Santi P. Maity[1], Malay K. Kundu[2]

[1]Deptt. of Electronics & Telecommunication Engg, B.E.College(D.U), Howrah, India.
[2]MIU, Indian Statistical Institute, Kolkata – 711108, India.
[1](spmaity@telecom.becs.ac.in),[2](malay@isical.ac.in)

INFORMATION THEORETIC APPROACH IN SPATIAL IMAGE WATERMARKING

Abstract

An information theoretic approach is used to hide a visually meaningful and recognizable two level watermark symbol in the spatial domain. Watermark insertion regions are selected using both Shannon's entropy measure as well as non-Shannonian entropy for image data. Experimental results confirm the robustness of the proposed scheme against several kinds of attacks, such as lossy compression, filtering, image rescaling, noise addition, cropping and translation etc.. Computational simplicity, less visual distortion and blind detection are the other advantages of the proposed technique.

keywords : Digital image watermarking, entropy, negative modulation and JPEG compression.

1 INTRODUCTION

Digital image watermarking, a kind of signature in digital image, is being widely used for copyright protection, hiding executables for access controls, embedded captioning, secret communication, temper detection of digital images [1]. Imperceptibility, noninvertibility and robustness are the key issues of a good watermarking technique. In general better the imperceptibility, the lower is the robustness of the scheme and a trade off always exists. In fact the design of robust watermarking always demands data embedding in regions of significant feature points such as edges, corners, textured areas, spatial uncertainty etc of the cover image [2]. Moreover robustness of a scheme increases if an attack adaptive modulation is used during watermark insertion.

Watermarking in spatial domain offers computational benefit and ease of implementation with greater control on visual quality but, in general, they are too fragile to withstand large varieties external attacks. On the other hand, most of the state of the art transformed domain schemes for data hiding offer better robustness due to the usage of decomposition scheme but at the cost of higher complexity of algorithms and low control on visual degradation. One of the popular transform domain approach for watermarking in multimedia documents is spread spectrum technique [3] proposed by Cox et al.

The present paper describes block based watermarking in spatial domain where the average information of edges and spatial gray level uncertainty of a block in the cover image have been considered as features. Robustness of the proposed method against common signal processing operations like compression, filtering, noise addition and image rescaling etc. have been shown.

The paper is organized as follows: section 2 describes entropy based region selection. Section 3 describes insertion & extraction of watermark. Experimental result is described in section 4 which is followed by conclusion in section 5.

2 ENTROPY BASED REGION SELECTION

If the probability of occurrence of the event ‘i’ is denoted by p_i where $0 \le p_i \le 1$ and $\sum p_i = 1$, Shannon’s [4] measure of entropy for a n-state system is then expressed as

$$H = -\sum p_i \log p_i \quad \text{...............(1)} \qquad \text{where } i = 1,2, \ldots n.$$

Pal and Pal [5] used a new mathematical expression of ignorance using $u_i=1-p_i$ with a new definition of the gain in information from an event with probability p_i as
$\Delta I\,(p_i)= e^{u_i} = e^{1-p_i}$ and the entropy $H = E\,(\Delta I)= \sum p_i\, e^{1-p_i}$. Kapur [6] suggested a parametric measure of this entropy for image data that gives a flexibility to be used to an advantage. This parametric measure of entropy is denoted by

$$H = E\,(\Delta I)= \sum p_i\, e^{a(1-p_i)} - 1 \quad \text{.........} \; (2)$$ where ‘a’ is a positive constant and i= 1,2, …n.

The present paper uses non-Shannonian parametric form of entropy [6] together with conventional Shannonian entropy measure to select the blocks within the cover image for watermark embedding and is described as follows.

(1) First the image to be watermarked is partitioned in (8x8) non-overlapping blocks. The average information of each block is calculated using the equation (2). This gives a measure of spatial uncertainty/ignorance of a block.

(2) The edge map is calculated using the conventional gradient edge detector. Now, from the edge map, the average edge information in each block is calculated using equation (1). The use of logarithmic function in this case signifies the relative independency of adjacent edges, unlike the 2D spatial correlation of pixel intensity that exits among neighboring pixels.

(3) The two measure of entropy thus obtained for each block is then summed up and the values thus obtained are sorted in ascending order. Now, the lowest value blocks in number equal to the size of watermark symbol, is selected from this ascending order arrangement.

