Color Image Watermarking Scheme using DWT and DCT Coefficients of R, G and B Color Components

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ABSTRACT
Digital image watermarking is the technology used to protect copy right information of multimedia objects. This paper presents a more secure method for copyright protection. In this scheme color image is decomposed into R, G, B channels and then DWT and DCT transformations are applied on these channels separately. The bits of watermark image are embedded into middle frequency coefficients of transformed R, G, B channels. Results reveal the performance of proposed algorithm using the metrics Peak Signal to Noise Ratio and Normalized Correlation and comparison of proposed scheme with the existing methods which used DWT-DCT transformations.

Keywords
Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), Peak Signal to Noise Ratio (PSNR), Normalized Correlation (NC).

1. INTRODUCTION
Digital watermarking is a branch of information concealment, which hides ownership information inside the cover image. Digital image watermarking techniques developed so far can be categorized into two types according to the processing domain of cover image. They are spatial-domain [1] and frequency-domain [2, 3, 4, 5] watermarking techniques. Imperceptibility and robustness are the essential requirements for any watermarking algorithm. Frequency-domain watermarking techniques provide more imperceptibility and robustness.

Two types of frequency-domain transforms, viz. DWT [2, 4, 5] and DCT [3] are most popularly employed in watermarking. DWT is used to get multi-resolution i.e. horizontal, vertical and diagonal components of an image. DCT separates each block of image into low, mid and high frequency bands. The reason behind amalgamating these two transforms is to at once overcome the inherent drawbacks in each of them eventually sharpening the technique.

Researchers are using DWT–DCT combination [6, 7] for embedding watermark into color images. This paper proposes an efficient algorithm based on DWT–DCT blend. The bits of watermark image are embedded into DWT-DCT transformed R, G and B channels of color image. To make the watermark more secure, we encode coefficients of one color channel with indices of the other color channel.

Performance of the proposed algorithm is measured by the standard metrics like Peak Signal to Noise Ratio (PSNR) and Normalized Correlation (NC). It is more robust and protracts common attacks such as Gaussian noise, Salt & pepper noise, Poisson noise, Gaussian Blur, Sharpening, etc.

The rest of the paper is organized as follows. Section 2 holds proposed method. Section 3 consists of the description of performance metrics. Results and analysis are given in Section 4.

2. PROPOSED METHOD
Our proposed method involves following steps

1. Decomposition of color image into its R, G, B channels.
2. Each color channel is decomposed into three spatial components using DWT.
3. Applying DCT to convert these components into respective frequencies.
4. Embedding bits of watermark image into mid frequency coefficients.

2.1 Decomposition of Color Image
A color image contains three channels called red, green and blue channels. We can easily divide a color image into its red, green and blue channels and similarly red, green and blue channels can simply be combined to get the corresponding color image.

2.2 Discrete Wavelet Transform
Wavelets are best in replicating the anisotropic properties of Human Visual System. Discrete Wavelet Transform decomposes an image into four multi-resolution components LL, LH, HL and HH by applying 2-D filters in each dimension. Embedding watermark into LL component corrupts the quality of image. If watermark is embedded into HH component then the presence of watermark may easily be identified. Usually watermark is embedded into either LH or HL component to achieve adequate performance of imperceptibility and robustness.

2.3 Discrete Cosine Transform
In DCT transformation the image is divided into non-overlapping blocks and then DCT is applied on each block. This confers low-frequency, mid-frequency and high-frequency sub-bands. Watermark is commonly embedded in mid-frequency sub-band as the low-frequency sub-bands contains significant visual components of image and high-frequency sub-bands are generally removed when the image is compressed.

2.4 Watermark Embedding Algorithm
Figure 1 shows the watermark embedding algorithm. Here, we are applying DWT and DCT transformations on the red, green and blue channels of the cover image to get transformed image and then embedding bits of grayscale watermark image into mid-frequency bands of transformed image. The steps in embedding algorithm are explained as follows.

1. Select any color image as cover image denote it by 'I'. Obtain R, G and B channels of cover image 'I'.
2. Apply DWT to R, G and B channels separately to get the multi-resolution sub-bands LL_1, HL_1, LH_1, and HH_1.
3. Apply DWT again to HL_1 (or LH_1) sub-bands of R, G and B channels and select HL_2 (or LH_2) sub-bands of R, G and B channels.
4. Divide the HL_2 (or LH_2) sub-bands of R, G and B channels into blocks of size 8×8.
5. Apply DCT to each of the blocks obtained in previous step.
6. Convert the watermark 'w' into string of 0's and 1's.
7. A bit is embedded in only one block out of the corresponding blocks of R, G and B channels (first bit is embedded in the first block of G channel alone leaving R and B channels. The second bit is embedded in the second block of B channel avoiding R and G channels. The third bit is embedded in third block of R channel and the cycle repeats where two channels are spared every time.)
8. The number of bits that can be embedded corresponds to the number of blocks in R or G or B channel.
9. To embed first bit, calculate average of middle band coefficients of first block of R component.

