A Cost Effective Region Specific Spatial Domain Color Image Watermarking Scheme

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Abstract. In object oriented images, ROI (Region of Interest) is an area which contains important information and attracts more attention of an image viewer. So it is desirable to embed robust watermark in ROI to give better protection. The present paper describes a region specific low cost (computational complexity) watermarking scheme in spatial domain by inserting data into the most valuable regions in the cover image. Those regions are selected by Quad tree decomposition of host image. Quad tree decomposition is a method of image segmentation which splits an image into regions such that large regions are formed when the intensities are uniform and small regions of variable sizes are created, in the comparatively non-uniform area of the image. Small regions represent the presence of critical information of the image, and hence are the important places of watermarking. Simulation results duly support this claims.

Keywords: Spatial Domain Watermarking; Copyright Protection; Segmentation; Quad Tree; ROI

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1 Introduction

Using communication network and World Wide Web digital image(s) can be distributed and transmitted easily and efficiently to the distant places. Unfortunately such applications become insubstantial whenever image security is required. Digital watermarking is a method of embedding watermark information into multimedia data to ensure the ownership and the integrity of data, thereby protecting the copyright. Common requirements of watermarking method are difficult to notice, acceptable fidelity, resistance to tempering or hostile attacks, scalable decoder, few false positives and false negatives. Apart from these watermarks should be robust to various images processing operations and bit rate of a watermark should be high (*Pan et al.*[9]).

Watermarking scheme can be classified into two categories: transfer domain (DCT, DWT etc.) and spatial domain. Although more than 80 % of image and video data are in DCT or DWT compressed form, data hiding in transform domain demands high computational complexity. Whereas the later class provides low computational complexity which is required for real time data embedding and retrieval process.

Most existing watermarking schemes embed watermarks in the entire image without taking the image content into account. For many applications (in the case of object oriented image) where certain parts of the image are of higher importance than others and attract more attention to the image viewer are called the ROI. It is desirable to embed robust watermarks in ROI to give better copyright protection. Moreover for video signal where the large numbers of data are redundant, it is desired to embed the watermark into the perceptually important area, to achieve a strong protection of important regions and efficient retrieval of video signals. So, cost effective region specific image and video watermarking is still an important research issue.

We briefly discuss here few watermarking schemes of digital image in spatial domain reported in the literature. *Tsekeridou et al*.[11] propose a blind self-similar chaotic watermarking algorithm.They claim that the use of self-similar chaotic watermark makes the algorithm highly robust against compression, low pass filtering, cropping and scaling.*Wong et al* [12] describe a block base secret key and public key watermarking schemes using cryptographic hash functions like MD5. Scheme is reported to detect and report any changes to the image.*Bangaleea et al*. [1] show how the performance of watermarking system could be improved by the application of channel coding. They study that decrease in inter weaver size produce a poor performance in turbo codes. They also study that turbo code give better performances than Bose-Chaudhuri-Hocquengem (BCH) block code. *Bas et al*. [2] and *Kim et al*. [7] present watermarking schemes based on image features. In these schemes invariant image features are set to some fixed value to watermark the image and at the decoder side their values are checked to detect the watermark. *Zheng et al*.[13] describe a novel multi-channel watermarking scheme. They generate watermarking template from image channel data and embed into one or more channels of an image. They claim that use of watermarking template makes the scheme high robust only for geometric attacks, but not for signal processing operations such as adding noise, low filtering and compression.

The present paper proposed a low cost (computational complexity) region specific image watermarking scheme using Quad tree image segmentation in spatial domain. Quad tree region splitting method of image segmentation splits image into regions such that large regions are formed when the intensities are uniform and small regions of variable sizes are formed in the comparatively non-uniform area of the image. Small regions (in our case 4x4 blocks) represent the presence of critical information of the image and hence are the good places for the watermark insertion. Before watermark insertion, watermark is encoded using soft convolution encoding, to increase the security and robustness of the scheme. Our proposed watermarking scheme is a good defense against various geometrical and common image processing attacks and embeds a watermark into the most valuable portion of an image without decreasing the perceptual quality of the image (PSNR 43.63 dB).

