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Hybrid Watermarking Scheme for Digital Images

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Abstract - The main objective of developing a digital image watermarking technique is to satisfy both imperceptibility and robustness requirements. Digital watermarking appears as an efficient means of securing multimedia contents such as copyright protection and authentication. The key aspects of watermarking techniques are robustness and tampering proofing. In this paper robustness is improved through combination of Discrete Wavelet Transform and Singular Value Decomposition method. DWT is used for decomposition of images into sub bands which gives linear flexibility of images in terms of scalability, resolution and distortion. By adding SVD along with DWT, Peak Signal to Noise Ratio can be improved. The result is analysed using MATLAB.

Keywords: *Digital Images, DWT, MATLAB, SVD.*

I. INTRODUCTION

Watermarking technology developed on the basis of image processing, is the most commonly used technique for the security of images .Thus the process by which the copyright information is embedded inside the original images, which is to be protected from the illegal replication and distribution is known as "Digital Watermarking". Digital watermarking provides a possible solution to the problem of easy editing and duplication of images, since it makes possible to identify the author of an image by embedding secret information in it [1].

Robust watermarks are designed to resist any modifications and are designed for the copyright protection. Fragile watermarks are designed to fail whenever the cover work is modified and to give some measure of the tampering. Fragile watermarks are used in authentication. The fragile watermarks can be embedded in either the space domain or the transformed domain of an image. In the space domain, several fragile watermarking methods that utilize the least significant bit (LSB) of image data.

A digital signature of the most significant bits of an image block is replaced by the least significant bits of the same block on a secret user key. It's expected that digital watermarking will have a wide span of practical applications such as digital cameras, finger print, and copyright protection, prevention of unauthorized copying, image authentication, medical imaging, image databases, and video on demand systems, among many others [5].

II. RELATED WORKS

A. Practical Model For Watermarking System

A generalized watermarking system may be devised in fig1. In the Watermark Insertion Block, copyright information is hidden inside the original piece of work in an encrypted form the original image, I is processed inside this watermark insertion system.

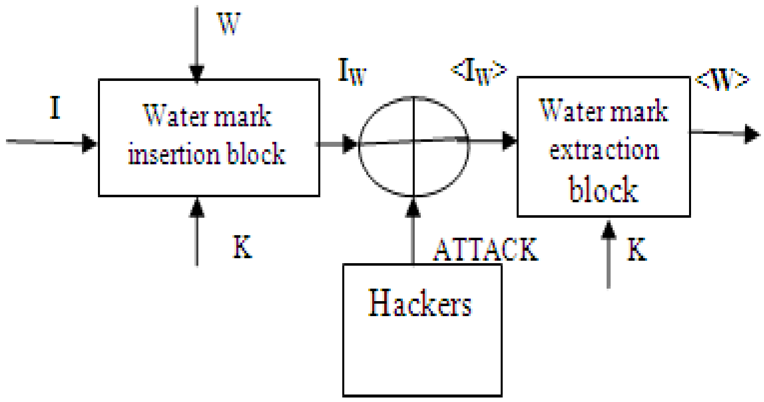

Figure 1: Model for Watermarking System

The other input to this block is the copyright information or the watermark, W to be embedded inside I using the secret key, K. Thus, the final image available in the market is a composite image, I_W containing the encrypted logo inside the original image. This composite image available in the market has every possibility of being attacked by the hackers in a bid to destroy the watermark embedded inside it, to generate the hacked version, <I_W> of the composite image. Once the hackers become successful in destroying the watermark the original piece of work becomes susceptible to all kinds of fraud.

The primary aim of the Watermarking Extraction Block is to successfully extract an estimate of the copyright information, <W> from the hacked version **<I_W>.** The better the watermarking system the more <W> resembles W [1].

B. Watermarking Constraints

The success of the watermarking Scheme largely depends upon the choice of the watermark structure and insertion strategy. The two main constraints involved in the problem of watermarking are those of maintaining the robustness of the watermark information while keeping visual perception of the original image intact. If the insignificant portions of the original image are used for hiding the watermark structure then the visual perceptions of the original image may remain unaffected but the robustness of the technique decreases.

