

# Hard Authentication Using Dot Array Carrier Structure

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**Abstract**— This paper describes an optical watermarking, for the authentication of original printed documents. An optical watermark is a two- dimensional binary image. It can be of any shape and can be printed on any part of a document. The hidden information is embedded using phase modulation. This hidden information becomes visible to the human eyes only when a right key is positioned on the top of the optical watermark with the right alignment. Here, keys play the similar role as keys in encryption that is to decode hidden information. Thus, with such a lock and key approach, it greatly improves the security level of optical watermark. Due to its high security and tight link with electronic document systems, the optical watermarks are widely used for hard document or printed documents for their authentication.

**Index Terms**— Co-ordinate mapping, watermarking, optical watermarking, encryption, phase modulation, information, hiding, decryption, authentication, printed document.



## Introduction

Digital watermarking is the process of embedding information into a digital signal. The signal may be audio, pictures or video. If the signal is copied, then the information is also carried in the copy.

In visible watermarking, the information is visible in the picture or video. Typically, the information is text or a logo which identifies the owner of the media. When a television broadcaster adds its logo to the corner of transmitted video, this is also a visible watermark.

In invisible watermarking, information is added as digital data to audio, picture or video. It cannot be visible to human eyes. An important application of invisible watermarking is to copyright protection systems, which are intended to prevent or deter unauthorized copying of digital media.

Optical watermarking presents a novel and simple system aiming at overriding some practical problems when the digital watermarking techniques are applied to authenticate the printed documents. This technique is differing from traditional digital watermarking in a sense that the watermark extraction is done by some optical and visual means like photocopier while no any digitization is required [1]. The system security is guaranteed by adopting content-based key share scheme originated from visual cryptography. The non-obtrusiveness effect of watermarked document is achieved by modulating the watermark into a higher resolution gratings level.

## Algorithms

### I] Information Hiding by Phase Modulation

This technique establishes the mathematical framework for information hiding by using a well-known principle of modulation and the low-pass filter property of human eyes in the context of visual information hiding. This serves as the basis of the optical watermark shown in Fig.1.

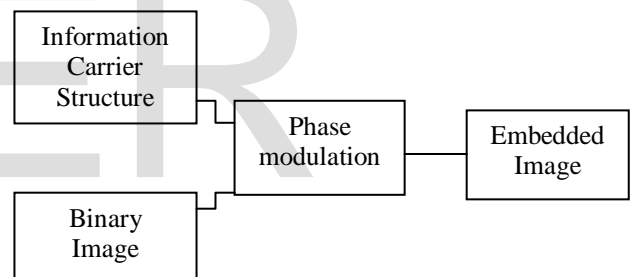


Fig.1.Embedding by Phase Modulation.

### A) Basic Information Carrier Structure

The basic (or simplest) information carrier structure can be a dot array, a simple repetitive structure. The dot array can be represented by a reflectance function.

### B) Phase Modulation to Embed Binary Images into Basic Information Carrier Structure

In phase modulation of Fig.1 a binary image is embedded along either x axis or y axis. The binary image is modulated in the direction of x axis, by shifting the image with a half period of dot matrix in the x direction. The basic information carrier structure is generated by using in Eq. (1), [2].

$$f_0(x, y) = 1 - \sum_{n=-\infty}^{\infty} \delta(x - nT) \sum_{m=-\infty}^{\infty} \delta(y - mT) \quad (1)$$

The phase-shifted dot array can be represented by Eq. (2) and (3),

$$f_1(x, y) = 1 - \sum_{n=-\infty}^{\infty} \delta(x - nT - \frac{T}{2}) \sum_{m=-\infty}^{\infty} \delta(y - mT) \quad (2)$$

$$f_2(x, y) = 1 - \sum_{n=-\infty}^{\infty} \delta(x - nT) \sum_{m=-\infty}^{\infty} \delta(y - mT - \frac{T}{2}) \quad (3)$$

Each  $f_1(x, y)$  and  $f_2(x, y)$  are corresponding to a modulation direction.

