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A Color Watermarking Scheme Based on Conway Game

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***Abstract*—This paper presents a new watermarking scheme based on Two Dimensional Cellular Automata Game-of-Life for color images in spatial domain. This scheme utilizes the live cells of Game-of-Life generations, in which the two most significant bits of gray watermark pixels are embedded into the color host image pixels in the blue component. The proposed scheme depends on the positions of cells that have the value of one in Game-of-Life generations. The watermark extraction can be performed without the original image, and watermark image is hidden inside the original image. Simulation results demonstrate that the watermark is not visible in watermarked image. The proposed method is secure to resist any passive attacks even though the algorithm is open and robust against various image processing operations.**

***Index Terms*— Game-of-Life, Image Watermarking and Two Dimensional Cellular Automata**

I. INTRODUCTION

THE rapid development of multimedia technology and the fast growth of the internet communications make it easy for digital media to be duplicated, distributed and tampered. The necessity of copyright protection, and ownership verification getting more and more attention nowadays. There are many solutions for these issues. Lately, digital watermarking techniques are the most popular one. Digital watermarking is used to embed or hide a secret data such as logo into a digital media (image, video, or audio) [1].

Digital watermark can be a logo, label, or a random sequence that contains useful information for the owner of the host media, such as producer's name, company logo, etc. Moreover, there are two types of digital watermark techniques, visible and invisible. The watermark can be extracted from the watermarked media for the purpose of authenticating and verifying digital [1, 2].

Invisible watermarks are classified into two types, robust and fragile watermarks. Robust watermarks are robust to all kinds of image processing operations such as rotation, so it is used for copyright protection and ownership verification. In the other hand, fragile watermarks are fragile to any operations and it is used for authentication purposes [2].

The embedding process in the host image could be in the spatial or frequency domain. The embedding process in the spatial domain is more robust to geometrical attacks, such as scaling, rotation, and cropping, while the embedding process in the frequency domain has more robustness to signal processing attacks, such as addition of noise, compression and low pass filtering [3].

In general, the digital watermark approach must have met the following properties. The first property, watermark image should be perceptually invisible. The second, watermark must be difficult for an attacker to be detected or removed and robust to common attacks [3].

Cellular Automata (CA) is a dynamic system in which the time and the space are discrete, it is operate on a lattice of cells in n-dimensional space. The cellular automata are introduced by Ulam and von Neumann. Recently, it is used in image processing including image enhancement, compression, encryption and watermarking [4].

The Game-of-Life (GL) is a Two Dimensional (2-D) CA that produces complex behaviors which are useful in many applications. The simple local rules of GL make it an interesting platform for digital image processing [5].

In this paper, an algorithm to embed a gray watermark image to a color host image based on (2-D) CA GL is presented. The two most significant bits for pixels in the gray watermark are embedded into the blue band of color host image pixels depending on the coordinates of live cells in the GL generations. The embedding process depend on the complex behavior of GL that improve the security and robustness. The blue band is chosen to hide the watermark because it is less sensitive to human eyes. The attacker cannot extract the watermark image even though the algorithm is public.

The rest of the paper is organized as follows. In section 2, we introduce the (1-D) CA and (2-D) CA GL. In section 3, we describe the proposed watermarking scheme. In section 4, experiment results are given to demonstrate the effectiveness and robustness of our scheme. Finally, we give conclusion in section 5.

II. CELLULAR AUTOMATA

Cellular Automata are dynamic systems in which space and time are discrete. CA can be implemented on a computer as regular array of cells or a matrix (i.e., lattice), which connect with one another in a neighborhood method and each cell has a definite state or value (e.g., 0 or 1) [5].

The CA cells containing a finite state machine. Also all cells' states are changed simultaneously depending on the transition rules; all cells use the same transition rule. The time advances in discrete steps and the rules are expressed in a small lockup table through which at each time step (generation) each cell determine its new state from that of its neighbors. Where the state of one cell at time t+1 depends on the states of neighboring cells at time t [6].

In addition, CA may have a number of dimensions, one, two, or three-dimensional arrays of cells [6, 7].

