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Robust Digital Color Image Watermarking in Hybrid Domain RDWT-DCT-SVD

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Abstract: *Digital watermarking techniques have been proposed for copyright protection and authentication of multimedia data. In this paper we are providing one such watermarking scheme for color images.The suggested method presents a watermarking scheme based on a Redundant Discrete Wavelet Transform (RDWT), Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD) in which two level RDWT is applied on the host image which results in four frequency bands LL2, LH2, HL2 and HH2. As it is found that lower frequency band is less prone to attack, so the singular values of the DCT Transformed coefficients of the LL2 band of the image are being modified using the singular values of the DCT transformed coefficients of the watermark by using scaling factor. Modification of the appropriate sub-band leads to a watermarking scheme which favorably preserves the quality. The experimental performance of the proposed system is analyzed against different types of attacks, the results show that the proposed RDWT-DCT-SVD method provide the improved imperceptibility, robustness under attacks, provide high data capacity and preserve copyrights. The results demonstrated that the proposed method is more robust to various attacks compared to DWT-DCT-SVD based method.*

Keywords: *Redundant Discrete Wavelet Transform, Singular Value Decomposition, Discrete cosine Transform, Hybrid RDWT-DCT-SVD, Peak signal-to-noise ratio (PSNR), Normalize Correlation (NC).*

I. Introduction

Now-a-days, the digital data transmission over the internet is getting increased, and tampering, copyright protection and illegal modifying become an important concern to protect the interest of data providers as well as data producers. Thus, ease of these illegal things lead to insecurity in data transmission. Various techniques have been developed for data protection and digital watermark is one of them.[1]. Watermarking is the process of embedding data in the content. A watermarking algorithm consists of the watermark structure, an embedding algorithm, and an extraction, or a detection algorithm. The watermarking procedure should maintain the following properties: the watermark should be undetectable and secret for an unauthorized user, the watermark should be invisible or inaudible in the information carrying signal and finally, the watermark should be robust on the possible attacks. The attacks include image processing operations like compression, smoothing, blurring, sharpening, or even cropping. [2].

For an effective watermarking technique [3,4], the watermark should be: (i) imperceptible: there should not be any visibledifference between the watermarked content and the original, (ii) secure: no other watermark other than the embeddedwatermark should be extracted from the watermarked content. This reduces ambiguity on the ownership of the content.No one without the secret key may know the locations of where the watermark is embedded in the host, (iii) robust: thewatermark should be able to withstand to some extent of content manipulation. There is no such watermark scheme thatcan perform well under all hostile attacks. However, with the growing need of sophisticated watermarking applications, weneed a scheme that should perform well under a specific set of conceivable attacks.

In the classification of watermarking schemes, an important criterion is the type of information needed by the detector.

- Non-blind schemes require both the original image and the secret key(s) for watermark embedding.
- Semi-blind schemes require the secret key(s) and the watermark bit sequence.
- Blind schemes require only the secret key(s).

The most important uses of watermarks include copyright protection (identification of the origin of content, tracing illegally distributed copies) and disabling unauthorized access to content. The requirements for digital watermarks in these scenarios are different, in general. Identification of the origin of content requires the embedding of a single watermark into the content at the source of distribution [5,6]. To trace illegal copies, a unique watermark is needed based on the location or identity of the recipient in the multimedia network. In both of these applications, non-blind schemes are appropriate as watermark extraction or detection needs to take place in special laboratory environment only when there is a dispute regarding the ownership of content. For access control, the watermark should be checked in every authorized consumer device, thus requiring semi-blind or blind schemes. Note that the cost of a watermarking system will depend upon the intended use, and may vary considerably. [7]. Watermarking can be performed in the spatial [8]transform domain [9]. Spatial domain methods are less complex but are not as robust as transform domain methods against various attacks [2]. One of the most common techniques in transform domain watermarking is to modify the coefficients obtained from singular value decomposition (SVD) of the cover image. The SVD based watermarking algorithm was first presented by Liu et al. [5]. In this algorithm, the authors after applying singular value decomposition to the cover image to modify these coefficients by adding the watermark. They apply SVDtransform again on the resultant matrix for finding the modified singular values. These singular values were combined with the known component to get the watermarked image.