The paper is organized as follows: Basic principles and key features of quad tree image segmentation and Convolution encoding with Viterbi decoding are outlined in section 2 and 3 respectively. Section 4 describes proposed watermarking scheme while in section 5 the performance evaluation of the scheme is demonstrated. Conclusions are drawn in section 6 along with the scope of future works.

2 Quad tree image segmentation: basic principles and features

The segmentation is the partitioning of an image into regions. This can be done by finding boundaries between regions based on discontinuities in intensity levels, or via threshold based on the distribution of pixel properties, such as intensity value or by a technique that are based on finding the regions directly. For the Region based segmentation one approach is to subdivide the entire image region successively into smaller and smaller quadrants region such that final partition satisfies following conditions (*Gonzalez et al*. [4]).

Let *R* represent the entire image region, then we may view region based segmentation as a process that partitions *R* into *n* sub regions, $R_1, R_2, \cdots, R_n$, such that

(a)$\bigcup_{i=1}^{n} R_i = R$.
(b)R_i is a connected region, $i = 1, 2, \cdots, n$.
(c)$R_i \bigcap R_j = \Phi$ for all i and j, i$\neq$ j.
(d)P(R_i)=TRUE for $i = 1, 2, \cdots, n$.

Here, P(R_i) is the criteria of homogeneity i.e. a logical predicate defined over the points in set R_i and Φ is the null set. Condition (a) indicates that the segmentation must be complete; that is, every pixel must be in region. The condition (b) requires that points in a region be connected in some predefined sense (e.g. 4-or 8-connected). Condition (c) indicates that region must be disjoint. Condition (d) deals with the properties that must be satisfied by the pixel in a segmented region for example P(R_i)=TRUE if all pixels in R_i have the same gray level.

We start with dividing a square image into four equal sized square blocks, and then test each block whether it meets the criterion of homogeneity. In our scheme the difference between maximum and minimum gray value of a block is taken as a homogeneity criteria and compared against a threshold. On the basis of our watermark size we have taken the threshold value to 10.If a block meets the criterion, it is not divided further, but if it does not meet the criterion, it is subdivided again into four blocks, and the test criterion is applied to those blocks. This process is repeated iteratively until each block meets the criterion. The result may have blocks of several different sizes.

This particular splitting technique has a convenient representation in the form of a quad tree. Quad tree is a tree in which each node has exactly four descendants as shown in Fig. 1. Parent node represents the entire image region and its four descendant's nodes represent the disjoint sub regions within the large region.

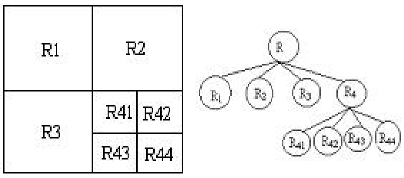

Figure 1: Quad tree

Quad tree region splitting method of image segmentation splits image into regions such that large regions are formed when the intensities are uniform and small regions of variable sizes are formed in the comparatively non-uniform area of the image. Large regions represent mainly the background area or less valuable information and absence of edges. Small regions represent the presence of critical information of the image and hence are the good place for the watermark insertion. We propose here Quad tree decomposition for selecting those 4x4 blocks, which pass the homogeneity test i.e. whose difference between the maximum gray values of the block elements and minimum gray value of the block elements is less than the threshold value 10.

In this note, we propose to demonstrate the capability of quad tree image segmentation in finding ROI with an application to image watermarking.

