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Robust Reversible Watermarking Using Integer Wavelet Transform and Histogram Shifting

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ABSTRACT
Along with the rapid development of multimedia technology, digital image is becoming an important vector of network information communication. But meanwhile, the security and reliability of the information are more and more unable to be guaranteed. Images often suffer certain degree destruction in the transmission process which influences the correct extraction of hiding information as well as the image authentication. As a good digital media copyright protection method, information hiding technology already has become a research hotspot. In medical, legal and some other sensitive fields, however, slightly modify to carrier image may cause irreparable damage. Consequently, robust reversible watermarking technology seems more important. However, conventional RRW methods have some drawbacks like- unsatisfactory reversibility, limited robustness, and invisibility for watermarked images. Therefore, it is necessary to have a method to address these problems. So we proposed a novel method using IWT, Histogram Shifting and clustering for watermark embedding and extraction.
Keywords – EPWM, INTEGER WAVELET TRANSFORM,PIPA,SQH, K-MEANS CLUSTERING.

I. INTRODUCTION

In recent years the growth of Internet and multimedia systems has created the need of the copyright protection for various digital medium (Ex: images, audio, video, etc.). To protect the digital medium (Images) from illegal access and unauthorized modification Digital Image watermarking is used. It is a branch of information hiding, which hides ownership information inside the cover image in the form of company logos, ownership descriptions, etc. Watermarking can be broadly classified into visible or invisible watermarking [1]. Generally invisible watermarking is used in digital multimedia communication systems. In visible watermarks, watermarks are generally clearly visible after common image operations are applied. Visible watermarks convey ownership information directly on the media and can determine attempts of copyright violations. The invisible watermarks aims to embed copyright information imperceptibly into host media such that in cases of copyright infringements, the hidden information can be retrieved to identify the ownership of the protected host. It is important for the watermarked image to be resistant to common image operations to ensure that the hidden information is still retrievable after such alterations. Embedding of watermarks, either Visible or invisible, degrade the quality of the host media in general. A group of techniques, named reversible watermarking, allow legitimate users to remove the embedded watermark and restore the original content as needed. The robust Reversible Watermarking (RRW) techniques are used for watermark embedding and extraction without distortion for the lossless channel, but also resist unintentional attacks and extract as many watermarks as possible for the noised channel.

Digital watermarking can be performed in the spatial domain or frequency domain. Techniques in the spatial domain modify pixel values in a cover image with various algorithms. In spatial domain, Chan C.K, et al. L.M. [2] proposed LSB substitution can be used to embed the secret data in cover image. In LSB technique 1 bit of secret message replaces the least significant bit of cover image pixel. LSB technique is relatively simple and has low computational complexity. A spiral based LSB approach for hiding message in images was proposed by Mathkour Hassan et al. in [3]. They used LSB substitution technique to embed the watermark and order of insertion of watermark based on spiral substitution algorithm.

In the frequency domain techniques, the cover image is transformed into a frequency domain by a transform such as Discrete Cosine Transform (DCT) and Integer Wavelet Transom (IWT). Then, the transform coefficients of sub-bands with little sensibility to the human visual system (HVS) are modified to embed secret messages. According to survey, the known lossless data hiding (LDH) algorithms can be classified into two categories:

histogram rotation (HR)-based schemes and histogram distribution constrained (HDC) schemes.

HR-based schemes were proposed by De Vleeschouwer et al. in [4] that are deemed as the start of robust lossless data hiding. By using a circular interpretation of bijective transformations, their scheme can achieve reversibility and robustness against high quality JPEG compression. In [4] a host image is first divided into the non-overlapping blocks. Then, two zones, denoted as A and B, are chosen randomly from each block and their histograms are mapped into a circle. Vectors pointing from the center of the circle to the centers of the mass of zones A and B are rotated clockwise and anticlockwise, respectively. By controlling the direction of the rotation, a bit of watermark, ‘0’ or ‘1’, is embedded into the host image. In the data embedding process, one may encounter the overflow and underflow problem. To prevent the overflow and underflow of pixels, the modulo-256 operation is utilized which leads to ‘salt-and-pepper’ noise in the watermarked images.

