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Research paper

A Novel Compressed Encrypted and Encoded Watermark Embedding Scheme for Digital Images

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Abstract

In this research work a novel idea of compressed, encrypted and encoded watermark embedding scheme for digital images is proposed. Initially watermark is compressed using Huffman encoder. Compressed watermark is encrypted using combined binary key sequence $\{K_i\}$ derived from sequence of logistic map and Lozi map. The compressed and encrypted binary watermark is encoded using (n,1) repetition code. This compressed, encrypted and encoded binary watermark is embedded in alternate locations of cover image pixels using of Least Significant Bit (LSB) and Second Least Significant Bit (SLSB). To study the watermarked image quality, parameters such as Signal to Noise Ratio (SNR) and Mean Square Error (MSE) are used. Also performance of the proposed system is compared with uncompressed, encrypted, encoded watermark embedding scheme. There is a significant improvement in MSE, SNR of watermarked image, when compressed watermark embedding scheme is compared to uncompressed watermark embedding scheme.

Keywords: *Spatial domain watermarking, Lozi mapping, Logistic mapping, Huffman code, repetition code*.

1. Introduction

With rapid advancement of electronic based digital devices and modern internet services, transmission and storage of multimedia information is common practice. This also facilitates users to create, manipulate and exchange data over internet. This imposes a threat of copyright of original or actual content of the owner. Watermarking is one of the solutions to protect copyright of the owner [1][2]. It is the process of embedding a piece of useful information such as company logo, text, audio etc. which is also known as watermark into cover object. So obtained image is known as watermarked image or watermark embedded image. The cover object may be in the form of audio, video, image etc. Based on visibility of watermark, image watermarking may be broadly divided into visible or invisible watermarking technique[1][3]. If watermark is visible to normal human eye then it is visible watermarking. Where as in case of invisible watermarking, watermark is not visible to normal human eye. Hence it is difficult to identify hidden information. In general image watermarking algorithm should satisfy basic requirement such as robustness, transparency, computational complexity and stability etc [3].
Digital image watermarking can be broadly classified into spatial domain and transform domain watermarking[1]-[7]. In spatial domain watermarking schemes, watermark is embedded directly by modifying cover image pixels with watermark data.
Hence it is computationally less complex and perceptual quality of watermark embedded image or watermarked image is better. Where as in case of transform domain technique, cover image is transformed using transformation technique to embed the watermark and inverse transformation is applied after embedding the watermark. Many researchers have used transformation techniques such as Discrete Cosine Transform (DCT) or Discrete Wavelet Transform (DWT) for obtaining robustness against compression and signal processing attacks. However, cover image transformation and inverse transformation involves high computation complexity, increased requirement of hardware circuitry and high power consumption when compared to spatial domain techniques [13][15].
Many researchers have developed algorithms using spatial domain and transform domain techniques [1]-[10]. In spatial domain techniques LSB based watermark embedding technique is popular [4][5]. Compressed watermark embedding scheme in LSB of the cover image is discussed in [6]. They have used run length coding for compressing the watermark. Compressed watermark was embedded in LSB of the cover image. Results show that compression improves perceptual quality of watermarked image. Block matching based LSB watermarking scheme is discussed in [7]. Watermark is encoded using Hamming code and embedded in cover image using LSB method. In [8] LSB technique for watermarking by using quick response encoding method is discussed. Result shows that the scheme is secured and robust against the attacks.
In [9] the author have used a Modified LSB algorithm with Singular Value Decomposition (SVD). They used SVD for watermark compression and compressed watermark is embedded in Modified LSB locations of cover image. The author also have performed

comparative analysis between simple LSB method and modified LSB algorithm. Result analysis shows modified LSB algorithm with SVD is better when compared to simple LSB algorithm. However obtaining compression using SVD is complex in computation. In [10] spatial domain watermarking scheme for the color image is discussed. They used Lorenz map and Arnold Cat map to encrypt the watermark and then watermarking was performed.

