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Robust Reversible Watermarking using Zero Mean Spreading Code

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ABSTRACT
Digital watermarking has been widely used to protect the copyright of digital images. Robust Reversible Watermarking (RRW) methods are popular in multimedia for the protection of data and providing robustness against unintentional attacks. This project presents a novel pragmatic framework, Wavelet-Domain Statistical Quantity Histogram Shifting and Clustering (WSQH-SC). WSQH-SC constructs a new watermark embedding and extraction procedures by histogram shifting and clustering, which are important for improving robustness and reducing run-time complexity. This proposes an image preprocessing method called Property Inspired Pixel Adjustment (PIPA). PIPA can effectively handle the overflow and underflow of pixels. For more security, zero mean spreading code is used before encryption. Furthermore, to increase the resolution with the reduction of data loss a single image super resolution method is used. This can be done by nearest embedding algorithm. So that, the secret input data is embedding only in the high resolution patches of the input image. K-means clustering algorithm is used to recover the watermarks by modeling the extraction process as a classification problem. Here the three parameters, such as Peak Signal to Noise Ratio(PSNR),Bit Error Rate(BER) and embedding capacity are estimated for the performance evaluation.

KEYWORDS: *Enhanced Pixel-Wise Masking (EPWM), Integer Wavelet Transform(IWT), Just Noticeable Distortion(JND), Statistical Quality Histogram(SQH),Mean of Wavelet Coefficients(MWC)*

I. INTRODUCTION

Digital image processing is the use of computer algorithms to perform image processing on digital images. As a subcategory or field of digital signal processing, digital image processing has manyadvantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing. Since images are defined over two dimensions (perhaps more) digital image processing may be modeled in the form of multidimensional systems. The embedding module inserts in a set of secondary data, which is referred to as embedded data, to obtain the marked media. The insertion or most embedding is done such that is perceptually identical. In cases, the embedded data is a collection of bits, which may come from an encoded character string, from a pattern, or from some executable agents, depending on the application.

The embedded data will be extracted from the marked media by a detector, often after has gone through various processing and attacks. Applications such as ownership protection, fingerprinting, and access control, accurate decoding of hidden data from distorted test media is preferred. In other applications such as authentication and annotation, robustness is not critical. Different types of watermarking domains are spatial domain and frequency domain. Spatial watermarking can be applied using color separation. In this way, the watermark appears in only one of the color bands. This renders the watermark visibly subtle such that it is difficult to detect under regular viewing. However, the mark appears immediately when the colors are separated for printing. This renders the document useless for the printer unless the watermark can be removed from the color band. Watermarking can be applied in the frequency domain (and other transform domains) by first applying a transform like the Fast Fourier Transform (FFT). Since high frequencies will be lost by compression or scaling, the watermark signal is applied to lower frequencies, or better yet, applied adaptively to frequencies that contain important information of the original picture.

Recently, a number of histogram-based methods have been proposed, and classified as grayscale histogram (GH) based and statistical quantity histogram (SQH) based ones. Although the GH based methods have achieved the advantages, e.g., low computational complexity and high visual quality, they fail to consider the diversity of grayscale histograms for various images. This makes their performance unstable. To overcome the limitations SQH based methods explored.

The focus of this paper is on finding high-resolution patches with the help of a set of one or more high resolution images. This is refer to as the single image super resolution problem. The single image super resolution problem arises in a number of real world applications. Zero mean spreading code is a spreading technique, which will spread the watermark bit before insertion to an input image and mistaken for noise, such that it goes undetected by an intruder. So it will provide secure communication system. Spreading of watermark [16] can be done by converting to antipodal bits and adding more bits in the watermark bits until it satisfies zero mean condition. The added number of bits should be stored as side information. This algorithm is very flexible and watermark can be added at wide range of PSNR values. This scheme is very robust even if watermark is added at high PSNR value. So, it can be used as irreversible watermarking algorithm for normal distribution of images in less sensitive applications

II. RELATED WORKS

Recently, a lot of RRW methods for digital images have been proposed [1],[2], which can be classified into two groups : histogram rotation (HR)-based methods and histogram distribution constrained (HDC) methods. The HR-based methods [3] accomplish robust lossless embedding by slightly rotating the centroid vectors of two random zones in the nonoverlapping blocks. Due to the close correlation of neighboring pixels, these methods were reported to be robust against JPEG compression. However, they are sensitive to “salt-and-pepper” noise. To solve this problem, the HDC methods have been developed in spatialand wavelet-domains , which divide image blocks into different types and embed the modulated watermarks for each type based on histogram distribution. Unfortunately, these methods suffer from unstable reversibility and robustness. In summary, the above analysis shows that both kinds of RRW methods are not readily applicable in practice.

