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Normalized Image Watermarking Scheme Using Chaotic System

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ABSTRACT

In contemporary years, different watermarking schemes are proposed for image authentication and copyright protection. In this paper, a novel normalized image watermarking scheme along with chaotic system (NCS) for higher embedding capacity and better robustness is presented. Normalization is useful to recover the watermark even in case of geometrical attacks. Arnold cat map and logistic map allows the proposed watermarking system to remain comprehensible for non experts and become more pleasant. The proposed method overcomes the degradation problem by embedding the watermarks in visually insensitive locations. Quite a lot of experiments have been carried out to test the performance of the proposed system against different attack scenarios. The proposed method highlights security, invisibility and quality, by preserving the original image, while maintaining robustness against common signal processing operations and attacks.

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1. INTRODUCTION

The rapid enlargement of information technology has enhanced the ease of access to digital information. It also leads to the difficulty of prohibited copying, copy protection, tampering and circulation of digital data. Digital watermarking emerged as a tool for protecting the multimedia information from copyright contravention. Image watermarking is a progression of embedding hidden information called watermark into original host image signals [9, 10, 11, 12,13]. It acts as a digital signature, by giving the image a sense of ownership or authenticity. Ideal properties of a digital watermark are stated in the literature [14, 15, 16, 17]. These properties include perceptual invisibility to stop difficulty of the original image, statistical invisibility, fairly simple extraction, and robustness to filtering, additive noise, compression and other forms of image manipulation as well as the ability to determine the owner of the original image.

Based on original image requirement during extraction the watermarking technique is classified as non blind, semi-blind and blind. Non-blind methods need the original image which limit their usage since the original image is complicated to obtain on occasion. Semi-blind methods do not require the original image as they need the watermark or little side information. Blind methods require neither the original image nor the watermark, which is more sufficient in some application scenarios but chock-a-block of challenges. Most of the existing watermarking method requires original image to extract the watermark and more recent watermarking schemes [18,19,20] cannot resist the common geometric attacks. The image normalization scheme is blind and it proposed rise above forefront mentioned drawbacks.

Image normalization are broadly used in pattern recognition and image registration [5]. It also helps researchers to achieve scaling invariance in watermarking systems. Some of such characteristic based watermarking systems are proposed in literature. In [6], the geometric invariant watermarking system is based on moments and image normalization. Geometric moments are used to geometrically normalize the image before watermark embedding at the encoder and before extracting the watermark at the decoder. The image normalization and orientation assignment, rotation, scaling, and translation invariant regions are used for watermark embedding and extraction. Then image normalization is applied to transform the disk region to its compact size, which is scaling invariant. In this way, the disk region for watermark embedding and extraction are rotated and scaled invariantly. A mathematical model is used to analyze the watermarking processes. The location of image information is determined using chaotic system. The proposed scheme is composed of different initial values of the chaotic and logistic map. In this scheme, the digital image is applied into image normalization initially and then the image is jumbled by using chaotic mapping and inserting the watermark using logistic maps. An experimental result shows that the method has good embedding effect and robustness to more attacks.

The rest of this paper is organized as follows. Section 2, introduce the concept of image normalization and chaotic mixing. Section 3 describes the watermark embedding and extraction methods. In Section 4, the experimental results and comparisons are discussed. The conclusions of the study are stated in Section 5.

2. THE BACKGROUND OF MOMENT BASED IMAGE NORMALIZATION

Transforming the images into its standard form requires defining the normalization parameters that are computed from the geometric moment of the image. Moment normalization is much a useful technique as the moments of an image is used to describe its contents with respect to the axes. Moments is used to characterize the images and to express the properties that have analogy in statistics. Moment normalization is done mainly to resist geometrical attacks [1, 2]. Here the Cartesian moment m_{pq} and Central moment μ_{pq} of a digital gray scale image f(x, y) of size M×N is defined as

