The Performance Analysis of Digital Watermarking based on Merging Techniques

Batgerel Ariunzaya*, Hyung-Suk Chu**, Chong-Koo An*

Abstract

Even though algorithms for watermark embedding and extraction step are important issue for digital watermarking, watermark selection and post-processing can give us an opportunity to improve our algorithms and achieve higher performance. For this reason, we summarized the possibilities of improvements for digital watermarking by referring to the watermark merging techniques rather than embedding and extraction algorithms in this paper. We chose Cox's function as main embedding and extraction algorithm, and multiple barcode watermarks as a watermark. Each bit of the multiple copies of barcode watermark was embedded into a gray-scale image with Cox's embedding function. After extracting the numbers of watermark, we applied the watermark merging techniques; including the simple merging, N-step iterated merging, recover merging and combination of iterated-recover merging. Main consequence of our paper was the fact of finding out how multiple barcode watermarks and merging techniques can give us opportunities to improve the performance of algorithm.

Keywords : watermarking, merging techniques, Cox's function, barcode watermark.

Ⅰ. Introduction

With intellectual property, its protection problem is taking strong consideration from its owners. Digital watermarking technique has been considered as a promising technique for the copyright protection of digital contents. The significance of digital watermarking is that by using digital watermark we can embed copyright information into digital content and so the information can travel with the digital content for all the time. In other words, copyright protection information is provided for the entire lifecycle of digital content thanks to the digital watermarking.[1] Then whenever, we can use that information for copyright protection as well as other purpose such as fingerprinting, authentication and so on.

There is a plenty of techniques have been proposed for digital watermarking so far.[2] Most of researchers consider only embedding and extraction part, and discover new algorithm for it. Watermark selection before embedding and a process after extraction could not take important attention in the most of existing techniques. But we can see several important points in some papers such as [3, 4]. In the paper [3], authors paid strong attention on watermark type and determined advantages and disadvantages of a binary sequence watermark and binary logo watermark. According to their paper, binary logo watermark does not require original watermark for detection and therefore it provides both subjective and objective detection while binary sequence watermark requires original watermark for detection. In the paper [4], authors proposed a redundant watermarking algorithm by using multiple watermarks. In the algorithm, multiple copies of the watermark image are inserted into the host image. When a region of the watermarked image is destroyed, the whole watermark can be extracted using other regions of the watermarked image. Extracted watermarks were merged to obtain final watermark. The merged watermark guaranteed that final watermark is much better than extracted watermarks.

In this paper, we analyze the performance of digital watermarking based on merging techniques. We employ Cox's function as main embedding and extraction algorithm, and multiple barcode watermarks as a watermark. Each bit of the multiple copies of barcode watermark is embedded into a gray-scale image with Cox's embedding function. After extracting the numbers

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of watermark with Cox's extraction function, we apply the watermark merging techniques; including the simple merging, N-step iterated merging, recover merging and combination of iterated-recover merging. Simulation results are compared to each other and even a result of algorithm which does not use any merging technique.

The rest of this paper is organized as follows. Section 2 summarizes the existing algorithm briefly. In section 3, the proposed algorithm is introduced. Section 4 represents experimental results and analysis. The paper is concluded in section 5.

Ⅱ. General Watermarking Technique

If the coefficient of the input image is C, the inserted watermark is W, and the coefficient of the watermark inserted into the image is C', the general watermark insertion technique can be expressed as shown in Fig.2.1.

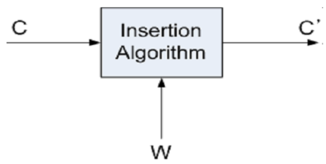

Fig.2.1. General watermark insertion technique

For the spatial domain technique, the watermark directly alters pixels of the image, whereas in the frequency domain technique, the watermark alters the coefficient in the frequency domain. The Cox's function is the most common method to insert a watermark and it can be expressed as below [5, 6]:

$$C' = C + \alpha \times W \tag{1}$$

$$C' = C(1 + \alpha \times W) \tag{2}$$

C is the coefficient of the input image and α is the weight factor used to insert the watermark and C' is the coefficient into which a watermark is inserted. As the size of the weighted value increases, the intensity of the watermark correspondingly increases and there is the advantage that the watermark becomes more resilient against attacks. However, as the resiliency of the watermark increases, the quality of the image degrades. Equation (1) inserts the watermark without reference to the size of the coefficient whereas equation (2) inserts the watermark proportionally to the size of the coefficient.

