Robust Digital Watermarking Method Based on Bit-Planes' Ranges

Akram M. Zeki[1] and Azizah A. Manaf[2]

Faculty of Computer Science and Information System, University Technology Malaysia

[1]akramzeki@yahoo.com, [2]azizah07@citycampus.utm.my

Abstract: Least Significant Bit (LSB) is simple and fast calculated method for hiding watermarking, but it cannot protect itself from signal processing variations due to attacks. A watermark is only useful if it is resistant to typical image processing operations as well as to malicious attacks. In this study, watermarking technique based on bit-planes has been developed in order to improve the robustness of direct embedding by LSB technique. The ranges of each bit-plane have been found that in each range the bit changes between 0 and 1. In this study, the middle of the range has been choosing to be the location of the watermarked pixel so any change on the pixel by attacks will minimally affect the selected bit and this is will improve the robustness of the extracted image.

Keywords: Watermarking, Bit-plane, LSB, Robustness.

Akram M. Zeki has obtained his B.Sc. from University of Jordan, Amman, Jordan in August 2000 and his MSc in Computer Graphics from Faculty of Computer Science and Information Technology at University Putra Malaysia in April 2004. Currently he is doing a PhD research in Watermarking at the Faculty of Computer Science and Information System at University Technology Malaysia.

Prof. Azizah A. Manaf, received her B.Sc. degree in Electrical Engineering at University Technology Malaysia in 1980 and her MSc in Computer Science at University Technology Malaysia in 1985. She holds a Ph.D. degree in Image Processing from the Computer Science Department at University Technology Malaysia in 1995. Her research interests include: Image Processing, Watermarking, Steganography, Pattern Recognition and Computer Graphics

1. Introduction

Watermarking is the direct embedding of additional information into the original content or host image. Ideally, it should be no perceptible difference between the watermarked and original image, and the watermark should be difficult to remove or alter without the degradation of the host image [1] [2]. A watermark usually is a binary sequence representing a serial number or credit card number, a logo, a picture or a signature. It is used to prove the copyright or ownership. Moreover, it is a best way to identify the source, creator, owner, distributor, or authorized consumer of a multimedia [3] owing watermarking scheme or having permanent and credit card number [2].

Clearly a watermark is only useful if it is resistant to typical image processing operations as well as to malicious attacks. However, it is important to note that the level of robustness required varies with respect to the application at hand [4] [5]. 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* as given by Equation 1, gives maximum value of *NCC* as unity [6] [7].

$$NCC = \frac{\sum_x \sum_y W(x,y)w'(x,y)}{\sum_x \sum_y [W(x,y)]^2} \qquad (1)$$

Another important requirement of an ideal watermarking system is that of statistical imperceptibility [8]. The watermarking algorithm must modify the bits of the cover in such a way that the statistics of the image are not modified in any telltale fashion that may betray the presence of a watermark. However, since users of watermarked data normally do not have access to the host data, they cannot perform this comparison. Therefore, it is sufficient that the modifications in the watermarked data go unnoticed as long as the data are not compared with the original data. The peak signal to noise ratio (PSNR) has been tested here to study the quality of the watermarking image. In general, a processed image is acceptable to the human eyes if its PSNR is greater than 30 dB [9]. The larger the PSNR, the better is the image quality. The PSNR is defined as given by Equation 2 [10] [11].

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

α_{ij} is the pixel of the cover image in which the coordinate is (i, j) and β_{ij} is the pixel of the watermarked image in which the coordinate is (i, j). (m, n) is the size of the cover image and watermarked image.

2. Bit-Plane Method

In the grey scale images, each pixel is decomposed into its 8 different bits. The plane formed by the same bit of each pixel in a grey scale image is called a bit-plane. Watermark object can be applied in any of this 8 bit-planes or may be in more than one plane. While embedding watermark within the 8^{th} bit-plane (Least Significant Bits LSB) gives best image quality, embedding within the 1^{st} bit-plane (Most Significant Bits MSB) gives worst image quality. The quality of watermarked image will be improved by embedding when starting from 1^{st} bit-plane to 8^{th} bit-plane; on the opposite side robustness of watermarking is improved by embedding when starting from 8^{th} bit-planes to 1^{st} bit-planes [12].

