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Comparative Performance Analysis of Multilevel Image Watermarking Using Cryptographic Algorithm

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Abstract— This paper presents the comparative performance analysis of multi-level image watermarking using cryptographic algorithm. The proposed technique has been implemented and compared with other image watermarking technique based on DWT-SVD. In both watermarking techniques, the cover image is decomposed into four sub bands (LL, LH, HL and HH) using DWT and thereafter SVD is applied to LL sub band. Both the watermarking techniques have also been compared. Performance of methodology is evaluated using different fidelity parameters .The experimental results show the effectiveness of hybrid image watermarking scheme.

Keywords— Digital Image Watermarking, DWT, SVD, cryptographic algorithm PSNR, NCC.

I. INTRODUCTION

Watermarking is the process of embedding the watermark into cover image with the help of embedding algorithm for security and other purposes. Later on, this embedded image can be extracted with the help of extraction algorithm.

Generally, the image watermarking can be done in spatial domain or transform domain. Compared to spatial domain techniques, transform-domain watermarking techniques proved to be more effective with respect to achieving the imperceptibility and robustness requirements of digital watermarking algorithms. Commonly used transform domain techniques are Discrete Wavelet Transform (DWT), the Discrete Cosine Transform (DCT) and Discrete Fourier Transform (DFT) etc. However, DWT has been used in digital image watermarking more frequently due to its excellent spatial localization and multi-resolution characteristics, which are similar to the theoretical models of the human visual system. Further performance improvements in DWT-based digital image watermarking algorithms could be obtained by increasing the level of DWT.

II. METHODOLOGY

A. Discrete Wavelet Transform (DWT)

Discrete Wavelet transform (DWT) is a mathematical tool for hierarchically decomposing an image.

It also provides both spatial and frequency description of the image. It splits an image into four different sub bands, i.e., LL, LH, HL and HH. Here, first letter refers to applying either low pass or high pass frequency operations to the rows and the second letter refers to the filter applied to the columns of the cover image. LL1 level is the lowest resolution level while rest of the three levels, i.e., LH1, HL1, HH1 give the detailed information of the image. Figure 1 shows the single level DWT decomposition structure.

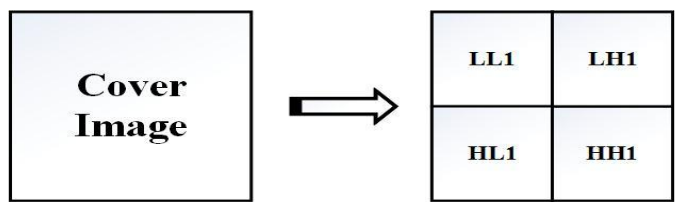


Figure 1. Decomposition Structure “Single level DWT

B. **Singular Value Decomposition (SVD)**

In SVD transformation, a matrix can be decomposed into a multiplication of three matrices that are left singular vectors, set of singular values and right singular vectors.

SVD of an image M with dimensions m x m is given by:

$$M = USV^T \qquad (1)$$

where, U and V are the orthogonal matrices:

$$U = [u_1, u_2, \ldots u_r, u_{r+1}, \ldots u_m]$$
$$V = [v_1, v_2, \ldots v_r, v_{r+1}, \ldots v_m]$$
$$UU^T = VV^T = I$$

The columns of U are known as left singular vector and columns of V are known as right singular vectors of M. U and V basically describe the geometry details of the original image. Horizontal and vertical details of the original image are represented by U and V, respectively. S is known as a diagonal matrix having positive singular values of matrix M.

C. Cryptographic algorithm

Here we used Arnold transform as a cryptographic algorithm for the encryption of an images.

- *Arnold Transform*

The Arnold transform was introduced by Arnold. For an image C with N *N, the Arnold transform operation on the position (x, y) pixel is given by

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} mod\ N \tag{2}$$

The Arnold transform, which changes the positions of the pixels, can be repeated many times in order to obtain a scrambled image.

- *Anti-Arnold Transform*

Use of the Arnold transform periodicity on a scrambled image to recover the original image could be achieved at the expense of possibly a large computational complexity depending on how many iterations have already been used to obtain the scrambled image. The anti-Arnold transform is given by

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} 2 & -1 \\ -1 & 1 \end{pmatrix} \begin{pmatrix} x' \\ y' \end{pmatrix} mod\ N \tag{3}$$

If a scrambled image is obtained by using n iterations of the operation of the Arnold transform, it needs the same number of iterations to recover the original image using the anti-Arnold transform.

III. WATERMARKING TECHNIQUE

The proposed algorithm is divided into two parts, watermark embedding and watermark extraction.