   To hide bit '0' : Identify the first coefficient R(i, j) of the middle band whose value is less than the average of the middle band coefficients, marking a value 'k' at the location G(i, j) of the first block of G channel.

   To hide bit '1' : Identify the first coefficient R(i, j) of the middle band whose value is greater than the average of middle band coefficients, marking value 'k' at the location G(i, j) of the first block of G channel.
10. To embed second bit use second blocks of G and B channels. Repeat this process for all bits of the watermark.
11. Apply IDCT to the blocks of R, G and B channels separately.
12. Apply IDWT for 2 levels to each of R, G and B channels separately.
13. Combine R, G and B channels to get watermarked image 'WI'.

2.5 Watermark Extraction Algorithm

Figure 2 demonstrates the watermark extraction algorithm. Extraction algorithm uses only watermarked image to extract the watermark and is elucidated as follows.

1. Obtain R, G and B channels of watermarked image 'WI'.
2. Apply DWT to R, G and B channels separately to obtain the multi-resolution sub-bands LL_1, HL_1, LH_1, and HH_1.
3. Apply DWT again to HL_1 sub-bands of R, G and B channels and select HL_2 sub-bands of R, G and B channels.
4. Divide the HL_2 sub-bands of R, G and B channels into blocks of size 8×8.
5. Apply DCT to each of the blocks obtained in previous step.
6. First bit of watermark is extracted from first blocks of R and G channels, Second bit from second blocks of G and B channels, third bit from third blocks of B and R channels and so on.
7. To extract first bit from the first blocks of R and G channels, calculate average of middle band coefficients of first block of R channel and then identify the coefficient R(i, j) of the middle band whose value is equal to 'k'. If the value of coefficient G(i, j) of first block of G channel is less than the average of middle band coefficients then interpret the bit as '0'. Otherwise, if it is greater than average then interpret the bit as '1'.
8. To extract second bit from the second blocks of G and B channels, calculate average of middle band coefficients of first block of G channel and then identify the coefficient G(i, j) of the middle band whose value is equal to 'k'. If the value of coefficient B(i, j) of first block of B channel is less than the average of middle band coefficients then interpret the bit as '0'. Otherwise, if it is greater than average then interpret the bit as '1'.
9. Repeat this process in a cycle to B and R channels and so on to extract all bits of the watermark.

