DC Coefficients Based Adaptive Color Image Watermarking Scheme in Transform Domain

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ABSTRACT

Digital watermarking is considered to be an important copyright protection mechanism for digital images. In this paper, watermarking algorithm for digital images is proposed in the transform domain. The proposed watermarking algorithm embeds the watermark by modulating the Discrete Cosine Transform (DCT) DC coefficients. DC coefficients are considered as robust components to insert a watermark, so that the watermarked image can withstand all kinds of attacks. In order to embed the watermark, the image data is transformed into frequency components using Discrete Wavelet Transformation (DWT) and Discrete Cosine Transformation (DCT). The DC components of the various DCT transformed blocks are used to insert the watermark. Moreover, in order to preserve the quality of images, scaling and embedding factors are calculated adaptively from the content of the cover images using Weibull distribution. The efficiency of the proposed algorithm is tested through various attacks and the obtained results are presented in this paper.

Keywords: Digital Watermarking, Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT), Singular Value Decomposition (SVD), Copyright Protection, Adaptive Watermarking.

1 Introduction

With the advent of technology, the Internet is exponentially expanding which in turn increases the amount of digital multimedia data being transferred through it such as images, videos, text data, audio data et cetera (D., 2010) (M., 1998) . This data has also become equally vulnerable to various malicious attacks. In order to protect the images from such attacks and avoid any kind of dispute over the image authorization, a technique called Digital Watermarking (DW) is used (H., 2003) . Digital Watermarking is a technique which embeds a piece of secret data called the watermark into an image, to avoid any copyright issues, ownership issues and image unauthorized reuse before being published in the market(D., 2010) (M., 1998) (H., 2003) (Su J. K., 1998) .It is equivalent to leaving a fingerprint in the cover image before being made

available to the public. The objective should be to alter the image in such a way that it should not affect the visual content of the original image. However, there are still many content owners who are reluctant to place their content for public access, considering the dearth of security and authorization attached to the content (M., 1998) . So it has become extremely necessary to provide the utmost content security and satisfaction to the content owners in order to have a willing contribution towards the open source concept of the Internet. Digital Watermarking is of two types: visible watermarking and invisible watermarking .This property of visibility is called the perceptibility of the watermark (D., 2010) (Su J. K., 1998) (Zhao J., 1998) (Wang B., 2009) . Since, the vulnerability of invisible watermark is usually quite high compared to the visible watermark, a novel, robust and adaptive invisible watermarking is proposed in this paper. Watermarking is quite often performed in two different working domains, one is called the spatial domain and the other is called the transform domain (Zhao J., 1998) (Yang W., 2011) . The former is the normal image space in which each pixel has some intensity value, which could be modified to insert watermark. The latter is normally used to provide high quality watermarked image known as transform domain watermarking, which is achieved by converting the spatial domain images through the application of transformation techniques. The transformation techniques which are commonly used are Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). The addition of watermark in the transform domain will not change the intensity values directly, and hence the change of intensity value per pixel is diminished in this approach (D., 2010) (Barni M., 1998) . In this paper, the proposed algorithm give better imperceptibility and robustness through the adaptive calculation of scaling factor which is used to adjust the strength of the watermark. In order to make the watermarking algorithm robust and also to make the impairment of the watermark minimum, the watermark insertion process is carried out in the transform domain. The original image to be watermarked is decomposed using various transformations like DWT, DCT and SVD techniques. Concerning the security prospective of the watermark, proper key value is selected from the cover image in order to give the owner exclusive access to extract the watermark from the watermarked image. The crux of the algorithm is to protect the watermark from malicious attacks and therefore to test the strength of the algorithm, the watermarked images are tested against various image processing attacks and are found to be robust against most of them.
The paper is orchestrated as follows; Review of related works is given in section 2. Preliminaries of DWT-DCT-SVD techniques are discussed in section 3.Proposed algorithm is discussed in section 4. Performance evaluation is elaborated in section 5. Concluding remarks are given in section 6.