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

and

$$\mu_{pq} = \sum_{x=1}^{M}\sum_{y=1}^{N} (x-\bar{x})^p (y-\bar{y})^q f(x,y) \quad (2)$$

where

$$\bar{x} = \frac{m_{10}}{m_{00}}, \bar{y} = \frac{m_{10}}{m_{00}}$$

Image normalization used in this chapter which based on the approach proposed in [4], and used in [3]. In general, an affine transformed image of cover image f(x,y) is defined as f (x_a,y_a), where

$$\begin{pmatrix} x_a \\ y_a \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} d_1 \\ d_2 \end{pmatrix} = A \begin{pmatrix} x \\ y \end{pmatrix} + d \quad (3)$$

In [3], the procedure of normalizing an image includes four steps:

1) Re-center the image: Find x and y. The re-centered image has supporting coordinate set of (x_c, y_c), where

$$x_c = x_a - \bar{x},\ y_c = y_a - \bar{y} \quad (4)$$

After re-centering, the translation is eliminated. The affine transform matrix used to normalize the image is separated as

$$\begin{pmatrix} x_n \\ y_n \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} x_c \\ y_c \end{pmatrix} = \begin{pmatrix} \cos\phi & \sin\phi \\ -\sin\phi & \cos\phi \end{pmatrix} \begin{pmatrix} \alpha & 0 \\ 0 & \delta \end{pmatrix} \begin{pmatrix} 1 & \beta \\ 0 & 1 \end{pmatrix} \begin{pmatrix} x_c \\ y_c \end{pmatrix} \quad (5)$$

Where α, β, δ € R, ϕ € (0,2Π] and $a^2_{11} + a^2_{21} \neq 0$ is required for uniqueness of separation and normalized image. In Equation (5), from right to left, the three matrixes used are x-shearing transform, scaling transform and rotation transform. If the order of the normalizations is neglected, then the normalizations destroy each other.

2) X_shearing normalization. The transform parameter β is calculated by normalizing the equation below to zero.

$$\mu^{sh}_{11} = \mu^{c}_{11} + \beta\mu^{c}_{02} = 0$$

$$\text{thus} \qquad \beta = \frac{\mu^{c}_{11}}{\mu^{c}_{02}} \quad (6)$$

Then the x_shearing invariant supporting coordinate set (x_{sh}, y_{sh}) will be:

$$\begin{pmatrix} x_{sh} \\ y_{sh} \end{pmatrix} = \begin{pmatrix} 1 & \beta \\ 0 & 1 \end{pmatrix} \begin{pmatrix} x_c \\ y_c \end{pmatrix} \quad (7)$$

3) Scaling normalization. From the transformed moments:

$$\mu^{sc}_{20} = \alpha^3 \delta \quad \mu^{sh}_{20} \text{ and } \quad \mu^{sc}_{02} = \delta^3 \alpha \quad \mu^{sh}_{02} \quad (8)$$

Let both of them be equal to 1, then the two scaling parameters α and δ are represented as

$$\alpha = \sqrt[8]{\frac{\mu^{sh}{}_{02}}{(\mu^{sh}{}_{20})^{3}}} \quad \text{and} \quad \delta = \sqrt[8]{\frac{\mu^{sh}{}_{20}}{(\mu^{sh}{}_{02})^{3}}} \tag{9}$$

There are four possible solution pairs. Unique solution is obtained by choosing, $\mu^{sc}{}_{50} > 0$ and $\mu^{sc}{}_{05} > 0$. The scaling invariant coordinate set is defined as

$$\begin{pmatrix} x_{sc} \\ y_{sc} \end{pmatrix} = \begin{pmatrix} \alpha & 0 \\ 0 & \delta \end{pmatrix} \begin{pmatrix} x_{sh} \\ y_{sh} \end{pmatrix} \tag{10}$$

4) Rotation normalization. The rotation parameter ϕ is computed by normalizing the equation below to zero.

$$\mu_{30} + \mu^{r}{}_{12} = 2(\mu^{sc}{}_{30} + \mu^{sc}{}_{12}) \cos\phi \; 2(\mu^{sc}{}_{03} + \mu^{sc}{}_{21}) \sin\phi = 0 \tag{11}$$