Least Significant Bit (LSB) technique is the earliest developed technique in watermarking and it is also the most simple, direct and common technique. It essentially involves embedding the watermark by replacing the least significant bit of the image data with a bit of the watermark data. The human visual system HVS is insensitive to the value change in these areas. Thus, we can use these areas to embed messages [13]. LSB method is very simple, time-saving and efficient, but the capacity of information store is limited and easy to be destroyed and it is unsafe [14]. An improvement on basic LSB substitution would be to use a pseudo-random number generator to determine the pixels to be used for embedding, based on a given key. Security of the watermark would be improved as the watermark could no longer be easily viewed by intermediate parties.

3. Related Works

Many researches have been conducted to eliminate the disadvantages of LSB technique. Some of them are proposed to embed robust watermark in digital images. Many others focus on the robustness to common signal processing [15] [16] [17] [18] and some claimed that their algorithms are robust to JPEG compression [19] [20] [21]. However, those algorithms usually use normalized correlation as the measurement to detect the existence of the watermark information that is not suitable for data hiding.

Schyndel [22] proposed a method based on bit plane manipulation of the least significant bit (LSB) which offers easy and rapid decoding. Bender [23] proposes patchwork in which a watermark is embedded into the image by modifying the statistical property of the image. The resulting watermark is predominantly high frequency. However the authors recognize the importance of placing the watermark in perceptually significant regions and consequently modify the approach so that pixel patches rather than individual pixels are modified, thereby shaping the watermark more to significant regions of the human visual system. Voyatzis and Pitas [24], provided the theory that applies torus automorphism on watermarking techniques in 1996. Watermarking scrambled by torus automorphism then hide into least significant bits, LSB of the images. The illegal person can change LSB and then remove the watermarking, so the method is very much insecure. In 1997, they provided an improved method [25], but still can only protect from the attack of JPEG (Join Photographic Experts Group) and fussy image processing. So the method was still not very practical. Langelaar [26] provided the method of dividing original images into 8x8 not overlapped blocks and take out Y-image (luminance channel) as to be the hiding place of watermarking. After getting the JPEG compression rate, the fix level of every image block will be determined. One bit will be hidden within one selected block, and this block will be determined by a secret key.

Hashida [27] provided the technology, which is used for digital watermarking images. This method which can prevent the destruction of JPEG compression can also retrieve the watermarking ID pattern after brightness/contrast image adjustment. Kutter [28] proposed a digital watermarking technique for color image in 1998. The proposed method used the amplitude modification scheme to embed the digital watermark into the blue channel of color image. The Kutter declared that the proposed method could resist the JPEG lossy compression attack, image blur processing and image rotation attacks. But the proposed method only can be applied to the color images. And attackers could easily remove the digital watermark from watermarked image by following the proposed watermark embedding process. Miller

[29] describes a better method using informed coding and embedding technique. Image fidelity is improved by the incorporation of perceptual shaping into the embedding process. Experiments indicate the watermark is robust to significant distortion, including additive noise, low pass filtering, changes in contrast, and lossy compression.

4. The Proposed Method

In this study, watermarking technique based on bit-planes ranges has been developed in order to improve the robustness of direct embedding by LSB technique. The first step is to select one bit-plane from 1 to 8 for embedding the watermark. That means the capacity of watermark embedding is 1/8 (12.5 % from the original image). The embedding process will be done by inserting the bits of watermark object within the selected bit-plane of the cover image.

The value of each bit of the 8 bit-plane can be presented by 2^n, where n is order of the plane starting from 0 to 7 as shown in Figure 1. i.e: (20 + 21 + 22 + 23 + 24 + 25 + 26 + 27) = (1 + 2 + 4 + 8 + 16 + 32 + 64 + 128) = 255. The maximum value that can fit in 8 bits is 255 and the minimum value is 0. Any modification to 8^{th} bit-plane will change the pixel value by ±1, the 7^{th} bit-plane by ±2, the 6^{th} bit-plane by ±4, the 5^{th} bit-plane by ±8, the 4^{th} bit-plane by ±16, the 3^{rd} bit-plane by ±32, the 2^{nd} bit-plane by ±64, and the 1^{st} bit-plane by ±128. As a result, if the changed value is small (such as in 8^{th} bit-plane), the image quality is good. While a big changed value (such as 1^{st} bit-plane) causes the image quality to be highly distorted.

$MSB_{n=7}$							**$LSB_{n=0}$**
1^{st} bit plane							8^{th} bit plane
128	64	32	16	8	4	2	1

The value of each of the 8 bit-plane (2^n)

Figure 1. Eight bit-planes from MSB to LSB.

