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Performance analysis of image watermarking using DCT, DWT and SVD

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Abstract
In the past of years of Internet Era, we have several digital image watermarking techniques have been proposed which is based on Transform Domain techniques like Discrete Cosine Transformation (DCT), Discrete Fourier Transformation (DFT), Discrete Wavelet Transformation (DWT) and Singular Value Decomposition (SVD) transformations.
In this paper, we review and analyse digital watermarking techniques which are based on Transform Domain. These approaches includes DCT, DWT and SVD transformation based watermarking techniques. For the analysis of them we take standard collection of images which can serve as cover image and Watermark image for proceeding of watermarking. We Implement Watermarked images respective to the DCT, DWT and SVD techniques which based on transform domain. We extract the watermark from the implemented watermarked image and compare it with original watermark. We also apply standard attacks on the watermarked image to check their robustness against the applied attacks on the watermarked image.
Experimental result shows that the quality of DCT, DWT and SVD based watermarking techniques.

Keywords: digital image watermarking, discrete cosine transformation, discrete wavelet transformation, singular value decomposition

1. Introduction
With the rapid increases in transmission and global information transformation, we have been facing problem of authentication of document. To overcome this problem, numerous watermarking techniques are being used for authorization checking and copyright protection. All these techniques can be broadly classified in two categories - Spatial Domain and Transform Domain [1]. Spatial domain uses bit level manipulation in original image to implement watermarked image whereas transform domain uses frequency domain techniques like DCT, DWT etc to transform original image into frequency domain. It is reported in available literature that Transform Domain Watermarking Techniques are more robust and efficient in compare to spatial Domain techniques.
In all frequency domain watermarking schemes, there is a conflict between robustness and transparency. If the watermark is embedded in perceptually most significant components, the scheme would be robust to attacks but the watermark may be difficult to hide. On the other hand, if the watermark is embedded in perceptually insignificant components, it would be easier to hide the watermark but the scheme may be less resilient to attacks.
Image watermarking has two main properties- imperceptibility and robustness. Imperceptibility describes the visual quality of the watermarked image. Robustness reflects the resilience of the watermark from different types of attacks which means that the watermark could be extracted or recovered even their watermarked image is altered. Hence, many new image watermarking schemes were proposed by researchers to improve the quality of watermarks [2, 5].
This paper is structured as follows. In Section 2, we present the review on Discrete Cosine Transformation (DCT), Discrete Wavelet Transformation (DWT) and Singular Value Decomposition (SVD) Techniques in brief. In Section 3, we describe algorithm for implementation as well as extraction of watermark using one of the Transform Domain Technique. In Section 4, we discuss experimental results and present comparison of the results. Finally, we draw a conclusion presenting the advantages and drawbacks of the work in Section 5.

2. Review of watermarking techniques
a) Discrete cosine transformation
DCT domain watermarking can be classified into Global DCT watermarking and Block based DCT watermarking. One of the first algorithms presented by Cox *et al*. (1997) [1] used global DCT approach to embed a robust watermark in the perceptually significant portion of the Human Visual System (HVS). Embedding in the perceptually significant portion of the image has its own advantages because most compression schemes remove the perceptually insignificant portion of the image. In spatial domain it represents the LSB however in the frequency domain it represents the high frequency components [3].
Discrete Cosine Transform is a technique which converts digital data into cosine frequency component which further used for processing [6, 7]. It converts X Image of $M \times N$ into frequency domain by following equation: [8].

$$x(u,v) = \sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}\, a_u\, a_v \sum_{u=0}^{M-1}\sum_{v=0}^{N-1} X(M,N)\, \cos\frac{(2M+1)u\,\pi}{2M} \cos\frac{(2N+1)v\pi}{2N}$$
.... (1)

Where x(u,v) are the DCT coefficient with row u and column v. The values of a_u and a_v both set to $1/\sqrt{2}$ when u. v=0, otherwise 1. Converted image again reconverted using the inverse of it by the following equation. [9].