In our paper novel idea of compressed, encrypted and encoded watermark has been embedded in cover image pixels using LSB and SLSB watermarking technique. Binary text patterned watermark image w(m, n) of size 50×100 is compressed using Huffman encoder. Binary compressed watermark is encrypted using combined binary key sequence $\{K_i\}$. The binary key sequence $\{K_i\}$ is obtained by key sequence of logistic map and Lozi map[14]. So obtained watermark is encoded using (n, 1) repetition code. where ‘n’ is encoded word. In this paper to study the performance n = 3, 5, 7, 9, 11, 13, 15, 17 is chosen.

Structure of the paper is organized as follows. Overview of the LSB and SLSB watermark embedding method, characteristics of logistic map and Lozi map, binary data compression using Huffman code and repetition code is discussed in Section II. The Proposed scheme of watermark embedding is discussed in Section III. Section IV presents Simulation results and performance analysis. Conclusion of the proposed work is given in Section V.

2. Overview

A. LSB and SLSB Modification Scheme

LSB modification scheme is simple and commonly used technique in spatial domain watermarking [5][6][8]. In this scheme, Least Significant Bit of the original image or also known as cover image pixel $\{P_i\} \in (0, 255)$ is replaced with watermark bit $\{W_i\} \in (0, 1)$. In an 8-bit gray scale image, alteration is ±1/255. This alteration of the cover image pixels is negligible to human eye and will not much affect the perceptual quality of the watermark embedded image. Also watermark can be easily recovered even when watermarked image is subjected to attacks such as cropping, lossy compression or any addition of undesirable noise. However attacks such as replacing all the LSB of pixel of watermark embedded image into ‘1’ or ‘0‘ will destroy the presence of watermark.

To overcome such attacks, one solution may be embedding watermark in higher order bits of cover image pixels. But embedding watermark bits in higher order bit plane increases the distortion of the watermarked image which in turn affects the visual quality of the watermark embedded image. However in case of Second Least Significant Bit (SLSB) embedding technique, visual quality of watermark embedded image reduces compared to LSB embedding scheme but the embedded data are secured and unauthorized alteration is not affected much compared to LSB embedding technique.

In this paper, considering the advantages of both LSB embedding scheme and SLSB embedding technique, a novel idea of combination of LSB and SLSB embedding technique is proposed.

B. Logistic Map

Logistic map [11] is one of the simple and widely used chaotic map. One dimensional Logistic map can be defined as follows.

$$X_{t+1} = r * X_t [1 - X_t] \quad (1)$$

Where $0 < X_0 < 1$ is initial parameter of Logistic map, $X_t \in (0, 1)$ is a chaotic sequence of logistic map, t = 0, 1, 2……… …Z. $0 < r < 4$ is a control parameter. The periodicity of the generated sequence X varies depending on the intial value X_0 and control parameter ‘r’. According to researchers [11] when the parameter ‘r’ ranges between $3.5 < r < 3.9999$ system enter into chaotic property. Figure.1 shows a sequence X obtained from logistic map vs length Z=500 with an initial value $X_0 = 0.5$ and r = 3.9999. It is observed that the sequence X is non periodic and pseudo random in nature.

