A Reversible Data Hiding Scheme Based on Histogram Shifting Using Edge Direction Predictor

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ABSTRACT

In this paper, we propose a novel reversible data hiding scheme based on histogram shifting using edge direction (ED) predictor. The ED predictor utilizes direction of adjusted pixels. Because of reversible character, existing predictor methods don't use all of cases edge direction. However, all of cases edge direction are used in ED predictor. In the proposed scheme, embedding and extraction procedures are classified by odd column and even column to use around adjusted pixels. In our experimental results, the hiding capacity of the proposed scheme is superior to other schemes. The image quality of the proposed scheme is similar or better than other schemes.

Categories and Subject Descriptors

D.2.11 [**Software Architectures**]: Information hiding

General Terms

Algorithms, Experimentation, Security

Keywords

data hiding, steganography, edge direction predictor, histogram shifting, information hiding

1. INTRODUCTION

As the development of the computing power, digital multimedia is used widespread. The digital multimedia requires information security technologies instead of giving useful information. These information security technologies are classified as follows: cryptography and data hiding.

Data hiding is a technique that hides secret data into digital multimedia to deliver the secret data. This technique is a hiding secret data, imperceptibly by third party [2, 10].

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Because of occurring the distortion in embedding procedure, data hiding technique has important risk in the sensitive images such as military and medical images.

For such a issue, reversible data hiding had researching important. The reversible data hiding technique is able to extract the embedded secret data and to recover the cover image.

Since the first reversible data hiding technique [1], several reversible data hiding schemes had been proposed [5, 6, 8, 9]. Tian proposed a reversible data hiding scheme using a difference expansion (DE) in 2003 [5]. DE technique uses a difference value and an average value of two neighboring pixel pair. This method is simple technique. However, it has low image quality with increasing hiding capacity.

In 2006, Ni et al. proposed a very simple concept of reversible data hiding technique based on the histogram shifting technique [16]. Ni et al.'s scheme modify pixel values between peak point and zero point to hide secret data and to recover cover-image. Their scheme has good image quality, because the pixel values change maximum 1. However, the hiding capacity is limited by the most frequent pixel value in the cover image by called peak value.

These scheme are the representative reversible data hiding scheme: DE and histogram shifting technique.

After proposed Tian and Ni et al.'s scheme, to improve a hiding capacity and image quality of their schemes had researched [7, 3, 11, 12, 14, 13]. In 2009, Wu et al. improved the DE scheme by using edge prediction [3]. Their scheme increased the hiding capacity by using the edge prediction technique. Li et al. proposed a reversible data hiding scheme using adjacent pixel difference (APD) in 2010 [14]. Their scheme is based on similarity between neighboring pixels that difference value of adjacent pixel is used. Such a prediction method is very simple. However, its has a lower hiding capacity then other predictor. In 2012, Hong proposed a reversible data hiding scheme using using dual binary tree and error energy control (EEC) methods [11]. Their scheme is based on median edge detection (MED) predictor. MED predictor is used to obtain a better prediction value. In 2013, Tsai et al. proposed a reversible data hiding scheme by using two neighboring pixel differences and division by a pixel value of quotient and remainder [15]. Their scheme has good image quality than other proposed scheme. However, the hiding capacity is smaller than recently proposed scheme.

In this paper, we propose a novel reversible data hiding scheme based on histogram shifting using edge direction pre-

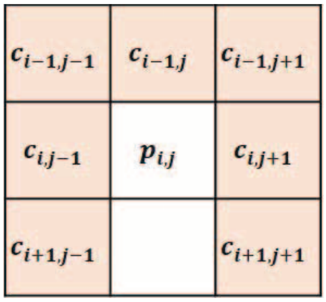


Figure 1: The example of indexing method with size of 3×3 for ED predictor

dictor. The ED predictor utilizes direction of adjusted pixels. Because of reversible character, existing predictor methods don't use all of cases edge direction. However, all of cases edge direction are used in ED predictor. In the proposed scheme, embedding and extraction procedures were classified by odd and even columns for using ED predictor. Because of divided image by odd and even columns, the proposed scheme used two point pairs. When an even line was embedded, its procedure used modified pixels.