A. Watermark Embedding

The watermark embedding process has been done by following steps:
Step.1: Load the cover image and watermark image.
Step.2: Decomposed both the image into four sub-bands using DWT for cover and encrypted watermark images respectively.
Step.3: after applying DWT, we decomposed both the image using SVD.
Step.4: Compute new singular matrix using fusion of both singular matrix.

$$S_{wm} = S_i + alpha * S_w \tag{3}$$

where, Swm ,Si and Sw and denote the singular values of watermarked, host and water mark image, respectively.
Step.5: Using new computed singular matrix Snew, New LL band is computed with inverse SVD.
Step.6: Finally, watermarked image is obtained by merging LLnew band and remaining sub band of cover image.

B. Watermark Extraction

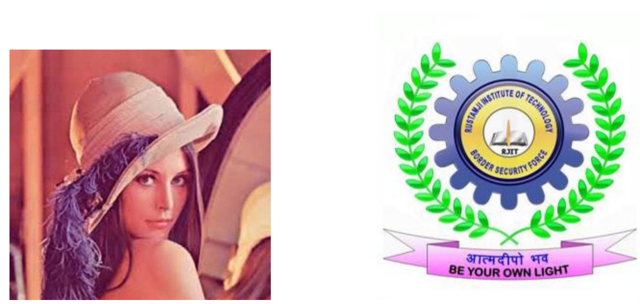
The watermark extraction process has been done by following steps:
Step.1: Load the cover image, watermark image and watermarked image.
Step.2: Decomposed the images into sub-bands using DWT respectively.
Step.3: after applying DWT, we decomposed images using SVD
Step.4: The new extracted singular matrix can be calculated by:

$$S_{w\_n} = (S_{wm} - S_c) / alpha \tag{4}$$

where, Sw_n denotes new singular value.
Step.5: Using new computed singular matrix, New LL band is computed with inverse SVD.
Step.6: finally, extracted watermark image obtained using inverse DWT based on LLnew band and reaming sub band.

IV. SIMULATION

In this Section, performance analysis of multi-level DWT-SVD has been carried out for Lena (512x512) as cover and RJIT Logo as Watermark images as shown in Fig.2. The values of PSNR (Peak Signal to Noise Ratio) and NCC (Normalized Correlation Coefficient) have been calculated to know the imperceptibility and robustness of the watermarking techniques.



(a) Lena (512x512) as Cover (b) RJIT Logo as Watermark

Figure 2. Input Images for Simulation

- **Peak signal-to-noise ratio (PSNR) :-**

For measurement of imperceptibility, PSNR in dB is given by:

$$MSE = \frac{1}{NM} \sum_{i=1}^{N} \sum_{j=1}^{M} \left(f_c(i,j) - f_{wm}(i,j) \right) \tag{5}$$

$$PSNR = 10 \log_{10} \frac{f_c^2(i,j)}{MSE} \tag{6}$$

where, fc2 (i, j) indicates the peak brightness value of pixel and fc, fwm represent the brightness of host and watermarked images at different pixels values.

- **Normalized Correlation Coefficient (NCC):-**

To check the robustness and image quality, the value of normalized co-relation coefficient (NCC) is measured by:

$$NCC = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M} g_w(i,j) * g_w^{'}(i,j)}{\sqrt{\sum_{i=1}^{N}\sum_{j=1}^{M} g_w^2(i,j)}\sqrt{\sum_{i=1}^{N}\sum^{M} g_w^2(i,j)}} \qquad (7)$$

where, gw and gw' are the brightness level of original and extracted watermark at different value of pixel.

A. *Performance Analysis (without Attacks)*

TABLE 3 VALUES OF PSNR AND NCC WITHOUT ANY ATTACK AT DIFFERENT SCALING FACTOR; ALPHA (LENA AS COVER AND RJIT LOGO AS WATERMARK)

Scaling Factor	DWT-SVD(Level-2)		DWT-SVD (level-1)	
α	PSNR	NCC	PSNR	NCC
0.01	41.4743 dB	0.9915	41.4502 dB	0.9980
0.02	35.5767 dB	0.9934	35.4896 dB	0.9992
0.03	32.0813 dB	0.9936	32.0060 dB	0.9991
0.05	27.6693 dB	0.9929	29.7725 dB	0.9980
0.1	21.8137 dB	0.9795	21.7975 dB	0.9880
0.2	16.1726 dB	0.9195	16.2167 dB	0.9443
0.5	9.7303 dB	0.7614	9.9233 dB	0.8383
1.0	6.4743 dB	0.5316	6.8539 dB	0.6872

