DWT-DCT-SVD based semi-blind reference image watermarking scheme using trignometric function

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Abstract— **DWT, DCT and SVD are used in this paper and a semi-blind algorithm is been developed using trigonometric function which is robust against several attacks like cropping, noise, rotation, filtering, translation, etc. Trigonometric function is used to closely relate the singular values of the original image and the watermarked image.**

In this algorithm, firstly DWT is applied on the host image to divide it in four frequency bands LL, LH, HL and HH. As the high frequency band lies on the edges of the image and is less prone to attacks so the singular values of the DCT Transformed coefficients of the HH band of the image is been modified using the singular values of the DCT transformed coefficients of the watermark and the scaling factor with the help of inverse-trigonometric function. And then this modified singular values are used to reconstruct the watermarked Host Image.

Now to validate the content authentication, the extraction technique is applied on the watermarked image. It consists of applying DWT on the watermarked image to get all the four frequency bands and then by using the singular values of the DCT coefficients of the high frequency band and the scaling factor using trigonometric function, the singular values of the watermark are extracted to reconstruct the watermark using inverse SVD.

Keywords- Watermarking, Trigonnometric function, Semi-Blind, DCT, DWT, SVD, Robust.

I. INTRODUCTION

Advances in computer hardware, software and networks have created threats to copyright protection, content integrity and authentication. Digital Watermarking is an efficient way in enabling digital content protection. Many transformation techniques are been introduced yet like Fast-Fourier Transform (FFT), Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), Singular Value Decomposition (SVD), etc.

Digital watermarking is a potentially good tool in enabling content protection. The watermarking process embeds a signal into the image without significantly degrading its visual quality. Nowadays Digital Watermarking has many applications such as transaction tracking, proof of ownership, broadcast monitoring etc. The principle of the watermark is to embed a piece of some additional information of the digital data and hide it in the digital content in such a way that it is inseparable from the data. It means that it remains present within the data after any decryption process. The objective is to produce an image that looks exactly the same to a human eye but still allows its constructive recognition in comparison with the owner's key if necessary. Watermarks can be embedded in the pixel/spatial domain or a transform domain.

Watermark robustness is one of the major characteristics that influence the performance and applications of digital image watermarks. The major advantage of transform domain methods is their superior robustness to common image distortions.

In this paper, we are interested in invisible watermarks because they have a wider range of applications compared to visible watermarks. On the other hand, invisible watermarks are imperceptible and do not change the visual appearance of images.

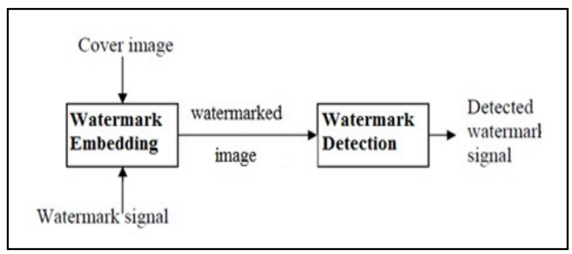


Fig1: Generic Watermarking Scheme

II. AIMS

The aims of this paper are three fold:

i. To investigate the strength and limitations of current watermarking schemes ,
ii. To design and develop new schemes to overcome the limitations, and
iii. To evaluate the new schemes using application scenarios of copyright protection, tamper detection and authentication.

Aimed at three goals mentioned above, we will find answers to these research questions:

i. What are the major challenges in robust watermarking?
ii. How can we reduce the computational cost of a robust watermarking method that is based on semi-blind scheme using trigonometric function?

iii. What are the new capabilities of robust watermarking?

III. EVALUATION OF WATERMARKING METHODS

A. Robustness:

It means the ability of a watermark to resist common image processing and to withstand non-malicious distortions which can be made on applying any type of attacks.

B. Imperceptibility:

It is the characteristics of hiding a watermark so that it does not degrade the visual quality of an image. It is tested through comparing the watermarked image with the original one.

C. Capacity:

It is the amount of watermark information in an image.