On the other hand if the hiding is done in the significant portions of the original image then the robustness of the technique increases at the cost of visual perceptions. Thus the cost of function of the problem of watermarking is a weighed sum of these factors [4]:

Cost Function, $S=F_R*R+F_V*V$

Where,

F_R = Weighted factor for Robustness,

F_V = Weighted factor for Visual Perceptions,

R = Robustness,

V = Visual Perceptions.

The challenge in any watermarking technique is to maximize this cost function.

C. Types of Watermarking

Digital watermarking techniques can be categorized into one of the two domains, according to the embedding domain of the host image [7].

1. Spatial Domain

Spatial domain methods are based on direct modification of the values of the image pixels, so the watermark has to be imbedded in this way. Such methods are simple and computationally efficient, because they modify the colour, luminance or brightness values of a digital image pixels, therefore their application is done very easily, and requires minimal computational power [7].

2. Transform Domain

Frequency (transform) domain methods are based on the using of some invertible transformations like, Discrete cosine transforms (DCT), Discrete Fourier transform (DFT), Discrete wavelet transforms (DWT), etc to the host image. Embedding of a watermark is made by modifications of the transform coefficients, accordingly to the watermark or its spectrum. Finally, the inverse transform is applied to obtain the marked image. This approach distributes irregularly the watermark over the image pixels after the inverse transform, thus making detection or manipulation of the watermark more difficult.

The watermark signal is usually applied to the middle frequencies of the image, keeping visually the most important parts of the image (low frequencies) and avoiding the parts (presented by high frequencies), which are easily destructible by compression or scaling operations[7]. These methods are more complicated and require more computational power.

D. Parameters Of Water Marking

1. PSNR

The quality of extracted watermark can be measured by PSNR (Peak Signal-to-Noise Ratio) and AR (Accuracy rate) PSNR is provided only to give us a rough approximation of the quality of the watermark [4].

$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20 \cdot \log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right)$$

2. Accuracy Rate

Accuracy rate of recovered image is calculated by using AR function AR = CP/NP. Where NP is the number of pixels of the watermark image and CP is the number of correct pixels in the watermark image that is retrieved from the attacked image [4].

E. Transforms

1. Discrete wavelet transform (DWT)

Wavelet transform decomposes an image into a set of band limited components which can be reassembled to reconstruct the original image without error. Since the bandwidth of the resulting sub-bands is smaller than that of the original image, the sub-bands can be down sampled without loss of information [2]. Reconstruction of the original signal is accomplished by up sampling, filtering and summing the individual sub bands.

2. Singular Value Decomposition (SVD)

SVD method can transform matrix A into product *(USV) ^T,* which allows us to refactoring a digital image in three matrices. The using of singular values of such refactoring allows us to represent the image with a smaller set of values, which can preserve useful features of the original image, but use less storage space in the memory, and achieve the image compression process [6]. The experiments with different singular value are performed, and the compression result was evaluated.

III. PROPOSED METHODOLOGIES

Watermarking is the process of adding information to an image; it can be done directly by manipulating the pixels of an image or by using transforms. The proposed method embeds watermark by using discrete wavelet transform (DWT) and singular value decomposition (SVD). The image to be watermarked can be decomposed in to four sub bands namely LL, LH, HL, and HH at level 1 in the DWT domain, where LH, HL, and HH represent the finest scale wavelet coefficients and LL stands for the coarse-level coefficients[3]. The LL sub band can further be decomposed to obtain another level of decomposition.

The decomposition process continues on the LL sub band until the desired number of levels determined by the application is reached. Since human eyes are much more sensitive to the low frequency part (the LL sub band), the watermark can be embedded in the other three sub bands to maintain better image quality and the apply SVD in LH or HL sub bands. The basic idea behind the SVD based watermarking techniques is to find the SVD of the cover image or each block of the cover image, and then modify the singular values to embed the watermark [6].

Then combine the sub bands into a single watermarked image by apply inverse discrete wavelet transform (IDWT). The original image can be extracted and it can be tested by peak signal to noise ratio (PSNR), zed cross correlation (NCC).