Histogram based Lossless Data Embedding (LDE) is an effective method for copyright protection. This data embedding method uses arithmetic average of difference histogram(AADH) to stable the performance of LDE. Experimental results demonstrated that this method produce good performance and capacity. But it performs based on assumptions, i.e., the peak points in AADH are -1 and 0,that will lead to gap between itTo further improve the performance of LDE ,a Generlized Statistical Quantity Histogram(GSQH)[4] based method has been introduced. It is a watermark embedding and extraction process based on histogram shifting and clustering.

Histogram plays an important role in digital watermarking. In which the statistical quantity histogram (SQH) of each non overlapping blocks can be generated using arithmetic average of difference method. The experimental results indicate that it provides good performance by combining both GSQH and histogram shifting. This method has drawbacks: 1)it increases the complexity of the watermark embedding; 2)it fails to optimize the watermark strength; 3)it suffers from poor robustness against JPEG compression.

A technique that embeds the watermark into perceptually significant wavelet coefficients using pixel wise masking. The watermark is embedded repeatedly into the detail subbands, thus increasing the robustness of the method. A PWM [5] algorithm proposed by Barni et al has became popular, which computes the JND threshold value[7] of each wavelet coefficient. JND calculation combines three human visual system(HVS) characteristics. They are brightness sensitivity, textual sensitivity and resolution sensitivity. But the estimation of texture and brightness sensitivity is approximate because the low pass subband at the fourth resolution level,i.e., C_3^{LL} , has less image content.

III. PROPOSED FRAMEWORK

In this section ,an alternative method for GSQH presents, i.e.,WSQH-SC. It constructs a new watermark embedding and extraction method by histogram shifting and clustering. To effectively handle the over flow and under flow of pixels, WSQH-SC include property inspired pixel adjustment (PIPA). It will determine the change of wavelet coefficients during the embedding process.

By incorporating these details, PIPA preprocess the input image. Before embedding, the watermark bit is going to spread using zero mean spreading code. The spreaded watermark bit is going to embed only in high resolution patches of the input image. That is because the eyes are less sensitive to noise in high resolution bands and in those bands having orientation of 45°. Neighbor embedding algorithm is using to find out the high resolution patches to embed. For that a high resolution reference image is taking as the training set. Extraction is based on k-means clustering.

3.1 Pixel Adjustment

Input image is a t-bit gray scale image I with the size of M×N. Performing PIPA to effectively handle the overflow and underflow of the input image. I'(i, j) is the adjusted one.

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

where *I (i, j)* is the grayscale value of the pixel at *(i, j)* in the image *I* , *η > λ* is the adjustment scale. PIPA can effectively avoid both overflow and underflow of pixels. It is a non-blind methode because the locations of the changed pixels need to be saved as a side information and transmitted to the receiver side to recover the original image.

3.2 Zero Mean Spreading Code

Every watermark bit is spread using a zero mean spreading code before insertion. Spreaded watermark is arithmetically added to wavelet coefficients. Let *W* be the watermark bit consisting of zeros and ones.

$$w = [w_1, w_2, ..., w_n]$$

The watermark bit is then converted to antipodal bits. It will get spreaded by adding +1 and -1 until it satisfies the condition

$$b_i \in \{-1, 1\}$$

'b_i' is the spreaded watermark bit and it should have zero mean.

$$b_i = [b_1, b_2, ..., b_k, .., b_l]$$

$$\sum_{i=0}^{l} b_i = 0$$

The number of added +1 and -1will get stored as a key value and send it to the receiver section as side information.

3.3 MWC generation

An integer wavelet transform is applied in order to decompose adjusted image into different subbands. This subbands are then divided into n nonoverlapping blocks of size h×w. In order to increase the resolution of the watermarked image, a high resolution reference image took as a training data set. This reference image consists of high resolution patches, that are needed at the construction of high resolution patches in the input image.

