

Robust Digital Image Watermarking Technique using Image Normalization and Discrete Cosine Transformation

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ABSTRACT

In recent days the computer communication and the usage of multimedia data is enormous over the Internet, so protection of these data from malicious attacks and signal processing operations are very important. A robust watermarking system must be developed to withstand attacks such as rotation, scaling and translation technique (RST attacks). In this paper, a robust watermarking technique using DCT transformation technique and normalization procedure is proposed. The image normalization is just used for calculating the affine transform parameters so that the watermark embedding and detection is performed in the original coordinates system. The results assure that the proposed algorithm is robust against various other types of attacks also such as salt & pepper, low-pass filter, high-pass filter, Gaussian noise, Speckle noise and perform much better for geometrical attacks e.g. rotation, scaling and the combination of these attacks, translation.

Keywords

Digital Watermarking, Geometric Distortion, Transform domain watermarking, Image normalization, Discrete Cosine Transformation

1. INTRODUCTION

The tremendous growth in e-world which is coupled with World Wide Web and advancement in computer performance facilitated the early distribution of digital data. In World Wide Web due to breach in security digital image can be easily duplicated and distributed without right permission. The digital watermarking schemes have been proposed to resilience these kinds of unauthorized access of digital multimedia data. At initial stage, encryption and control access techniques are used to copyright protection, content authentication and ownership protection. But now days, the digital watermarking techniques are used prominently to keep digital multimedia secure [1] [2] [3] [4].

Watermarking is a pattern of bits inserted into a digital image, audio or video file that identifies the files copyright information. The name digital watermarking comes from the faintly visible watermark imprinted in stationary that identifies the manufacturer of the stationary. [5] The purpose of the digital watermarks is to provide copyright protection for intellectual property that's in digital format. So watermark is the hidden information within the digital signal. There are many applications of digital watermarking but among all copyright protection, content authentication, copy and usage control and content description are important application area

of the digital watermarking. [6] [7] In this paper, we proposed watermarking approach to alleviate the problem or geometric attacks. We describe a robust logo embedding algorithm that is robust to geometric attacks. The synchronization is recovered using an image normalization technique for the detection process. An idea of image normalization is used to calculate the affine transformation parameter so that the watermark embedding and detection is performed in the original coordinate system. The watermark is based on a DCT transform method. The paper is organized as follows. In section 2, presents the existing related works to the RST invariants watermarking systems. In Section 3 and 4, there is a description about a related terminology of DCT block structure and image normalization is presented. In section 5, the proposed approach is described, which includes watermark insertion and detection mechanism. Experimental results and discussions are given in section 6, and finally the conclusions are presented in section 7.

2. RELATED WORKS

Digital image watermarking algorithms are most sensitive to geometric distortions, compression, linear and non-linear filtering. In a simple way, if a watermarked image undergoes manipulations, watermark cannot be usually detected in original format. Till date, there are various digital image watermarking algorithms have been proposed in the literature survey to solve this robustness problem.

O'Ruanaidh et al. [8] have presented the theory of integral transform invariants and explained that this technique can be used to embed watermarks that are resistant to rotation, scaling, and translation. In their approach, the discrete Fourier transform (DFT) of an image is computed and then the Fourier-Mellin transform is performed on the magnitude, the watermark is embedded in the magnitude of the resulting transform. The watermarked image is reconstructed by performing the inverse transforms (an inverse DFT and an inverse Fourier-Mellin transform) after considering the original phase [9][8]. Fourier-Mellin transform is a log-polar mapping (LPM) followed by a Fourier transform, while an inverse Fourier-Mellin transform is an inverse log-polar mapping (ILPM) followed by an inverse Fourier transform. In the scheme, the embedded watermark may be extracted by transforming the watermarked image into RST invariant domain. This approach was effective in theory, but difficult to implement.

