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A Robust Watermark Embedding in Smooth Areas

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ABSTRACT

Robustness is one of the most important properties of watermarking, the watermark should be readable from images that underwent common attacks such as lossy compression or Joint Photographic Experts Group (JPEG). While many publications consider the relation between smoothness and quality of the images, few studies only concentrate on the relation between smoothness and watermarking robustness. This study focuses on watermark robustness on different smooth areas. The effectiveness of lossy compression on different smooth intensity areas was tested and the average of pixel value change before and after compression for each field of smoothness intensity was found to embed the watermark objects within less effective areas.

Key words: Smoothness, human visual system, pixels intensity, lossy compression, joint photographic experts group

INTRODUCTION

A digital watermark is a perceptually transparent pattern inserted in an image using an embedding algorithm and a secret key. One of the most important properties of a watermark is robustness with respect to image distortions, it must be difficult for an attacker to remove watermark purposely (Qureshi and Tao, 2006). this means that the watermark should be readable from images that underwent common attacks (Fridrich, 1998).

In recent years, many algorithms were proposed to embed robust watermark in digital images. Many of them focused on the robustness to common signal processing such as low pass filtering, rotation, scaling, cropping and compression (Abdulfetah *et al*., 2010; Khan *et al*., 2008; Jin and Peng, 2006) and some claimed that their algorithms are robust to Joint Photographic Experts Group (JPEG) compression (Langelaar *et al*., 1999; Wong *et al*., 2000). However, these algorithms usually use normalized correlation as the measurement to detect the existence of watermark information that is not suitable for data hiding. In study of Bender *et al*. (1996), several data hiding techniques are proposed but they are not robust to JPEG compression. Embedding a bit sequence in the digital image is a difficult task since the bit sequence should be decoded correctly. Spread spectrum techniques (Cox *et al*., 1997; Wong *et al*., 2000), use to embed the watermark but the embedded data, may be significantly suppressed by JPEG compression.

Another important attribute of watermarking is the perceptual invisibility. The quality of the watermarked image is very important for the final user (Al-Jaber and Aloqily, 2003) and no compromise should be made on this issue when parallelizing the watermarking scheme (Oscar *et al.*, 2001). The human visual system HVS is less sensitive to changes in regions of high luminance. This fact can be exploited by making the watermark gain factor luminance dependent (Kutter *et al.*, 1997). Furthermore, since the human eye is least sensitive to the blue channel, a perceptually invisible watermark embedded in the blue channel can contain more energy than a perceptually invisible watermark embedded in the luminance channel of a color image (Kutter *et al.*, 1997; Areepongsa *et al.*, 2000; Karybali and Berberidis, 2004). Around edges and in textured areas of an image, the HVS is less sensitive to distortions than in smooth areas. This effect is called spatial masking and can also be exploited for watermarking by increasing the watermark energy locally in these masked image areas (Macq and Quisquater, 2005; Jain and Uludag, 2002). In other words, the pixel intensities in a block are changed depending on the contrast of the block. If the contrast of the block is large, the intensities can be changed by a bigger amount without introducing any noise. If the contrast is small, the intensities can only be tuned slightly (Lee and Lee, 1999).

The smoothness concept is different from one study to another; smooth areas, edge areas, texture and contrast, all these words refer to the concept of smoothness. Bruyndonckx *et al.* (1995) developed an algorithm to manipulate the luminance of zones of pixies in pixel blocks of size 8×8. This gives XY/64 possible sites. Random site selection was used and qualitative site selection was introduced. Another algorithm based on 8×8 has been developed by Zhao and Koch (1995). The algorithm is compatible with JPEG compression with quality factor 50%.

