Introducing a new method of Robust Digital Image Watermarking against Cropping and Salt & Pepper Noise using Sudoku

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ABSTRACT:
With rapid development of digital technology, protecting information such as copyright, content ownership confirmation has become more important. In image watermarking, information of the image is inserted such that the visual quality of the image is not reduced and the receiver is able to get the required information. Some attacks such as image cropping and salt & pepper noise, destroy the watermark's information. In this article, a new watermarking scheme is proposed which is robust against salt & pepper noise and tough cropping. A Sudoku table comprises 9 regions, each row and column of the table contains different numbers from 1 to 9. In the proposed scheme, Sudoku table and both watermarking approaches based on spatial domain and transform domain are used. Robustness of watermarking against cropping attack is 86% and its robustness against salt and pepper noise is about 75%, which shows good and effective performance of the proposed scheme.

KEYWORDS: *Digital Image Watermarking, Sudoku, Spatial domain, Transform domain, Cropping, Salt & Pepper Noise*.

1. INTRODUCTION

Now a days, transferring saved information, documents, images, films and audio files in digital form is very common. For most people, transferring digital files over internet is a daily task. Due to rapid development of digital technology and widespread use of internet, living has become considerably easier than before. Despite this convenience, there are some difficulties. Creating unlimited copies of information, changing their contents and rapid transmission of the copies in the internet are very easily done. Thus, protecting copyright, ownership confirmation and detecting interference in information seems very important. One of the solutions for this problem is to use digital watermarking techniques. Watermarking registers inserting information in formats like audio, image, film and etc, in a host signal. Host signal can also be audio, image or any other digital document [1]. In image watermarking, information of the image is inserted such that the visual quality of the image is not reduced and information is transferred to the final user. Example of watermarking is observed in currency, government documents, and stamp and information communication.

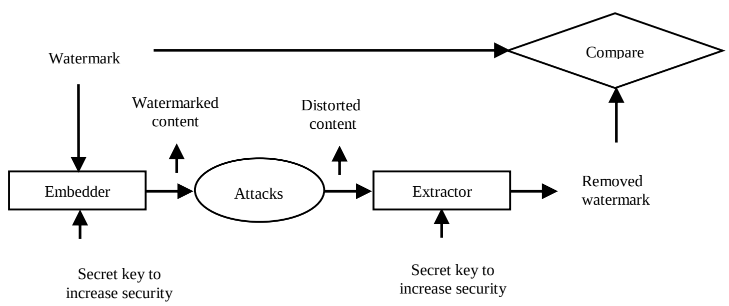

Fig. 1. Typical watermarking system framework

Watermarking provides a certainty level for documents' ownership confirmation [2]. Each watermarking algorithm comprises two fundamental stages: watermark embedding and watermark extraction. In Figure 1, schematic of a watermarking system is shown. For embedding information, spatial domain, transform domain or both can be used. Watermark extraction is also done through watermark correlation with reference image or dependent of the reference image, though blind watermarking.

Information watermarking in spatial domain is simple and fast and has a high capacity for inserting information, but it is not robust against noise and JPEG compression attacks. Watermarking in transform domain has a lower capacity but it shows a better robustness against attacks. Robustness, security, perceptual transparency and capacity are the characteristics of a watermarking system [3], [4].

Preserving ownership, copy control, authentication and integrity verification, hiding various data with transactional watermarks and image indexing feasibility are the applications of watermarking.

One of the important issues in watermarking is attacks which corrode the inserted information. One of the most important attacks is geometrical attack. Examples of such attacks include changing the scale of an image for a website or cropping an image in order to extract its desired area. In cropping, an attacker eliminates a certain part of the images' desired area, while other parts remain the same. As the cropping area increases, corrosion of the image becomes larger, thus detecting and extracting information becomes more difficult. Additionally, salt & pepper noise which is an impulse noise with different densities, changes pixel's value of the gray image to minimum value of 0 or maximum value of 1. Therefore, original content of the image changes in spatial and transform domain [5].

Different approaches have already been used to make the watermarked image robust against cropping. Recent researches show that watermarked information with 50-75% cropping in different approaches is recoverable. In [6], five sets of 4KB information are inserted in image, where 4sets are inserted in corners and one set is inserted at the center. In this method, where information with 75% cropping is recoverable, reference image is required, thus watermarking is not blind.

In another article with a larger insert of information, 22 Kb is inserted but cropping more than 50% is not covered and reference image is required [7].

Up to here, none of these schemes can cover more than 75% cropping, because there are limitations in the insert of inserted information and randomize of cropping.

