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# An Improved DWT-SVD Based Robust Digital Image Watermarking for Color Image

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## Abstract

The Digital Watermarking Technique has gained its importance due to its ability to provide the secure mechanism for copyright protection and authenticity of the digital data in this high growing internet and computer technology where the tampering and distribution of digital data illegally from unauthorized users is inevitable. For these two important properties of Digital Watermarking, i.e. Robustness and Imperceptibility of watermarked image must take into consideration. In this paper, invisible robust digital watermarking is proposed using Discrete Wavelet Transform and Singular Value Decomposition in YCbCr Color space. The performance of the proposed algorithm is compared with some previous works and results found are more robust against various geometric attacks.

**Index Terms:** Non-Blind Digital Watermarking, Discrete Wavelet Transform, Singular Value Decomposition, Alpha Blending, Arnold Transformation.

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## 1. Introduction

The rapid growth of internet technology has increased exchange and transmission of digital information. Due to this, it demanded the need of techniques and methods to prevent the tampering and illegal distribution of digital data. One of the techniques used to achieve copyright protection and authenticity of digital data is Digital Watermarking. Digital watermarking is the act of hiding a message related to a digital signal (i.e. An image, song, and video) within the signal itself. Watermarking tries to hide a message related to the actual content of the digital signal [1]. There are several applications of Digital Watermarking such as Broadcast Monitoring, Owner Identification, Proof Ownership, Transaction Tracking, Content Authentication, Copy Control and Device Control [2] [3].

The watermarking techniques fall into two categories. Spatial-Domain methods and Frequency Transform

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Domain methods [4] [5]. In Spatial Domain, it directly manipulates digital data to hide the watermark. Its main advantage is low computational complexity. However, this method is vulnerable to different attacks. In frequency domain, digital data to be protected are converted into a frequency domain. Compared to spatial domain methods, it needs more computation, but it can provide better robustness from different attacks [6].

According to distinction, the watermarking system can be classified as Blind, Semi-Blind and Non-Blind [7]. The Blind watermarking scheme is also known as public watermarking scheme. This is the most challenging type of watermarking system as it requires neither the cover (original data), nor the embedded watermark. These systems extract  $n$  bits of the watermark data from the watermarked data (i.e. the watermarked image). The Semi-blind watermarking scheme is also known as semi-private watermarking scheme. This system does not require the cover (original data) for detection. The purpose of this system is to find whether that the watermark can be detected. Non-blind watermarking scheme is also known as private watermarking scheme. This system requires at least the cover (original data) for detection. The System extracts the watermark from the possibly distorted data and uses the original data as a hint.

The paper is organized as follows: Section 2 describes related works, Section 3 described the fundamental concept, in brief, Section 4 describes the proposed Scheme, and Section 5 describes the experimental results. The paper concluded in Section 6 followed by references.

## **2. Related Works**

A number of earlier works related to digital image watermarking inspired us to do this research. Some of such recent researches are briefly described in this section.