The rest of this paper is organized as follows: In Section2, edge direction predictor, the embedding and extraction and recovery procedures of the proposed method are presented. Experimental results are given in Section 3 and ending with conclusions in Section 4.

2. THE PROPOSED SCHEME

In this section we describe the proposed scheme using edge direction (ED) predictor based on histogram shifting technique.

2.1 Edge-direction predictor

We propose a novel predictor that uses edge direction of adjusted pixels in Figure 1.

Let a set D be $\{D_k | d_k = p_d, 0 \le k \le 8\}$, where p_d is the most frequent d_k.

d_k is a difference value for weighted edge direction, D_k is a sum value of d_k, $0 \le k \le 8$, and these are represented by the following equation (1) and (2).

$$\begin{cases} d_0 = |c_{i,j-1} - c_{i,j+1}| \\ d_1 = |c_{i-1,j-1} - c_{i+1,j-1}| \\ d_2 = |c_{i-1,j+1} - c_{i+1,j+1}| \\ d_3 = |c_{i-1,j-1} - c_{i+1,j+1}| \\ d_4 = |c_{i-1,j+1} - c_{i+1,j-1}| \\ d_5 = |c_{i-1,j-1} - c_{i,j+1}| \\ d_6 = |c_{i,j-1} - c_{i+1,j+1}| \\ d_7 = |c_{i-1,j+1} - c_{i,j-1}| \\ d_8 = |c_{i,j+1} - c_{i+1,j-1}| \end{cases} \tag{1}$$

$$\begin{cases} D_0 = c_{i,j-1} + c_{i,j+1} \\ D_1 = 2c_{i-1,j} \\ D_2 = 2c_{i-1,j} \\ D_3 = c_{i-1,j-1} + c_{i+1,j+1} \\ D_4 = c_{i-1,j+1} + c_{i+1,j-1} \\ D_5 = c_{i-1,j-1} + c_{i,j+1} \\ D_6 = c_{i,j-1} + c_{(+1,j+1} \\ D_7 = c_{i-1,j+1} + c_{i,j-1} \\ D_8 = c_{i,j+1} + c_{i+1,j-1} \end{cases} \tag{2}$$

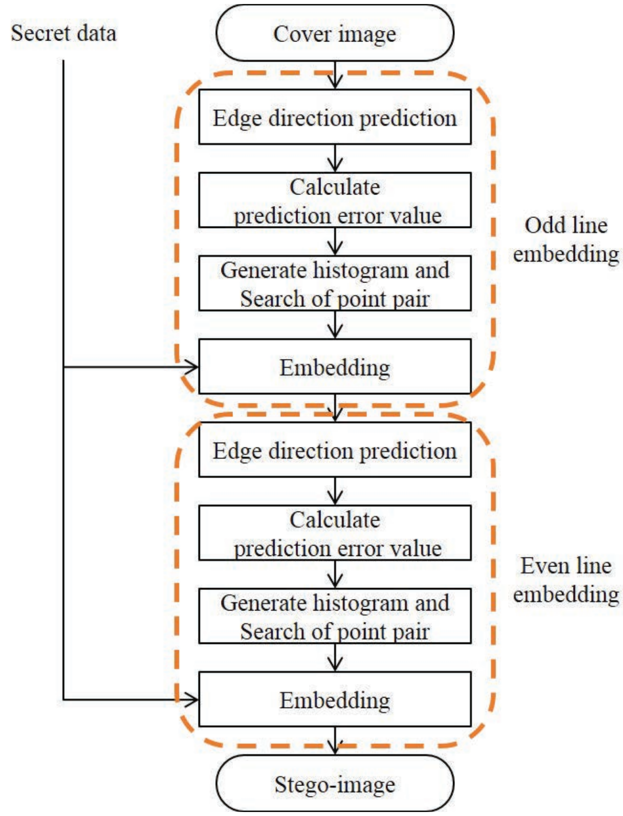


Figure 2: The embedding procedure

The prediction value $p_{i,j}$ is calculated with set of D and q by following equation (3):

$$p_{i,j} = \left\lfloor \frac{sum(D)}{2q} \right\rfloor \tag{3}$$

where the symbol $\lfloor \cdot \rfloor$ is the floor function, $sum(D)$ is sum value of element of D and q is the frequency of p_d.

