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Strictly as per the compliance and regulations of:

Digital Color Image Watermarking using DWT-DCT Coefficients in RGB Planes

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Abstract - Digital image watermarking is used to identify the authenticity and integrity and to show the identity of its owners. This paper presents a more secure method for copy right protection. In the proposed method, the color image is decomposed into 3 color channels Red, Green and Blue and then DWT and DCT are applied to B channel of the R, G and B channels. The colored Watermark image is decomposed into R, G, B channels and DCT is applied to all the channels separately. R, G, B channels of watermark image are embedded into mid frequency coefficients of B channel already selected. The performance of proposed algorithm is measured by using Mean Square Error, Peak Signal to Noise Ratio, Standardized Correlation and Normalized Correlation. A comparative study of proposed scheme with the existing methods which uses DWT-DCT transforms is carried here and results shown.

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I. Introduction

Now a days we can transmit any type of information either data(in the form of image) or images(pictures) by using the Internet. The data may also accessible by unauthorized persons while transmit data through ordinary commercial information transmitting channel like Internet. So for providing data security we need advanced authentication methods. One of such authentication method is digital watermarking.

Data hiding techniques can be classified into 2 types: Spatial domain [1] and Transform domain [2 3 4 5].Transform domain techniques are Discrete Wavelet Transform (DWT) [2, 3, 4], Discrete Cosine Transform (DCT) [5] and Discrete Fourier Transform (DFT). Spatial domain techniques are Least Significant Bit insertion (LSB) etc. In our proposed method we use combination of Discrete Wavelet Transform and Discrete Cosine Transform [6 7] for embedding the watermark images.

In our proposed method we embed the watermark image in the blue channel. Cones are the sensors in the human eye responsible for color vision. Detailed experimental evidence has established that the 6 to 7 million cones in the human eye can be divided into three principal sensing categories, corresponding roughly to red, green and blue. Approximately 65% of all cones are sensitive to red light, 33% are sensitive to green light, and only 2% are sensitive to blue light. Human eye is less sensitive to blue light, so we embed the image in blue channel.

The performance is measured by the PSNR, SC and NC and also apply different attacks like salt & Pepper, Gaussian Blur, Gaussian Noise, Sharpening& Cropping and analyze the results.

a) Discrete Wavelet Transform

Discrete Wavelet Transform [24] decomposes an image into 4 multi-resolution sub-bands. Those are LL1, LH1, HL1, HH1.In this LL1 contains the original information and HH1 contains edges and textures. If we embed the watermark information in LL1 and HH1 the image quality is disturbed. So, we cannot embed the watermark information in these two sub-bands. The human visual system is less sensitive to HL1 than LH1. So, we can identify the sub-band HL1 then apply the 2nd level DWT to that sub-band and we get LL2,LH2,HL2,HH2 sub-bands and select HL2 for embed the watermark.

b) Discrete Cosine Transform

The sub-band (HL2) divided into 8×8 blocks. Apply DCT [27] to each block. Each block contains low-frequency, mid-frequency and high-frequency sub-bands. Generally we choose the mid-frequency sub-bands for embedding the watermark image. If we compress the image then high-frequency coefficients are generally removed. The low-frequency sub-bands are the visualized components. So we can't insert in low and high-frequency sub-bands.

II. Proposed Method

This method involves the following steps:

1. Decompose the image into 3 color components: red, green and blue.
2. Apply 2 levels DWT to Blue channel and then convert it into frequency components using DCT.
3. For providing security embed the watermark into Blue color component.

a) Watermark Embedding Algorithm

1. Select any color image as the original image 'OI'. Decompose the image into 3 color components R, G and B.
2. Apply DWT to B channel. Then we get multi-resolution sub-bands LL1, HL1, LH1, and HH1.
3. Apply DWT again to HL1 and we get LL2, HL2, LH2 and HH2.Select the HL2 sub-bands.

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4. Divide the HL2 sub-band into 8X8 size blocks (consider each block as cell).
5. Apply DCT to each cell of HL2 sub-band.
6. Select any color watermark image 'WI'. Obtain the R, G, B channels of WI.
7. Apply DCT to each R, G and B channels separately.
8. Embed one pixel of every R, G and B channels of Watermark image WI into each cell of HL2.
9. Apply IDCT to the each cell of HL2 sub-band.
10. Apply 2 levels IDWT to B channel.
11. Combine the R, G and B channels to get the watermarked image 'WMI'.