Ⅲ. Watermark Merging Techniques

3.1. Simple merging

An ordinary merging technique is simple merging that gets one watermark from the numbers of watermark by computing average value. For n numbers of extracted watermark W', the simple merging equation is defined as [4 and 7, 8]:

$$W'(i,j) = \begin{cases} 1, & \sum_{k=1}^{n} W_k'(i,j) \geq \frac{n+1}{2} \\ 0, & \sum_{k=1}^{n} W_k'(i,j) < \frac{n+1}{2} \end{cases} \tag{3}$$

It is quite clear that a merged watermark is more similar to the original watermark than most of extracted watermarks individually, refer Fig.3.1.

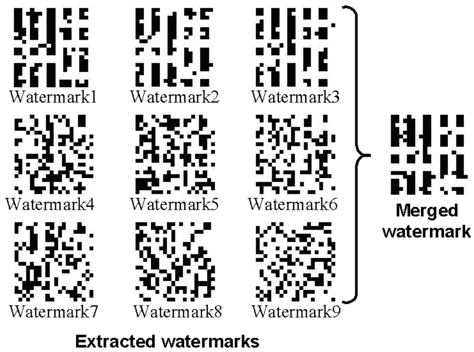

Fig.3.1. Simple merging technique

3.2. N-stepiterated merging

Unlike a simple merging technique which merges all extracted watermarks once, the iterated merging technique merges extracted watermarks two times or more. In the first step, all extracted watermarks are merged by using the merging equation (3) and a merged watermark is considered as a sample watermark which will be used for the second merging step. Among the extracted watermarks some numbers of watermark, which have higher correlation value with the sample watermark, are chosen and merged again. This process is repeated iteratively until either we reach final watermark that we want or number of residual watermarks is less than two. As an example, nine extracted watermarks from each bands of 3 level DWT except LL band are merged using 3-step iterated merging technique and shown in Fig.3.2.

3.3. Recover merging

Recover merging contains simple merging as one of its steps. After obtaining a merged watermark by merging once, equation (4) is applied to the merged watermark as a recover merging [9].

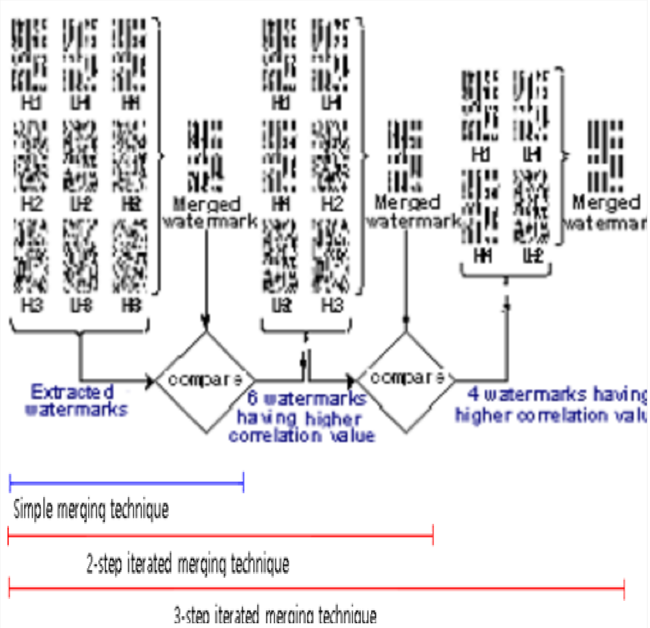

Fig.3.2. N-step iterated merging technique

$$S\_WM'(j)=\begin{cases}1, & \sum_{i=1}^{n} B\_WM'(i,j)\geq \frac{n+1}{2}\\ 0, & \sum_{i=1}^{n} B\_WM'(i,j)\geq \frac{n+1}{2}\end{cases} \quad (4)$$

Unlike the equation (3) which used for merging a number of watermarks, equation (4) merges one watermark itself in vertical direction. In other words, all pixels in the certain column are merged and give one pixel value. As a result of this process, sequence with length of numbers of column of the barcode watermark is obtained. The sequence is converted into a barcode watermark B_WM'' as Fig.3.3. This barcode watermark is a final watermark and will be used for ownership proof.