The number of states (colors) must also be specified. The simplest model when the number is binary with k=2. For a binary CA, it is commonly a white color when the state is 0 and a black when the state is 1. In addition to the states, the neighborhood of each cell must also be specified. The simplest model when the "nearest neighbors"; in which the adjacent cells on either side (left, and right) to a given cell may be affected at each time step with r =2 [8], as shown in Fig. 1.

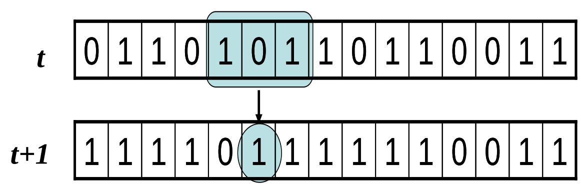

Fig. 1. A binary cellular automaton with two states (0,1)

In two-dimensional CA, there are two common neighborhoods methods are used: von Neumann neighborhood; in which each cell has neighbors to the north, south, east and west, and the Moore neighborhood; which adds the diagonal cells [9], as shown in Fig. 2.

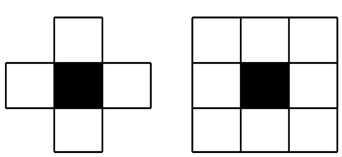

Fig. 2. Neighborhood Systems (von Neumann and Moore)

A. *Conway's Game of Life*

Game of Life (GL), is a two dimensional grid of cells, which is the most famous example of CA. The mathematician John Conway was interested in CA model that could build copies of itself [9, 10].

GL is an example of emergence and self-organization. Because of the surprising ways of evolving the patterns, GL has attracted much interest. The complex patterns can emerge from very simple rules in GL, therefore, It is interesting for physicists, biologists, economists, mathematicians, philosophers and others [11, 12].

B. *Game of Life Rules*

Game of Life is a (2-D) lattice of square cells, each of which is in one of two possible states, live or dead, each cell connect with its von Neumann or Moore neighborhood. At each time step, which is called a generation, each cell computes its new state by determining the cells neighborhood to these cells, then it applies updated or transition rule to compute its new state. Each cell follows the same transition rule, and all cells are updated simultaneously, where the state of a cell is determined as follow [12, 13]:

- "Birth": A cell that is dead at time t becomes alive at time t+1 if exactly three of its neighbors are alive at time t
- "Death by overcrowding": A cell that is alive at time t will die at time t+1 if four or more of its neighbors are alive at time t.
- "Death by exposure": A cell that is alive at time t will die at time t+1 if it has one or no live neighbors at time t
- "Survival": A cell that is alive at time t will remain alive at time t+1 only if it has either two or three live neighbors at time t

III. WATERMARKING EMBEDDING AND EXTRACTION

Digital Watermarking is the process of embedding digital information into a digital media, and it is used to protect media (i.e., images, video, and audio) from illegal copying and exploitation. In color watermarking the gray watermark image is embedded into the blue component of color host image. The embedding process can be expressed as a linear combination as shown in the below notation [14]:

$$CW(x,y) = 4\left(\frac{BI(x,y)}{4}\right) + \frac{GI(x,y)}{64} \qquad (1)$$

Where, CW(x,y): Color Watermarked Image, BI(x,y) : The blue band of the Host Image, and GI(x,y): The Gray Watermark(logo).

However, Dividing and multiplying by 4 sets the two least significant bits (LSB) of BI to 0, dividing GI by 64 shifts its two Most Significant Bits (MSB) into the two Least Significant Bits (LSB) positions and adding the two results generates the watermarked image [14].

A. *Proposed Embedding Scheme*

First of all, the proposed scheme is implemented in a spatial domain, it is a blind scheme. The embedding process which based on the information of GL generations is proposed, the complex behavior of these generations is produced to add a diffusion property to the embedding process as shown in Fig. 3.

The steps of the proposed algorithm are the following:

1. Let BI and GI denote the blue band of Color Image and the Gray Watermark Image, respectively.
2. Let BH denote the blue band of the Host image (after dividing and multiplying BI by 4); GW denotes the gray Watermark image (after dividing GI by 64).

