RESEARCH ARTICLE OPEN ACCESS

Digital Image Watermarking Based On Gradient Direction Quantization and Denoising Using Guided Image Filtering

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ABTRACT
Digital watermarking is the art of hiding of information or data in documents, where the embedded information or data can be extracted to resist copyright violation or to verify the uniqueness of a document which leads to security. Protecting the digital content has become a major issue for content owners and service providers. Watermarking using gradient direction quantization is based on the uniform quantization of the direction of gradient vectors, which is called gradient direction watermarking (GDWM). In GDWM, the watermark bits are embedded by quantizing the angles of significant gradient vectors at multiple wavelet scales. The proposed scheme has the advantages of increased invisibility and robustness to amplitude scaling effects. The DWT coefficients are modified to quantize the gradient direction based on the on the derived relationship between the changes in the coefficients and the change in the gradient direction. In this paper, we propose a novel explicit image filter called guided filter. It is derived from a local linear model that computes the filtering output using the content of guidance image, which can be the input image itself or any other different image. The guided filter naturally has a fast and non approximate linear time algorithm, regardless of the kernel size and the intensity range. Finally, we show simulation results of denoising method using guided image filtering over bilateral filtering.
Keywords: *Bilateral filter, Denoising, Digital watermarking, Gradient direction quantization,, Guided image filtering.*

I. INTRODUCTION

In general, watermarking approaches can be classified into two categories: spread spectrum (SS)-based watermarking and quantization-based watermarking. In SS type watermarking, a pseudorandom noise-like watermark is added to the host signal which has been shown to be robust to many types of attacks. Different types of optimum and locally optimum decoders have been proposed based on the distribution of the coefficients in the watermark domain. Many SS-based methods have been developed. Wang et al. used a key dependent randomly generated wavelet filter bank to embed the watermark. Lahouari et al. proposed a robust watermarking algorithm based on balanced multiwavelet transform. Bi et al. proposed a watermarking scheme based on multiband wavelet transform and empirical mode decomposition (MWT-EMD). In quantization watermarking, a set of features extracted from the host signal are quantized so that each watermark bit is represented by a quantized feature value. Kundur and Hatzinakos proposed a fragile watermarking approach for tamper proofing, where the watermark is embedded by quantizing the DWT coefficients. Chen and Wornell introduced quantization index modulation (QIM) as a class of data-hiding codes,

Which yields larger watermarking capacity than SS-based methods. Gonzalez and Balado proposed a quantized projection method that combines QIM and SS. Chen and Lin embedded the watermark by modulating the mean of a set of wavelet coefficients. Wang and Lin embedded the watermark by quantizing the super trees in the wavelet domain. Bao and Ma proposed a watermarking method by quantizing the singular values of the wavelet coefficients. Kalantari and Ahadi proposed a logarithmic quantization index modulation (LQIM) that leads to more robust and less perceptible watermarks than the conventional QIM.A QIM-based method, that employs quad-tree decomposition to find the visually significant image regions, has also been proposed. Quantization-based watermarking methods are fragile to amplitude scaling attacks. Such attacks do not usually degrade the quality of the attacked media but may severely increase the bit-error rate (BER).Ourique et al. proposed angle QIM (AQIM), where only the angle of a vector of image features is quantized. Embedding the watermark in the vector's angle makes the watermark robust to changes in the vector magnitude, such as amplitude scaling attacks. One promising feature for embedding the watermark using AQIM is the angle of the gradient vectors with large magnitudes, referred to as significant gradient vectors .In this paper , an image embedding scheme that embeds the watermark using uniform quantization of the direction of the significant gradient vectors obtained at multiple wavelet scales is proposed. Traditional redundant multistage gradient estimators, such as the multiscale Sobel estimator, have the problem of inter scale dependency. To avoid this problem, we employ DWT to estimate the gradient vectors at different scales. To quantize the gradient angle, we first derive the relationship between the gradient angle and the DWT coefficients. Thus, to embed the watermark bits, the gradient field that corresponds to each wavelet scale is obtained. This is illustrated in Fig.1

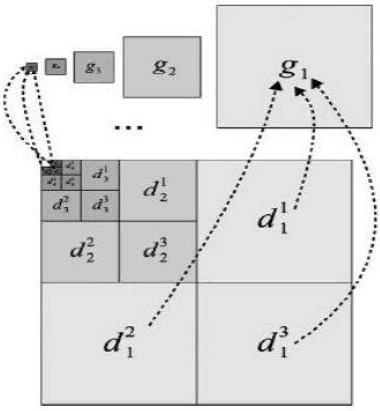

Fig. 1. Illustration of five-level gradient field, obtained from five-level wavelet decomposition.