In [10, 11], Z. Dong has proposed to embed watermark in the log-polar mappings of Fourier magnitude spectrum of original

image, and use the phase correlation between the LPM of the original image and the LPM of the watermarked image to calculate the displacement of watermark positions in LPM domain. The scheme preserves the image quality by avoiding computing inverse log-polar mapping (ILPM). After this researchers turns towards some new technique which was based on image normalization. In [12], a watermarking scheme is implemented by improving image normalization based watermarking (INW). Image normalization is based on the moments of the image, Invariant Centroid (IC) is proposed and the only central region(R), which has less cropping possibility by RST, is used for normalization. Other then normalization Pereira and Pun[13] put forward an another technique , in which additional technique, known as “pilot” signal in traditional communication systems, besides the watermark was embedded in the DFT domain of the image. This embed template was used to estimate the affine geometric attacks in the image. The image first corrected with estimated distortion, and the detection of the watermark was performed afterwards. A theoretical analysis was also provided in the in [14] on the bit error rate for this pilot – based approach under a number of geometric attacks. This requires the detection of both the synchronization pattern and the watermark. A potential problem arises when a common template is used for different watermarking images, making it susceptible to collusion-type detection of the template. [15]

J. Xuan and H.Zhang [16] proposed a rotation, scaling and translation (RST) resilient watermarking method through embedding watermark in RST invariant derived from Radon transform and Fourier transform. Based on the translation and rotation properties of Radon transform and the translation invariant property of Fourier magnitude, the RST invariant is obtained.

material on each page should fit within a rectangle of 18 x 23.5 cm (7" x 9.25"), centered on the page, beginning 2.54 cm (1") from the top of the page and ending with 2.54 cm (1") from the bottom. The right and left margins should be 1.9 cm (.75"). The text should be in two 8.45 cm (3.33") columns with a .83 cm (.33") gutter.

3. Basics of Discrete Cosine Transformation Technique

The discrete cosine transform is a technique for converting a signal into elementary frequency components. [17][18] It represents an image as a sum of sinusoids of varying magnitude and frequencies. The DCT is similar to the Discrete Fourier transformation. [19] With an input image, x , the DCT coefficient for the transformed output image, y , are computed according to equation 1 shown below. In the equation, x , is the input image having $N \times M$ pixels, $x(m,n)$ is the intensity of the pixel in row m and column n of the image , and $y(u,v)$ is the DCT coefficient in row u and column v of the DCT matrix.

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

Where

$$\alpha_u = \begin{cases} \frac{1}{\sqrt{2}} & u = 0 \\ 1 & u = 1, 2, \dots, N-1 \end{cases}$$

$$\alpha_v = \begin{cases} \frac{1}{\sqrt{2}} & v = 0 \\ 1 & v = 1, 2, \dots, N-1 \end{cases}$$

The image is reconstructed by applying inverse DCT operation according to equation 2:

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

The popular block-based DCT transform segments an image non-overlapping block and applies DCT to each block. This result in giving three frequency sub-bands: low frequency sub-band, mid-frequency-sub band and high frequency sub-band. DCT –based watermarking is based on two facts. The first fact is that much of the signal energy lies at low-frequencies sub-band which contains the mist important visual parts of the image. The second fact is that high frequency components of the image are usually removed through compression and noise attacks. The watermark is therefore embedded by modifying the coefficients of the middle frequency sub-band so that the visibility of the image will not be affected. [20, 21, 22, 23].

4. Basics of Image Normalization Technique

The method of normalization starts with special parameters, called function parameters, which explains the given object or image of interest. Such parameters can be the given moments, the Fourier coefficients, the coordinates of an ordered set of points, or any other parameters describing the object. Invariants are quantities which do not change under a transformation, so the main task in order to derive invariants is the elimination of the effects that the transformation has on the function parameters [24]. Normalization is the process of transforming the image function $g_1(x,y)$ into the function $g_2(x,y)$ so that it retains all the relevant information of the original image and also satisfies the criteria of the normalized image. Therefore $g_2(x,y)$ can be considered as “standard” version of the original image $g_1(x,y)$. Image Normalization refers to vanish the image variations that are related to the

image state of image acquisition, and are irrelevant to object identity. There are total four steps in normalization including centering the image (translation), shearing image in x-direction, shearing image in y-direction. The parameter by which the image is normalized are estimated from the geometric moment of the image. [25][26] Normalization is used for the purpose of increasing watermark robustness for geometrical distortions such as rotation, translation and scaling. The typical geometrical attacks include rotation, scaling and translation of the image. These kinds of attacks can be represented by affine transformation. The affine transform with scaling parameters (a,b) rotation angle ϕ and translation parameters (T_x, T_y) can be defined as [27][26]

$$\begin{bmatrix} x_a \\ y_a \end{bmatrix} = \begin{bmatrix} a & 0 \\ 0 & b \end{bmatrix} \begin{bmatrix} \cos \phi & -\sin \phi \\ \sin \phi & \cos \phi \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} T_x \\ T_y \end{bmatrix} \quad (3)$$