2 Review Of Related Work

The primordial watermarking schemes used Least Significant Bit (LSB) manipulation to hide undetectable electronic watermark (Van Schyndel R. G., 1994) (Zhao J., 1995). Later, a DCT domain invisible watermarking scheme came, which could embed bits using bidirectional approach (Ruanaidh J. ., 1996). This embedding technique was applied to embed more bits in highly robust region by modifying significant coefficients. On the similar line, another DCT do-

main based spread spectrum approach was suggested in (Kankanhalli M. S., 1998), where N highest valued coefficients were used for inserting watermarks to make the watermark more robust to common attacks. Soon after this, researchers also started exploiting the hierarchical nature of the image wavelet representation by adding a Gaussian distributed random vector to all the high pass bands (Zhu W., 1999) to improve the previously applied techniques.
In (Podilchuk C. I., 1998), digital watermarking techniques for images and video signals were designed to exploit human visual system in order to provide an invisible but robust watermark. Their approach could be classified as image adaptive watermarks, which not only depended on the frequency response of the human eye but also on the properties of the image itself. Likewise recently in (Makbol N.M. and T.H, 2016), a block based approach to embed watermark in the DWT domain based on SVD and human visual system is proposed. It uses the entropy and edge entropy as HVS characteristics for selecting the significant blocks to insert the watermark in the host image. An image adaptive algorithm is suggested in (Andalibi M., 2015), for adding invisible grayscale logo watermark via adaptive logo texturization. It recasts the watermarking task into texture-similarity task based on the texture of the host image. Such adaptive techniques have been very fruitful in providing utmost security in the host image. Researchers have also used various mathematical tools such as Hadamard transformation (Chan H.T and C.J, 2015) and multivariate Cauchy distribution technique to insert watermark in the colour image in the past (Sadreazami H. and M.N.S, 2015). These image dependent mathematical tools provide the least visual effect in the host image and at the same time withstand any attacks intended to disrupt the watermark in it. In this proposal, the watermarking is carried out by combining features of DWT, DCT and SVD to construct watermarked image with minimum distortion and maximum robustness. In order to achieve robustness the watermarking algorithm is implemented in the transform domain.

3 Preliminaries

3.1 Discrete Wavelet Transform (DWT)

DWT is a wavelet transform in which the wavelets are discretely sampled. The major advantage of DWT over Fourier transform is that it provides the temporal resolution i.e. it contains both frequency and location information (Dubolia R., 2011). In this approach, the cover image is decomposed through wavelet transform and four different band frequencies are obtained. Each band consists of a complete spectrum of the entire image. The major energy of the image is concentrated in the low frequency band or the LL band. This band is considered to be the approximation image whereas the rest of the three bands contain vertical details, horizontal details and the diagonals details of the image (Wang B., 2009).

3.2 Discrete Cosine Transform (DCT)

DCT is another type of transformation which is also used to transform an image from spatial domain to frequency domain (Dubolia R., 2011). In DCT the resultant matrix consists of one

DC coefficient and the remaining coefficients are called AC coefficients. Since the major perceptible part of the image lies in the lower frequencies, the rest of the higher frequencies may be easily modified for inserting the watermark or removed to achieve higher compression. The DC coefficient at the first position of a matrix is the most significant value representing the average energy of the entire image (Santhi V., 2011)(Lusson F., 2013). These components are obtained through the below mentioned formula.
The forward transform is given by (3.1) and (3.2) and the inverse transforms by (3.3):

$$C(0,0) = \frac{1}{\sqrt{MN}} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} f(x,y) \tag{3.1}$$

$$C(u,v) = \frac{2}{\sqrt{MN}} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} f(x,y) cos\frac{(2x+1)u\pi}{2M}\ cos\frac{(2y+1)v\pi}{2N} \tag{3.2}$$

$$Where\ u = 1 \ldots M-1\ and\ v = 1 \ldots .N-1$$

$$f(x,y)\ = \frac{2}{\sqrt{MN}} \sum_{x=0}^{m-1} \sum_{y=0}^{n-1} c(u,v) cos\frac{(2x+1)u\pi}{2M}\ cos\frac{(2y+1)v\pi}{2N} \tag{3.3}$$

3.3 Singular Value Decomposition(SVD)

For a given matrix $A \in R^{mxn}$ the SVD is calculated as given in (3.4).

$$A\ =\ US(V^T) \tag{3.4}$$

where $U \in R^{mxm}$, $V \in R^{nxn}$ are the orthogonal matrices and $S \in R^{mxn}$ is a singular matrix. The singular matrix consists of non-zero elements along the diagonal and zero valued elements elsewhere. The orthogonal matrices should satisfy the properties given in (3.5) and (3.6).

$$UU^T =\ U^TU =\ I_m \tag{3.5}$$

$$VV^T =\ V^TV =\ I_n \tag{3.6}$$

These singular values are the representation of intrinsic algebraic image properties. The fundamental idea behind using SVD is that the addition of the perturbation in the singular values of an image will hardly make a difference to the perceptibility of the image. Therefore the image can be easily reconstructed with approximately the same visual perception even after the addition of noise (Liu R. Z., 2001)(Run R. S., 2012)(Ali M., 2014).