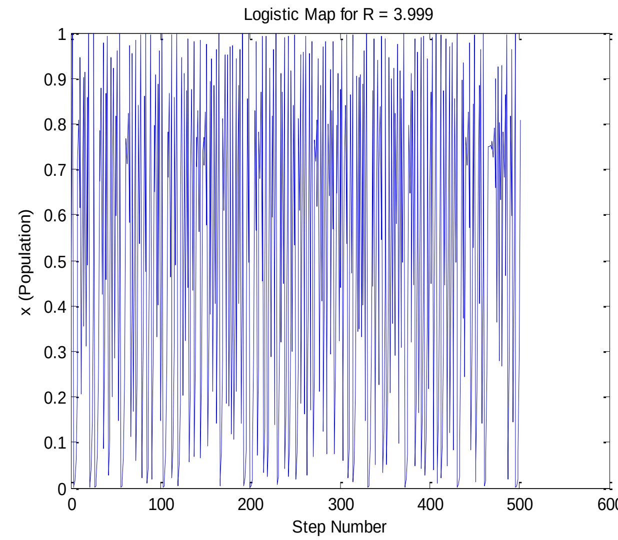

Fig. 1: Sequence X obtained from logistic map of length Z=500 for the initial condition X_0=0.5 and control parameter r=3.9999

By using logistic map equation given in (1) with appropriate initial condition X_0 and control parameter r sequence $\{X_t\} \in (0, 1)$ can be generated. So obtained sequence can be binarized using Equation 2.

$$\{K_{1i}\} = \begin{cases} If\ X_i \le 0.5 & '0' \\ If\ X_i > 0.5 & '1' \end{cases} \quad (2)$$

The binary sequence $\{K_{1i}\}$ derived from logistic map using Equation (2) is used as key sequence for watermark encryption.

C. Overview of Lozi Map

Lozi map was originally introduced by Lozi R in 1978 [12]. Like other chaos methods Lozi map also exhibits a special type of bifurcation property with one dimensional discontinuous piecewise. The main feature of this bifurcation is the presence of a continuum of neutrally stable cycles which is a necessary property of chaotic sequence. The 2-Dimensional Lozi map is given in Equations (3) and (4).

$$Y_t = Q * S_t \quad (3)$$

$$S_{t+1} = 1 - P * |S_t| + Y_t \quad (4)$$

Where ‘P’ and ‘Q’ are initial values ‘t’ is number of iterations.. The sequence Y_t is normalized to [0, 1]. Here $\{Y_t\} \in (0, 1)$ is used as a key sequence. The parameters P=1.7and Q=0.5 are used as initial values [12][14].

The key sequence $\{Y_t\}$ obtained from Equation (3) and (4) is used to obtain binary key sequence $\{K_{2i}\}$ as given in Equation (5).

$$\{K_{2i}\} = \begin{cases} 0 & If\ Y_i \le 0.5 \\ 1 & If\ Y_i > 0.5 \end{cases} \quad (5)$$

Several papers demonstrate image encryption using multiple chaos based key sequence achieves best performance than single chaos map. Hence in this paper Key sequence derived from logistic map and Lozi map proposed in [14] is used.

D. Huffman Coding

Huffman coding [17] is used to compress audio, image, text, etc. Huffman coding is generally used for lossless compression of information based on probability of occurrences of the symbol. The idea behind this technique is assigning of variable length code to input symbol and assigned code length is depends on frequency of symbols. This technique uses smallest code to encode most frequently occurred symbol and largest code for less frequently occurred symbol. Huffman code can be obtained by constructing Huffman tree.

E. Repetition Codes

In coding theory, repetition code [16] is a one of the basic error control coding scheme in which (n, 1) repetition code of length n can detect up to (n-1) errors and further can correct [(n-1)/2] errors.

Encoding Process

In (n, 1) repetition code is a simple error control code in which the each input bit is repeated 'n' number of times to obtain the encoded code word. For example if the information is D = 01011101 then in case of (3, 1) repetition codes, encoded information is E = 000111000111111111000111. In this paper eight different 'n' values such as 3, 5, 7, 9, 11, 13, 15 and 17 are chosen to study the performance. As higher the 'n' value in (n,1) repetition code introduces more redundancy, But improves robustness of watermark against random noise [13][15]. Also repetition code is a simple encoding technique, computational time and complexity involved in embedding process is low compared to well known error control encoding schemes [16].