Next is to find out the mean wavelet coefficient of each nonoverlapping blocks. So consider the SQH construction[8] task with a threshold constraint. The Mean of Wavelet Coefficients (MWC) histogram having the property,i.e., it is designed in high-pass sub-bands of wavelet decomposition. It can decompose I using IWT to obtain the sub-bands, and then divide into n nonoverlapping blocks. Let S = [S_1,.,S_k,.,S_n] be the MWCs in the sub-band.S_k is thye MWC of k[th] block.

$$s_k = \frac{1}{(h-2)\times(w-2)} \sum_{i=2}^{h-1} \sum_{j=2}^{w-1} P_k^{(i,j)}$$

Where, $P_K^{(i.j)}$ represents the k[th] block's wavelet coefficient at (i, j). This will simplify the embedding process. Only the peak and its neighbors in the histogram are mostly consider for the embedding task. Therefore, a threshold constraint is applied to the blocks, in which each blocks satisfies the following condition

$$d(x, S_k) \leq \delta, \ 1 \leq k \leq n$$

where d (·) computes the Euclidean distance of two elements, represents the two peak points, and δ is a predefined constant for threshold control. The capacity can be controlled with the help of threshold constraint.

To find the high resolution patches in the input image, taking a high resolution image as a reference image[6]. Apply both IWT, MWC and threshold constraint to the reference image. The watermark bit is going to embed only in high resolution patches of input image. For that the nearest neighbor algorithm is used between the input image and the reference image. The block with minimum difference can be find by the following equation.

$$S_K = \min \left\| s_k - r_k \right\|$$

where r_k is the MWC of the reference image. From the minimum difference the high resolution patches can be find out.

3.4 Embedding Process

To balance the invisibility and robustness an EPWM based embedding is proposed by utilizing the Just Noticeable Distortion (JND) thresholds of wavelet coefficients to optimize watermark strength. The watermark strength can be obtained by using the following method.

$$\lambda = \frac{\alpha}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} JND_{\rho}^{\omega}(i, j)$$

where, λ represents the watermark strength, α is a global parameter , M × N is the sub-band size and

$$JND_{\rho}^{\omega}(I, J) = \Theta(\omega)\psi(\rho, I, j)^{\upsilon}\, \Pi(\rho, i, j)^{0.2}$$

Here, $\Theta(\omega)$, $\psi(\rho, I, j)$ and $\Pi(\rho, i, j)$ evaluate resolution, brightness, and texture sensitivities, respectively After this embed the k^{th} watermark bit b_k with S_K using the following equation.

$$S_K^w = S_K + \beta\lambda b_k$$

Here S_K^w is the obtained MWC after the k^{th} watermark bit $b_k \in \{0,1\}$ is embedded. β is a factor defined as

$$\beta = (S_K - S^*) / abs(S_{*K} - S^*)$$

$$S^* = \arg\min_{x \in \{xl, xr\}} d(S_k - S^*)$$

Thereafter, the IWT reconstruction is performed to obtain the watermarked image.

3.5 Watermark Extraction

Extraction of watermark is based on k-means clustering. In order to extract the watermarked image, first decompose the image with IWT. To find out the high resolution patches, again find the minimum difference between the watermarked image and reference image. Then construct the MWC histogram by calculating the MWCs of blocks. Classify that with *k*-means clustering. Based on the results , the embedded watermarks can be extracted by

$$b_k^r = \begin{cases} 0, \text{ if } s_k^w \in \text{classII} \\ 1, \text{ if } s_k^w \in \text{classI/classIII} \end{cases}$$

In which s_k^w is the k^{th} MWC, b_k^r is the extracted watermark bit, and Classes I -III denote the set of clusters. Thereafter recover the MWCs with

$$S_K^r = S_K^w - \beta\lambda b_k^r$$

Then perform inverse IWT to obtain the recovered image. Extracted watermark is spread again using same spreading codes and subtracted from the wavelet coefficients of watermarked image. After all this procedure, the input image and the input string is obtained without any loss.

IV. EXPERIMENTAL RESULTS

The input image is shown in Fig 4.1.The input image should be in gray scale. PIPA is applied to the input image. Fig 4.2 shows the input high resolution reference image. Input reference image shown in Fig 4.2 contain high resolution patches. The Integer Wavelet Transform(IWT) subbands are shown in Fig 4.2.this is the simulation results after the integer wavelet transform process. IWT has been employed in order to preserve the high frequency components of the image by decomposing a frame into different subband images, namely Low-Low(LL), Low-High(LH), High-Low(HL) and High-High(HH).