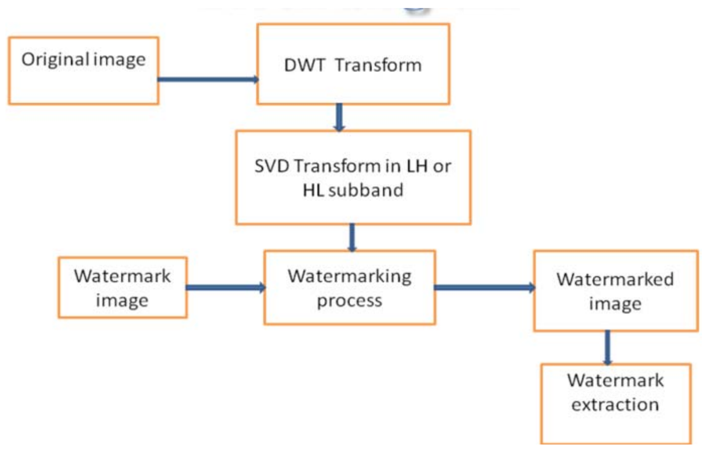

Figure 2: Block Diagram for Proposed Methodology

Transformation

Transforms used are discrete wavelet transform (DWT) and singular value decomposition (SVD)

Discrete Wavelet Transform (DWT)

Discrete Wavelet Transform (DWT), which transforms a discrete time signal to a discrete wavelet representation [8]. It converts an input series x_0, x_1,..x_m, into one high pass wavelet coefficient series and one low-pass wavelet coefficient series (of length n/2 each) given by

$$H_i = \sum_{m=0}^{k-1} x_{2i-m} \cdot s_m(z)$$

$$L_i = \sum_{m=0}^{k-1} x_{2i-m} \cdot t_m(z)$$

Where $s_m(Z)$ and $t_m(Z)$ are called wavelet filters, K is the length of the filter, and i=0, ..., [n/2] - 1.

In practice, such transformation will be applied recursively on the low pass series until the desired number of iterations is reached. Wavelet transform decomposes an image into a set of band limited components which can be reassembled to reconstruct the original image without error.

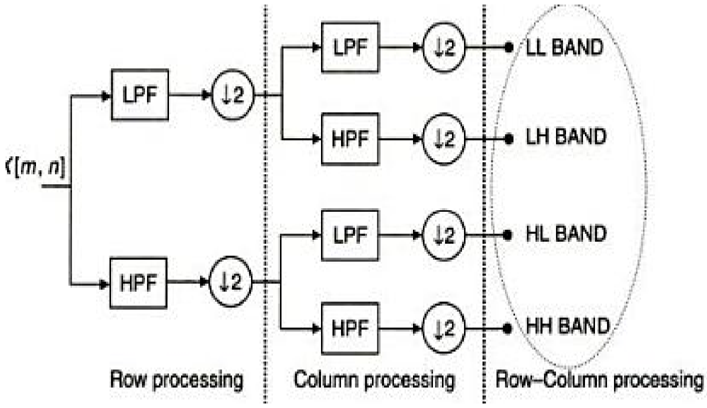

Figure 3: Block Diagram of DWT

Since the bandwidth of the resulting sub-bands is smaller than that of the original image, the sub bands can be down sampled without loss of information. Reconstruction of the original signal is accomplished by up sampling, filtering and summing the individual sub bands [3].