Thus,

$$\phi_1 = \arctan\left(\frac{-\mu^{sc}{}_{30} + \mu^{sc}{}_{12}}{\mu^{sc}{}_{03} + \mu^{sc}{}_{21}}\right) \quad \text{or} \quad \phi_2 = \phi_1 + \Pi$$

Choose one of the two solutions by requiring $\mu^{1}{}_{03} + \mu^{1}{}_{21} < 0$. Finally, the normalized coordinate set (x_n, y_n) is

$$\begin{pmatrix} x_n \\ y_n \end{pmatrix} = \begin{pmatrix} \cos\phi & \sin\phi \\ -\sin\phi & \cos\phi \end{pmatrix} \begin{pmatrix} x_{sc} \\ y_{sc} \end{pmatrix} \tag{12}$$

Now standard position of image is obtained. And the inverse normalization procedure is performed by multiplying of (x_n, y_n) with A^{-1} step by step. The order too cannot be neglected.

3. PROPOSED SCHEMES

In this section, a detail of the proposed watermarking scheme is explained. The two main phases of watermarking system are embedding of the watermark and its extraction or detection process. In the proposed NCS approach Moment normalization is employed to acquire the scaling invariance for the circular region. It transforms the image into its standard form by translating the origin of the image to its centroid. With the scaling normalization, the aligned circular regions are transformed to its compact size. Therefore, the selected circular regions are scaling invariant and are ready for watermark embedding using NCS approach. Based on the above analysis, the rotation and scaling invariant regions are located in the image for watermark embedding.

3.1 Proposed normalization based chaotic system (NCS) approach

The block diagram of entire process of proposed NCS approach is given in the Figure 1.

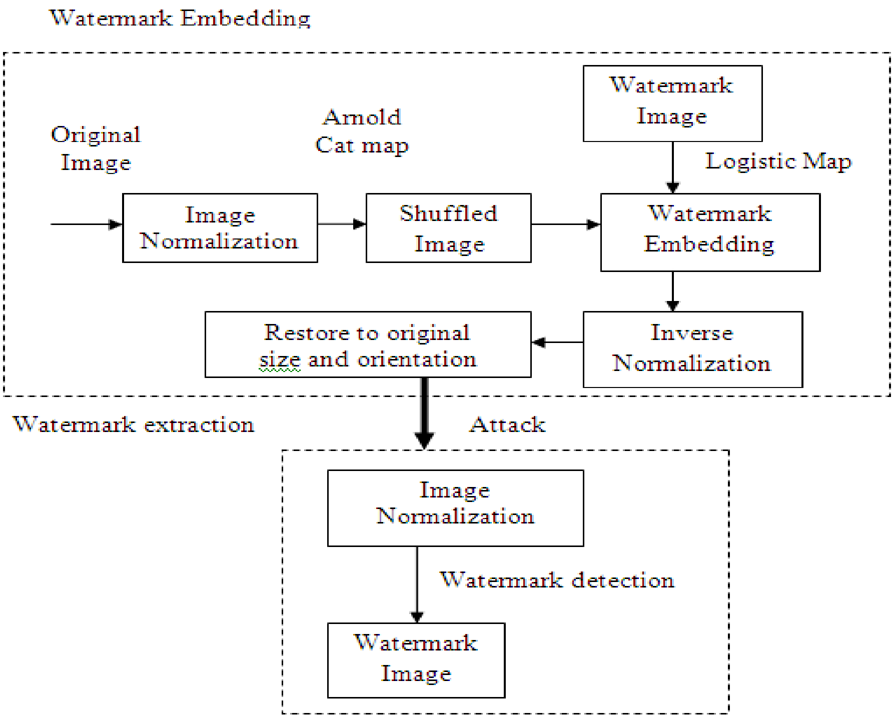


Figure 1. Block diagram of proposed NCS approach

3.1.1 Watermark embedding

The idea of embedding the watermark design is to modify the original image with moment based image normalization. Normalized image is shuffled using Arnold cat map, to achieve better authentication and protection. Chaotic maps are used to increase the security of a digital watermark system. Chaotic signals are complex in nature and impossible to predict over a long time [7, 8]. They are generated by a simple dynamic system such as logistic map and Chebyshev map. The chaotic signals are reproduced easily. In order to shuffle the embedding position of the host image, two dimensional Arnold cat map is employed in the proposed scheme, which is described in Equation (13).

