Information Hiding: A New Multi Watermark Algorithm Using Radon Transformation

Omer Siddik and Ersin Elbasi

***Abstract*—There are basically two approaches to embed a watermark in a multimedia element: spatial domain and transform domain watermarking. In the spatial domain, the watermark is embedded by modifying the pixel values in the original image. Transform domain watermarking is similar to spatial domain watermarking; in this case, the coefficients of transforms such as Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT) or Discrete Wavelet Transform (DWT) are modified. In this research work we used Radon Transformation (RT) in binary image watermarking. Experimental results show that this new algorithm gives very promising results for geometric attacks.**

***Index Terms*—Copyright protection, discrete wavelet transformation, radon transformation, watermarking.**

I. Introduction

Digital watermarking is the process that embeds data called watermark into a multimedia object (such as text, audio, image and video) such that watermark can be detected or extracted later to make an assertion about the object. Digital watermarking has received increasing attention especially in recent years. Apart from copy control and copyright protection; broadcast monitoring, fingerprinting, indexing, medical applications and content authentication are other application areas of digital watermarking. For the purpose of designing and developing a new watermarking algorithm in those application areas, the most important properties are robustness and invisibility. Watermark detection is classified into three categories: Non-blind, blind, and semi-blind watermarking. Non-blind watermarking requires the original image to detect the watermark. A blind technique does not require the original image and logo to detect watermark. Semi-blind watermarking technique requires the key and the watermarked document for detection. In general, blind methods are more useful than non-blind methods, because the original image may not be available when the detection process is applied.

In this research work we will explain RT based non-blind binary image watermarking algorithm. In Section II related works in transformation based watermarking, then radon transformation and proposed algorithm, after that experimental results and conclusion will be given.

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II. Related Works

In the spatial domain, the watermark is embedded by modifying the pixel values in the original image [1]. Transform domain watermarking is similar to spatial domain watermarking. In the transform domain case, the coefficients of transforms such as Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT) or Discrete Wavelet Transform (DWT) are modified [2], [3]. Spatial domain embedding techniques [4] are very simple and effective, but they are not robust against many attacks.

Because of its great frequency component separation properties, the DWT, in contrast to DCT, is very useful to identify the coefficients to be watermarked [5]. Dugad et al. proposed wavelet based scheme for watermarking images by embedding the watermark into LL band coefficients [5]. Selection of coefficients is in the same way Cox *et al*. proposed before [6]. Hsieh and Tseng proposed DWT-based algorithm in the following steps: An original image is decomposed into wavelet coefficients. Then, multi-energy watermarking scheme based on the qualified significant wavelet tree (QSWT) is used to achieve a robust algorithm [7]. Elbasi and Eskicioglu embedded a pseudo-random sequence as a watermark in two bands (LL and HH) by using DWT [8].

In general, most of the image energy is concentrated at the lower frequency coefficient sets LLs and therefore embedding watermarks in these coefficient sets may degrade the image significantly. However, embedding watermark in the LL bands increase robustness effectively [9]. The fact that makes our study novel is that we will increase robustness of the watermarked image under certain attacks without degrading the image by embedding binary watermark on LL band.

Any square matrix F can be written as a product of *L* and *U* matrices [10]. LU decomposition for the example of 3-by-3 matrix is shown in Equation (1).

$$F = L \times U = \begin{bmatrix} 1 & 0 & 0 \\ l_{21} & 1 & 0 \\ l_{31} & l_{32} & 1 \end{bmatrix} \times \begin{bmatrix} d_1 & u_{12} & u_{13} \\ 0 & d_2 & u_{23} \\ 0 & 0 & d_3 \end{bmatrix} \quad (1)$$

In this study, we divided out of U a diagonal matrix D which is made up entirely of the d_n coefficients as shown in Equation (2).

$$F = L \times D \times U = \begin{bmatrix} 1 & 0 & 0 \\ l_{21} & 1 & 0 \\ l_{31} & l_{32} & 1 \end{bmatrix} \times \begin{bmatrix} d_1 & 0 & 0 \\ 0 & d_2 & 0 \\ 0 & 0 & d_3 \end{bmatrix} \times \begin{bmatrix} 1 & u_{12}/d_1 & u_{13}/d_1 \\ 0 & 1 & u_{23}/d_2 \\ 0 & 0 & 1 \end{bmatrix} \quad (2)$$

There are almost few studies of LU decomposition in watermarking applications. Shao-zhang *et al.* transformed the

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corresponding nonnegative matrix of the image into G-diagonally dominant matrix in order to apply LU decomposition with DCT mid-frequency coefficients [10]. However, that study is based on the combination of DCT and LU decomposition. Moreover proposed algorithm in [10] is blind watermarking. Wang *et al*. transformed the input image into wavelet domain by DWT, computed the variances of the last details, and selected detail matrix information among sub bands whose variance is the maximum one. Then, they decomposed the preprocessed image into LU factorization and embedded the watermark into the non-zero pixels of two triangular matrices adaptively [11].

