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Robust Digital Image Watermarking Based on Gradient Vector Quantization and Denoising using Bilateral Filter and its Method Noise Thresholding

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Abstract: Digital watermarking is a solution to the problem of copyright protection and authentication of multimedia data while working in a networked environment. We propose a robust quantization-based image watermarking scheme, called the gradient direction watermarking (GDWM), and based on the uniform quantization of the direction of gradient vectors. In GDWM, the watermark bits are embedded by quantizing the angles of significant gradient vectors at multiple wavelet scales. The proposed scheme has the following advantages: 1) Increased invisibility of the embedded watermark, 2) Robustness to amplitude scaling attacks, and 3) Increased watermarking capacity. To quantize the gradient direction, the DWT coefficients are modified based on the derived relationship between the changes in coefficients and the change in the gradient direction. This watermarking technique is more robust to various sizes of watermark images. The Gaussian filter is a local and linear filter that smoothens the whole image irrespective of its edges or details, whereas the bilateral filter is also a local but non-linear, considers both gray level similarities and geometric closeness of the neighboring pixels without smoothing edges. The extension of bilateral filter: multi-resolution bilateral filter, where bilateral filter is applied on approximation sub bands of an image decomposed and after each level of wavelet reconstruction. The application of bilateral filter on the approximation sub band results in loss of some image details, where as that after each level of wavelet reconstruction flattens the gray levels there by resulting in a cartoon-like appearance. To tackle these issues, it is proposed to use the blend of Bilateral and its method noise thresholding using wavelets. In various noise scenarios, the performance of proposed method is compared with bilateral denoising method and found that, proposed method has inferior performance.

Keywords: Bilateral, Bilateral and Detailed Thresholding, Denoising, Digital Watermarking, Gradient Direction Quantization, Robust.

1. INTRODUCTION

Watermarking approaches can generally be classified into two categories: Spread Spectrum (SS)-based watermarking and quantization-based watermarking. The SS type watermarking, adding a pseudorandom noise-like watermark into the host signal, has been shown to be robust to many types of attacks. Based on the distribution of the coefficients in the watermark domain, different types of optimum and locally optimum decoders have been proposed. Many SS based methods have been developed. In quantization watermarking, a set of features extracted from the host signal are quantised 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 [1].Chen and Wornell [2] 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 methods [3]. Chen and Lin [4] embedded the watermark by modulating the mean of a set of wavelet coefficients. Wan and Lin embedded the watermark by quantizing the super trees in wavelet domain [5]. Bao and Ma proposed a watermarking method by quantizing the singular values of the wavelet coefficients [6]. Kalantari and Ahadi proposed a logarithmic quantization index modulation (LQIM) [7] that leads to more robust and less perceptible watermarks than conventional QIM. Recently, a QIM-based method, that employs quad tree decomposition to find the visually significant image reasons, has 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 increased the bit error rate (BER). Ourique et al. Proposed Angle QIM (AQIM), where only the angle of a vector of image features is quantized [8]. Embedding the watermark in 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 gradient vectors which large magnitudes, referred to as significant gradient vectors. . This paper proposes an image embedding scheme that embeds the watermark using uniform quantization of the

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direction of the significant gradient vectors obtained at multiple wavelet scales. The proposed method has several advantages:1)by embedding the watermark in the direction of the gradient vectors (using angle quantization techniques),the watermark is rendered robust to amplitude scaling attacks 2)by embedding the watermark in the significant gradient vectors, the imperceptibility of the embedded watermark is increased, since the HVS is less sensitive to minor changes in edges and textured areas than in smooth region 3)by embedding the watermark at multiple scale, the watermarking capacity is enhanced. Traditional redundant multistage gradient estimators, such as multiscale sobel estimator have the problem of interscale dependency.

To avoid this problem, we employ DWT to estimate the gradient vectors at different scales. To quantize the gradient direction, we propose the absolute angle quantization index modulation (AAQIM). AAQIM solves the problem of angle discontinuity at θ = π by quantizing the absolute angle value. 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

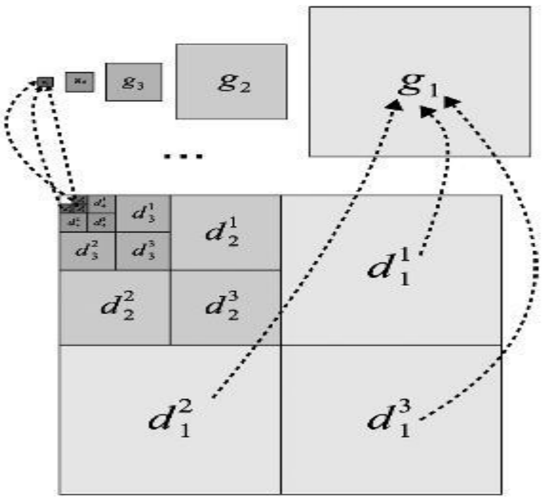

Fig.1. Illustration of five-level gradient field, obtained from five-level wavelet decomposition.