$$x_n+1 = (x_n + y_n) \bmod 1,$$
$$y_n+1 = (x_n + 2y_n) \bmod 1 \quad (13)$$

where notation "x mod1" denotes the fractional part of a real number x by adding or subtracting an appropriate integer. Therefore, (x_n, y_n) is confined in a unit square of [0, 1] × [0, 1]. The Equation (13) is represented in matrix form as given in Equation (14).

$$\begin{bmatrix} x_n + 1 \\ y_n + 1 \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix} \begin{bmatrix} x_n \\ y_n \end{bmatrix} = A \begin{bmatrix} x_n \\ y_n \end{bmatrix} \bmod 1 \quad (14)$$

To make the determinant of its linear transformation, matrix |A| is made equal to 1. To make the cat map as area preserving, a unit square is first stretched by linear transformation and then folded by modulo operation. This type of map is known as chaotic and this is a one to one map. In this each point of the unit square is uniquely mapped onto another point in the unit square. Hence, watermark pixel of different positions is getting different embedding position. The cat map above is extended as follows. Initially, the phase space is generalized to [0, 1, 2, . . . , N −1]×[0, 1, 2, . . . , N − 1], i.e., only positive integers from 0 to N − 1 are taken, then Equation (14) is generalized to two-dimensional invertible chaotic map as given in Equation (15).

$$\begin{bmatrix} x_n + 1 \\ y_n + 1 \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x_n \\ y_n \end{bmatrix} = A \begin{bmatrix} x_n \\ y_n \end{bmatrix} \bmod \quad (15)$$

where a, b, c and d are positive integers, and |A| = ad−bc = 1, therefore, only three among four parameters of a, b, c and d are independent under this condition. In Equation (15) the coordinate (i,j) of watermark pixel is served as the initial value. The three independent parameters of Equation (15) and the iteration time n serves as the secret key. After 'n' iterations, iterating result (x_n, y_n) is served as the embedding position of the watermark pixel (i,j). The arbitrary adjacent two watermark pixels separates apart largely in the host image when the iteration time n is big enough and different watermark pixels will get different embedding positions, so that the embedded watermark pixels is spread in the host image randomly.

After shuffling process, the present method adopted logistic map in step three, to determine in which bit positions of image pixels, the watermark is to be embedded. Logistic map is an example of chaotic map, and it is described as follows in Equation (16).

$$z_{n+1} = \mu z_n(1-z_n) \quad (16)$$

Where μ€ [0,4], z_n € (0, l), n = 0,1, 2 .. . The system is in chaotic state under the condition that 3.569945 < μ ≤ 4. With different initial values and different sequences are generated. The advantage of this system is i) the sequence is normally distributed in the interval of (0, 1) and is non-periodic ii) The interval of (0, 1) is divided into several sub intervals which correspond to different pixel bits for watermark embedding.