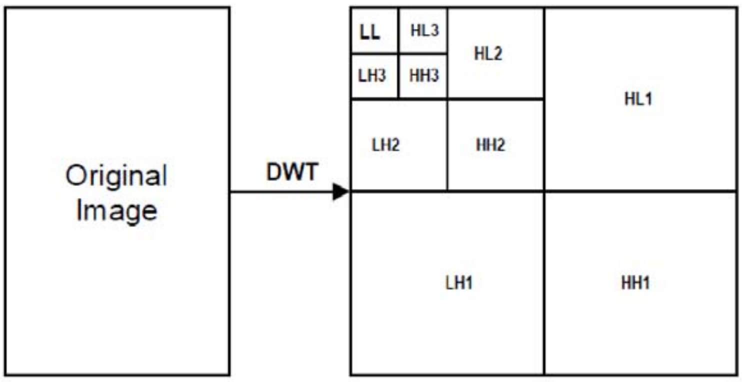

Figure 4: Work Flow of DWT Transformation

Discrete 2D Wavelet Transform/Sub Band Coding

An important imaging technique with ties to multi resolution analysis is Sub band coding. In sub band coding, an image is decomposed into a set of band limited components, called sub bands, which can be reassembled to reconstruct the original image without error. Each sub band is generated by band pass filtering the input. Since the bandwidth of the resulting sub-bands is smaller than that of the original image, the sub-bands can be down sampled without loss of information [2]. Reconstruction of the original image is accomplished by up sampling, filtering and summing the individual sub bands.

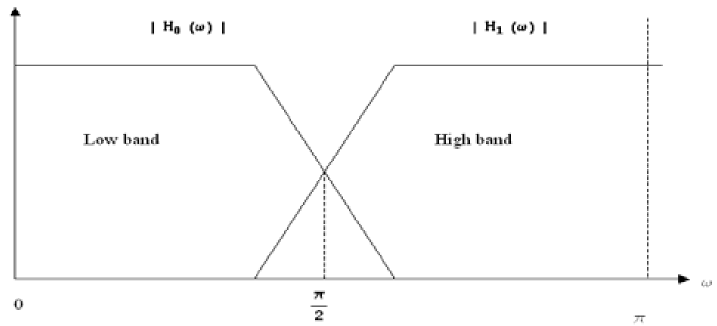

Figure 5: Subbands of DWT Transformation

Singular value decomposition (SVD)

SVD method can transform matrix A into product USV^T, which allows us to refactoring a digital image in three matrices. The using of singular values of such refactoring allows us to represent the image with a smaller set of values, which can preserve useful features of the original image, but use less storage space in the memory, and achieve the image compression process. The experiments with different singular value are performed, and the compression result was evaluated by compression ratio and quality measurement [6].

Process of Singular Value Decomposition

Singular Value Decomposition (SVD) is said to be a significant topic in linear algebra by many renowned mathematicians. SVD has many practical and theoretical values; Special feature of SVD is that it can be performed on any real (m, n) matrix [6]. Let's say we have a matrix A with m rows and n columns, with rank r and $r \leq n \leq m$. Then the A can be factorized into three matrices: $A = USV^T$

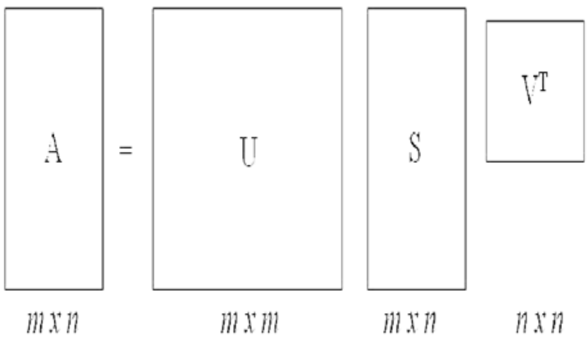

Figure 6: SVD Transformation

SVD based watermarking scheme in which the watermark is added to the SVs of the whole image or a apart of it. A single watermark is used in this scheme which may be lost due to attacks. To avoid this disadvantage, we propose an approach in which, the original image is segmented into blocks and the watermark is added to the SVs of each block in a modified

manner. The SVs of the modified Ubiquitous Computing and Communication Journal watermarked blocks are used to extract the watermark after the attacks. As a result of using several watermarked blocks, several watermarks can be recovered.
So if any attack affects the watermarked image, some of the watermarks will survive. This block by block method gives robustness against JPEG compression, cropping, Gaussian noise, resizing and rotation as the results will reveal. The SVD mathematical technique provides an elegant way for extracting algebraic features from an image. The main properties of the SVD matrix of an image can be exploited in image watermarking. The SVD matrix of an image has good stability. When a small perturbation is added to an image, large variation of its SVs does not occur.

