ภาคผนวก ก

ผลงานวิจัยที่ได้รับการตีพิมพ์เผยแพร่

AISTA 2004 in Cooperation with the IEEE Computer Society Proceedings / ISBN : 2-9599776-8-8
15-18 November, Kirchberg - Luxembourg

An Image Watermarking Technique using Overlap-block

Somkiat WANGSIRIPITAK, Sorakit MORASILPIN, and Kritawan SIRIBOON

***Abstract*-- An image watermarking technique using overlap-block is proposed in this paper. The proposed method uses a binary watermark image, which is permuted before being embedded into a host image. To embed a watermark bit, the block of size 3x3 with 9 predefined weights is used to add/subtract its weights to/from the pixel intensities inside the corresponding block of size 3x3 of the host image. Since the embedded position of the block is in every other pixel and every other line of the host image, each embedded block overlaps each other. Therefore the binary watermark image size is approximately as large as 1/4 of the host image. The abruption between any two blocks is also smoothed by the use of the overlap-block. In the proposed method, the values of the weights are selected adaptively depending on the contrast of the block in the host image. This makes it robust for some lossy image processing operations even though the host image is small, such as the image used in a cell phone. In addition, its simple algorithm makes it easy to implement. Experimental results show the effectiveness of the proposed watermarking method without introducing any distortion.**

***Index Terms*-- copyright protection, image watermarking, overlap-block**

I. INTRODUCTION

IN the past, people kept their visual memories by taking a photograph with a camera using a negative film. When they needed to print it on the paper, they might go to a studio to make a print of a photograph. This made it inconvenient until last decade. However, after scanners and digital cameras are developed, a file of digital image is easily printed to a paper by a personal color printer. Moreover, the evolution of a cell phone attached digital camera makes photo-taking easier and more convenient. According to today technologies, an unlimited number of identical copies of these digital images can be easily reproduced either by the owner or by an unauthorized person who can access these images. If there is no mechanism to assert the ownership of the image owner, most people tend to disregard the intellectual property rights of the image owner. Therefore, an image watermarking technique using overlap-block is proposed in this paper to protect and enforce the intellectual property rights of the image owner.

In the proposed spatial domain method, once the watermark bit at some position is determined, the weighted overlap-block of size 3x3 is selected depending on the value of that watermark bit and the contrast of the corresponding 3x3 neighborhood in the host image. The weights of this block are used to modify the pixel intensities in that neighborhood. This 3x3 overlap-block centers at every other pixel and every other line in the host image, thus each block overlaps one another. In addition, the number of blocks determines the size of the watermark image, which is actually about 1/4 of the host image. The embedding algorithm is not complicated. Although some lossy image processing operations are applied to the watermarked image, the extracted watermark will still be visibly recognizable.

II. PROBLEMS IN SOME PREVIOUS METHODS

"An adaptive digital image watermarking technique for copyright protection" [1] proposed by C. Lee and Y. Lee embed the watermark bit by modifying the pixel intensities within the non-overlap fixed-size block of the host image. If the host image is small in size, such as the image used in a cell phone of which the size is about 128x128 or smaller, and the block is of size 4x4, the watermark image will be of size 32x32 (1/8 of the host image) which is too small to be used in copyright protection. Furthermore, if the 4x4 block is used with the small host image, the variance of each block is prone to have higher value than that of the block in the same host image but larger in size. As the result, its intensities modification will affect the perceptual quality of the underlying host image. Decreasing the block size in order to cope with the problems of the watermark image size and the quality of the host image, however, raises a new problem of the robustness.

III. THE PROPOSED APPROACH

In this section, the image watermarking technique using overlap-block is proposed to solve the problems mentioned above. The proposed method adaptively embeds one of the

Manuscript received September 5, 2001.
S. Wangsiripitak is with the Computer Engineering Department, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520 Thailand (telephone: (+66) 2-739-2400, facsimile: (+66) 2-739-2404, e-mail: kwsomkia@ kmitl.ac.th).
S. MORASILPIN is with the Computer Engineering Department, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520 Thailand (telephone: (+66) 2-739-2400, facsimile: (+66) 2-739-2404, e-mail: s6061007@ kmitl.ac.th).
K. SIRIBOON is with the Computer Engineering Department, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520 Thailand (telephone: (+66) 2-739-2400, facsimile: (+66) 2-739-2404, e-mail: kkkritaw @ kmitl.ac.th).