Bender proposes patchwork in which a watermark is embedded into the image by modifying the statistical property of the image (Bender *et al.*, 1996). The difference between any pair of randomly chosen pixels is Gossip distributed with a mean zero. He also proposed texture block coding in which a block from a region with a random texture is copied and placed in a region with similar texture. In study of Lee and Chen (2000), 3×3 pixels for each study area have been selected and each pixel, the capacity evaluation component uses the grey-scale variation of neighboring pixels and its intensity to evaluate its embedding capacity. Wang and Wiederhold (1999) extracted a rough smoothness region overlay for each image; they used the variances of 4×4 blocks in the intensity band to distinguish five different smoothness classes. Wu and Tsai (2003) partitioned the host image into non-overlapping blocks of two consecutive pixels, say p_i and p_{i+1}. From each block they can obtain a difference value d_i by subtracting p_{i+1} from p_i, if $d_i \approx 0$, the pixels p_i and p_{i+1} are located within the smooth areas. Otherwise, the pixels are located on the edged areas.

Another study on detection of embedding by noise adding is the paper by Harmsen and Pearlman (2003) where the detection relies on the fact that adding noise to the host image smoothes out its histogram. Yilmaz *et al.* (2003) applied different methods for smooth and non-smooth blocks by embedding into edge orientation. The block is first classified as an edge block by computing the gradient magnitude. In study of Campisi *et al.* (2004), the image has been partitioned into blocks in such a way that a curved edge in the edge image is represented as segments of line in some adjacent blocks.

Robust watermarking using the wavelet transforms and edge detection has been described by Ellinas (2007). This is attained by embedding the watermark transparently with the maximum possible strength. The watermark embedding process is carried over the subband coefficients that lie on edges, where distortions are less noticeable, with a subband level dependent strength.

Three different steganographic methods for gray level images have been presented by Hossain *et al.* (2010): Four neighbor's diagonal neighbors and eight neighbors' methods are employed in their scheme. The methods utilized a pixel's dependency on its neighborhood and psycho visual redundancy to ascertain the smooth areas and complicated areas in the image. In the recent research (Zeki and Manaf, 2011) used Intermediate Significant Bit (ISB) watermarking method based on average of block of pixels together in order to improve the watermarking method to be more resistant against attacks than a single pixel.

From the above studies, it is clear that many researches study the relation between smoothness and quality of the images, while few studies only concentrate on the relation between smoothness and robustness. This study concentrates on smoothness and robustness with acceptable image quality.

THE RESEARCH APPROACH

This study focuses on the watermark robustness on the different smooth areas. The effectiveness of lossy compression on different smooth intensity areas will be tested here and the less effective areas will be selected for hosting watermark objects. In this study, one of these common attacks is Joint Photographic Experts Group (JPEG) which is considered a lossy compression; this compression will be applied to the images in order to test the robustness of the watermarking. JPEG is a common image format in the internet and can potentially be used to hide data of embedding watermark for copyright control. The following steps will be applied for this study:

Step1: Selecting different host images
Step2: Partitioned each image into blocks, each block contains 3×3 pixels
Step3: The maximum pixel value P_{max} and the minimum pixel value P_{min} in each block will be found
Step4: The difference between P_{max} and P_{min} will be found
Step5: Lossy compression will be applied to the images
Step6: Comparison between the images before and after the compression based on different smooth areas will be done
Step7: The average of pixels value change for each field of smoothness intensity will be found
Step8: Embedding watermark objects within less effective areas

IMPLEMENTATION AND EXPERIMENTAL RESULTS

In this study, three gray scale images have been chosen in order to study the watermark robustness on the smooth areas, each of the selected images contains 300×300 pixels. The images have been partitioned into blocks, each block contains 3×3 pixels and the total number of partitioned blocks is 10,000 blocks (example for one block is shown in Fig. 1).

The maximum pixel value P_{max} and the minimum pixel value P_{min} in each block have been found, the difference between them d has been found as shown in Eq. 1, in order to calculate the intensity of the blocks.

$$d = P_{max} - P_{min} \tag{1}$$

The smoothness intensity has been arranged in a table starting from smooth areas to edged areas and the number of blocks in each field of smoothness intensity has been found for all host images: Image 1, 2 and 3, as shown in Table 1.