The next step after selecting one bit-plane for embedding is finding ranges of the chosen bit-plane, the length of the range L is 2^n (L is the maximum value of each range – the minimum value of the range + 1) and the number of ranges in each bit-plane are 256 / L, we can notice that in each range the bit changes between 0 and 1. The number of ranges for the first bit-plane are 2 only, as follows [0:127] and [128:255]. In other words, the bit in the first range is 0, while the bit in the second range is 1 and the length of each range of the first bit-plane is 128. For the second bit-plane there are 4 ranges as follows: [0:63] [64:127] [128:191] [192:255] and the length of the ranges is 64, and so on, as shown in Table 1.

Table 1. Ranges of each bit-plane with the length.

Bit -Plane	Length of the ranges	Number of ranges	Ranges
1	128	2	[0:127] [128:255]
2	64	4	[0:63] [64:127] [128:191] [192:255]
3	32	8	[0:31] [32:63] … [192:223] [224:255]
4	16	16	[0:15] [16:31] … [224:239] [240:255]
5	8	32	[0:7] [8:15] … [240:247] [248:255]
6	4	64	[0:3] [4:7] … [248:251] [252:255]
7	2	128	[0:1] [2:3] … [252:253] [254:255]
8	1	256	[0] [1] … [254] [255]

In this method, every pixel used for embedding (watermarked pixel) will be moved to be in the middle of the range, so that any change on the pixel by attacks will minimally affect the selected bit. While if the pixel value is located in the in the edges of the range, any small change by attacks will move the pixel from a range to the next or previous range. In this case, the selected bit will be changed from 0 to 1 or vice versa. Due to this change, the watermark cannot be extracted. By choosing the watermarked pixel to be in the middle of the range, the same range will be selected if the embedded bit is 1 and the selected bit of the original pixel value was 1 too, or embedding 0 if the original pixel value was 0. But if the selected bit of the original binary pixel is not the same as the embedded one, the middle of the previous or next range will be selected. The new range will be determined depending on its distance to the original pixel value. In other words, selecting nearest range to the original pixel will improve the quality of watermarked image, while choosing the middle of the range to be the location of the watermarked pixel will improve the robustness of the extracted image. Notice that there are two middle values since the number of pixels in a range is even, so the nearest value to the original pixel will be selected to be the watermarked pixel.

Although there are few ways to calculate the middle value of the ranges, one of these methods will be used here as follows: each range will be divided into two equal groups, the length of each group is $M = L/2 - 1$. In case the original bit is the same as the embedded one and the original pixel was in the left group, the watermarked pixel will be (the maximum value of the same range – M). Otherwise if the original pixel was in the right group, the watermarked pixel will be (the minimum value of the same range + M). In case the original bit is not same as the watermark (logo) bit and the original pixel was in the left group the watermarked pixel will be (the maximum of the previous range - M), while if the original pixel was in the right group (the watermarked pixel will be the minimum of the next range + M). The proposed method can be presented by few steps as follows:

- Selecting the level of LSB (bit-plane) from 0 to 8.
- Finding the length of the range of the selected bit-plane by $L = 2^n$ (n for 1st bit-plane is 7 while for 8th bit-plane is 0).
- Creating ranges' table of the selected bit-plane. (Number of ranges is 256 / L).
- Each range will be divided into two equal groups, the length of each group is $M = L/2 - 1$.
- In case the original bit is the same as the watermark bit, the following steps will be done:
    - If the original pixel is in the left group, the watermarked pixel will be (the minimum value of the same range + M).
    - While if the original pixel is in the right group, the watermarked pixel will be (the maximum value of the same range – M).
- In case the original bit is different from the watermark bit, the following steps will be done:
    - If the original pixel is in the left group, the watermarked pixel will be (the maximum of the previous range – M).
    - While if the original pixel is in the right group, the watermarked pixel will be (the minimum of the next range + M).
    - If the original pixel is in the first range (no matter if it is in the left or right group), the watermarked pixel will be (the minimum of the next range + M).
    - If the original pixel is in the last range (no matter if it is in the left or right group), the watermarked pixel will be (the maximum of the previous range – M).

Figure 2 shows the details of embedding example by the proposed method.

Example

Assume that the original pixel is 130 (10000010) and the third bit-plane has been selected for embedding. Assume that 1 bit from watermark object will be embedded within the selected pixel.