Where each gradient vector gj corresponds to the three wavelet coefficients dj^1, dj^2 and dj^3. The straight forward 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 to vectors with similar magnitudes in each block.

Image denoising is an important research area serving as the actual foundation for many applications, such as object recognition, digital entertainment, and remote sensing imaging. The simple spatial filtering of a corrupted image can be successful when high frequency noise is to be removed from the corrupted image. The main difficulty associated with this is, the computational complexity involved in performing the convolution. Various noises have been added to watermarked image and denoising of images was carried out using bilateral and its method noise thresholding.

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:

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

Where the positive real number represents the Angular Quantization step size and [.] denotes the floor function, where the following rules are used to embed a watermark into an angle θ.

- If Q (θ) =w, then takes the value of the angle at the centre of the sector it lies in.
- If Q (θ) ≠w, then takes the value of the angle at the centre of one of the two adjacent sectors whichever is closer to θ.

2. PROPOSED WATERMARK EMBEDDING 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. The watermarking can be embedded in the gradient magnitude and/or in the gradient direction. One disadvantage of the former option is the sensitivity of the watermark to amplitude scaling attacks. However, the second option, embedding the watermark in the gradient direction is robust to many types of attacks. The angles of the significant gradient vectors, however, remain almost unchanged.

The gradient directions form a robust feature of an image since their values are not easily changed unless the image quality is severely degraded. The above properties of the gradient direction make the inserting watermark both robust and imperceptible. We, therefore propose embedding in the directions of the significant gradient vectors of the image.

AQIM is one of the best methods for angle quantization. However, it does not account for the angle discontinuity at θ=π. The discontinuity problem arises when the angle is close to π. 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).

The watermark bits are decoded following the reverse encoding steps, as shown in fig.3.

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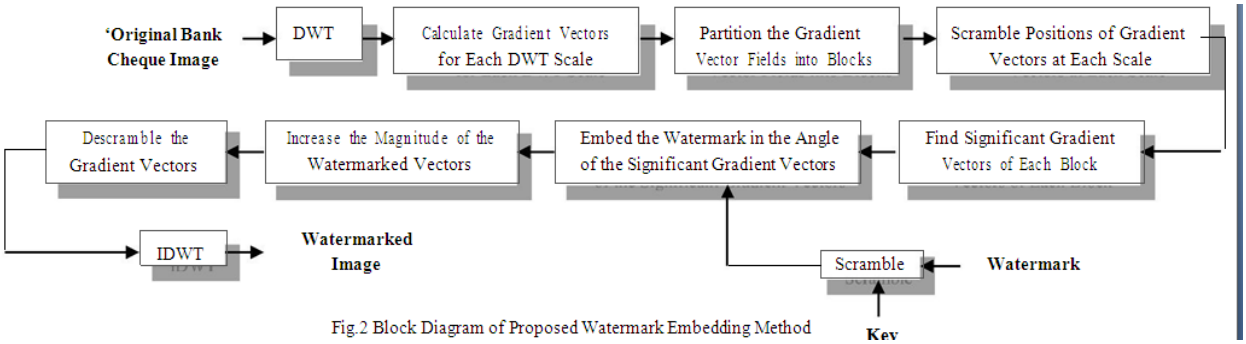