3. An M×N game of life automaton is set up with an initial random values A0, then Apply the GL transition rules to A0 for N times to produce {A1, A2, … Ak} matrices.
4. Get in succession the gray value of two LSB of pixel GW(i,j) where A1(i,j)=1, and add it with the blue value of two LSB of pixel BH(row,col) to generate WM(row,col) starting from row=1, col=1 as shown in Fig. 4.
5. Starting at q=2, get in succession the gray value of two LSB of pixel GW(i,j), where Aq(i,j) =1 and An(i,j) ≠ 1, (for n=1, …. q-1) and add it with the blue value of two LSB of pixel BH(row,col). Repeat this step for q=q+1 while q≠k.
6. After k iterations, get the gray value of two LSB of the remaining pixels in GW(i,j) for all Aq(i,j) = 0 (where q=1, 2 , …. K), and add them with the blue value of two LSB of pixel BH(row,col).

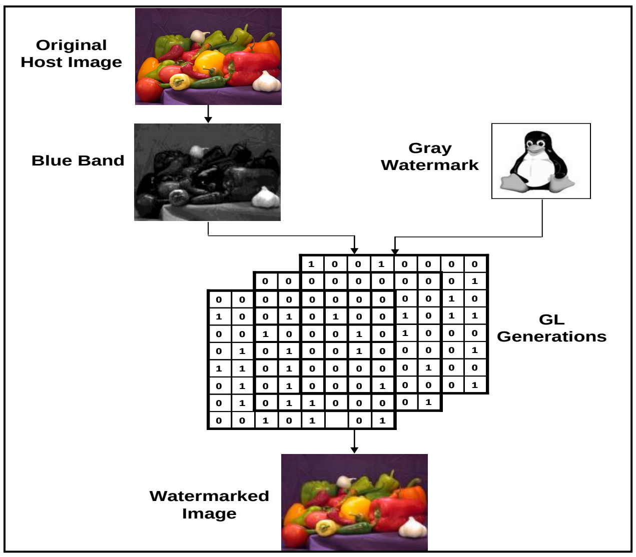

Fig. 3. The color watermarking embedded process based on Conway game generations

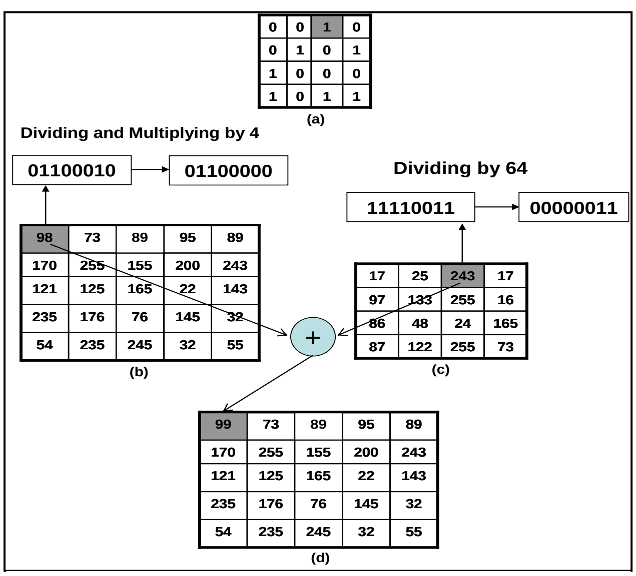

Fig. 4. Digital watermarking embedded process based on GL. (a) GL generation. (b) Host image. (c) Watermark image. (d) Watermarked image.

B. Watermark Extraction

To extract the watermark image, the inverse process of the Embedding algorithm is implemented. However, the same GL's generations are used to extract the watermark image, and the blue value of two LSB of pixel WM(row , col) where Aq(i , j) =1 and An(i , j) ≠ 1 (n=1, …. q-1) is gotten successively and it is put in EW(i, j), where EW is the Extracted watermark. Actually, the watermark extraction is simple and accurate.

IV. EXPERIMENTAL RESULTS

In this simulation experiment, the GL, watermarking embedment, and extraction algorithms are implemented using Matlab software. To verify the effectiveness of the proposed method, a series of experiments is conducted. For this, several original color images and gray watermark images are used. Original color image of Baboon, Peppers, Training Image #239096, and Test Image #69015 (size of 256×256) and gray watermark image of Google logo, and Linux logo, Rose, Apple logo (size 128×128 pixels) are tested as shown in Fig. 5. Incidentally, the watermark is invisible, any modification by the attacker to watermarked image pixels can be detected.