R. Kaur and H. Singh [13], introduced DWT-DCT-SVD based digital watermarking and implement different attacks on watermarked image such as Gaussian Noise Attack, Salt and Pepper attack and Compression attack. The maximum NC value recorded was 0.995 for Salt and Pepper noise attack. M. Chaudhary, S. Srivastava and V. Chaubey [14], introduced digital watermarking based on DWT-DCT-SVD and Salt and Pepper as an attack on watermarked image. The maximum PSNR value recorded was 19.0941 dB after the Salt and Pepper attack on the watermarked image. S. R. Hallur, S. Kuri and G. H. Kulkarni [15], proposed a DWT-DCT-SVD based color image digital watermarking in RGB Planes. Different attacks such as AWGN Noise, JPEG 50% compression, Median filter, Wiener filter, Gaussian Filter, Salt and pepper etc. The the maximum recorded NC value was 1. C. N. Sujatha and P. Satyanarayana [16], proposed DWT-DCT-SVD based color image digital watermarking in RGB planes. Different attacks such as Gaussian Noise, Salt and pepper, Compression, Median Filtering, Average filtering, Sharpening, Rotation etc. to check the robustness of the watermarked Image. The the maximum recorded NC value was 0.9800 for Autumn image for sharpening attack. K. Chaitanya, S. Reddy and G. Rao [17], proposed a color image digital watermarking in RGB planes using DWT-DCT-SVD Coefficients. The the maximum recorded NC value was 0.99 without attack. N. Divecha and D. N. N. Jani [18], proposed a Non-Blind DWT-DCT-SVD based digital watermarking technique for RGB image. Different attacks like JPEG 50%, Rotation, Cropping, Gaussian Noise, Gamma Correction, etc. are carried out to check the robustness of the watermarked image. The the maximum recorded NC value was 0.987 for pepper image for Gaussian noise attack. M. A. Rahman and M. M. F. Rabbi [19], proposed a Non-Blind DWT-SVD based watermarking technique for RGB Image. 3-Level DWT is applied on each RGB planes of The cover image and watermark. The SVD is applied to embed the watermark into the cover image. Different attacks like Gaussian, Laplacian, Sobel, Average, Prewitt, Cropping etc. are carried out to check the robustness of the watermarked image. The PSNR value after attacks seems to be at around 54db to 8db with different attacks. S. Shekhawat and S. Yadav [20], proposed a NonBlind DWT Based Multiplicative SVD Watermarking Algorithm. 1 -Level DWT is applied to the red component of the RGB planes and SVD is applied to embed the watermark into the cover image. J. Guru, H. Dhamecha and B. Patel [21], proposed a Digital Watermarking using a fusion of DWT and SVD. 1 -Level DWT is applied to the red component of the RGB planes and SVD is applied to embed the watermark into the cover image. Different attacks such as Salt and Pepper Noise, Speckle Noise are carried out to check the robustness of the algorithm.

### 3. Concepts

#### 3.1. Discrete Wavelet Transform

Discrete wavelet transformation is based on small waves of limited duration and varying frequency. This is a frequency domain technique in which the firstly the cover image is transformed into the frequency domain and then its frequency coefficients are modified in accordance with the transformed coefficients of the watermark and watermarked image is obtained which is very much more robust. DWT decomposed image hierarchically, providing both spatial and frequency description of the image. It decomposes an image in basically three spatial directions, i.e. horizontal, vertical and diagonal in result separating into four different components, namely LL, LH, HL and HH. Here the first letter refers to applying either low pass frequency operation or high pass frequency operations to the rows and the second refers to the filter applied to the columns of the cover image. LL level is the lowest resolution level, which consists of the approximation part of the cover image and rests three levels, i.e., LH, HL, HH give the detailed information of the cover image.

For the second level of decomposition, any one sub-band is selected and is further decomposed into four levels. The maximum the level of decomposition, the maximum will be the robustness of the watermarked image. At every level of decomposition, the magnitude of DWT coefficients is larger in lower bands (LL), and is smaller in other three bands (LH, HL and HH). The larger magnitude of wavelet coefficients shows their higher significance in comparison with the wavelet coefficients of smaller magnitude. Human Visual System is more sensitive to the low frequency parts (the LL sub-band), so the watermark is preferably placed in other three sub-bands to retain the quality of the original image [10].

#### 3.2. SVD (Singular Value Decomposition)

Singular Value Decomposition transform is a linear algebra transform which is used for factorization of a real or complex matrix with numerous application in various fields of image processing. As a digital image, can be represented in a matrix form with its entries giving the intensity value of each pixel in the image, SVD of an image  $M$  with dimension in  $m \times m$  is given by.

$$M=USV^T \quad (1)$$

Where,  $U$  and  $V$  are orthogonal matrices and  $S$  known as singular matrix is a diagonal matrix carrying non-negative singular values of matrix  $M$ . The columns of  $U$  and  $V$  are call left and right singular vectors of  $M$ , respectively. They basically specify the geometry details of the original image. Left singular matrix, i.e.  $U$  represents the horizontal details and right singular matrix, i.e.,  $V$  represents the vertical details of the original image. The diagonal value of Matrix  $S$  is arranged in decreasing order which signifies that importance of the entries is decreasing from the first singular value for the last one, this feature is employed in SVD based compression techniques. [10]

There are two main properties of SVD to employ in digital watermarking scheme.

- Small Variation in singular values does not affect the quality of image and
- Singular Values of an image have high stability so; they don't change after various attacks.

