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Statistical Features Based Image Watermarking Resisting to Geometrical Attacks

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ABSTRACT: The aim of our robust technique using watermarking is to reconstruct watermark from geometric attacks. Various geometric transformations, such as rotation, scaling, cropping, shear, translation, resize, scattering, bending, and so on, provides the displacement of some of its picture elements. The existing watermarking algorithms countermeasures the attacks related to pixel positions. In our paper, we use the histogram of image based watermarking system. While the histogram, is invariant to scaling mathematically, resistant to cropping statistically and independent of pixel position. By modifying the histogram shape a PN sequence is generated and uses as key, which is computing from the Gaussian filtered low-frequency component of images. Finally, the proposed watermarking scheme is more resistant to geometric deformations, including cropping, filtering, scaling, JPEG compression, shear and random bending attacks.

KEYWORDS: Image based watermarking, Histogram, Gaussian filter, Geometric attacks.

I. INTRODUCTION

The rapid growth of the multimedia has created an essential demand for the ownership protection since the digital information is easily reproduced and manipulated. Digital watermarking has been introduced as a solution for such problems. One of the prominent applications of watermarking is using a robust and practical digital watermarking to protect image and video data [1]. The attacks against image watermarking systems have become more and more complicated due to the various watermarking techniques. In a desired watermarking system, the watermark should be robust to attacks including geometric deformations and image processing operations. From the point of view of image watermarking, geometric attacks mainly causes synchronization errors between the encoder and the decoder. Even though the watermark is present in watermarked image, but the detector is unable to extract it. Different from geometric attacks, the content-preserving image processing operations, such as addition of noises, common compression and filtering operations reduce the watermark energy. Many of the previous watermarking schemes have shown robustness against common image processing operations by embedding the watermark into the low-frequency component of images, such as the low-frequency subbands of discrete wavelet transform [2]. Only a less number of algorithms have presented the topics of the robustness against geometric attacks. When the original image is available in the detection, the cost for resynchronization can be reduced by comparing the original image with the watermarked image with attacks [3], [4]. These non-blind schemes are effective to compensate for small local distortion, but the computation cost is dramatically increased under global affine transform [5]. When the original image is not available during the detection, some specialized methods have been addressed the issue against geometric attacks by relying on • Exhaustive search: One obvious solution to de-synchronization is to search randomly for the watermark in the special coordinate system including a set of attack parameters. The exhaustive search [6] is the computational cost in the larger search space. Another is the false alarm probability during the search process.

• Embedding watermark in invariant domains: In [7]–[9] researchers have embedded the watermark in affine-invariant domains such as the Fourier–Mellin transform to achieve robustness to affine transforms. Watermarking techniques involving invariant domains are usually vulnerable to cropping and random bending attacks (RBAs) and is difficult to implement [10].

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• Embedding template as side information: Another way against geometric attacks is in addition to the watermark a template embedding [2], [11], [12] or inserting the watermark many times. The performance of the template based watermarking techniques depends on the dimensionality of the attack parameter in special domain. For some complicated geometric attacks such as RBAs, the template based methods will be incompetent to estimate the attack parameters. As for cropping, due to the permanent loss of parts of the image content, the template may lose its role. In [13], the authors have provided a solution for small local geometric distortions by using the invariance properties of fractal coding. The synchronization bits as part of the hidden information is used to estimate and compensate small local or global geometric distortion. They mentioned that the watermarking scheme [13] is sensitive to the distortion by global transforms such as an affine transform.

II. GEOMETRIC ATTACKS AND HISTOGRAM-BASED WATERMARKING SCHEMES

A. Analysis of Geometric Attacks

Each geometric transformation is defined by a set of parameters that determine the operation implemented over the target image. We classify these geometric transformations into three categories according to the complexity of the attack parameter space.

Invertible global attacks: Some geometric attacks are invertible, such as affine transformation including rotation, scaling and translation. Because these attacks are global and the attack parameters are not complicated, some existing countermeasures focus on these geometric deformations by embedding bits in invariant domains.

Invertible local attacks: Invertible local attacks usually include the combination of a group of localized attacks. In the case that the attack is unknown, it is impractical to estimate the attack parameters. These kind of attacks mainly include bilinear transform, curved transform, random displacement (also known as random jitter attack), global bending and high-frequency bending. The watermark against RBAs was claimed as an important issue due to the high complexity of the attack parameter space.