Different schemes are proposed for making the watermarked image robust against salt & pepper noise. In [8], information is inserted several times. Recovering the watermark in this method is enhanced but performance of this method against noises above 40% has degraded.

In [9], eight random copies of information is inserted in HL, LH bands of discrete wavelet transform (DWT), where information is recoverable with 40% noise.

In [10], a CDMA watermarking algorithm is proposed which uses 2-level DWT and Arnold transform. In this scheme, after inserting information and applying 50% noise, information is recoverable. But the problem is that in images with different contents, performance of this scheme changes. In [11], employing 3-level DWT and fuzzy logic for inserting information and applying 20% noise, information is recoverable. But peak-signal-to-noise ratio (PSNR) decreases about 20 db.

In another method proposed in [12] which inserts four random sets of information in four constant locations and applies 70% noise, information is recoverable but watermarking is not blind. For detecting information, reference image is required. In the researches that have already been done, image watermarking is not robust against salt & pepper noise with more than 70% density even if there exists a reference image.

In [13], Sudoku is used to watermark information. Employing a 9*9 Sudoku and 9 copies of watermark image, cropping has increased to 94% for recovering a portion of the hidden image. This method is also used to make watermarking robust against salt & pepper noise, in which information is recoverable with 78% noise and inserting 9 copies of watermark [14].

One limitation of the schemes proposed in [13], [14] is that by applying cropping or salt & pepper noise, we can only recover some parts of the inserted information and the watermarked image cannot be recovered completely. Another limitation is that, for detecting information, Sudoku table must be known.

In section 2, we will review watermarking in transform domain and spatial domain. In section 3, we propose our scheme. Section 4, presents simulation results of the proposed scheme and section 5, concludes the paper.

2. Watermarking in Spatial and Transform Domain

2.1 Watermarking in Spatial Domain

Inserting watermarking in spatial domain in components of the cover image is a straightforward task. Usually, watermarking schemes based on spatial domain selects some of the cover image's pixels and changes illumination's value of the selected pixels according to the watermarking bits being inserted. Image contains these changed pixels, thus, from now on; image carries information of the watermark. For extraction or detection of the inserted watermark, usually the pixels used in inserting stage should be selected form the watermark image. Then according to type of method, carried bit in each pixel can be detected. By collecting all extracted bits or all detected results, hidden watermark is obtained.

These methods are simple and fast and provide a high capacity for inserting watermark. Another advantage of these methods is that a small watermark can be inserted several times such that possibility of eliminating all watermarks with any type of attack is very low. Therefore, even singular watermarks may satisfy the requirements. However, spatial domain methods cannot tolerate noise or compression methods. One of the spatial domain's method is that watermark is inserted into least significant bits (LSB) of the host image. Input image should be first binarized with LSB method. Then right hand bits of each pixel are replaced with the input bits of the watermark and finally, changed binary pixels are again transformed into decimal pixel values [4].

2.2 Watermarking in Transform Domain

Watermarking in transform domain, before inserting watermark, transforms such as discrete Fourier transform (DFT), discrete cosine transform (DCT), discrete wavelet transform (DWT), dual tree complex wavelet transform (DTCWT), Contourlet transform (CT) and singular value decomposition (SVD) are used in host image for generating transform coefficients. Watermarked image is obtained by changing these coefficients. Robustness factor is increased by changing coefficients such that human visual system (HVS) has the lowest sensitivity to these changes [15]. In the following, use of discrete cosine transform and discrete wavelet transform in the proposed scheme are studied.

2.2.1 Discrete Cosine Transform

A method based on discrete cosine transform is a technique based on block. Using this transform, image is divided into three frequency bands. Low frequency band (FL), medium frequency band (FM) and high frequency band (FH). Discrete cosine transform is shown in Figure 2.

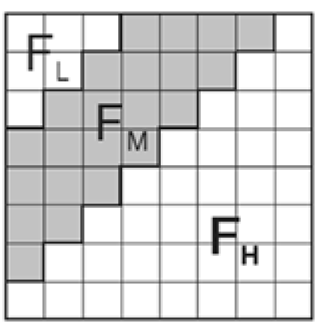

Fig. 2. DCT regions definition

Coefficients in FL bands carry a large part of the transformed image's energy. While coefficients of FH contain lowest energy value.
Two-dimensional direct and inverse discrete cosine transform in (1) and (2) are given respectively.

