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A Robust Image Watermarking Based On Gradient VectorQuantization and Denoising Using Contourlet Transform

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ABTRACT

We propose a robust quantization-based image watermarking scheme, called the gradient direction watermarking (GDWM).This is 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 because the watermark is embedded in significant gradient vectors, 2) robustness to amplitude scaling attacks because the watermark is embedded in the angles of the gradient vectors, and 3) increased watermarking capacity as the scheme uses multiple-scale embedding.. This watermarking technique is more Robust tovarious sizes of watermark Images.we construct a discrete-domain multiresolution and multidirectional expansion using non-separable filter banks, in much the same way that wavelets were derived from filter banks. This construction results in a flexible mutiresolution, local, and directional image expansion using contour segments, and thus it is named the contourlettransform. The discrete contourlet transform has a fast iterated filter bank algorithm that requires order N operations for N-pixel images. Finally, we show simulation results using contourlet denoising method over wavelet.

Keywords—ContourletTransform ,denoising, digital watermarking,gradientdirection quantization, wavelets.

I. INTRODUCTION

Watermarkingapproaches can generally be classified into two categories: spread spectrum (SS)-based watermarking andquantization - 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 quantized so that each watermark bit is represented by a quantized feature value. Kundur and Hatzinakos proposed a fragile watermarking approach for the DWT coefficients [1]. Chen and Wornell[2] introducedtamper proofing, where the watermark is embedded by quantizing *quantizationindexmodulation*(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[3] . Chen and Lin [4] 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 thewavelet 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 the conventional QIM. Recently, a QIM-based method, that employs quad-tree decomposition to find the visually significant image regions, 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 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[8].. 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*.This paper proposes an image embedding scheme that embeds the watermark using *uniform quantization* of the *direction* of the *significant gradient vectors* obtained at multiple wavelet *scales*. The proposed method has several advantages:1) by embeddingthe watermark in the direction of the gradient vectors(using angle quantization techniques), the watermark is renderedrobust to amplitude scaling attacks2) by embedding thewatermark in the significant gradient vectors, the imperceptibilityof the embedded watermark is increased, since the HVSis less sensitive to minor changes in edges and textured areasthan in smooth region3) by embedding the watermark at multiplescales, the watermarking capacity is enhanced.Traditional redundant multistage gradient estimators, such as themultiscaleSobel 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 quantizationindex 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

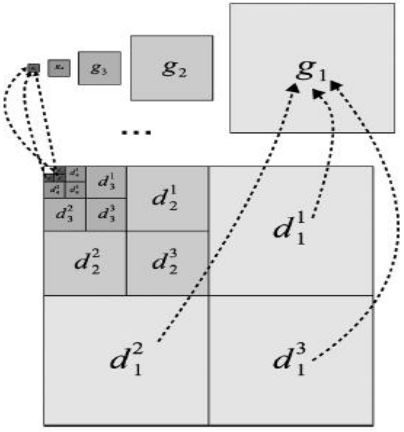

Fig.1. Illustration of five-level gradient field, obtained from five-level wavelet decomposition.

Where each gradient vectorg_j corresponds to the three wavelet coefficients d_j^1,d_j^2, and d_j^3. The straightforward way to embed the watermark bits is to partition the gradient fieldsinto 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 blockImage.

Denoisingis an important research area servingas the actual foundation for many applications, such asobjectrecognition, digital entertainment, and remote sensing imaging. A wish list for new image representation comes with multiresolution, localisation, critical sampling, directionality and anisotropy. The first three are successfully provided by separable wavelets. While, the last two requires contourlets. Denoising of image is achievedthrough contourlets which will be observed in simulation results.