50	30	100
199	70	66
45	144	90

Fig. 1: Finding the maximum point (2,1) and minimum point (1,2)

Table 1: The number of blocks in each field of smoothness intensity for three images

Number of blocks in image 3	Number of blocks in image 2	Number of blocks in image 1	$d = P_{max} - P_{min}$	
4963	4881	5910	[0-15]	Smooth area
2744	1645	1392	[16- 31]	
792	1196	772	[32-47]	
453	697	430	[48-63]	
278	491	355	[64-79]	
223	380	296	[80-95]	
188	348	269	[96-111]	
119	198	295	[112-127]	
95	110	149	[128-143]	
69	40	70	[144-159]	
54	10	35	[160-175]	
18	4	22	[176-191]	
4	0	5	[192-207]	
0	0	0	[208-223]	
0	0	0	[224-239]	
0	0	0	[240-255]	Edge area

From the above results, it is clear that the intensity of most of the blocks is located in the first range which is considered very smooth areas, while the number of blocks in other ranges gradually decreased from smooth to edged areas. JPEG, as an example of lossy compression, is applied to Image 1, 2 and 3. JPEG is a simple attack that does not change the geometry of the image and does not use any of prior information about the watermark. This attack does not treat the watermark as noise. Three different compression rates of JPEG have been applied as follows: JPEG90, JPEG70 and JPEG50. The pixel values of the images have been changed after compression. The total pixel value change has been calculated here for each block (3×3 pixels) by calculating the difference between the pixel value before and after compression. By dividing the above value by 9, the average of pixel value changed for each block will be found. Finally the average pixel value change Av for each field of smoothness intensity was found in Eq. 2:

$$Av = \left(\sum_{n=1}^{9} p' - p/9\right)/N \qquad (2)$$

p is the original pixel and p' is the pixel after compression. N is Number of blocks in each field of smoothness intensity. Table 2 shows the pixel value change for each field of smoothness intensity for all the images at different percentages.

Table 3 shows the average of the pixels when changed for the three images together at different percentages, 90, 70 and 50%.

Table 2: The pixels value change of each field of smoothness intensity for three images

	JPEG 90 %			JPEG 70 %			JPEG 50 %		
$d = P_{max} - P_{min}$	Image 1	Image 2	Image 3	Image 1	Image 2	Image 3	Image 1	Image 2	Image 3
[0-15]	12.6269	13.7822	17.8243	17.3164	19.3886	24.1056	20.7421	22.2858	27.3885
[16-31]	21.6559	22.2547	22.0477	36.2227	38.2122	33.6596	42.6494	46.7745	38.6261
[32-47]	24.4741	24.1798	24.5253	45.0725	45.9339	42.4217	53.9016	56.3336	50.3573
[48-63]	24.9256	24.7719	25.1722	50.0977	50.2669	47.6600	61.4791	63.9412	57.5960
[64-79]	25.9239	24.8574	24.5432	57.0366	53.7780	50.0288	71.7831	69.7862	61.9820
[80-95]	26.7905	26.0395	24.8789	60.4561	56.0605	52.9955	77.5439	73.3079	64.2960
[96-111]	27.3383	25.9080	24.9255	60.2825	56.5172	55.0213	82.0743	76.3793	69.0691
[112-127]	23.8508	25.0606	24.1008	52.1153	57.7626	50.1765	68.7051	75.2626	68.7983
[128-143]	26.1812	24.6727	24.6000	62.6309	60.8455	54.6105	82.3154	82.2000	79.5579
[144-159]	24.2857	23.5000	24.3768	56.3429	63.7250	55.2609	74.4571	91.2250	72.1884
[160-175]	24.5714	28.0500	23.2407	49.2000	65.3000	48.3148	75.8286	70.7000	69.8333
[176-191]	28.3182	22.5000	21	60.9545	85.5000	46	90.1364	111.750	62.0556
[192-207]	28	0	24.2500	88.6000	0	56.2500	126	0	98.5000
[208-223]	0	0	0	0	0	0	0	0	0
[224-239]	0	0	0	0	0	0	0	0	0
[240-255]	0	0	0	0	0	0	0	0	0

