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A Novel DWT-Based Watermarking for Image with The SIFT

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Abstrak

Operator transformasi fitur skala invarian (SIFT) pada domain DWT diusulkan untuk algoritma water marking. Frekuensi rendah pada gambar diperoleh dengan DWT dan kemudian transformasi SIFT digunakan untuk menghitung titik-titik fitur kunci pada sub-gambar frekuensi rendah. Berdasarkan titik-titik kunci ruang yang dipilih dengan skala moderat maka terbentuk lingkaran sebagai daerah watermark. Berdasarkan hasil penelitian, algoritma watermark digital baru yang diusulkan lebih baik dibanding karakteristik titik-titik kunci SIFT dan waktu-frekuensi lokal pada DWT. Algoritma ini tidak hanya memiliki ketahanan yang baik untuk operasi seperti kompresi, shearing, penambahan noise, median filtering dan scaling, tetapi juga memiliki pertahanan yang baik untuk verifikasi watermark palsu.

Kata kunci: *DWT,ketahanan, SIFT, watermarking*

Abstract

A kind of scale invariant features transformation (SIFT for short) operators on DWT domain are proposed for watermarking algorithm. Firstly, the low frequency of the image is obtained by DWT. And then the SIFT transformation is used to calculate the key feature points for the low frequency sub-image. Based on the chosen space's key points with moderate scale, a circular area as watermark embedding area is constructed. According to the research and final results, the novel digital watermark algorithm is proposed benefiting from the characteristics of SIFT's key points and local time-frequency of DWT. The algorithm not only has good robustness to resist on such operations as compression, shearing, noise addition, median filtering and scaling, but also has good inhibition to possible watermark fake verification.

Keywords*: watermarking, DWT, SIFT, robustness*

1. Introduction

Digital multimedia information and the development of network technology are convenient for information to expression and transmission. But many more operations like access violation, deliberately change, damaged copyright, make the protection work become worse than ever before. Nevertheless, digital watermarking [1-4], is considered as the effective measures for the protection of the copyright, while its purpose is to use the personal secret information hidden in the products as the proof of copyright reliability. In recent years, research on the digital watermark technology has made a great progress. The typical algorithms are almost airspace algorithm, transform algorithm, the compressed domain algorithm, NEC algorithm and physical model algorithm and so on. And most of the watermark extraction algorithm use relevant detector to verify the existence of watermark.

Discrete Wavelet Transformation (DWT [5]) can decompose signal into components by different scales. It is also considered as multi-resolution analysis method. So, the original image can be broken into a series of low and high frequency components by wavelet transforming. According to the human's feel mask effect, embedding the digital watermark information into the low frequency area is not easy to be percepted.

SIFT [6-7], namely scale invariant features transformation, can extract local characteristics which keep the invariant features after image rotation and scale zoom. Presently, some digital watermark algorithms [8-13] always apply the SIFT to test and verify the ability of resisting geometric attack such as rotating, compression, cutting, while ignore the robustness analysis under the general signal attack. At the same time, the SIFT algorithm often extract

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many more points, while only a small part of the feature points can be used. Thus, it led to low efficiency searching for the feature points.

Sincerely, a new watermark algorithm based on SIFT operator applied on DWT domain is proposed. It can effectively reduce calculation about carrier images. What's more, there are several advantages when compared to these algorithms which using SIFT transform after compressed image, one is the wavelet transformation can inhibit the noise, the other is the wavelet transformation can enhance the watermarking information to be invisible, In addition, SIFT transformation can keep invariant features although image translation, rotation and scale zoom。This method can reach the balance between watermark visibility and attack-against.