Using this property of the SVD matrix of an image, the watermark can be embedded to this matrix without large variation in the obtained image if we divide image by n, probability of correct prediction will increase n times [6].

IV. IMPLEMENTATION OF WATERMARKING SCHEME

The proposed DWT SVD watermarking scheme is formulated as given here.

Watermark Embedding

1. Use one level Haar DWT to decompose the cover image A into four sub bands (i.e., LL, LH, HL, and HH)
2. Apply SVD to LH and HL sub bands, i.e., $A_k = U_k S_k V_k^T$, k= 1, 2 …. where k represents one of two sub bands
3. Divide the watermark into two parts $W = W_1 + W_2$, where W_k denotes half of the watermark
4. Modify the singular values in HL and LH sub bands with half of the watermark image and then apply SVD to them, respectively, i.e.,$S_k + \alpha W_k = U_k^W S_k^W V_k^{TW}$ where α denotes the scale factor. The scale factor is used to control the strength of the watermark to be inserted
5. Obtain the two sets of modified DWT coefficients, i.e., $A^*_k = U_k S_k^W V_k^T$, k= 1, 2….
6. Obtain the watermarked image AW by performing the inverse DWT using two sets of modified DWT coefficients and two sets of non modified DWT coefficients

Watermark Extraction

1. Use one level Haar DWT to decompose the watermarked (possibly distorted) image A^*W into four sub bands: LL, LH, HL, and HH.
2. Apply SVD to the LH and HL sub bands, i.e., $A^*_k{}^W = U^*_k S^*_k{}^W V^*_k{}^T$, k= 1, 2… where k represents one of two sub bands.
3. Compute $D^*_k = U_k^W S^*_k{}^W V_k^{TW}$, k = 1, 2…
4. Extract half of the watermark image from each sub band, i.e.,$W^*_k = (D^*_k - S_k)/\alpha$, k = 1, 2…
5. Combine the results of Step 4 to obtain the embedded watermark: $W^* = W^*_1 + W^*_2$.

V. EXPERIMENTAL RESULTS

The proposed algorithms are tested and evaluated on the digital image database using MATLAB. Fig7 shows the input image and the logo image. The input image is transformed by using DWT. In DWT the image is subdivided into different bands and its show in Fig 8. In this the logo is added to one particular band to produce the water marked image. Here we choose the LL band. Fig 9 shows the image in the LL band before and after adding the logo. Finally the watermarked image is produced by taking the IDWT and shown in Fig 10.The watermarking parameters can be tested after extracting the original image from the water marked image.