Decoding Process

When encoded data is transmitted through a channel, due to noise, encoded data may be corrupted. Based on the severity of noise, decoder can decode the data. Higher the noise, lead to more loss of information. In (n, 1) repetition code, to decode, here majority decoding rule is used. According to the rule, in a 'n' bit block received, for 'n' odd, if number of '1's are less than or equal to [(n+1)/2] then decoded bit as '0' else decoded as '1'.

$$Decoded\ bit = \begin{cases} 0, & If\ number\ of\ 1's \leq \frac{n+1}{2} \\ 1, & Otherwise \end{cases} \tag{6}$$

3. Proposed Scheme and Algorithm

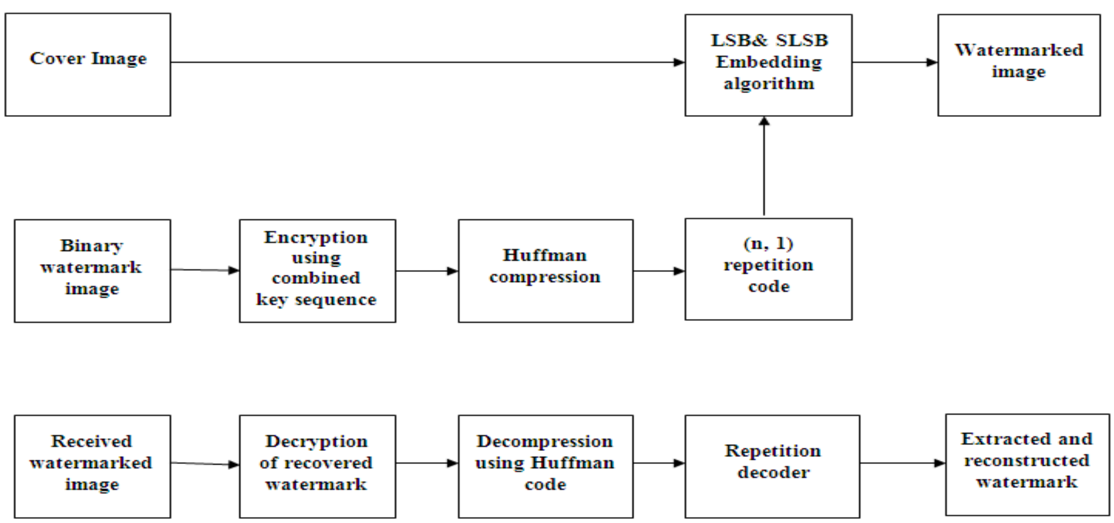

Fig. 2: Proposed watermarking embedding and extraction scheme

In this section watermark embedding and extraction process is discussed. Figure. 2 shows proposed watermark embedding and extraction process. Initially binary image watermark W(m,n) of size 50×100 is compressed using Huffman coding process. The compressed watermark is encrypted using key sequence $\{K_i\}$ obtained from combination of logistic mapK_{1i} and Lozi mapK_{2i}. Obtained compressed and encrypted watermark encoded using (n, 1) repetition code. The encoded watermark is inserted in alternate location of LSB and SLSB of cover image pixels. So obtained image is known as watermarked image.

During watermark extraction process, watermark bits present in LSB and SLSB of watermarked image pixels are recovered the same way how it was embedded. Majority decoding rule applied to decode the watermark bits. Here repetition code provides immunity against noise or any other attacks. Based on severity of noise, 'n' value can be chosen. So obtained bits are decrypted using same combination of binary key sequence $\{K_i\}$ obtained from logistic map $\{K_{1i}\}$ and Lozi map $\{K_{2i}\}$ which was used during encryption process. These decrypted bits are decompressed using Huffman decoder to obtain original watermark bits. Obtained decompressed W_m bits are reconstructed to A×B where A=50 and B=100.

