# Reversible Watermarking Based on Sorting Prediction Scheme


Khalid Edris, Mohammed Adam Ibrahim Fakhreldin, Jasni Mohamed Zain, Tuty Asmawaty Abdul Kadir, Khalid Adam

Faculty of Computer Systems & Software Engineering
Universiti Malaysia Pahang
26300 Gambang, Kuantan, Pahang, Malaysia
Khalod07@yahoo.com, adamibrahim@ump.edu.my, Jasni@ump.edu.my, tuty@ump.edu.my, khalidwsn15@gmail.com



*Abstract*— **Reversible watermarking has drawn a lot of interest in recent years. To be reversible mean the original digital carrier can be completely restored. Sachnev et al proposed reversible watermarking algorithm by combining prediction technology, histogram shifting technology and sorting technology, which has good performance, however, their method is against the characteristics of the human visual system. In this paper, we propose a reversible watermarking algorithm to improve Sachnev et al algorithm by using new sorting method. The performance of the proposed reversible watermarking algorithm is evaluated and compared with Sachnev et al method. The results indicate that the proposed scheme can embed data with less distortion.**



***Keywords: prediction error expansion; Reversible watermarking; Sorting;***


## I. Introduction

In some certain applications areas, such as law, medicine, military, requirements of the integrity of the original carrier are relatively high, even distortion brought by the watermarking is not allowed, which requires lossless embedding watermark information so a reversible watermarking technique is invented because it can restore the original carrier without distortion after the watermarking information is extracted.

Tian [1] proposed the Difference Expansion Method when the research of reversible watermarking with large capacity begins. This method divides the image into pairs of pixels, and finds the difference and average values of pixels then expand into its binary form and add watermark bit right after most significant bit. One bit can be embedded in every two pixels. Alattar [2] extends the Tian's algorithm [1] by extending the two pixels difference values to three or four adjacent pixels difference, and thus more than one bit watermark can be embedded. Ni et al [3] presented an algorithm based on histogram shift. To embed data into image, firstly, find the maximum point and the minimum zero point of the image histogram, then slightly modifies the pixel grayscale values. Kamstra and Heijmans [4] greatly improved Tian's difference expansion technique. They sort pairs according to correlation measures to facilitate compression, which leads to reduction in location map size. The main idea of this technique is its efficient utilization of the correlation between neighboring pixels in the image. Difference values of neighboring pixels in a cell highly correlate with average values of neighboring pairs. Sorting by exploiting the correlation between neighboring pixels can strongly enhance embedding capacity of the difference expansion method. Jasni and Fauzi, proposed Authentication Watermarking with Tamper Detection and Recovery (AW-TDR) method that could detect tamper and subsequently recover the image. They used 800x600x8 bits ultrasound (US) greyscale images in their experiment and tested the algorithm for up to 50% tampered block and obtained 100% recovery for spread-tampered block [5, 6]. Thodi and Rodriguez [7] presented a prediction error expansion plan, they replaced the difference between the adjacent pixels by a pixel prediction, Later they combined the histogram shift algorithm with prediction technology. Lee et al [8] introduced reversible watermarking scheme based on integer-to-integer wavelet transforms. To embed the watermark, first divides the image into non overlapping blocks, and then embeds into the high-frequency wavelet coefficients of each block by LSB substitution. The payload to be embedded contains the messages and side information used to recover the original image. This scheme outperforms many existing methods by using high - frequency subbands and efficient data hiding technique. Tai et al [9] proposed a reversible watermarking scheme based on histogram modification by using a binary tree structure to solve the communicating pairs' problem of peak points. In order to obtain large hiding capacity with low distortion, pixel differences distribution is used. To forbid overflow and underflow, histogram shifting technique is adopted. Li et al [10] introduced a high- fidelity reversible data hiding scheme for digital images based on pixel value ordering and prediction-error expansion technique. This method has an advantage in reducing the number of shifted pixels, and thus it can improve the image quality so this method can embed sufficient data into a host image with limited distortion. Afsharizadeh and Mohammadi [11] proposed a new sorting technique to improve the hiding capacity and visual quality by using prediction expansion, histogram shifting and new sorting technique. Wu and Huang [12] presented a new algorithm by selecting the histogram bins to be modified. Sachnev et al [13] combined prediction technology, histogram shifting technology, sorting technology and put forward sorting prediction scheme, which has the best effect among all the mentioned reversible watermarking algorithms. The basic thought of the above algorithm comes from Tian's Difference Expansion Method. By extending the vacant position for the watermark embedding, and in order to reduce the distortion, the watermarks are usually embedded on the smooth pixel block, because the smooth area pixel values are close, so it can provide smaller pixel difference or predict error value. Embedding watermark in the smooth area is against the characteristics of the human visual system (HVS), because human visual system is not too sensitive to the change of texture in complex area, but it is more sensitive to the change of smooth zone [14].