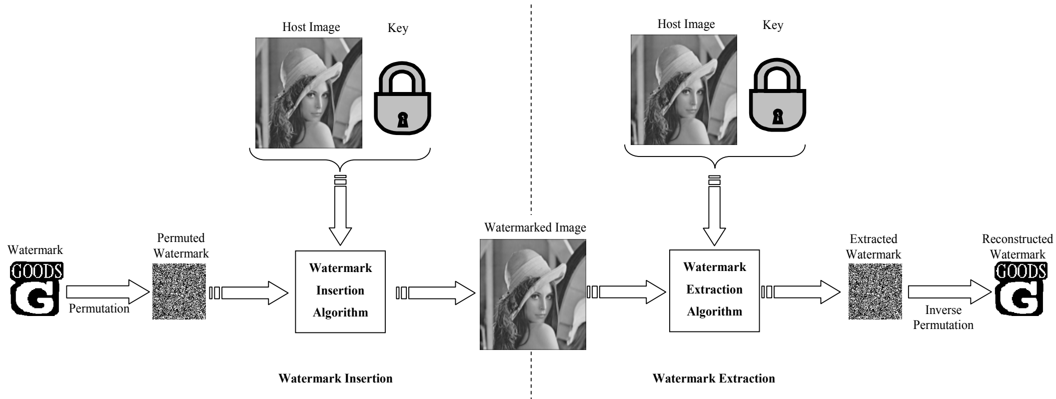


Fig. 1. A block diagram of the proposed watermarking system.

predefined 3x3 blocks representing the watermark bit into the host image at the corresponding image block. The center of embedded position of the predefined 3x3 blocks in the host image is in every other pixel and every other line, thus the embedded blocks are overlapped each other. As the result, the watermark image size is larger than that proposed by C. Lee and Y. Lee [1]. For example, in case of a 128x128 host image, the watermark image is of size 63x63 (1/4 of the host image). In the proposed method, there are 3 types of 3x3 predefined blocks. According to the contrast of the corresponding image block, one of these predefined blocks is selected so that the embedded values could be as large as possible whereas they are not too large to be noticeable to human eyes. This is designed for compromising between the robustness and the perceptual transparency of the embedded watermark. In addition, to prevent tampering, counterfeiting, or unauthorized access, the watermark is first permuted into scrambled data. Fig. 1 shows the block diagram of the proposed watermarking system. In the following subsection, the watermark permutation, embedding, and extraction process are described.

A. Watermark Permutation Algorithm

To prevent the watermark from tampering, counterfeiting, or unauthorized access by attackers, the watermark image is first permuted to be scrambled data before insertion. The watermark permutation strategy is the same as that described in [1]. In addition, another advantage of permutation is the characteristic of distributing a cluster of attacks, i.e., after the watermark extraction and inverse permutation, any attacks concentrating on some area of the watermarked image will be distributed over the reconstructed watermark image. Therefore the watermark image is still overall discernible and perceptive.

B. Watermark Embedding

After the binary watermark image is permuted, each watermark bit is inserted into the host image at every other pixel and every other line. The inserted value is not the value of the watermark bit itself, but the predefined 3x3 weighted block. There are 3 types of predefined 3x3 weighted block used in the proposed method. Fig. 2 shows all of them.

Two important requirements for embedding watermark into the host image are perceptual transparency and robustness. If the image block embedded the watermark block has small

