A image watermark resisting geometrical attacks based on quaternion moments

Ge Wu
Department of Electronic Engineering, Changchun University of Science and Technology, Changchun, China, 130022
E-mail: 651837271@qq.com

Abstract. This paper, proposes a method that by generating a quaternion moments, which will work as the watermark by multiply the quaternion orthogonal moments. Firstly, quaternion orthogonal moments matrix is gotten from source image and watermarking image separately. Secondly extract N dimension matrix of two matrixes, multiply two matrixes to get a new matrix as the copyright information. Finally the matrix is sent to the copyright center. The watermark can be detected effectively, and it is robust against RST attacking such as rotating attack, cropping and scaling attack.

1. Introduction
Classically two types of watermarks are presently under consideration, namely robust watermarking and fragile watermarking. Researches are mostly focused on the development of robust watermarking, designed for the copyright protection of multimedia content.

Now more watermarking algorithms are applied, quaternion moments algorithms have been applied popularly in recent years. He Bing[1] proposed a zero watermarking algorithm based on Radon transform and real matrix of quaternion, in the algorithm three components are extracted from color image and each component is decomposed, then the invariant moments of the real matrix is calculated and used to design zero watermarking. Zhong Minjie [2] proposed a RST invariant color image watermarking based on quaternion zernike moments, the algorithm can diffuse the error caused by watermark embedding to three component images.

This paper describes an image watermarking algorithm based on quaternion orthogonal moments. The algorithm is related in various degrees to much earlier work on scalable image compression.

2. Basic Methods

2.1. Quaternion Orthogonal Moments
The image orthogonal moments are projective coefficients that are projected onto a set of orthogonal polynomials, and image noise and other related operations has higher robustness.

Real moment of RGB image is usually described as:

$$I = \begin{bmatrix}
0 & R & G & B \\
-R & 0 & B & -G \\
-G & -B & 0 & R \\
-B & G & -R & 0 
\end{bmatrix}$$

(1)
Left quaternion orthogonal moments [3] in polar coordinate is shown as formula 1,

\[ Q_{n,m}^l = \int_0^{2\pi} \int_0^{\infty} r^{n+m} e^{-\lambda(n-m)\theta} f(r,\theta) r dr d\theta \]  

(2)

\( f(x,y) \) denotes the form in rectangular coordinate, \( f(r,\theta) \) denotes the form in polar coordinate, \( \lambda \) is Scaling factor. Suppose the image is rotated by the angle \( \alpha \), it becomes

\[ Q_{n,m}^l [f^\prime(r,\theta)] = k^{n-m-2} \cdot e^{-\lambda(n-m)\alpha} \cdot Q_{n,m}^l [f(r,\theta)] \]  

(3)

Left quaternion Fourier-Mellin moment [4]:

\[ F_{n,m}^l = \int_0^{2\pi} \int_0^{\infty} r^{n-1} e^{-\lambda m \theta} f(r,\theta) dr d\theta \]  

(4)

Suppose the image is rotated by the angle \( \alpha \), it becomes

\[ F_{n,m}^l [f^\prime(r,\theta)] = \lambda^{-n} \cdot e^{\lambda m \alpha} \cdot F_{n,m}^l [f(r,\theta)] \]  

(5)

According to the conjugate property of the product of quaternion\[5], the phase is gotten,

\[ \alpha_{n,m} = \frac{1}{2\pi} \sum_{m=1}^{M} \sum_{n=1}^{N} (\psi_{n,m} - (m-1)\alpha) \]  

(6)

Because the phase information contained in quaternion orthogonal moments is more important than the corresponding amplitudes information, the quaternion orthogonal moments could be used as the important factor to identify the image.

Right quaternion orthogonal moments is as follow,

\[ OF_{n,m}^c = \frac{D+1}{\pi} \int_0^{2\pi} \int_0^{\infty} f(r,\theta) Q_n(r) e^{-\mu m \theta} r dr d\theta \]  

(7)

\[ Q_n(r) = \sum_{s=0}^{n} (-1)^{n+s} \frac{(n+s+1)!}{(n-s)!s!(s+1)!} \]

With the increasing orders of quaternion orthogonal moment, the NIRE values of the reconstructed color images showed a decreasing trend.