Where each gradient vector g_j corresponds to the three wavelet coefficients d^1_j, d^2_j, and d^3_j. The straightforward way to embed the watermark bits is to partition the gradient fields into non overlapping blocks. Uniform vector scrambling increases the gradient magnitude entropy, and thus reduces the probability of finding two vectors with similar magnitudes in each block. Image Denoising is used in many applications such as object recognition, digital entertainment and remote sensing imaging. Most applications in computer vision and computer graphics involve image filtering to suppress and/or extract content in images. In this paper, the filtering output using guided filter is locally a linear transform of the guidance image. On one hand, the guided filter has good edge-preserving smoothing properties like the bilateral filter, but it does not suffer from the gradient reversal artifacts. Denoising of image is achieved using guided filter which is shown in simulation results.

II. PROPOSED WATERMARK EMBEDDING AND DECODING METHOD

Fig. 2 shows the block diagram of the proposed embedding scheme. The watermark is embedded by changing the value of the angle (the direction) of the gradient vectors. First, the 2-D DWT is applied to the image. At each scale, we obtain the gradient vectors in terms of the horizontal, vertical, and diagonal wavelet coefficients. To embed the watermark, the values of the DWT coefficients that correspond to the angles of the significant gradient vectors are changed. AQIM is an extension of the quantization index modulation (QIM) method. The *quantization function*, denoted by Q(θ), maps a real angle to a binary number as follows:

$$Q(\theta) = \begin{cases} 0, & \text{if } [\theta/\Delta] \text{ is even} \\ 1, & \text{if } [\theta/\Delta] \text{ is odd} \end{cases}$$

Where the positive real number Δ represents the *angular quantization step size* and [.] denotes the floor function, where the following rules are used to embed a watermark bit into an angle θ:

• If *Q(θ)= w*, then takes the value of the angle at the center of the sector it lies in.

• If *Q(θ) ≠ w*, then takes the value of the angle at the center of one of the two adjacent sectors, whichever is closer to θ.

These rules can be expressed as

$$\theta^w = \begin{cases} \Delta\lceil\theta/\Delta\rceil - \Delta/2, & \text{if } Q(\theta) = w \\ \Delta\lceil\theta/\Delta\rceil + \Delta/2, & \text{if } Q(\theta) \neq w \text{ and} \\ & \quad \theta > (\Delta\lceil\theta/\Delta\rceil - \Delta/2) \\ \Delta\lfloor\theta/\Delta\rfloor - \Delta/2, & \text{if } Q(\theta) \neq w \text{ and} \\ & \quad \theta \leq (\Delta\lceil\theta/\Delta\rceil - \Delta/2)\,. \end{cases}$$

However, it does not account for the angle discontinuity at θ=π. The discontinuity problem arises when the angle is close to. In the proposed watermarking method, as shown in, the change in each DWT coefficient is computed in terms of dθ. To address this angle discontinuity issue, we propose the absolute angle quantization index modulation (AAQIM). In AAQIM, instead of quantizing the value of the angle, its absolute value is quantized in the interval θ ϵ [0, π]. The watermark bits are decoded following the reverse encoding steps, as shown in Fig.3.At the transmitter side, each watermark bit is embedded into the BR most significant gradient vectors of each block. The watermark bit of the BR most significant vectors

and assign weights to the decoded watermark bits based on the following rules:
1) A watermark bit extracted from a large gradient vector should be given more weight than a bit extracted from a small gradient vector.

2) A watermark bit extracted from an angle close to a sector centroid should be given more weight than a bit extracted from an angle close to a sector boundary.