$$G(u,v)=\frac{2}{\sqrt{mn}}\alpha(u)\alpha(v)\sum_{x=0}^{m-1}\sum_{y=0}^{n-1}g(x,y)\times\cos\frac{(2x+1)u\pi}{2m}\times\cos\frac{(2y+1)v\pi}{2n} \tag{1}$$

$$g(x,y)=\frac{2}{\sqrt{mn}}\sum_{u=0}^{m-1}\sum_{v=0}^{n-1}\alpha(u)\alpha(v)G(u,v)\times\cos\frac{(2x+1)u\pi}{2m}\times\cos\frac{(2y+1)v\pi}{2n} \tag{2}$$

Where g(x,y) are the values of spatial domain and G(U,V) is the DCT coefficient. Size of block with coefficients m, n, a is calculated as follows:

$$\alpha(u),\alpha(v)=\begin{cases}1/\sqrt{2} & \text{If u,v=0}\\ 1 & \text{Else}\end{cases} \tag{3}$$

Sub-band middle coefficients of DCT are usually used to insert watermark and avoid changes in important visual parts of the image which are FL. Additionally, watermarking systems based on DCT are more robust against compression. Disadvantage of the methods based on DCT is that if the original image is corroded its irreversibility is such that information cannot be restored [16].

2.2.2 Discrete Wavelet Transform

DWT is a powerful mathematical tool used in various applications such as image processing. Multi-scale capabilities of wavelet transform which features public and local properties of a signal, makes it an effective tool for image processing in watermarking softwares.
DWT divides image into four different frequency bands. As shown in figure 3, these four bands are shown in approximation of image (LL_k), horizontal detail (HL_k), vertical details (LH_k) and diagonal details (HH_k). This process can be applied several times in approximation part.

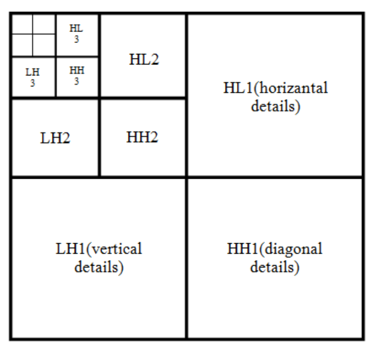

Fig. 3. Wavelet decompositions of an image

In watermarking applications, lower levels of decomposition are more vulnerable to image changes because their energy is lower than higher levels of decomposition. Energy (4) is defined as:

$$E_K = \frac{1}{M_K N_K} \sum_i \sum_j \left| I_K(i,j) \right| \tag{4}$$

K is a decomposition level, I_k implies sub-band coefficients, N_k and M_k are the sub-band dimensions. Comparing sub-bands' energies in the same level, it can be seen that energy accumulation in horizontal detail coefficients or HL_k is considerably more than vertical and diagonal coefficients. Therefore, horizontal sub-band is more robust against changes. In other words, even if image approximation has the highest part of the original image's energy, inserting watermark in this part, reduces quality of the image. Thus, in order to preserve quality of the image, horizontal sub-band in each level can be selected as the best region for inserting watermark. Among the advantages of wavelet transform is that it models human visual system better than other transforms and image compression standard is based on wavelet transform [4], [17].

3. Proposed Watermarking Scheme

A Sudoku table comprises a column-row network of cells which is divided into N regions of N cells and is filled with a set of different symbols. One feature of Sudoku table is that Sudoku's limitations cause uniform scattering of symbols or numbers throughout the table. Another feature of Sudoku is its unique solution. In the proposed scheme, classic Sudoku table which is a 9*9 table, has been used. Advantage of this method is that information is not stored intensively in one region of the image, but information is scattered throughout the image according to Sudoku table.

In this scheme we have used pepper image with 512*512 pixels which is selected from standard images of MATLAB's image processing toolbox as the reference image and a Baboon's image is used as the watermark image

Host image with m_n*m_c dimensions and watermark image with m_w*n_w dimensions are considered where m and n are height and width of the images respectively. For inserting watermark image inside the reference image, according to selected solution of Sudoku table, watermark image should be distributed in the host image. As shown in Figure 4, each Sudoku table comprises 9 regions and each region includes 9 cells, thus there are 81 cells in Sudoku table. Size of each row and each column is calculated according to (5) and (6). [13], [14].

$$RS_{row} = {m_c}/{m_w} \times \sqrt{N} \tag{5}$$

$$RS_{coloumn} = {n_c}/{n_w} \times \sqrt{N} \tag{6}$$

8	6	1	3	5	7	4	2	9
2	5	3	8	9	4	1	6	7
9	4	7	2	1	6	5	8	3
1	8	4	9	7	2	3	5	6
5	3	2	1	6	8	9	7	4
7	9	6	4	3	5	2	1	8
6	2	9	7	4	1	8	3	5
4	7	8	5	2	3	6	9	1
3	1	5	6	8	9	7	4	2

region cell

Fig.4. Selected Sudoku table in the proposed scheme and illustration of region and cell in Sudoku table

In order to determine the size of watermark, (7) is used in which w_{org} is the original watermark and w_t is the watermark whose size has changed.

$$w_t = resize(w_{org}, RS_{row}, RS_{coloumn}) \tag{7}$$

Therefore, dimensions of each region of the watermark image after applying the above formula would be 168*168 pixel and dimensions of each cell in the watermark image would be 56*56. Each cell of the watermark image is labeled as shown in Figure 5, and then each cell is placed at its relevant location, as shown in Figure 6.