Table 3: The average pixels value change of each field of smoothness intensity for three images

$d = P_{max}-P_{min}$	JPEG 90%	JPEG 70%	JPEG 50%
[0-15]	32.35053333	44.7402	47.26393333
[16-31]	51.25983333	85.65476667	79.81142222
[32-47]	56.829	105.1469667	91.87798889
[48-63]	58.08823333	116.2512667	96.83865556
[64-79]	58.96236667	127.4908667	101.4593222
[80-95]	61.12296667	134.1817667	105.8502222
[96-111]	61.5548	135.1401333	106.6015111
[112-127]	56.945	126.6034	99.14613333
[128-143]	59.0539	141.6799	78.73853333
[144-159]	55.9113	138.4882	130.4597
[160-175]	60.3683	130.6049333	103.9032778
[176-191]	57.8182	161.7878333	111.7474778
[192-207]	40.125	116.725	58.3625

From the above results, it can be noticed that the compression rate for smooth blocks is lower than for textured block images. The Table 2 and 3 also show that only if the difference between maximum and minimum pixel value in each block is less than 16 ($d<16$) will minimum change happen; while for other fields of smoothness intensity the change was too big, this was also seen in the values.

EMBEDDING PROCESS

The calculation is done without embedding any watermark objects within the host images. The result showed that the effect of JPEG compression on smooth areas was less than on edge areas. In this section, the real watermarking embedding is introduced by spatial domain technique, gray scale images (8 bits per pixel) eight planes can be presented. The first plane presents the most significant bits and the last plane present the least significant bits. While the most significant bits give the best robustness of watermarking and worst image quality, the least significant bits give the best image quality and worst robustness of watermarking. In this study, the fifth plane has been selected for watermark embedding because this plane gives acceptable image quality for whatever type of images applied (Zeki and Manaf, 2009). Logo image with 70×70 pixels, will be embedded within the above three host images. The embedding will be done within the smooth blocks first and then within the textured blocks.

The Bit Correct Ratio (BCR) will be used to compare the extracted object (logo) after applying JPEG compression to all host images, the BCR is shown in Eq. 3:

$$BCR_{(W,W')} = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} W_{i,j} \oplus W'_{i,j}}{m \times n} \quad (3)$$

where, W is the original watermark object while, w′ is the extracted one, m and n is the size of watermark object in 2 dimensions. The quality of the watermarking image was tested after every embedding by calculating the Peak Signal to Noise Ratio (PSNR) value which is use to calculate image quality (Eggers *et al.*, 2000). The PSNR must be greater than 30 dB, otherwise the watermark will be visible. The greater the PSNR, the better the image quality. The PSNR is defined as Eq. 4:

$$PSNR = 10\log_{10}\left(\frac{255^2}{\frac{1}{m \times n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}(aij - \beta ij)^2}\right) dB \quad (4)$$

α_{ij} is the pixel of the host image in which the coordinate is (i, j) and β_{ij} is the pixel of the watermarking image in which the coordinate is (i, j). (m, n) is the size of the host image. Table 4 shows the bit correct ratio for the extracted logo from smooth areas in additional to PSNR, while Table 5 shows the bit correct ratio for extracted logo from textured areas in additional to PSNR. The watermark embedding was done for the three different host images. Three qualities of JPEG compression have been applied as shown in Table 4 and 5.

Table 6 shows the difference of BCR between textured areas (d = 16) and Smooth areas (d>16) for all images together, for different levels of images lossy compression JPEG 90%, JPEG 70% and JPEG 50% and are further represented in Fig. 2.