#### 3.3. Alpha Blending

In Digital Watermarking, the Alpha Blending Technique can be used for embedding watermark into the cover image and extracting watermark from the watermarked image using the below equations, [12].

For Watermarking Embedding,

$$WMI = k * (LL1) + q * (WM1) \quad (2)$$

For Watermarking Extraction,

$$RW = (WMI - k * LL1) / q \quad (3)$$

Where, WMI=Watermarked Image, LL1=Frequency Approximation of the Original Image, WM1=Watermark Image, RW=Extracted Watermark Image and k, q are the scaling factors of the original image and watermark respectively.

### 3.4. Arnold Transformation

Arnold transform is used to scramble the watermark image. Arnold transformation is posed in the research of Arnold and the Ergodic theory, which is also called face transformation. For N\*N image, Arnold transform is defined as

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} \text{mod}(N) \quad (4)$$

Where x, y are the coordinates of the watermark image and x', y' are the coordinates after scrambling and N is the size of the watermark image. The time of restoring a watermark image after scrambling by using Arnold transform is rising with increasing the image size [6].

### 3.5. YCbCr Color Space

YCbCr is a family of color space used as a part of the color image pipeline in video and photography system. Y is the luma component that shows the brightness and Cb and Cr are blue difference and red difference Chroma components. YCbCr is not an absolute color space; rather, it is a way of encoding RGB information. RGB to YCbCr conversion can be obtained from the following equations

$$\begin{aligned} Y &= 0.299R + 0.587G + 0.114B \\ Cb &= 0.596R - 0.272G - 0.321B \\ Cr &= 0.212R - 0.532G - 0.311B \end{aligned} \quad (5)$$

## 4. Proposed Algorithm

The algorithm proposed here is a Non-Blind Digital Watermarking where there is a need of the cover image for the watermark extraction.

### 4.1 Watermark Embedding

1. Read RGB Color The cover image
2. Convert RGB Color Image into YCbCr each color space
3. Select by Color channel and apply 4-level DWT to subdivide the image into LL4, LH4, HL4 and HH4
4. Select HH4 sub-band and apply SVD to that sub band, resulting CU, CS, CV

5. Read Color watermark image
6. Extract R Channel from RGB Color Watermark
7. Apply Arnold Transformation to Scramble the R Color Channel.
8. Apply 3-level DWT on the scrambled R Channel to divide the image into WLL3, WLH3, WHL3 and WHH3
9. Select WHH3 sub band and apply SVD to that sub band, resulting WU, WS, WV
10. Embed watermark to the cover image using following alpha blending equation
11.  $SNEW = CS * k + q * WS$  where k and q are scaling factor
12.  $S = CU * SNEW * CV$
13. Apply inverse 4-Level DWT on S to obtain Y Channel Watermarked Image
14. Combine Y, Cb and Cr color channels to form RGB Color Space watermarked image

#### 4.2 Watermark Extraction

1. Read The cover image and Watermarked Image
2. Convert The cover image and Watermarked Image From RGB Color Space to YCbCr Color Space
3. Apply 4-Level DWT on Y Channel of The cover image to sub divide the cover image into HLL4,HLH4,HHL4 and HHH4
4. Apply 4-Level DWT on Y Channel of Watermarked Image to subdivide the Watermarked Image into WMLL4, WMLH4, WMHL4 and WMHH4
5. Read Color Watermark Image
6. Extract R,G and B Channel from RGB Color watermarkImage
7. Apply Arnold Transformation to Scramble the R Color Channel.
8. Apply 3 level DWT on scrambled R channel to divide the it into WLL3, WLH3, WHL3 and WHH3
9. Select WHH3 sub band and apply SVD to that sub band, resulting WU, WS, WV
10. Select a HHH4 sub - band and apply SVD to that sub band, resulting CU, CS, CV
11. Select WMHH3 sub-band and apply SVD to that sub band, resulting WMU, WMS, WMV
12. Extract watermark using following alpha blending equation
13.  $SNEW = (WMS - q * CS) / k$  where k and q are scaling factor
14.  $S = WU * SNEW * WV$
15. Apply Inverse 3-Level DWT on S
16. Apply Anti-Arnold Transformation to unscramble the image extracted from Step15
17. Combine R, G and B Color Channel to get the RGB Color Watermark

## 5. Experiments and Results

In this section, experimental results of the proposed method are presented. The algorithm is realized in C#. The performance is evaluated using Peak Signal to Noise Ratio (PSNR) and Normalized Cross-Correlation (NC). The Standard RGB color images (Lena and Pepper) of size 512x512 are used as the cover image and RGB color image of size 256x256 is used as the watermark image. The cover images and watermark image are shown in figure 1. Two major tests, imperceptibility and robustness are carried out with varying values of scaling factor k and q and results are compared with other existing watermark algorithms.