1	2	3
4	5	6
7	8	9

Fig.5. labeling watermark image

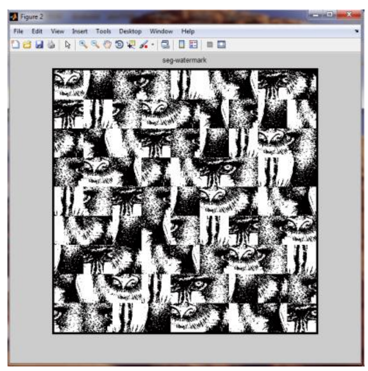

Fig.6. the 81 baboon watermark tiles according to Sudoku table

3.1 Watermarking Process Using Two-Dimensional Discrete Cosine Transform in the proposed scheme

In this section, we propose our first scheme using discrete cosine transform described in 2.2.1. Figure 6, which we will call it sectional image from now on, is a binary image. Hence, all numbers are put burst in binary form and a binary sequence of information is generated. In the stage of inserting watermark, 2 dimensional DCT is applied to the sectional image and the obtained image is divided into 8*8 blocks, and one bit of information sequence is put in each block. Then an inverse 2 dimensional DCT is applied. Due to variation of coefficients, image exits binary mode and transforms into 2-bit image. Then this information is put into the second and third bit of the host image and the sectional image is put into the first bit of the host image.

In detection stage, second and third bits of watermark image are detached and obtained image from second and third bits are transformed into 8*8 blocks. 2-dimensional DCT is applied to each block, and then binary information is extracted. Information is returned to Sudoku table and Baboon's image is restored completely with the assistance of the obtained Sudoku table and detaching the first bit from the watermarked image. In this method, we have not used the reference image in detection stage, thus watermarking is blind. Since 9 images are obtained in detection stage, if cropping or noise is applied to the watermarked image, Baboon's image can be extracted.

3.2 Watermarking Process Using Two-Dimensional Discrete Wavelet Transform in the Proposed Scheme

In this section, we propose our second scheme using discrete wavelet transform described in section 2.2.2. Sectioned image is a binary image, thus, in Sudoku table all numbers are put burst in binary form and a binary sequence of information is generated. In this scheme, 7 bits of the host image are detached and it is called a changed host image. Then the changed host image is divided into 81 cells of 56*56 pixels and DWT is applied to each cell individually. The number assigned to this cell in Sudoku table is put repeatedly and in binary form in horizontal sub-band of the wavelet transform. Then the obtained image is placed in its location. This task is done for all 81 cells and then the sectioned image is placed in the LSB of the host image and the watermarked image is obtained.

In detection stage, 7 bits of watermarked image are detached and transformed in to 9*9 blocks, and then DWT is applied to each block. Corresponding cell's number is extracted from horizontal sub-band and the Sudoku table is completed as far as possible. Once the Sudoku table and extracted image are obtained, 9 images of Baboon are extracted from the first bit of watermarked image. In this method, reference image is not used, thus watermarking is blind. If Sudoku table is obtained completely, other cells can be used to restore the watermark image if noise or cropping is applied.

4. Simulation Results of the Proposed Scheme

In order to investigate and evaluate the watermarked image, evaluation criteria in Table 1 are used. In these equations I (i,j) presents the original image and I_w is the watermarked image and dimensions of image is N*M. In order to measure the validity of the extracted watermark, (8) this is called bit error rate, is used. In this equation, DB is the number of bits that are decoded incorrectly and NB is the total number of original watermark image.

$$BER = \frac{DB}{NB} \tag{8}$$

Table 1. Evaluation of the Watermarked Image's Quality

Evaluation Criteria	Equation
Mean Square Error (MSE)	$\frac{1}{MN}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left(I(i,j)-I_w(i,j)\right)^2$
Peak-Signal-to-Noise Ratio (PSNR)	$10\times\log_{10}\frac{MAX_I^{\ 2}}{MSE}$
Image Fidelity (IF)	$1-\frac{\sum_{i,j}\left(I(i,j)-I_w(i,j)\right)^2}{\sum_{i,j}\left(I(i,j)\right)^2}$

4.1 Simulation Results of Watermarking Scheme Using Discrete Cosine Transform

Using the method stated in section 3.1, watermarked image after applying salt & pepper noise and cropping are shown in Figures 7 and 8 and simulation results are summarized in Table 2.