Original image (1st pixel)

The length of the range L is $2^n = 32$
The number of ranges are 256 / L = 8

130 (10000010) Binary code of 130
Selected Bit-plane (3rd) → finding the ranges of 3rd bit-plane
[0:31] [32:63] [64:95] [96:127] **[128:159]** [160:191] [192:223] [224:255]

Each range will be divided into two equal groups, the length of each group is M = L/ 2– 1 = **15**. i.e: [(0:15)(16:31)] [(32:47)(48:63] [(64:79) (80:95)] [(96:111)(112:127)] **[(128:143)(144:159)]**[(160:175)(176:191)][(192:207)(208:223)][(224:239)(240:25)]
Notice that the original pixel is in the right group of the range

Embedding Process

Direct embedding (LSB method)
The Watermarked pixel is 10100010 = 162.

Notice that the difference between original and watermarked pixel is |130-162| = 32 and this value is enough to destroy the image quality. At the same time, small changing to the pixel ± 4 by attacks will change the selected pixel from 1 to 0 and the extraction cannot be done

1

Logo image (1st bit)

The Proposed Method
The watermarked pixel is 127-15=112 (the maximum of the previous range-M)
(Because the original pixel is in the left group of the range).

Notice that the difference between original and watermarked pixel is |130-112| = 18, the result is better than the basic LSB which was 32. At the same time, big changes need ± 16 by attacks to the watermarked pixel to change the bit from 1 to 0.

Figure 2. The details of embedding example by the proposed method.

4.1 Experimental Results

The logo of University Technology Malaysia which is in grey scale level image is shown in Figure 3 contains 90 × 90 pixels and will be embedded within three grey scale host images which is shown in Figure 4, and they are containing 256 × 256 pixels.

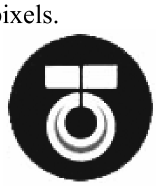


Figure 3. Grey scale logo with 90 × 90 pixels.

Image 1 **Image 2** **Image 3**

Figure 4. Grey scale host images with 256 × 256 pixels.

The peak signal to noise ratio PSNR has been calculated before applying any attacks for the proposed method and the direct embedding method to test the quality of all watermarked images as shown in Table 2. All bit-planes are tested starting from 1st bit-plane (the most significant bits, MSB) through to 8th bit-plane (the least significant bits, LSB).

Table 2. PSNR values of the proposed method and direct embedding method for all bit-plane.

Bit - Planes	Proposed Method			Direct Embedding Method		
	Image 1	Image 2	Image 3	Image 1	Image 2	Image 3
1	9.551874	9.968305	10.92874	8.749611	8.890079	9.274789
2	16.61218	17.09119	16.91668	15.27354	15.2985	14.88271
3	22.89059	23.11656	23.17483	21.01023	21.17093	21.17653
4	29.35279	29.25824	29.34273	27.16578	27.08183	27.1556
5	35.72715	35.71826	35.76612	33.1107	33.10336	33.15363
6	42.71523	42.76842	42.74367	39.1325	39.17207	39.13945
7	51.23908	51.19686	51.20412	45.2193	45.17626	45.18352
8	51.20492	51.1864	51.18962	51.20492	51.1864	51.18962

From the above results, we can notice that the quality of watermarked image has been lightly improved by using the proposed method, although the method is designed to improve the robustness.