3.4 Weibull Cumulative Distribution

Weibull distribution is a well-known continuous probability distribution specifically used in the probability theory and statistics. It has a wide range of applications in the field of survival studies, breaking strength, animal bioassay and life expectancy. (3.7) gives the Weibull distribution.

$$f\left(x\right)\ =\frac{\alpha}{\beta}\frac{\left(x-\alpha\right)^{\delta-1}}{\beta}e^{-(x-\alpha)/\beta};\ \alpha<x<\infty\ ,\ \ \beta>0\ and\ \delta>0 \tag{3.7}$$

Weibull distribution can also be used to calculate the corresponding Weibull cumulative distribution function or the reliability function. It is characterized by parameters like location(α) , shape($\delta > 0$) and scale (β >0). The shape (δ) and scale (β) parameters in the probability cumulative function play a vital role in deciding the values while the location parameter in the formula is normally neglected and is considered here as zero (Asgharzadeh A., 2011). Weibull cumulative distribution function is given in (3.8).

$$F\left(x\right)=1-\ e^{\left(\frac{x-\alpha}{\beta}\right)^{\delta}};\ \alpha<x<\ \infty,\ \ \beta>0\ ,\ \ \delta>0 \tag{3.8}$$

Different combinations of scale and shape parameters give different values for the cumulative function and it is used for producing a key value for inserting the watermark in the image. The value of the reliability function will never exceed the value of 1 and this makes it an appropriate choice for this proposal.

Selection of the above mentioned parameters should minimize the distortion in the watermarked image. Therefore in the proposed watermarking algorithm, the parameters are considered as β=1 and δ=1.5. The selection of parameters values are not concrete since the set of values that the function provides are in the range of 0 to 1. Using our chosen value the maximum value that the function can achieve is 0.6321.

3.5 Conversion of Image from RGB to YIQ format

In general images in RGB color spaces can be converted into various other color spaces based on the requirements. The RGB components of Lena test image of size 512 X 512 is shown in Fig 1.

Figure 1: RGB components of Lena Image

In this proposal the cover image is converted from RGB color space into YIQ color space using (3.9).The Y component in the formula represents the luminance components of an image whereas I and Q components represent the chrominance space of the image (Liu Z., 2008).

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.274 & -0.322 \\ 0.211 & -0.523 & 0.312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{3.9}$$

The obtained YIQ components of the Lena test image are illustrated in the Fig 2.

Figure 2: YIQ components of Lena Image

4 Proposed Work

In the prospect of providing a robust watermarking scheme the proposed algorithm uses a pair of transformation techniques combined with the SVD technique. The entire watermarking procedure is represented in two parts namely the embedding algorithm and the extraction algorithm. In order to make the inserted watermark invisible, the scaling parameter is calculated from the content of the cover image instead of selecting it empirically. In the following section the procedure for calculating the adaptive scaling factor is presented.

4.1 Adaptive calculation of scaling factor

In order to calculate the adaptive scaling factor, the cover image A of size 512 x 512 is converted from RGB components into YIQ components. The Y component of the image is decomposed into frequency components using the DWT technique. The element in the middle frequency band LH is considered as one of the components for adaptive calculation of scaling factor. The absolute value of every element of matrix LH is taken and a new matrix is constructed called Z_{LH}. In order to keep the scaling factor between the range of 0 to 1, the normalization process is applied to each element of the matrix Z_{LH}. using the formula given in (4.1).

$$Z_1\,(i,j) = \frac{element(Z_{LH}) - \min(z_{LH})}{\max\,(z_{LH})\ - \min(z_{LH})}, \tag{4.1}$$

$$where\ i\ = 0,1,2,\ldots N-1\ and\ j\ =\ 0,1,2,3\ \ldots M-1$$

Weibull cumulative distribution is applied to the matrix Z_1 by selecting the appropriate value of scale and shape parameters, as shown in (4.2).

$$Z_2 = \ Wblcdf(Z_1,\ 1\ ,\ 1.5\ ) \tag{4.2}$$

In this proposal the value for scale parameter β is set as 1 and the shape parameter δ is set as 1.5. The mean value of Z_2 is calculated using (4.3) and to avoid zero mean value of the parameter, β_1 is added with minimum value of 0.001, as shown in (4.4).

