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A Hybrid Model of Watermarking Scheme for Color Image Authentication Using Discrete Wavelet Transform and Singular Value Decomposition

Sukanta Kumar Tulo, Dr. Nalinikanta Barpanda, Subhrajit Pradhan,
A. Amiya Kumar Gupta
Department of Electronics Engineering, GIET, GUNUPUR, INDIA

Abstract: *Digital Watermarking is a process of embedding information in the multimedia content (host or cover image) for image authentication. An ideal watermarking system would embed an amount of information that could not be removed or altered without making the cover object entirely unusable. Over the past few years digital watermarking has become popular due to its significance in content authentication and legal ownership for digital multimedia data. A digital watermark is a sequence of information containing the owner's copyright. It is inserted invisibly in another image so that it can be extracted at later times for the evidence of rightful ownership. Available digital watermarking techniques can be categorized into one of the two domains, viz., spatial and transform, according to the embedding domain of the host image. Based on these domains digital watermarking can be done by FFT, DCT, DWT, SVD. The analysis proves that the proposed DWT-SVD hybrid model is much more superior to other models as it is found to be more robust and effective. The results revealed that the hybrid model is able to withstand a variety of attacks and shows high level of security.*
Keywords: *Digital Watermarking, Discrete Wavelet Transform, Hybrid model, Singular Value Decomposition, Peak Signal to Noise Ratio (PSNR).*

I. Introduction

The growth of digital media and the fact that unlimited numbers of perfect copies of such media can be illegally produced is a threat to the rights of content owners. A copy of digital media is an exact duplicate of the original. The authors of a work are hesitant to make such information available on the Internet as it may be copied and retransmitted without the permission of the author. An issue facing electronic commerce on the Internet for digital information is how to protect the copyright and intellectual property rights of those who legally own or posses' digital works. Copyright protection involves ownership authentication and can be used to identify illegal copies. One approach to copyrighting is to mark works by adding information about their relationship to the owner by a digital watermark. Digital watermarking is the process of embedding information into a digital signal which may be used to verify its authenticity or the identity of its owners, in the same manner as paper bearing a watermark for visible identification. In digital watermarking, the signal may be audio, pictures, or video. This information may be perceptible or imperceptible to the human senses. Early watermarking work investigated how documents can be marked so they can be traced in the photocopy process. If the signal is copied, then the information also is carried in the copy. A signal may carry several different watermarks at the same time. In visible digital watermarking, the information is visible in the picture or video. Typically, the information is text or a logo, which identifies the owner of the media. The image on the right has a visible watermark. When a television broadcaster adds its logo to the corner of transmitted video, this also is a visible watermark. In invisible digital watermarking, information is added as digital data to audio, picture, or video, but it cannot be perceived as such (although it may be possible to detect that some amount of information is hidden in the signal). The watermark may be intended for widespread use and thus, is made easy to retrieve or, it may be a form of Steganography, where a party communicates a secret message embedded in the digital signal. Digital watermarks are employed in an attempt to provide proof of ownership and identify illicit copying and distribution of multimedia information. This contributes an overview of information hiding methods for digital media and proposes a new way of watermark technique. The main objective of this work is to develop a watermarking technique to satisfy both imperceptibility and robustness requirements. To achieve this objective different watermarking scheme like DWT and SVD are discussed and a hybrid model of watermarking scheme based on discrete wavelet transform (DWT) and singular value decomposition (SVD) is proposed. In our approach, the watermark is embedded on the elements of singular values of the cover image's DWT sub bands. Remaining paper is organized as follows: section 2 discusses the existing related work in the field of digital image watermarking. Section 3 explains the proposed watermarking model. Section 4 shows the result and performance analysis. Section 5 contains conclusion.