In this paper, we propose a reversible watermarking algorithm to improve Sachnev et al algorithm by using new sorting method.

## II. PROPOSED METHOD

To ensure distortion of image to the least after embedding-watermark, the order of embedding-watermark in the image becomes very important. Therefore, we proposed new sorting method based on Sachnev predictive value $u'_{i,j}$ , which can be calculated from the four pixels nearby being plus $u_{i,j}$ as follow:

$$u'_{i,j} = \left\lfloor \frac{v_{i,j-1} + v_{i+1,j} + v_{i,j+1} + v_{i-1,j}}{4} \right\rfloor \quad (1)$$

$u'_{i,j}$ is suitable to predict the value of prediction-error. There are two key features:

1. The value of $u'_{i,j}$ keeps the same after embedding-watermark.

2. The value of $u'_{i,j}$ can predict the value of prediction-error more accurately.

In Fig. 1, five pixels constitute a mark for information embedding, the middle one among which is for embedding-watermark, other four pixels are used to predict $u_{i,j}$, the predictive-value.

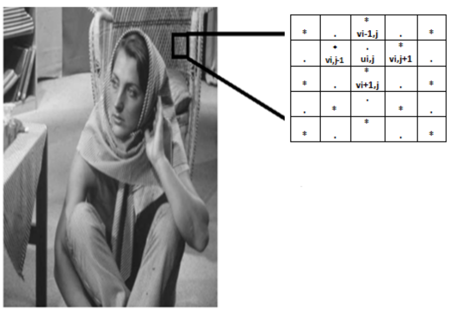


Figure 1. Prediction pattern. The pixel u and the four neighboring pixels.

### A. HVS-based embedding-watermark algorithm

Considering the influence of HVS, people are very sensitive to the change in the even area while not that sensitive to the change in the area rich in textures, therefore, the embedding-watermark in texture area can improve the visual quality greater. As the pixel-values differs greatly in the texture area, the prediction-error value offered is big, thus there is a big image distortion when reversible-watermarking algorithm is embedded by the method of enlargement. Therefore, we suggest embedding-watermark of the smooth pixel-block in the texture area, i.e., choosing the smooth pixel-block in the big texture area to take embedding-watermark first. Thus it can ensure to get a higher visual quality.

Divide the image into 64 blocks before embedding-watermark. The images are 512*512, therefore, each block contains 64*64 pixels. Then calculate the variance of each block to sort. To ensure the parameters sorting not to change before or after embedding-watermark, here the predictive pixels only are chosen among each block for calculating the variance of this block:

$$MSE = \frac{1}{2048} \sum_{i=1}^{2048} (v_i - \bar{v})^2 \quad (2)$$

$v_i$ in the above formula shows 2048 pixel-value for prediction in each block, and the pixel-value will not change in embedding-watermark, $\bar{v}$ stands for the mean value of 2048 pixel-value. If the MSE is big, it means it is rich in texture area. If the MSE is small, it means this block is smoother. Sort these 64 blocks according to the MSE of each block and give each block a parameter value $K_i$ after sorting. $K_i = i$ and $1 \le K_i \le 64$. The parameter of the block with most complicated texture is $K_1 = 1$, the parameter of the smoothest block is $K_{64} = 64$, all the pixel-value in a block shares a parameter value $K_i$.

$$FV_{i,j} = u'_{i,j} \times C + K_i \ , C = 64 \quad (3)$$

By revising the sorting-parameter $u'_{i,j}$, $FV_{i,j}$ comes out in the formula 3 and finally be used to sort. In formula 3, C is a constant value, meaning 64 here. $K_i$ is the parameter of each block mentioned above. The main function of C is to identify different sorting space while $K_i$ is to identify the embedding order of pixel in the same sorting-parameter. According to the sorting result, watermark will be embedded from the pixel-block having the smallest sorting-parameter on and in order, until the last watermark-information has been embedded.

### B. Embedding watermark

We classify all the pixels into two groups, one for embedding-watermark, and the other for prediction. Then divide the image into 64 blocks, the carrier image is 512*512 large, thus the pixel of each block after division is 64*64. Then we calculate the MSE of each block and we sort according to the MSE value. Then we calculate the predictive-value $u'_{i,j}$, prediction-error $d_{i,j}$ , sorting-parameter of each pixel-block $FV_{i,j}$ . Then rank the order of all the pixel-blocks according to the calculated value of $FV_{i,j}$. Collect the first LSB value of first 34 prediction-errors to be $S_{LBS}$ and then constitute the watermark-information as a part of watermark. After that we find the most suitable threshold limit value $T_n, T_p$ according to the capacity and the rank result of embedding-watermark. Classify the pixel-block into group A, B and C, and then build a location plan (if there is a location plan). We embed the watermark and location plan into the carrier image according to the Histogram-shifting-algorithm. From the 35th pixel-block of embedding-watermark on, those pixel-block in group A can have embedding-watermark, those pixel-block in group B will not have embedding-watermark but take some revision and those in group C will skip over without any revision. Replace the LSB of the first 34 prediction-error after sorting with the 34-bit information with additional information which contains 7 bits for threshold value $T_n$, 7 bits for threshold value $T_p$, 20 bits for payload. After the first embedding-watermark, change the roles of the two groups of pixel-block for the second embedding-watermark. Here the embedding-watermark ends.