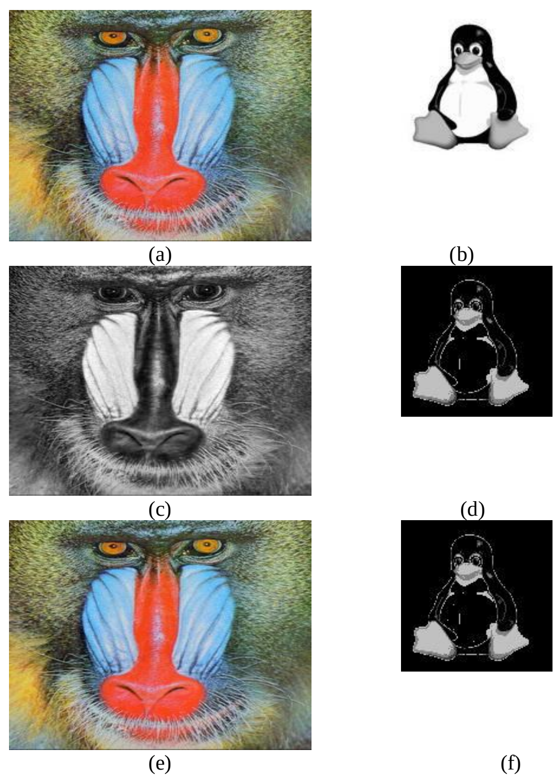

Fig. 5 . (a) Host image Baboon (b) Watermark Linux-log (c) Blue Band of Baboon (d) 2MSB of Linux-logo (e) Watermarked Baboon (f) Extracted Watermark .

To measure the similarity between the host image HI and the watermarked image WI the Peak Signal-to-Noise-Ratio (PSNR) is introduced as shown in the below notation [15]:

$$PSNR = 10\log_{10}\left(\frac{F^2}{MSE}\right) \quad (2)$$

where

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[HI(i,j) - WI(i,j)]^2$$

Where, F represents the maximum fluctuation in the input image data type. In order to evaluate the proposed scheme performance, the PSNR values are calculated for several images as shown in TABLE I.

TABLEI
The PSNR values for different color host and watermark images

Host Image	Watermark Image	PSNR
Lena	Rose	40.26090
Peppers	Linux_logo	40.78411
Baboon	IEEE_logo	45.65046

From TABLEI, it is clear that the value of PSNR between color host image and color watermarked one lies between 40 and 46dB, so that the proposed algorithm does not distort the host images, it preserve the quality of these images.

A. Correlation Analysis of GL Configurations

The Game-of-Life has different configurations depending on the neighborhood methods (Moore or Non-Neumann) and boundary conditions (Periodic or closed). Practically, the Periodic boundary is applied by connecting the leftmost column to the rightmost column and the topmost row to the bottommost row. While in the closed boundary, the extreme cells are connected to logic 0-state.

In an effort to illustrate which GL configurations will give the best watermarking effect, the GL is configured with all combinations between neighborhood methods and boundary conditions to produce different generations, the proposed algorithm uses these generations to embed the gray IEEE-logo with the size of 128 × 128 into the color image Test Image #69015 with the size of 256 × 256, as shown in Fig. 6 and TABLE II.

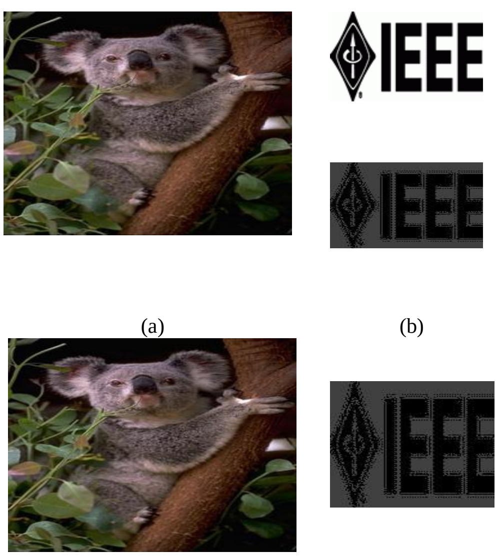

Fig. 6. (a) Host image Test Image #69015 (b) Watermark IEEE-logo (c) (c) Watermarked Test Image #69015 (f) Extracted Watermark

TABLEII
PSNR values with different neighborhood methods and boundary condition, where number of generations (k) is 5

	K	Von Neumann	Moore
Periodic Boundary	5	45.95232	45.95224
Closed Boundary	5	45.96156	45.95963

Therefore, it can be observed from TABLE II that the highest value of PSNR is 45.96156, when configurations are Von Neumann neighborhood and Closed boundary.