Fig.2 Block Diagram of Proposed Watermark Embedding Method

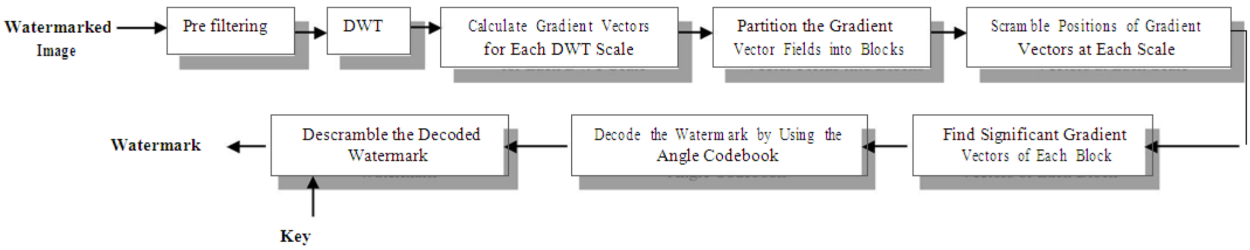

Fig.3. Block Diagram of Proposed Watermark Decoding Method

3. BILATERAL VS BILATERAL AND ITS METHOD NOISE THRESHOLDING

3.1 .Gaussian and bilateral filter

The goal of image denoising is to remove the noise while retaining the important image features like edges, details as much as possible. Filters based on Gaussian functions are of particular importance because their shapes are easily specified and both the forward and inverse Fourier transforms of a In AAQIM, instead of quantizing the values of the angle its absolute value is quantized. In the interval | θ |ε [0,π]. The absolute angle quantization function is defined as follows.

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

Gaussian function is real Gaussian function. Further if the frequency domain filter is narrower, the spatial domain filter will be wider which attenuates the low frequencies resulting in increased smoothing/blurring. These Gaussian filters are typical linear filters and that have been widely used for image denoising.

Gaussian filters assume that images have smooth spatial variations and pixels in a neighborhood have close values, by averaging the pixel values over a local neighborhood suppresses noise while preserving image features. However, this assumption fails at edges where the spatial variations are not smooth and the applications of Gaussian filter blurs the edges.

Bilateral filter overcomes this by filtering the image in both range and domain (space). Bilateral filtering is a local, nonlinear and non-iterative technique which considers both gray level (colour) similarities and geometric closeness of the neighboring pixel.

3.2. Gaussian/Bilateral filter and its method noise thresholding

The proposed scheme of image denoising uses the combination of Gaussian/bilateral filter and its method noise thresholding using wavelets and is shown in fig.4.

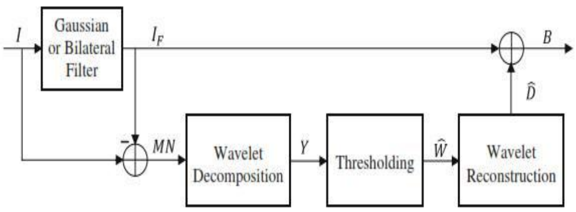

Fig.4. Proposed image denoising block diagram

A difference between the original image and its denoised image shows the noise removed by the algorithm, which is called as method noise. In principle, the method noise should look like a noise. Since even good quality images have some noise, it makes sense to evaluate any denoisy method in that way, without the traditional "add noise and then remove it" trick. Mathematically it is given by

$$MN = A - IF$$

Where A is original image (Noisy watermarked image) and IF the output of denoisy operator for is a input image A. The definition of method noise is redefined as the difference between the noisy image and its denoised image. Hence, the above equation can be rewritten as

$$MN = I - IF$$

Where, I=A+Z is a noisy image obtained by corrupting the original image A by a White Gaussian noise Z and IF is the output of Gaussian/bilateral filter for a input image I.

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The Gaussian/ Bilateral filter has removed the noise as well as image details by averaging the pixels; the method noise will consists of noise as well as image details along with some edges.

The method noise due to Gaussian filtering will have more strong edges as compared to that of bilateral filtering as the edges are preserved by range filtering. So, the method noise MN is a combination of image details D and a white Gaussian N and is written as

$$MN=D+Nw$$

The above equation can be rewritten as Y=W + Nw

Where Y is noisy wavelet coefficient (method noise), W is true wavelet coefficient (Detail image) and Nw is independent Gaussian noise.

In wavelet domain, the goal is to estimate the true wavelet coefficient W from Y by thresholding Y with a proper value of threshold which minimizes MSE so that it can retain the original image features and edges/ sharp boundaries very well in the final denoised image. The estimate of the true wavelet coefficient is represented as W^ and its wavelet reconstruction gives an estimate of detail image D^. The summation of this detail image D^ with the Gaussian/ Bilateral filtered image IF will give the denoised image B, certainly have more image details and edges as compared with Gaussian / Bilateral filtered image IF.

4. EXPERIMENTAL RESULTS

The experimental results are simulated using MATLAB.A 512 x 512 Lena as gray scale original host image and Boat as watermarked image as shown in Fig a. and b. Different noise is added to watermark image like Gaussian, speckle, Poisson and AWGN. For different sizes of watermark images, MSE and PSNR values are displayed in TABLE 1, 2, and 3.