Aiming to remedy this problem Zou [5], Ni [6], [7] deigned the HDC embedding schemes in the spatial and wavelet transform domain, respectively. HDC schemes embed the watermark by modifying the statistical characteristics of the cover image according to the histogram distribution of the image blocks. Ni et al. calculate the arithmetic average difference of each block; a bit 1 is embedded by shifting the arithmetic average difference value away from 0 by a shift quantity. If a bit 0 is to be embedded, this block remains unchanged. Zou et al. compute the integer wavelet transform of cover image. After calculating the mean value of the HL1 or LH1 block coefficients, a bit 1 is embedded by shifting the mean value away from 0 by a shift quantity. If a bit 0 is to be embedded, this block remains unchanged. To handle the overflow and underflow, some watermark bits are changed from ‘1’ to ‘0’. This intentional errors is corrected by the error correction coding (ECC) in the watermark extraction. Because of this, the capacity of HDC schemes is decreased considerably. Hui-Yu Huang [8] presented a lossless data-hiding approach based on quantized coefficients of discrete wavelet transform (DWT) in the frequency domain to embed secret message. They use the quantized coefficients for 9/7 wavelet filter in DWT and embed secret data into the successive zero coefficients of the medium-high frequency components. In, [9], Zhao et al. proposed a method in 2011 that exploited the technique of the multilevel histogram modification to generate an integer pointer called “embedding level” (EL) for indicating the embedding bin. First, the right bins of the pointer were shifted EL + 1 levels to the right, and the left bins of the pointer were shifted EL levels to the left to create the embedding space that used the hierarchical concept to embed secret data level by level. Therefore, a larger EL indicated that more secret data could be embedded. In the above histogram-shifting method, regardless of high partly capacity, this algorithm causes serious destruction in the image quality. So to provide a RRW framework with Reversibility, Robustness, and Invisibility is required.

II. PROPOSED WORK

Our proposed work has two steps: watermark Embedding and watermark Extraction.Fig.1. Shows steps for watermark embedding.

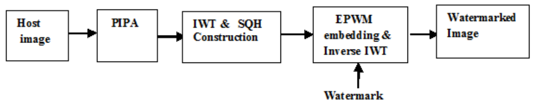

Fig.1. Watermark embedding.

2.1 Watermark embedding :

To embed watermark, steps shown in Fig.1 should be carried out.

2.1.1 PIPA (Property inspired Pixel Adjustment):

One of the problem in reversible watermarking is to avoid overflow and underflow of pixels. In some cases, the pixel values in a block are very close to the ends of histogram, such as 0 or 255 in the 8-bit case. The modification of the pixel values may lead to overflow and underflow problem, which means the modified pixel values are beyond the range of [0,255]. So preprocessing on the original image should be carried out. Pixel values should be adjusted.

Given a t-bit host image I with the size of 2M ×2N, the pixel adjustment is performed using,

$$I' = \begin{cases} I(i,j) - \eta & \text{if } I(i,j) > 2t - 1 - \eta \\ I(i,j) + \eta & \text{if } I(i,j) < \eta \end{cases} \quad (1)$$

Where-

$\eta > \lambda$ is the adjustment scale.

I (i, j) is the grayscale value of the pixel at (i, j) in the image I

I'(i, j) is the adjusted one ($1 \le i \le 2M$, $1 \le j \le 2N$)

To make a scheme non-blind to some extent the locations of the changed pixels need to be saved as a part of side information and transmitted to the receiver side in order to recover the original grayscale values of pixels. Location map with the same size as host image is used to mark the changed pixels position as,

$$\text{Location map} = \begin{cases} 1; & \text{changed pixel} \\ 0; & \text{no changed pixel} \end{cases} \quad (2)$$

2.1.2 IWT and SQH Construction:

IWT (Integer to Integer Wavelet Transform) is used. The integer wavelet transform maps integers to integers, and allows for perfect invertibility with finite precision arithmetic. Cohen et al. [12] proposed a novel technique named lifting scheme to construct fast and concise transform steps for wavelet transform. From then on, lifting scheme has been received more and more attention as it can offer not only fast transform, but "you can construct your owner wavelet in home". Theoretically, lifting scheme is designed based on matrix algebra theory and phase filter bank theory such as perfect reconstructed filter bank theory. Lifting scheme includes three steps

1. Splitting
2. Prediction
3. Update

It has turned out that every wavelet can be decomposed into lifting steps. The number of lifting steps is bounded by the length of the original filters.