2. Research Method

2.1. The Image of LEVEL 1 Wavelet Transformation

Before seeking for the characteristic point of an image, wavelet decomposing is needed, in which the original image will be decomposed into a series of low frequency sub-images and high frequency ones. Then we select them through the sensibility of HVS. The coefficient structure after Level 1 wavelet transform is:

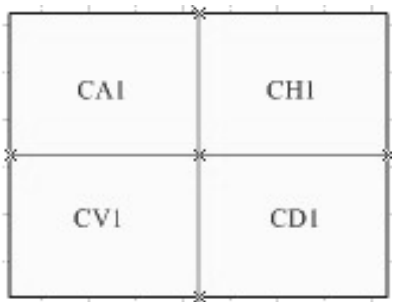

Figure 1. Schematic diagram of the image level wavelet

In brief, CA1 is the low frequency of wavelet transform. It decided the basic information of the image. As long as it was unchanged, it will keep the image's visual effect. So it can be used to hide digital watermark information. Applying a sift transform on this part, it not only combines with the local characteristics of wavelet and can expresses the original carriers, but also reduces the scale for SIFT algorithm seeking the feature points, makes this embedded regional more clearly, shortens the matching time, improves the efficiency greatly.

2.2. The Image of Wavelet Transformation

SIFT algorithm main steps are:

(i) Detecting scale-space's extreme points;
(ii) Removing the low contrast and edge feature points;
(iii) Specifying the direction parameter for each feature point.

A two-dimensional image, under different scale with Gauss kernel convolution:

$$L(x,y,\sigma)=G(x,y,\sigma)*I(x,y) \quad (1)$$

$G(x,y,\sigma)$ is the scale variable Gaussian function, it means:

$$G(x,y,\sigma)=\frac{e^{-(x^2+y^2)/2\sigma^2}}{2\pi\sigma^2} \quad (2)$$

(x,y) is the image's pixel position, σ is scale-space factor. Large-scale is corresponding to the features of the image; small-scale is corresponding to the detail of the image.

2.2.1. Space Coordinates of Extreme points of The Test

DoG operator is defined as two different scales of the Gaussian kernel of difference, that:

$$\begin{aligned} D(x,y,\sigma) &= (G(x,y,k\sigma) - G(x,y,\sigma)) * I(x,y) \\ &= L(x,y,k\sigma) - L(x,y,\sigma) \end{aligned} \tag{3}$$

By computing a sampling point in each scale value of the DOG operator, it can receive characteristic scale's trajectory curve. Characteristic scale curve of the local extreme point is the scale of the sampling points. In order to find the extreme points of the scale space, each sampling point need to be compared with the 8 adjacent points in the same scale and the corresponding upper and lower the 18 adjacent scale points. All of 26 points ensure that the scale space and two-dimensional image space can be used to detect the extreme points.

2.2.2. Precise Positioning of Extreme Points

SIFT algorithm needs to give the low contrast's feature points and unstable edge response points to enhance stability and improve noise immunity. DoG's main curvature calculated by the Hessian matrix H (2*2). It is:

$$H = \begin{bmatrix} D_{xx} & D_{xy} \\ D_{xy} & D_{yy} \end{bmatrix} \tag{4}$$

DoG's main curvature is proportional to the feature points of H, α as the largest feature value of the matrix H, β is the smallest feature value of the matrix H, The trace and determinant of matrix H are:

$$Tr(H) = D_{xx} + D_{yy} = \alpha + \beta, Det(H) = D_{xx}D_{yy} - (D_{xy})^2 = \alpha\beta \tag{5}$$

If $\alpha = \gamma\beta$

$$\frac{Tr(H)^2}{Det(H)} = \frac{(\alpha+\beta)^2}{\alpha\beta} = \frac{(\gamma\beta+\beta)^2}{\gamma\beta^2} = \frac{(\gamma+1)^2}{\gamma} \tag{6}$$