$$y(M,N) = \sqrt{\frac{2}{u}}\sqrt{\frac{2}{v}} \sum_{u=0}^{M-1}\sum_{v=0}^{N-1} a_u a_v\, x(u,v)\, \cos\frac{(2M+1)u\,\pi}{2M} \cos\frac{(2N+1)v\pi}{2N}$$
.... (2)

The 2D-DCT can not only concentrate the main information of original image into the smallest low frequency coefficient, but also it can cause the image blocking effect being the smallest, which can realize the good compromise between the information centralizing and the computing complication.
The DCT allows an image to be broken up into different frequency bands, making it much easier to embed watermarking information into the middle frequency bands of an image. In order to invisibly embed the watermark that can survive lossy data compressions, a reasonable tradeoff is to embed the watermark into the middle-frequency range of the image.
The middle frequency bands are chosen such that they have minimized that they avoid the most visual important parts of the image (low frequency) without over-exposing themselves to removal through compression and noise attacks. DCT domain watermarking can survive against the attacks such as noising, compression, sharpening, and filtering.

b). Discrete wavelet transformation
The basic idea of discrete wavelet transform (DWT) in image process is to multi-differentiated decompose the image into sub-image of different spatial domain and independent frequency district. After the original image has been DWT transformed, the image is decomposed into four sub-band images by DWT: three high frequency parts (HL, LH and HH, named detail sub images) and one low frequency part (LL, named approximate sub-image). In Fig. 1, 2 level wavelet transform process of the image is shown, HL, LH, HH are the horizontal high frequency, the vertical high frequency and the diagonal high frequency part respectively and LL is the approximation low frequency part. The energy of the high-frequency part (horizontal, vertical and diagonal part) is less, which represent the information of the original image, such as the texture, edge, etc. The low frequency part concentrates most of the energy of the image and represents an important component and it can be decomposed continuously. The energy of the image is diffused better and the stronger image intensity can be embedded, with the more levels the image is decomposed by wavelet transform. Hence, the wavelet decomposing levels adopted in the algorithms can be chosen as far as possible.

LL	HL
LH	HH

Fig 1: Wavelet decomposition

In this technique, we use wavelets which are special functions based on basal functions to represent digital signals. They apply on two dimensional images for processing of images by 2D filters of each dimension [10,11]. These filters can be divide into four sub bands CA, CH, CV, CD where CA represents approximation coefficient, CH represents Horizontal, CV Vertical and CD represents Diagonal coefficients of the DWT.

c. Singular value decomposition technique
SVD is one of the effective numerical analysis tools used to analyze matrices [12, 14]. In SVD transformation, a matrix can be decomposed into three matrices that are the same size as the original matrix. SVD is one of a number of effective numerical analysis tools used to analyze matrices. In SVD transformation, a matrix can be decomposed into three matrices that are the same size as the original matrix. Given a real n · n matrix A, this matrix can be transformed into three components, U, D and V, respectively, such that

$$[U\ D\ V] = SVD(A),\ A' = UDV^T \qquad \text{........... (3)}$$

$$= \begin{bmatrix} u_{1,1} & \cdots & u_{1,n} \\ u_{1,2} & \cdots & u_{2,n} \\ \vdots & & \vdots \\ u_{1,n} & \cdots & u_{n,n} \end{bmatrix} \begin{bmatrix} \sigma_{1,1} & \cdots & 0 \\ 0 & \sigma_{2,1} & 0 \\ & \vdots & \\ 0 & \cdots & \sigma_{n,n} \end{bmatrix} \begin{bmatrix} v_{1,1} & \cdots & v_{1,n} \\ v_{1,2} & \cdots & v_{2,n} \\ \vdots & & \vdots \\ v_{1,n} & \cdots & v_{n,n} \end{bmatrix}^T$$