Noninvertible attacks: Under cropping, the original image cannot be recovered due to the permanent loss of partial content. In addition, cropping may introduce desynchronization problem of a watermark. This is why cropping is usually considered to be a severe attack in the watermarking community.

B. Existing Histogram- Based Watermarking Algorithms

Some existing histogram-based watermarking methods have been presented for the purposes of robust watermarking, fragile watermarking and reversible watermarking. The well-known patchwork watermarking methods [14],[15] inserted a message by supposing that two sets of randomly selected pixels are Gaussian distributed with zero mean. The watermark sequence was embedded by shifting the mean values between groups of two sets of pixels. The patchwork method is sensitive to desynchronization operations because the watermark is highly related to the position of those marked patches.

The template-based patchwork watermarking for color image was reported against geometric attacks. The watermark is robust to geometric attacks due to the fact that the marked patches can be localized by computing the robust features in the Y and V. The watermarking scheme is only fit for color images.

Another class of histogram-based watermarking algorithms [16], [17] is developed by using histogram specification the watermark is a predefined histogram. By referring to the predefined histogram, the pixels in the original image are rejoined to generate the watermarked image, which has the same shape of histogram as the watermark has. In the extraction, an image is judged as “watermarked” or not by matching the image histogram and the watermark.

III. PROPOSED WATERMARKING ALGORITHM

In the existing methods, the watermark is difficult to survive under RBAs because the exploited robust features are more or less related to the pixel position. Thus, a possible way to cope with RBAs is to embed the watermark into those feature representations independent of the pixel position. Towards this direction, we use the scaling invariance of shape of an image’s histogram and the property of the histogram to be independent of the pixel position against various geometric attacks, which is implemented by representing the histogram shape as the ratios of population between groups of two neighboring bins and then modify the ratios to carry a key-based pseudo-random noise (PN) sequence. Considering the interpolation errors and common image processing operations, the two features are extracted from the Gaussian filtered low-frequency component.

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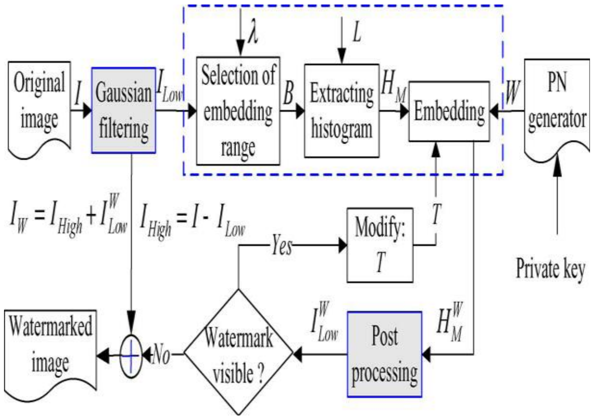

Fig.1 Watermark embedding framework

A. Watermark Insertion

As illustrated in Fig. 1, the watermark insertion consists of three main steps: Gaussian filtering, histogram-based embedding and post processing.

1) Gaussian Filtering: The input image (I) is filtered with a Gaussian kernel lowpass filter for removing the high-frequency Information I_{High}. The lowpass filtering operation can be represented as the convolution of the Gaussian function G(x,y,σ) and an image I(x,y)

$$I_{Low}(x,y)=G(x,y,\sigma)*I(x,y)$$

In 2-D case, an isotropic (i.e., circularly symmetric) Gaussian function has the form

$$G(x,y,\sigma)=\frac{1}{2\pi\sigma^2}\exp^{-\frac{x^2+y^2}{2\sigma^2}}$$

where σ is the standard deviation of the distribution. Because G(x,y,σ) is isotropic and circular in shape, the resulting response $I_{Low}(x,y)$ is invariant to rotation, which is beneficial for obtaining a geometric distortion-resilient watermark.

2) Histogram-Based Embedding: The histogram (H_M) is extracted from the filtered image by referring to its mean value in such a way that the watermark is immune to the operation of scaling the value of all pixels, and the watermark recovery process can avoid exhaustive search.