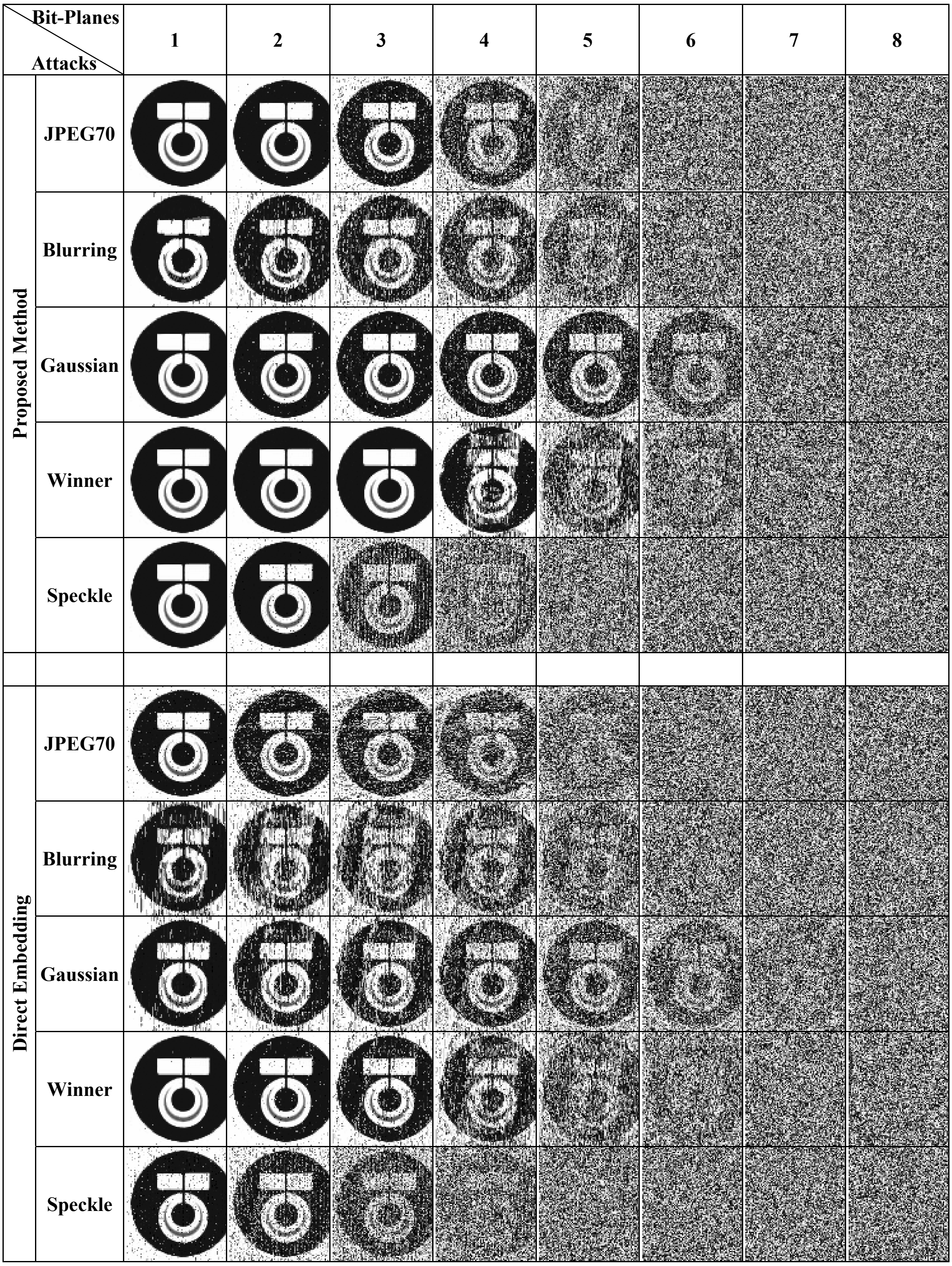
The robustness has been tested after applying different types of attacks, the first attacks has been applied here is JPEG or losy compression. Image Compression is considered as one of the most famous attacks which can be applied on watermarking system. Image compression schemes work by removing redundancy from the image. The part of the image that is considered to be redundant is usually the part that does not affect the perceptual quality of the image. The lower the compression bit-rate is, the larger the amount of redundant data that will have to be removed [30]. The quality of the compression has been tested here is 70. The second attack is blurring the image, this type of filter that softens an image and make it looked blurred, this filter returns a circular averaging filter (pillbox) within the square matrix of side 2 × radius+1 [31], the radius has been used here is 1. The third attack is Gaussian filter [32], which is designed to pass a step function with zero overshoot and minimum rise time; this filter returns a rotationally symmetric Gaussian lowpass filter of size [3 3], it has been used here with standard deviation sigma (0.5). The forth attack is Wiener filter, the goal of this filter is to filter out noise that has corrupted a signal. Wiener method is based on statistics estimated from a local neighbourhood of each pixel of size m-by-n to estimate the local image mean, standard deviation in this study (m and n) is 3. Wiener filter estimates the additive noise power before doing the filtering [33]; the noise in this study is 0.001. The final attack has been tested here is Speckle noise; this method adds multiplicative noise to the image with mean 0 and variance (0.01 in this study) [33].

Table 3 shows the normalized cross correlation NCC for the proposed method compared with direct embedding method in all bit-planes after applying chosen attacks on image 1, and the extracted logos are illustrated in Table 4.

Table 3. NCC value of the proposed method and direct embedding method for all bit-planes after applying chosen attacks on image 1.