A. Combined Key Sequence Generation

To provide more security to watermark in this work combination of sequence of Logistic map $\{K_{1i}\}$ and Lozi map $\{K_{2i}\}$ is used for encryption of the water mark. To obtain the combined binary key sequence $\{K_i\}$, bit by bit XOR operation is applied between generated key sequence of logistic map $\{K_{1i}\} = \{K_{11}, K_{12}, K_{13}\ldots.. K_{1p}\}$ and generated key sequence of Lozi map $\{K_{2i}\} = \{K_{21}, K_{22}, K_{23}\ldots.. K_{2p}\}$. where 'p' is size of the watermark. The binary key sequence generation is defined as follows,

$$\{\mathbf{K}_i\} = (\{K_{1i}\} \oplus \{K_{2i}\}) \tag{7}$$

The binary key sequence $\{\mathbf{K}_i\}$ obtained from Equation (7) is used for encryption of watermark, where i = {1, 2, …….p}.

B. Binary Watermark Image Encryption

In this section binary image watermark encryption process is discussed.

Step 1: Initially binary image watermark W(m,n) is converted into one dimensional watermark bits $\{W_i\} = \{W_1, W_2, \ldots W_{(A\times B)}\}$, where $\{W_i\} \in (0, 1)$ A=50 and B=100 is chosen.

Step 2: The XOR operation applied between one dimensional watermark $\{W_i\} = \{W_1, W_2, \ldots \ldots W_{(A\times B)}\}$, with the key sequence $\{K_i\}=\{K_1, K_2, K_3 \ldots K_p\}$, to get the encrypted watermark $\{E_i\} = \{E_1, E_2, \ldots E_{A\times B}\}$. The encryption operation can be defined as

$$\{E_i\} = [\{W_i\} \oplus \{K_i\}] \tag{8}$$

C. Watermark Embedding Process Using Lsb And Slsb Method

In this section watermark embedding process is discussed.

Step 1: The binary encrypted image pixels $\{E_j\} = \{E_1 \ldots E_p\}$ obtained in Section-B is compressed using Huffman encoding process to reduce the length of the watermark bits.

Step 2: The Compressed and Encrypted bits of watermark are encoded by (n, 1) repetition code. in this work n = 3, 5, 7, 9, 11, 13, 15 and 17 to study the performance.

Step 3: Compressed, encrypted and encoded bits of watermark are inserted in alternate locations of LSB and SLSB of cover image pixels. Hence watermarked image is obtained.

D. Watermark Extraction Process

The steps of watermark extraction process is as follows

Step 1:The alternate location LSB and SLSB bits of the watermarked image are extracted to obtain the encoded bits that are used in embedding process.

Step 2: The extracted bits are decoded using majority decoding technique discussed in Section II..

Step 3: The decoded watermark bits are decompressed using Huffman decoding scheme.

Step 4: The decompressed watermark bits are decrypted using key sequence $\{K_i\}$ generated using logistic map and Lozi map.

Step 5: The decrypted watermark bits are resized to size of original watermark.

4. Result Analysis

The Implementation of the proposed watermarking scheme is done using MATLAB software with version R2013a. To analyze the performance five random 8-bit gray scale images of size 256×256 pixels are selected as cover image shown in Figure.3 (a-e). The binary image of size 50×100 pixels with 1-bit depth is selected as watermark is shown in Figure. 4.

Fig. 3: (a-e). 8-bit grayscale image with a size of 256×256 pixels

Fig. 4: Binary image watermark W(m,n) with a size of 50×100

A. Perceptual Quality of Watermarked Image

In this section study of the perceptual quality of the watermarked image is discussed. As discussed in section III the compressed, encrypted and encoded watermark embedded in alternate locations of LSB and SLB bits of cover image pixels. To encode the watermark (n, 1) repetition code where n = 3, 5, 7, 9, 11, 13, 15 and 17 are considered. Hence for (n, 1) repetition code, the required number of pixels in the cover image is 'n' times the number of pixels of the compressed watermark. However increase in the value of n in (n,1) repetition code improves the robustness of the extracted watermark from watermarked image in the presence of noise[13][15]. In this paper size of the cover image is 256×256 = 65536 pixels and size of the watermark image is 50×100 = 5000 is chosen. The number of pixels required in the cover image to embed watermark, for different value of 'n' of (n, 1) repetition code is depicted in the Table I. It shows the comparison of total number of cover image pixels affected if the single watermark bit embedded in each cover image pixel location for both uncompressed and compressed watermark condition.

