides copyright protection to image by hiding appropriate information in original image to declare rightful ownership. Aim of this paper is to provide complete overview of Digital Image watermarking. The study focuses on quality factors essential for good quality watermarking, Performance evaluation metrics (PSNR and Correlation Factors) and possible attacks. Overview of several methods with spatial and Transform Domain watermarking is done with detail mathematical formulae, their implementations, strengths and weaknesses. The generalized algorithms are presented for DWT, CDMA based, DCT-DWT combined approach. The Ridgelet Transform is also introduced. Comparative results of Digital Image Watermarking using LSB, DCT and DWT are also presented. The paper recommends DWT based techniques for achieving Robustness in Digital Image Watermarking.

Keywords: Replication, CDMA, DCT-DWT, Ridgelet Transform.

1. INTRODUCTION

Now-a-days, Internet and Multimedia technologies have become our daily needs. Hence it has become a common practice to create copy, transmit and distribute digital data. Obviously, it leads to unauthorized replication problem. Digital image watermarking provides copyright protection to image by hiding appropriate information in original image to declare rightful ownership [1] . There are four essential factors those are commonly used to determine quality of watermarking scheme. They are robustness, imperceptibility, capacity, and blindness.

- **Robustness:** Watermark should be difficult to remove or destroy. Robust is a measure of immunity of watermark against attempts to image modification and manipulation like compression, filtering, rotation, scaling, collision attacks, resizing, cropping etc.
- **Imperceptibility:** means quality of host image should not be destroyed by presence of watermark.
- **Capacity:** It includes techniques that make it possible to embed majority of information.
- **Blind Watermarking:** Extraction of watermark from watermarked image without original image is preferred because sometimes it's impossible to avail original image.

2. CLASSIFICATION OF WATERMARKING TECHNIQUES

Watermarking algorithms can be classified on several criteria as given below:

- According to domain of watermark insertion:
  i) Spatial Domain Watermarking Techniques
  ii) Transform or Frequency Domain Techniques.

- According to Watermark detection and extraction:
  i) Blind Watermarking
  ii) Non-blind Watermarking.

The non-blind watermarking requires that original image to exist for detection and extraction whereas blind techniques do not require original image.

- According to ability of watermark to resist attack:
  i) Fragile Watermarking
  ii) Semi-fragile Watermarking

- According to Visibility:
  i) Visible Watermarks
  ii) No visible Watermarks

3. PERFORMANCE EVALUATION OF DIGITAL IMAGE WATERMARKING ALGORITHMS.

Performance Evaluation of watermarking algorithm is done by two performance evaluation metrics: Perceptual transparency and Robustness. [3]. Perceptual transparency means perceived quality of image should not be destroyed by presence of watermark. The quality of watermarked image is measured by PSNR (Peak signal to Noise Ratio). Bigger is PSNR, better is quality of

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watermarked image. PSNR for image with size M x N is given by:

$$PSNR(db) = 10\log_{10}\frac{(Max_I)^2}{\frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N}[f(i,j)-f'(i,j)]^2} \quad (1)$$

Where, f (i, j) is pixel gray values of original image. f '(i, j) is pixel gray values of watermarked image. Max_I is the maximum pixel value of image which is equal to 255 for gray scale image where pixels are represented with 8 bits. In general, Watermarked Images with PSNR more than 28 are acceptable. Robustness is measure of immunity of watermark against attempts to remove or destroy it by image modification and manipulation like compression, filtering, rotation, scaling, collision attacks, resizing, cropping etc. It is measured in terms of correlation factor. The correlation factor measures the similarity and difference between original 'watermark and extracted watermark. It' value is generally 0 to 1. Ideally it should be 1 but the value 0.75 is acceptable. Robustness is given by:

$$\rho = \frac{\sum_{i=1}^{N} w_i w_i'}{\sqrt{\sum_{i=1}^{N} w_i}\sqrt{\sum_{i=1}^{N} w_i'}} \quad (2)$$

Where, N is number of pixels in watermark, wi is original watermark, wi' is extracted watermark.

4. DIFFERENT POSSIBLE ATTACKS

PSNR and Normalized Correlation of Watermarked Image should be checked for different attacks: Following are possible attacks: i] Noise Addition ii] Rotation iii] Cropping iv] Scaling v] Resizing vi] Compression

5. OVERVIEW OF DIGITAL IMAGE WATERMARKING TECHNIQUES IN SPATIAL AND TRANSFORM DOMAIN

5.1 Spatial Domain Watermarking

Early watermarking schemes were introduced in the spatial domain, where watermark is added by modifying pixel values of host image. Least Significant Bit insertion is example of spatial domain watermarking. But such algorithms have low information hiding capacity, they can be easily discovered and quality of watermarked image and extracted watermark is not satisfactory as pixel intensities are directly changed in these algorithms. One sample Spatial Domain watermarking algorithm with Least Significant Bit insertion is given below. Any watermarking algorithm has two parts: embedding algorithm and detection (extraction) algorithm.