Where (x,y) are the pixel coordinates of an input image and (x_a, y_a) are the pixel coordinates of a transformed image. The affine transform parameters can be estimated using image moments. The image moment or geometric moment of order p+q is defined in the two dimensional Cartesian coordinates, which is as follows:

$$m_{p,q} = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} x^p y^q f(x,y) \quad (4)$$

And central moment can be stated in the following mathematical expression form

$$\mu_{p,q} = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} (x - \bar{x})^p (y - \bar{y})^q f(x,y) \quad (5)$$

Where p,q = 0,1,2...

The centroid of the image can be calculated using zeroth and first moments using following equations:

$$\bar{x} = m_{10}/m_{00}, \quad \bar{y} = m_{01}/m_{00}$$

An image g(x,y) is said to be an affine transform of f(x,y) in there is a matrix $A = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$ and vector $d = \begin{pmatrix} d1 \\ d2 \end{pmatrix}$ such that $g(x,y) = f(x_a, y_a)$ where

$$\begin{pmatrix} x_a \\ y_a \end{pmatrix} = A \cdot \begin{pmatrix} x \\ y \end{pmatrix} - d.$$

And MxN is the support of the host image f(x,y) to be normalized. The normalization is achieved by applying the tree transformation to the host image. In order to obtain translation invariance, the host image f(x,y) is shifted to its central point and a centralized image $f_a(x_a, y_a)$ is determined. For this purpose, the following spatial coordinate's transformation is used:

$$x_c = x_a - \bar{x}_a, \quad y_c = y_a - \bar{y}_a$$

The normalization procedure takes place though following steps for a given image f(x,y). [28]

1. Determine the center of the image f(x,y): this can be achieved by using the equation

$$\begin{pmatrix} x_a \\ y_a \end{pmatrix} = A \cdot \begin{pmatrix} x \\ y \end{pmatrix} - d.$$

As the matrix $A = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$ and the vector $d = \begin{pmatrix} d1 \\ d2 \end{pmatrix}$ with $d_1 = m_{10}/m_{00}$,

$$d_2 = m_{01}/m_{00}$$

Where m_{01}, m_{10} and m_{00} are the moments of f(x,y). Let $f_1(x,y)$ denote the new resulting centered image.

2. Apply shearing transform in X-direction:

After making image centered apply shearing transform on $f_1(x,y)$ in the X-direction with matrix $A_x = \begin{pmatrix} 1 & \beta \\ 0 & 1 \end{pmatrix}$ so that the resulting image denoted by $f_2(x,y) = A_x[f_1(x,y)]$. The value of β can be calculated using following equation

$$\mu_{30} = \mu_{30} + 3\beta\mu_{21} + 3\beta^2\mu_{12} + \beta^3\mu_{03}$$

3. Apply a shearing transform in Y-direction: the next step is apply shear transform to $f_2(x,y)$ in the Y-direction with

matrix $A_y = \begin{pmatrix} 1 & 0 \\ \gamma & 1 \end{pmatrix}$ so that the resulting image denoted

by $f_3(x,y) = A_y[f_2(x,y)]$ the value of γ can be calculated using following equation

$$\mu_{11} = \gamma\mu_{20} + \mu_{11}$$

Thus, the parameter γ has a unique solution.

4. Apply scale $f_4(x,y)$ in both X and Y-directions such

that $A_s = \begin{pmatrix} \alpha & 0 \\ 0 & \beta \end{pmatrix}$ so that the resulting image denoted by $f_4(x,y) = A_s[f_3(x,y)]$