	Bit-Planes / Attacks	1	2	3	4	5	6	7	8
Proposed Method	JPEG70	1	0.9972	0.9398	0.8033	0.6321	0.5565	0.5537	0.5503
	Blurring	0.9717	0.9207	0.8779	0.7957	0.6682	0.5855	0.5533	0.5499
	Gaussian	1	0.9885	0.9759	0.9259	0.8244	0.7033	0.5862	0.5637
	Winner	1	1	1	0.9062	0.7232	0.6252	0.5495	0.5346
	Speckle	1	0.9721	0.7861	0.6211	0.5787	0.5622	0.5494	0.5484
Direct Embedding	JPEG70	0.9803	0.9251	0.8308	0.7376	0.6188	0.5543	0.5446	0.5508
	Blurring	0.8572	0.8647	0.7949	0.7242	0.6382	0.5807	0.5540	0.5566
	Gaussian	0.9489	0.9278	0.8692	0.8147	0.7449	0.6710	0.5946	0.5627
	Winner	0.9995	0.9898	0.9377	0.8108	0.6673	0.5997	0.5579	0.5352
	Speckle	0.9614	0.8778	0.6884	0.5953	0.5620	0.5607	0.5482	0.5532

Table 4. Extracted logo after applying chosen attacks of the proposed method and direct embedding method for all bit-planes on image 1.



The same embedding done on image 2 and image 3, the NCC for the both methods has been calculated and all bit-planes have been tested after applying chosen attacks on image 2 as shown in Table 5 and on image 3 as shown in Table 6.

Table 5. NCC value of the proposed method and direct embedding method for all bit-planes after applying chosen attacks on image 2.

	Bit-Planes / Attacks	1	2	3	4	5	6	7	8
Proposed Method	JPEG70	1	0.9954	0.8732	0.6541	0.5711	0.5478	0.5431	0.5313
	Blurring	0.9797	0.7280	0.6688	0.6151	0.5651	0.5514	0.5454	0.5367
	Gaussian	1	0.9126	0.8443	0.6990	0.6250	0.5661	0.5578	0.5431
	Winner	1.0000	1	1.0000	0.9622	0.8026	0.6172	0.5526	0.5446
	Speckle	1	0.9690	0.7351	0.5568	0.5424	0.5491	0.5484	0.5413
Direct Embedding	JPEG70	0.9658	0.9049	0.7762	0.6176	0.5693	0.5511	0.5517	0.5598
	Blurring	0.8875	0.7011	0.668	0.6076	0.5705	0.5585	0.5568	0.5546
	Gaussian	0.9692	0.8142	0.7765	0.6614	0.6004	0.5655	0.5495	0.5465
	Winner	0.9992	0.9855	0.9495	0.8648	0.7145	0.5976	0.5404	0.5506
	Speckle	0.9519	0.8672	0.6377	0.5326	0.5486	0.5464	0.5517	0.5546

Table 6. NCC value of the proposed method and direct embedding method for all bit-planes after applying chosen attacks on image 3.

	Bit-Planes / Attacks	1	2	3	4	5	6	7	8
Proposed Method	JPEG70	1	0.9955	0.9047	0.7068	0.5870	0.5516	0.5502	0.5413
	Blurring	0.9830	0.9501	0.8097	0.6674	0.5953	0.5617	0.5558	0.5489
	Gaussian	1	0.9897	0.9494	0.8472	0.7072	0.6062	0.5724	0.5569
	Winner	1	1	1	0.9282	0.7059	0.6007	0.5565	0.5479
	Speckle	1	0.9878	0.8241	0.5615	0.5664	0.5593	0.5438	0.5454
Direct Embedding	JPEG70	0.9738	0.8957	0.8139	0.6894	0.5885	0.5557	0.5482	0.5454
	Blurring	0.9508	0.8167	0.7522	0.6774	0.5977	0.5614	0.5477	0.5535
	Gaussian	0.9815	0.8798	0.8451	0.7847	0.6720	0.5882	0.5683	0.5608
	Winner	0.9994	0.9826	0.9474	0.8428	0.6706	0.5823	0.5473	0.5455
	Speckle	0.9653	0.8562	0.6952	0.5489	0.5548	0.5632	0.5577	0.5629

From the above results, we can notice that by using the proposed method which choose the middle of the range to be the location of the watermarked pixel, the normalized cross correlation of the extracted logo is better than the direct embedding method, especially in firsts bit-planes which they have big range table. This improvement is decreased when we go from 1st to 8th bit-planes and we can see that for 7th bit-plane and 8th bit-plane (least significant bits) the quality of extracted logo have not been improved nor affected by using this method because the length of the range (7th and 8th bit-plane is 2 and 1 respectively), so the watermarked pixel is in the edges of the range. The results have been found here prove the theory of the middle of the range because the image processing attacks modify the unused bits of the images, and these modifications are very small that the human eyes can not detect. By choosing the middle of the range to be the location of the watermarked pixel, any small changes by attacks will minimally affect the selected bit.