3 Convolution coding and viterbi decoding: basic principles and features

Convolution coding and block coding are the methods of channel coding. Convolution code operates on serial data, while block coding operates on block of information symbols. This method is particularly useful for high data rate application. However, very large block length has the disadvantage that unless the entire block of encoded data is received at the receiver, the decoding procedure cannot start, which may result in delays (*Bose* [3]). For decoding convolution code mainly Sequential Decoding, Threshold Decoding and Viterbi Decoding are used. Sequential decoding has the advantage that it can perform very well with long constraint length convolution codes, but it has a variable decoding time. Threshold Decoding lost its popularity especially because of its inferior bit error performance. The Viterbi Decoding technique became the dominant technique because of (*Bose* [3]) highly satisfactory bit error performance, high speed of operation, ease of implementation, low cost, fixed decoding time. Convolution encoding with Viterbi Decoding is a Forward Error Correcting Code (FEC) technique that is particularly suited to a channel in which the transmitted signal is corrupted mainly by additive white gaussian noise (AWGN). Description of convolution codes is given in (*Johansson and Jonsson* [6]; *Johannesson and Zigangirov* [5]). We have used here convolution coding (Rate=1/2) and viterbi decoder with constraint length 7 for the reasons discussed above.

In this note, we propose to demonstrate the capability of convolution coding with viterbi decoding in handling robustness with an application to image watermarking.

4 Proposed watermarking scheme

The proposed watermarking scheme, like other watermarking method, consists of two parts namely watermark encoding and decoding. The block diagram representation of proposed scheme is shown in Fig. 2 and 3.

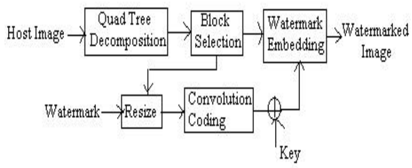

Figure 2: Block diagram of watermark encoding process

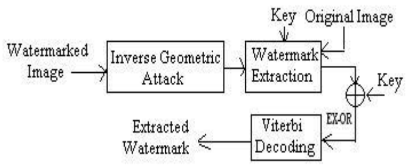

Figure 3: Block diagram of watermark decoding process

4.1 Watermark encoding

Watermark encoding process consists of the following steps.

Step I: Selection of blocks using quad tree decomposition of host image

Apply quad tree decomposition on color image *I (X, Y)* and select all 4x4 blocks *(H)* from the blue channel that passes the homogeneity test and lies in the co-centric square area within the image with side equal to half the entire image side as shown in Fig. 4. Embedding in the central area gives the method resistance against cropping. Watermark is inserted into the blue channel as this is less sensitive to human visual system (HVS).

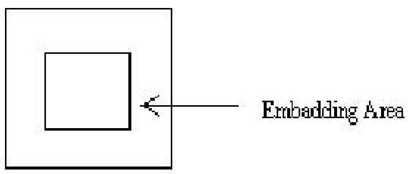

Figure 4: Watermark embedding region

Step II: Encoding of watermark using convolution codes

In the proposed scheme binary image is used as a watermark. Watermark Image is resized such that number of pixel in watermark is less than or equal to half of the total number of 4x4 blocks *(H)* found by step 1. Then Watermark image after converting into the bit sequence, is encoded using convolution coding with rate(*r*) =0.5, which doubles its size and increase redundancy. If we increase the coding rate, this will amplify in redundancy and robustness, in the mean time capacity of the scheme will be low. Coded watermark is then bit wise exclusive-ORed with 128-bit user define key for better protection.

Step III: Watermark bit embedding

The bit embedding strategy is the same as that proposed in (*Lee and Lee*[8]) with some modification and is described as follows.

Repeat (for each selected 4x4 block *(H)*of blue channel){

A: Compute the average(I_{mean}) , minimum(I_{min}) and maximum (I_{max}) of the pixels in *H*.

B: Classify each pixel into one of two categories, based on whether its intensity value is above or below the mean intensity of the block, i.e., the ij^{th} pixel, bit_{ij} is classified depending on its intensity, *I* as:

$bit_{ij} \in Y_H$ if $I > I_{mean}$
$bit_{ij} \in Y_L$ if $I \leq I_{mean}$

where Y_H and Y_L are the high and low intensity classes, respectively.

C: Compute the means, $mean_L$ and $mean_H$, for the two classes, Y_L and Y_H.