D. Computational Cost:

It is the measure of computing resources required to perform watermark embedding or detection process. It can be measured using the processing time for a given computer configuration.

E. Mean Squared Error:

MSE is one of the earliest tests that were performed to test if two pictures are similar. A function could be simply written according to equation1.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(X_i - X_i^*)^2 \quad \dots (1)$$

F. Peak Signal to Noise Ratio:

PSNR is a better test since it takes the signal strength into consideration (not only the error).PSNR is used to measure the difference between two images.

Equation (2) describes how this value is obtained.

$$PSNR = 10.\log_{10}\left(\frac{MAX_i^2}{MSE}\right) \quad \dots (2)$$

PSNR is generally deployed for comparing imperceptibility performance although it is not a perfect metric. The more similar between a watermarked image and its cover image, the higher is its PSNR.

IV. PRELIMINARIES

Three **essential factors** used to determine quality of watermarking scheme*:*

A. Discrete Cosine Transform (DCT)

The Discrete Cosine Transform (DCT) is a technique that converts a spatial domain waveform into its constituent frequency components as represented by a set of coefficients.

DCT is one of the most popular linear transforms and a compression tool of digital signal processing. It is a lossless procedure and has been widely used because of its good capacity of energy compression and de-correlation. These transforms are the members of real-valued discrete sinusoidal unitary transforms.

$$C(u,v) = \alpha(u)\alpha(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)\cos\left[\frac{(2x+1)u\pi}{2N}\right]\cos\left[\frac{(2y+1)v\pi}{2N}\right] \quad \dots(3)$$

For u, v=0, 1, 2……N-1

Where

$$\alpha(u) = \{\frac{1}{\sqrt{2}} \text{ for } u = 0, 1 \text{ for } u = 1,2,\dots N-1,\ \alpha(v) = \{\frac{1}{\sqrt{2}} \text{ for } v = 0, 1 \text{ for } = 1,2,\dots N-1.$$

B. Discrete Wavelet Transform(DWT)

This watermarking method is focusing on its embedding strength would provide useful insight in how to improve its performance. The performances measured include robustness, imperceptibility and computational cost.DWT decomposes an image into a low-pass sub band and three high- pass sub bands. In this study, this method embeds a watermark in high-pass (or higher frequency) band of the DWT domain. This is due to the good imperceptibility provided by high-pass band. To reconstruct an image, an inverse DWT is used after modification has been made by using singular values of SVD of watermark.

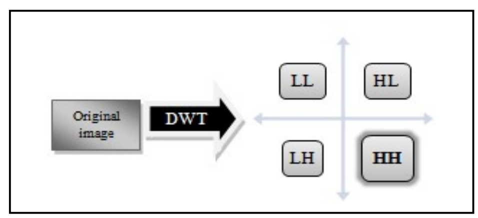


Fig2: DWT decomposition

C. Singular Value Decomposition (SVD)

It is a linear algebra transform technique used in watermarking. It is composed of three vectors in which one vector consists of diagonal matrix and two vectors consist of orthogonal matrices. This diagonal matrix is responsible for an image luminance and orthogonal matrices are responsible for the geometry of an image. In this algorithm, the authors found the singular values of cover image and then modified them by adding a watermark. SVD transform is again applied on the resultant matrix for finding the modified singular values. These singular values are combined with the known orthogonal components to get the watermarked image. For watermark extraction, inverse process is used.

D. Semiblind Watermarking Scheme

In the semi-blind watermarking scheme the host image is not needed at the time of extraction but the watermark.

V. PROPOSED METHOD

We assume the dimension of the cover image I is N x N and the dimension of the visual watermarking W is N x N.
The main idea of our proposed method is as follows.