Fig.1. Standard Test and Watermark Image (a) Pepper (b) Lena (c) Watermark

### 5.1. Imperceptibility Test

Imperceptibility is measure of transparency and is measured via performance measures like a peak signal to noise ratio (PSNR) and Mean Square Error (MSE). The peak signal to noise ratio (PSNR) is typically used as a measure for the imperceptibility of a watermarked image using performance measures. If  $W$  is the original image and  $W'$  is modified image, then PSNR is calculated as

$$PSNR_{dB} = 20 \times \log_{10} \left( \frac{MAX}{\sqrt{MSE}} \right) \quad (6)$$

Where MSE= Mean square Error is given by

$$MSE = \frac{1}{m \times n} \sum_{k=1}^m \sum_{l=1}^n (f(k, l) - f'(k, l))^2 \quad (7)$$

Where,  $f(k, l)$  is host image and  $f'(k, l)$  is watermarked image to determine the optimum value of  $k$  and  $q$ , both are varied from 0.01 to 0.90 and best value of PSNR, MSE and NC are recorded at  $k=0.3$  and  $q=0.9$ . The Table 1 shows the recorded value of PSNR for Lena and Pepper.

Table 1. PSNR and MSE (The cover image vs. Watermarked Image) for Pepper and Lena with  $q=0.3$  and  $k=0.9$

Image	MSE	PSNR (dB)	NC
Peppers	0.98828	48.1819	0.9999
Lena	1.3015	47.9971	0.9999

Figure 2 below shows the watermarked Pepper image and Lena image



Fig.2. Watermarked Image (a) Pepper (b) Lena

## 5.2. Robustness Test

To test the robustness of the proposed algorithm, different geometric attacks were performed on the watermarked image and watermark was extracted. Robustness of image was tested by comparing the similarity of extracting a watermark image with the original watermark image. Similarity of watermarks were carried out on the basis of normalized cross correlation (NC).

NC is expressed as follows

$$NC = \frac{\sum \sum [W(u,v)W'(u,v)]}{\sqrt{\sum \sum W(u,v)^2} \sqrt{\sum \sum W'(u,v)^2}} \quad (8)$$

The Table below shows the NC value between the original watermark and extracted watermark at k=0.3 and q=0.9

Table 2. NC (Original watermark Image vs. Extracted watermark) for Pepper and Lena with q=0.3 and k=0.9

Attacks	Pepper	Lena
JPEG Compression 10%	0.9998	0.9999
JPEG Compression 50%	0.9999	0.9999
Rotation 5 Degree	0.9999	0.9999
Rotation 45 Degree	0.9999	0.9999
Rotation 90 Degree	1	1
Normal Blur	0.9998	0.9999
Gaussian Blur	0.9998	0.9998
Motion Blur	0.9998	0.9999
Salt and Pepper (80)	0.9996	0.9996
Gaussian Noise	1	1
Contrast Stretching	1	1
Sharpening	0.997	0.9972
Histogram Equalization	0.9998	0.9999
Gray Scale	1	1
Median Filter	0.9999	0.9999
Mean Filter	0.9998	0.9999
Top Cropping	1	1
Bottom Cropping	1	1
Left Cropping	1	1
Right Cropping	1	1
Center Cropping	1	1

The recorded NC values are close to 1 which depicts high similarity between the original watermark and extracted watermark after different geometric attacks. The different geometric attacked watermarked pepper image is shown in figure 3.



Fig.3. Geometric attacked Pepper Watermarked Images

### 5.3. Comparison with existing Algorithms

For Comparison, the performance measures recorded for proposed algorithm were compared with performance measures of 3 other existing algorithms. The same cover image and watermark that was used by comparing algorithm was used to compare the performance measures.