D: Define the contrast value of block (H) as

$$C_B = max(C_{min}, \beta(I_{max} - I_{min}))$$

where β is a constant and C_{min} is a constant which defines the minimal value a pixel's intensity can be modified.

E: Select a watermark bit (bit_w) randomly depending on the key value.

F: Given the value of bit_w is 0 or 1, modify the pixels in *H* according to:

if $bit_w = 1$,
$I_{new} = I_{max} + \lambda$ if $I > mean_H$
$I_{new} = I_{mean} + \lambda$ if $mean_L \leq I < I_{mean}$
$I_{new} = I + \delta$ otherwise

if $bit_w = 0$,
$I_{new} = I_{min} - \lambda$ if $I < mean_L$
$I_{new} = I_{mean} - \lambda$ if $I_{mean} < mean_H$
$I_{new} = I - \delta$ otherwise

Where I_{new} is the new intensity value for the pixel which has original intensity value *I*. δ is a random value between 0 and C_B and λ is the watermark strength.

G: The modified block of pixels, H_{new}, is then positioned in the watermark image in the same location as the block *(H)*, of pixels from the original host image.

} Until all watermark bits are inserted.

H: Marge red, green and blue channel.

4.2 Watermark decoding

The Proposed watermarking scheme is non-blind and requires the original image. The watermark decoding process are described below.

Step I: Selection of blocks using quad tree decomposition

Blocks of size (4x4) are selected using quad tree decomposition of original image *I(X,Y)* using the same strategy which is used at the time of encoding (step-I of encoding process).

Step II: Watermark bit extraction

Repeat {

A: Take one 4x4 blocks of the host image and corresponding 4x4 block of watermarked (possibly distorted version of the watermarked) image using the same coordinate value as of 4x4 block of host image.

B: A watermark bit is decoded by making the comparison of the two resultant values:

If $Average_w > Average_o$, then
bit_w = 1
If $Average_w \leq Average_o$, then
bit_w = 0

Where $Average_o$ and $Average_w$ are the averages for the 4x4 blocks of the host and corresponding 4x4 block of watermarked images, respectively.

} Until all watermark bit are extracted.

Step III: Viterbi decoding of extracted bit sequence

The decoded bits are then arranged in an order using the same key which was used during embedding. Then, the encoded watermark is exclusive ORed by 128 bit key and decoded by viterbi decoding.

5 Performance evaluation

The performance of the proposed scheme is tested over large number of bench mark images [10]. Lena Fig. 5 (a) is a test image of size (512x512), 24 bit/pixel RGB color image and watermark (Fig. 5 (b)) is a binary bitmap of size (50x50).

On the basis of large number of experimentation,the value of constants has been taken as $C_{min} = 15$, $\beta = 1$ and $\lambda = 15$ and convolution encoding rate $r = 1/2$.

The similarity of extracted and original watermark is quantitatively measured by the Normalized Cross Correlation (NCC) (*Lee and Lee* [8]) and is defined by the following rule:

$$NCC = \frac{\sum_i \sum_j W_{ij} W'_{ij}}{\sum_i \sum_j (W_{ij})^2} \quad (1)$$

Where W_{ij} and W'_{ij} represent the pixel values at location (i,j) in the original and extracted watermark image.

To measure the distortion incorporated by the watermarking scheme we have used Mean Square Error (MSE) and Pick Signal to Noise Ratio (PSNR). For color images with color components R, G, and B, PSNR is described by the following rule.

$$PSNR = 10 \log_{10}[\frac{255^2}{AMSE}] \quad (2)$$

where AMSE(Average Mean Square Error) is defined as:

$$AMSE = \frac{M_R + M_G + M_B}{3} \quad (3)$$

where M_R,M_G and M_B are the Mean Square Error for Red,Green and Blue components respectively.