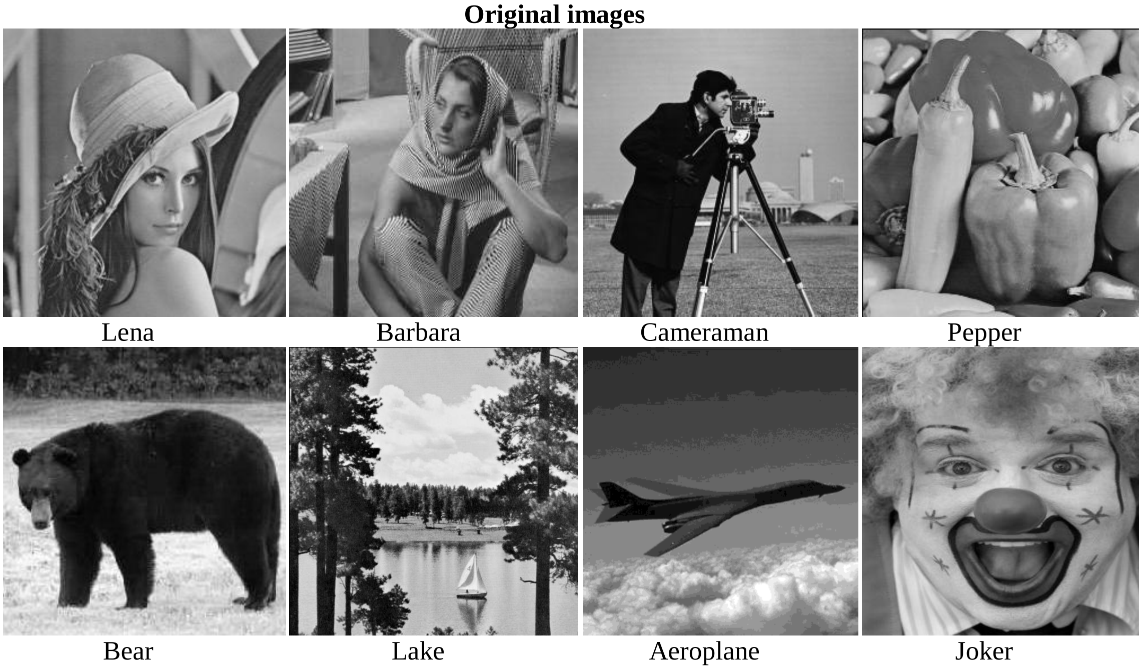
3.1.2 Watermark extraction

The original image is not necessary at the watermark extraction stage. This refers to a "blind" watermarking process. To extract the watermark, sequences of embedding locations are utilized. Inverse moment based image normalization is applied in the watermarked image. Perform the inverse NCS approach to obtain the pixel locations and watermark contents.