Apart from DWT, SVD in Equation (3) is not only decomposes the image, F, into left (U) and right (V) singular vectors which represent horizontal and vertical details respectively, but also obtains luminance (gray scale) values of the image layers produced by U and V [12].

$$F = U \times S \times V^T \quad (3)$$

The U and V matrices provide orthogonality so that $U \times U^T = I$ and $V \times V^T = I$, where I is the unit matrix. Therefore, in order to prevent the degradation of orthogonality, watermark is usually embedded in the singular values in the S matrix.

Studies in [13]-[18] show that small change in singular values for SVD or SVD-DWT based watermarking algorithms both increase robustness, especially for geometric attacks [19]. Moreover, those changes have small effect on perceptual of the watermark. There are almost few studies of LU decomposition in watermarking applications. Therefore, the other novel side of this study is to expand the application areas of watermarking with an algorithm (consisting DWT, SVD and LU together) based on chaotic maps.

Comparatively investigated chaotic maps are Logistic Map (LM), Asymmetric Tent Map (ATM), and Arnold's Cat Map (ACM). One of chaotic maps used in this study is called Logistic Map (LM) and is described in Equation (4).

$$x_{n+1} = \mu x_n(1 - x_n) \quad (4)$$

where $0 < \mu \leq 4$. When $3{,}5699456 < \mu \leq 4$, the map is in chaotic state [20]-[22]. Logistic map is one of the simplest forms of a chaotic approach. Another chaotic map applied in this study is Asymmetric Tent Map (ATM). This chaotic map is distorted, but piecewise linear version of tent map approach as seen in Equation (5) [23], [24]

$$x_{n+1} = \begin{cases} x_n/t, & 0 \leq x_n < t \\ (1 - x_n)/(1 - t), & t \leq x_n \leq 1 \end{cases} \quad (5)$$

LM and ATM generate chaotic sequences within [0, 1] interval with different distribution by any initial conditions x_n. In this study, number of iterations is equal to the number of watermark pixels. Hence, the vector x_n is reshaped by the size of the watermark before using XOR operation in the embedding algorithm.

In image watermarking, a chaotic map technique called Arnold's Cat Map (ACM) is generally used for the randomization of the pixel locations in order to increase the security of the algorithm. 2D ACM for any $N \times N$ square image is described in Equation (6), where (x_n, y_n) and (x_{n+1}, y_{n+1}) are the locations of the pixels before and after ACM respectively.

$$\begin{pmatrix} x_{n+1} \\ y_{n+1} \end{pmatrix} = \left[\begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix} \begin{pmatrix} x_n \\ y_n \end{pmatrix}\right] mod N \quad (6)$$

The pixels of the square image can be scrambled by using Equation (6), but when the transformation is repeated enough times, the original image will appear again. Fig. 1 shows scrambled forms of the watermark in each iteration. As seen in Fig. 1, original form of the watermark is retrieved in 192nd iteration. Therefore, if X iteration is applied in the embedding algorithm, (192-X) iteration should be implemented in the extracting algorithm in order to obtain the host image again. As a binary image in size 256 × 256, Fig. 1(a) is used as the watermark in this study and number of iteration is experimentally chosen as 102.

In order to increase the security; LM, ATM and ACM are frequently used in watermarking algorithms. Nevertheless, this study is unique in the sense that the combination of DWT, SVD and LU decomposition are secured by those chaotic maps in a comparatively way.

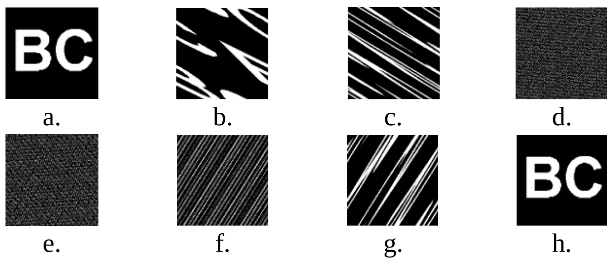

Fig. 1. (a) Original watermark, Number of iteration in ACM: (b) 1, (c) 2, (d) 90, (e) 102, (f) 188, (g) 190 and (h) 192.