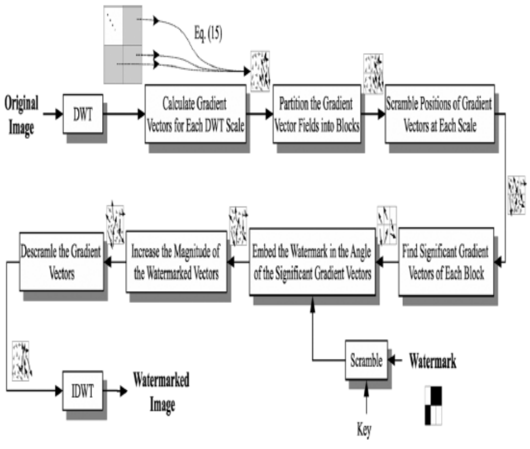

Fig. 2 Block diagram of the proposed watermark embedding scheme.

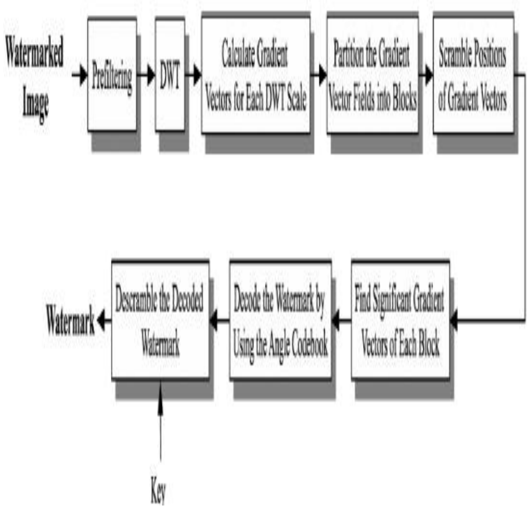

Fig.3. Block diagram of the proposed watermark decoding scheme.

III. BILATERAL VS GUIDED IMAGE DENOISING

A bilateral filter is a non-linear, edge-preserving and noise reducing smoothing filter for images. The intensity value at each pixel in an image is replaced by a weighted average of intensity values from nearby pixels. This weight can be based on a Gaussian distribution. On the other hand, the filtering output of guided filter is locally a linear transform of the guidance image. The guided filter has good edge-preserving smoothing properties like the bilateral filter, but it does not suffer from the gradient reversal artifacts. On the other hand, the guided filter can be used beyond smoothing: With the help of the guidance image, it can make the filtering output more structured and less smoothed than the input. Moreover, the guided filter naturally has an O(*N*) time (in the number of pixels *N*)non approximate algorithm for both gray-scale and high dimensional images, regardless of the kernel size and the intensity range. We first define a general linear translation-variant filtering process, which involves a guidance image I, a filtering input image *p*, and an output image *q*. Both I and *p* are given beforehand according to the application, and they can be identical. The filtering output at a pixel is expressed as a weighted average:

$$q_i = \sum_j W_{ij}(I) p_j, \qquad (1)$$

Where i and *j* are pixel indexes. The filter kernel *Wij* is a function of the guidance image I and independent of *p*. This filter is linear with respect to *p*.

Algorithm: Guided Filter.
Input: filtering input image *p*, guidance image *I*, radius *r*, regularization ϵ
Output: filtering output *q*.

1. $\text{mean}_I = f_{\text{mean}}(I)$, $\text{mean}_p = f_{\text{mean}}(p)$
   $\text{corr}_I = f_{\text{mean}}(I.*I)$, $\text{corr}_{Ip} = f_{\text{mean}}(I.*p)$
2. $\text{var}_I = \text{corr}_I - \text{mean}_I.*\text{mean}_I$
   $\text{cov}_{Ip} = \text{corr}_{Ip} - \text{mean}_I.*\text{mean}_p$
3. $a = \text{cov}_{Ip}./(\text{var}_I + \epsilon)$, $b = \text{mean}_p - a.*\text{mean}_I$
4. $\text{mean}_a = f_{\text{mean}}(a)$, $\text{mean}_b = f_{\text{mean}}(b)$
5. $q = \text{mean}_a.*I + \text{mean}_b$

The guided filter has good edge-preserving smoothing properties like the bilateral filter, but it does not suffer from the gradient reversal artifacts.

The guided filter can be used beyond smoothing: With the help of the guidance image, it can make the filtering output more structured and less smoothed than the input. The guided filter naturally has an O(N) time (in the number of pixels N) non approximate algorithm for both gray-scale and high dimensional images, regardless of the kernel size and the intensity range. This is one of the fastest edge preserving filters.

