



Providing an Image Watermarking Scheme Based on Chaotic Sequence and Cosine Transform, to Strengthen Interaction with a Variety of Software Attacks

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Abstract

It's important and necessary to detect and prove the ownership of a digital work in the communication technology era. The purpose of this paper is to propose a digital watermarking scheme for images. In this scheme, first, a watermark signal is produced by a chaotic sequence. Then the watermark is placed in the cosine transform coefficients of a host image. Next, the watermarked image is exposed to some attacks such as filtering, compression, rotation and addition of noise. The simulation results show the ability of the proposed method in maintaining the watermark after conducting these attacks. In the following, in addition to comparing the propose method with other similar methods, the superiority of this scheme over other methods will be remarkable and confirmable.

Keywords: Security, Discrete Cosines Transform (DCT), Robustness and Watermarking, Chaotic Sequence

1. Introduction

Watermarking is a solution for protecting digital data from illegal forging and copying, which originates from hundreds of years ago: [3]. With the innovations and inventions that researchers create in the creation of a watermarking scheme, they have been able to offer useful methods for this purpose: [4],[5].

With the advent of chaotic sequences and due to their wonderful effects, the designers of watermarking methods have become interested in using these sequences in their proposed methods: [12], [13], [1], [6], and [7]. Generally, chaotic sequences can be used in secure telecommunications. Of the obvious advantages of these sequences, their intense sensitivity to primary conditions and the fact that they cannot be repeated can be mentioned: [2].

In: [12], [13] watermarking methods are categorized into 5 categories in terms of watermark embedding and extraction methods; 2 of these categories are for embedding methods and the other 3, are defined for the extraction model. Depending on whether the embedding happens in pixel or transform domain, the watermarking methods are named in the domains of location and transform. And also depending on the level of the need to watermark signal information during extraction and detection of watermark, the watermarking schemes can be categorized into the three categories of blind, semi-blind and non-blind. In fact, a blind scheme does not require the original watermark at the

extraction stage, whereas in the non-blind and semi-blind methods, the watermark and some of its information are needed, respectively. The proposed method in this investigation is a transform-based method, whose security is guaranteed with the help of chaotic sequences, and since it requires the addresses of watermark storage location from the host image during the extraction of watermark, then this scheme, is considered to be a semi-blind scheme.

The paper in reference: [8], proposes a blind watermarking algorithm in FRFT¹ domain. In this method, the main image is divided into some blocks; after applying the FRFT to the blocks, some of the transform coefficients are selected randomly and the embedding operation is performed on these coefficients. The method proposed in: [4] initially, mixes a watermark image with the help of chaotic sequences, then embeds the watermark in the wavelet transform domain. The proposed idea of: [5] is based on discrete cosine transform which divides an image into smooth and rough blocks; the watermark signal concealment operation is performed based on the energy level of each block. The technique proposed in: [9] uses nonlinear wavelet transform, and embeds watermark information transform coefficient in in the transform coefficients of a host image based on an adaptive algorithm. The proposed algorithm in [10], has used chaotic sequences to randomly select the embedding positions.

Usually, transform dependent methods; show a good robustness from themselves in protecting watermark signal against image processing operations. Therefore, here, it was tried to use DCT² to achieve high robustness. However in: [12],[13] using the chaotic sequences in watermark production stage and considering the starting point and the parameter existing in the chaotic sequence as a key, the security of the method has been increased. In the following, DCT³ will be briefly introduced and the proposed watermarking algorithm will be described.

2. Cosine Transform

DCT is a Fourier-related transform which is very similar to DFT⁴, with the difference that it only uses real numbers. Since smaller cosine functions⁵ are needed to estimate a normal signal, the use of cosine function instead of sine in compression is necessary. Also, proportional to differential functions, cosine functions have clearer boundary conditions. A DCT, shows a limited sequence of data points as the collection of cosine functions which fluctuate in different frequencies. This transform, has much use in science and engineering. From compression with audio data loss (like MP3) and images (like JPEG), which are small fractions with high removable frequencies, to spectral methods from the numerical solution of a differential equation are all of the uses of DCTs. For the $f(x, y)$ image, the FCT is calculating as below [11]:

$$F(u, v) = c(u)c(v) \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y) \cos \frac{\pi(2x+1)u}{2M} \cos \frac{\pi(2y+1)v}{2N} \quad (1)$$

$$u = 0, \dots, M-1; v = 0, \dots, N-1$$

1 Fractional Fourier Transform

2 two-Dimensional Discrete Cosine Transform

3 Discrete Cosine Transform

4 Discrete Fourier Transform

5 proportional to sine function

Here, M is row number and N is column number. C (u) and C (v) too, are obtained by (2):

$$c(u) = \sqrt{1/M} \quad , c(v) = \sqrt{1/N} \quad (2)$$

The DCT introduced in (1), is for 2-d images. Therefore if a host image is colored, all we need to do is to change it from colored to greyed, and then apply this transform.