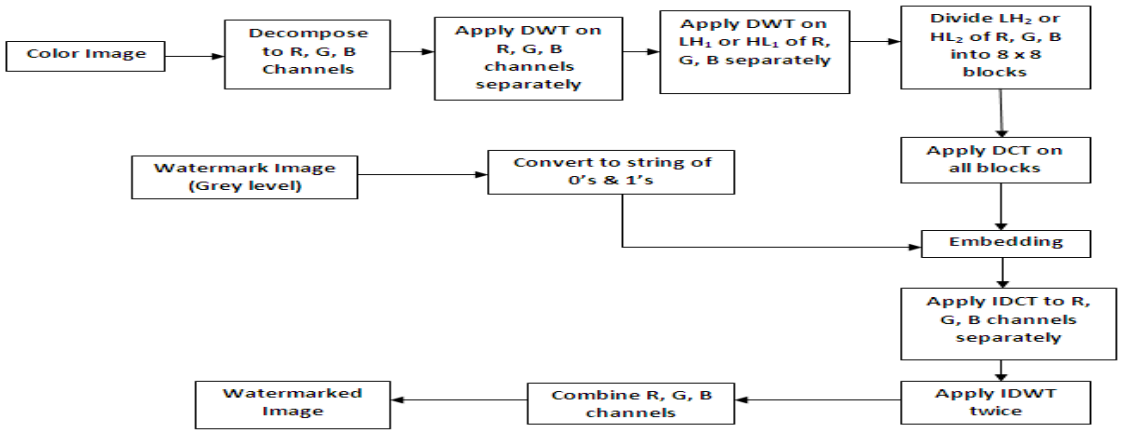

Fig 1: Watermark embedding process

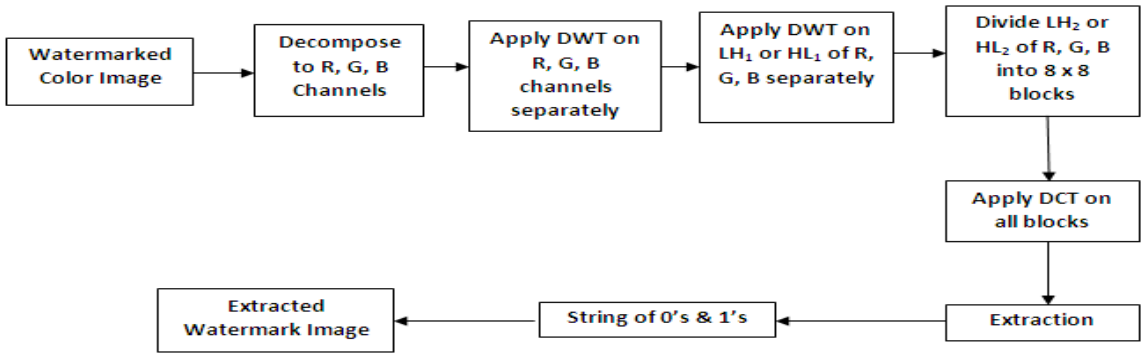

Fig 2: Watermark extraction Process

3. PERFORMANCE EVALUATION METRICS

The quality of watermarked image is studied with peak signal to noise ratio (PSNR). Watermark image quality is analyzed using Normalized Correlation (NC) between the extracted and the original watermark.

Peak Signal to Noise Ratio is calculated by the following formula

$$\text{PSNR}=\log\frac{(2^n-1)^2}{\text{MSE}}$$

Where n is the number of bits used for color representation and MSE refers to the Mean Square Error between original and watermarked image and is calculated with the formula.

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

Here, M and N are the height and width of image respectively. I[i, j] indicates the (i, j)th pixel value of the original image and I'[i, j] specifies the (i, j)th pixel value of watermarked image.

Normalized correlation is one of the metrics used to find the quality of extracted watermark image with respect to the original watermark image. It is found by using the following formula.

$$\text{NC}=\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}w(i,j)w'(i,j)}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}w(i,j)\text{^}2}\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}w'(i,j)\text{^}2}}$$

Here, w(i, j) is the original watermark, w'(i, j) is the extracted watermark.

4. RESULTS AND ANALYSIS

We used a color image of flower with size 512×512 to test our method. Figure 3 shows the test image before watermarking.

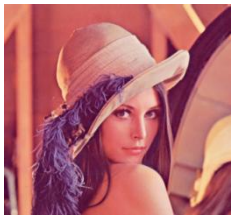

Fig 3: Original image

Fig 4: Watermark image

Figure 4 is the watermark image. Watermarked image is shown in Figure 5.

Fig 5: Watermarked image

Table 1 shows PSNR value of watermarked image and NC value of extracted watermark image when the watermarked image is not attacked and undergoes any attack like Gaussian noise, salt & pepper noise, Poisson noise, Gaussian blur, sharpening and image manipulation operation like, JPEG compression is applied.

Table 1. PSNR and NC values

Attack / Operation	PSNR	NC
No attack	84.7692	1.0000
Gaussian noise	65.4625	0.9841
Salt & Pepper noise	65.4823	0.9696
Poisson noise	84.8863	0.9999
Gaussian blur	84.2531	0.9993
Sharpening	78.6435	0.9982
JPEG compression	75.8326	0.9812

Table 2 summarizes comparison results of the proposed method with the existing methods that are using DWT-DCT transformation [8] based on the NC value between original and extracted watermark when the watermarked image undergoes any attacks.

Table 3 demonstrates the watermarked image of flower without any attack and under different types of attacks. It also shows the extracted watermark when the watermarked image undergoes different types of attacks.

Table 2. Comparison results

Attack / Operation	DWT-DCT	RGB
No attack	1.0000	1.0000
Gaussian noise	0.9828	0.9841
Salt & Pepper noise	0.9674	0.9696
Poisson noise	-	0.9999
Gaussian blur	0.9938	0.9993
Sharpening	0.9970	0.9982
JPEG compression	0.9714	0.9812

Table 3. Watermarked and extracted watermark images

Attack / Operation	Watermarked Image	Extracted Watermark
No attack		
Gaussian noise		
Salt & Pepper noise		
Poisson noise		
Gaussian blur		
Sharpening		
JPEG compression		

5. CONCLUSION

At present digital technology is rapidly increasing because of globalization. The technology shows its effects on cybercrimes too. Hence to reduce this kind of incidents here we propose a new method by using DWT and DCT. In the proposed method the R, G, B channels of cover image are transformed using DWT and DCT and then watermark image is embedded into mid frequency coefficients. To improve security, data embedding location of one color channel is placed in other color channel. Experimental results based on attacks confirm that the proposed algorithm performs better than the other DWT-DCT based schemes and is more robust. Proposed scheme is not robust against rotation and cropping attacks and our future work is to design a method, which sustain these attacks.

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