The watermark, denoted by W= $\{w_i|i=1,\ldots,L_w\}$ is a key-based PN sequence. The average value of the low-frequency component I_{Low} of an image is calculated as Ā. By referring to Ā, an embedding range denoted by B= [(1-λ) Ā, [(1+λ)Ā] is computed to generate the histogram with L equal-sized bins of width M , denoted by H=$\{h_M(i)|i=1,\ldots,L\}$. L should not be less than $2L_w$ in order to embed all bits.

Let Bin_1 and Bin_2 be two consecutive bins in the extracted histogram. Suppose their population is a and b, respectively. The embedding rules are formulated as

$$a/b\geq T,\ \text{if } w(i)=1 \quad (1)$$
$$b/a\leq T,\ \text{if } w(i)=0$$

where T is a threshold controlling the number of modified samples.

Consider the case that w(i) is bit value "1." If a/b≥T, no operation is needed. Otherwise, the number of pixels in two neighboring bins, a and b , will be reassigned until satisfying the condition $a_1/b_1\geq T$. When w(i) is "0," the procedure is similar. If w(i) is "1" and a/b<T, I_1 randomly selected samples from Bin_2 will be modified to Bin_1, achieving $a_1/b_1\geq T$. If w(i) is "0" and , randomly selected pixels from Bin_1 will be moved to Bin_2, satisfying $b_0/a_0\geq T$.

$$f'_1(i)=f_1(i)+M,\ 1\leq i\leq I \quad (2)$$
$$f'_2(j)=f_2(j)-M,\ 1\leq j\leq I_1$$

where M is the bin width, $f_1(i)$ is the ith selected pixel in Bin_1, and $f_2(j)$ denotes the jth selected pixel in Bin_2. The modified pixels $f'_1(i)$ and $f'_2(j)$ belong to Bin_2 and Bin_1, respectively. I_0 and I_1 can be computed by the following expressions:

$$I_0=T.b-a/1+T\ ,\ I_1=T.a-b/1+T \quad (3)$$

where $a_1=a+I_1, b_1=b-I_1, a_0=a-I_0$, and $b_0=b+I_0$.

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3) Post Processing: According to the property of the Gaussian kernel filter, we know the extracted watermark energy $G(I_w\text{-}I)$ is different from the embedded watermark energy $I^w_{Low} - I_{Low}$.. The difference reflects a loss of the watermark energy caused by the Gaussian filtering in the extraction. Considering the effect, we introduce a corresponding post processing step in the watermark embedding phase by computing the maximum difference of the pixels between $G(I_w\text{-}I)$ and $I^w_{Low} - I_{Low}$, formulated as

$dGau = \max (|G(I_w\text{-}I) - (I^w_{Low} - I_{Low})|) - M.$ (4)

Then, the histogram H^w_M is further modified to compensate the loss of the watermark energy as follows:

$f(i)=(k-1)M+\mu$, if $f(i)< (k-1)M+\mu$ (5)

$f(i)=kM-\mu$, if $f(i)> kM-\mu$

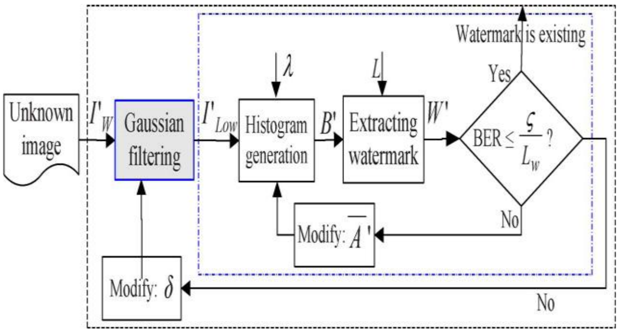

Fig:2 Watermark extraction framework

B. Watermark Recovery

First, we use σ (the same as in the embedding) for the Gaussian filtering to start the mean-based search process.

1. Compute the histogram of I'_W from the range B= [(1-λ) Ā', [(1+λ)Ā'] with L equal-sized bins as in the process of watermark embedding.

2. Divide the histogram bins as groups, two neighboring bins as a group. Suppose that the population in two consecutive bins, are a' and b', respectively. By computing the ratio between a' and b', one inserted bit is extracted in reference to the following equation:

w'(i)=1,if a"/b≥1 (5)

w'(i)=0, otherwise.