$$\mu_1 = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n} Z_2(i,j) \tag{4.3}$$

$$\alpha_1 = \beta_1 + \mu_1 \tag{4.4}$$

The same procedure is applied to calculate the value of α_2 from HL band. The element of second middle frequency band HL is considered as another component for adaptive calculation of scaling factor. The absolute value of every element of matrix HL is taken and a new matrix is constructed calledZ_{HL}. Then normalization technique is applied to each element of the matrix Z_{HL} using the formula given in (4.5).

$$Z_3\,(i,j) = \frac{element(Z_{HL}) - \min(z_{HL})}{\max\,(z_{HL})\ - \min(z_{HL})}, \tag{4.5}$$

$$where\ i\ = 0,1,2,\ldots N-1\ and\ j\ =\ 0,\ 1,\ 2,\ 3\ldots M-1$$

Weibull cumulative distribution is applied to the matrix Z_1 by selecting the appropriate value of scale and shape parameter., as show in (4.6).

$$Z_4 =\ Wblcdf(Z_3,\ 1\ ,\ 1.5\ ) \tag{4.6}$$

In this proposal the value for scale parameter$\beta$is set as 1 and the shape parameter δ is set as 1.5. The mean value of Z_4 is calculated using (4.7) and to avoid zero mean value of the parameter, β_1 is added with minimum value of 0.001, as shown in (4.8).

$$\mu_2 = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n} Z_4(i,j) \tag{4.7}$$

$$\alpha_2 = \beta_1 + \mu_2 \tag{4.8}$$

$$\alpha =\ \frac{1}{2}\,(\alpha_1 + \alpha_2) \tag{4.9}$$

The scaling factor is obtained by taking average of both α_1 and α_2 as shown in (4.9) and it is used for inserting the watermark during the embedding and extraction processes.

4.2 Embedding Process

In the proposed work, a color image of the size 512 x 512 is taken as a cover Image. Similarly, the color watermark of the size 512 x 512 is taken for embedding purpose. Both images are converted into their corresponding YIQ components. For the conversion of image into frequency components DWT is applied using ”db1 filter” and the image is further decomposed using DCT and SVD before the insertion of the watermark. The purpose to abate the contribution of noise in the watermarked image is majorly taken into account and so the value of key is calculated in such a way that the disturbance in the intensity values of the image is very minimal. The process flow diagram of watermark embedding process is shown in Fig.3

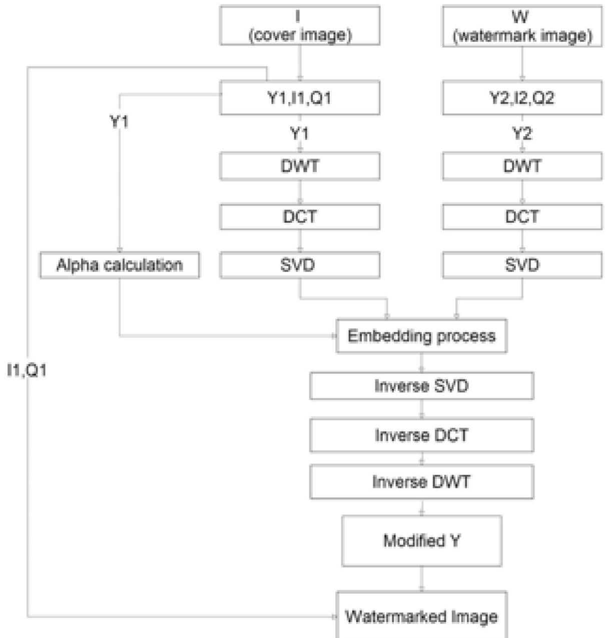

Figure 3: YIQ components of Lena Image

The algorithm for watermark embedding process is given below:

Embedding Algorithm

Input : A, W // **A cover image, W watermark Image**

Output: A'' // A'' ***watermarked Image***

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1. $Read(A, W)$ // Read Cover image and the Watermark image
2. $[Y1\ I1\ Q1] \leftarrow RGB2YIQ(A)$ // Convert Cover image to YIQ components
3. $[Y2\ I2\ Q2] \leftarrow RGB2YIQ(W)$ // Convert Watermark image to YIQ components
4. $[LL1\ LH1\ HL1\ HH1] \leftarrow DWT(Y1)$ // Apply DWT to Y_1 component of cover image
5. $[LL2\ LH2\ HL2\ HH2] \leftarrow DWT(Y2)$ // Apply DWT to Y_2 component of watermark
6. $[LL1'\ LH1'\ HL1'\ HH1'] \leftarrow DCT([LL1\ LH1\ HL1\ HH1])$ // Apply DCT to each band of cover image
7. $[LL2'\ LH2'\ HL2'\ HH2'] \leftarrow DCT([LL2\ LH2\ HL2\ HH2])$ // Apply DCT to each band of watermark image
8. $[\ U1\ \ S1\ \ V1T\ ] = [LL1'\ LH1'\ HL1'\ HH1']$ // Apply SVD to each band of cover image

9. $[\,U2\;\; S2\, V2T\,] = \;[LL2'\; LH2'\; HL2'\; HH2']$ // Apply SVD to each band of watermark image

10. $Snew \;=\; S1 \;+\; \alpha S2$ // Watermark insertion using key

11. $Y'' \;=\; iDWT + iDCT + iSVD(Snew)$ // Extract new Y" from the image

12. $A'' \; = YIQ2RGB([Y''\; I1\; Q1])$ // Reconstruct using Y" to get

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4.3 Watermark Extraction Process

During the watermark extraction process, both the watermarked image and the original image are converted into their corresponding YIQ components. For the conversion of image into frequency components DWT is applied using "db1 filter" and the image is further decomposed using DCT and SVD for watermark extraction. The algorithm for watermark extraction process is given below.

Extraction Algorithm

Input : A'',A, W // **Watermarked Image, Original Image and watermark**
Output: W'' ***Extracted Watermark***

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1. $Read(A'', A, W)$ // Read the Watermarked image, Cover image and Watermark

2. $[Yw\; Iw\; Qw] \;\leftarrow\; RGB2YIQ(A'')$ //Convert Watermarked image to YIQ

3. $[LLw\; LHw\; HLw\; HHw] \;\leftarrow\; DWT(Yw)$ //Apply DWT to Y component of Watermarked image

4. $[LL'w\; LH'w\; HL'w\; HH'w] \;\leftarrow\; DCT([LLw\; LHw\; HLw\; HHw])$ //Apply DCT to each band

5. $[\,USw\;\; VwT\,] = \;[LL'w\; LH'w\; HL'w\; HH'w]$ // Apply SVD to each band

6. $S''w = \;(\;Snew \;-\; S1)\;/\;\;\alpha$ // Calculation for extracting Watermark

7. $Y''w \;=\; iDWT + iDCT + iSVD(S''w)$ // Extract Y"$_w$ from the image

8. $W'' \;=\; YIQ2RGB([Y''w\;\; I2\;\; Q2])$ // Reconstruct Watermark using Y"$_w$

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5 Performance Evaluation

The performance of the proposed algorithm is experimented with four different color images of the size 512 x 512 pixels and with watermark of size 512 x 512 pixels. The proposed algorithm is implemented and tested using Matlab version R2013b simulation tool.

5.1 Measure of Invisibility

There are various procedures to test the invisibility of the watermark embedded in the original cover image. The objective metric Peak Signal to Noise Ratio (PSNR) gives us the degree to which our host image is distorted due to noise. This metric is calculated between the image H and the original watermarked image H'. The higher the value of PSNR, the more watermark is imperceptible to human eyes. The maximum value of PSNR defines that the watermarked image is exactly the same as the host image, or in other words, there is absolutely no noise content or watermark content in the output image (Dubolia R., 2011)(Santhi V., 2011)(Su Q., 2013). PSNR is the most commonly accepted metric to get some intuition, as to what percentage the image has been altered by the addition of the noise. The value of PSNR and MSE is calculated using (5.1) and (5.2) respectively.

$$MSE = \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} \left[H\left(i,j\right) - H'(i,j)\right]^2 \tag{5.1}$$

Here, m and n denote the number of rows and columns of the host image H. In order to calculate the $PSNR$ value, calculated MSE value is used in (5.2).

$$PSNR \ = \ 10 \ log10 \ (\frac{255^2}{MSE}) \tag{5.2}$$

5.2 Measure of Similarity

Robustness of the watermark in the watermarked image is analyzed using Normalized Correlation Coefficient (NCC)(Santhi V., 2011) (Su Q., 2013). This is calculated using the original watermark image W and the extracted watermark image W' as shown in (5.3).

$$NCC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} W\left(i,j\right) W'(i,j)}{\sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n} W(i,j)}\sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n} W'(i,j)}} \tag{5.3}$$

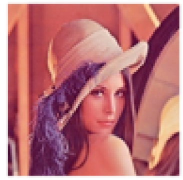
The maximum value of NCC is 1 which signifies that the extracted watermark is exactly the same as the original watermark image whereas the NCC value 0 indicates that there is no resemblance between the original and the extracted watermark.