	j-1	*j*	*j+1*
i-1	0	1	0
i	1	5	1
i+1	0	1	0

(a) $\boldsymbol{W_1}$

	j-1	*j*	*j+1*
i-1	0	1	0
i	1	9	1
i+1	0	1	0

(b) $\boldsymbol{W_2}$

	j-1	*j*	*j+1*
i-1	0	1	0
i	1	15	1
i+1	0	1	0

(b) $\boldsymbol{W_3}$

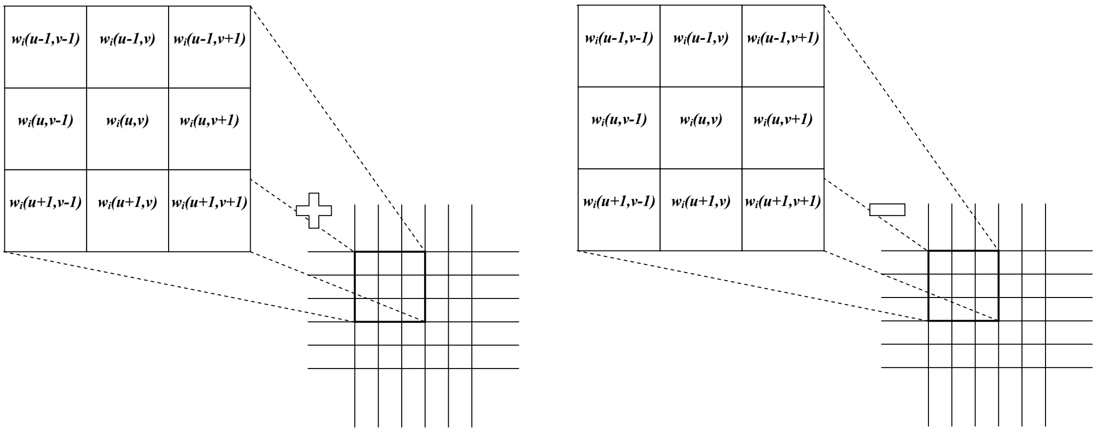
Fig. 2. The block used to embed the watermark bit.

value of variance, i.e., all pixel intensities in the block are approximately the same, modification of pixel intensities in that block with large value will be perceptive by an observer. Thus the value embedded into that image block should be small. On the other hand, if the variance of image block being embedded the watermark block is large, i.e., all pixels in the block have various values, modification of pixel intensities in that block with larger value could be possibly done without any recognition by the observer. In fact, the embedded value should be as large as possible to make watermark robust, whereas should not be too large to be visible by the observer. In the proposed method, considering the optimization between the robustness and invisibility, the center weight values of 3 watermark blocks are designed to be proportional to the standard deviation values of the corresponding image block, i.e., if the standard deviation of the image block is small, the watermark block with small center weight value is chosen, otherwise the watermark block with larger value is chosen instead.

In the insertion algorithm, as the inserted position of the 3x3 watermark block is at every other pixel and every other line of the host image, the inserted values of one block will overlap and interfere the neighbor blocks. However, if these block values are designed properly, the interference will not only not corrupt the neighbor watermark blocks which have the different watermark bit value, but also enhance the neighbor watermark blocks which have the same watermark bit value.

One caution while inserting the watermark is that the neighbor overlap-blocks will be corrupted. Thus before the insertion process starts, the standard deviation of each overlap-block of the host image must be calculated.

Suppose that an image $\boldsymbol{f}$ is of size NxN, where N is an even



(a) If $b_w = 1$. (b) If $b_w = 0$.

Fig. 3. An illustration of the rules for modification of pixel intensities.

number larger than 2. The pixel intensity at coordinates *(i,j)* are represented by *f(i,j)*, where $i,j = 0,1,\ldots,N-1$. Let **B** be a selected image block, the watermark insertion method is described as follows:

Step 1: Calculate the standard deviation, $SD_{B\_u,v}$, of all 3x3 image blocks, $\mathbf{B_{u,v}}$, centering at *(u,v)*, where $u,v = (2*n)-1$ and $n = 1,2,\ldots,(N-2)/2$. Keep all of the $SD_{B\_u,v}$ values in some place for later use

Step 2: Assuming that the embedded value b_w is 0 or 1. Depending on the pre-calculated standard deviation of the corresponding block $\mathbf{B_{u,v}}$ in the host image, select one of the watermark blocks, $\boldsymbol{W_1}$, $\boldsymbol{W_2}$, or $\boldsymbol{W_3}$, in Fig. 2 and use it instead of the watermark bit itself to modify the 9 pixel values in that image block centering at *(u,v)* according to the following rules:

if $b_w = 1$:
- if $SD_{B\_u,v} < 8$: $f(x,y) = f(x,y)+w_1(x,y)$,
- if $8 \le SD_{B\_u,v} < 30$: $f(x,y) = f(x,y)+w_2(x,y)$,
- if $SD_{B\_u,v} \ge 30$: $f(x,y) = f(x,y)+w_3(x,y)$,

if $b_w = 0$:
- if $SD_{B\_u,v} < 8$: $f(x,y) = f(x,y)-w_1(x,y)$,
- if $8 \le SD_{B\_u,v} < 30$: $f(x,y) = f(x,y)-w_2(x,y)$,
- if $SD_{B\_u,v} \ge 30$: $f(x,y) = f(x,y)-w_3(x,y)$,

where $w_i(x,y)$ is the weight value of watermark block $\boldsymbol{W_i}$ at coordinates *(x,y)*, $x = u-1, u, u+1$ and $y = v-1, v, v+1$. Fig. 3 depicts the modification of pixel intensities according to the rules described above.