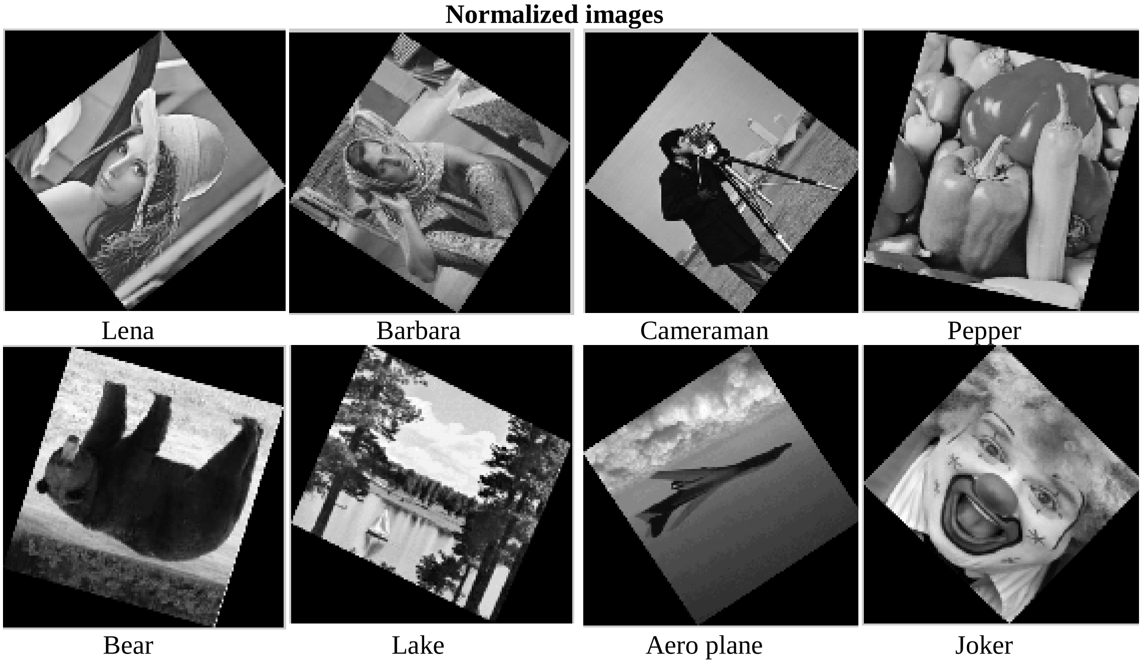
4. EXPERIMENTAL RESULTS

Experiments are accomplished on eight gray images to verify the proposed method. These eight images are Lena, Barbara, Cameraman, Pepper, Bear, Lake, Aeroplane and Joker. They are represented by 8 bits/pixel and size is 256×256. Images used for experiments are shown in Figure 2. In this experiment, a 64×64 binary image, as shown in Figure 3 is considered as the watermark of image. The upshots expose that there are no discernibly visual degradations on the watermarked image presented in Figure 2 with a PSNR of 40. Extracted watermark without attack is presented in Figure 2 with NCC unit. The proposed method solemnized that there are no visual degradations on the reverenced watermarked images. For all the different original test images, the watermark is successfully extracted with unit NCC.

Original images



Normalized images



Watermarked images

Lena	Barbara	Cameraman	Pepper
PSNR 45.42	PSNR 44.72	PSNR 45.35	PSNR 43.13
NCC 0.98	NCC 0.98	NCC 0.99	NCC 0.98

Bear	Lake	Aeroplane	Joker
PSNR 44.60	PSNR 45.27	PSNR 45.36	PSNR 44.89
NCC 0.99	NCC 0.98	NCC 0.98	NCC 0.98

Figure 2. Original, Normalized and Watermarked images with PSNR and NCC values

DrMGR

(a)

Figure 3. Watermarked image (a) Logo 'MGR'

Figure 4. Attacked watermarked images (a) Cropping 5% (b) Cropping 10% (c) Cropping 15% (d) Gaussian Blur 1px (e) Gaussian Blur 2px (f) Gaussian Blur 3px (g) Noise 10% (h) Noise 15% (i) Noise 20% (j) Rotate 2^0 (k) Rotate 4^0 (l) Rotate 6^0

To provide evidence of the competence of proposed method, the proposed scheme test's the watermarked images with Cropping (5%, 10% ,15%) , (Gaussian Blur 1px, 2px, 3px), Noise (10%,15%,20%), Rotate (2^0,4^0,6^0). Figure 4(a)-(i) expose the watermark recognition upshots of the different attack of the Barbara image. From the upshots, the proposed method is proficient to perfectly detect the watermark in the watermarked images. The proposed method can detect perfectly the watermark from the watermarked images and it is well built robustness to the geometric and non-geometric attacks. The experimental results show that the proposed algorithm performs well against rotation, cropping, and other attacks such as Gaussian noise pollution and Gaussian Blur. Extracted watermark images of proposed NCS approach is given in the Figure 5.