5.3 Result Analysis

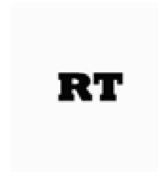
In the prospect of balancing the PSNR and the NCC values for the images and to provide the utmost security to the watermark the scaling factors are calculated adaptively for the test images and tabulated in Table. 1. The sample test images and the watermark are shown in Fig.4.

(a)Pepper

(b) Lake



(c) Lena



(d) Original Watermark

Figure 4: Host Images and Watermark

It is essential to keep the value of the scaling factor between the values 0 and 1 to embed the watermark without destroying the underlying cover data. The proposed algorithm is tested with different images and it is observed that the value of the scaling factor always ranges between 0.01 to 0.05. The calculated PSNR values for various test images and the corresponding watermarked images are shown in Table 2. The proposed algorithm has shown better results in terms of PSNR values when compared to Santhi et al. watermarking methods.

Image	Scaling Factor
Pepper	0.01781
Lake	0.02366
House	0.02483
Lena	0.02529

Table 1: Calculated Scaling Factor

Similarly, in order to check the quality of the extracted watermark, the NCC value is calculated between the original watermark and the extracted watermark. In Fig.5,the original and extracted watermarks and its corresponding NCC values under normal condition without implementing any attacks are shown. It is quite evident from the results that the NCC values are very close to 1, and is approximately equivalent to the original watermark.

Name of the Watermarked Images	PSNR in dB
Pepper	35.4678853
Boat	32.9375932
Car	32.52741559
Lena	32.40484709

Table 2: Calculated Scaling Factor

(b)NCC=0.993 (c)NCC=0.991 d)NCC=0.996 (e)NCC=0.995

Figure 5: b,c,d,e are Extracted Watermark from Various Test Images

In order to examine and test the robustness of the watermark, various attacks are implemented on the watermarked images. The attacks which are tested are noise addition, sharpening, median filtering, compression, cropping, Gaussian blur, resizing, rotation and intensity adjustments. Initially salt and pepper noise and Gaussian noise attacks are implemented and the performance of the proposed algorithm is tested by varying the variance of noise such as 0.0001, 0.001 and 0.01. It is observed from the Fig. 6 in the salt and pepper attack that the PSNR value of the watermarked image is hardly affected by the initial two noise values, whereas it gets affected slightly due to the high concentration of noise added (0.01). On the contrary, there is no such disparity, when it comes to the NCC values of the extracted watermark image under the same conditions.