III. Proposed Method

The Radon transform name comes from the Austrian mathematician Johann Radon that he showed the description of the function in terms of its projections and the Radon transform is the mapping from the function into the projections. Radon transform is used to compute the projection of an image f (x, y) for a given angles it can compute the projection of the image along the given angles. Radon transform is using in several applications in science and technology. RT has good feature of transforms the information from two dimensional image into a string of one dimensional projections because many applications can be performed on the one dimensional data faster than the two dimensional image. Radon transform has many advantages especially in linear feature detection such as the ability to detect line width and has robustness in noisy images.

$$P(t,\theta) = R(t,\theta)[f(x,y)] = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} f(x,y)\delta(t - x cos\theta - y sin\theta)dxdy \quad (7)$$

RD has following advantages in image processing:

1) If image scaled as Θ angle, radon transformation is also change in same size.

$$I(x\, cos\emptyset - y\, sin\emptyset, x\, sin\,\emptyset + y\, cos\,\emptyset) \leftrightarrow R(x, \theta + \emptyset) \quad (8)$$

2) If image resized as p, radon transformation is also change with same size.

$$I\ (px, py) \leftrightarrow \frac{1}{p}\ R(pX, \theta) \tag{9}$$

3) We can formula inverse of RD as follows:

$$g(s,\theta) \cong R\, f, -\infty < s < +\infty, 0 \le \theta \le \pi \tag{10}$$

$$f(x,y) = \frac{1}{2\pi^2}\int_0^{\pi}\int_{-\infty}^{+\infty}[(\frac{\partial g}{\partial s})(s,\theta)]dsd \tag{11}$$

$$x\ cos\theta + y\ sin\theta - s \tag{12}$$

$$fp(r,\emptyset) \cong f\ (r\cos\theta, rsin\theta) \tag{13}$$

$$f(x,y) = \frac{1}{2\pi^2}\int_0^{\pi}\int_{-\infty}^{+\infty}[(\frac{\partial g}{\partial s})\ (s,\theta)]\ dsd\theta \tag{14}$$

$$r\ cos(\theta - \emptyset) - s$$

In multi watermark embedding we use following algorithm with radon transformation:

1) Convert RGB cover image to YUV image.
2) In Y layer apply discrete wavelet decomposition. Embed watermark in LL and HH bands.
3) Apply 0:2:179 RD to D_1 and D_2 watermarks.
4) Using α scaling factor embed both watermark to LL and HH bands using formula in the below.

$$LL'(i,j) = LL\ (i,j) + \propto . D_1(i,j) \tag{15}$$

$$HH'(i,j) = HH\ (i,j) + \propto . D_2(i,j) \tag{16}$$

5) D_1 and D_2 are two different watermarks and, α value is 0.05.
6) Inverse DWT to get watermarked image.

To extract embedded watermark we follow following procedure:

1) Watermarked and possibly attacked image converted to DWT.
2) Use coefficients of LL and HH bands find out D_1 and D_2 values.

$$D_1 = \frac{[LL'(i,j) - LL\ (i,j)]}{\alpha} \tag{17}$$

$$D_2 = \frac{[HH'(i,j) - HH\ (i,j)]}{\alpha} \tag{18}$$

IV. Experimental Results

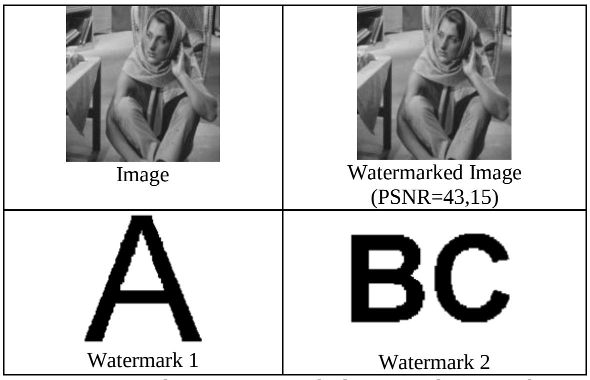

Fig. 2. Original image, watermarked image and watermarks.

There are two different waterrmark "A" and "BC" has been embedded in cover images (lena, Barbara and cameraman) using radon transformation. Embedding results show that watermarked images has PSNR values more than 40.

In Fig. 2-Fig. 5, original cover image, watermarks, watermarked images after attacks and extracted binary watermarks have been given. Results are very promising. In Table I and Table II Similarity Ratio and PSNR values has been given after common attacks.