Now we can normalize the input image of size $l_x \times l_y$ using the image moments. Let the width and the height of the normalized image be $l_x = a.l_x$ and $l_y = b.l_y$ and so that the aspect ratio of the normalized image should be one. [27]

$$\hat{y} = \frac{b.l_y}{a.l_x} = 1 \quad (6)$$

If the aspect ratio of the input image is $y = l_y/l_x$, we can get by replacing the location into equation

$$a = b.y \quad (7)$$

Let $I(x/a, y/b)$ be the normalized image of the input image. Then, the zeroth moment of the normalized image can be obtained by changing the variables in equation (4)

$$\widetilde{m}_{00} = a.b.m_{00} \quad (8)$$

By solving the simultaneous equations of (7) and (8), finally we can calculate the scaling parameters.

$$a = \sqrt{y \cdot \frac{\widetilde{m}_{00}}{m_{00}}}, b = \sqrt{\frac{\widetilde{m}_{00}}{y \cdot m_{00}}} \quad (9)$$

The image normalization against rotation can be performed using tensor theory. The rotation angle ϕ for image normalization can be calculated using the following equations

$$t^1 = \mu_{21} + \mu_{30} \quad \text{and} \quad t^2 = \mu_{03} + \mu_{21}$$

$$\phi = \tan^{-1}\left(\frac{-t^1}{t^2}\right) \quad (10)$$

Equation (10) has two possible solutions, thus, we choose ϕ such that to ensure a unique solution.

We can transform any input image to a normalized form by identifying the transform parameters, (a,b), ϕ and (\bar{x}, \bar{y}) . If two different images are an affine transform pair, the normalized form of these images will be the same.

5. PROPOSED ALGORITHM

There are two main phase of any watermarking system, the first one is the embedding of the watermark in the original image and second one is the extraction or detection of the watermark. In this proposed method, the embedded watermark is a binary image of size 64x64, where the size of the cover image is 512x512 bitmaps. For embedding, normalization technique is applied on the cover image. After this DCT technique used on the normalized image by converting normalized image into 8 x 8 blocks. Then embed the watermark image into the blocked image. Again apply inverse DCT and inverse normalization process to get the watermarked image. Proposed algorithm works for non-blind domain. So for the purpose of watermark extraction original image get uses.

5.1 WATERMARK EMBEDDING ALGORITHM

1. Apply the normalization procedure to the original image to get the normalized image.
2. Divide the normalized image in blocks of 8x8 pixels

3. Apply the Discrete Cosine Transformation (DCT) technique to the normalized blocked image.

$$y(k) = w(k) \sum_{n=1}^N x(n) \cos\left(\frac{\pi(2n-1)(k-1)}{2N}\right) \quad k = 1, 2, \dots, N \quad (11)$$

Where

$$w(k) = \begin{cases} \frac{1}{\sqrt{N}} & k = 1 \\ \sqrt{\frac{2}{N}} & 2 \leq k \leq N \end{cases}$$

N is the length of x , and x and y are the same size. If x is a matrix, dct transforms its columns

4. Take the watermark image of size 64x64; decompose this image into 8x8 blocks. So those embed the watermark image block into the cover image block.

5. Watermark vector W is multiplied by a gain factor 'e'.

$$I_w = I_0 + (w * e)$$

6. Apply the Inverse Discrete Cosine Transformation.

7. Finally use Inverse Normalization Technique to get the "Watermarked Image" Where I_w is the watermarked image and I_0 is the original cover image.

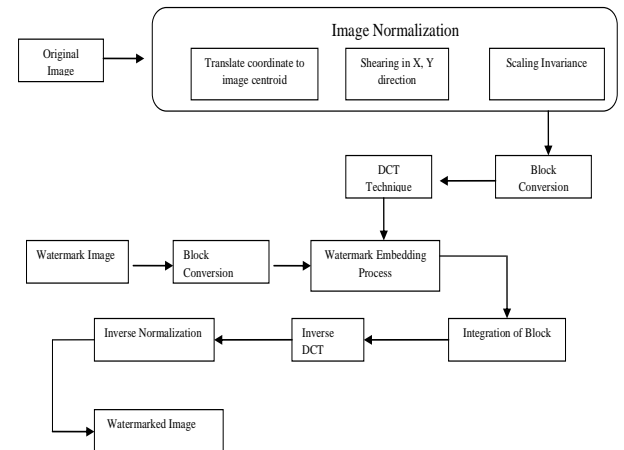


Figure1. General block diagram for the watermark embedding process

The whole procedure is equivalent to embedding the watermark into the DCT domain of the normalized image.