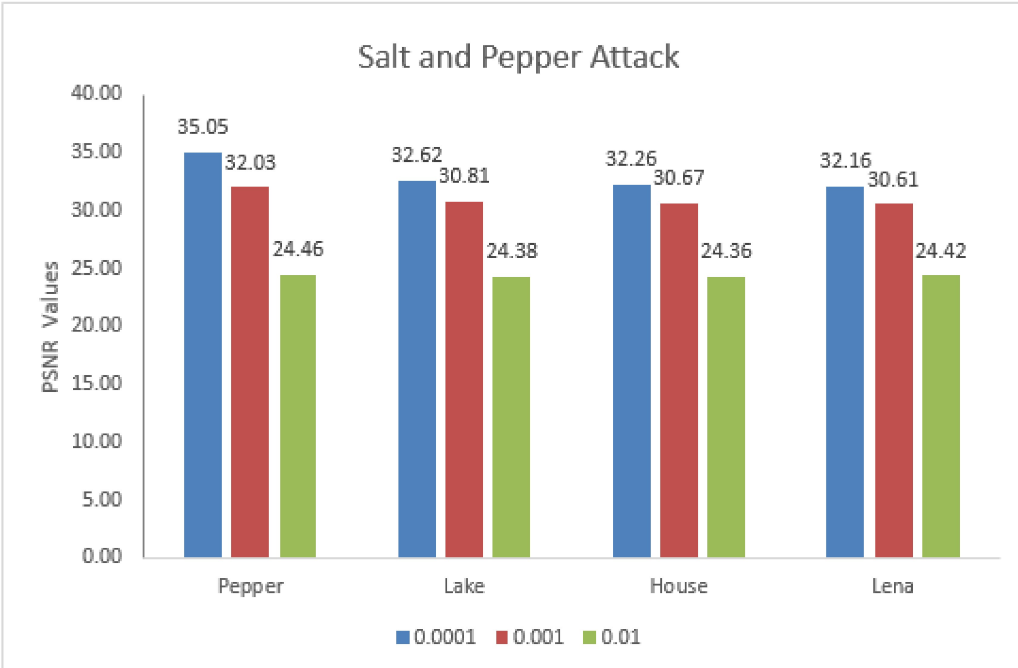


Figure 6: Calculated PSNR values after Salt and pepper noise attack

To further analyze the proposed algorithm the Gaussian noise attack is implemented and the obtained results are shown in Fig. 7. The experimental results of salt and pepper attack are shown in Table 3 and for Gaussian attack it is shown in Table 4. For both these results Lena Image is taken as a standard for illustration purpose.

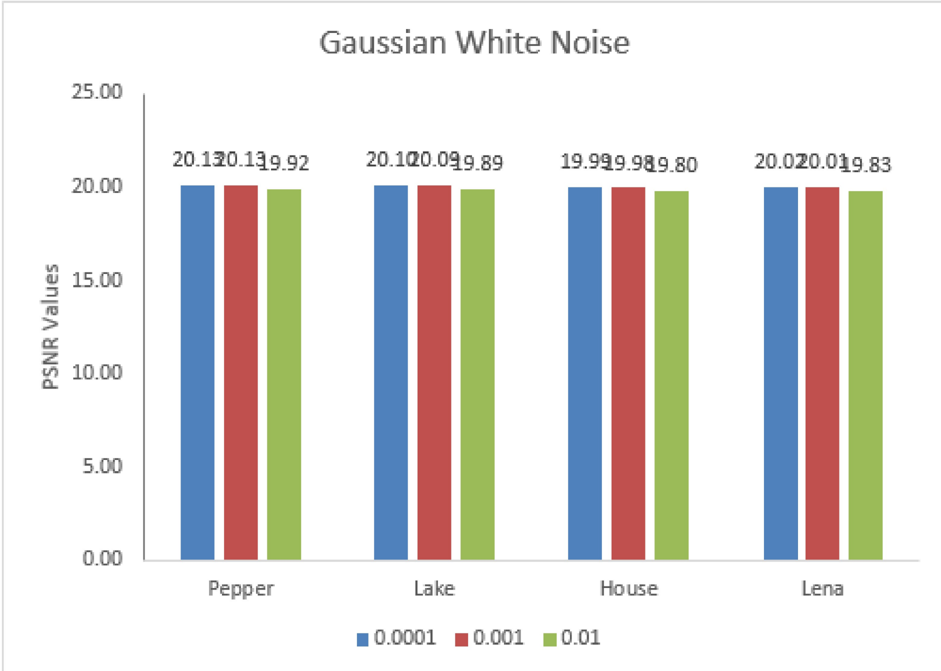


Figure 7: PSNR values of watermarked image under various values of Gaussian white attacks

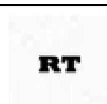
Salt and pepper Noise	Extracted watermark	NCC value
0.0001		0.994844
0.001		0.980098
0.01		0.946304

Table 3: Extracted Watermark and its NCC value for various salt and pepper noise values Using Lena Image

Gaussian Noise	Extracted watermark	NCC value
0.0001		0.95018
0.001		0.88902
0.01		0.48071

Table 4: Extracted Watermark and its NCC value for various Gaussian noise values Using Lena Image

Further, the robustness of the extracted watermark with various other attacks is tested and the results are shown in Table 5. The calculated NCC values are shown in Fig. 12. The results of the experiment are quite impressive. The strength of the algorithm can easily be visualized through the NCC values obtained after the various image attacks except rotation attack. It is seen that although the similarity of the extracted watermark and the original watermark lies between approximately 75 to 100 % in the various attacks , the rotation attack is only capable of delivering 35 to 45 % similarity. To show the experimental results for each attack, Lena image is taken as the standard for testing purpose and various attacks and their corresponding results are shown in Table 6.