5. Conclusion

Least Significant Bit (LSB) technique is the earliest developed, direct and common technique. It is very simple, time-saving and efficient, but the capacity of information store is limited and easy to be destroyed (It is unsafe). In this study, a grey scale logo has been embedded within host grey scale images by proposed method which is an improved LSB method to be more robust with better quality of watermarked image. In this study range's table for each bit-plane have been found, and the nearest range to the original pixel has been selected to be in the location for the watermarked pixel in order to improve the quality of watermarked image. Choosing the middle of the range to be the location of the watermarked pixel will improve the robustness of the extracted image. Few image processing attacks have been applied such as lossy compression, Blurring, Gaussian filter, Winner filter and Speckle noise to test the robustness of the proposed method. The results show that the quality of watermarked images and extracted image have been improved by using the proposed method except least significant bits 7th bit-plane and 8th bit-plane which showed no improvement because the range is small in these planes.

Acknowledgements

We would like to thank Malaysian government for sponsoring this research under IRPA grant number: 7424904.

REFERENCES

1. VOYATZIS, G and PITAS, I., **Protecting Digital-Image Copyrights: A Framework**, IEEE Trans. On Computer Graphics and Application, Vol. 19, No. 1, 1999, pp. 18-24.
2. CHEN, WEN-YUAN., **A Comparative Study of Information Hiding Scheme Using Amplitude, Frequency and phase Embedding**, PhD thesis. National Cheng Kung University, Tainan, Taiwan, 2003.
3. PODILCHUK, C. I. DELP, E.J., **Digital watermarking: algorithms and applications**, IEEE Signal Process. Magazine. 18 (4) (2001) 33-46, 2001.
4. HARTUNG, F. SU, J. K. and GIROD, B., **Spread spectrum watermarking: Malicious attacks and counterattacks**, Proc. SPIE Security and Watermarking of Multimedia Contents 99, San Jose, CA., January, 1999.
5. KAMAL, G., **Information Hiding Using Fractal Encoding**, Master thesis, Indian Institute of Technology Bombay, Mumbai, 2003.
6. MAITY, S. P. KUNDU, M. K**., Robust and Blind Spatial Watermarking In Digital Image**, Proc. 3rd Indian Conf. on Computer Vision, Graphics and Image Processing (ICVGIP '2002), pp. 388 -393, Ahmedabad, India, 16-18th December, 2002.
7. PARAMESWARAN, L. ANBUMANI, K., **A Robust Image Watermarking Scheme using Image Moment Normalization**, Transactions on Engineering, Computing and Technology. ISSN 1305-5313, Vol. 13, May, 2006.
8. PETITCOLAS, F. A. P., **Watermarking Schemes Evaluation**, IEEE Signal Processing Magazine, Vol. 17, September, 2000, pp. 58-64.
9. WU, N., **A Study on Data Hiding for Gray-Level and Binary Images**, Master thesis, Chaoyang, University of Technology, Taiwan, 2004.
10. EGGERS, J. J. SU, J.K. and GIROD, B., **Robustness of a Blind Image Watermarking Scheme**, International Conference on Image Processing (ICIP 2000), Special Session on WM, Canada. September, 2000.
11. STEFAN, W. ELISA, D. GELASCA, T., **Perceptual Quality Assessment for Video Watermarking**, Proc. International Conference on Information Technology: Coding and Computing (ITCC), Las Vegas, NV, April 8-10, 2002, pp. 90-94.
12. AZIZAH, A. MANAF, AKRAM M. ZEKI, SAUYTHI JAAFAR and MOHAMMAD SHAHIDAN, **A Secure Digital Watermarking: An Overview**, Malaysian Science and Technology Congress (MSTC 2006). Putra World Trad Center, Kuala Lumpur,18-20, September, 2006, pp. 225-229.
13. YEUAN, K. L. and LING, H. C., **High Capacity Image Steganographic Model**, IEEE Proc.-Vis. Image Signal Process., Vol. 147, No. 3, June, 2000.
14. WU, C. F., **The Research of Improving the Image Quality of Digital Watermarking Technique and Its Applications**, National Sun Yat-sen University, Kaohsiung, 80424, Taiwan etd-0612101-142904, 2001.
15. SWANSON, M. D. ZHU, B. and TEWFIK, A. H., **Multiresolution Scene-Based Video Watermarking Using Perceptual Models**, IEEE Journal on Selected Areas in Communication, Vol. 16, No. 4, May 1998, pp. 540-550.
16. COX, I., J. KILIAN, J. LEIGHTON, T and SHAMOON, T., **Secure Spread Spectrum Watermarking for Multimedia**, NEC Research Institute, Technical Report, 1995.

