DIGITAL COLOR IMAGE WATERMARKING BASED ON GRADIENT DIRECTION QUANTIZATION AND DENOISING USING GUIDED IMAGE FILTERING

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Abstract: In this paper, watermarking based on the uniform quantization of the direction of gradient vectors is proposed which is called gradient direction watermarking(GDWM). In GDWM, the angles of significant gradient vectors are quantized to embed the watermark bits. The proposed scheme has the advantages of increased invisibility and robustness to amplitude scaling effects. To quantize the gradient direction, corresponding DWT coefficients are modified according to the relationship derived between gradient direction and the coefficients. And also, we propose an image filter called guided filter. It gives the filtered output using the 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, irrespective of size of the kernel and the intensity range. Finally, we show simulation results of denoising method using guided image filtering over bilateral filtering.

Index Terms: digital watermarking, gradient direction quantization, bilateral filter, guided image filtering.

I.INTRODUCTION

In general, we have two approaches in watermarking namely 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. In quantization watermarking, a set of required 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) which gives larger watermarking capacity compared to SS-based methods. Chen and Lin embedded the watermark by modulating the mean of a set of wavelet coefficients. 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 watermarks that are less perceptible than the conventional QIM. 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. Watermark embedding in the vector's angle makes the watermark robust to changes in the vector's magnitude. One promising feature for embedding the watermark using AQIM is the angle of the significant gradient vectors which are the gradient vectors with large magnitudes. Traditional redundant multistage gradient estimators like the multiscale Sobel estimator, have interscale dependency problem. To avoid this problem, we use DWT to obtain the gradient vectors at different scales. The relationship between the gradient angle and the DWT coefficients is derived first to quantize the gradient angle. Thus, to embed the watermark bits, the gradient field that for each wavelet scale is obtained. This is illustrated in Fig.1

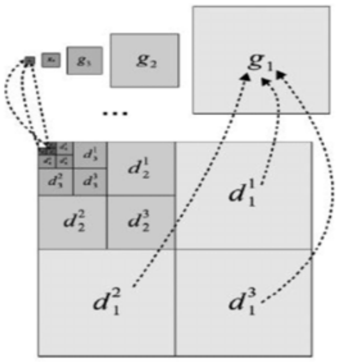


Fig. 1. Illustration of five-level gradient field, obtained from five-level wavelet decomposition.

where each gradient vector g_j corresponds to the three wavelet coefficients d^1_j, d^2_j, and d^3_j. The direct way to embed the watermark bits is to partition the gradient fields into nonoverlapping blocks. Uniform vector scrambling 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. In computer vision and computer graphics, most applications 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 other 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. First, the 2-D DWT is applied to the image. At each scale, we obtain the gradient vectors in terms of wavelet coefficients. To embed the watermark, the values of the DWT coefficients are changed that correspond to the angles of the significant gradient vectors. AQIM is an extension of the quantization index modulation(QIM) method. The *quantization function*, denoted by Q(θ), given by

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

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

- If $Q(\theta) = w$, it takes the value of the angle at the center of the sector it lies in.
- If $Q(\theta) \neq w$, it takes the value of the angle at the center of one of the two adjacent sectors, whichever is closer to.

Here we have discontinuity problem at θ=π, arises when the angle is close to. In the watermarking method proposed, the change in each DWT coefficient is given in terms of dθ. To avoid this angle discontinuity problem, we propose the absolute angle quantization index modulation (AAQIM). In AAQIM, instead of quantizing the angle value, its absolute value is quantized in the interval θ ϵ [0, π]. The watermark is extracted following the reverse steps as shown in Fig.3.

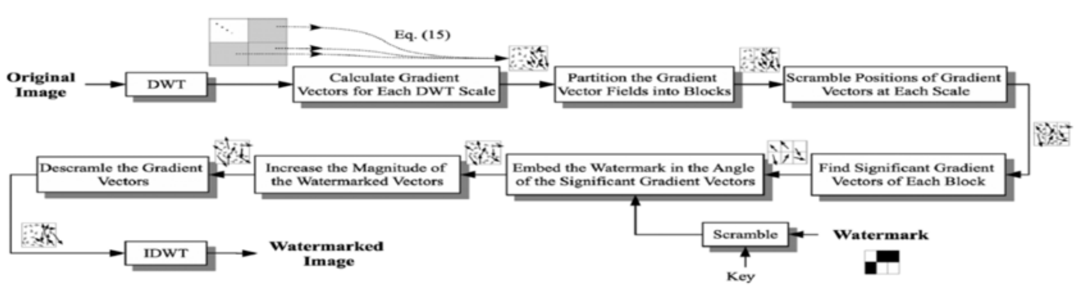


Fig. 2. Block diagram of the proposed watermark embedding scheme.

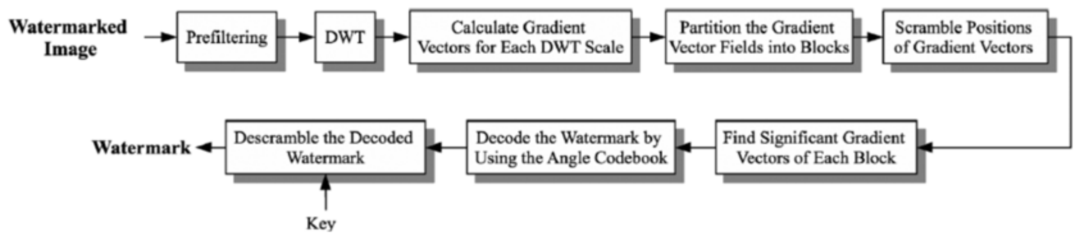


Fig.3. Block diagram of the proposed watermark decoding scheme.