Table 1: Total Number of Watermark Bits used for Embedding Process

Different value of n in (n, 1) repetition code	Total number of cover image pixels affected for uncompressed watermark	Total number of cover image pixels affected using compressed watermark
Without coding	5000	3081
(3, 1)	15000	9243
(5, 1)	25000	15405
(7, 1)	35000	21567
(9, 1	45000	27729
(11, 1)	55000	33891
(13, 1)	65000	40053
(15, 1)	75000	46215
(17, 1)	85000	52377

Figure. 5(a-e) shows the watermarked images after embedding of compressed, encrypted and encoded using (17, 1) repetition code using proposed LSB and SLSB embedding scheme. It is observed in all the five images that visual quality of the watermarked image is almost same as cover image.

Fig. 5: (a-e). Watermarked 8-bit grayscale test images with a size of 256×256

To study the perceptual quality of the watermarked image Mean Square Error(MSE) and Signal to Noise Ratio(SNR) is used. MSE between watermarked image C'(x,y) and cover image C(x,y) computed using Equation (9).

$$MSE = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}[C(x,y) - C'(x,y)]^2 \tag{9}$$

Where C(x, y) and C'(x, y) are the 8-bit pixel value at location (x, y) of the cover image and watermarked image respectively. M and N are number of rows and columns of the cover image and watermarked image.

Table II also shows perceptual quality comparison in terms of MSE for (i) LSB (ii) SLSB (iii) Proposed LSB and SLSB for compressed and uncompressed watermark embedding for different (n,1) repetition. Lower value of the MSE indicates that perceptual quality of watermark image is better. It is observed that MSE parameter in case of LSB embedding scheme is minimum for all the values of 'n' in (n, 1) repetition code compared to the scheme using SLSB or proposed LSB and SLSB. It is observed that MSE value is minimum for compressed watermark embedding scheme compared to uncompressed watermark embedding scheme. Perceptual quality of watermarked image is better in case of proposed LSB and SLSB embedding scheme compared to SLSB embedding scheme alone. However the value of 'n' in (n, 1) repetition code is completely depends on the type of channel and severity of noise[13][14][15].

Table 2: Perceptual quality measured using MSE of watermarked image for the case i. compressed watermark ii. uncompressed watermark embedding for various (N,1) repetition code

Repetition code	LSB		SLSB		LSB and SLSB	
	With compression	Without compression	With compression	Without compression	With compression	Without compression
Without coding	0.0234	0.0386	0.0938	0.1551	0.0579	0.0958
(3, 1)	0.0710	0.1136	0.2857	0.4521	0.1806	0.2814
(5, 1)	0.1174	0.1905	0.4666	0.7551	0.2919	0.4728
(7, 1)	0.1658	0.2679	0.6575	1.0629	0.4105	0.6649
(9, 1)	0.2087	0.3438	0.8480	1.3796	0.5315	0.8582
(11, 1)	0.2574	0.4198	1.0370	1.6850	0.6444	1.0518
(13, 1)	0.3056	0.4965	1.2172	1.9708	0.7542	1.2358
(15, 1)	0.3542	0.4972	1.4205	1.9955	0.8852	1.2469
(17, 1)	0.4024	0.4957	1.6053	1.9875	0.9974	1.2431

B. Perceptibility of Watermarked Image in Terms of Snr

Perceptual quality of watermarked image in terms of Signal to Noise Ratio (SNR) is de fined as

$$SNR = 10\log_{10}\left[\frac{C(x,y)^2}{MSE}\right] \quad (10)$$

Where C(x,y) 8-bit pixel value at location (x, y) of the cover image, MSE is Mean Square Error and It can be calculated using Equation (9). In general SNR value should be high as high as possible. If the SNR value of watermarked image is greater than 40dB [18] then visual quality of watermarked image is acceptable.