II. Related Work

2.1 Literature Review

G. Bhatnagar et.al [1] represented a reference watermarking scheme based on DWT-SVD for an image. Here a basic idea has been given regarding this scheme. J. Sang et.al. [2] Investigated the fragility and robustness of binary-phase only filter-based fragile/semi fragile digital image watermarking. Here main concern is given on fragile and semi fragile digital watermarking and the robustness is been calculated. X.W Kong et.al [7], proposed the scheme for Object Watermarks for Digital Images and Video. He proposed the SVD based scheme for embedding the watermarks in the digital image and coloured video. Z. Xinzhong et.al. [10], has developed A modern Digital Watermarking Algorithm Based on Improved SVD. The improved algorithm is applied on different samples of images and verified that the improved algorithm is more robust than the algorithm based on SVD.

2.2 Different Schemes of Watermarking

General digital watermark life-cycle phases with embedding-, attacking and detection and retrieval functions. The information to be embedded in a signal is called a digital watermark, although in some contexts the phrase digital watermark means the difference between the watermarked signal and the cover signal. The signal where the watermark is to be embedded is called the host signal. A watermarking system is usually divided into three distinct steps, embedding, attack, and detection. In embedding, an algorithm accepts the host and the data to be embedded, and produces a watermarked signal. Then the watermarked digital signal is transmitted or stored, usually transmitted to another person. If this person makes a modification, this is called an attack. There are many possible modifications, for example, lossy compression of the data (in which resolution is diminished), cropping an image or video or intentionally adding noise. Detection (often called extraction) is an algorithm which is applied to the attacked signal to attempt to extract the watermark from it. If the signal was unmodified during transmission, then the watermark still is present and it may be extracted. In robust digital watermarking applications, the extraction algorithm should be able to produce the watermark correctly, even if the modifications were strong. In fragile digital watermarking, the extraction algorithm should fail if any change is made to the signal.

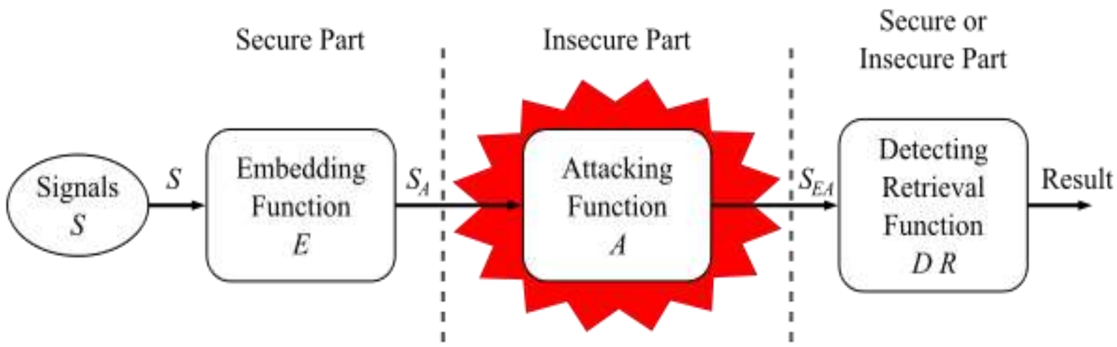

Figure 1**:** Digital Watermarking Life Cycle

2.2.1 Watermarking Using DWT

Discrete wavelet transform (DWT) is a transform-domain technique where the watermark is embedded by modulating the magnitude of coefficients in a transform domain, such as wavelet transform. Due to its excellent spatial-frequency localization properties, the DWT is very suitable to identify areas in the cover image where a watermark can be imperceptibly embedded. The main idea behind DWT results from multiresolution analysis, which involves decomposition of an image in frequency channels of constant bandwidth on a logarithmic scale. It has advantages such as similarity of data structure with respect to the resolution and available decomposition at any level. The DWT can be implemented as a multistage transformation. An image is decomposed into four sub bands denoted 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. 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.