Table 3. Comparison of Robustness between Proposed Algorithm and Referenced Algorithm

Attacks/Image	Referenced Algorithm [16]	Proposed Algorithm
<b>Autumn</b>	<b>NC</b>	<b>NC</b>
Gaussian Noise	0.9797133	0.999962
Salt and Pepper (80)	0.9799189	0.999464
JPEG Compression	0.9795032	0.999943
Median Filter	0.9795671	0.999965
Average Filter	0.9795031	0.999948
Sharpening	0.9800366	0.998923
Rotation	0.9795475	0.999968
Histogram Equalization	0.9798538	0.999929
Right Cropping	0.9766723	0.999997
Left Cropping	0.9763842	0.999997
Top Cropping	0.9732001	0.999997
Bottom Cropping	0.9730237	0.999997
Motion Blur	0.9794848	0.99995



The NC value of the proposed algorithm observed to be better for geometric attacks listed in table 3 than that of reference algorithm.

Table 4. Comparison of Robustness between Proposed Algorithm and Referenced Algorithm

<b>Attacks/Image</b>	<b>Referenced Algorithm [15]</b>	<b>Proposed Algorithm</b>
<b>Pepper</b>	<b>NC</b>	<b>NC</b>
AWGN Noise	0.9983	0.99998
JPEG Compression 50 %	0.9999	0.99996
Median Filter	0.9999	0.99994
Gaussian Filter	1	0.99991
Salt and Pepper	0.999	0.99993
Sharpen Image	1	0.99822
Image Rotation 45	0.9997	0.99996
Image Rotation 90	0.9999	1

The NC value of the proposed algorithm observed to be better for geometric attacks listed in table 4 than that of reference algorithm.

Table 5. Comparison of Robustness between Proposed Algorithm and Referenced Algorithm

<b>Attacks/Image</b>	<b>Referenced Algorithm [18]</b>	<b>Proposed Algorithm</b>
<b>Peppers</b>	<b>NC</b>	<b>NC</b>
JPEG 20%	0.9995	0.999839
Crop	0.9992	0.999996
Rotation 45	0.9988	0.999901
Gamma Correction 0.8	0.999	0.999919
Gamma Correction 1.2	0.9991	0.999911
Gaussian Noise	0.985	0.999989
Contrast Adjust	0.9991	0.999994
Salt and Pepper	0.994	0.999594
Sharpen	0.9952	0.996976

The NC value of the proposed algorithm observed to be better for geometric attacks listed in table 5 than that of reference algorithm.

The proposed algorithm seems to be very robust for different geometric attacks as compared to the other existing watermarking algorithm because of the following reasons. The YCbCr Color Space is used instead of RGB Color space as, RGB Color Channel is complex in describing the color pattern and has redundant information between each component and are highly correlated. Also, according to [11], embedding watermarks in the color channels of YCbCr are more robust and imperceptible than RGB Color Channels. The Arnold Transformation is used as an image scrambling technique to scramble the watermark image. The image scrambling technique is used as the pre-processing or post-processing, to transform a meaningful image into meaningless or disordered image in order to enhance the power to resist attacks and in turn increase the robustness [6]. For embedding watermark image in the cover image and extraction watermark from watermarked image, Alpha blending technique is being used. In this technique, two scaling parameters are opted for watermarking. With, Alpha Blending has two scaling factors, we can vary scaling factors for both watermark image and the original image to get better results for embedding and extraction of the watermark [12]. In this paper, 4 Level DWT is carried out for the cover image and 3 Level DWT for watermark image. The higher the DWT Level, the higher will be the robustness of the watermarked image [10].

## 6. Conclusion

In this paper, a DWT-SVD based digital watermarking was proposed using Alpha Blending and Arnold Transformation in YCbCr Color space. The proposed method is the Non-Blind Digital Watermarking where there is a need of the cover image for the watermark extraction. With the good value of PSNR that defines the imperceptibility, we can say that the cover image and watermarked image are visually same. And with high value of NC that defines the robustness, after different geometric attacks, shows the high similarity between the original watermark and extracted watermark. These readings show that the proposed algorithm seems to behave more robustness against different geometric attacks in comparison to referenced algorithms.

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