Table 3: Perceptual quality measured using SNR in DB of watermarked image for the case i. compressed watermark ii. uncompressed watermark embedding for various (N,1)repetition code

Repetition code	LSB		SLSB		LSB and SLSB	
	With compression	Without compression	With compression	Without compression	With compression	Without compression
Without coding	59.035	56.8637	53.009	50.826	55.1057	52.917
(3, 1)	54.216	52.1798	48.172	46.179	50.1639	48.238
(5, 1)	52.034	49.9331	46.042	43.952	48.0788	45.985
(7, 1)	50.536	48.4519	44.553	42.466	46.5990	44.504
(9, 1)	49.535	47.3687	43.447	41.334	45.4765	43.396
(11, 1)	48.625	46.5016	42.573	40.465	44.6400	42.512
(13, 1)	47.880	45.7728	41.878	39.785	43.9569	41.812
(15, 1)	47.239	45.7665	41.207	39.731	43.2616	41.773
(17, 1)	46.68	45.7797	40.67	39.74	42.7430	41.787

Table III shows the SNR value of watermarked image compared between the schemes using (i) LSB (ii) SLSB (iii)Proposed LSB and SLSB for compressed and uncompressed watermark embedding for different values of (n, 1) repetition code. It is observed that SNR value decreases as the value 'n' in (n, 1) repetition code increases. This is because of more number of cover image pixels are affected by watermark bits. It is also observed that SNR value is maximum for compressed watermark embedding compared to uncompressed watermark embedding, It is seen that SNR value of proposed LSB and SLSB watermark embedding scheme is high and acceptable compared to SLSB embedding scheme.

For the proposed watermarked embedding scheme SNR value of watermarked image is 42.74dB for (17, 1) repetition code. It indicates that quality of the watermarked image using proposed scheme is better compared to SLSB embedding scheme.

C. Time and Computational Complexity of Embedding Algorithm

Spatial domain and transform domain based watermarking techniques have been addressed in several papers [1]-[7]. To reduce computational complexity, in this paper simple embedding scheme is proposed. First, compressed and encrypted watermark is prepared. Then, only position needs to be selected in cover image pixel and watermark needs to be placed in that location. In this paper logical AND operation is used for masking the location in pixels of cover image and for placing the watermark bit logical OR operation is used. Number of logical AND and OR operations required completely depends on 'n' in (n,1) repetition code. Total number of operations including logical AND and logical OR operation for embedding is equal to 2 ×n ×l. Where 'l' is length of compressed and encrypted watermark bits. For a watermark of size 50×100 = 5000 shown in Figure. 4, after compression, size of the watermark reduced to 3081. Hence number of logical operations including logical AND and OR operations for n= 17 is 2×17×3081 = 104754 which is required to embed the watermark.

5. Conclusion

In this paper we have implemented compressed, encrypted and encoded watermark embedding scheme for grayscale image. To compress the watermark, Huffman encoding technique is used. Combined key sequence of logistic and Lozi map is used to encrypt the watermark. (n, 1) repetition code used to encode the watermark. Also to improve the disadvantages of LSB and SLSB watermark embedding technique, combination of SLSB and LSB technique is proposed. The scheme includes features such as improvement in capacity of the watermark, improved security to the watermark, robustness against noise and simplicity in watermark embedding with minimal distortion of the cover image. The analysis of perceptual quality of watermarked image, in terms of MSE and SNR is measured. It is observed that SNR of the watermarked image, when compressed and encrypted watermark encoded using for (17, 1) repetition code embedded using proposed LSB and SLSB watermark embedding scheme is 42.743dB. This is better when compared to uncompressed watermark embedding schemes. Also the scheme is simple and with low time and computational complexity and suitable for real time application.

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