Table 2. Evaluation Criteria of the Watermarked Image

Evaluation Criteria	Results for Salt & Pepper noise with 75% density	Results for 83% Croppin***g***
MSE	0.0596	0
PSNR	36/59 dB	36/59 dB
IF	0	0
BER	0.0833	0

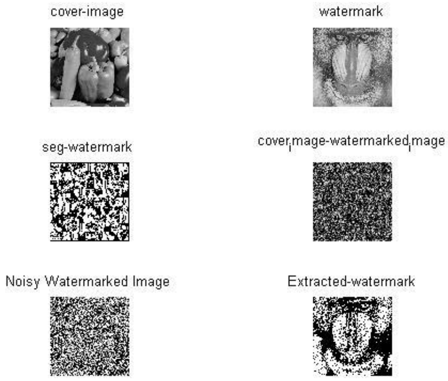

Figure 7. Stages of Applying Salt & Pepper Noise with 75% Density and Watermark Extraction

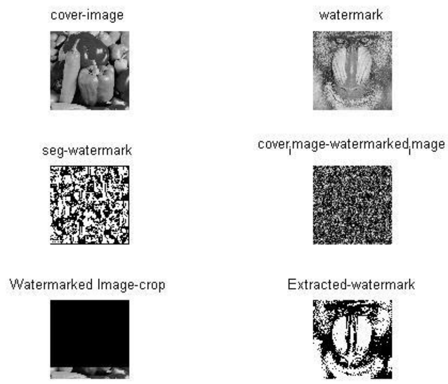

Figure 8. Stages of Applying 83% Cropping and Watermark Extraction

4.2 Simulation Results of the Watermarking Scheme Using Discrete Wavelet Transform

Using the method stated in section 3.2, simulation results of the proposed scheme using discrete wavelet transform are summarized in Table 3. Simulation result after applying cropping is shown in Figure 9.

Table 3. Evaluation Criteria of the Watermarked Image

Evaluation Criteria	Results for Salt & Pepper noise with 65% density	Results for 86% Cropping
MSE	0.158	0
PSNR	31/16 dB	31/16 dB
IF	0	0
BER	0.3	0

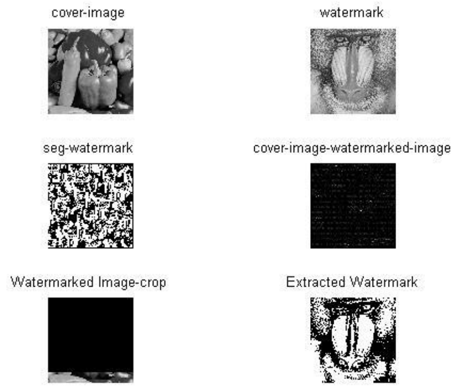

Figure 9. Stages of Applying 86% Cropping and Watermark Extraction

In this scheme, where DWT was used for watermarking, despite the good results obtained for 86% cropping, a more effective method is required to eliminate salt & pepper noise. Although watermark image can be extracted with 65% density of noise, noise is too high.

4.3 Analysis of the Proposed Scheme's Simulation Results

Comparing the two proposed schemes we observe that PSNR of the watermarked image using DWT has degraded but this scheme performs better against higher percentages of cropping compared to the scheme which uses DCT. But robustness of DCT against Salt & pepper with 75% density performs better. In Table 4, proposed scheme is compared to previous watermarking schemes.

Table 4. Comparison Between Proposed Scheme and previous watermarking schemes

Performance Comparison	Cropping	Density of Salt & Pepper Noise	Number of Watermark	Blind watermark and non-blind watermark
Other Schemes	50%-75%	10%-70%	1 to 5 copies of watermark for cropping and 1 to 8 copies of watermark for noise	Combination of both watermarks
Proposed Scheme	86%	75%	9 copies of watermark	Blind watermark

5. Conclusion

In this article, a new scheme is proposed to make watermarking of digital images robust against cropping and salt & pepper noise using Sudoku table. Using features of Sudoku table like distributed information and unique solution of the Sudoku table and exploiting watermarking advantages in transform domains like robustness against attacks and noise, we obtain acceptable results in making the scheme robust.

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