III. BILATERAL VS GUIDED IMAGE DENOISING

A bilateral filter is a non-linear, edge-preserving and noise reducing smoothing filter for images. At each pixel in an image, the intensity value is replaced by a weighted average of intensity values from nearby pixels. This weight can be obtained from 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 is like the bilateral filter that has good edge-preserving smoothing properties, but it does not have the gradient reversal artifacts. The guided filter can be used beyond smoothing: By using the guidance image, it gives the filtering output more structured and less smoothed compared to the input. Also, the guided filter has an O(*N*) time (N is the number of pixels) non approximate algorithm for gray-scale and high dimensional images, regardless of the kernel size and the intensity range. We first define a linear translation-variant filtering process, which has a guidance image I, an input image *p*, and a filtering output image *q*. Both I and *p* are given according to the application, and they can be identical or different. The filtered output at a pixel *i* is expressed as a weighted average as follows:

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

where *i* and *j* are indexes for pixel. *Wij* is the filter kernel and a function of the guidance image I and is independent of input image *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. $mean_I = f_{mean}(I)$, $mean_p = f_{mean}(p)$
   $corr_I = f_{mean}(I.*I)$, $corr_{Ip} = f_{mean}(I.*p)$
2. $var_I = corr_I - mean_I.*mean_I$
   $cov_{Ip} = corr_{Ip} - mean_I.*mean_p$
3. $a = cov_{Ip}./(var_I + \epsilon)$, $b = mean_p - a.*mean_I$
4. $mean_a = f_{mean}(a)$, $mean_b = f_{mean}(b)$
5. $q = mean_a.*I + mean_b$

IV. SIMULATION RESULTS

(a) (b)

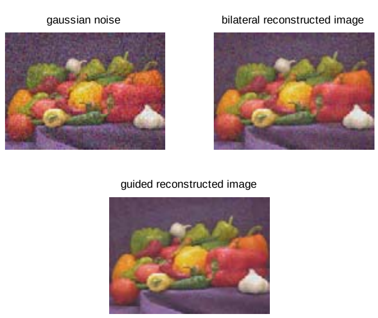
Fig. 4. (a) Original image (b) Watermark image

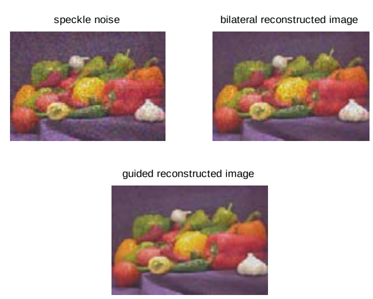
(c) (d)

Fig. 5. (c) Watermarked image (d) Extracted watermark

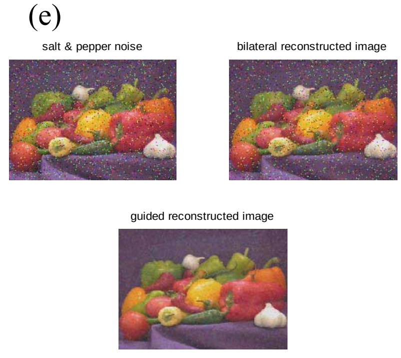
We considered gradient direction quantization for watermarking with standard test images. For image denoising, Gaussian noise, Speckle noise and Salt & Pepper noises are added to the watermarked image. A main advantage of the guided filter over the bilateral filter is that it naturally has an O(N) time non approximate algorithm which is independent of the intensity range and the window radius r. The filtering process given in equation (1) is a translation-variant convolution.

When the kernel becomes larger, its computational complexity increases. The main computational burden is the mean filter f_{mean} with box windows of radius r. Following figures display a comparison of denoising when applying bilateral and guided image filtering on the watermarked peppers image. The guided filter denoising is shown to be more effective both visually as well as in PSNR.





(e) (f)



(g)

Fig.6. (e) Gaussian Denoised Images using Bilateral and Guided, (f) Speckle Denoised Images using Bilateral and Guided, (g) Salt & Pepper Denoised Images using Bilateral and Guided.

V. TABLE I

MSE & PSNR Calculations of Watermarked Image

Type of the Image			Bilateral filtering		Guided image filtering	
	MSE	PSNR	MSE	PSNR	MSE	PSNR
Watermarked image	24.35	78.89	-	-	-	-
Gaussian noise	0.0168	65.88	0.0121	67.31	0.0077	69.245
Speckle	0.021	64.90	0.016	65.99	0.008	68.62
Salt & Pepper	0.022	64.66	0.021	64.79	0.0092	68.51

VI. CONCLUSION

We present a watermarking scheme based on gradient direction quantization for color images. The watermark is embedded in the direction(angle) of significant gradient vectors. The absolute angle quantization index modulation (AAQIM) was proposed to embed the watermark in each gradient angle. To extract the watermark correctly, the gradient vectors that were watermarked and the embedding order should be identified by the decoder .To overcome these problems, we propose scrambling the positions of gradient vectors uniformly over the wavelet transform of the image. To help identify the watermarked vectors correctly, increase in magnitude difference of the watermarked and unwatermarked vectors was also proposed. From the above results, it is clear that the proposed watermarking technique is efficient. And also, the guided filter proposed is widely applicable in computer vision and graphics. From the simulation results, we observed that guided image filter is preferred.

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