The embedding weights of watermark block are categorized to 3 categories: low weights, mid weights, and high weights, which are for the image block of low contrast, mid contrast, and high contrast, respectively. Thus it provides the invisibility guarantee and robustness improvement of the watermark. In addition, using overlap-block prevents the blocking artifact since the abruption transition between each neighbor block is merged and smoothed by the overlapped area. Let $\mathbf{B_{u,v}}$ and $\mathbf{B'_{u,v}}$ denote the original and watermarked block at coordinates *(u,v)*, respectively. If the value of inserted watermark bit b_w is 1, the sum of pixel intensities of $\mathbf{B'_{u,v}}$ will be larger than that of $\mathbf{B_{u,v}}$. On the contrary, if the value of inserted watermark bit b_w is 0, the sum of pixel intensities of $\mathbf{B'_{u,v}}$ will be smaller than that of $\mathbf{B_{u,v}}$.

C. Watermark Extraction

In the proposed algorithm, the extraction of the watermark must refer to the original host image. For each position that the watermark block, whcih represents watermark bit, is embedded, the watermark bit value b_w is determined by comparing the sum of the pixel intensities inside the corresponding 3x3 overlap-block of the original host image, denoted S_O , and that of the watermarked image, denoted S_N :

$b_w = 1$ if $S_N > S_O$;
$b_w = 0$ otherwise. ;

The extracted watermark bit values, b_w's, are then inversly permuted to get the reconstructed watermark.

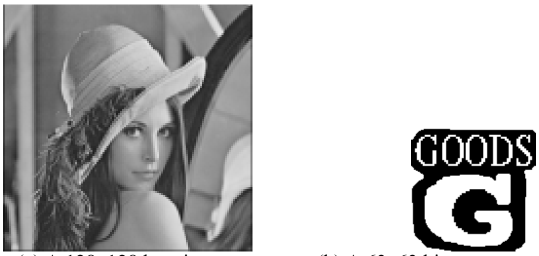
IV. Experimental Results

In the experiments, the host image is of size 128x128 with 256 gray levels. The watermark is a visually recognizable binary image of size 63x63. Figs. 4(a) and 4(b) show a 128x128 host image and a 63x63 binary watermark image, respectively.

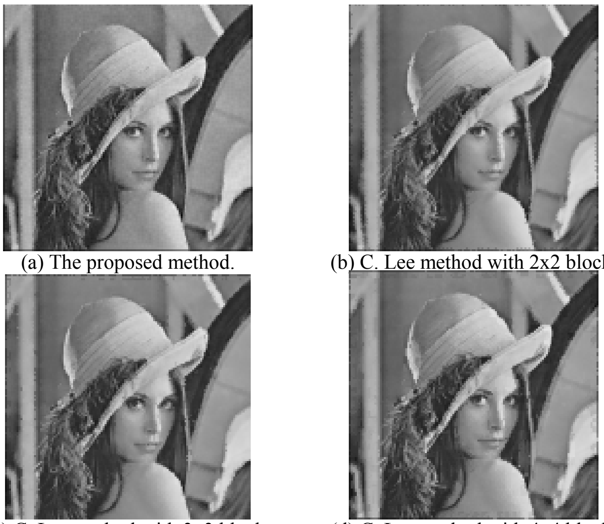
To show the superiority of the proposed method over the method proposed by C. Lee and Y. Lee [1], some lossy image processing operations, such as median filtering, low-pass filtering, lossy JPEG image compression, rotation, resampling, and crop are applied to the watermarked image generated by both methods.

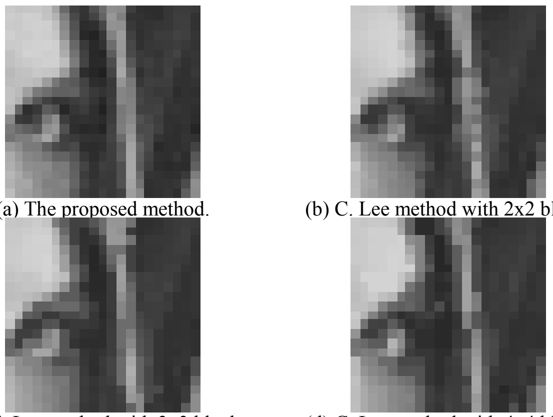
Fig. 5 shows the watermarked images constructed by the proposed method and C. Lee method with the block of size 2x2, 3x3, and 4x4. The corresponding PSNR values are 35.86, 33.97, 32.36, and 31.23 dB, respectively. From PSNR values, the watermarked image constructed by the proposed method has better quality than those constructed by C. Lee method when the original image is of size 128x128.