In another similar work,Chandra et al. [10], embed singular values of the watermark in the singular values of entire host image.The most important drawback of SVD-based algorithms is quality degradation of the watermarked image. In addition, the extracted watermark is not robust enough against common attacks in SVD based algorithms. Thus researchers, usually combine SVD with other algorithms such as DCT and DWT. In [11], authors combined DWT-DCT with SVD technique. In that paper, after decomposing the hostimage into four sub-bands, then DCT is applied to each sub-band then SVD is applied to obtain singular values and embedded singular values of the watermark into the sub-bands. When DWT-DCT is combined with SVD technique the watermarking algorithm outperforms the conventional DWT algorithm with respect to robustness against rotation, compression and cropping attacks. Despite good performance of DWT methods in Watermarking, they suffer from drawbacks which are mentioned in section II. To overcome the drawbacks of DWT based watermarking, one solution is the use of Redundant Discrete Wavelet Transform (RDWT). In this paper, color image watermarking using hybrid RDWT-DCT-SVD method is proposed in which the two levelRDWT has been applied on host image to decompose the host image into four non-overlapping sub-bandsin order to perform thewatermarking. The sub-band LL2 is considered on which DCT is applied and then SVD is applied to obtain singular values. The singular values of the watermark image arethen embedded into singular values of LL2 sub-band of cover image. To obtain the watermarked image, inverse transform is applied and same process is followed for the extraction purpose. The experimental results depict the improved imperceptibility and robustness under different types of attack.

II. Background review

Section II contains the frequency domaintransform being used for watermarking. Redundant Discrete WaveletTransform, Discrete cosine transform and Singular Value Decomposition are themethods that are elaborated in this section and worked on.

A. Redundant Discrete Wavelet Transform (RDWT) : One of the most common methods used for watermarking is DWT[12,13], but one of the main drawback of this method is that because of the down-sampling of its bands, it does not provide shift invariance. This causes a major change in the wavelet coefficients of the image even for minor shifts in the input image. The shift variance of DWT causes inaccurate extraction of the cover and watermark image [7],since in watermarking, we need to know the exact locations of where the watermark information is embedded, to overcome this problem, researchers have proposed Redundant Discrete Wavelet Transform. To describe RDWT, a 1D DWT and RDWT with their inverses are illustrated in Fig. 1(a) and Fig. 1 (b), where f[n] and f '[n] are the input and reconstructed signals. h[-k] and g[-k] are the low pass and high pass analysis filters and h[k] and g[k] are the corresponding low pass and high pass synthesis filters. c_j and d_j are the low-band and high-band output coefficients at level j. RDWT analysis and synthesis are given by[14] as follows:

a. Analysis:

$$c_j[k] = (c_{j+1}[k] * h_j[-k]) \qquad d_j[k] = (c_{j+1}[k] * g_j[-k]) \quad (1)$$

b. Synthesis:

$$c_{j+1}[k] = \frac{1}{2}(c_j[k] * h_j[k] + d_j[k] * g_j[k]) \quad (2)$$

where*denotes convolution. RDWT eliminates downsampling and upsampling of coefficientsduring each filter-bank iteration

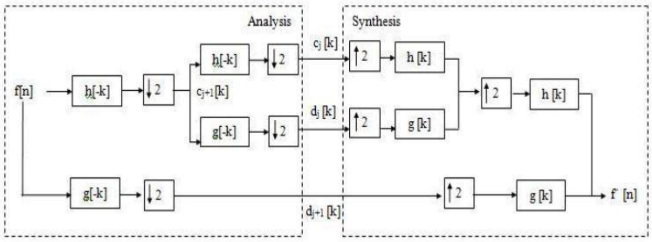

Fig. 1. (a) 1D DWT analysis and synthesis filter banks

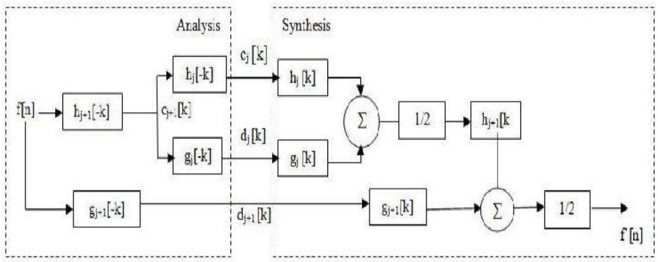

Fig. 1. (b) 1D RDWT analysis and synthesis filter banks

Redundant representation of the input sequence is obtained byeliminating downsampling in the RDWT analysis. Since frame expansion increases robustness withrespect to additive noise, RDWT based signal processing is more robust than DWT method.