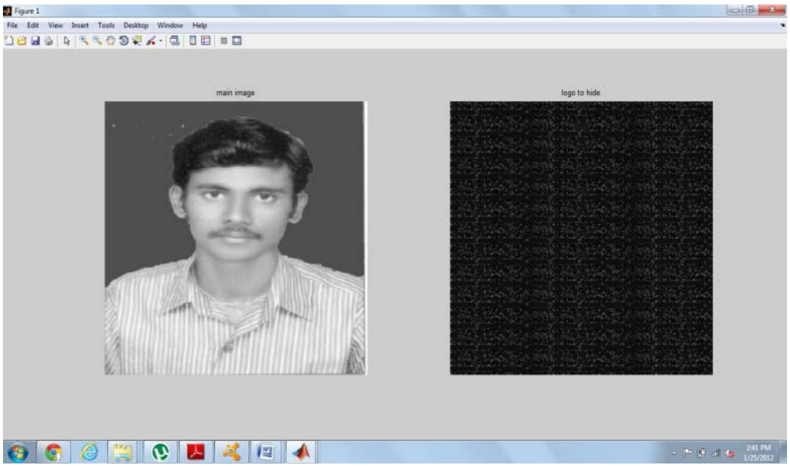

Figure7: Reading Input Image and Logo Image in Matlab

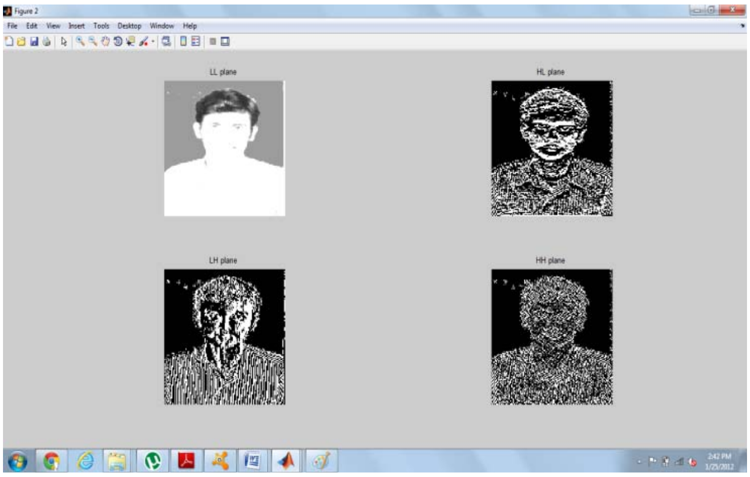

Figure 8: DWT Transformation

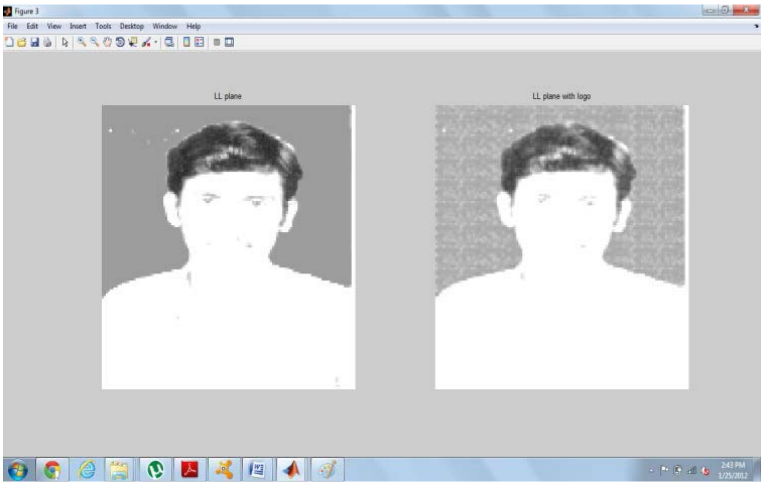

Figure 9: Watermarked Image in LL Plane

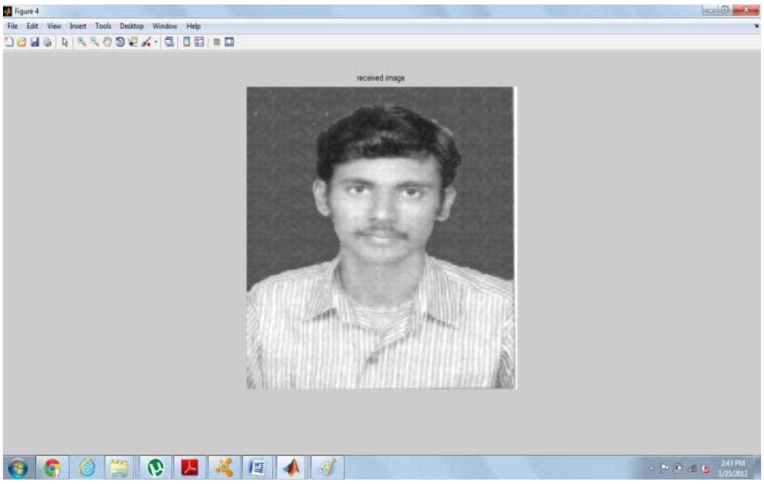

Figure10: Detransformation and Watermarked Image

VI. CONCLUSION

In this paper, a hybrid image watermarking technique based on DWT and SVD has been presented, where the watermark is embedded on the singular values of the cover image's DWT sub bands. The technique fully exploits the respective feature of these two transform domain methods namely spatio frequency localization of DWT and SVD efficiently represents intrinsic algebraic properties of an image. Experimental results of the proposed technique have shown both the significant improvement in imperceptibility and the robustness under attacks. Further work of integrating the human visual system characteristics into our approach is in progress.

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