IV. SIMULATION RESULTS

The experimental results are simulated using MATLAB . A 512 x 512 Lena as the gray scale original host image and boat as watermark image with size 128 x 128 shown in Fig. 4 (a) and (b). The watermark is embedded by changing the value of the angle (the direction) of the gradient vectors. First, the 2-D DWT is applied to the host image. At each scale, we obtain the gradient vectors in terms of the horizontal, vertical, and diagonal wavelet coefficients. To embed the watermark, the values of the DWT coefficients that correspond to the angles of the significant gradient vectors are changed. The watermark can be embedded in the gradient direction. The watermarked image and Extracted watermark is shown in Fig.4 (c) and (d) respectively

(a) Original Image

(b) Watermark Image

(c) Watermarked Image

(d) Extracted Watermark

Fig. 4 (a) Original Image, (b) Watermark, (c) Watermarked Image (d) Extracted Watermark

We considered gradient direction quantization for watermarking with standard test images. For image denoising, Gaussian noise, Speckle noise,Salt & pepper noise and Localvar noises are added to the watermarked image. A main advantage of the guided filter over the bilateral filter is that it naturally has an O(N) time non approximate algorithm, independent ofthe window radius r and the intensity range. The filtering process in (1) is a translation-variant convolution. Its computational complexity increases when the kernel becomes larger. The main computational burden is the mean filter fmean with box windows of radius r. Following figures display a comparison of denoising when applying bilateral and guided image filtering on the watermarked Lena image. The guided filter denoising is shown to be more effective both visually as well as in PSNR.

Fig. 5 Localvar Denoised Images using Bilateral and Guided Filters

Fig . 6Gaussian Denoised Images using Bilateral and Guided Filters

Fig. 7 Speckle Denoised Images using Bilateral and Guided Filters

Fig. 8 Salt& Pepper Denoised Images using Bilateral and Guided Filters

Table 1:MSE & PSNR Calculations using bilateral and guided filters

Type Of The Image	Bilateral Filter		Guided Filter	
	MSE	PSNR	MSE	PSNR
Watermarked Image	0.00351	98.24	0.00351	98.24
Gaussian Noisy Image	0.0098	68.23	0.0098	68.23
Gaussian Denoisy Image	0.0037	72.48	0.0033	72.94
Speckle Noisy Image	0.0107	67.84	0.0107	67.84
Speckle Denoisy Image	0.0059	70.44	0.0033	72.93
Salt & Pepper Noisy Image	0.0145	66.51	0.0145	66.51
Salt & Pepper Denoisy Image	0.0143	66.57	0.0044	71.69
Localvar Noisy Image	0.0226	64.58	0.0226	64.58
Localvar Denoisy Image	0.0133	66.89	0.0047	71.43

Table 1 presents the comparison of MSE and PSNR between proposed Guided Filter with that of Bilateral Filter. The simulation results demonstrate that Guided filter denoised better than Bilateral Filter.

Table 2: Comparison of Correlation Coefficient between bilateral and guided filters

TYPE OF NOISE	CORRELATION COEFFICIENT	
	BILATERAL FILTER	GUIDED FILTER
GAUSSIAN	0.9476	0.9863
SPECKLE	0.9200	0.9854
SALT & PEPPER	0.8197	0.9795
LOCALVAR	0.8400	0.9713

Table 2 presents the comparison of Correlation Coefficient between Guided Filter and Bilateral Filter. By observing the simulation results the Guided filter gives better values than Bilateral Filter.

V. CONCLUSION

We present a gradient direction quantization-based watermarking scheme for Gray scale images. The proposed method embeds the watermark in the direction (angle) of significant gradient vectors, at multiple wavelet scales. To embed the watermark in each gradient angle, the absolute angle quantization index modulation (AAQIM) is proposed. To extract the watermark correctly, the decoder should be able to identify the gradient vectors that were watermarked and the embedding order .To solve these problems, we propose scrambling the positions of the gradient vectors uniformly over the wavelet transform of the image. Increasing the difference in the magnitude of the watermarked and the unwater marked vectors was also proposed to help identify the watermarked vectors correctly. From the above experimental results, it is clear that the proposed watermarking technique is efficient and also the guided filter is preferred for denoising. The guided filter is widely applicable in computer vision and graphics. Finally we observed that guided image filter is preferred for denoising compare to bilateral filter.

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