The process is repeated until all bits are extracted.

IV. PERFORMANCE ANALYSIS

In this section, we evaluate the performance of the proposed watermarking algorithm in terms of peak signal-to-noise ratio (PSNR) computation, embedding capacity, and computational cost in the extraction, false positive probability and possible key-estimation attack.

A. PSNR Computation

In the watermarking algorithm, the high-frequency component is unchanged. That is, the watermark is only inserted in the low-frequency component to generate watermarked image.

PSNR is defined as:

$PSNR=20\log_{10}(MAX^2/MSE)$ (6)

MAX-maximum pixel value of the frame

MSE-mean squared error

The above conclusion is very useful for reducing the computational cost in the embedding since we use to control the embedding distortion.

B. Capacity:

Suppose that the mean of the Gaussian filtered image is Q and the parameter P is applied to compute the embedding region. The embedding capacity Lw of the proposed algorithm can be expressed as [5]

$L_w = 2P.Q/M.G$ (7)

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where M denotes the bin width, and G is the number of the bins in a group designed to embed one bit. In this paper, G is 2 (two neighboring bins as a group). For images of D-bit depth, the maximum embedding capacity of the watermarking algorithm is mathematically calculated as 2^D/M.G which can achieve 128 bits for the 8-bit images in case of M=1.. In practice, the M value should be not less than 2 so that the watermark can tolerate the interpolation error due to geometric attacks, and the distortion of the pixel values due to image processing manipulations (such as JPEG compression, median filtering, etc.). We have shown that the histogram shape invariance to various geometric attacks is satisfactory when is 0.6. In case that the parameters are given as Q=128(half of 256 gray levels), P=0.6, M=2 and G=2 , the watermark embedding capacity is estimated as L_w = (2*0.6*128)/(2*2)=40.

Considering the fact that the mean values for some images are far less than 128, the effective embedding capacity of the proposed algorithm is from 20 to 30 bits.

C. Watermark Search Cost

In Section III-B, the watermark is searched from the space by referring to the key-based PN sequence. According to the definition of, a suggested searching step is designed as 1/P so that the selected range B is added or reduced with a gray-level at a time, such as from 100 to 99 or to 101. The maximal searching times C are estimated as

$$C= Q.(m1+m2)/S \quad (8)$$

Equation shows that the computational cost in the extraction procedure is corresponding to the mean Q, and the percentages of the maximal proportional deviation of the mean m1and m2 due to various attacks.

D. Watermark Security Discussion:

We can see that the length of the exploited PN sequence has an important role on the security of the watermarking scheme. In the proposed framework, the information is embedded into the histogram bins of the low-frequency component. With consideration of the robustness, the number of the bins is limited (refer to Section V-B). Thus, the exploited PN sequence is limited in length, and cannot provide a sufficient randomization. Once the watermarking algorithm is public, an attacker may use such a lack of randomization to mount an attack to estimate the parameter P by matching the extracted bits with the randomly generated PN sequence, and then modify the bins to remove the watermark. In the watermarking scheme, the parameter P is selected from the range [0.5, 0.7]. Suppose the mean value Q of a marked image is 128. Respectively, we discuss the security when the key-based sequence is known or unknown as follows.

1) In the case that the key used in the embedding is known, the attacker can estimate the value of P by matching the key-based sequence with the detected sequence. For a reliable search, the step size is related to the mean, theoretically equal to 1/Q. Thus, the total searching times for P is around (0.7-0.5)128=26.

2) When the key is unknown, given the fact that the PN sequence is typically 25 bits long, the attacker can try 2^{25}= 33,554,432 different candidates of the key to find the P value. In this case, the total search times are around 33,554, 432 26=872,415,232. Even if the attacker has no the knowledge of the length of the key-based PN sequence, due to the fact that the watermark embedding capacity is limited in the range from 20 to 30 bits, he or she still can estimate the key and the value used in the embedding by trying different alternatives. We can see from the above analysis that in the event that the watermarking algorithm is open, the watermark may suffer from the above key estimation attack due to the limitation of the watermark capacity.