2.2.2 Watermarking Using SVD

Singular value decomposition (SVD) is a transform-domain technique where the watermark is embedded by modulating the magnitude of coefficients in a transform domain. One of attractive mathematical properties of SVD is that slight variations of singular values do not affect the visual perception of the cover image, which motivates the watermark embedding procedure to achieve better transparency and robustness. From the perspective of image processing, an image can be viewed as a matrix with nonnegative scalar entries. The SVD of an image A with size m×m is given by $A = USV^T$, where U and V are orthogonal matrices, and $S = diag(\lambda i)$ is a diagonal matrix of singular values λi, i = 1, . . . , m, which are arranged in decreasing order. The columns of U are the left singular vectors, whereas the columns of V are the right singular vectors of image A. 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.

III. Proposed Hybrid Model Of Watermarking Using Dwt & Svd

In this approach, the watermark is not embedded directly on the wavelet coefficients but rather than on the elements of singular values of the cover image's DWT sub bands. Since performing SVD on an image is computationally expensive, this study aims to develop a hybrid DWT-SVD based watermarking scheme that requires less computation effort to yield better performance. After decomposing the cover image into four sub bands by one-level DWT, we apply SVD only to the intermediate frequency sub bands and embed the watermark into the singular values of the afore mentioned sub bands to meet the imperceptibility and robustness requirements.

The main properties of this approach can be identified as:

- It needs less SVD computation than other methods
- Unlike most existing DWT-SVD-based algorithms, which embed singular values of the watermark into the singular values of the cover image, our approach directly embeds the watermark into the singular values of the cover image to better preserve the visual perceptions of images.

The DWT-SVD watermarking scheme can be formulated as given here.

a) 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.

$A^k = U^k S^k V^{kT}$, k= 1, 2 (1)

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.,

$S^k + \alpha W^k = U_w^k S_w^k V_W^{kT}$ (2)

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.

$A*^k = U^k S_W^k V^{kT}$, k= 1, 2 (3)

6) Obtain the watermarked image by performing the inverse DWT using two sets of modified DWT coefficients and two sets of non modified DWT coefficients.

The block diagram representation of the above mentioned procedure of watermark embedding is shown in figure 2.

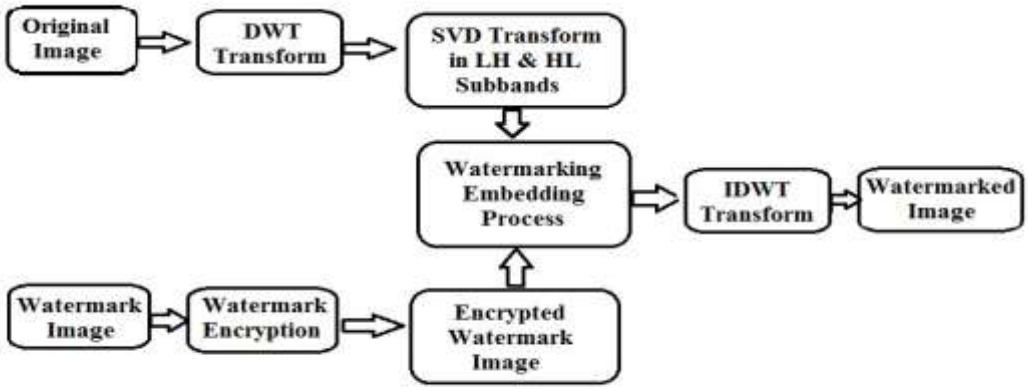

Figure 2: Watermark embedding

b) 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.

$A_W^{*k} = U^{*k} S_W^{*k} V^{*kT}$, k= 1, 2 (4)

Where k represents one of two sub bands.

3) Compute $D^{*k} = U_W^{k} S_W^{*k} V_W^{kT}$, 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)

5) Combine the results of Step 4 to obtain the embedded watermark:

$W^{*} = W^{*1} + W^{*2}$.

The block diagram representation of the above mentioned procedure of watermark extraction is shown in figure 3.