Test Images	Sharpeni ng	Gaussia n Blur	Croppin g	Rotatio n	Resize	Median Filterin g	Compr ession	Poisson attack	Intensity Adjustme nt
Pepper	0.5783	0.9798	0.7456	0.1938	0.8334	0.9638	0.9235	0.9668	0.6927
Lake	0.6665	0.9625	0.9709	0.3609	0.9504	0.9478	0.9751	0.9809	0.5521
House	0.6056	0.9818	0.9489	0.4411	0.9860	0.5797	0.9761	0.9668	0.4224
Lena	0.9375	0.9863	0.9879	0.3725	0.9341	0.9878	0.9699	0.9732	0.7400

Table 5: NCC values of the extracted images after the attacks

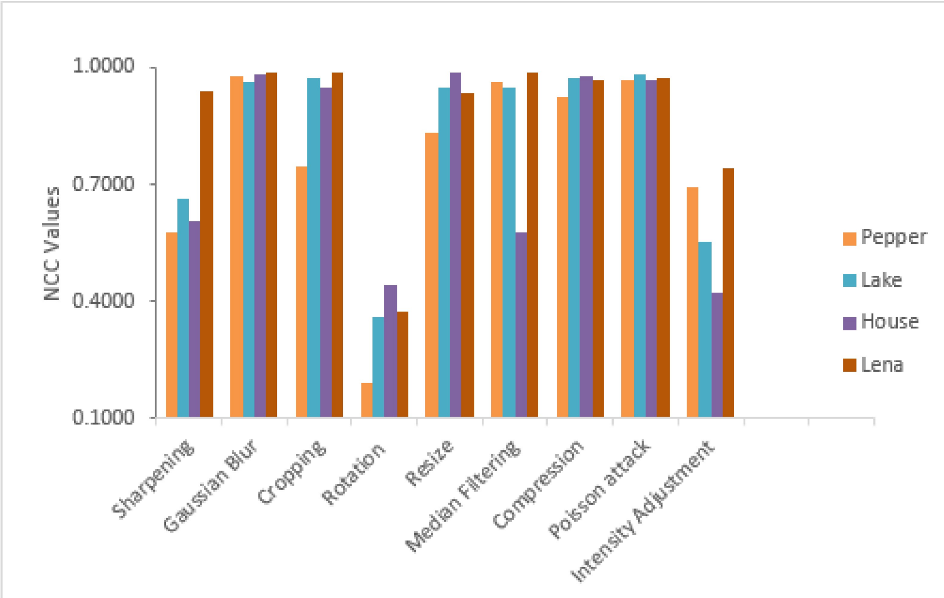


Figure 8: Obtained NCC values after each attacks

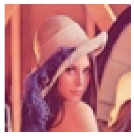
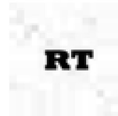
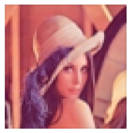
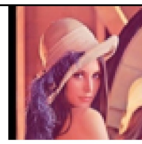
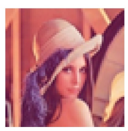
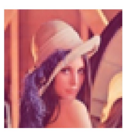
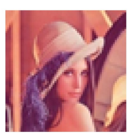
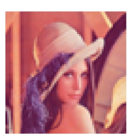
Attack	Watermarked Image	Extracted watermark	NCC
Sharpening			0.937501
Gaussian Blur (standard deviation: 1Size:5*5)			0.986329
Cropping			0.987868
Resize (70%)			0.9340983
Median Filtering			0.9878491
Compression (60%)			0.9699484
Poisson attack			0.9731926

Table 6: Extracted watermark after various attacks and calculated NCC values Using Lena Image

Thus the proposed algorithm for the extraction of watermark has indeed shown much better results in the experiments when compared to Santhi et al.s work.

6 Conclusion

A new adaptive invisible watermarking algorithm in transform domain using Weibull distribution function is proposed in this paper. The major contribution of the proposed method is that it uses adaptive mathematical model using Weibull cumulative distribution function that inserts watermark invisibly. The proposed invisible watermarking results are compared with the results of Santhi et al.s method and it is proved that the performance of the proposed adaptive invisible watermarking scheme is better than the results of Santhi et al.s method. Thus the performance of proposed adaptive watermarking model for invisible watermarking scheme confirmed its efficiency through experimental analysis. The PSNR and the NCC values obtained are considerably high, which proves that this algorithm which uses cumulative distribution function inserts watermarks that are robust and can withstand various attacks.

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