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Analysis of LWT-SVD Domain Based Digital Image Watermarking Technique

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Abstract*: In This paper presents blind digital image watermarking technique to achieve copyright protection. In order to protect copyright material from illegal duplication, various technologies have been developed, like key-based cryptographic technique, digital watermarking etc. In digital watermarking, a signature or copyright message is secretly embedded in the image by using an algorithm. In This paper, implement that algorithm of digital watermarking by combining both LWT and SVD techniques. Initially, we decompose the original (cover) image into using LWT, and then apply the SVD on each band by modifying their singular values. After subjecting the watermarked image to various attacks like blurring, adding noise, pixilation, rotation, rescaling, contrast adjustment, gamma correction, histogram equalization, cropping, sharpening, lossless compression etc, we extract the originally inserted watermark image from all the bands and compare them on the basis of their MSE and PSNR values. In experimental results if we perform modification in all frequencies, then it will make our watermarked image more resistant to a wide range of image-processing attacks (including common geometric attacks).

Keywords*: *Blind watermarking, steganography, digital watermarks, authentication, copyright material, cryptographic techniques, lifting wavelet transform (LWT), digital cosine transform (DCT), singular value decomposition (SVD), MSE, PSNR, compression.

I. INTRODUCTION

The Internet is an excellent distribution system for digital media as it is inexpensive, eliminates warehousing and stock, delivery is almost instantaneous, and has become more user friendly and it quickly become clear that people want to download videos, pictures, and music. However, content owners also see a high risk of piracy. The sudden increase in watermarking interest occurs due to the increase in concern over copyright protection of data on Internet. Steganography and watermarking are the two methods which can be used to embed information transparently into these contents. Watermarking is distinguished from other techniques in 3 important ways. First, watermarks are imperceptible. Unlike bar codes, they cannot detract from the aesthetics of an image. Second, watermarks are inseparable from the main content in which they are embedded. Finally, watermarks undergo the same transformations as the main content. The Performance of the watermarks can be evaluated on the basis of small set of properties like robustness, fidelity, and imperceptibility etc.

Watermarking schemes can be divided into two main categories according to the embedding domain: First is spatial and second is transform domain. In spatial domain, the watermark in embedded into specific pixels of the host image. In transform domain, the host image is first transformed to a frequency domain and then watermark is inserted into the frequency coefficients. Since high frequencies will be lost by compression or scaling, the watermark signal is applied to the lower frequencies, or better yet, applied adaptively to frequencies that contain important information of the original picture. The major advantage of transform domain method is their superior robustness to common image distortions. But the transform domain watermarking techniques has more computational cost than spatial-domain techniques LWT are the transform methods used in transform domain watermarking schemes, also used in JPEG and JPEG2000 respectively [14].

Since high frequency components are affected by most of the signal processing techniques such as lossless compression; so in order to increase the robustness, the watermark is preferred to be placed in the low frequency components. But, at the same time, human visual system is very sensitive to changes in low frequency range. So, in LWT-based watermarking techniques, the LWT coefficients are modified to watermark data. Because of the conflict between robustness and transparency, the modification is usually made in LH, HL and HH sub-bands to maintain better image quality as HH band contains finer details and contribute insignificantly towards signal energy. Hence, watermarking embedding in this region will not affect the perpetual fidelity of the cover image.

In this paper, we have introduced LWT-SVD technique to embed watermark image into the main or cover image, which proves robust to various kind of attacks which are mentioned l

II. BACKGROUND REVIEW AND APPROACH FOLLOWED

A. LWT

The wavelet domain has become an attractive domain for the watermarking of digital images due to its well matching behavior with human visual system (HVS) [16]. It is used in variety of signal processing applications, such as video compression, Internet communications compression, object recognition and numerical analysis. The main feature of LWT is multi-scale representation of function and it is also better than LWT.

The LWT processes the image by dividing it into four non overlapping multi-resolution sub-bands LL, LH, HL and HH .The sub-band LL represents the coarse-scale LWT coefficients (the approximation) while other sub-bands represent the fine-scale of LWT coefficients.

Figure 1illustrates this concept.