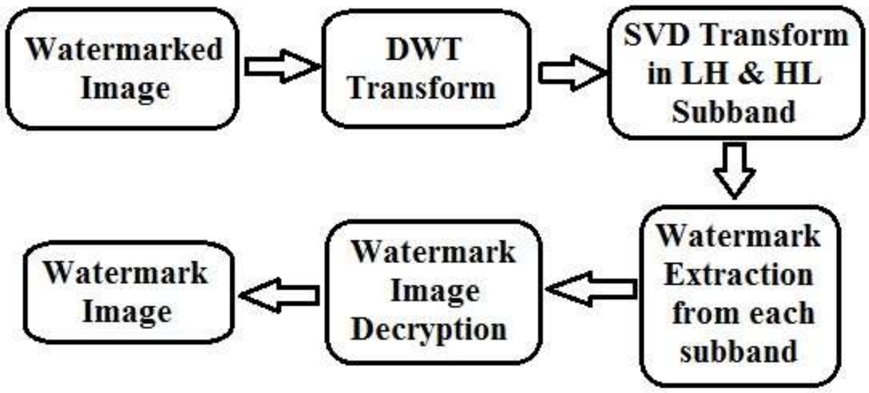

Figure 3: Watermark Extraction

c) Sequence Followed

The approach mainly dealt with the following items in sequence

1. Representing an image in the form of a Matrix
2. **Taking out the Transformation let it be DWT or SVD**
3. Embedding the watermark/secret image with the cover image to get the watermarked image
4. Neglecting fine details which also involves in elimination of noise
5. **Reconstructing the watermark image from the watermarked image.**
6. **Calculating the PSNR for various levels of approximations and comparing them.**

Transformation and Reconstruction

DWT performs wavelet decomposition of vector X with respect to a particular wavelet or particular wavelet filters that you specify. Instead of transmitting the original matrix as a whole, proper choice of these coefficients is made out and only selected coefficients are transmitted. The reverse procedure is carried out while reconstructing the image. The inverse transformation is carried out for each of the available coefficients and the representation matrix is obtained. IDWT carries out Wavelet reconstruction.

PSNR (Peak signal to noise ratio)

As a measure of the quality of a watermarked image, the peak signal-to noise ratio (PSNR) was used. We use the PSNR as an objective means of performance. PSNR is used to measure the difference between two images. It is defined as

$$PSNR=20* \text{Log}_{10} (b/rms)$$

Where b is the largest possible value of the signal (typically 255 or 1), and rms is the root mean square difference between two images. The PSNR is given in decibel units (dB), which measure the ratio of the peak signal and the difference between two images. An increase of 20 dB corresponds to a ten-fold decrease in the rms difference between two images. There are many versions of signal to noise ratios, but the PSNR is very common in image processing, probably because it gives better sounding numbers than other measures.

IV. Result And Performance Analysis

4.1 Result Using DWT Scheme of Watermarking

- The cover image and the watermark image to be watermarked are shown in the figure 4 and figure 5 respectively.

Figure 4: Original Cover Image

Figure 5: Watermark Image

- The watermarked image obtained from the DWT scheme is shown in figure 6.

Figure 6: Watermarked Image Using DWT

- Figure 7 and Figure 8 represents the difference between the original cover image and the watermarked image and key generated respectively.

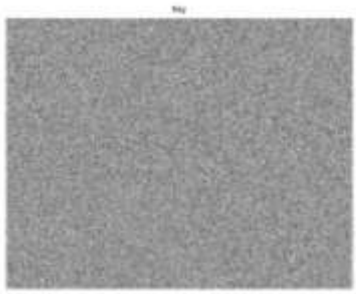

Figure 7: Difference Image

Figure 8: Key Generated

- The calculated **PSNR** values in DWT scheme with different scaling factor (α) are listed in Table 1.

α = 0.01	**α = 0.05**	**α = 0.09**
40.1538	**38.8375**	**37.0752**

Table 1: PSNR values for different scaling factor in DWT scheme

4.2 Result Using SVD Scheme of Watermarking

- Figure 9 and figure 10 shows the watermarked image and watermarked with noise image after SVD technique respectively.

Figure 9: Watermarked Image

Figure 10: Watermarked and Noised Image

- The watermark image can be reconstructed from the watermarked image and the recovered watermark image is shown in the figure 11.