### *C. Extracting watermark*

We classify the pixels in the image into two groups, and then divide the image into 64 blocks. Then calculate the MSE of each block. Sort the 64 blocks according to the MSE value, and then give each block a parameter value $K_i$, $K_i = i$, among which the parameter value of the smoothest block is 64 and that of the one with the most textures is $K_1 = 1$. Calculate the predictive-value $u'_{i,j}$, prediction-error, $FV_{i,j}$ being the sorting-parameter of each pixel-block. Then rank the order of all the pixel-blocks according to the calculated value $FV_{i,j}$. Read the LSB value of the first 34 prediction-error according to the rank result, from which the threshold value $T_n, T_p$, the embedding-watermark capacity P come out. Classify the pixel-blocks into three groups, namely group A, group B and group C. According to the histogram shifting algorithm, to have embedding-watermark from the 35th pixel-block on, those pixel-block in group A can have embedding-watermark, those pixel-blocks in group B will not have embedding-watermark but take some revision and those in group C will skip over without any revision. Extract from the watermark-information and replace the LSB of the first 34 prediction-error, recover the value of the first host 34 prediction-error. After the first extracting-watermark, take the second extracting-watermark. Here the whole extracting-watermark ends.

## III. EXPERIMENTAL RESULTS

The proposed algorithm is compared with the Sachnev algorithm using 512*512 grayscale images namely Lena and Airplane as explained in Fig. 2; these images are similar to testing images applied in Sachnev algorithm.

(a) (b)

Figure 2. (a) Lena (b) Airplane.

Fig. 3 and Fig. 4 describe the PSNR effect of Lena and Airplane images respectively by using the sorting-method put up in the paper and that put up by Sachnev et al. It is observed that the sorting-method put up in this paper improves the PSNR of both images.

From Fig. 3 and Fig. 4 we can learn that the sorting-method put up in this paper improves the PSNR of airplane image greatly, while improves the PSNR of Lena image slighter. As for the improvement of PSNR, it is because that a more effective sorting-method is put up in this paper, which is more effective to improve the relatively smooth images while not that significant to improve the relatively texture images. The proposed sorting method works better than Sachnev et al method because it is based on the characteristic of human visual system, and in the embedding process, the priority is for complicated area, then choose smooth pixel inside complex area.

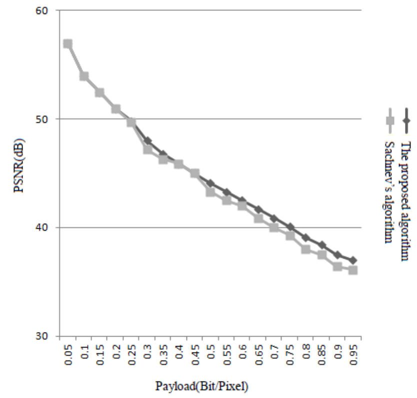


Figure 3. The payload vs distortion for Lena image.

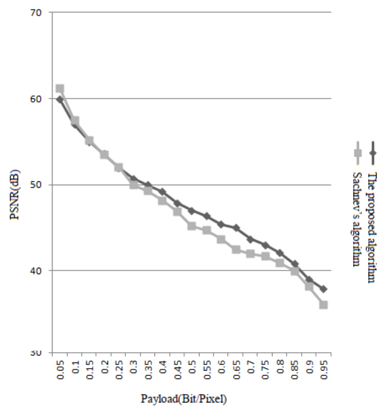


Figure 4. The payload vs distortion for Airplane image.

## IV. CONCLUSION

This paper proposed a reversible watermarking based on new sorting-method, with which the sorting result will be more effective than other sorting method in the same condition. The sorting-parameter $u'_{i,j}$ can be more accurately and effectively predict the value of prediction- error. Therefore we suggested embedding-watermark of the smooth pixel-block in the texture area, choosing the smooth pixel-block in the big texture area to take embedding-watermark first. Thus it can ensure to get a higher visual quality. After ranking all the pixel-blocks based on the calculated value of $FV_{i,j}$, we embed the watermark and location plan into the carrier image according to the Histogram-shifting-algorithm. Experimental results show that the proposed method has better results compared to the Sachnev et al method.

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