17. XIA, X. G. BONCELET, C. G. and ARCE, G. R., **A Multiresolution Watermark for Digital Images**, Proc. of IEEE Int. Conf. Image Processing, Vol. 1, 1997, pp. 548-511.

18. RUANIDH, J. and PUN, T., **Rotation, Scale and Translation Invariant Digital Image Watermarking**, Proc. of IEEE Int. Conf. Image Processing, Vol. 1, 1997, pp. 536-538.

19. LANGELAAR, G. C. LAGENDIJK R. L. and BIEMOND, J., **Watermarking by DCT Coefficient Removal: A Statistical Approach to Optimal Parameter Settings**, Proc. of SPIE Sym. of Security and Watermarking of Multimedia Contents, 1999, pp. 2-13.

20. HARTUNG, F. GIROD, B., **Fast Public-Key Water-marking of Compressed Video**, Proc. of IEEE Int. Conf. Image Processing, Vol. 1, pp-528-531, 1997.

21. WONG, P. H. W. AU O. C. and WONG, J. W. C., **Image Watermarking Using Spread Spectrum Technique in Log-2-Spatio Domain**, to appear in Proc. of IEEE International Symposium on Circuits & Systems (ISCAS). 2000.

22. SCHYNDEL, R. TIRKEL, A. and OSBORNE, C., **A Digital Watermark**, Proc. IEEE International Conference on Image Processing , ICIP-94, Vol. II, 1994, pp. 86-90.

23. BENDER, W. GRUHL, D. MORIMOTO N. and LU, A., **Techniques for Data Hiding**, IBM System Journal, Vol. 35, NOS 3&4, 1996, pp. 313-336.

24. VOYATZIS, G. and PITAS, I., **Chaotic Mixing of Digital Images and Applications to Watermarking**, in Proceedings of European Conference on Multimedia Applications, Services and techniques (ECJVL4ST '96), Vol. 2, May, 1996, pp. 687-695.

25. VOYATZIS, G. and PITAS, I., **Embedding Robust Watermarks by Chaotic Mixing**, in Proceedings of 13t11 International Conference on Digital Signal Processing (DSP'97),Vol. 1, 1997, pp.213-216.

26. LANGELAAR, G. C. VAN DER LUBBE, J. C. A. and LAGENDILK, R. L., **Robust Labeling Methods for Copy Protection of Images**, in Proceedings of SPIE Electronic Imaging'97, Storage and Retrieval for Image and Video Database, pp. 298-309, San Jose(CA), February, 1997.

27. HASHIDA, K. I. and SHIOZAKI, A., **A Method of Embedding Robust Watermarks Into Digital Color Images**, JEICE Transactions on Fundamentals of Electronics, Vol. E81-A, October, 1998, pp. 2133-2137.

28. KUTTER, M. JORDAN, F. and BOSSEN, F., **Digital Watermarking of Color Image Using Amplitude Modulation**, Journal of Electronic Imaging, Vol. 7, No. 2, 1998, pp. 326-332.

29. MILLER, M. L. DOERR, G. J. and COX. I. J.**, Applying Informed Coding and Embedding to Design a Robust, High Capacity Watermark**, IEEE Trans, on Image Processing, June 2004.

30. RAMKUMAR, M., **Data Hiding in Multimedia - Theory and Applications**, PhD thesis, New Jersey Institute of Technology, Newark, New Jersey 07102, January, 2000.

31. MathWorks, Inc. **www.mathworks.com**, last accessed on February 2007.

32. YUAN, Y. B. VORBURGER, T.V. SONG, J. F. RENEGAR, T. B., **A Simplified Realization for the Gaussian Filter in Surface Metrology**, International Colloquium on Surfaces, Chemnitz (Germany), Jan. 31 - Feb. 02, 2000.

33. ALASDAIR, MC. A., **Introduction to Digital Image Processing with MATLAB**. Course Technology. ISBN-10: 0534400116, March 2004.