3 INSERTION & EXTRACTION OF WATERMARK

A block based spatial domain algorithm is used to hide watermark in the non -edgy less information bearing M^2 blocks of the cover image. The cover image (I) is a gray-level image of size N x N where $N= 2^p$ and digital watermark symbol (logo) W is a two level image of size M x M where $M=2^n$. About the value of p and n, p>>n where $(p/n) \geq 4$. In the present work a watermark symbol of (16 x16) binary image and cover image of size (256x256), 8 bit gray image are used.

3.1 Insertion of Watermark

Step I: Watermark embedding and formation of secret image :

A two level intermediate image map of size (N/8 x N/8) is constructed where different blocks of the cover image are mapped as point in the intermediate image. The location of a block (selected for insertion) in the cover image is represented by value '1' while all other blocks by value '0'.

The mean or average value of selected blocks is calculated. These averages values are used for watermark insertion. Let for one such block this average value and its integer part are denoted by A and $\acute{A}=\lfloor A \rfloor$ respectively. Now one pixel of watermark symbol replaces a particular bit in bit plane representation of Á, denoted by $M_7M_6M_5M_4M_3M_2M_1M_0$, for each selected block. The bit selection starts from most significant bit (msb) of mean value. The positional information of the proper most significant bit, in bit plane representation of the mean value, that matches with the current value of watermark symbol is taken into consideration for future analysis. Watermark pixel is inserted by changing the value of a bit in any of the least significant bit planes when such matching does not occur even up to the third bit planes (M_2) from the bottom most bit.

Step II: Negative modulation:

An attack adaptive negative modulation technique is adopted for the pixels used for watermark embedding. The average brightness value of the selected block is compared before and after mean filtering of the image. If it is found that the average brightness value is decreased after mean filtering, an increase in average brightness value before mean filtering will produce greater visual distortion but with high immunity of the embedded information after such attack. The implementation is done by suitably modifying the least significant bit planes of the average brightness value. Similarly the average value is decreased by suitable modification if it is found that average brightness value of the block is increased after mean filtering. This type of modification for watermarked pixels is termed here as negative modulation.

3.2 Watermark Extraction

The extraction of watermark requires only the secret image(s). The watermarked image under inspection with or without external attacks is partitioned into non-overlapping block of size 8x8 pixels. Now from the secret image, position of the non edgy low information bearing blocks are selected and gray value of the secret image indicates the corresponding bit position in mean gray values where watermark pixel was inserted.

A quantitative estimation for the quality of extracted watermark image $W^{/}(x, y)$ with reference to the original watermark W (x, y) may be expressed as normalized cross correlation (NCC) where

$$NCC = \frac{\sum_x \sum_y W(x,y) w^{'}(x,y)}{\sum_x \sum_y [W(x,y)]^2}$$

gives maximum value of NCC as unity.

4 RESULT

Figure 1 shows Lena image used as cover image and Figure 2 is the watermarked image (PSNR= 44.11 dB) using logo/hidden symbol M as shown in Figure 9. Robustness against different attacks is shown in table 1 and 2 for other five test images such as Fishing boat, Pills, Black bear, New York and Opera images shown in figure 16,17,18,19 and 20 [7,8].

Mean Filtering : Figure10 shows extracted watermark (NCC=0.92) from blurred version of watermarked image using 11 x 11mask with PSNR 23.24 dB and is shown in Figure 3.

Image Cropping Operation : Robustness of the proposed method, changing all pixels values of twenty rows and columns from both ends of the watermarked image by the value 150 with PSNR=18.63dB is shown in figure 4. Extracted watermark, although interfered by noise, still recognizable with NCC=0.87 and is shown in figure 11.

Median Filtering : Figure12 shows extracted watermark (NCC=0.97) from median filtered watermarked image using 11 x 11mask with PSNR 27.90 dB and is shown in Figure 5.

Image Rescaling : The watermarked image was scaled to one fourth of its original size and up sampled to its original dimensions. Figure 6 shows the modified image (PSNR=23.36dB) with many details lost. Extracted watermark (with NCC=0.94) is shown in Figure 13.

JPEG Compression : Figure 14 shows the extracted watermark with NCC=0.95 from the watermarked image (PSNR=18.73 dB) as shown in Figure 7 obtained after JPEG compression with compression ratio 55.3.

Least Significant Bits manipulation : Four Least Significant bit(s) for all pixels of the watermarked image are complemented and the modified image with PSNR=28.28dB is shown in Figure 8. The extracted watermark with NCC=0.97 is shown in Figure 15.