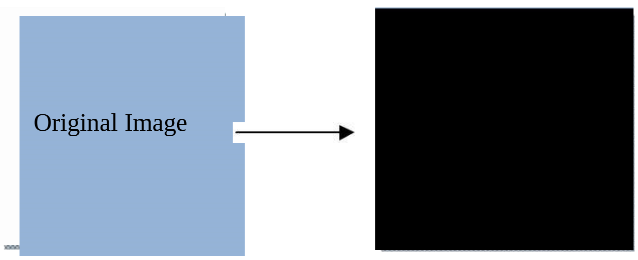


Figure 1. Two level LWT Decomposition

B. SVD-based Watermarking

The singular value decomposition (SVD) of m×n real valued matrix A with m n, performs orthogonal row and column operations on A in such a way that the resulting matrix is diagonal and diagonal values (singular values) are arranged in decreasing value and coincide with the square root of the Eigen values of A^TA [14]. The column of the m×m, U has mutually orthogonal unit vectors, as are the columns of the n×n, V matrix. U and V are orthogonal matrices i.e.

$$U^TU = V^TV = VV^T = I$$

S is a pseudo-diagonal matrix, having diagonal elements as singular values. We can get the matrix A again by using following approach:

$$A=USV^T$$

There are few main properties to employ the SVD method in digital watermarking scheme:

- Few singular values can represent large portion of signal's energy. It can be applied to both rectangular and square images.
- The singular values of an image have very good noise immunity, i.e. when a small perturbation is added to an image, large variation to its singular values does not occur. Singular values represent intrinsic algebraic properties.

C. Watermark Embedding

- First of all, we decompose the cover image into 4 sub-bands. In this we use one level transformation for decomposition of cover image A into 4 sub-bands.
- After performing LWT, we perform SVD to each sub-band images i.e.,

  $A^k = U_a^kS_a^kV_a^{kT}$, k=1, 2, 3, 4

  Where k denotes LL, LH, HL and HH sub-bands and $_i^k$, i=1… n denotes the singular values of S_a^k.
- In the same way, we apply SVD to watermark image, i.e.,

  $W = U_WS_WV_W^T$ where $_{Wi}$, i=1… n denotes the singular values of S_W.
- After this, we modify the singular values of cover image in each sub-band with the singular values of watermark image, i.e.,

  $_i^{*k} = {}_i^k + {}_k\, {}_{Wi}$ where i=1, …, n and k=1, 2, 3, 4.
- So, we obtain 4 sets of modified LWT coefficients, i.e.

  $A^{*k} = U_a^kS_a^{*k}V_a^{kT}$ where k=1, 2, 3, 4
- Obtain the watermarked image A_W by performing the ILWT using these 4 modified sub-bands.

D. Watermark Extraction

- First of all, we use one-level Haar LWT to decompose watermarked (possibly distorted due to various kinds of attacks) image A^{*k} into 4 sub-bands.
- Then, we apply SVD to each sub-band, i.e.

  $A^{*k} = U_a^kS_a^{*k}V_a^{kT}$, k=1, 2, 3, 4 where k denotes the attacked sub-band.
- Then, we extract the singular values from each sub-band, i.e.

  $_{wi}^k = ({}_i^{*k} - {}_i^k)/ {}_k$ where i=1, …, n and k=1, 2, 3, 4.
- Construct the four visual watermarks using the singular vectors, i.e.

  $W^k = U_WS_WV_W^T$, k=1, 2, 3, 4

III. PERFORMANCE EVALUATION METRICS

In order to evaluate the performance of the watermarked images, there are some quality measures such as MSE (mean square error), PSNR (peak signal to noise ratio), and NCC (normalized cross correlation).

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \quad (1)$$

Where

$$MSE = \left(\frac{1}{M\times N}\right) \sum_{m=1}^{M}\sum_{n=1}^{N} [I(m,n) - I_W(m,n)]^2 \quad (2)$$

And,

$$NCC = \frac{\sum_i \sum_j w(i,j)\, w'(i,j)}{\sum_i \sum_j |w(i,j)|^2} \quad (3)$$

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The magnitudes of the singular values for each sub-band of the Lena image are shown in the fig. 1. Fig. 2 shows 512×512 gray scale cover image Lena, the 256 × 256 gray scale visual watermark copyright, the watermarked image, and the watermarks constructed from the four sub-bands. The scaling factor i.e. k for LL sub-band is taken to be 0.05 and 0.0005 for other three sub-bands.

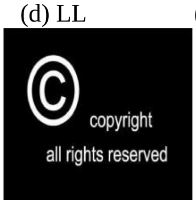
Our implemented scheme is based on the idea of replacing singular values of the HH band with the singular values of watermark. In table I, maximum and minimum singular values of all sub-bands of original image Lena are given. The wavelet coefficients are found to have largest value in LL band and lowest for HH band. Fig.3 shows the plot for singular values of LL, HL, LH and HH sub-bands of original Lena image.