As $(\gamma+1)^2 / \gamma$, Its value can reach the smallest when the two feature values are equal, with the increases in γ, so testing whether the principal curvature values in a field, the only test:

$$\frac{Tr(H)^2}{Det(H)} < (\gamma+1)^2 / \gamma \tag{7}$$

Generally

γ =10

2.2.3. Direction of Feature Points

SIFT algorithm uses feature point neighborhood distribution characteristics of pixel gradient direction to specify the direction parameter for each feature points, it makes the operator have rotation invariance, which is denoted by

$$m(x,y) = \sqrt{(L(x+1,y) - L(x-1,y))^2 + (L(x,y+1) - L(x,y-1))^2} \quad (8)$$

$$\theta(x,y) = a\tan((L(x,y+1) - L(x,y-1)) / (L(x+1,y) - L(x-1,y)) \quad (9)$$

L is the scale, which is each feature point in their respective scale, $m(x,y)$ is the gradient value and $\theta(x,y)$ is the direction of the (x,y). Practice, in the feature point as the center of the neighborhood within the sampling window, and pixels with histogram neighborhood gradient direction histogram peak represents the characteristic point of the neighborhood's main direction of the gradient, that is, as the feature points the main direction of the main direction of normalization can be an effective anti-rotation.

2.3. Watermark's Embedding and Extraction

2.3.1. Watermark's Embedding

Let the original image is I, and the key digital watermark's embedding steps are:

(i) In order to ensure security, make scrambling encrypt for the watermark before embedding, while the number of scrambling as a key.
(ii) Make a wavelet transform to the image, and the low frequency part is obtained.
(iii) Use the SFIT algorithm, select the feature points from the wavelet low-frequency region.
(iv) According to the experimental analysis, the obtained characteristics of large-scale and small-scale feature points are re-detection rate is too low, and large-scale corresponding to the region on a large is lower robustness. So we choose the scale of feature points between 2 and 10 and calculate the average coordinates of these chosen points as the center. To the center of a circle, take as much as possible, including a circular area with the vast majority of moderate scale. Then in the large circular area, the construction of multiple non-overlapping features 8 * 8 regions that are invariant with zoom and pan through the main direction of each region normalized to obtain rotation invariance.
(v) The watermark change into one column, divided into four parts, then use the additive rule, the watermark is embedded into each small area. PSNR is often used in experiments to measure the watermark invisibility, its expression is as follows:

$$PSNR = \frac{M * N \max_{m,n}(I_{m,n}^2)}{\sum (I_{m,n} - I'_{m,n})^2} \quad (10)$$

Watermark embedding process shown in Figure 2:

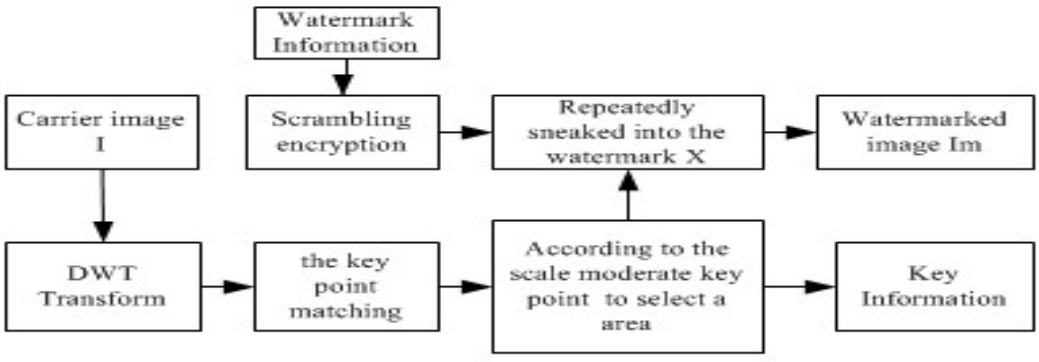

Figure 2. The flow chart of the watermark embedded

According to this process, embedded watermark compared with the not watermarked image I, provided in Figure 3.

Figure 3. Embed watermarked image contrast before and after the carrier

According to the results shown in Figure 3, when the embedding factor a = 0.25, the image of the peak signal noise ratio is the 40.3543db, the difference is not to be recognized simply by visually intuition.

2.4. Watermark's Extraction

The extraction of embedded watermark is the inverse of the process, For 32 * 32 of the size of the watermark information, no matter what kind of attack, the extraction process is the same.