Figure 3. Watermarked and Recovered Images for 2-Level at α=0.02

Figure 4. Watermarked and Recovered Images for 2-Level at α=1.0

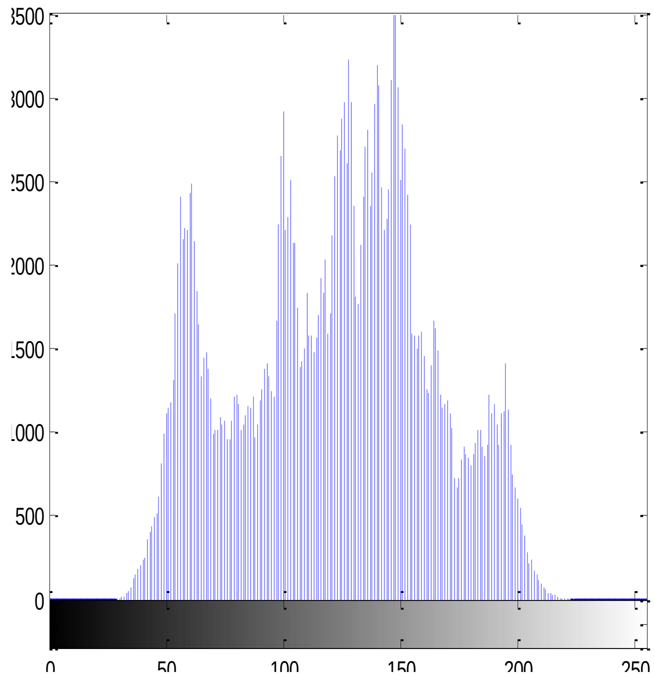


Figure 5. Histogram of watermarkimage

Table I shows the values of PSNR and NCC without applying any attack. The values of scaling factor; α has been varied from 0.01 to 1.0. Figures 3-4 show the watermarked and recovered watermark images at different value of α.Fig 5 show the histogram of watermarked image.

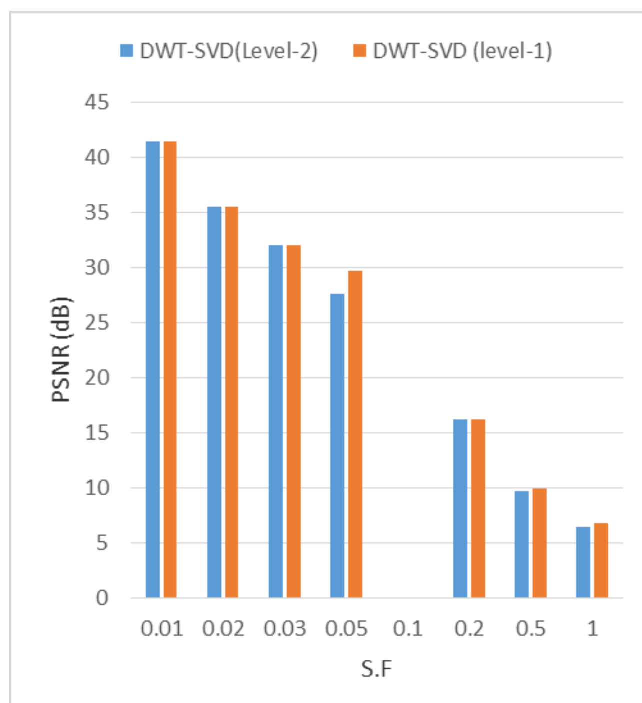


Figure 6. Comparative bar chart

V. COMPARATIVE PERFORMANCE ANALYSIS

Comparative performance analysis of presented work with other existing techniques has also been carried out on the basis of imperceptibility.

TABLE 2 COMPARISON OF IMPERCEPTIBILITY

Host image	Watermark Image	Proposed	Ref [16]
Lena	Dell logo	41.35dB	39.06 dB
Mandrill	Dell logo	41.31dB	39.06 dB

Figure 7. Watermarked and Recovered Images for proposed work at α=0.02

Figure 8. Watermarked and Recovered Images for proposed work at α=0.02

All the simulations have been carried out in MATLAB. The popular test images like: Lena, Mandrill and Dell logo have been used for simulation purpose. From simulated results shown in Tables 2, it has also been observed that proposed work gives better results as compared to DWT-SVD technique in term of imperceptibility. Using cryptographic algorithm propose work is highly secured during recovery of image All the recovered images are identical to the original images

VI. CONCLUSIONS

In this paper, comparative performance analysis of multilevel image watermarking using cryptographic algorithm has been presented. All the simulations have been carried out in MATLAB using test images. The imperceptibility test have been performed to evaluate the performance. Cryptographic algorithm provide the better security during recovery of image.The proposed work gives high stability and perfect reconstruction of images. It has also been observed that proposed work gives better results as compared to DWT-SVD technique. On the basis of simulated results, it can be concluded that watermarking technique is more imperceptible, secure, efficient and capable of recovery of image as compared to other available techniques.

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