AQIM is an extension of the quantization index modulation (QIM) method. The *quantization function*, denoted by Q(θ), maps a real angle θ 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 numberΔrepresents the *angular quantization step size* .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 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.

where wdenotes the watermark bit to be embedded (i.e. w = 0 or 1)

II. PROPOSEDWATERMARKEMBEDDING 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-DDWT is applied to the image.At each scale, we obtain the gradient vectors in terms of the horizontal, vertical, and diagonal wavelet coefficients. The values of the DWT coefficients that correspond to the angles of the significant gradient vectorsare embedded with watermark image. The watermark can be embedded in the *gradient magnitude*and/or in the *gradient direction*. One disadvantage ofthe former option is the sensitivity of the watermark to amplitudescaling attacks. However, the second option, embeddingthe watermark in the gradient direction, is robust to many typesof attacks.The angles of the significant gradient vectors, however, remain almost unchanged. The gradient directions form a robust featureof an image since their values are not easily changed unless the image quality is severely degraded.The above properties of the gradient direction makes the inserting watermark both robust and imperceptible. We, therefore propose embedding in the directions of significant gradient vectors of the image.

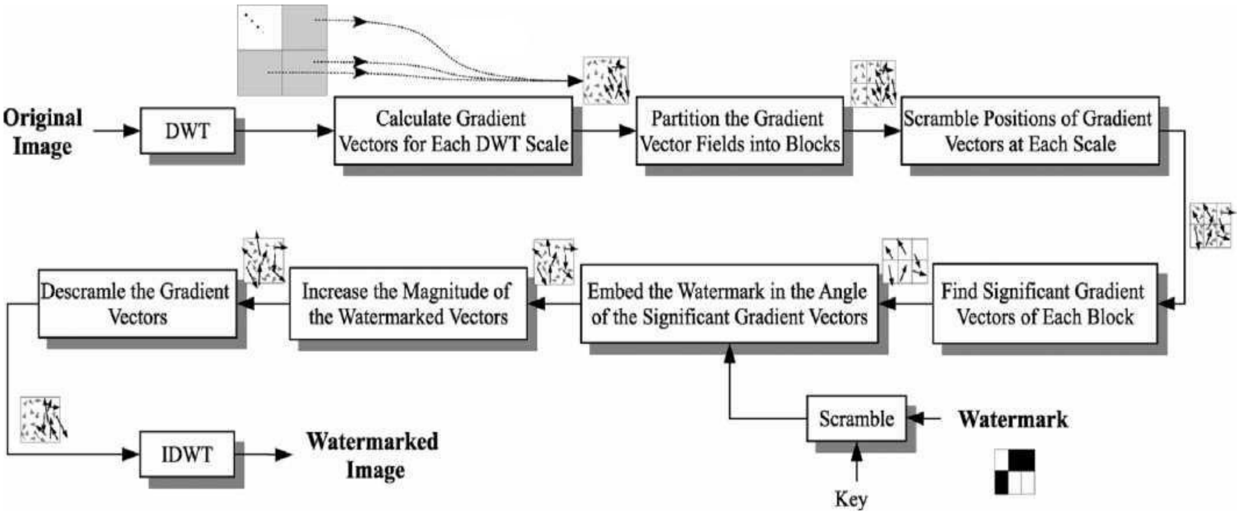

Fig.2. Block diagram of the proposed watermark embedding scheme

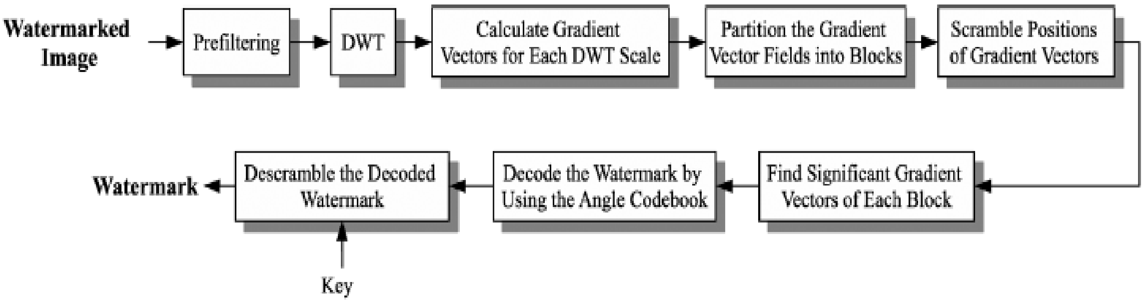

Fig. 3. Block diagram of the proposed watermark decoding method

2.1 Embedding the Watermark Bit in the Gradient Angle

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 toπ . 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 ofthe angle, its absolute value is quantized in the intervalθ ϵ [0, π]. The absolute angle quantization function is defined as follows:

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

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

III. WAVELET VS CONTOURLET DENOISING

Efficient representation of visual information lies at the heart of many image processing tasks, including compression, denoising, feature extraction, and inverse problems. Efficiency of a representation refers to the ability to capture significant information about an object of interest using a small description. For one-dimensional piecewise smooth signals, like scan lines of an image, wavelets have been established as the right tool, because they provide an optimal representation for these signals in a certain sense . In addition, the wavelet representation isinterest using a small description. For one-dimensional piecewise smooth signals, like scan lines of an image, wavelets have been established as the right tool, because they provide an optimal representation for these signals in a certain sense . In addition, the wavelet representation is enable to efficient algorithms; in particular it leads to fast transforms and convenient tree data structures. These are the key reasons for the success of wavelets in many signal processing and communication applications. Separable extension from 1-D bases, wavelets in 2-D are good at isolating the discontinuities at edge points, but will not “see” the smoothness along the contours. Contourlet transform is obtained by combining the Laplacian pyramid with a directional filter. Contourlet transform provides a flexible multi-resolution, local and directional expansion for images. In Contourlet transform there are two stages 1) a Laplacian pyramid followed by 2) directional filter bank(DFB).

Laplacian pyramid mids provide a multi-resolution system while directional filter banks give a directional nature to the Contourlet transform. The Laplacian pyramid decomposition at each level generates a down-sampled low-pass version of the original and the difference between the original and the prediction resulting in a band-pass image. Bandpass images from the Laplacian pyramid are fed into a DFB so that the directional information can be captured

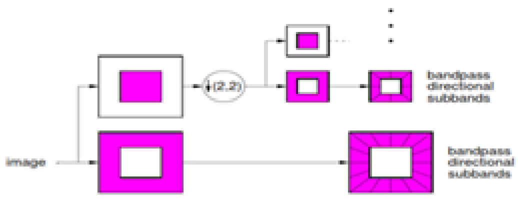

Fig. 4 The contourlet Filter

IV. EXPERIMENTAL 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. 5 (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.5 (c) and (d) respectively.

(a) (b) (c) (d)

Fig. 5 (a) Original Image, (b) Watermark, (c) Watermarked Image (d) Extracted Watermark

Denoising

The improvement in approximation by contourlets based on keeping the most significant coefficients will directly lead to improvements in applications, including compression, denoising, and feature extraction. As an example, for image denoising different noise are added to watermark image like speckle noise, Poisson noise,andGaussian noise.A simple thresholding scheme applied on the contourlet transform is more effective in removing the noise than it is for the wavelet transform. For different sizes of watermark images, MSE and PSNR values are displayed in Table 1. The contour let transform is shown to be more effective in recovering smooth contours, both visually as well as in PSNR