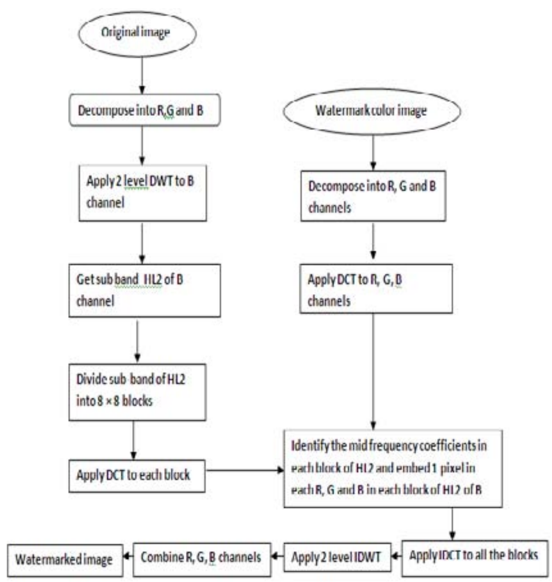

Figure 1 : Watermark Embedding Algorithm

b) Watermark Extraction Algorithm

1. Take the watermarked image 'WMI' and decompose into R, G and B channels.
2. Apply DWT to B channel. Then we get multi-resolution sub-bands LL1, HL1, LH1, and HH1.
3. Apply DWT again to HL1 and we get LL2, HL2, LH2 and HH2.Select the HL2 sub-bands.
4. Divide the HL2 sub-band into 8X8 size blocks (consider each block as cell).
5. Apply DCT to each cell of HL2 sub-band.
6. Extract the first bits of watermark from first cell of B channel and placed in first positions of WR, WG and WB channels. Extract the second bits of watermark from the second cell of B channel and placed in second positions of WR, WG and WB channels.
7. Repeat the previous step until we get all the pixels into the WR, WG and WB channels of 'WI' separately.
8. Apply IDCT to WR, WG and WB channels.
9. Combine WR, WG and WB channels, then we get Extracted color watermark image 'EWI'.

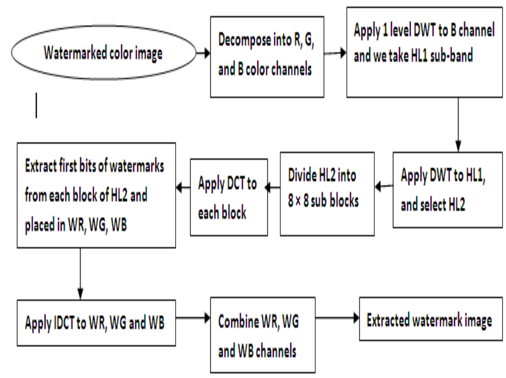

Figure 2 : Watermark Extraction Algorithm

III. Performance Analysis

The performance of watermarked image is calculated by the two error matrices Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) between Original Image and Watermarked Image. The quality of Extracted Watermark is calculated by Normalized Correlation (NC) and Standard Correlation (SC) between watermark image and Extracted Watermark image.

The following are the equations for calculating MSE, PSNR, NC and SC.

a) Mean Square Error (MSE)

MSE and PSNR are the two error metrics used to compare watermarked image quality. The MSE represents the cumulative squared error between the watermarked image and the original image, whereas PSNR represents a measure of the peak error. The lower the value of MSE, the lower the error.

To compute the PSNR, the block first calculates the mean-squared error using the following equation:

$$MSE=\frac{\sum_{R,G,B}\sum_{i=1}^{M}\sum_{j=1}^{N}(OI[i,j]-WMI[i,j])^2}{3MN}$$

Where M and N are the height and width of the image. OI is the Original Image and WMI is the Water marked Image.

b) Peak Signal to Noise Ratio (PSNR)

$$PSNR=10\log_{10}\left[\frac{R^2}{MSE}\right]$$

In the previous equation, *R* is the maximum fluctuation in the input image data type. For example, if the input image has a double-precision floating-point data type, then *R* is 1. If it has an 8-bit unsigned integer data type, *R* is 255, etc.

c) Normalized Correlation (NC)

$$NC=\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(WI[i,j]EWI[i,j])}{\sum_{i=1}^{M}\sum_{j=1}^{N}(WI[i,j])^2}$$

Where WI [i, j] is the original watermark image and EWI [i, j] is the extracted watermark image .M is the Height and N is the Width of the image.

d) Standard Correlation (SC)

$$SC=\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(WI[i,j]-WI1)(EWI[i,j]-EWI1)}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(WI[i,j]-WI1)}\ \sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(EWI[i,j]-EWI1)}}$$

Where WI [i, j] is the original watermark image andWI1 is the mean of original watermark image, EWI [i, j] is the extracted watermark image and EWI1 is the mean of the extracted watermark image.