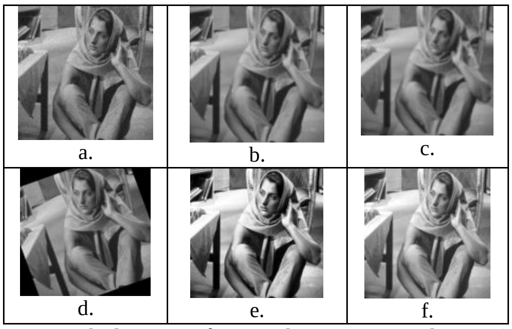

Fig. 3. Watermarked image after attacks. a. Gauss Filtering (Mean=0, Varyans=0.001) b. Mean Filter (3×3) c. Resizing (256-128-256) d. Rotation (20 degree) e. Histogram Equalization f.Contrast Adjustment ([*L*=0 *H*=0,8], [*B*=0 *T*=1]).

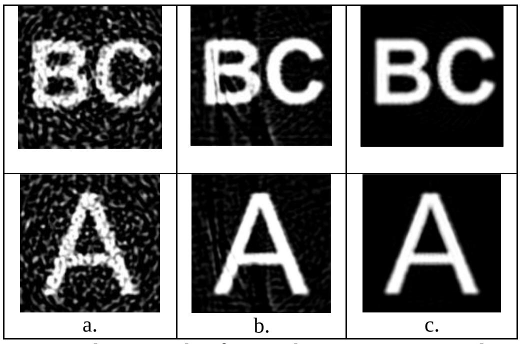

Fig. 4. Extracted watermarks after attacks. a. Histogram equalization b. Resizing c. Rotation.

TABLE I: Watermarked Image and PSNR, SR Values after Extraction (Barbara Image)

	PSNR Value	Average SR Value
Watermarked Image	45,7275	1.0000
Gauss Noise	29,9227	0,8216
Mean Filtering	25,0134	0,7784
Resizing	24,7021	0,8975
Rotation	11,7035	0,7144
Histogram Equalization	18,0411	0,8253
Contrast Adjustment	18,2639	0,8806

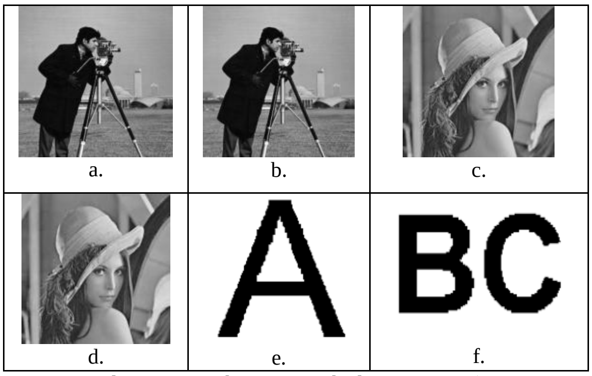

Fig. 5. a. Orijinal cameraman b. Watermarked cameraman (TSGO=49,15) c. Orijinal lena d. Watermarked lena (PSNR=48,12) e. Extracted watermark "A" (SR= 1.0) f. Extracted watermark "BC" (SR= 1.0).

TABLE II: WATERMARKED IMAGE AND PSNR, SR VALUES AFTER EXTRACTION (CAMERAMAN IMAGE)

	PSNR Value	Average SR Value
Watermarked Image	49,1517	1.0000
Gauss Noise	30,0751	0,8841
Mean Filtering	24,6875	0,7984
Resing	10,4949	0,7152
Rotation	19,1462	0,7367
Histogram Equalization	17,7347	0,8052
Contrast Adjustment	18,6155	0,8913

V. CONCLUSION

In DWT based non-blind watermarking, a binary watermark is embedded in two bands (LL and HH), using coefficients that are higher than a given threshold T. In this research work we used DWT and Radon transformation in non-blind binary watermarking. Multi watermarks are converted to Radon Transformation, and these coefficients are embedded into LL and HH bands of discrete wavelet transformed cover image. Experimental results show that:

- Watermarked image has high PSNR value.
- For one group of attacks (JPEG compression, resizing, adding Gaussian noise, low pass filtering, and rotation), the correlation with the real watermark is higher than the threshold in the LL band, and for another group of attacks (histogram equalization, contrast adjustment, gamma correction, and cropping), the correlation with the real watermark is higher than the threshold in the HH band.
- This method gives better results in geometric attacks.

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