In [10] GSQH driven method used SQH has its pros and cons. On one hand, it combines GSQH and histogram shifting together to obtain good performance. On the other hand, however, it has three shortcomings: 1) it uses the AADs of all of the blocks, both reliable and unreliable, to generate the SQH of the host image, which increases complexity of watermark embedding; 2) it fails to consider the optimization of watermark strength; and 3) it suffers from unstable robust- ness against JPEG compression.

So here we are combining PIPA, SQH shifting, clustering, and EPWM into a novel RRW framework, which effectively overcomes the above shortcomings and makes our work intrinsically different from existing RRW methods. SQH (statistical quantity histogram) with threshold constraint is used to embed the watermark. The watermark embedding is done by shifting the histogram in both the direction, which gives superior robustness also makes watermark embedding and extraction process simple. In this method MWC (mean of wavelet coefficients) histogram is generated. We focus on the mean of wavelet coefficients (MWC) histogram by taking the following two properties into account: 1) it is designed in high-pass sub-bands of wavelet decomposition, to which HVS is less sensitive, leading to high invisibility of watermarked images and 2) it has almost a zero-mean and Laplacian-like distribution

Let $S = [S1 . . . Sk, . . . , Sn]$ be the MWCs in the sub-band, then the MWC of the kth block, Sk, is defined as,

$$Sk = \frac{1}{(h-2)*(w-2)} \sum_{i=2}^{h-1} \sum_{j=2}^{w-1} pk(i,j) \quad (3)$$

Where, $P_k(i, j)$ - represents the wavelet coefficient at (i, j) in the kth block, and h x w- size of blocks of HL sub-band of 5/3 IWT image.

To construct the MWC histogram, our concern is the possibility of utilizing the blocks of interest in a sub-band, which will be helpful for simplifying the embedding process. In view of the histogram distribution of MWC, only the peak and its neighbours in the histogram are mostly useful for the embedding task. Therefore, a threshold constraint is applied to the blocks to retain those of interest, each of which satisfies the following condition,

$$d(x, Sk) \le \delta, \ 1 \le k \le n \quad (4)$$

where $d(\cdot)$ computes the Euclidean distance of two elements, $x \in \{xl, xr\}$ represents the aforementioned two peak points, and δ is a predefined constant for threshold control. When $\delta \ge \max\{d(xl, \min(S)), d(xr, \max(S))\}$, all of the blocks will be retained for embedding, which is a special case of this constraint.

2.1.3 Enhanced Pixel-Wise Masking (EPWM):

The past years have witnessed the significance of HVS in various applications [13], [14] and many visual masking algorithms revealing the perceptual characteristics of HVS have been applied to digital watermarking [15]–[17]. In particular, a PWM algorithm proposed by Barni et al. [18] has received much publicity, which computes the JND threshold of each wavelet coefficient based on resolution sensitivity, brightness sensitivity, and texture sensitivity. However, it is not precise enough because the low-pass sub-band at the forth resolution level, has less image content, which ends up with the approximate estimation of texture and brightness.

To solve this problem, we design the EPWM to better depict local sensitivity of HVS, which not only improves texture and brightness sensitivities but also optimizes the sensitivity weight. To effectively balance robustness and invisibility, the local sensitivity of human visual system (HVS) in wavelet domain is considered in the design of an EPWM. Lingling An et.al. [19]. It evaluates the just noticeable distortion (JND) thresholds in terms of texture, brightness and resolution of wavelet coefficients, which thereafter are used to optimize watermark strength (λ). JND threshold can be obtained by,

$$JND_p^w(i,j) = \Theta(\omega)\Psi(p,i,j)\Pi(p,i,j)^{0.2} \quad (5)$$

Where- $\Theta(\omega)$ – Resolution sensitivity can be defined by,

$$\Theta(\omega) = \begin{cases} \sqrt{2} & \omega = HH \\ 1, & otherwise \end{cases} \quad (6)$$

$\Psi(p,i,j)$- Brightness sensitivity can be defined by using [17],

$$\Psi(p,i,j) = max\left\{f_v^{\rho}\left(\iota_b^{\rho}(i,j)\right), f_s^{\rho}\left(\iota_b^{\rho}(i,j)\right), \left(\iota_b^{\rho}(i,j)\right)\right\} \quad (7)$$