3. Proposing A Method

Usually, watermark signal, is a binary image with a pseudo-random binary sequence. In this examination, we use a chaotic sequence to produce watermark. Actually, by using the chaotic sequence, we produce the watermark signal and increase the algorithm's security. The chaotic sequence of use is Tent map: [13]. Equation (3), defines this sequence: [11].

$$\begin{aligned} x_{n+1} &= ax_n \quad \text{for } 0 \leq x \leq 0.5 \\ x_{n+1} &= a(1 - x_n) \quad \text{for } 0.5 \leq x \leq 1 \end{aligned} \quad (3)$$

In this equation, is the turbulence parameter, also and, are the numbers of the repetitions for the making of the sequence. The starting point and the chaotic parameter (a) are as the keys of the desired watermarking system. The numbers produced from equation (3), are all floating-point numbers in the [0-1] range. By rounding the numbers resulting from equation (3), a binary sequence can be obtained which is a watermark signal (w), which must be embedded in a host image. The watermark embedding process goes through the following steps. Step 1: A DCT is taken from the main image and if the original image is colored, it should first be turned into grey .

Step 2: The transform coefficients obtained from the previous step, are rounded and placed in set A. Of course the arrangement of the coefficients in this set is such that coefficients with higher repetitions are at the top of set A. In other words, the coefficient with the highest repetitions, is placed at the beginning of set A and the coefficient with the lowest repetitions, is placed at the end of the set .

Step 3: the first coefficient from set A is taken and named M. Another coefficient (N), is also taken from this set whose selection is done according to (4) and the condition of this equation.

$$|M - N| > 45 \quad (4)$$

Condition: N should also have high repetitions. In other words, N should be in an immediate neighborhood of M .The number 45 is an arbitrary number, whose value has been obtained experimentally through trial and error. In fact, the greatness of this number will lead to the increase of the watermarking system robustness and the decrease of capacity; and the capacity is the number of the watermark bits that can be hidden inside the host image. Therefore, 45 is an exchange between the capacity and robustness. In: [12], [13] to embed more bits and also have an optimal robustness, they obtained the number 35 empirically with a number of experiments, and we obtained the number 45 by repeating that. Step 4: embedding operation is performed by applying (5).

$$I(i, j) = \begin{cases} M - 1 & \text{if } I(i, j) = M \text{ \& } w_k = 0 \\ N & \text{if } I(i, j) = N \text{ \& } w_k = 1 \end{cases} \quad (5)$$

$k = 1, \dots, L$

In this equation, $I(i, j)$ is CTC¹ of host image, w is watermark signal, L watermark sequence length, and M and N have been explained in step 3. Step 5: here, inverse discrete cosine transform is applied. The watermarked image is obtained in this step.

$$w'_k = \begin{cases} 0 & \text{if } |I'(i, j) - M| \leq \frac{|M - N|}{2} \\ 1 & \text{others} \end{cases} \quad k = 1, \dots, L \quad (6)$$

In this equation, $I'(i, j)$, are the CTCs of the watermarked image, and their coordinates' address from the embedding step, are available as the watermarking system keys. Figure (1), in part A and B, shows the watermark embedding and watermark extraction in the block diagram of the proposed watermarking system, respectively