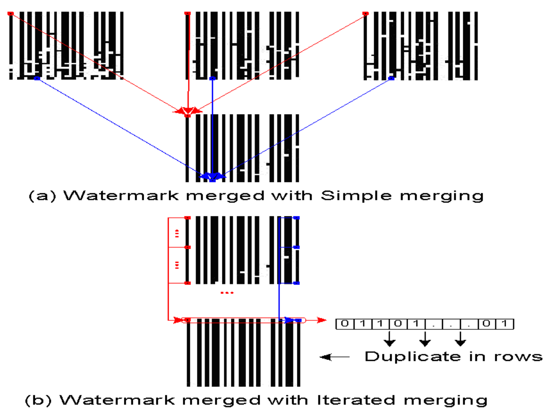

Fig.3.3. Recover merging technique

In this merging, we should be careful about the selection of watermark. Unlike the previous merging techniques which can merge any type of watermark such as a pattern barcode watermark, logo watermark, sequence watermark and even an image watermark, the recover merging technique can only use a line barcode watermark which consists of parallel lines with different width and different spacing.

From Fig.3.3 (b), we can see that the merged watermark with simple merging intends to illustrate the original watermark with even some noise while the watermark obtained by merging in vertical direction illustrates either the exact watermark that is the same as the original watermark or nothing.

3.4. Iterated Recovermerging

It is the combination of the iterated merging technique and the recover merging technique. Since recover merging technique is used, the watermark should be a line barcode. After obtaining a merged watermark with iterated merging, recover merging is applied to the merged watermark. The resulting sequence watermark from recover merging step is duplicated in rows in order to give us the final barcode watermark.

Ⅳ. simulation and experimental results

Our goal is to find out how the merging techniques work and improve the performance of algorithm without any additional visual effect on the image which could be caused due to an embedding algorithm. We will use the popular Cox's function as watermark embedding and extraction algorithm. Since we do not need to test the algorithm on different images, we did an experiment for Lena image (gray-scale image with size of 512 by 512) and 3 different noises, including Salt and pepper noise, Gaussian noise and JPEG compression, with different noise density in order to have enough data to conclude.

As a simulation scheme, first we embed 9 identical barcode watermarks with size of 32 by 32, which are obtained from a single watermark series with length of 32 bits, shown in Fig.4.1, with Cox's embedding function in 3-step wavelet domain (embed one watermark into one wavelet high-pass band). After we apply some noise to the watermarked image, we extract nine watermarks from each noisy band and then merge those watermarks with 4 different techniques that are explained in Chapter 3. In order to show an advantage of merging techniques, we also do a simulation in case of the algorithm without merging. For the same condition of simulation, the algorithm with no merging uses a watermark with length of 9216 (32 * 32 * 9 = 9216) which is obtained by connecting watermark bits one after one.

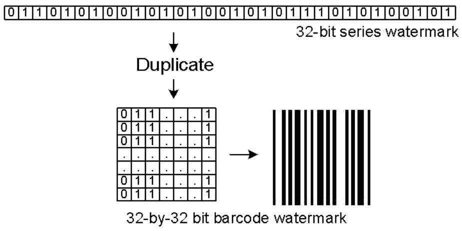

Fig.4.1. Barcode watermark

In Fig.4.2, we can see the test result on Lena image and Salt and pepper noise case in a term of correlation. From the figure, we can see that either of merging techniques obviously improved the performance of watermarking algorithm compared to the results of the algorithm without merging. In more specifically, each merging technique can be concluded as follow. With high noise density, the correlation value of simple merging was decreased. But it still could keep higher correlation than result of no merging. When the noise density was less, the 2-step iterated merging technique gained higher correlation than that of the simple merging whereas the noise density was high the performance of 2-step iterated merging technique had been dropped because of bad quality of the sample watermark. In other words, when noise density was high the quality of sample watermark, which is obtained by simple merging, was bad, so bad qualities of watermarks were selected for the second step.

In case of the recover merging techniques, first let us recall that the recover merging techniques demonstrate either the exact watermark that is same as the original watermark or nothing. That means a correlation value less than 1 shows the fail of the recover merging technique. In order words, we can only consider that the recover merging technique is successful as long as its correlation value equals to 1. In this point of view, we must determine a threshold value which shows where the recover merging technique fails. From the first result shown below, the recover merging technique failed when the correlation of simple merging was below 0.36 and the iterated recover merging technique failed when the correlation of 2-step iterated merging was below 0.44.