$\Pi(p,i,j)^{0.2}$ - Texture sensitivity can be defined by using [18],

$$\Pi(p,i,j) = \sum_{k=0}^{3-p} \sum_{\omega(LH,HL,HH)} \sum_{x=0}^{1} \sum_{y=0}^{1} \left[c_{k+p}^{\omega}\left(y + \frac{i}{2^k}, x + \frac{j}{2^k}\right)\right]^2 X \frac{1}{\gamma_\rho^{-3}} \gamma_\rho^3(i,j) \quad (8)$$

Where, γ_ρ^{-3} is mean of the approximation sub-image γ_ρ^3.

2.2 Algorithm for watermark Embedding

By using above modules watermark can be embedded or extracted using following procedures,

Watermark Embedding Algorithm

Input: A t-bit host image I with the size of $2M \times 2N$, a watermark sequence $b = [b1, . . . , bm]$, and block size $h \times w$.

Output: The watermarked image Iw.

1. Apply Pixel Adjustment Strategy to host image I to obtain the adjusted image I', and record the locations of the pixels changed by this processing and construct location map.
2. Decompose I' using 5/3 IWT and divide the sub-band C_0^{HL} into n nonoverlapping blocks with the size of $h \times w$;
3. Compute the MWCs of all of the blocks and obtain $S = [S_1, . . . , S_k, . . . , S_n]$;
4. Retain blocks of interest with the threshold constraint and construct SQH;
5. Perform EPWM to compute the watermark strength
$$\lambda = \frac{\alpha}{M \times N} \sum_{i=1}^{m} \sum_{j=1}^{n} jnd_p^W(i,j)$$
6. For $k = 1$ to m do
7. Embed the kth watermark bit b_k with $s_k^W = s_k + \beta\lambda b_k$;
8. End for
9. Reconstruct the watermarked image I_w with inverse 5/3 IWT.

2.3 Watermark Extraction:

If watermarked images are transmitted through an ideal channel, we can directly adopt the inverse operation to recover host images and watermarks. If watermarked images are transmitted through channel, degradation may be imposed on watermarked images due to unintentional attacks, e.g. lossy compression and random noise. Therefore, it is essential to find an effective watermark extraction algorithm so that it can resist unintentional attacks in the lossy environment. To extract the embedded watermarks, the key issue is to partition these parts dynamically. In the lossy environment, this is very difficult because the histogram distribution of MWC is destroyed by unintentional attacks. By investigating the effects of unintentional attacks on histogram, we treat the partition as a clustering problem with a certain number of clusters and adopt the k-means clustering algorithm [21],[22] to tackle this problem for simplicity.

2.3.1 Classification Process for Watermark extraction:

Input to classification process are MWCs; and the number of clusters μ, and output will be the set of clusters
$g = \{g1, . . . , g\mu\}$.

1. Initialize the cluster centers $f_1^{(1)}, \ldots, f_\mu^{(1)}$, and iteration time ε;
2. Do
3. For $k = 1$ to m do
4. Assign the kth s_k^W to one of the clusters according to the distance between it and cluster centers:
$$s_k^W \in g\,j \text{ , if } d\,(s_k^W, f_j^{(\varepsilon)}) \leq d(s_k^W, f_l^{(\varepsilon)})$$
for all $l = 1, 2, . . . \mu$;
5. End for
6. Update the cluster centers with $f_j^{(\varepsilon+1)} = (1/|g_j^{(\varepsilon)}|).\sum_{s_k^W \in g_j^{(\varepsilon)}} s_k^W$
7. While
$$arg\ min_g \sum_{j=1}^{\mu} \sum_{s_k^W \in g_j^{(\varepsilon)}} \|s_k^W - f_j^{(\varepsilon+1)}\|^2$$

2.4 watermark extraction Algorithm

Input: watermarked image Iw with the size of $2M \times 2N$, block size $h \times w$, watermark strength λ and the location map.

Output: The recovered watermark sequence b_r and image I_r.