5.1.1. Watermark Embedding

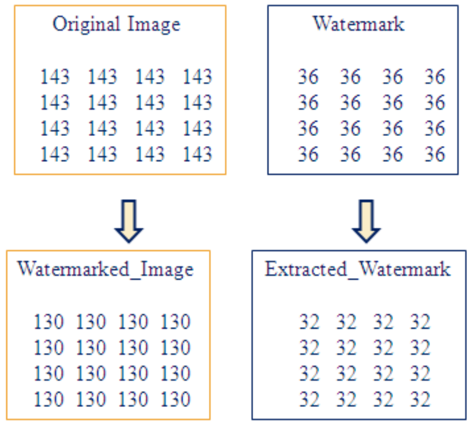

Figure: 1 Pixel of Cover image (Original Image), Watermark, Watermarked Image and Extracted Watermark

Step 1: Read gray scale Cover Image and Watermark.

Step 2:Consider binary of pixel values of Cover Image and make its n Least Significant Bits 0
e.g. For n=4, Binary of 143=>10001111 and Making 4 LSB 0 =>10000000=>128 is decimal equivalent.

Step 3: Consider binary of pixel values of Watermark and right shift by k bits where k=8-n. For n=4, k will be 4. Binary of 36=>100100 and after right shift by 4: 000010=>2 is decimal equivalent

Step 4: Add result of step 1 and step 2 to give watermarked image. E.g. Add 128+2=>130. This gives pixel value of watermarked image=>10000010. Here, pixel values or cover image get changed. Hence Quality of watermarked image is degraded.

5.1.2. Watermark Extraction

Take pixels of watermarked Image and left shift by k bits where k=8-n. e.g. Left shift by 4=>00100000 =>32. This gives pixels of Extracted Watermark. The sample value of Pixel of Cover image, Watermark, Watermarked Image and Extracted Watermark are shown in figure.1.

LSB based watermarking in spatial domain is the straightforward method, but once algorithm is discovered, watermark will be no more secured.[3].An improvement on LSB substitution is to use pseudo random generator to determine pixels to be used for embedding, based on given seed or key. Security can be improved but algorithm is not still such techniques are not completely secured [3].

5.2 Transform (Frequency) Domain Watermarking

The Frequency domain the watermark is inserted into transformed coefficients of image giving more information hiding capacity and more robustness against watermarking attacks [1]. Watermarking in frequency domain is more robust than watermarking in spatial domain because information can be spread out to entire image. For frequency transform, we are having different options like: Fourier Transform (FT), Short Time Fourier Transform (STFT), and Continuous Wavelet Transform (CWT), Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) or Combination of DCT and DWT.

5.2.1 Digital Image Watermark using 'Discrete Wavelet Transform'.

DWT has become researchers focus for watermarking as DWT is very similar to theoretical model of Human Visual System (HVS). ISO has developed and generalized still image compression standard JPEG2000 which substitutes DWT for DCT. DWT offers mutiresolution representation of a image and DWT gives perfect reconstruction of decomposed image. Discrete wavelet can be represented as

$$[\psi]_{(j,k)}(t) = a_0^{(-j/2)}\,\psi\,(a_0^{(-j)}\,t - k\,b_0) \qquad (3)$$

For dyadic wavelets a_0 =2 and $_{b0}$ =1, Hence we have,

$$\psi_{j,k}(t) = 2^{-\frac{j}{2}}\psi\,(2^{-j}t - k) \quad j, k \in Z \qquad (4)$$

Image itself is considered as two dimensional signal. When image is passed through series of low pass and high pass filters, DWT decomposes the image into sub bands of different resolutions [11][12]. Decompositions can be done at different DWT levels. DWT offers mutiresolution representation of a signal. One Level DWT-Decomposition is given in figure 2.

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

Figure 2: One Level Image Decomposition

It has been widely accepted that maximum energy of most of natural images is concentrated in 'approximate (LL) subband' which is low frequency subband. Hence modification to the coefficients of these low frequency subbands would cause severe and unacceptable image degradation. Hence, we do not embed watermark in LL subband. The good areas for watermark embedding are high frequency sub bands (vertical, horizontal and diagonal components). The human naked eyes are not sensitive to these high frequency sub bands. So, effective watermark embedding is achieved without being perceived by human eyes. The generalized DWT based watermarking is shown in figure-3. Actually, 'embedding' will include 'specific algorithmic steps' those are to be implemented in wavelet domain.