Where  $\delta(x) = 0, |x| > \frac{1}{2}$

$\delta(x) = 1, |x| \leq \frac{1}{2}$

Binary image hiding by phase modulation along x direction is obtained by using Eq. (4).

$$w(x, y) = 1 - \left\{ g(x, y) \sum_{n=-\infty}^{\infty} \prod \left( \frac{x - nT_x}{D_x} \right) + [1 - g(x, y)] \sum_{n=-\infty}^{\infty} \prod \left( \frac{x - nT_x - \frac{T_x}{2}}{D_x} \right) \right\} \quad (4)$$

Where,  $g(x, y)$  is a binary image.

The above technique can also be used for hiding two binary images, using in Eq. (5).

$$w(x, y) = g_1(x, y)g_2(x, y)f_0(x, y) + [1 - g_1(x, y)]f_1(x, y) + [1 - g_2(x, y)]f_2(x, y) \quad (5)$$

Where,  $g_1(x, y)$  and  $g_2(x, y)$  are the two binary images.  $f_0(x, y)$  is basic dot array.  $f_1(x, y)$  and  $f_2(x, y)$  are the dot arrays in 'x' and 'y' directions respectively.

The demodulation is achieved by implementing Eq. (6) and (7).

$$f_d(x, y) = 1 - \sum_{n=-\infty}^{\infty} \delta(x \cos \theta - y \sin \theta - nT) \quad (6)$$

$$d(x, y) = w(x, y) f_d(x, y) \quad (7)$$

Here,  $d(x, y)$  is used to demodulate. Fourier series expansions is applied to Eq. (1), (2) and (3) and get results Eq. (8), (9) and (10) respectively.

$$f_0(x, y) = 1 - \left[ \frac{1}{T} + \frac{2}{T} \sum_{n=1}^{\infty} \cos(2\pi \frac{n}{T} x) \right] \left[ \frac{1}{T} + \frac{2}{T} \sum_{n=1}^{\infty} \cos(2\pi \frac{n}{T} y) \right] \quad (8)$$

$$f_1(x, y) = 1 - \left[ \frac{1}{T} + \frac{2}{T} \sum_{n=1}^{\infty} \cos(n\pi) \cos(2\pi \frac{n}{T} x) \right] \left[ \frac{1}{T} + \frac{2}{T} \sum_{n=1}^{\infty} \cos(2\pi \frac{n}{T} y) \right] \quad (9)$$

$$f_2(x, y) = 1 - \left[ \frac{1}{T} + \frac{2}{T} \sum_{n=1}^{\infty} \cos(2\pi \frac{n}{T} x) \right] \left[ \frac{1}{T} + \frac{2}{T} \sum_{n=1}^{\infty} \cos(n\pi) \cos(2\pi \frac{n}{T} y) \right] \quad (10)$$

Eq. (11) is the result of expansion of Eq. (6).

$$f_d(x, y) = \left( 1 - \frac{1}{T} \right) - \frac{2}{T} \sum_{n=1}^{\infty} \cos \left[ 2\pi \frac{n}{T} (x \cos \theta - y \sin \theta) \right] \quad (11)$$

## II] Multiple Layered Watermark Structure

A multiple-layered optimal watermark structure, which is systematically, superposes multiple "single layer" optical watermark and is as shown in Fig.2.

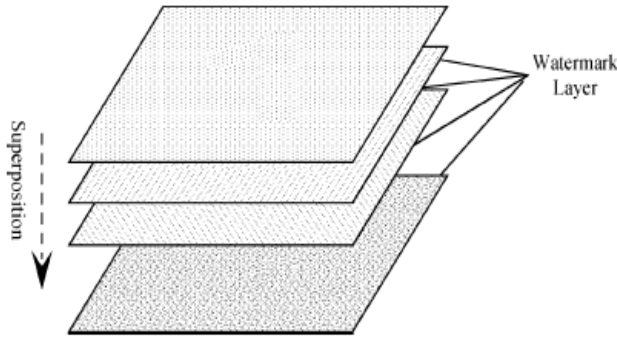


Fig.2. Multi e-Layered Watermark Structure.

