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Research Article

Research on a New Rotated-Resistant Transform Domain Digital Watermarking Algorithm

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Abstract: For the shortcoming that transform domain watermarking cannot resist image rotation attack, this study draws LPT (Log-Polar-Transform) theory into watermarking field, then puts forward a new improved algorithm based on LPT and DFT. Before embedding watermarking, first do LPT and DFT of the carrier image, because LPT and DFT theories respectively have good scale invariability and synchronicity when image rotation happens, they can provide an environment with an ability of resisting rotation; then spread the watermarking information spectrum with a pseudorandom sequence. In the end, embed the sequence into the low frequency band of the carrier to complete the embedding part. In process of detecting, rotate different angles of the carrier and extract the watermarking, calculate the correlation value between extracted watermarking image and carrier image. The experimental result proved that the algorithm could manifest a good robustness when it was attacked by image rotation and some other image attacking methods.

Keywords: DFT, digital watermarking, image rotation, LPT, transform domain

INTRODUCTION

Digital watermarking technology is an effective method to solve the problem of protecting multimedia information copyright. Massive algorithms have emerged as digital watermarking technology's constant development. In Cox *et al*. (1996) first put forward a transform domain theory by referencing spread spectrum technology (Cox *et al*., 1996), it regarded the frequency domain of carrier image as the communications channel and correspondingly the watermarking was the signal which was transmitted in the channel and the attacks were all kinds of noise in the system. The transform domain watermarking theory opened a new direction for the development of digital watermarking. In recent years, transform domain watermarking theory has received large attention; it was widely applied in the field of digital watermarking and it has been manifested a good robustness when facing thermal noise and image compression. But regrettably, an obvious flaw was in existence all along-having no means of resisting image rotation attack. When the carrier image was rotated, the watermarking information embedded it without the ability of synchronicity. Therefore, it is difficult to detect the watermark in the extracting process and copyright protection couldn't be realized. So improving the anti-rotation ability of transform domain watermarking has become a difficulty in a digital watermark field.

In order to solve this problem, many scholars have given many ideas. In Bing *et al*. (2009) and Bing (2010), He respectively proposed a zero watermark algorithm resisting to rotation attack based on radon Transform (Bing *et al*., 2009) and a digital image watermarking method against rotation attack based on LSB (Bing, 2010), successfully solving the problem of zero and spatial domain watermarking resisting to image rotation. To transform domain watermarking theory, in, Ying *et al.* (2006) imposed a rotation resilient watermarking algorithm based on frequency domain (Ying *et al.*, 2006). In Li (2007), put forward a theory named research and implement on digital image watermarking against geometric attacks (Li, 2007; Jiufen *et al*., 2003), introduced an image watermark algorithm robust to geometric distortion in DWT domain (Jiufen *et al*., 2003); and after some time, (Fei *et al*., 2010) imposed a watermarking algorithm against rotation based on DCT (Fei *et al*., 2010). It proved that by the experiment, all of theory above can improve the robustness of resisting to image rotation to a certain extent. But there are more or less some shortcomings in these algorithms, we couldn't get a good performance by some of theories above, what's more some of methods are too complicated even though the experimental result.

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By researching and analyzing current situation, this article proposes a new algorithm based on LPT and DFT, bringing Log-polar-transform theory into transform domain watermarking. We need to do LPT and DFT of carrier image before embed watermarking information. Owing to scale invariability and synchronicity they have, it make sure that the carrier image can hold the same ability, if we embed the watermarking into it, then no matter what angle the carrier rotates, it can extract a clear watermarking image. At the same time, this algorithm is fairly simple to implement, we could save lots of time and programs when achieve it.

LOG-POLAR-TRANSFORM THEORY

Log-polar-transform derives from the research on human visual mechanism (Bo *et al.*, 2008). Any pixel I of the image could be expressed with Cartesian coordinate I (x, y) and it can also be indicated in Polar coordinate form $I(r, \theta)$, then the definition of the LPT from between $I(x, y)$ and $I(r, \theta)$ is:

$$r = \log\sqrt{(x-x')^2+(y-y')^2} \tag{1}$$

$$\theta = \arctan(\frac{y-y'}{x-x'}) \tag{2}$$

In the formula (1) and (2), (r, θ) are polar radius and polar angle of log polar coordinate? (x', y') is the selected coordinate origin. If we choose the origin (0, 0), they would meet the relation as formula (3):

$$r = \sqrt{(x^2+y^2)}\,,\ \theta = \arctan(\frac{y}{x}) \tag{3}$$

It can be expressed in the complex plane:

$$z = x + iy = r(\cos\theta + i\sin\theta) = re^{i\theta} \tag{4}$$

And the LPT is:

$$w = \log(z) = \log(re^{i\theta}) = \log r + i\theta \tag{5}$$

According to formula (5) we can make a conclusion that scale axes are independent of the angle axes:

$$\rho = \log r\,,\ \varphi = \theta \tag{6}$$

If taking point of fixation as the center zoom k times and rotate $\Delta\theta$, we can get:

$$\begin{cases} \rho_1 = \log kr = \log k + \log r = \rho + \Delta\rho \\ \varphi_1 = \theta + \Delta\theta \end{cases} \tag{7}$$