$$= \sum_{i=1}^{n} u_i \sigma_i\, v_i^t$$

where U and V components are n x n real unitary matrices with small singular values, and the D component is an n x n diagonal matrix with larger singular value entries which satisfy $\sigma_{1,1} \geq \sigma_{2,2} \geq \ldots\ldots \geq \sigma_{r,r} > \sigma_{r+1,r+1} = \ldots. = \sigma_{n,n} = 0$. A' is the reconstructed matrix after the inverse SVD transformation. Also, the relationship between A and the three matrices U, D, and V satisfies $A v_i = \sigma_i \mu_i$ and $\mu_i^T A = \sigma_i\, v_i^T$.
In 2002, Sun *et al*. proposed an SVD and quantization- based watermarking scheme. The D component with a diagonal matrix was explored. In the embedding procedure, the largest coefficients in D component were modified and used to embed a watermark. The modification was determined by the quantization mechanism.
After that, the inverse of the SVD transformation was performed to reconstruct the watermarked image. Because the largest coefficients in the D component can resist general image processing, the embedded watermark was not greatly affected. Also, the quality of the watermarked image can be determined by the quantization. Thus, the quality of the watermarked image quality can be maintained.

3. Implementation of Watermarking:
For the comparative analysis of We implement image watermarking using DCT, DWT and SVD based Transform Domain Techniques. For implementation of the watermarking, we use following algorithms.

a. Algorithm for implementation of watermarked image
Step 1: Read the cover and watermark Image.
Step 2: Convert both images into frequency domain (Using

DCT or DWT or SVD as we require analyzing of watermark)
Step 3: Embed the watermark image with the cover image with the specific α Time.
Step 4: Retransform to convert them into original image back (Using IDCT, IDWT or inverse SVD)

b. Algorithm to Extract Watermark from Watermarked Image

Step 1: Read the Watermarked Image and the Cover Image.
Step 2: Convert both images into frequency domain (Using DCT or DWT or SVD)
Step 3: Subtract Cover Image from the Watermarked Image.
Step 4: Multiply Extracted Watermark with specific α Time.
We also apply different attacks on the Watermarked Image to check its robustness. For this purpose we use the common type of attacks like JPEG Compression, Cropping, Rotation, Salt & Pepper, and Resizing then analyze them.

4. Performance Measurements

Imperceptibility is related to the visual quality of the watermarked image caused by embedding the watermark. For quantitative evaluation, PSNR (Peak Signal-to-Noise Ratio) is introduced to evaluate the performance of the image quality. When PSNR is more than 40 dB, human observer cannot virtually distinguish original and reconstructed images.
In this work, we use the Peak Signal to Noise Ratio (PSNR) measure to analyze the imperceptibility of DCT, DWT and SVD based image watermarking schemes. A high PSNR values signifies that the watermarked image is closer the original image. Hence, the watermark in less perceptible (i.e. PSNR of 100% indicates completely imperceptible watermark).
Let *A* be the original image, *A'* be the watermarked image, *R* be the maximum fluctuation in the input image data type, and *M* be the number of rows or columns in the input image.
The PSNR between *A* and *A'* is given by following equations.

$$\mathrm{PSNR} = 10 \times \log_{10}\left(R^2 / \left(\sum_{i=1}^{M}\sum_{j=1}^{N}[A(i,j) - A'(i,j)]^2\right)\right)$$

……………… (4)

Where i=1, 2, 3,…………..M; j=1, 2, 3,………..N
$\mathrm{MSE} = (((I_1 - I_2)^2/(m*n))$

Where
I_1: retrieved image
I_2 : original image
m: number of rows
n: number of columns

4.1 Imperceptibility

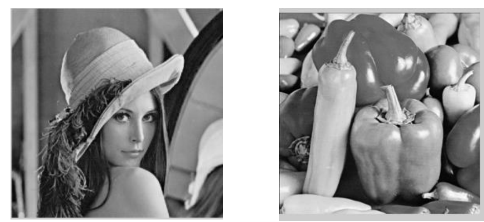
Imperceptibility means that the perceived quality of the host or cover image should not be distorted by the presence of the watermark. We can measure the quality of a watermarked image, the peak signal to noise ratio (PSNR) is typically used in decibels (dB).