1. Decompose Iw using 5/3 IWT and divide the sub-band c_0^{HL} into n non-overlapping blocks with the size of $h \times w$;
2. Compute MWCs of blocks of interest with and obtain $S^w = [S_1^w, . . . , S_k^w, . . . , S_m^w]$;
3. Classify S^w with k-means clustering;
4. For $k = 1$ to m do
5. Extract the embedded watermarks
$$b_k^r = \begin{cases} 0, & if\ s_k^W \in \text{Class II} \\ 1, & if\ s_k^W \in \text{Class I or Class III} \end{cases} \quad \text{for } \mu = 3$$
6. Recover the MWCs with $s_k^r = s_k^W - \beta\lambda b_k^r$;
7. End for
8. Perform inverse IWT followed by PIPA to obtain the recovered image I^r.
9. Return the recovered watermarks b^r and image I^r.

III. EXPERIMENTAL RESULTS

These algorithms are tested on three types of images, natural, medical and SAR images. As we see,in fig.2 and fig.3.Original image and watermarked image are same, so it fulfill the invisibility property. Also we tested proposed method under different attacks, such as jpeg compression, rotation and salt and pepper noise, and is proved robust against unintentional attacks. Watermarked image quality is tested by using MSE and PSNR.As shown in fig.4 and fig.5 if we increase threshold value, more blocks will be selected and PSNR will decrease and MSE will increase. Fig.6 and fig.7shows effect of block size on output image quality.

Fig.2 Original image

Fig.3. Watermarked image

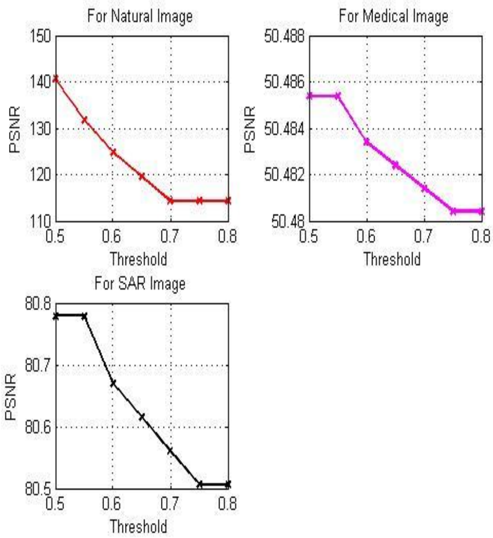

Fig.4. Effect of threshold values on PSNR of different kind of images.

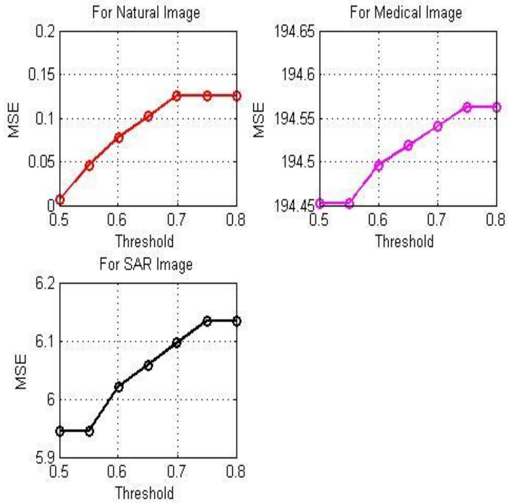

Fig.5. Effect of threshold values on PSNR of different kind of images.

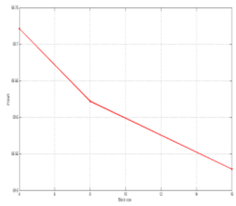

Fig.6. Effect of Block size on PSNR.

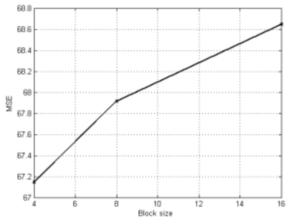

Fig.7. Effect of Block size on PSNR.

IV. CONCLUSION

In proposed scheme Integer Wavelet Transform (IWT) is used so it can reconstruct the original image without any distortion. EPWM provides invisibility and robustness for the robust and lossless watermark embedding. Thus this method provides enhanced performance in terms of reversibility, robustness, invisibility, capacity and run-time complexity. It is readily applicable to different kinds of images. In future, we will add security to the watermark by scrambling it.

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