Table 1: MSE and PSNR of watermark size: 16*16

TYPE OF THE IMAGE	MSE	PSNR
Watermarked image	229.5541	56.4639
Gaussian noisy image	39.4881	74.0653
Gaussian denoisy image(b)	11.5448	86.3629
Gaussian denoisy Image(BFMT)	8.7732	89.1082
Speckle noisy image	21.4996	80.1449
Speckle denoisy image(B)	8.8062	89.0707
Speckle Denoisy Image (BFMT)	10.4776	87.3326
Poisson Noisy Image	25.7467	78.3422
Poisson Denoisy Image(B)	9.9872	87.8122
Poisson Denoisy Image(BFMT)	7.8601	90.2072
AWGN Image	82.9504	66.6428
AWG Denoisy Image(B)	17.7402	82.0669
AWG Denoisy Image(BFMT)	17.5314	82.1853

The results reveal that the MSE and PSNR values are almost same for various sizes of watermark image. The simulation results demonstrate that the proposed method yields superior robustness in comparison with other watermarking methods.

Table 2: MSE and PSNR of Watermark Size: 32*32

Type of the image	MSE	PSNR
Watermarked image	229.5787	56.4628
Gaussian noisy image	39.4881	74.0653
Gaussian denoisy image(B)	11.5365	86.3701
Gaussian denoisy Image(BFMT)	8.7743	89.1070
Speckle noisy image	21.3264	80.2258
Speckle denoisy image(B)	9.0857	88.7583
Speckle denoisy image(BFMT)	10.4501	87.3591
Poisson noisy image	25.7034	78.3590
Poisson denoisy image(B)	10.2455	87.5569
Poisson denoisy image(BFMT)	7.9544	90.0880
AWGN image	82.9397	66.6441
AWG denoisy image(B)	17.8203	82.0219
AWG Denoisy Image(BFMT)	17.5432	82.1786

Table 3: MSE and PSNR of Watermark Size: 64*64

Type of the Image	MSE	PSNR
Watermarked Image	229.5690	56.4632
Gaussian Noisy Image	39.4881	74.0653
Gaussian denoisy Image(B)	11.5503	86.3581
Gaussian denoisy Image(BFMT)	8.7926	89.0862
Speckle Noisy Image	21.2446	80.0862
Speckle Denoisy Image(B)	8.8171	89.0583
Speckle Denoisy Image (BFMT)	10.5878	87.2283
Poisson Noisy Image	25.7118	78.3558
Poisson Denoisy Image(B)	10.0800	87.7198
Poisson Denoisy Image(BFMT)	8.0647	89.9503
AWGN Image	82.9504	66.6428
AWG Denoisy Image(B)	17.7416	82.0661
AWG Denoisy Image(BFMT)	17.5084	82.1984


Fig. a. Original Image


Fig. b. Watermark


Fig. c. Watermarked Image


Fig. d. Extracted Watermark


Fig. e. Gaussian noisy image


Fig. h. Speckle noisy image


Fig. f. Gaussian Bilateral denoisy image


Fig. i. Speckle Bilateral denoisy image


Fig. g. Gaussian BFMT denoisy image


Fig. j. Speckle BFMT denoisy image


Fig. k. Poisson noisy image


Fig. n. AWG noisy image


Fig. l. Poisson Bilateral denoisy image


Fig. o. AWG Bilateral denoisy image


Fig. m. Poisson BFMT denoisy image


Fig. p. AWG BFMT denoisy image

Fig.5.Simulation Results of watermark size 64*64

5. CONCLUSION

We present a gradient direction quantization-based watermarking scheme. The proposed method embeds the watermark in the direction (angle) of significant gradient vectors at multiple wavelet scales. To embed the watermark in the gradient direction, we find the gradient vector interms of the wavelet coefficients in sub bands LH,HL and HH. The gradient angle is then quantized by modifying the DWT coefficients that correspond to the gradient vector. 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 this problem, 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 unwatermarked vectors was also proposed to help identify the watermarked vectors correctly. From the above simulation results we observe that this watermarking technique is more robust to various sizes of watermark images. The performance of the proposed method Bilateral and its method noise thresholding (BFMT) is compared with Bilateral filter (BF). From the above simulation results BFMT denoisy technique is preferred.

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BIOGRAPHIES

I.KULLAYAMMA received graduation degree from JNTU Anantapur in the year 1996.She received her post graduation degree from JNTU in the year 2006. She is pursuing her Ph.D degree in the Department of ECE ,SVUCE, Tirupati in the Image Processing worked as Lecturer at SPW Tirupati from 1998 to 2007 and domain. Her Polytechnic, presently she is as Assistant professor at SVUCE Tirupati.

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