(i) To the carrier of watermark image on a wavelet transform, the low frequency extraction area.
(ii) In conventional attack, find watermarking embedding area directly extracted and each of the watermark encryption of small, then embedded in accordance with the order of good, a combination of extracted watermark encryption.
(iii) In geometrical attack. Such as rotating, minus cut, displacement, compression, these will use the feature points, according to the matching of the Euclidean distance to positioning geometric attacks after the watermarking embedding area, in order to achieve the watermark encryption of orientation, complete watermark extraction.
(iv) According to the scrambling encryption with periodic, subtract the number of encryption cycle, and then to scrambling encryption, he extracted remove the watermark encryption.

The watermark extraction flow chart is as follows:

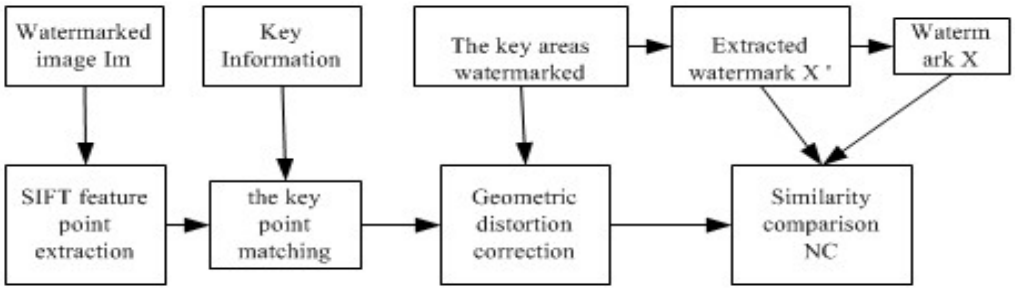

Figure 4. The flow chart of the watermark extract

When the image Im containing the watermark is not attacking, the extracted watermark information X "and the original watermarking information X a contrast shown below:

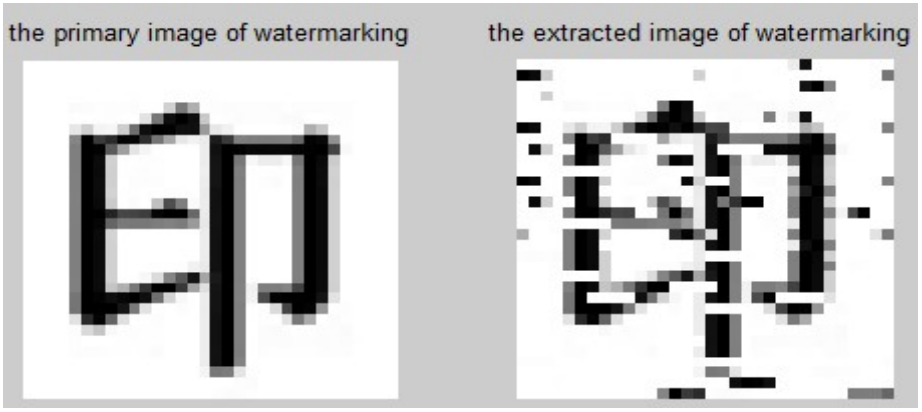

Figure 5. Contrasting between the watermark and the extracted watermark

In the studying of digital watermarking, there is a similarity comparison about the extracted watermark image of a measure of quality, it is mainly comparing with the original image information. Especially after the attack, according to the similarity to judge a algorithm of the strength of the ability against the attack. Use the following formula extracted watermark measure quality: $W = (w_1, w_2, \ldots w_n)$ and extraction of the watermark signal similarity: $W' = (w_1', w_2', \ldots w_n')$

$$NCC = \frac{\sum_{i=1}^{n} w_i w_i'}{\sqrt{\sum_{i=1}^{n} (w_i)^2} \sqrt{\sum_{i=1}^{n} (w_i')^2}} \quad (11)$$

If $NCC \geq T$, it is determined by measuring the picture that the watermark exists, and vice versa. And among them, T is the threshold. Generally, when T = 0.7, it means the watermark exists.