Algorithm

1. Read original image
 $I = \text{imread}('lena.tif');$
2. Normalize 'I' using
 $\text{Normim} = \text{Imnorm}(im);$
3. Decompose the image into blocks of 8 x 8 using DCT

 $\text{dct} = @(block_struct) T * block_struct.data * T';$
 $D = \text{blockproc}(I,[8\ 8],\text{dct});$
4. Read Watermark Image
 $w = \text{imread}('watermark.bmp');$
5. Decompose watermark image into 8 x8 blocks
6. Embed watermark
If(original image block = watermark image)
embedding process completed else dimension matrix
dimension no match
7. Watermark vector W is multiplied by a gain factor 'e'.
$$I_w = I_0 + (w * e)$$
8. Use inverse DCT to the embed image
 $\text{invdct} = @(block_struct) T' * block_struct.data * T;$
 $I1 = \text{blockproc}(B2,[8\ 8],\text{invdct});$
9. Apply inverse Normalization to get the watermarked image
 $\text{invnormim} = \text{iminvnorm}(I1);$

5.2 WATERMARK EXTRACTION ALGORITHM

The process of the watermark detection is:

1. Apply the normalization procedure to watermarked image to get the normalized watermarked image.
2. Divide the normalized image in blocks of 8x8 pixels
3. Apply the Discrete Cosine Transformation (DCT) technique to the normalized blocked image.
4. Subtract the blocks of the watermarked image from the blocks of the cover image by using following mathematical expressions

$$I_E = (I_W - I_O)/e$$

I_E :
watermarked image blocks

I_O = cover image blocks

5. Integrate the extracted watermark blocks and recover the extracted watermark image

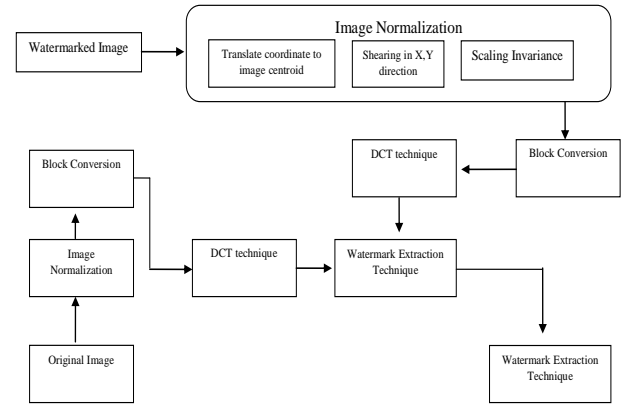


Figure2. General block diagram for the watermark extracting process

Algorithms

1. Read the watermarked image
 $I2 = \text{imread}('watermarked.bmp');$
2. normalize 'I2' using
 $\text{normim} = \text{Imnorm}(I2);$
3. Decompose the image into blocks of 8 x 8 using DCT
 $\text{dct} = @(block_struct) T * block_struct.data * T';$
 $D = \text{blockproc}(I2,[8\ 8],\text{dct});$
4. Subtract the blocks of the watermarked image from the blocks of the cover image by using following mathematical expressions

$$I_E = \frac{I_w - I_O}{e}$$

I_E = extracted blocks of watermark image

I_W = watermarked image blocks

I_O = cover image blocks

5. Integrate the extracted watermark blocks
6. Get back the extracted watermark image.

6. EXPERIMENTAL RESULTS AND PERFORM ANALYSIS

In the experiment shown below the original image is a 512*512 Lena gray image and the watermark is 64*64 binary image. In order to quantitatively analyze the invisibility and robust of the algorithm, two guide lines are employed: one is peak signal- noise ratio, psnr (unit's db), which is used to measure the invisibility of the water mark. The other one is correlation coefficient NC (between [0, 1]), which is used to measure the correlation between the original and recovered watermark.



Figure3(a).Original image 3(b).Watermarked image

Figure (3) shows that the original image and watermarked image. Clearly it can be seen that there is no significant degradation for the normal human vision. For testing the algorithms, applied the various kinds of attack on the watermarked image. After applying the attacks, results and all the relative changes are tabulated in respective tables with their psnr and nc values. To evaluate the degradation between the original image and the watermark image ,peak-signal-to-noise ratio(PSNR) is used . Mathematically it is represented as

$$PSNR = 10 \times \log_{10} \frac{255^2}{MSE} \quad (12)$$

Where

$$MSE = \frac{1}{N \times N} \sum_{i=1}^N \sum_{j=1}^N (c_{i,j} - c'_{i,j})^2 \quad (13)$$

$c_{i,j}$ denotes a pixel color of the original host image and $c'_{i,j}$ denotes a pixel color of the watermarked image. Finally $N \times N$ is the image size.