**A) Watermark Layer**

The basic information carrier structure of each watermark layer is a dot array, as in Eq. (1). Incorporating the orientation, it can be represented by Eq. (12).

$$\begin{aligned}
 &L(f_u, f_v, D_u, D_v, \theta, g_u, g_v) \\
 &= 1 - \left\{ g_u(x, y) \sum_{n=-\infty}^{\infty} \Pi\left(\frac{x \cos \theta + y \sin \theta - \frac{n}{f_u}}{D_u}\right) \right. \\
 &\quad \left. + [1 - g_u(x, y)] \sum_{n=-\infty}^{\infty} \Pi\left(\frac{x \cos \theta + y \sin \theta - \frac{n}{f_u} - \frac{1}{2f_u}}{D_u}\right) \right\} \\
 &\left\{ g_v(x, y) \sum_{n=-\infty}^{\infty} \Pi\left(\frac{y \cos \theta - x \sin \theta - \frac{n}{f_v}}{D_v}\right) \right. \\
 &\quad \left. + [1 - g_v(x, y)] \sum_{n=-\infty}^{\infty} \Pi\left(\frac{y \cos \theta - x \sin \theta - \frac{n}{f_v} - \frac{1}{2f_v}}{D_v}\right) \right\} \quad (12)
 \end{aligned}$$

Here 'fu' and 'fv' are frequencies along 'u' direction and 'v' direction respectively.  $\theta$  is angle between 'y' axis and 'v' direction. To further incorporate the orientation, and represent a watermark layer as: The watermark layer  $L(f_u, f_v, D_u, D_v, \theta, g_u, g_v)$  can be considered as a rotated information carrier structure. Where,  $f_u$  and  $f_v$  are frequencies along u and v directions respectively.

**B) Superposition of Watermark Layers**

The superposition of multiple watermark layers can be represented as the product of reflectance functions of all watermark layers. The superposition of watermark layers can be represented as in Eq. (13).

$$W = 1 - \prod_{n=1}^N L_n(f_{u,n}, f_{v,n}, D_{u,n}, D_{v,n}, \theta_n, g_{u,n}, g_{v,n}) \quad (13)$$

Where, 'N' is the number of layers.

**III] Advanced Watermark Layers**

**Coordinate Mapping of the Basic Watermark Layer**

In the information carrier structure for watermark layers only frequency and orientation are variable parameters. This paper applies coordinate mapping as shown in Fig.3, to watermark layers to increase the dimensionality of the information carrier structure.

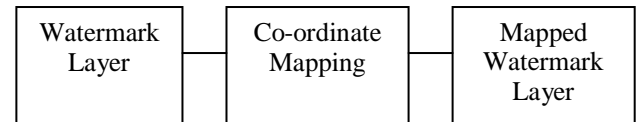


Fig.3. Coordinate Mapping.

**Algorithm for Co-ordinate Mapping**

$$f(p, q) = 1 - \sum_{n=-\infty}^{\infty} \Pi\left(\frac{p - nT}{D}\right) \sum_{m=-\infty}^{\infty} \Pi\left(\frac{q - nT}{D}\right) \quad (14)$$

The dot array of basic watermark layer given in Eq. (14) is then mapped to the dot array of coordinate mapped watermark layer to give in Eq. (15).

$$f'(x, y) = 1 - \sum_{n=-\infty}^{\infty} \Pi\left(\frac{x - \sin \frac{2\pi}{T_{\sin}} y - nT}{D}\right) \sum_{m=-\infty}^{\infty} \Pi\left(\frac{y - nT}{D}\right) \quad (15)$$

Where, sine function is used to map the coordinate according to Eq. (16).

$$\begin{cases} x = \sin \frac{2\pi}{T_{\sin}} p + q \\ y = q \end{cases} \quad (16)$$

(p, q) is used to denote the original coordinate of each dot in the watermark layer and (x, y) to denote the new coordinate of the dot after mapping. There are different coordinate mapping functions such as sine function.