From Table 4-6, it can be noticed that the Bit Correct Ratio (BCR) in smooth blocks is bigger than BCR for textured blocks. That means the watermark extracted percentage in the smooth blocks is better than in the textured blocks. In other words, embedding watermark within

Table 4: Bit correct ratio (BCR) for the extracted logo from smooth areas in three images and the peak signal to noise ratio (PSNR)

	Smooth areas (d<16)					
Qualities of JPEG	Image 1		Image 2		Image 3	
compression	BCR	PSNR	BCR	PSNR	BCR	PSNR
JPEG 90	74.5893	46	74.2194	46	70.2296	45
JPEG 70	69.3061	42	67.8393	42	62.1837	43
JPEG 50	67.1913	40	65.9439	41	60.4643	41

Table 5: Bit correct ratio (BCR) for the extracted logo from textured areas in three images and the peak signal to noise ratio (PSNR)

Qualities of JPEG compression	Textured areas (d> = 16)					
	Image 1		Image 2		Image 3	
	BCR	PSNR	BCR	PSNR	BCR	PSNR
JPEG 90	67.8036	45	65.2653	46	65.9158	45
JPEG 70	55.7679	42	52.2321	42	53.0179	43
JPEG 50	54.6633	40	51.3087	41	51.8469	41

Table 6: The difference of BCR between textured areas (d = 16) and smooth areas (d>16)

Qualities of JPEG compression	Smooth areas BCR (d<16)	Textured areas BCR (d = 16)
JPEG 90	73.01276667	66.32823333
JPEG 70	66.44303333	53.67263333
JPEG 50	64.53316667	52.6063

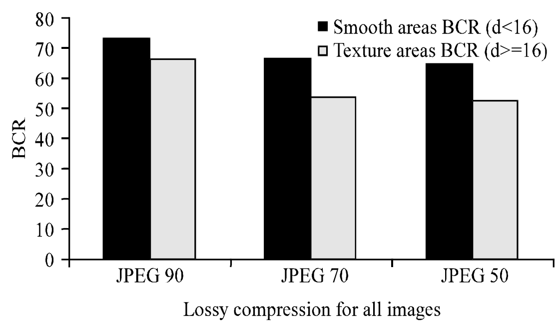

Fig. 2: The difference of bit correct ratio (BCR) between textured areas (d = 16) and smooth areas (d>16)

smooth areas gives more robust watermarking than textured areas. The Peak Signal to Noise Ratio (PSNR) for every embedding ranges between (40-46 dB), that means the watermark is invisible for every embedding.

CONCLUSION

An important property of a watermark is robustness with respect to image distortions. This means that the watermark should be readable from images that underwent common image processing operations. In this paper JPEG compression has been applied to test the robustness of the watermarking. Three gray scale images with 300×300 pixels have been chosen in this study, the images have been partitioned into blocks and each block contains 3×3 pixels. The maximum pixel value P_{max} and the minimum pixel value P_{min} in each block have been found. The difference between them was found, in order to calculate the intensity of the blocks. The average of pixel value change for each field of smoothness intensity has been tested here after applying JPEG90, JPEG70 and JPEG50. It can be noticed that the compression rate decrement for textured blocks is lower than for smooth block images. The result shows that only when d<16 is applied, the minimum change may happen; while for other fields of smoothness intensity (d = 16) the change was too big. The bit correct ratio in smooth blocks and texture blocks has been tested here and it can be seen that the watermark extracted percentage in smooth blocks is better than in textured blocks. In other words, embedding watermark within smooth areas gives more robust watermarking than textured areas.

FUTURE WORKS

- Although this study use LSB technique, further research can be extended to apply to any techniques based on LSB such as Intermediate Significant bits ISB
- The PSNR which is the standard measurement method for testing the quality of the images, needs more studies, because it couldn't differentiate between smooth and textured areas, while the eyes can detect the noise in smooth area more than in textured areas
- Although in this study, grayscale host images have been used to cover watermark objects, this research can be applied directly to color images (RGB) for each color of Red, Green and Blue are exactly the same as the color of gray, the color images have a chance to host triple information compared to grayscale images

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