To evaluate the similarity between the original watermark and the recovery watermark after a geometrical distortion, Normalized Correlation (NCC) is used.

$$NCC = \frac{\sum_{i=1}^P \sum_{j=1}^Q w(i,j)w'(i,j)}{\sum_{i=1}^P \sum_{j=1}^Q |w(i,j)|^2} \quad (14)$$

Where W is the original watermark and W' is the recovered watermark. And the watermark size is $P \times Q$.







Analysis of attacks

Rotation: A two dimensional rotation is applied to an image by repositioning it along a circular path in X-Y plane. Transform equation can be obtained by rotating a point at (x, y) through an angle ϕ about the origin clockwise:

$$x' = x \cos \phi + y \sin \phi$$

$$y' = -x \sin \phi + y \cos \phi$$

TABLE 1: Rotation attack

In degree	Normalized Correlation	PSNR
10	 0.9986	 30.5879
20	 0.9986	 30.5879
30	 0.9984	 30.5879

Scaling: A scaling transformation alters the size of an image, obtain the transformation equations by multiplying the coordinate values (x, y) by scaling factors a and b to produce the transformed coordinates (x_-, y_-) :

$$x' = x.a$$

$$y' = y.b$$

TABLE 2: Scaling


	Normalized Correlation	PSNR
[400 800]	 0.9980	 30.5879
[200 700]	 0.9986	 30.5879
[500 900]	 0.9985	 30.5879

Table 1 and Table 2 list the experimental results. The results show that the recovered watermark can all be easily recognized after the various geometric attacks. It claims that the proposed scheme is giving best results as compare to previous one for these geometric attacks. The accuracy rate is very high. Other then geometric attacks it also works well for noise attacks.

Translation: A translation (or shift) is applied to an image by repositioning it along a straight-line path from one coordinate location to another .A two-dimensional point by adding translation distances, x_0 and y_0 , to the original coordinate position (x, y) to move the point to a new position (x_-, y_-) .

$$x' = x + x_0$$

$$y' = y + y_0$$

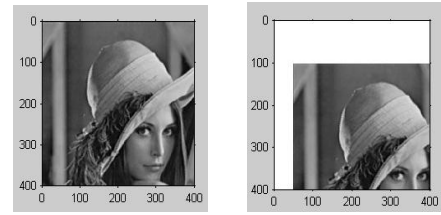


Figure4 (a) Translated Image



Figure 4(b) Extracted Watermark

PSNR = 28.9721

NC = 0.9976

Experimental results for noise attacks are shown in Table 3 and Table 4

TABLE 3 Salts & peeper noise attack










Embedding factor	Normalized Correlation	PSNR
0.0001	 0.9988	 30.9182
0.001	 0.9981	 29.4121
0.01	 0.9965	 24.0882
0.1	 0.9744	 14.9867

TABLE 4 Gaussian Noises

	Normalized Correlation	PSNR
0.3	 0.8867	 10.2690
0.2	 0.9368	 13.1270
0.1	 0.9729	 16.9331
0.01	 0.9914	 19.8124
0.001	 0.9939	 19.8896

7. Conclusion

This paper proposed a new non-blind watermarking algorithm that is robust to general affine geometric affine transformation attacks. The proposed algorithms secure its robustness by both embedding and detecting watermark message in the normalized image. This research article has tested the proposed algorithms for different attacks and noise condition. The results shows that the algorithm is robust enough to resist noisy attacks e.g. salt & peeper noise, Gaussian noise and speckle and gives best performance for geometric attacks e.g. Rotation, Scaling and Translation. Here proposed technique

for embedding image into the gray-scale images may find applications in the intellectual property protection and anonymous. It is to be noted that the algorithm presented in primary stage only works for gray-level images. It can be further enhanced for color images and video sequence. Some more advance schemes such as neural network and fuzzy logic can also be tested to make it more secure and robust.

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