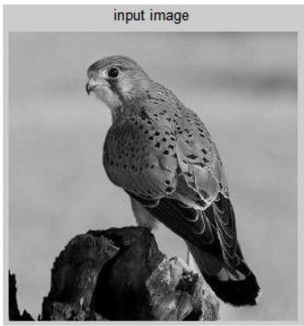

Fig 4.1 Input Gray Scale Image

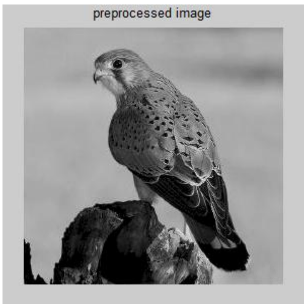

Fig 5.3 Preprocessed Image

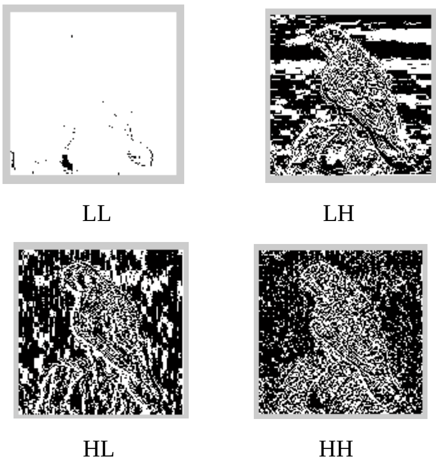

Fig 4.3 IWT Subband Images of Input Image

Color images cannot be processed using integer wavelet transform. But it is a strong transform for monochrome image processing. Since it is a wavelet, this will process on certain range of pixel values. Each image in the Fig 4.3 represent LL, LH, HL and HH respectively. This will get decomposed into n nonoverlapping blocks with size of h×w. Fig 4.4 represents the embedded image. To obtain high resolution patches for embedding, nearest neighboring algorithm is used. From that minimum difference between the high resolution patches obtained.

Fig 4.4 Embedded Image with Data

Fig 4.5 Reconstructed Image after Extraction

If watermarked images are transmitted through an ideal channel, the inverse operation can be performed to extract. However, in the real environment, degradation may be occurred. So the Extraction process is based on k-means clustering to reduce the unintentional attacks. Fig 4.6 shows the reconstructed image.

The three parameters calculated here are PSNR, Bit Error Rate (BER) and embedding capacity. Table 4.1and 4.2 shows the comparison result of EPWM and zero mean spreading code.

Sample images of size 256×256	PSNR(i/p-Watermarked image, in dB)	PSNR(i/p-Extracted image, in dB)	BER (bit per sec)	Embedding Capacity(in bits)
Input-1	32.2090	31.5396	0.0278	17,566
Input-2	32.5073	31.8378	0.0849	22,528
Input-3	31.9691	31.2997	0.0706	12,208
Input-4	32.1552	31.4858	0.0446	19,876

Table 4.1 Parameter Comparison (EPWM)

Table 4.2 Parameter Comparison (Zero Mean Spreading Code)

Sample images of size 256×256	PSNR(i/p-Watermarked image, in dB)	PSNR(i/p-Extracted image, in dB)	BER (bit per sec)	Embedding Capacity(in bits)
Input-1	42.2067	41.4368	0.0218	20,566
Input-2	43.5063	41.7657	0.0458	22,273
Input-3	38.9641	38.7688	0.0406	14,564
Input-4	42.1672	41.4658	0.0498	22,006

V. CONCLUSION AND FUTURE WORK

This project present a robust reversible watermarking method based on enhanced pixel-wise masking. In order to adjust overflow and underflow of the input image, PIPA technique is used and to reduce the embedding data loss, high resolution patches are used. To provide more security, watermark bit can be spreaded using zero mean spreading code before insertion. At the extraction part k-means clustering algorithm has been used to tackle the problems like unintentional attacks. When compared to the proposed method, a traditional method called GSQH (Generalized Statistical Quantity Histogram), which increases complexity of watermark embedding, fails to consider the optimization of watermark strength and it suffers from unstable robustness against JPEG compression. The experimental results demonstrate that the proposed method outperforms the representative baselines like comprehensive performance in terms of reversibility, robustness, invisibility, embedding capacity and run-time complexity. From the parameter comparisons, it can be seen that the efficiency of the proposed method is better than other existing methods. The proposed system provides robustness and reversibility in order obtain good results. In future the proposed system can be implement for additional data hiding by reserving room before encryption methode. Also, the extraction k-means clustering algorithm can be compared with other clustering techniques to verify their performance.

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