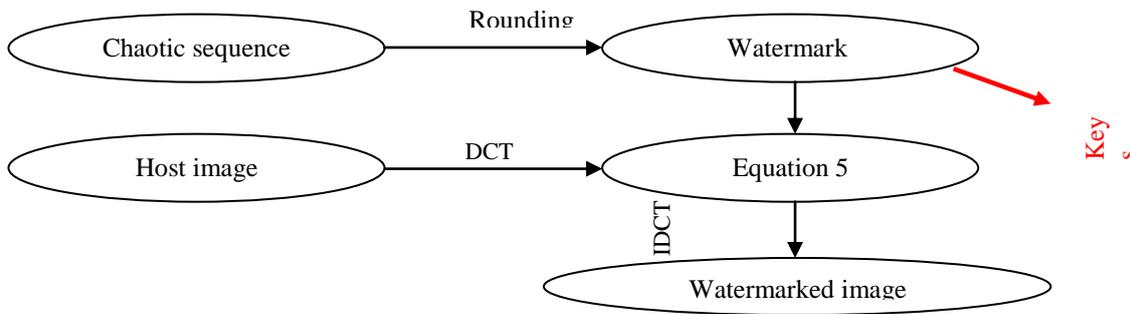


Figure 1 (a). Watermark embedding process

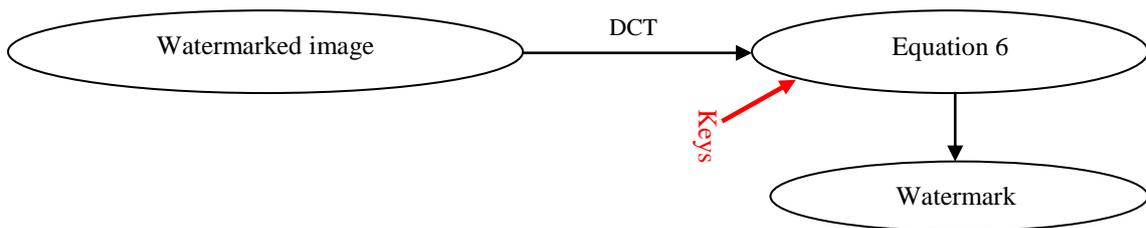


Figure 1 (b). Watermark extraction

4. Results

Some experiments have been conducted to assess the scheme. The simulations were run in MATLAB environment. The turbulence parameter and primary value of equation (3), are considered as respectively. We have demonstrated the original watermarked

¹ Cosine Transform Coefficient

image in figure (2). We used PSNR¹ criterion to measure the transparency of the method.

$$PSNR = 10 \log((255^2) / MSE)$$

$$MSE = \sum_{i=1}^M \sum_{j=1}^N |X(i, j) - X'(i, j)| \quad (7)$$

X and X', are the original and watermarked signal, respectively. As we know, one of the factors for evaluating the performance of a watermarking scheme is transparency percentage. Transparency means that watermark sequence would be difficult to observe by human eye. The PSNR values mentioned below the watermarked images, along with images (2b) and (2d), clearly show the high transparency percentage of the method.

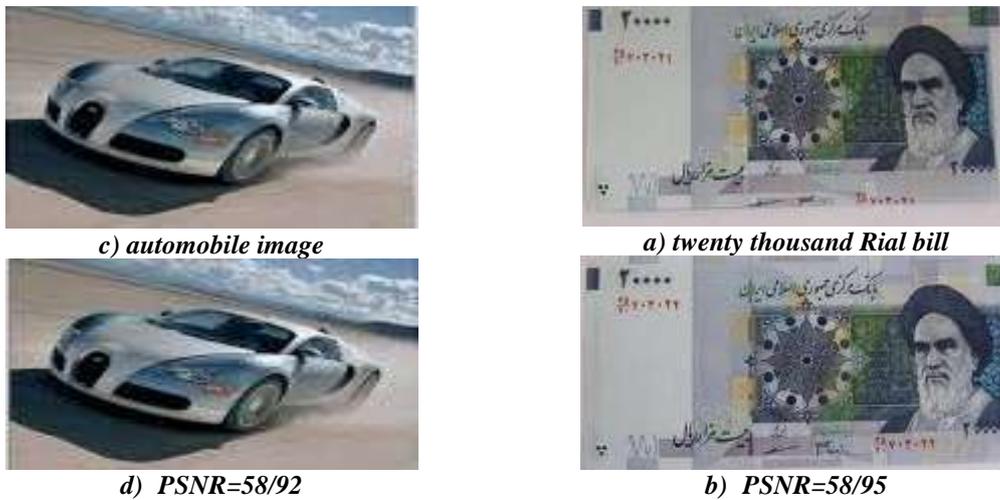


Figure 2. (a) And (c) are the original images; (b) and (d) are the watermarked images

Table 1 has been drawn to determine and measure the ability and robustness of the proposed algorithm in maintaining the watermark signal. First, the watermarked image, is exposed to attacks such as filtering, addition of noise, rotation and JPEG compression, and next, the watermark will be extracted. We have registered the robustness results that are the NC values (normalized correlation) in table (1).

The more identical the extracted watermark to the original one is, the nearer the value of NC to 1 will become, and 1 is the ideal number. The NC value is calculated using equation (8).

$$NC = \frac{\sum_i^j W(i, j) * W'(i, j)}{\sqrt{\sum_i^j W(i, j)^2 * \sum_i^j W'(i, j)^2}} \quad (8)$$

W and W' are the signal of the original and extracted watermark.

¹ Peak signal-to-noise ratio

Table 1. ability and robustness of the proposed algorithm in maintaining the watermark signal

Twenty thousand Rial bill image	Automobile image	Attacks
1.01	1.00	Without attack
0.87	0.89	Salt and pepper noise (0.01)
0.98	0.99	Gaussian noise (0.001)
0.89	0.85	Median filter
0.96	0.98	1 degree rotation
0.94	0.96	5 degree rotation
0.89	0.95	10 degree rotation
1.00	1.00	JPEG compression or QF=95
1.01	1.01	JPEG compression or QF=80
0.99	0.99	JPEG compression or QF=70

According to the results of table (1), we observe that the method can extract the watermark with insignificant error after conducting image processing operations such as filtering and addition of noise. Also by rotating the image in different angles and compressing it by different QF¹, the method proposed in this paper, can properly extract the watermark. In order to understand the performance level of the proposed method, we compared it with methods: [4], [5], and placed the comparison results in tables (2) and (3).