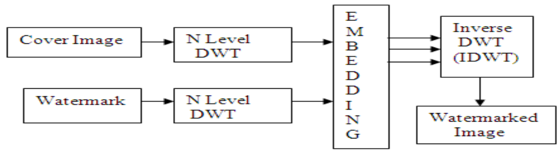

Figure: 3 Generalized DWT based Watermarking Scheme

- Many of the researchers have developed watermarking algorithms using DWT. But most of them are failed to provide perceptual transparency and robustness simultaneously, since these two watermarking requirements are conflicting to each other. Na Li et. all proposed a DWT based method [14] in which watermark was embedded in middle frequency coefficient using :

$$F'(u,v) = F(u,v) + \alpha W(u,v) \qquad (5)$$

where, F(u,v) is wavelet coefficient, W is randomized binary watermarking, α is flexing factor with α =β |m| where m is mean value of all coefficients watermarking embedded. But this method doesn't provide enough security.

- The method proposed in [14] using DWT was extended in [15] to enhance security of algorithm by using Arnold's Transform pretreatment for watermark. The magic property of Arnold Transform is that, when it is applied to image, after specific number of iterations, image comes to it's original state. Arnold Transform is given by:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{bmatrix} 1 & 2 \\ 1 & 2 \end{bmatrix} \begin{pmatrix} x \\ y \end{pmatrix} (mod\ N) \qquad (6)$$

Where, (x,y) ={0,1,.....N} are pixel coordinates from original image. (x', y') are corresponding results after Arnold Transform.

- As given in [16] two phase watermark embedding process was carried out using DWT. Phase1: Visible watermark logo embedding, Phase2: Feature extracted watermark logo embedding. The algorithm was based on Texture Based Watermarking.

- In 2007, A Integer Wavelet Transform with Bit Plane complexity Segmentation is used with more data hiding capacity. [2]. But this method needs separate processing for R, G and B components of color image.

- In 2008, as given in [17] using DWT, host image is decomposed into 3 levels recursively. In level one we get 4 sub bands. In level 2, each subband of level 1 is divided to 4 sub bands to give total 16 sub bands. Finally, each subband of level 2 is again divided into 4 sub bands each to give total 64 sub bands. Then' Generic algorithm' was applied to find the best subband for watermark embedding to provide perceptual transparency and robustness. But the process is too lengthy and time consuming.

5.2.2 Digital Image Watermarking using DCT or combination of DWT and DCT

The discrete cosine transform (DCT) represents an image as a sum of sinusoids of varying magnitudes and frequencies. The DCT has special property that most of the visually significant information of the image is concentrated in just a few coefficients of the DCT. It's referred as 'Energy compaction Property'. The DCT for image A with M x N size is given by:

$$DCT_{pq} = \alpha_p \alpha_q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} A_{mn} \cos\left(\frac{\pi(2m+1)p}{2M}\right) \tag{7}$$

Where,

$0 \leq p \leq M-1$ and $0 \leq q \leq N-1$

$$\alpha_p = \begin{cases} 1/\sqrt{M}, & p = 0 \\ \sqrt{\frac{2}{M}}, & 1 \leq p \leq M \quad 1 \end{cases}$$

and

$$\alpha_q = \begin{cases} 1/\sqrt{N}, & q = 0 \\ \sqrt{\frac{2}{N}}, & 1 \leq q \leq N-1 \end{cases}$$

As DCT is having good energy compaction property, many DCT based Digital image watermarking algorithms are developed. Common problem with DCT watermarking is block based scaling of watermark image changes scaling factors block by block and results in visual discontinuity.[1][6]. Digital Image Watermarking with DWT-DCT combined approach can significantly improve PSNR with compared to only DCT based watermarking methods. DWT-DCT based Image watermarking improves PSNR compared to only DCT based watermarking. The generalized DWT-DCT based scheme is depicted in figure 4.

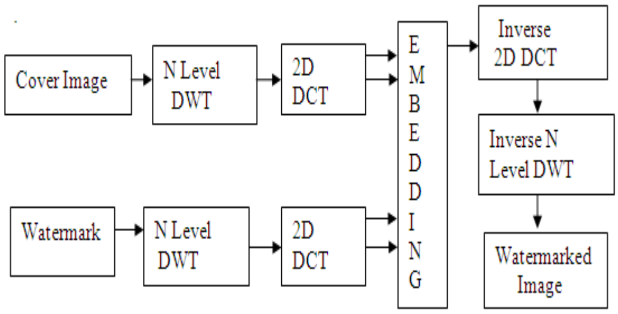

Figure: 4 Generalized DWT –DCT based Watermarking

5.2.3 CDMA based Spread Spectrum Digital Image Watermarking

In spread Spectrum communication, a narrow band signal is transmitted over much larger bandwidth such that signal energy present in any frequency is undetectable. The image in frequency domain is viewed as communication channel, and the watermark is considered as a signal that is transmitted through it. Attacks and unintentional signal distortions are thus treated as noise. Spreading the watermark through spread spectrum of image ensures large measure of security. Many existing CDMA based Spread Spectrum Digital Image Watermarking are developed in spatial domain and frequency domain with DCT and DWT .But common problem with CDMA based Spread Spectrum methods is that they support low information hiding capacity.