Fig. 5(c) and (d) show the watermarked image and extracted watermark respectively without any attack. Fig. 5(e) shows selected region where watermarked is embedded. From Fig. 5(e) it is evident that watermark is embedded into the most valuable portion of the image and deletion of those regions will cause significant loss of the commercial value of the host image. From Fig. 5(a) and (c), it is clear that proposed embedding scheme does not distort host image much because these looks almost the same(PSNR=43.63 dB). Graphs in Fig. 5(f) show the variation of PSNR with respect to various values of λ for the test image. From the graph it is clear that if we increase the value of λ then the value of PSNR is decreased, which implies perceptual quality of watermarked image is decreased. In our test case we select $\lambda = 15$ which give PSNR value = 43.63, which is quite high. High value of PSNR implies the distortion incorporated by the watermarking scheme is quite low, which is one of the requirements of watermarking.

5.1 Robustness test

To test the robustness of the proposed watermarking scheme, some typical signal processing attacks, such as filtering, sampling, histogram equalization, various noise addition and lossy JPEG compression are performed.The scaling operation is done by scaling the watermarked image(s) by a factor of 0.75 of its original size and rescaled back to 512x512 i.e. the original size, using bilinear interpolation. Bringing the watermarked image(s) to their original size is essential because the scheme requires the pixels in the watermarked image(s) to be in the corresponding location as the original host image(s) in order to extract the watermark correctly. For rotation operation we have estimated the rotation angle of watermarked image by control point selection method and then rotated the host image by same angle then corrected the rotation of host image by bilinear interpolation and then these two rotation corrected images are compared for watermark detection. This is done to avoid the effect of loss of data in the rotation. Fig. 6 shows the extracted watermark under different attack operations. In all above cases extracted watermark, from attack watermarked images are still recognizable, and can be efficiently used for ownership verification.

Table 1 lists the NCC values for various image processing operations. Table 2 lists the PSNR between original host image and watermarked image for various value of λ. Graphs in Fig. 7 shows the performance of the algorithm for various operations (attacks) of variable strength. From the graphs it is clear that the algorithm is rotation and scale invariant and can detect watermark 100 % for mask size up to 7x7. Our algorithm is also quite efficient in case of lossy JPEG compression and can detect watermark 100 % up to lossy JPEG 75.

6 Conclusions and scope of future works

In this study a spatial domain region specific color image watermarking scheme for ownership verification is presented. The result shows that watermark is embedded into the most important area of the image without any visual distortion (PSNR 43.63dB). This method is especially good against rotation and scaling down unto 0.25. The main drawback of the scheme is that algorithm requires original image to recover the watermark, which is considered unsecured.

Future work can be concentrated on blind watermarking of video data where location is very important due to large volume of redundant data.

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Table 1: Normalized Cross Correlation values for different operations

$No.$	$ImageprocessingOperation$	$NCCValue$
1	Straight(no attacked)	1.00
2	Wiener Filter (3x3)	1.00
3	Median Filter(3x3)	1.00
4	Scaled down 0.75	1.00
5	JPEG 100	1.00
6	JPEG 80	1.00
7	JPEG 60	0.95
8	Cropped	1.00
9	Rotated -17 DEG	1.00
10	Noise(salt & pepper var. 0.06)	0.99
11	Noise(speckle ,var. 0.06)	1.00
12	Noise(gaussian ,var. 0.06)	0.81
13	Histogram equalization	0.86

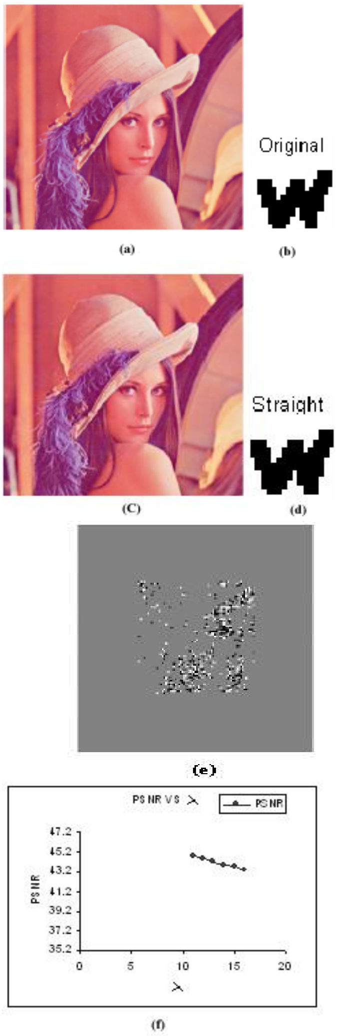


Figure 5: (a) original or host image ,(b) watermark image, (c) watermarked images, (d) extracted watermark, (e) watermark embedded region, (f) variation of PSNR w.r.t. various values of λ.