A. Watermark embedding:

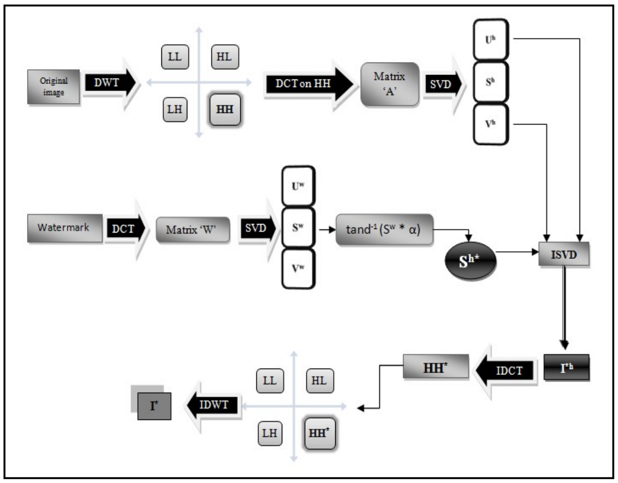


Fig3: Block Diagram of Embedding Process

Algorithm:

1. Using DWT, decompose the original image I into 4 sub-bands: LL, HL, LH, and HH.
2. Apply DCT on HH sub-band to obtain the coefficient matrix 'A'.
3. Apply S VD on coefficient matrix 'A':
$$A = U^h \; S^h V^h$$
4. Apply DCT on the watermark to obtain the coefficient matrix 'W'.
5. Apply SVD to coefficient matrix 'W':
$$W=U^w S^w V^w$$
6. Modify S^h: $S^{h*}= \text{tand}^{-1} (\alpha * S^w)$ where α[=0.00015] is scaling factor.
7. Obtain the modified high frequency matrix component I^{*h}
$$I^{*h} = [U^h . S^{h*} . V^{h'}]$$
8. Apply IDCT on matrix I^{*h} to obtain the modified high frequency band HH^*.
$$HH^*= \text{IDCT} (I^{*h})$$
9. Using LL, HL, LH, and HH^*, apply IDWT to obtain the watermarked image I^*.

B. Watermark extraction:

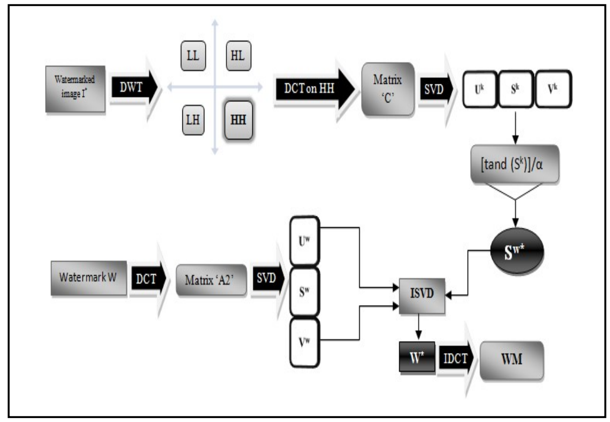


Fig4: Block Diagram of Extraction Process

Algorithm:

1. Using DWT, decompose the watermarked image I^* into 4 sub-bands: LL, HL, LH and HH.
2. Apply DCT on HH band to obtain the coefficient matrix 'C'.
3. Apply SVD to matrix 'C':
$$C = [U^k S^k V^k]$$
4. Apply DCT on watermark W to obtain a coefficient matrix A2.
5. Apply SVD to matrix A2:

$$W^*= [U^w S^w V^w]$$
6. Extract the singular values of watermarking:
$$S^{w*}= [\text{tand}(S^k)]/ \alpha$$
Where S^k are the singulars of watermarked image after applying DCT. [α=0.00015]
7. Recover the watermark: $w^*= (U^w) * (S^{w*}) * (V^w)$
8. Apply IDCT on w^* to obtain an extracted watermark WM.
9. Compare W & WM for finding correlation (e.g. PSNR).