**A) Secret Sharing Watermark Layer**

To further improve the security level of the optical watermark, this method makes use of the secret sharing principle [2] to increase the complexity of the decoding keys by using a random dot matrix.

A cryptographic image encoding method referred to as "visual cryptography" was presented by Adi Shamir [3]. It uses a cryptographic secret sharing theory and thus has a very high security level. This

algorithm develops a secret sharing method in the context of an optical watermark. In a secret sharing watermark layer, let the information of the latent image be randomly distributed to two parts. The watermark layer will be generated based on one part, while the decoder of this watermark layer will be generated based on the other part. Hence, both the watermark layer and the decoder hold half of the information of the latent image as shown in Fig.4. The latent image is recoverable only when both watermark layer and the decoder are present.

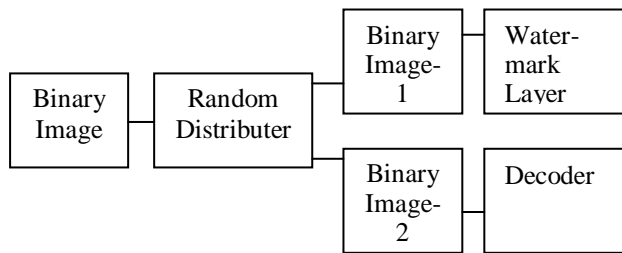


Fig.4. Secret Sharing Watermark Layer.

**Algorithm for Secret Sharing**

Here, first generate two functions  $g_w(x,y)$  using in Eq. (17) and  $g_d(x,y)$  using Eq. (18) based on latent image  $g(x,y)$  and a random number generating function  $r(x,y)$ .  $r(x,y)$  will generate a random sequence of 0's and 1's. Then, modulate function  $g_w(x,y)$  on the dot array of the secret sharing watermark layer with phase modulation, and modulate function  $g_d(x,y)$  on the reference line grating, this acts as a decoder, with phase modulation. All functions  $g(x,y)$ ,  $r(x,y)$ ,  $g_w(x,y)$  and  $g_d(x,y)$  take a value of either 1 or 0.

$$g_w(x,y) = g(x,y)r(x,y) + [1 - g(x,y)][1 - r(x,y)] \tag{17}$$

$$g_d(x,y) = r(x,y). \tag{18}$$

The representation of the secret sharing watermark layer  $w(x,y)$  and its corresponding decoder  $d(x,y)$  are as given in Eq. (19) and (20).

$$w(x,y) = g_w(x,y) \left[ 1 - \sum_{n=-\infty}^{\infty} \Pi \left( \frac{x - nT_x}{D} \right) \sum_{n=-\infty}^{\infty} \Pi \left( \frac{y - nT_y}{D} \right) \right]$$

$$+ [1 - g_w(x,y)] \left[ 1 - \sum_{n=-\infty}^{\infty} \Pi \left( \frac{x - nT_x - \frac{1}{2}T_x}{D} \right) \cdot \sum_{n=-\infty}^{\infty} \Pi \left( \frac{y - nT_y}{D} \right) \right] \tag{19}$$

$$d(x,y) = g_d(x,y) \left\{ 1 - \sum_{n=-\infty}^{\infty} \Pi \left( \frac{x - nT_x}{D} \right) \sum_{n=-\infty}^{\infty} [u(y - nT_y) - u(y - nT_y - T_y)] \right\}$$

$$+ [1 - g_d(x,y)] \left\{ 1 - \sum_{n=-\infty}^{\infty} \Pi \left( \frac{x - nT_x - \frac{1}{2}T_x}{D} \right) \sum_{n=-\infty}^{\infty} [u(y - nT_y) - u(y - nT_y - T_y)] \right\} \tag{20}$$

**Implementation and Results**

**I] Information Hiding by Phase Modulation**

Eq. (1) is used to generate the basic dot array and illustration of dot array parameters are as shown in Fig.5. While generating this grid array the inter pixel distance  $t_x$  and  $t_y$  is adjusted.