- As given in [13], J. Cox et. al had presented 'Spread spectrum based watermarking schemes', Chris Shoemaker has developed CDMA based Spread spectrum watermarking with one scale DWT and got PSNR between 35-40 db for various attacks.
    - As given in [10], Harsh Varma et. al tested CDMA based watermarking scheme with spatial domain and frequency domain with DCT as well as DWT. But these algorithms have low information hiding capacity.

5.2.4 Digital Image Watermarking using 'Ridgelet Transform'.

Ridgelets are next generation wavelets and they are best options for line singularities. Ridgelets have high coding performance for 1D wavelet transform. Actually Ridgelet transform is based on radon transform and 1D wavelet transform. It can rotate the picture by operation in ridge let domain. The Continuous Ridgelet Transform for a given image F(x,y) is given by

$$CRT(a,b,\theta) = \int_{R^2} \psi_{a,b,\theta}(x,y).F(x,y)dx\,dy \tag{8}$$

Where, a is scaling parameter, b is shifting parameter and θ is rotation, R^2 indicates real line. The Ridgelet is defined as follows for 1D.

$$\psi_{a,b,\theta}(x,y)=\frac{1}{\sqrt{a}}\psi\left(\frac{x\cos\theta+y\sin\theta-b}{a}\right) \quad (9)$$

Thus, image can be brought in Ridgelet Domain as shown in figure 5.

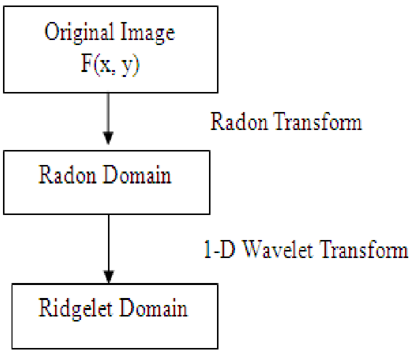

Figure 5: Image in Ridgelet domain

Thus, mathematically, Continuous Ridgelet transform is expressed as combination of one dimensional wavelet and radon transform:

$$CRT(a,b,\theta)=\int_{R}\psi_{a,b}(t).RDN_f(\theta,t)dt \quad (10)$$

And Radon Transform is given by:

$$RDN_f(\theta,t)=\int_{R^2}F(x,y).\delta(x\cos\theta+y\sin\theta-t)dx\,dy \quad (11)$$

Ridgelet Transform is efficiently used for Image Compression. It can be used for achieving Robust Digital Image Watermarking.

6. COMAPARATIVE RESULTS USING LSB, DCT AND DWT

Plotting of PSNR versus Noise Density for LSB. DCT and DWT is shown in figure 6

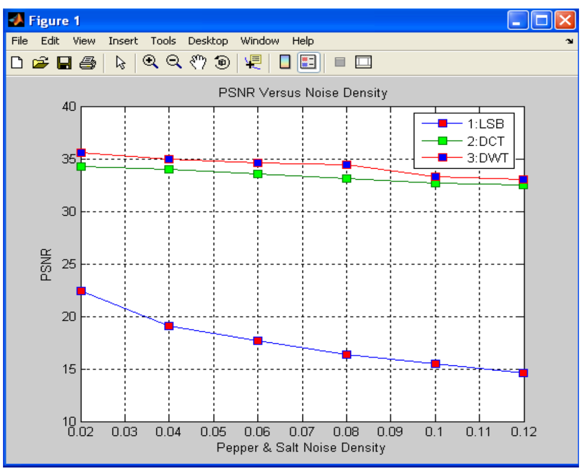

Figure: 6 Comparative plotting of PSNR Versus Noise Density for LSB, DCT and DWT based watermarking

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7. CONCLUSION

This paper provides complete overview of Digital Image Watermarking techniques in Spatial as well as transform domain. The Transform domain watermarking techniques are recommended to achieve robustness. As per ISO Norms, JPEG2000 has replaced DCT by DWT. Hence more researchers are focusing on DWT.

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