4.2 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. In this paper we will report on robustness results which we obtained for digital signal processing attacks such as compression, cropping, rotation, salt & paper and resizing.

5. Experimental Results

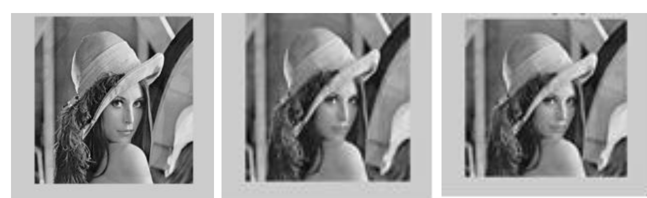
In Fig. 2 shows the 512x512 gray scale cover image Lena, and the 256X256 gray scale watermark image Peppers, the watermarked cover image, and the visual watermarks constructed.



(a) Cover Image (b) Watermark Image

Fig 2: Cover and Watermark Image.

We implemented the watermarking using DCT, DWT and SVD Frequency Domain watermarking. Fig. 3 shows the results of the generated watermarks.



(a) **(b)** **(c)**

Fig 3: Watermarked Images, (a) Water ked images using DCT, (b) watermar ked image using DWT, (c) watermarked image using SVD

We extract the applied watermark from watermarked image and calculate the Peak Signal Noise Ratio between the extracted and the original watermark created by DCT, DWT and SVD technique. Table 1 displays the compared analysis of extracted watermark and the original watermark on the basis of their PSNR with the Matlab parameters.

Table 1: Comparison of original and extracted watermark on the basis of PSNR

α	DCT	DWT	SVD
0.01	34.3244	53.4250	258.5349
0.02	35.3452	54.2432	264.3879
0.03	36.7623	54.3473	266.6490
0.04	37.0125	54.3540	268.4100
0.05	37.2343	54.4044	268.7000
0.06	37.3411	54.4011	268.6460
0.07	37.3418	54.3514	268.2310
0.08	37.3429	54.3001	267.3800
0.09	37.3455	54.0011	266.2360

In watermark extraction, the singular values of the original image are subtracted from the singular values of the watermarked image. The constructed visual watermark looks like a negative film if the difference is negative for the largest singular values, (i.e., darker parts become lighter and lighter parts of the image become darker).

A comparison of Tables 1 and 2 indicates that the SVD based watermarking scheme is superior. In particular, the watermarks constructed after some attacks (e.g., JPEG compression, cropping, rotation, salt & pepper and resizing) have good visual quality compare to DCT and DWT watermarking, making SVD-based approach very reliable. The performance of the watermark among the DCT, DWT and SVD technique were compared after applying the standard attacks, Table 2 shows the respective results.

Table 2: Comparison of Different attacks on DCT, DWT and SVD based Watermarks

Type of Attack	DCT	DWT	SVD
JPEG Compression	35.0571	41.1613	48.1245
Cropping (25%)	12.7936	30.2715	35.2413
Rotation (20°)	7.2761	17.7241	20.3453
Salt & Pepper	25.2432	35.3782	39.5412
Resizing (0.4)	5.6864	14.3231	17.2232

6. Conclusion

The Discrete Wavelet Transforms (DWT), Discrete Cosine Transform (DCT) and Singular Value Decomposition have been applied successfully in many digital image watermarking. A comparison of the DCT, DWT and SVD watermarking scheme based algorithm shows that the SVD scheme performs much better, providing more robustness and reliability. One more advantage of SVD-based watermarking is that there is no need to embed all the singular values of a visual watermark. Depending on the magnitudes of the largest singular values, it would be sufficient to embed only a small set.

In SVD watermarking, we embed singular values. In DCT-DWT domain watermarking, we obtained very similar results. Watermark embedding in the DCT, DWT is resistant to attacks including JPEG compression, cropping, rotation, salt & pepper and resizing. We find that SVD technique is comparatively better than other frequency domain image watermarking techniques.

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