B. Evaluation of the Proposed Scheme

In this section the Normalized correlation (NC) is introduced to judge the similarity between the Original Watermark OW and extracted watermark EW as shown in the below notation. In principle, if the NC value is closer to 1, the extracted watermark is getting more similar to the embedded one [15]. As shown in Fig. 6 and TABLEIII.

$$NC = \frac{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} OW(i,j)\,EW(i,j)}{\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} OW(i,j)^2} \quad (3)$$

TABLEIII
The NC values for different input and watermark images

Image Name	Host Image	Watermark Image	NC
Training Image #239096			1
Peppers		Google	1
Test Image #197017			1

From TABLEIII it can be observed that the NC value for all images is 1, which means that the watermark image and the extracted one are the same.

C. Effectiveness and Robustness of the Proposed Scheme

The watermark algorithm should be robust to various types of image processing techniques. To verify the robustness of the proposed scheme, different experiments are performed, including traditional signal processing attacks (salt and pepper noise, Gaussian noise, blurring, and median filter) and geometric attacks such as rescaling. As show in Fig. 7 and TABLE IV.

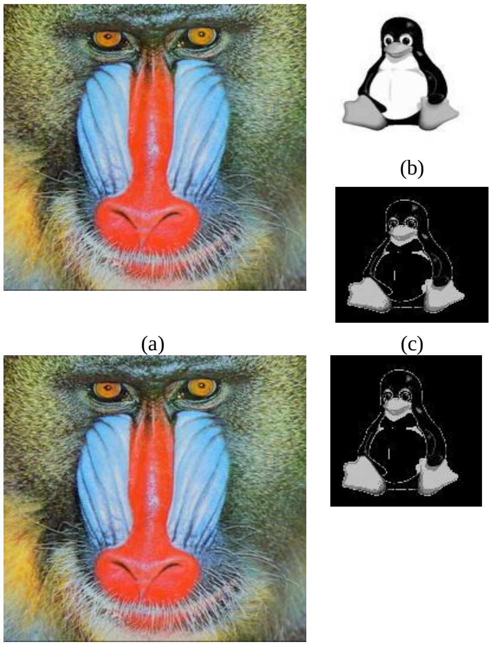

Fig. 7. (a) Host Baboon image of size 256×256 (b)Watermark Linux of size 128×128 (c)The 2MSB of watermark Linux (d)The watermarked image Baboon (PSNR=40.662536)

TABLE IV
Quality (NC) of extracted watermark under various attacks

Attack Method		NC
No attack		1
Salt and Pepper Noise	density = 0.02	0.99125
	density = 0.05	0.97854
Gaussian Noise	variance=0.01	0.74413
	variance=0.05	0.69487
Median Filter	2 × 2	0.81009
	3 × 3	0.98172
	5 × 5	0.99562
Rescaling	scaling ratio=0.5	0.73659
	scaling ratio=1.5	0.75367
	scaling ratio=2.0	0.75009
Blurring	angle =11	0.75923

Experimental results are shown in TABLE IV. The results demonstrate our scheme is robust to the common image processing operations.

V. CONCLUSION

A color watermark scheme based on GL is presented, which operates in spatial domain by embedding the watermark image into the color host image using GL generation's data. The simulation results illustrate that, our technique has robustness against various image processing techniques, and low visible distortions in the host image. also it is impossible for the attackers to crack in the condition of known keys. Moreover, the lawless person can't extract the watermark image event if the algorithm is open. The extraction process can be easily carried out following the inverse steps of embedding process. The proposed algorithm is suitable to any size of digital image, and can be used to embed binary image.

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