Fig.5. Dot Array and illustration of its parameters

A binary Image given Fig. 6 is taken as a watermark to embed into watermark layer in Fig.7.



Fig.6. Binary Image.

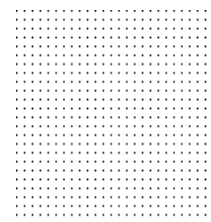


Fig.7. Watermark Layer.

**Middle Stages of Embedding**

While embedding the binary image the stages are obtained as shown in Fig.8.



Fig.8.Middle Stages

**Demodulation**

Here binary image is embedded into dot array using phase modulation with half period [4]. The superposition of the watermarked dot array and the decoder is represented by  $d(x,y)$ . The phase demodulation result is as shown in Fig.9.

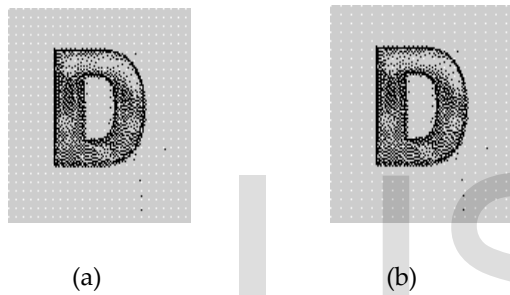


Fig.9.Demodulation Results.

**II] Coordinate Mapping of Watermark Layer**

The basic dot array as shown in Fig.5 and hiding image as shown in Fig.6. The binary image is embedded [5] in dot array by phase modulation so that we get watermark layer. The coordinate mapping is applied on this watermark layer and get coordinate mapped watermark layer.

**Multiple-Layer Watermark Structure**

Two watermark layers with different frequencies are generated as shown in Fig.10.

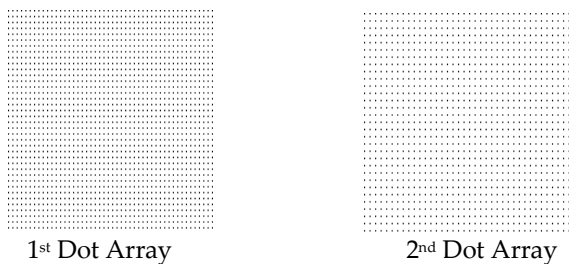


Fig.10.Two Dot Arrays

Two binary images are taken as watermarks given in Fig.11.



1<sup>st</sup> Binary Image

2<sup>nd</sup> Binary Image

Fig.11.Two Binary Images

**Middle Stages of Embedding**

The 1<sup>st</sup> and 2<sup>nd</sup> binary images in Fig.11 are modulated on 1<sup>st</sup> and 2<sup>nd</sup> dot arrays in Fig.10. The intermediate results of the process are shown in Fig.12.

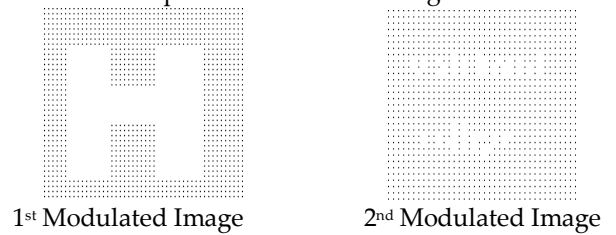


Fig.12.Modulated Images

And finally these two watermark layers having different watermark structure using are superimposed Eq.12.

**III] Secret Sharing Watermark Layer**

Here, the carrier structure is random dot array as shown in Fig.13 and hiding image is as shown in Fig.6.