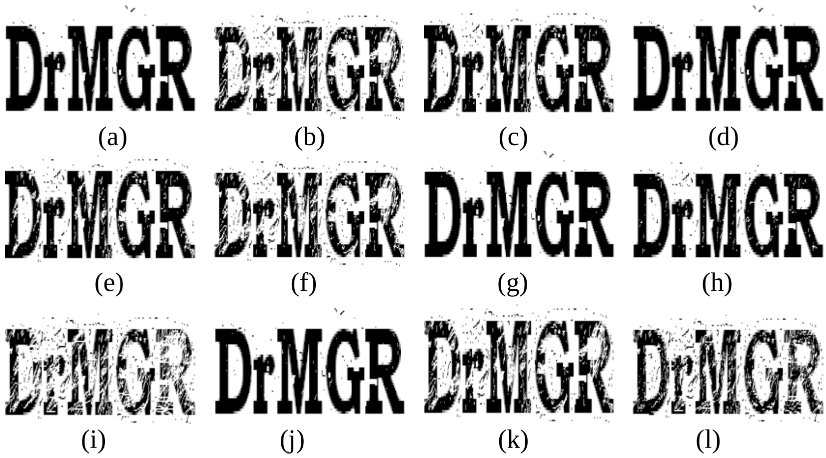


Figure 5. Extracted watermark images (a) Cropping 5% (b) Cropping 10% (c) Cropping 15% (d) Gaussian Blur 1px (e) Gaussian Blur 2px (f) Gaussian Blur 3px (g) Noise 10% (h) Noise 15% (i) Noise 20% (j) Rotate 2^0 (k) Rotate 4^0 (l) Rotate 6^0

Table 1(a) PSNR and NCC values with various attacks by the proposed NCS approach

Type of Attack	**Lena**		**Barbara**		**Cameraman**		**Pepper**	
	PSNR	**NCC**	**PSNR**	**NCC**	**PSNR**	**NCC**	**PSNR**	**NCC**
Cropping 5%	42.14	0.93	42.56	0.96	42.99	0.95	41.46	0.96
Cropping 10%	41.28	0.91	39.67	0.88	40.58	0.90	40.27	0.93
Cropping 15%	37.89	0.84	36.36	0.82	36.19	0.80	38.36	0.89
Gaussian Blur 1px	41.37	0.91	41.37	0.94	42.07	0.93	40.27	0.93
Gaussian Blur 2px	40.81	0.90	40.17	0.91	41.11	0.91	38.17	0.88
Gaussian Blur 3px	38.14	0.84	38.13	0.86	37.24	0.82	36.48	0.84
Noise 10%	43.26	0.96	43.12	0.98	42.86	0.91	40.62	0.91
Noise 15%	42.48	0.94	40.67	0.92	40.60	0.90	38.27	0.89
Noise 20%	40.91	0.90	38.29	0.87	39.78	0.88	35.49	0.82
Rotate 2^0	42.40	0.94	41.27	0.93	41.50	0.92	40.47	0.94
Rotate 4^0	40.37	0.89	39.38	0.89	40.97	0.91	37.48	0.87
Rotate 6^0	37.19	0.82	36.19	0.82	38.59	0.85	35.79	0.83

Table 1(b) PSNR and NCC values with various attacks by the proposed NCS approach

Type of Attack	**Bear**		**Lake**		**Aeroplane**		**Joker**	
	PSNR	**NCC**	**PSNR**	**NCC**	**PSNR**	**NCC**	**PSNR**	**NCC**
Cropping 5%	42.37	0.96	42.56	0.94	42.39	0.94	41.37	0.94
Cropping 10%	41.38	0.94	40.38	0.89	40.27	0.89	39.68	0.90
Cropping 15%	39.05	0.88	38.69	0.85	38.29	0.85	37.59	0.85
Gaussian Blur 1px	42.91	0.97	43.49	0.96	43.56	0.96	42.49	0.96
Gaussian Blur 2px	40.39	0.91	40.38	0.89	41.37	0.91	40.12	0.91
Gaussian Blur 3px	37.49	0.85	38.37	0.85	39.01	0.86	37.49	0.85
Noise 10%	43.28	0.98	43.59	0.96	42.48	0.94	42.59	0.96
Noise 15%	41.38	0.94	41.42	0.92	40.78	0.90	40.33	0.91
Noise 20%	40.38	0.91	39.68	0.88	38.91	0.86	38.79	0.88
Rotate 2^0	42.01	0.95	42.47	0.94	42.34	0.94	41.39	0.94
Rotate 4^0	39.48	0.89	40.38	0.89	39.27	0.87	39.87	0.90
Rotate 6^0	37.79	0.82	37.94	0.84	36.48	0.81	36.45	0.82

The experimental results show that the proposed algorithm performs well against Rotation, Cropping, and other attacks such as Gaussian noise pollution and Gaussian Blur. Table 1(a)-(b) shows PSNR and NCC values respectively with various attacks on the considered images. Table 1 (a)-(b) clearly indicates the high robustness and image quality of the NCS approach even in the presence of various attacks.