In formula (7), the scale varies k times, the image downward moves $\Delta\rho$ units; in terms of angle, when rotate $\Delta\theta$, it will parallel moves $\Delta\theta$ units in angle axes of the log polar coordinates. Obviously, scale and angle moving in Cartesian coordinate leads to the parallel moving along the polar radius r and polar angle θ in log polar coordinate, so the LPT has an advantage of scale invariability when rotated.

RESEARCH ON EMBEDDED AND EXTRACTED PROCESS OF WATERMARKING

The embedded process: The embedded process of watermarking is as follows:

- Let the carrier image be P (x, y) and do LPT of P (x, y), the image after transform is G (x, y)
- Do 8×8 blocking of G (x, y), then we can get m sub-blocks
- Carry out each block 2 d DFT
- Spread the spectrum of watermarking image with pseudo-random sequence n, we could get a group of sequence code of period m
- Calculating the DFT coefficient of each block and embedding the sequence into the middle frequency band of each block, the principal is as follows:

$$H'_i(x, y) = H_i(x, y) + a\, w_i(x, y) L_i(x, y) \tag{8}$$

$H_i(x, y)$ is the DFT coefficient of the *i*-th sub-block in the region (x, y). $H'_i(x, y)$ is the DFT coefficient after embedded watermarking. $w_i(x,y)$ is the watermarking sequence embedded into the carrier, α is embedded strength; it could be expressed by the formula (9):

$$w_i(x, y) = I_i n_i(x, y) \tag{9}$$

I_i is the *i*-th value of the watermarking image matrix and $n_i(x, y)$ is the value of sequence n which is in the *i*-th blocks, L_i (x, y) stands a brightness shield characteristic threshold of HVS in position (x, y), within this threshold, the embedded effect could achieve the best by the way of moderating α appropriately (Jing and Xiangyang, 2011). This method could avoid that the overlarge embedded strength affecting the result just like traditional watermarking theory.

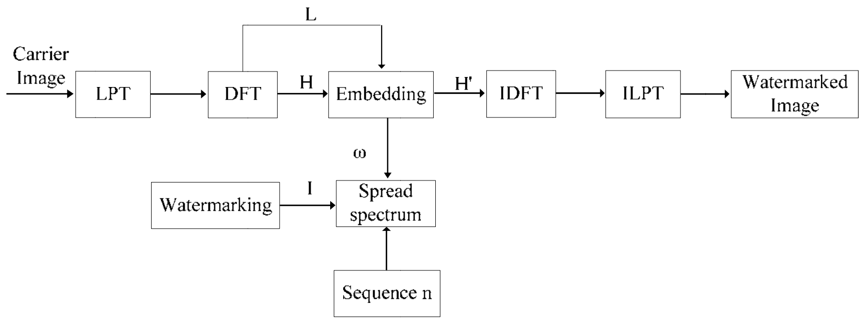


Fig. 1: The whole embedded process

Fig. 2: Carrier image

Fig. 3: Watermarking image

Fig. 4: Watermarking image

- Do IDFT and ILPT to reconstruct the image, then we get the watermarked image G′ (x, y). The embedded process is as follows as Fig. 1.

The extracted process: Extracting watermarking is the counter process to embedding:

- Do LPT of image *G′* (x, y)
- Do DFT of image *G′* (x, y) and carry out it 8×8 blocking
- Find the watermarking sequence from the sub-blockings and extracted them
- Get the image matrix by de-spreading the sequence