(a) Original Cover Image

(b) Watermarked Image

(c) Watermark Image

(d) LL (e) LH (f) HL



(g) HH

Figure 2. (a) Cover Image. (b) Watermarked Image (c) Watermark Image (d)-(g) Extracted Watermark Images from 4
Sub-Bands

TABLE I. SINGULAR VALUES OF ALL SUB-BANDS FOR ORIGINAL IMAGE
LENA

Singular values of all sub-bands of image Lena	Max. & Min. values of sub-bands for original image Lena		
	Sub-band	***Maximum Value***	***Minimum Value***
1.	LL	64736	0
2.	HL	589.414	0
3.	LH	314.041	0
4.	HH	183.803	0

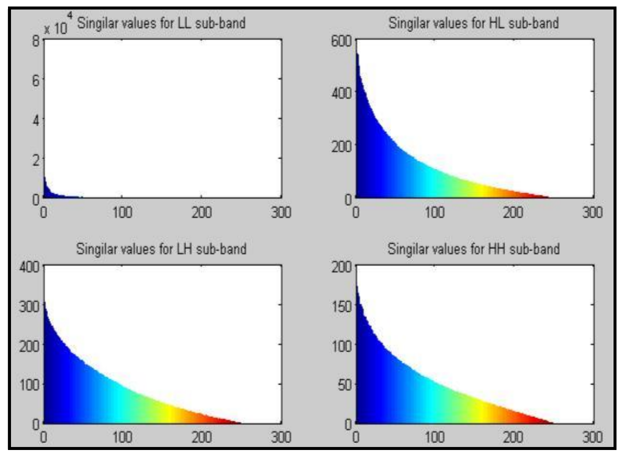


Figure 3. Singular values of all sub-bands for original image Lena.

Table II Shows the Maximum and Minimum Singular Values of All Sub-Bands of Original Image Copyright.

TABLE II. Singular Values Of All Sub-Bands For Original Watermark Image Copyright

Singular values of all sub-bands of image Copyright	Max. & Min. values of sub-bands for original watermark image Copyright		
	Sub-band	***Maximum Value***	***Minimum Value***
1.	LL	153450	0
2.	HL	2550	0
3.	LH	2330.5	0
4.	HH	590.280	0

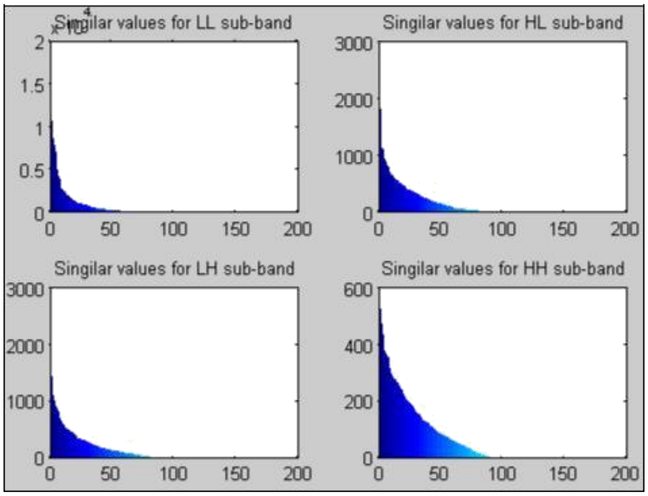


Figure 4. Singular Values of all Sub-bands for Original Image Copyright.

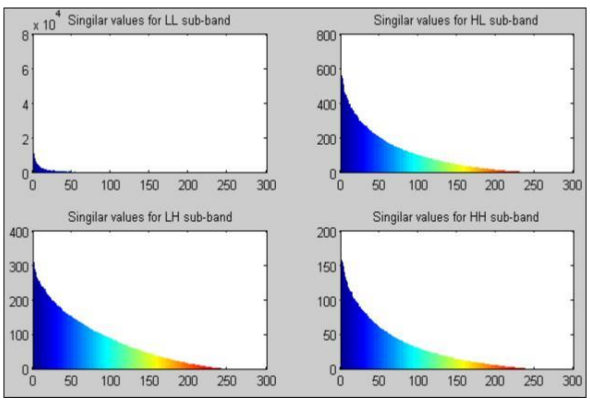


Figure 5. Singular Values of all Sub-Bands for Watermarked Image Lena

Fig.4 shows the plot for singular values of LL, HL, LH and HH Sub-bands of original Lena image. Correspondingly, singular values with the highest magnitudes are found in LL sub-band and lowest in HH sub-band. So, instead of assigning four different scaling factors for each sub-band, we have defined only two scaling factors. One for LL whose value is chosen to be 0.05 and a smaller value of 0.0005 for rest other sub-bands. Similarly, Table III shows the singular values for all sub-bands of watermarked image Lena.