Fig. 6 Speckle noise image and denoised images usingwavelet and contourlet

Fig. 7 Poisson noise image and denoised images usingwavelet and contour let

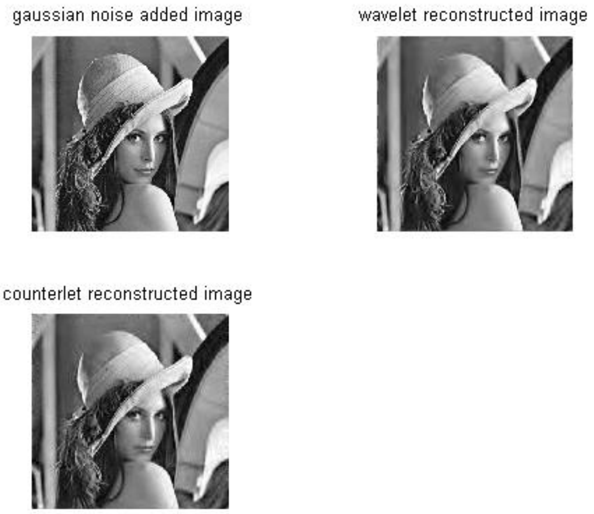

Fig. 8 Gaussian noise image and denoised images usingwavelet and contour let

TABLE 1
MSE and PSNR values for various Watermark Sizes

TABLE1.1 : Watermark Size 8 x 8

Size of water mark	Water marked	Speckle noise	Wavelet	Contour let	Poisson	Wavelet	Contourlet	Gaussian	Wavelet	Contourlet
MSE 8*8	229.5541	242.5315	0.0019	0.0019	242.5334	0.0012	0.0012	242.5315	8.3373e-04	8.3074e-04
PSNR 8*8	56.4639	55.9140	173.4774	173.5399	55.9139	177.7213	177.8390	55.9140	181.7213	181.7572

TABLE1.2 : Watermark Size 16 x 16

Size of water mark	Watermarked	Speckle noise	Wavelet	Contourlet	Poisson	Wavelet	Contourlet	Gaussian	Wavelet	Contourlet
MSE16*16	229.5541	242.5315	0.0019	0.0019	242.5334	0.0012	0.0012	242.5315	8.3396e-04	8.3515-e04
PSNR16*16	56.4639	55.9140	173.4306	173.4468	55.9139	177.7178	177.8408	55.9140	181.7185	181.7042

TABLE1.3 : Watermark Size 32 x 32

Size of water mark	Watermarked	Speckle noise	Wavelet	Contourlet	Poisson	Wavelet	Contourlet	Gaussian	Wavelet	Contourlet
MSE32*32	229.6008	242.5315	0.0019	0.0018	242.5334	0.0012	0.0012	242.5315	8.3459e-04	8.1542e-04
PSNR 32*32	56.4618	55.9140	173.7185	173.7868	55.9139	178.1066	178.2366	55.9140	181.7110	181.9434

TABLE1.4 : Watermark Size 64 x 64

Size of watermark	Watermarked	Speckle noise	Wavelet	Contourlet	Poisson	Wavelet	Contourlet	Gaussian	Wavelet	Contourlet
MSE64*64	**229.5818**	**242.5315**	**0.0019**	**0.0019**	**242.5334**	**0.0012**	**0.0012**	**242.5315**	**8.3449e-04**	**8.2678e-04**
PSNR64*64	**56.4627**	**55.9140**	**173.6201**	**173.6949**	**55.9139**	**177.8941**	**178.0366**	**55.9140**	**181.7121**	**181.8050**

The above tables showsMSE and PSNR values for different watermark image sizes such as 8x8 , 16 x 16 , 32 x 32 ,and 64 x 64 with Speckle , Poisson , and Gaussian noises to watermarked image . By Observingwavelet and contourlet hard –thresholding for denoising , the contourlet transform isshown to be more effective in recovering smooth contours both visually as well as in PSNR

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

V. 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 in terms of the wavelet coefficients in subbands LH, HL, and HH. The gradientangle is then quantized by modifying the DWT coefficientsthat correspond to the gradient vector. To embed the watermarkin each gradient angle, the absolute angle quantization indexmodulation (AAQIM) is proposed. To extract the watermarkcorrectly, the decoder should be able to identify the gradientvectors that were watermarked and the embedding order .To solve theseproblems, 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 watermarkedand the unwatermarked vectors was also proposed to helpidentify the watermarked vectors correctly.From the above experimental results we observe that this watermarking technique is more Robust to various sizes of watermark Images.The contour let filter bank, that can provide a flexible multiscaleand directional decomposition for images.

The simulation results demonstrate that the proposed method is robust for different sizes of watermark images. Finally we observed that contour let transform preferred for denoising

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