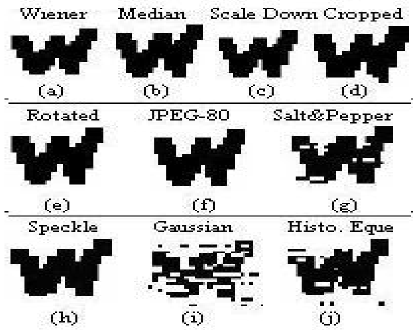
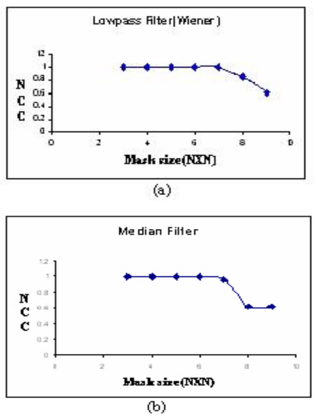
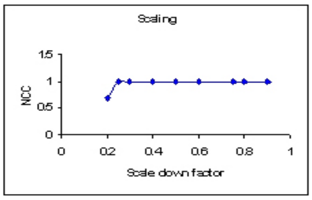
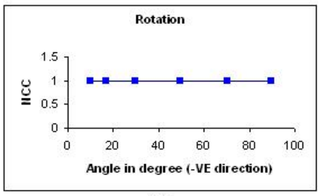


Figure 6: Extracted watermarks after different attack operations: (a) is the extracted watermark after wiener filtering (3x3); (b) is the extracted watermark after median filtering; (c) is the extracted watermark after down sampling by .75; (d) is the extracted watermark after cropping by a mask 444x444; (e) is the extracted watermark after rotation by -17 degree ; (f) is extracted watermark after lossy JPEG compression by factor 80; (g) is the extracted watermark after salt & pepper noise by variance 0 .06; (h) is the extracted watermark after speckle noise by variance 0 .06; (i) is the extracted watermark after gaussian noise by variance 0 .06; (j) is the extracted watermark after histogram equalization .

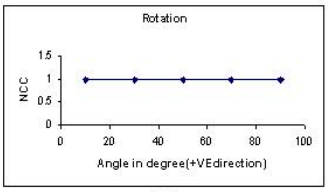




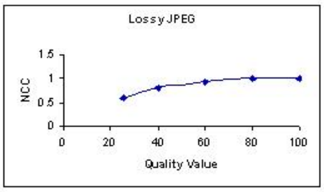
(c)



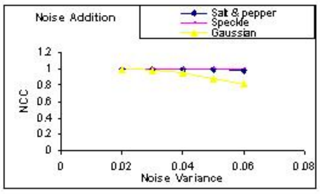
(d)



(e)



(f)



(g)

Figure 7: Graphs for different operations showing variation of NCC value against various factors,(a): NCC vs. mask size in case of wiener filtered watermarked image, (b): NCC vs. mask size in case of median filtered watermarked image,(c): NCC vs. scale down factor,(d): NCC vs. angle (in degree) change in negative direction,(e): NCC vs. angle (in degree) change in positive direction,(f): NCC vs. Lossy JPEG,(g): NCC for various noise addition.

Table 2: Lists of PSNR between original host image and watermarked image for various value of λ

λ	MSC	RMS	$PSNR$
11	2.17	1.47	44.75
12	2.32	1.52	44.47
13	2.47	1.57	44.19
14	2.64	1.62	43.91
15	2.82	1.68	43.63
16	3.01	1.73	43.34