TABLE III. Singular Values of All Sub-bands for Watermarked Image Lena

Singular values of all sub-bands of watermarked image Lena	Max. & Min. values of sub-bands for watermarked image Lena		
	Sub-band	***Maximum Value***	***Minimum Value***
1.	LL	65504	0
2.	HL	604.594	0
3.	LH	312.157	0
4.	HH	167.100	0

From Table III, it is clear that LWT-SVD watermarking technique merely affects the energy of the original image.

In order to test the robustness of LWT-SVD based watermarking scheme, the watermarked image was tested against 20 kinds of attacks: 1) Blur 2) Motion Blur 3) Gaussian Blur 4) Sharpening 5) Gaussian Noise 6) Salt and Pepper Noise 7) Histogram Equalization 8) Contrast adjustment 9) Rotation 10) Median Filtering 11) Oil Painting 12) Mirroring (Vertical and Horizontal) 13) Mosaic 14) Lens effect 15) Compression: JPEG 16) Masking with other image 17) Swirl effect 18) Negative 19) Embossing 20) Crop.

Table IV includes all these attacks on watermarked image. Table V includes the constructed watermarks from all 4 sub-bands for a given attack. MSE and PSNR values are shown from table VI to table IX for all sub-bands.

Since we are getting different values of MSE and PSNR for each sub-band for different sub-band, we can conclude few points from these values:

- Watermark embedding in LL band is resistant to attacks including Gaussian noise, salt & pepper noise, mirroring (both vertical as well as horizontal), and JPEG compression.
- Watermark embedding in LH band is resistant to sharpening, oil painting (for higher value of intensity), majority of masks, and swirl (for lower intensity).
- Watermark embedding to HL band is resistant to oil painting and negative.

  Watermark embedding in HH band is resistant to attacks including blurring, motion blurring, Gaussian blurring, histogram equalization, contrast stretching, rotation attack, gamma correction, median filtering, mosaic, swirl (for larger values of intensity), cropping, emboss, and JPEG compression (if image quality=0%).

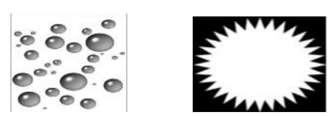


Figure 6. Images used to mask the Watermarked Image

TABLE IV. ATTACKED WATERMARKED IMAGES
Watermarked Images with Various Kinds of Attacks

Attacked Watermarked Images						
Blur	Motion Blur (LEN=20 & =45°)	Gaussian Blur (hsize=3 & =5)	Sharpening	Gaussian Noise	Salt & Pepper Noise (d=0.02)	Contrast
20° rotation	50° rotation	Median Filtering	Oil Painting (Intensity=3)	Oil Painting (Intensity=16)	Vertical Mirroring	Horizontal Mirroring	Equalization
Mosaic (Intensity=25)	Mosaic (Intensity=64)	Lens (Intensity=70)	Lens (Intensity=100)	Emboss	Swirl (Intensity=100)	Swirl (Intensity=200)	Negative
Compression (Image Quality=50%)	Compression (Image Quality=10%)	Masking-1	Masking-2	Crop (200×200)		

Figure 7. PSNR Values for LL Sub-band of Extracted Watermark Image.

Figure 9. PSNR Values for HL Sub-band of Extracted Watermark Image.

Figure 8. PSNR Values for LH Sub-band of Extracted Watermark Image.

Figure 10. PSNR Values for HH Sub-band of Extracted Watermark Image.

TABLE V: EXTRACTED WATERMARK IMAGES FROM VARIOUS ATTACKS

5. CONCLUSION

Our implemented LWT-SVD scheme has proved a high degree of robustness against majority of attacks including strong geometric attacks including cropping and various other kinds of signal processing attacks which can be validated by recovering the watermark from any of the sub-band, which clearly indicates that transform domain is more robust than spatial domain. So, given method can be effectively used for copyright protection of visual information.

Generally, LL band is not modified as any kind of changes in it can be easily perceived by human eyes. But, in LWT-SVD approach, we experienced no such problem.

If we insert watermark in any of the sub-band, then it makes our image resistive to only few kinds of attacks. But, if we insert watermark into all sub-bands, then it would be very difficult to remove it from all frequencies. Since we have inserted watermark in LH and HL sub-bands, so inserting watermark in these bands would make our image impervious to attacks like histogram equalization, swirl effect, oil painting, and gamma correction.

As a future work, the implemented algorithm can be improved using full band LWT-DCT-SVD and further can be extended to color images and video processing.

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