Compared to method: [4], we evaluated the methods based on NC, and in another comparison, the HC criterion (equation 9), has been used to evaluate the methods. HC shows the recovery rate of the watermark from the extracted watermark.

$$HC = 1 - \frac{\sum w \oplus w'}{L} \quad (9)$$

In this equation, w and w' are the original and extracted watermark, respectively, and L, is the watermark length. From the results of this table, the superiority of the watermark signal maintenance method is clear after conducting some attacks.

Table 2. The results of the comparison with: [5] based on NC

Examined method	Method [5]	Attacks
0.96	0.92	Gaussian noise (0.001)
0.87	0.81	Median filter [3 3]

Table 3. The results of the comparison based on HC

Examined method	Method [6]	Attacks
1.00	0.95	Gaussian filter
1.00	0.97	JPEG Compression or QF=90
0.97	0.95	JPEG Compression or QF=70
0.87	0.81	JPEG Compression or QF=30

¹ Quality Factors

5. Conclusion

In this investigation, using chaotic sequences and digital cosine transform, a reliable and robust method has been offered. We saw that the method can extract the watermark with minimal error rate after applying image processing such as filtering and adding noise. Also by rotate the image at different angles and pressed it with a different quality, this method can extract the watermark well. We made some comparisons between the ability of the investigated method, and some other methods, based on watermark robustness and signal maintenance after conducting the attacks. The results of the comparisons show a high robustness of the proposed method.

References

- [1] Kathleen T. Alligood, Tim D. Sauer and James A. Yorke, *Chaos: An Introduction to Dynamical systems*, Springer, New York, 2001.
- [2] Vandana S. Inamdar, Priti P. Rege, Meenakshi S. Arya, "Offline Handwritten Signature based Blind Biometric Watermarking and Authentication Technique using Biorthogonal Wavelet Transform", *International Journal of Computer Applications*(0975-8887) , Vol. 11, No. 1, December 2010.
- [3] Zhao Yuxia, Fan Jingbo, "A Double-function Digital Watermarking Algorithm Based on Chaotic System and LWT", *Physics Procedia* 33 pp. 1947-1956, 2012.
- [4] Mei Yu, Aihong Wu, Ting Luo, Gangyi Jiang, Wujie Zhou, Songyin Fu, "A New Stereo Image Watermarking Method for 3D Media", *Procedia Engineering* 29 pp. 2399-2404, 2012.
- [5] S. Mohammadi, A. Hakimi, "A chaos-based video watermarking algorithm", *The ISC Int'l Journal of Information Security*, Vol 4. 4, pp. 77-86, 2012.
- [6] S. Mohammadi, Si Talebi, A. Hakimi, "Two Novel Chaos-Based Algorithms for Image and Video Watermarking", *Iranian Journal of Electrical & Electronic Engineering*, Vol 8. No. 2, pp. 97-107, 2012.
- [7] Jun Lang, Zheng-guang Zhang, "Blind digital watermarking method in the fractional Fourier transform domain", *Optics and Lasers in Engineering* 53, pp. 112-121, 2014.
- [8] Xiaosheng Huang, Sujuan Zhao, "An Adaptive Digital Image Watermarking Algorithm Based on Morphological Haar Wavelet Transform", *Physics Procedia* 25, pp. 568-575, 2012.
- [9] Qiaolun Gu, Tiegang Gao, "A novel reversible robust watermarking algorithm based on chaotic system", *Digital Signal Processing* 23, pp. 213-217, 2013.
- [10] Z. J. XU, Z. Z. WANG, Q. LU, "Research on Image Watermarking Algorithm based on DCT", *Procedia Environmental Sciences* 10, pp. 1129-1135, 2011.
- [11] Narendra Singh, Alok Sinha, "Digital image watermarking using gyrator transform and chaotic maps", *Optic* 121, pp. 1427-1437, 2010.
- [12] Mohammadi, S, Talebi S, Hakimi A. " A Digital watermarking method for gray and color images using chaotic sequence ", 19Th Iranian Conference on Electrical Engineering, 2242-2247, Amirkabir University of Technology, 2012.
- [13] Mohammadi, S, Maleknejad M. " image watermarking in the Wavelet transform domain based on chaotic sequences ", First National Conference on Computer Engineering and Information Technology PNU, 353-359, PNU-of Tiran Isfahan, 2014.