B. Discrete Cosine Transform (DCT) : The Discrete Cosine Transform (DCT) is a Fourier-like transform. While the Fourier Transform represents a signal as the mixture ofsines and cosines, the Cosine Transform performs only the cosine-series expansion. Thepurpose of DCT is to perform decorrelation of the input signal and to present the output inthe frequency domain. The DCT is known for its high "energy compaction" property,meaning that the transformed signal can be easily analyzed using few low-frequencycomponents. It turns out to be that the DCT is a reasonable balance of optimality of theinput decorrelation (approaching the Karhunen-Loève transform) and the computationalcomplexity. DCT operates on 8x8 blocks and its inverse. The DCT is utilized in JPEG compression routines and has become a de-facto standard inimage and video coding algorithms and other DSP-related areas. The two-dimensional inputsignal is divided into the set of non-overlapping 8x8 blocks and each block is processedindependently. This makes it possible to perform the block-wise transform in parallel, which is the key feature of the DCT. The DCT transforms a signal from a spatial representation into a frequencyrepresentation. In an image, most of the energy will be concentrated in the lowerfrequencies, so if we transform an image into its frequency components and throwaway the higher frequency coefficients, we can reduce the amount of data needed todescribe the image without sacrificing too much image quality [15]. For a input image function f(x,y) with dimension of M × N, the 2D-DCT F(u,v) also has dimension M × N and is computed as

$$F(u,v)=\alpha_u \alpha_v \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) \cos\frac{(2x+1)u\pi}{2M} \cos\frac{(2y+1)v\pi}{2N} \quad (3)$$

where,

$$\alpha_u=\begin{cases} \sqrt{\frac{1}{M}}, & \text{if } u=0 \\ \sqrt{\frac{2}{M}}, & \text{if } 1\le u\le N-1 \end{cases} \quad \text{and } \alpha_v=\begin{cases} \sqrt{\frac{1}{N}}, & \text{if } v=0 \\ \sqrt{\frac{2}{N}}, & \text{if } 1\le v\le N-1 \end{cases}$$

Using DCT, an image is easily split into pseudo frequency bands and in this work watermark is inserted into middle band frequencies because as we discussed in all frequency domain watermarking schemes, there is a conflict between robustness and transparency.

C. Singular Value Decomposition (SVD)

The theory of linear algebra called singular valuedecomposition. SVD method can transform into product$A=U_A S_A V_A^T$ which allows us to refactoring a digital image inthree matrices.The using of singular values of suchrefactoring allow us to represent the image with a smallerset of values, which can preserve useful features of theoriginal image. SVD method factors A into three matrices U,S, V such that

$$A=U*S*V^T \quad (4)$$

where U is an m×m orthogonal matrix and V is an n×northogonal matrix and S is m×n diagonal matrix of singular values of the original matrix arranged in decreasing order[16]. The usage of singular values volume to the robustness ofthe image, i.e. when any perturbation is added to the imagelarge variations in the singular values do not occur. Additivelysingular values represent intrinsic algebraic properties [15,16]. The basic idea behind SVD technique of watermarking is to find SVD of image and the altering the singular value to embed the watermark[7,19]. In digital watermarking schemes, SVD is used due to its main properties:

a. A small agitation added in the image, does not cause large variation in its singular values.

b. The singular value represents intrinsic algebraic image properties.

SVD has following advantages in digital image watermarking:

1. Singular value has interstices algebraic properties.
2. Size of matrices is not rigid.
3. Singular values in adigital image are not affected on small perturbation and isresistant under various attacks.

III. PROPOSED RDWT-DCT-SVD SCHEME

This algorithm combines the properties of RDWT, DCT and SVD. RDWT is used to decompose the original image into four band of frequency. DCT technique is applied on each band to collect significant coefficients in which watermark is to be hidden. SVD technique is applied to the watermark and it is hidden into the host image by adding the singular values of host image and singular values of watermark.

1. Algorithm for Watermark Embedding

Step 1: Let „H" be the host image to be watermarked.

Step 2: Apply two level RDWT to decompose the host image into four non-overlapping multi-resolution sub bands:

LL2, HL2, LH2, and HH2.

Step 3: Apply DCT to LL2 sub-band. Let „*A*" denote the matrix obtained after applying DCT.

Step 4: Apply SVD to decompose step 3.

$$A= U_A S_A V^T_A$$

Step 5: Let „W" be the watermark and proceed with the same steps [1-4] .

Step 6: Modify the singular values of host image with singular values of watermark images.

whereβ (0.02)is scaling factor, and are the diagonal matrices of singular values of the host image watermark images, respectively.

Step 7: Apply inverse SVD and DCT.

Step 8: Apply inverse RDWT to get the watermarked image.