2.4. Matching Feature Points

Use the feature descriptors that are generated by sift, take the image characteristics description of A critical point, according to the characteristics of the key points and find out the vector and image of the corresponding key characteristic vector of the Angle (the smaller the more similar). If the key point a in the figure A, it is simile to b_1 than b_2, they are the key point in figure B, And then satisfy the condition: if the angle between a and b_1 is less Dist Ratio (0.6) times than the angle of a and b_2,the a b_1 match. Whether, the a point is not matched any points in the figure B.Reduce this ratio threshold, the number of match points will be reduced, but more stable.

In the algorithm, SIFT characteristic vector is used for local image matching feature points, according to the important basis of general characteristic vector to measure the distance between the, Figure 6 give accord with moderate scale for (2-10) feature point distribution and watermarking embedding interest area figure 7,To moderate scale out two similar image of Lena SIFT the matching feature points. One of the original images which for a quarter of the size. Through this feature point matching, we can better location geometric attacks embedding area. Thus extract the watermark.

Figure 6. Moderate-scale distribution of key points

Figure 7. The feature point matching chart

3. Results and Analysis

The Lena image (size is 512 *512,256) for example, accordance with the article 2 section of the algorithm steps, when embedded factor is 0.3, embedded in a meaningful gray image, got the registered watermark works shown in Figure .

Not to attack the watermark extraction is shown in Figure 5, the embedded watermark image after various attacks, use the correlation coefficient reflects the strength of watermark robustness, a variety of conventional signal attack correlation coefficient as follows:

Table 1. before and after the attacks on the relevance of extracted watermark

Description of image manipulation	***Normalized correlation coefficients of the watermark detection results***			**The latter is relate to the former**
	our algorithm	**Ref.[10]**	**Ref.[6]**	
No attack	0.9576	*	*	
Smooth 3*3	0.9369	*	*	
Gaussian low-pass filter 5*5	0.9575	0.9521（3*3）	*	Better
Histogram equalization	0.7221	*	*	
Salt-pepper noise 0.8	0.9580	*	*	*
Salt-pepper noise 0.01	0.9577	**0.9722 （ 0.005 ）	*	
Gaussian noise 0.01	0.9576	0.9607	*	similar
Gaussian noise 0.8	0.9579	*	*	
Sharpen	0.9269	*	*	
10degress before rotation correction	0.8879	*	*	
15degress after rotation correction	0.6584	0.4783		Better
Cut 205*205	0.9576	0.9026		Better
Zoom 128*128	0.8879	*		Better
Zoom 200*200	0.8736	0.9542	*	worse
Displacement 10 row	0.8880	*	*	
Displacement 50 row	0.8879	*	*	

The experimental results to know, * represent the other authors of references for this attack did not experiment. The algorithm in the conventional signal attacks manifest good robustness, the algorithm to make up for the many papers only the SIFT in the anti-rotation, displacement, shear analysis of the shortcomings of this attack. Sift can be used as a watermark and wavelet transform in a complementary in the piece of research. What's more compare to other thesis [6],[10], it reflect more robust on the attack by cutting. According to the experimental results, add salt and pepper noise intensity from 0.01 to 0.8 across the 10 times, extracted from the watermark of the similarity transformation is very small, reflecting a very good resistance to attack. This anti-attack capability is also very good on Gaussian low-pass filtering attacks. While on the anti-geometric attacks, NCC values are above 0.8, measured by the similarity of standards, the algorithm is also strong resistance to geometric attacks.

In short, the experimental results demonstrate the feasibility of ideas of the algorithm.

4. Conclusion

In this paper, the watermarking algorithm which used DWT domain coefficients based on SIFT features transform, is relative to other thesis to use the sift algorithm that it is supplement and improvement in watermark's robustness analysis. This algorithm in the clear wavelet low-frequency region, where be better to find a subspace to embed watermark, save the time to find feature points. The analysis experimental results of the algorithm prove the correctness of the theory, reflecting the general attack on the algorithm robustness is better, and also has good resistance to geometric attack.

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