IV. Results

We use 3 color images candle, flower, lotus and leaf of size 1024 × 1024 for testing this method. The watermark image used for embedding is shown in figure4 of size 32 × 32.The figure 3 shows the results before watermarking and after watermarking of the original color image. Figure 4 shows the results of watermark and extracted watermarking.

Figure 3 : Candle, flower, lotus and leafimages before and after embedding watermark

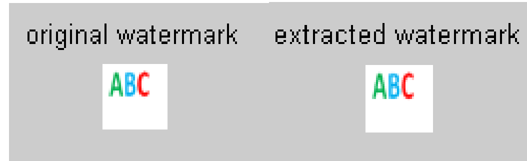

Figure 4 : Original watermark and extracted watermark images

V. Analysis

We analyze the proposed method by calculating the MSE and PSNR between original image and watermarked image, by calculating the NC and SC between Original watermark image and Extracted watermark image.Table1 shows the MSE, PSNR between original and watermarked images for candle, flower, lotus and leaf images.Table2 shows the NC, SC between original watermark and extracted watermarked images for candle, flower, lotus and leaf.

Table 1 : MSE, PSNR between original and watermarked images

Image	MSE	PSNR
Candle	$3.5699e^{-005}$	92.6042
Flower	$4.4328e^{-005}$	91.6640
Lotus	$3.5049e^{-005}$	92.6841
Leaf	$3.5678e^{-005}$	92.6068

Table 2 : NC and SC between original and extracted watermark images candle, flower, lotus and leaf

Image	NC	SC
Candle	1	1
flower	1	1
Lotus	1	1
leaf	1	1

a) Attacks

Salt & Pepper noise with noise density 0.002 is added to the watermarked images, Gaussian blur with disk radius 1,sharpening with parameter 0.5,cropping with 20 percent, Gaussian noise is added with length=2 and theta=4 and the corresponding PSNR of the original and watermarked after attack, NC of the original watermark and extracted watermark after attack.

Table 3 : PSNR of Extracted watermark from watermarked images after attacks

	PSNR(dB)			
	Candle	Flower	Lotus	Leaf
Salt and Pepper	79.6051	79.1953	79.3784	79.7989
Gaussian Blur	89.1485	76.3084	94.6734	88.8786
Sharpening	75.5086	63.5381	79.8306	75.2392
Gaussian Noise	78.2971	78.3414	78.3462	78.0324
Cropping	90.1163	89.0328	90.1372	89.9924

Table 4 : NC between original watermark and extracted watermark after attacks

	NC			
	Candle	Flower	Lotus	Leaf
Salt and Pepper	1	0.9995	1	1
Gaussian Blur	0.9974	0.9974	0.9974	0.9974
Sharpening	0.9507	0.9507	0.9507	0.9507
Gaussian Noise	0.9998	0.9998	0.9998	0.9998
Cropping	1	1	1	1

b) *Comparison Results*

Table 5 shows the comparison results with the existing transformation methods Bi-Ortho [7], DCT- Coef [21], DWT-DCT based on the NC value between original watermark and extracted watermark if the watermarked image undergoes any attacks.

Table 5 : Comparison with existing methods

Attack	Bi-Ortho	DCT-Coef	DWT-DCT
Salt and Pepper	0.8518	0.998	0.9995
Gaussian Blur	--	0.998	0.9974
Sharpening	--	0.995	0.9507
Gaussian Noise	0.8575	0.996	0.9998
Cropping	0.8484	0.920	1

VI. Conclusion

This robust watermarking technique is proposed for increasing the security of data hiding and robustness and quality compared to existing algorithms. For improving the security we use the frequency transformations DWT and DCT applied to the Blue channel of original image and embed the color watermark image.

Our future work is to implement Video watermarking by embed the watermark image in the video instead of image.

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