Fig. 6 shows the zoomed portions of Fig. 5. From Fig. 6, the horizontal transition from the black hair to the highlighted hair closed to the left eye of the proposed method is smoother than that of C. Lee method, as well as the continuity along the



(a) A 128x128 host image. (b) A 63x63 binary watermark image.
Fig. 4. A host image and a binary watermark image.

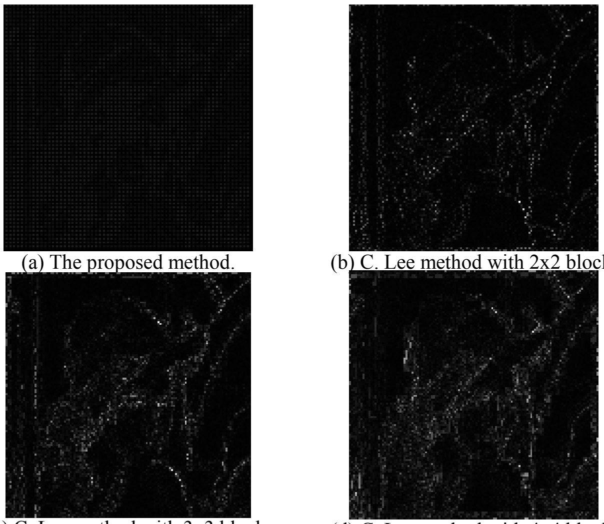

(a) The proposed method. (b) C. Lee method with 2x2 block.
(c) C. Lee method with 3x3 block. (d) C. Lee method with 4x4 block.
Fig. 5. The watermarked images.


(a) The proposed method. (b) C. Lee method with 2x2 block.
(c) C. Lee method with 3x3 block. (d) C. Lee method with 4x4 block.
Fig. 6. The zoomed portions of watermarked images in Fig. 5.

vertical highlighted hair. The superior quality of the proposed method over C. Lee method is evident in the zoomed images of Fig. 6.

Fig. 7 shows the images of the intensity difference between the original host image of Fig. 4(a) and the watermarked image of Figs. 5(a)-5(d). The images in Fig. 7 are scaled for display purposes. From Fig. 7, the embedded values of the watermarked image constructed by the proposed method are not as large as those of C. Lee method even though the area which is embedded the watermark have high contrast. But this does not mean that the proposed method is not robust.

Fig. 8 shows the comparison of PSNR values for variant


(a) The proposed method. (b) C. Lee method with 2x2 block.
(c) C. Lee method with 3x3 block. (d) C. Lee method with 4x4 block.
Fig. 7. The images of the intensity difference between the original host image and the watermarked image.

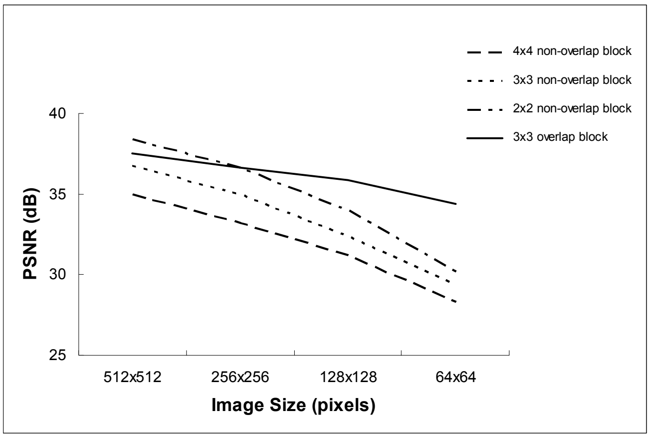


Fig. 8. A comparison of PSNR values for variant image size.

image size. From this figure, the PSNR of the proposed method is better than those of C. Lee method when the image size is equal to or smaller than 256x256 pixels.