2.2 Embedding procedure

The embedding procedure is classified three parts: odd line embedding, even line embedding and Generate the stego-image. After the odd line embedding, even line embedding is started with modified odd column. The steps of the embedding procedure are as follows:

Input: $N \times N$ pixels cover-image C with pixel value $c_{i,j}$, secret data sd_l

Output: $N \times N$ pixels stego-image S with pixel value $s_{i,j}$, peak and zero points pairs (P_{odd}, Z_{odd}), (P_{even}, Z_{even})

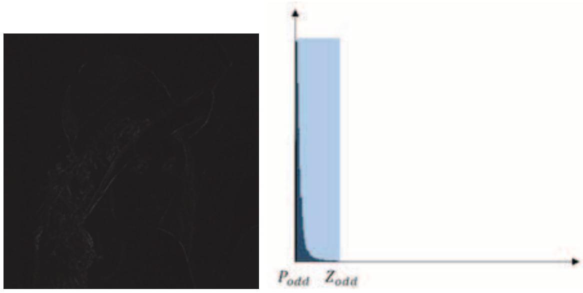
- Odd line embedding:

Step 1: Calculate the prediction value $p_{i,j}$ by edge direction predictor with adjusted pixels of $c_{i,j}$.

Step 2: Calculate the prediction error value $e_{i,j}$ by following equation:

$$e_{i,j} = |c_{i,j} - p_{i,j}| \tag{4}$$

Step 3: Generate histogram with $e_{i,j}$ and search of point pair (P_{odd}, Z_{odd}).



(a) (b)

Figure 3: The results of odd line embedding: (a) Prediction error value image;(b) Histogram of prediction error value image

Step 4: Embed secret data sd_l in peak point P_{odd} and odd columns of stego-image is obtained by following conditions:

$$s_{i,j} = \begin{cases} c_{i,j} + sd_l, & \text{If } e_{i,j} = P_{odd} \\ c_{i,j} + 1, & \text{If } P_{odd} < e_{i,j} < Z_{odd} \\ c_{i,j}, & \text{otherwise} \end{cases} \tag{5}$$

- Even line embedding:

Step 1: Calculate the prediction value $p_{i,j}$ by edge direction predictor with adjusted stego-image pixels of $s_{i,j}$.

Step 2: Calculate the prediction error value $e_{i,j}$ by following equation:

$$e_{i,j} = |c_{i,j} - p_{i,j}| \tag{6}$$

Step 3: Generate histogram with $e_{i,j}$ and search of point pair (P_{even}, Z_{even}).

Step 4: Embed secret data sd_l in peak point P_even and even columns of stego-image is obtained by following conditions:

$$s_{i,j} = \begin{cases} c_{i,j} + sd_l, & \text{If } e_{i,j} = P_{even} \\ c_{i,j} + 1, & \text{If } P_{even} < e_{i,j} < Z_{even} \\ c_{i,j}, & \text{otherwise} \end{cases} \tag{7}$$

- Generate the stego-image: Combine odd columns with even columns

Figure 3. shows the results of odd line embedding. we calculate $e_{i,j}$ using equation (4). Figure 3-(a) is odd line prediction error value image. Then, histogram with $e_{i,j}$ is generated as following Figure 3-(b). In the odd line histogram, we find the odd line point pairs (P_{odd}, Z_{odd}). First, pixel values are shifted from $P_{odd} + 1$ to Z_{odd} (blue area) for making empty space to embed secret data. Then, if the secret data is 1, which can be embedded into $P_{odd}+1$. If the secret data is 0, which can be embedded into P_{odd}, but pixel values are not modified. Finally, the pixel values are not included in the blue area, which also are not modified. After the odd line embedding procedure, even line embedding is performed with odd line stego-pixels.