2. Algorithm for Watermark Extraction

Step 1:Let ‘W*’ be the watermarked image.

Step 2: Apply two level RDWT to decompose the host image into four non-overlapping multi-resolution sub bands: LL2, HL2, LH2, and HH2. Step 3: Apply DCT to LL2 sub-band, let „*A**‟ denote the matrix obtained after applying DCT.

Step 4: Apply SVD to decompose step 3.

$$A^* = U_{A^*} S_{A^*} V^T_{A^*}$$

Step 5: Extract the singular values from the low frequency sub-band of watermarked and cover image:

$$S_W = (S - S_A)/\beta$$

where contains the singulars of the host image.

Step 6: Watermark image is extracted from sub-band of watermarked image.

Step 7: The process is done for retrieval purpose.

IV. Experiment Results

Experiments are conducted to demonstrate the proposed approach. The colored image “Pepper” of size 512 × 512 isused as the host image and “Lena” of size 512 × 512 isused as the watermark image. These images are shown in Fig.2(a) and 2(b) which are of the host image and watermarkrespectively. Fig. 2(c) is the watermarked image.

Fig. 2. (a) Host Image

Fig. 2. (b) Watermark

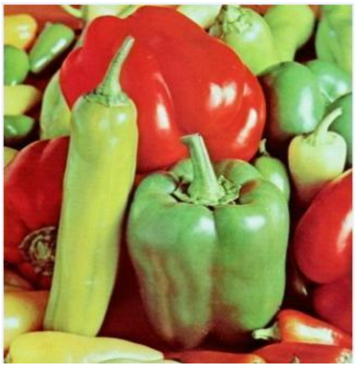

Fig. 2. (c) Watermarked

Table I.Watermarkingand Extraction of watermarks with and without attacks

Attack Type	Attacked Watermarked Image	Extracted Watermark
No Attack		
Salt and Pepper Noise (**'salt & pepper'**, 0.03)		
Speckle Noise (**'speckle', 0.03)**		
Gaussian Noise (**'gaussian',0, 0.01)**		
Image Rotation **(45°)**		
Cropping **(50%)**		

The observation of the proposed approach yields the preserved high perpetual quality of the watermarked image. As a parameter of quality, peak signal-to-noise ratio (PSNR) has been used [16]. The PSNR illustrates the maximum fluctuation of pixels with the mean square error of the images and helps in easy analysis of the variations and degradations being caused on the image by comparing the peaking pixel values. PSNR and MSE can be computed as –

$$PSNR = 10 \log_{10} (R^2 / MSE) \quad (4)$$

$$MSE = sum\, [(H1\, (m, n) – H2\, (m, n))^2] / m*n \quad (5)$$

where, R is the maximum fluctuation of pixels and m, n are the row and column matrix of the images.

In watermark embedding process, scaling factor β is set to 0.02. Two-level of wavelet decomposition of host image are used. To verify the presence of watermark, different measures can beused to show the similarity between the original and the extracted singular values. In the proposed algorithm, normalized correlation coefficient (NC) is used to measure the similarity. Correlation coefficient is used to measure the similarity between watermarks and extract watermark image. Correlated Coefficient is the number that lies between [−1, 1]. If the value of Correlated coefficient is equal to 1 then the extracted singular values are just equal to th e original one, if it is −1 then the difference is negative for the largest singular values. To contemplate the robustness of the presented approach the watermarked image is tested against various attacks. Table I demonstrates the effect of noise on the watermarked image and the extracted watermark with high robustness and

Table II.Comparison of proposed technique with DWT-DCT-SVD in terms of PSNR and NC

	DWT-DCT-SVD		RDWT-DCT-SVD	
Attack type	**PSNR**	**NC**	**PSNR**	**NC**
No attack	52.89	0.9987	54.89	0.9998
Salt& pepper noise **(salt & pepper',0.03)**	42.96	0.9897	43.96	0.9997
Speckle noise **('speckle',0.03)**	40.29	0.9896	44.78	0.9996
Gaussian noise **(gaussian',0,0.01)**	34.93	0.9887	40.93	0.9987
Image Rotation **(45,'bilinear','crop)**	31.11	0.9016	40.03	0.9906
Cropping **(50%)**	30.89	0.9088	40.12	0.9488
Sharpening **(30%)**	34.58	0.9213	43.58	0.9593

imperceptibility. In order to prove the performance of this algorithm, this paper compares experiments through the PSNR and NC in Table II, the results indicated that the algorithm outperform under various noise and geometrical attacks. Table II gives the extracted results PSNR and NC on, speckle noise, salt and pepper noise, Gaussian noise rotation, cropping, sharpening attack. After attack, the watermark can be correctly extracted and have very low visual distortion. The peak signal-to-noise ratio (PSNR) is used as a measure of the quality of a watermarked image. PSNR is more than 40db shows imperceptibility and robustness.