Fig. 9 shows the watermarks extracted from the results of applying a median filtering with a mask of size 3x3 to the watermarked images of Fig. 5. The error between the original watermark of Fig. 4(b) and the extracted watermarks of Fig. 9(a)-(d) are 23.86, 35.43, 23.58, and 14.45%, respectively.

Fig. 10 shows the watermarks extracted from the results of applying a low-pass filtering with a mask of size 3x3 to the watermarked images of Fig. 5. The error between the original watermark of Fig. 4(b) and the extracted watermarks of Fig. 10(a)-(d) are 32.80, 42.16, 33.11, and 23.15%, respectively.

Fig. 11 shows the watermarks extracted from the results of applying a lossy JPEG compression with a compression ratio (CR) of 4.08 to the watermarked images of Fig. 5. The error between the original watermark of Fig. 4(b) and the extracted watermarks of Fig. 11(a)-(d) are 10.96, 25.78, 9.86, and 2.83%, respectively.

Fig. 12 shows the watermarks extracted from the results of

Proposed method. | C. Lee method with 2x2 block. | C. Lee method with 3x3 block. | C. Lee method with 4x4 block.

Fig. 9. Extracted watermark from the result of a median filtering.

Proposed method. | C. Lee method with 2x2 block. | C. Lee method with 3x3 block. | C. Lee method with 4x4 block.

Fig. 10. Extracted watermark from the result of a low-pass filtering.

Proposed method. | C. Lee method with 2x2 block. | C. Lee method with 3x3 block. | C. Lee method with 4x4 block.

Fig. 11. Extracted watermark from the result of a lossy JPEG compression with CR = 4.08.

Proposed method. | C. Lee method with 2x2 block. | C. Lee method with 3x3 block. | C. Lee method with 4x4 block.

Fig. 12. Extracted watermark from the result of a rotation and inverse rotation.

Proposed method. | C. Lee method with 2x2 block. | C. Lee method with 3x3 block. | C. Lee method with 4x4 block.

Fig. 13. Extracted watermark from the result of a shrinking and zooming operation.

Proposed method. | C. Lee method with 2x2 block. | C. Lee method with 3x3 block. | C. Lee method with 4x4 block.

Fig. 14. Extracted watermark from the result of a crop and zooming operation.

applying a rotation and inverse rotation to the watermarked images of Fig. 5. The error between the original watermark of Fig. 4(b) and the extracted watermarks of Fig. 12(a)-(d) are 22.65, 32.30, 21.60, and 11.23%, respectively.

Fig. 13 shows the watermarks extracted from the results of applying a shrinking and zooming operation to the watermarked images of Fig. 5. The error between the original watermark of Fig. 4(b) and the extracted watermarks of Fig. 13(a)-(d) are 38.30, 43.07, 35.94, and 23.93%, respectively.

Fig. 14 shows the watermarks extracted from the results of applying a crop and zooming operation to the watermarked images of Fig. 5. The error between the original watermark of Fig. 4(b) and the extracted watermarks of Fig. 14(a)-(d) are 33.74, 33.74, 33.62, and 31.74%, respectively.

From Figs. 9 and 14, the extracted watermark of C. Lee and Y. Lee method with the block of size 2x2 has the same size, but is less robust than that of the proposed method. Increasing the block size to 3x3 or 4x4 improves the robustness of the watermark, but the size of watermark becomes smaller, and the corruption in the watermarked image becomes more discernible, as shown in Figs. 5(c), 5(d), 6(c), and 6(d).

From the above experimental results, the proposed algorithm is robust to common image processing operations and the embedded watermark is more invisible than the non-overlap-block method even though the host image is small.

V. Conclusion

In this paper, an image watermarking technique using overlap-block is proposed. Using the overlap-block to embed the watermark makes the watermark image size be approximately 1/4 of the host image. This is useful when the host image is small in size. Depending on the standard deviation of the block in which the watermark will be inserted next, the proper weight values of the predefined block are added into or subtracted from the pixel intensities of the corresponding block in the host image. This intensities modification also changes the intensities of the neighbor overlap-blocks. However this makes the transition between the neighbor overlap-blocks become smoother than that of the non-overlap-block method. Moreover, Experimental results show that the embedded watermark is robust to common image processing operations without introducing any distortion.

References

[1] C. Lee and Y. Lee, "An adaptive digital image watermarking technique for copyright protection," *IEEE Transactions on Consumer Electronics*, Vol. 45, No. 4, pp. 1005-1015, Nov. 1999.