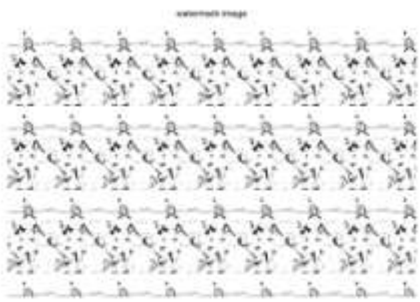

Figure 11: Recovered Watermark Image

- Figure 12, 13, 14 and 15 shows the watermarking of a text file in cover image using SVD scheme of watermarking.

Figure 12: Cover image

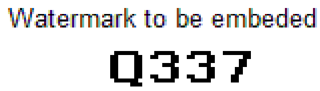

Figure 13: Watermark to be embedded

Figure 14: Watermarked image

Figure 15: Watermarked and noised image

- The watermark text can be reconstructed from the watermarked image. The recovered watermark image is shown in the figure 16.

Figure 16: Recovered watermark image

- The calculated **PSNR** values in SVD scheme with different scaling factor (α) are listed in Table 2.

α = 0.01	**α = 0.05**	**α = 0.09**
40.2439	38.9437	37.0012

Table 2: PSNR values for different scaling factor in SVD scheme

4.3 Result using the hybrid DWT-SVD Scheme of Watermarking

- The figures 17 and 18 show the cover image and the gray scale converted image of the cover image used in DWT-SVD scheme of watermarking

Figure 17: Cover image

Figure 18: Gray scale converted image

- The figures 19 and 20 show the watermark image and the gray scale converted image of the watermark image.

Figure 19: Cover image

Figure 20: Gray scale converted image

- The figures 21 and 22 show the SVD image of the cover image and watermarked image after applying DWT-SVD technique.

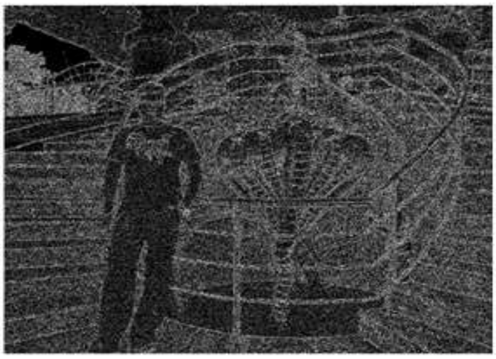

Figure 21: SVD image

Figure 22: Watermarked image

- The calculated **PSNR** values in DWT-SVD scheme with different scaling factor (α) are listed in the Table 3.

α = 0.01	**α = 0.05**	**α = 0.09**
40.4387	39.0513	37.1996

Table 3: PSNR values for different scaling factor in DWT-SVD scheme

Here three watermarking schemes namely: Watermarking using DWT, SVD and a hybrid model using DWT & SVD are implemented and compared. Watermark extraction was performed on watermarked images using these three models. The output images and results are observed to compare the performance of these schemes. The values of the scaling factors are taken as 0.01, 0.05 and 0.09 and the results are illustrated in Table 4.

WATERMARKING SCHEME	PSNR, WITH α =0.01	PSNR, WITH α =0.05	PSNR, WITH α =0.09
DWT	40.1538	38.8375	37.0752
SVD	40.2439	38.9437	37.0012
DWT-SVD	40.4387	39.0513	37.1996

Table 4: Comparison of PSNR for DWT, SVD and Hybrid model DWT-SVD Scheme of Watermarking

V. Conclusion

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: Spatio-frequency localization of DWT and SVD efficiently represents intrinsic algebraic properties of an image. The results show that the proposed hybrid DWT-SVD scheme has both the significant improvement in imperceptibility and the robustness. It is observed that the larger the scaling factor, the stronger is the robustness of the applied watermarking scheme and it can withstand a variety of image-processing attacks. In addition to quantitative measurement, the hybrid model has also given better visual perceptions of the extracted watermarks. Thus the DWT-SVD hybrid model watermarking scheme significantly outperforms the other two schemes of watermarking.

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