4.1 Comparison of the proposed with various other methods

The proposed method is compared with Sridevi. T et.al method [18, 19], Ping Dong et.al method [3] and Chun-Shien Lu [20] results are furnished in the Table 2. Compared with other Normalized based watermarking methods, the robustness against various attacks is significantly improved by the proposed method, and the image quality after watermarking is still preserved. The proposed method is having better PSNR and Normalized correlation values compared to other normalized based watermarking schemes [18] [19] [3] [20]. Compare to many watermarking schemes, the proposed method has simple steps for watermarking and extraction and it is resistant against many image processing attacks. For Cropping, Rotation and Noise affects the proposed method is more robust than other four methods. Figure 6 clearly indicate that the proposed method shows very high PSNR value when compared with the other existing methods.

Table 2. Comparison of the proposed NCS approach with various other methods

Test Images	**T.Sridevi et.al method**		**Ping Dong et. al method PSNR(dB)**	**Chun-Shien Lu method**	**Proposed method**
Lena	35.21	33.26	29.29	43.94	45.42
Barbara	35.28	33.89	29.37	43.28	44.72
Cameraman	34.28	34.37	29.18	42.98	45.35
Pepper	36.58	33.27	28.38	40.47	43.13
Bear	35.83	33.58	29.24	43.1	44.6
Lake	35.82	33.81	28.87	43.76	45.27
Aero plane	34.37	33.1	29.45	43.99	45.36
Joker	34.69	34.21	28.65	42.87	44.89

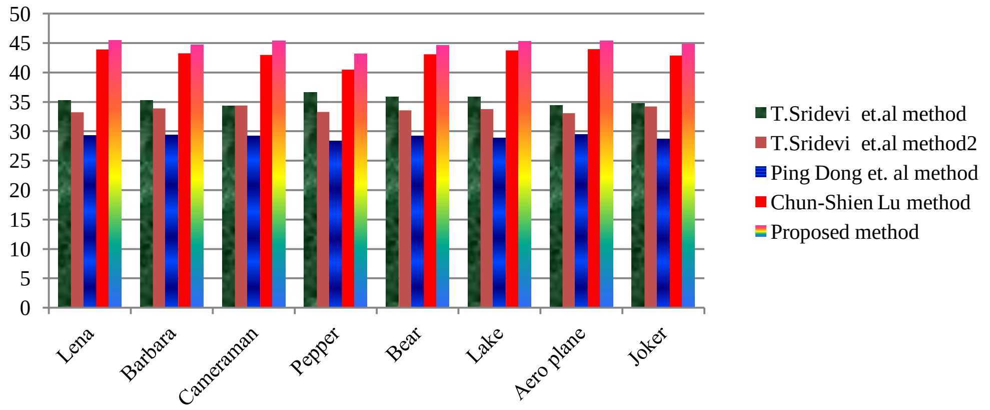


Figure 6. Comparison graph of the proposed method with various other methods

5. CONCLUSION

The present paper demonstrated a novel scheme called NCS approach. In the proposed scheme each watermark bit is embedded in normalized image and the information of the watermark bit is spread throughout large spatial regions. The proposed watermarking scheme achieve high perceptual quality of the watermarked image for human eyes, it possesses high performance of robustness to various malicious manipulations including median filtering, low pass filtering, image rescaling, image cropping, JPEG, and JPEG 2000 compression. Even the proposed scheme is implemented to provide that the value of NCC of the extracted watermark is as high as 0.9 while the watermarked image is attacked by the JPEG compression with a quality factor as low as 40%. The high PSNR value of the proposed NCS indicates that it is robust to various attacks. The high NCC value of the proposed NCS with or without attacks indicates that an embedded watermark is still recoverable. Thus the proposed NCS achieves high security, authenticity, robustness, good quality, with bulk data capacity, high data redundancy, and high sensitivity to secret keys even in the presence of various attacks. The proposed NCS offer a sufficient level of security for a whole range of applications in computer science.

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