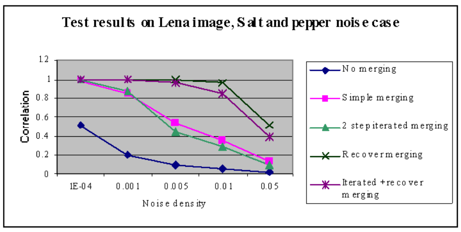

Fig.4.2. Test result on Lena image with Salt and pepper noise

Fig.4.3 shows the result of Lena image and Gaussian noise case. From the result, we can have similar conclusion as above. But the both recover merging techniques could extract the exact watermark, even the correlation values of simple merging and 2-step iterated merging were less than 0.48

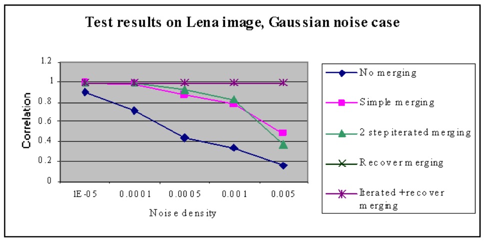

Fig.4.3. Test result on Lena image with Gaussian noise

In Fig.4.4, the correlation values that were obtained in case of Lena image and JPEG compression are shown. As above, the performances of algorithm with merging techniques were higher than that of algorithm with no merging. And also the 2-step iterated merging technique could keep higher correlation value than simple merging. Like results in Fig.4.3, recover merging techniques could extract the exact watermark in all case of compression rate. However, we set that the threshold value is 0.5 by referring to results on Fig.4.2 as well as the other results that are even not shown in this paper.

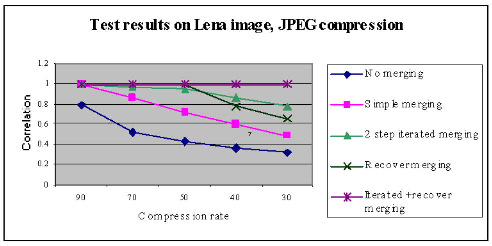

Fig.4.4. Test result on Lena image with Gaussian noise

Since the same number of watermarks embedded into the image with the same algorithm (alpha = 0.3), the visual quality of watermarked image was the same, as PSNR = 41.49, in above experiments. However, the performance of correlation value was the different due to different merging techniques as we just saw above. In other words, a merging technique gives an opportunity to improve the performance of algorithm without additional visual effect on the host image.

In Fig.4.5, we see the average correlation values of results on Lena image and Salt and pepper noise against the weight factor alpha. From the results, it is clear that the performance of recover merging was the highest. In this case, the threshold value does not matter because of average value.

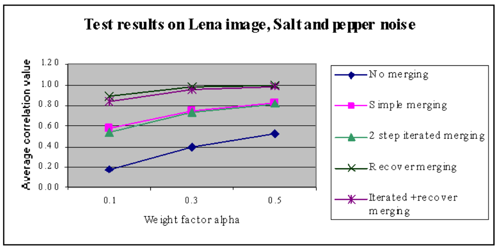

Fig.4.5. Test result on Lena image with Salt and pepper noise

V. Conclusion

In this paper, we summarized the performance of watermarking algorithm regarding to merging techniques. We embedded multiple barcode watermarks into a gray-scale image in wavelet domain with the Cox's algorithm and obtained the final watermark, which will be used for copyright protection, from extracted watermarks with four different merging techniques as well as with no merging. From the simulation result, it was clear that either of four merging techniques significantly improved the performance of the simple watermarking algorithm. We observed some important points as below:

■ Watermark type and its selection can affect the performance of a watermarking algorithm. For example, multiple barcode watermarks give opportunities of subjective and objective detection as well as chance to use a merging technique.

■ A merging technique gives an opportunity to improve the performance of algorithm without additional visual effect on the host image.

■ Line barcode watermark give more opportunities with recover merging.

■ Recover merging technique can restore the exact watermark from noisy watermark as long as its correlation value is higher than 0.4.

As a final conclusion, since merging the extracted watermarks gives better performance than that of no merging case and merging the merged watermark again in vertical direction gives the exact watermark, the recover merging technique was the best among the others.

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