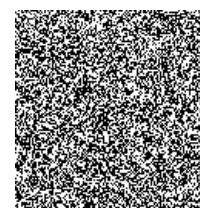


Fig.13.Random Dot Array

First, randomly distribute the binary image in two parts; the watermark layer will be generated based on one part while, the decoder of this watermark layer will be generated based on the other part.

**Results**

The experiments are carried out using Matlab7.0<sup>©</sup> and results are obtained. The Work is tested varying the values of  $t_x$  and  $t_y$ . Few of the test watermark

images are shown in Fig.14. The corresponding demodulated results are given in Fig.15.

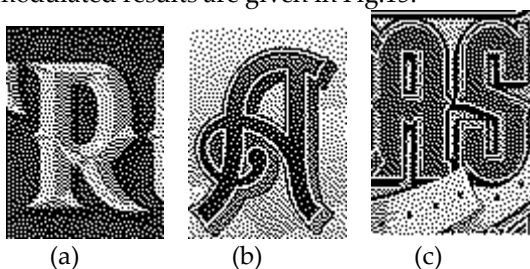


Fig.14. Binary Images used as watermark.

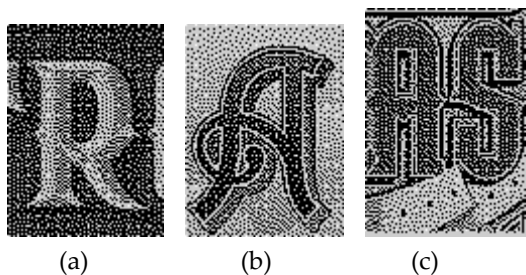


Fig.15. Demodulation result

To check the performance of the demodulation the PSNR values of original and extracted watermarks are obtained. Table lists these PSNR values for sample images given in Fig.14. The results in Table I and its graph which is given in Fig.16 indicate that for the acceptable range of demodulated results i.e. PSNR value 30-40dB. The range for tx and ty should be 12-15 pixels.

Sr. No.	tx & ty	Image PSNR dB		
		r.bmp	a.bmp	as.bmp
1	2	5.58	5.10	5.09
2	3	8.94	7.55	8.08
3	4	11.44	9.67	10.69
4	5	13.28	11.44	12.94
5	6	15.75	13.72	14.40
6	7	16.92	15.33	16.19
7	8	18.45	17.21	17.78
8	9	20.60	18.51	19.03
9	10	24.55	20.19	22.96
10	11	20.42	19.59	20.51
11	12	31.39	25.24	29.18
12	13	39.17	28.08	31.81
13	14	39.17	34.45	33.57
14	15	39.17	39.22	39.59

Table1. PSNR value of different image.

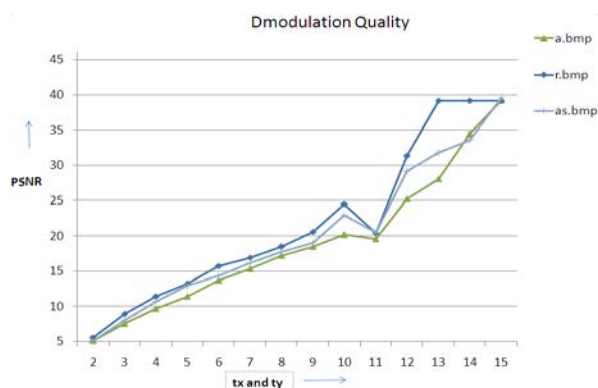


Fig.16. PSNR value vs. 'tx' and 'ty' value.

### CONCLUSION

To obtain optical watermarking three modules-Information Hiding by Phase Modulation, Logical Multiple-layered Watermark Structure, Coordinate Mapping of the Basic Watermark Layer and Secret Sharing Watermark Layer are implemented. The Demodulation is tested only for the first method and decided the range for tx and ty for the same. The remaining two modules use the superposition of the two watermark layers, hence it become critical to demodulate the layers. Thus this work can be extended further for demodulation of the combined layers and improvement in the quality of extracted watermark.

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