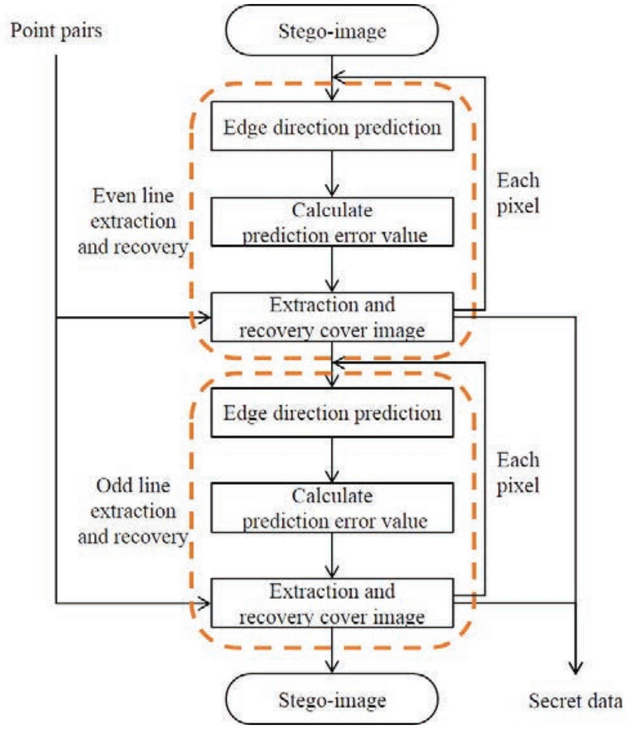


Figure 4: The extraction and recovery procedure

3. EXTRACTION AND RECOVERY PROCEDURE

The extraction and recovery procedure is also classified three parts: odd line extraction and recovery, even line extraction and recovery and recover the cover image. However, extraction and recovery order is the reverse to recover cover image. After the end of even line extraction and recovery, odd line is started with recovered cover image pixel. Also, all of the process is performed by each pixel.

Input: $N \times N$ pixels stego-image S with pixel value $s_{i,j}$, peak and zero points pairs (P_{odd}, Z_{odd}), (P_{even}, Z_{even})

Output: $N \times N$ pixels recovered cover-image C with pixel value $c_{i,j}$, secret data sd_l

- Even line extraction and recovery:

Step 1: Calculate the prediction value $p_{i,j}$ by edge direction predictor with adjusted stego-image pixels of $s_{i,j}$.

Step 2: Calculate the modified prediction error value $e'_{i,j}$ by following equation:

$$e'_{i,j} = |s_{i,j} - p_{i,j}| \tag{8}$$

Step 3: Extract secret data (equation (10))and recover the cover image (equation (11)) by using point pair.

$$sd_l = \begin{cases} 0, & \text{If } e'_{i,j} = P_{odd} \\ 1, & \text{If } e'_{i,j} = P_{odd} + 1 \end{cases} \tag{9}$$

$$c_{i,j} = \begin{cases} s_{i,j}, & \text{If } e'_{i,j} = P_{odd} \\ s_{i,j} - 1, & \text{If } P_{odd} < e'_{i,j} \le Z_{odd} \\ s_{i,j}, & \text{otherwise} \end{cases} \tag{10}$$