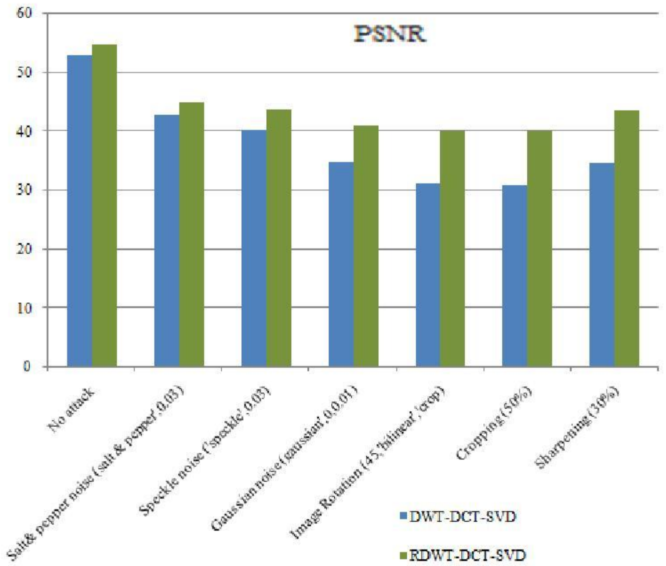

Fig. 3. Comparison of proposed technique with DWT-DCT-SVD in terms of Peak Signal to Noise Ratio (PSNR)

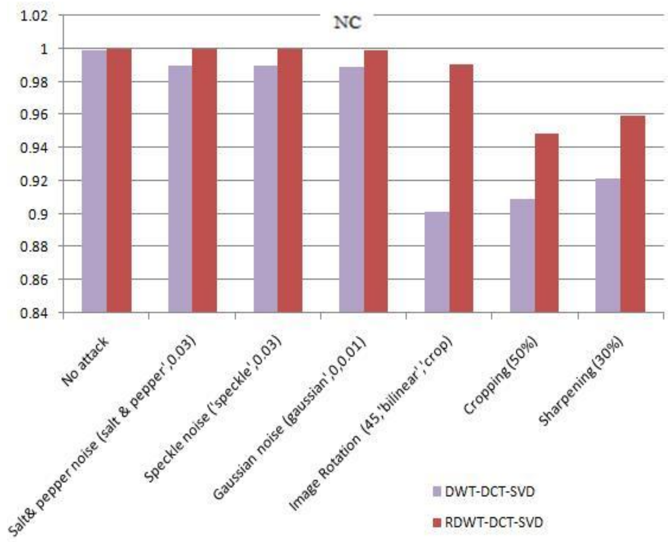

Fig. 4. Comparison of proposed technique with DWT-DCT-SVD in terms of Normalized Correlation (NC)

The comparison of the proposed technique RDWT-DCT-SVD with DWT-DCT-SVD in terms of PSNR and NC is demonstrated in the graphs as shown in Fig. 3 and Fig. 4. So, this algorithmcan well withstand such noise attacks as well as geometrical attack. It also has good imperceptibility, robustness high security and big watermark capacity.The robustness of the image is of great authentication and proves to enhance the copyrights and amenable to various attacks being forecast on the image.

V. Conclusion

In the paper, a new watermarking method based on RDWT-DCT-SVD is presented to embed a watermark image which can be as large as the cover image.From the results, it is observed that by increasing the level of decomposition and using RDWT with DCT and SVD, the robustness and imperceptibility is improved. Modifying singular values of the cover image in RDWT domain provide high robustness against common attacks. High PSNR and correlation coefficient of watermarked image is another beneficial point of the algorithm as the result of RDWT implementation. The results demonstrated that the proposed method is more robust to various attacks compared to DWT based methods. RDWT is shift invariant, and its redundancy introduces an over complete frame expansion. It is known that frame expansion increases robustness with respect to additive noise. Thus, RDWT based signal processing tends to be more robust than DWT based techniques. Another advantage of this method is the possibility to embed a large watermark in the cover image.
The new method was found to satisfy all the requisites of an ideal watermarking scheme such as mperceptibility, robustness and good capacity. This method can be used for authentication and data hiding purposes.

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