5 CONCLUSIONS

Proposed technique offers three advantages in spatial domain image watermarking. The first advantage is that it involves simple computation. The second advantage is that method does not/ does make very little change in pixels of the host image and visual quality of the cover image is well preserved. The third advantage of the method is robustness & blind detection. The method is found to be tolerant against different image attacks such as blurring, median filtering, lossy JPEG compression, image rescaling & noise addition etc. Further research works are being carried out in spatial domain watermarking to show resiliency against other types of external attacks such as the image flip, scaling and image rotation.

Tab 1 Result of mean, median filtering and cropping operation for five test images

Test Image	Target image(dB)	Mean filter(dB)	Logo NCC	Median filter(dB)	Logo NCC	Cropped image	Logo NCC
Bear	44.47	22.43	0.85	26.73	0.97	26.15	0.91
N. York	44.47	18.28	0.99	19.31	1.0	19.49	0.87
Opera	44.50	22.91	0.95	25.05	0.95	20.84	0.91
F. boat	44.60	22.02	0.94	24.90	0.95	22.05	0.93
Pills	44.60	22.29	0.94	25.69	0.90	23.45	0.86

Tab 2 Result of rescaling, JPEG and LSB manipulation for five test images

Test Image	Image rescaling	Logo NCC	JPEG image PSNR; C.R.	Logo NCC	Bit manipulation	Logo NCC
Bear	22.96	0.93	21.7; 40.5	0.85	29.30	0.98
N. York	18.76	1.0	16.1; 44.2	0.97	27.34	0.91
Opera	23.68	0.89	21.9; 45.5	0.90	27.13	0.87
F. boat	22.52	0.92	17.7; 47.7	0.89	28.66	0.92
Pills	22.24	0.91	17.5; 36.1	0.91	31.15	0.87

REFERENCES

[1] M. Ramkumar and A.N. Akansu, "Capacity estimates for data hiding in compressed images", IEEE Transactions on Image Processing, 10, pp. 1252-1263,2001.

[2] M. Kutter, S.K. Bhattacharjee and T. Ebrahimi, " Towards second generation watermarking schemes", Proceedings of the 6th International Conference on Image Processing (ICIP'99), 1,pp.320-323, 1999, Japan

[3] I. J. Cox, J. Kilian, F. T. Leighton and T. Shammon, " Secure spread spectrum watermarking for multimedia" IEEE Transaction on Image Processing, 6, pp. 1673-1687,1997.

[4] Shannon. C. E,"A mathematical theory of communication", Bell System Tech. Jr., 27, pp.379-423, 1948.

[5] N.R.Pal and S.K.Pal,"Object-back ground segmentation using new definitions of entropy" IEE Proceedings, 136,pp.284-295, 1989.

[6] J.N.Kapur,"Generalized measure of information, generalized optimization principles and their applications"in Current trends in information theory, Statistics and O.R., Om Prakash, pp.1-13, Guru Nanak Dev University, Amritsar, India, 2001.

[7] http// www.cl.cam.ac.uk/~ fapp2/watermarking.

[8] http // sipi.use.edu /services/database/ Database /html.

Fig. 1

Fig. 2

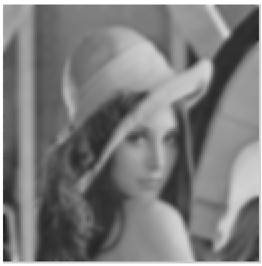

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig. 12

Fig. 13

Fig. 14

Fig. 15

Fig. 16

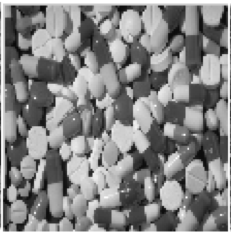

Fig. 17

Fig. 18

Fig. 19

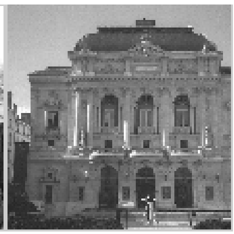

Fig. 20

Fig. 1 Cover image Lena; Fig. 2 Watermarked image; Fig. 3 Watermarked image after mean filtering; Fig. 4 Watermarked image after cropping; Fig. 5 Watermarked image after median filtering; Fig. 6 Watermarked image after rescaling; Fig 7 Watermarked image after JPEG (C.R.=55.32); Fig. 8 Watermarked image after LSBs manipulation; Fig. 9 Watermark image; Fig. 10 Watermark from fig. 3; Fig. 11: Watermark from fig. 4; Fig. 12 Watermark from fig. 5; Fig. 13 Watermark from fig. 6; Fig. 14 Watermark from fig.7; Fig. 15 Watermark from fig. 8; Fig. 16 Fishing boat; Fig. 17 Pills; Fig.18 Bear; Fig. 19 New york; Fig. 20 Opera.