VI. RESULTS

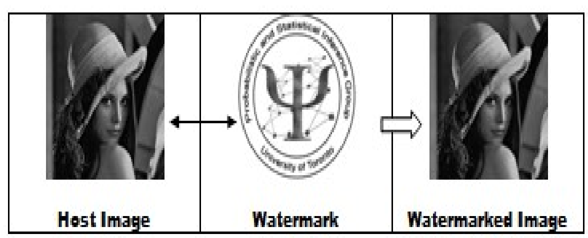
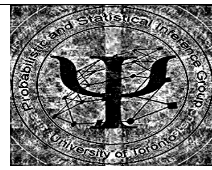
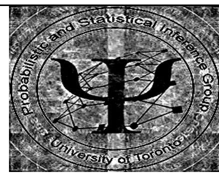
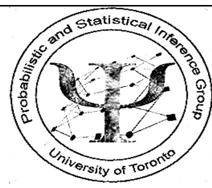
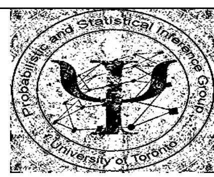
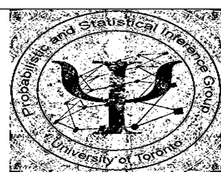
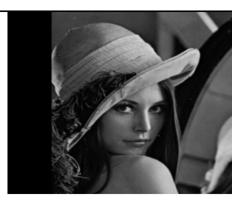
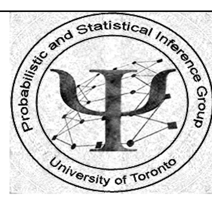
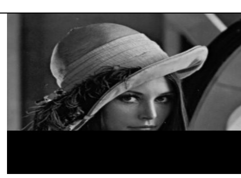


Fig5: Embedding Process

Results of various attacks applied on the watermarked image and watermark extracted with its PSNR values is given in the following table:

TABLE: COMPARISON OF PROPOSED METHOD WITH EXISTING METHOD IN TERMS OF IMAGE PROCESSING BY VARIOUS ATTACKS WITH THEIR PSNR VALUES AND CORRELATIONS

ATTACKS (PARAMETERS)	**ATTACKED WATERMARKED IMAGE**	**WATERMARK**	**PROPOSED METHOD**		**EXISTING METHOD**	
			PSNR	**CORRELATION**	**PSNR**	**CORRELATION**
Rotate(75˚)			**+53.56dB**	**0.5308**	**+34.22dB**	**0.7193**
Medfilt2			**+53.74dB**	**0.6019**	**+34.28dB**	**0.7033**
Histeq			**+65.52dB**	**0.9123**	**+34.87dB**	**0.8831**
Gaussian noise (0.01)			**+56.36dB**	**0.6320**	**+33.79dB**	**0.7037**
Salt & Pepper Noise (0.03)			**+56.54dB**	**0.6500**	**+33.80dB**	**0.6949**
Left Cropping (1,1,100,512)			**+68.59dB**	**0.9665**	**+33.86dB**	**0.8369**
Bottom Cropping (1,375,512,512)			**+56.07dB**	**0.8730**	**+35.67dB**	**0.9850**

VII. CONCLUSION

In this paper, we proposed a semi-blind reference image watermarking by using the technique DWT-DCT-SVD. The proposed method has a good performance in the case of robustness and imperceptibility. It is more robust to some common image processing including Gaussian noise, Left cropping, Bottom cropping, Salt & Pepper noise, Histogram equalization, Medium filter, Rotation, etc. PSNR values are computed to find out the imperceptibility performance between watermarked image and its cover image. The maximum PSNR values is of Left Cropping i.e. +68.59 dB and the minimum PSNR values is of Rotation i.e. +53.56 dB.

Correlation values are also computed here for finding the relation between them. The maximum correlation exists for left cropping attack whose value is 0.9665 and the minimum correlation exists for rotation attack whose value is 0.5308.

We compared the results of our proposed method with the existing method of Nidhi H. Divecha and N.N.Jani [3]. The PSNR values and correlation factor of the proposed method are much more robust than the existing one. In the existing method, an original image is of 256 * 256 pixel values while in the proposed method, we took an original image of 512 * 512 pixel values.

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