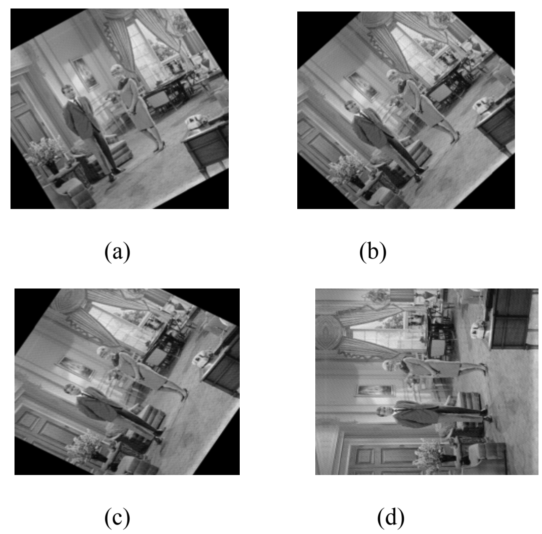


Fig. 5: Rotate watermarked image, (a) rotate 30°, (b) rotate 45°, (c) rotate 60°, (d) rotate 90°

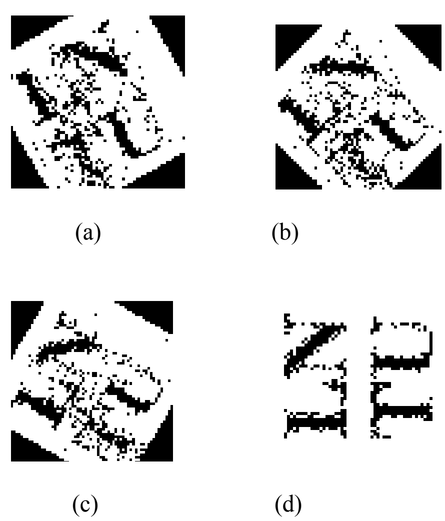
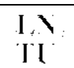
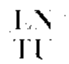


Fig. 6: Extract watermarking after rotate, (a) rotate 30°, (b) rotate 45°, (c) rotate 60°, (d) rotate 90°

Table 1: NC value after image rotation (Qiyang and Baolin, 2009)

Rotate angle	NC	Li (2007)	Jiufen *et al.* (2003)	Fei *et al.* (2010)
30°	0.9033	0.8556	0.8662	0.9011
45°	0.8758	0.8586	0.8415	0.8535
60°	0.9012	0.8621	0. 8593	0.9147
90°	0.9671	0.9458	0.9587	0.9735

Table 2: NC value after image rotation

Attack method	Extracted image	NC
White noise		0.9871
Gaussian LPF		0.9787
Image compression		0.9835
Pepper noise		0.9812
Affine transform		0.9618
Enlarge		-
Reduce		-
Histogram equalization		05166
Change contrast		0.3945

- Reconstruct the watermarking image in the right order

EXPERIMENTAL RESULTS

Choosing a Couple images whose size is 512×512 as the carrier image, which is shown in Fig. 2. The watermarking image is a 64×64 binary image as follows as Fig. 3. Embed it into the carrier by the way of the algorithm we introduced above and get the watermarked image as in Fig. 4

We begin to attack Fig. 4, rotate it with different angles as shown in Fig. 5, according to extracted method, the extracted watermarking after attack is in Fig. 6.

De-noise and work out the NC value based on formula (10):

$$NC=\frac{\sum_{x,y} I^2(x,y)}{\sum_{x,y} I(x,y)I'(x,y)} \tag{10}$$

It is used to represent the similarity between the original watermarking and extracted watermarking. The bigger NC value is, the more similar is and the better robustness will be, the NC value is shown in Table 1 (Qiyang and Baolin, 2009).

No matter what angles the watermarked image rotated, the extracted watermarking images are relatively clear. We can get the conclusion that this algorithm has a good robustness. By means of the experiment, it proved that NC value is bigger than the one in Li (2007) and Jiufen *et al*. (2003) in most cases. Although the result in Fei *et al*. (2010) is better to a certain extent, the algorithm we propose is much simpler and more easily to understand. Under the similar circumstances, if take the theory in Fei *et al*. (2010), it will cost much more space, time and code. So we put forward this algorithm.

Then we would take other methods to attack Fig. 4 and the NC value is shown in Table 2. For enlarge and reduce attacks that the size of watermarking is changed, so we observed the experiment result directly instead of calculating the NC value.

We learned from Table 2 that this algorithm can resist many image attacks, but regrettably, once the watermarking was attacked by changing contrast or histogram equalization, the extracted watermarking would emerge obvious distortion, so we will go on doing some research on this shortcoming.

CONCLUSION

According to digital watermarking, combining with Log-polar-transform theory, this study proposed a new transform domain watermarking algorithm which has the ability of resisting image rotation. It proved with experiment that the algorithm in this article could improve the robustness to geometric attack of transform domain watermarking, but once facing some other attacks, there are some limitations in this algorithm, so the author will do further research.

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