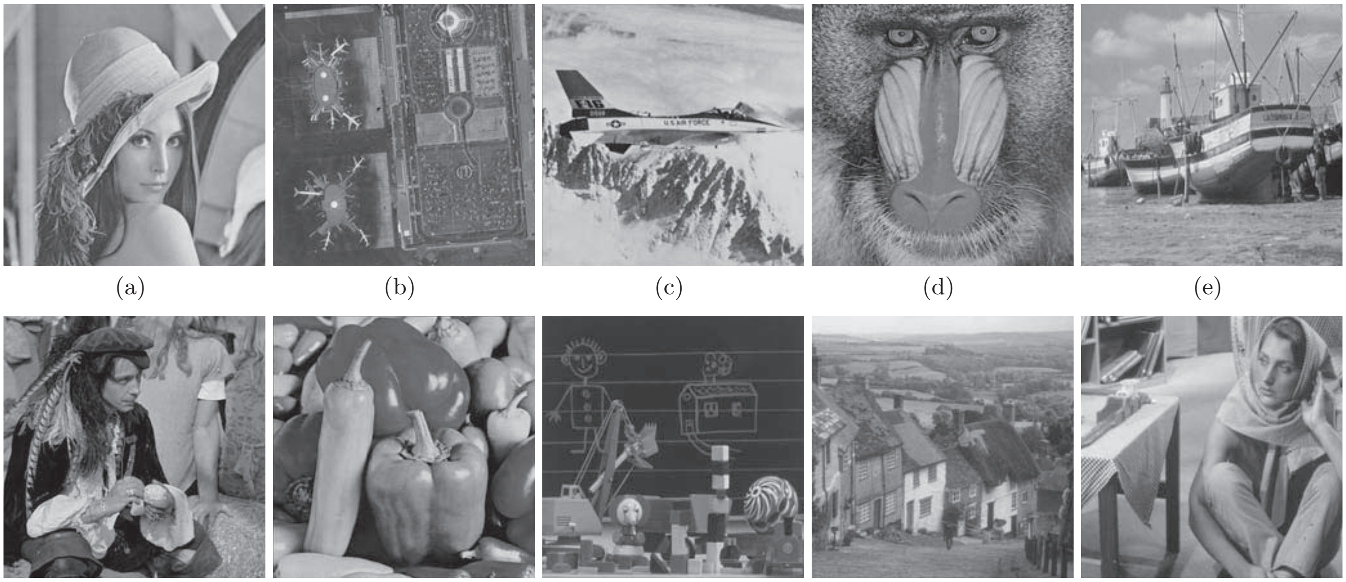


Figure 5: Ten 512 × 512 size gray-scale images: (a) Lena;(b) Airport;(c) Avion;(d) Baboon;(e) Boat;(f) Man;(g) Peppers;(h) Toy;(i) Village;(j) Woman

Table 1: The results of hiding capacity (bit) and PSNR (dB) with several scheme and the proposed scheme

Test image	Li et al.'s scheme		Hong's scheme		Tsai et al.'s scheme		Proposed scheme	
	Capacity	PSNR	Capacity	PSNR	Capacity	PSNR	Capacity	PSNR
Lena	42,977	48.50	51,815	48.60	48,982	50.23	56,747	49.24
Airport	30,631	48.39	35,572	48.49	31,216	50.50	36,539	48.79
Avion	57,137	48.62	63,615	48.79	57,523	50.55	63,685	49.44
Baboon	18,539	48.28	19,046	48.34	17,327	50.31	21,025	48.50
Boat	29,210	48.37	32,812	48.45	31,211	50.16	36,119	48.79
Man	40,871	47.33	50,452	48.71	44,503	50.59	47,569	49.10
Peppers	35,155	48.43	32,327	48.46	35,023	49.76	47,099	49.01
Toy	57,099	48.62	60,641	48.70	58,222	50.14	66,124	49.45
Village	35,868	48.43	39,572	48.52	34,481	50.46	40,937	48.88
Woman	32,086	48.40	39,911	48.54	34,688	50.24	43,243	48.95
Average	37,957	48.44	42,576	48.56	39,318	50.29	45,909	49.02

- Odd line extraction and recovery:

Step 1: Calculate the prediction value $p_{i,j}$ by edge direction predictor with adjusted recovered cover image pixels of $c_{i,j}$.