V. EXPERIMENTAL RESULTS

In this section, we first investigate the effect of the Gaussian filter-based preprocessing on the watermark extraction for the design of the post processing operation in Section III. Then, the watermark imperceptibility and robustness are evaluated by using 50 different 512 images as example images, respectively. The example images include 48 standard grayscale test images [18] and Benchmark image Leon. In the experiments, a 16-bits of PN sequence was embedded into the 50 histogram bins. The test results show that the proposed watermarking scheme can achieve the requirement of imperceptibility while the watermark is resistant to various geometric attacks and common image processing operations.

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Fig: a) Original Image. (Leon)

A. Effect of the Gaussian Filtering

As discussed in Section III-A, a post processing step is designed to compensate the loss of the watermark energy due to Gaussian filtering in the extraction. We can see that the maximum absolute errors for all the 50 test images are between 0.2 and 0.75. Thus, in the post processing phase the parameter μ is set equal to 0.75 for tolerating the effect.

Fig: b) Watermarked Image.(Leon)

B. Watermark Imperceptibility:

Taking Leon as example, we plot the watermarked images and the amplitude of the watermark in Fig. a. We can see that the watermarked images are perceptibly similar to the original images. The maximal pixel distortion in the spatial domain due to the watermark is within 3 gray levels. In Fig. b, we investigate the effect of the watermark on the mean. The mean values of these images remain almost unchanged after watermarking (the mean errors are between 0.15 and 0.25). The reason is that the pixels are marked by adding or reducing the bin width with the same probability in reference to [2]. It ensures the recovery of the watermark from a marked image.

The PSNR values of the 50 watermarked images are between 44 and 58 dB. we can see that for an image, the bigger the mean, the lower the PSNR value.

In the embedding, the distortion on an image relies on the embedding threshold T, the parameter P and the length of the PN sequence. In [1], the number of the watermarked pixels is controlled by T. The greater T , the more pixels are marked. Referring to [2], the value of M represents the distortion on the marked pixels. The greater P , the greater M , the more the distortion on the marked pixels. The value of L_w also has an effect on the embedding distortion. Given the parameters T and P, L_w will decide the number of the bins. The longer the sequence L_w the more the bins L, the smaller the bin width M, thus the lower the distortion on the marked pixels.

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The above analysis shows that the embedding distortion can be controlled by using the threshold T. In our experiments, the PSNR value is controlled to be over 40 dB. In the proposed watermarking scheme, only part of the samples is modified with a low amplitude, which is beneficial to generating the high quality watermarked images.

C. Watermark Robustness:

In the 50 test images, we adopt four well-known benchmark images to report the watermark robustness performance. After watermarking, their PSNR value of Leon image is 53.19 (dB).

The BER, defined as the ratio between the number of incorrectly decoded bits and the length of the PN sequence. The false-positive error probability is when is set equal to 3, which can satisfy the requirement of most applications.

In the experiments, the error bits are not greater than 3 for most content-preserving attacks. we choose a set of geometric transforms and common image processing operations are examine the robustness of the watermark. The main image editing and attacking tools adopted in our experiments are ACD see and .Net. or each example image, 140 distorted but similar versions are generated by performing a set of 14 different content-preserving manipulations. For each manipulation, there are 10 groups of different parameters.

Fig : c) Key Image

Grayscale image of size 50 X 50

Key based Generated Pseudo Random Sequence

16 bit of PN sequence

1 1 1 0 1 1 1 0 1 1 1 1 1 1 1 0

VI. CONCLUSION

In both theoretical analysis and experimental method, in this paper we present a robust image watermarking algorithm against different geometric attacks including challenging cropping operations and RBAs by using the property of the histogram shape to be independent of the pixel position, mathematically invariant to the scaling, statistically resistant to cropping. A key-based PN sequence is successfully inserted by modifying the histogram shape, which is computed from the low-frequency component of Gaussian filtered images by referring to the mean. The watermark can be detected without knowledge of original images by sharing the exploited private key in the detector.

VII.FUTURE ENHANCEMENT

In our future research, one consideration is to enhance the security of the watermarking scheme by introducing the color information of color images [19] or seeking new ways to watermark the histogram shape so that a longer PN sequence can be embedded.

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