3. Proposed Algorithm

3.1. Watermarking Embedding Algorithm

Fig.1 depicts the watermark embedding algorithm.
Figure 1. Watermarking Embedding Algorithm

Firstly, Quaternion orthogonal moments matrix is gotten from source image and watermarking image separately, secondly extract N dimension matrix of two matrixes, multiply the two matrixes to get a new matrix as the copyright information. Finally the matrix is sent to the copyright center.

For $N \times N$ image, its N+M rank Tchebichef moment is defined as following:

$$T_{nm} = \frac{1}{\rho(n,N) \rho(m,N)} \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} t_n(x) t_m(y) f(x, y)$$

(8)

In which $t_n(x)$ is the polynomial of n rank Tchebichef, it is defined as following:

$$t_n(x) = \frac{T_n(x)}{N^n}$$

$$t_n(x) = n! \sum_{k=0}^{n} (-1)^{n-k} \binom{N-1-k}{n-k} \binom{n+k}{n} x^k$$

(9)

In fact, discrete image could be gotten by next formula,

$$f(x, y) = \sum_{n=0}^{N-1} \sum_{m=0}^{N-1} T_{nm} t_n(x) t_m(y)$$

(10)

The watermark image is calculated according to the same way to get $W(x, y)$, then watermarking matrix $W'(x, y)$ is gotten from

$$W'(x, y) = W(x, y) \times f(x, y)$$

(11)

$W'(x, y)$ is sent to the copyright center to save.

3.2. Watermarking Detection Algorithm

Given a watermarked image, because the stability of quaternion orthogonal moments, the detector still needs two other inputs for the watermarking and source image, the process is the same as the first two steps in generating watermarking. Then we can get the result of the copyright of image.
Step 1: Calculating the quaternion orthogonal moments matrix of the source image and extract the first $N \times N$ dimension of it, that is $W(x, y)$.

Step 2: Getting watermarking matrix from copyright center, that is $W'(x, y)$, and execute dividing algorithm of the two matrix to get a new matrix.

Step 3: Recover the source watermarking image from the new quaternion orthogonal moments matrix according to formula 11.

4. Experimental Results
Firstly, we extract $256 \times 256$ orthogonal matrix from the source image and watermarking image, then multiply two matrixs to get the copyright watermarking matrix. From Table 1 and Fig.2, it is clear that when the watermarked image undergo the rotation which angle is less than 2 degree, the algorithm can detect the watermark correctly, which is better than EZW algorithm.

**Table 1.** Comparison of small rotation attack and the detection result

| Rotation angle | Normalized correlation coefficient | Rotation angle | Normalized correlation coefficient |
|----------------|-----------------------------------|----------------|-----------------------------------|
| 0.5            | algorithm | 0.42 | Ezw | 0.37 | -0.5 | algorithm | 0.46 | Ezw | 0.32 |
| 1.0            |          | 0.34 | Ezw | 0.31 | -1.0 | algorithm | 0.36 | Ezw | 0.30 |
| 1.5            |          | 0.28 | Ezw | 0.25 | -1.5 | algorithm | 0.31 | Ezw | 0.25 |
| 2.0            |          | 0.26 | Ezw | 0.21 | -2.0 | algorithm | 0.27 | Ezw | 0.20 |

![Figure 2. Watermarked image after rotating attacking](image)

From fig.3 and Table 2, the algorithm is robust to the cropping and scaling attack, when the remaining area after cropping is only 49% of the original image, the watermarking could be detected correctly.

**Table 2.** Detection result under cropping and scaling attack

| Rotation angle | Normalized correlation coefficient | Rotation angle | Normalized correlation coefficient |
|----------------|-----------------------------------|----------------|-----------------------------------|
| 0.5            | algorithm | 0.42 | EZW | 0.37 | -0.5 | algorithm | 0.46 | EZW | 0.32 |
| 1.0            |          | 0.34 | EZW | 0.31 | -1.0 | algorithm | 0.36 | EZW | 0.30 |
| 1.5            |          | 0.28 | EZW | 0.25 | -1.5 | algorithm | 0.31 | EZW | 0.25 |
| 2.0            |          | 0.26 | EZW | 0.21 | -2.0 | algorithm | 0.27 | EZW | 0.20 |
Figure 3. Watermarked image after cropping and scaling attacking

5. Conclusion
In this paper, we have presented a digital watermarking scheme for both watermarking embedding and detection, our scheme is effective. Our experiments confirmed that the watermarked image is nearly rate-distortion optimized, the decoder can recover the original image, the watermark can be detected effectively, and it is robust against geometric attacking such as rotating attack, cropping and scaling attacking.

6. References
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