Step 2: Calculate the modified prediction error value $e'_{i,j}$ by following equation:

$$e'_{i,j} = |s_{i,j} - p_{i,j}| \tag{11}$$

Step 3: Extract secret data (equation (13))and recover the cover image (equation (14)) by using point pair.

$$sd_l = \begin{cases} 0, & \text{If } e'_{i,j} = P_{even} \\ 1, & \text{If } e'_{i,j} = P_{even} + 1 \end{cases} \tag{12}$$

$$c_{i,j} = \begin{cases} s_{i,j}, & \text{If } e'_{i,j} = P_{even} \\ s_{i,j} - 1, & \text{If } P_{even} < e'_{i,j} \leq Z_{even} \\ s_{i,j}, & \text{otherwise} \end{cases} \tag{13}$$

- Recover the cover image: Combine odd columns with even columns

4. EXPERIMENTAL RESULTS

In this chapter, the proposed scheme is compared with several schemes in terms of capacity (bit) and image distortion (PSNR). Ten test images are 512 × 512 gray-scale image, as shown in Figure 4. The embedded secret data used to generate the random number.

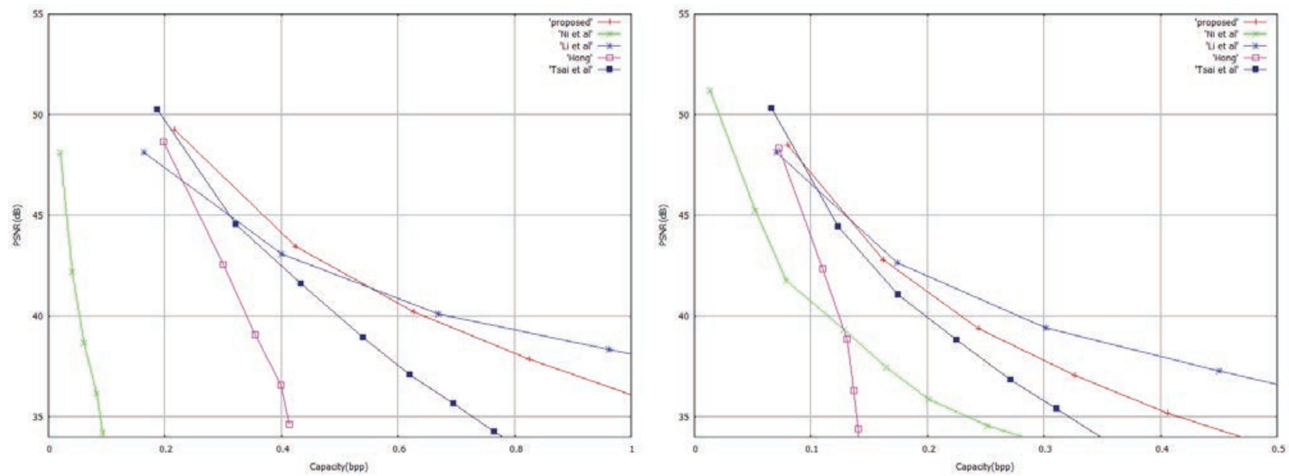
The image distortion is measured in $PSNR$ [4], which is defined as follows equation (14).

$$PSNR = \left(10 \cdot \log_{10}\left(\frac{255^2}{MSE}\right)\right), \tag{14}$$

where MSE is the $Mean\ Square\ Error$ between the original image and the stego-image, and can be calculated using the following equation (15).

Table 2: Multi-layer embedding with the proposed scheme

Test image	1 times		2 times		3 times		4 times		5 times	
	Capacity	PSNR	Capacity	PSNR	Capacity	PSNR	Capacity	PSNR	Capacity	PSNR
Lena	56,747	49.24	111,664	43.45	164,728	40.23	216,376	37.86	265,748	35.97
Airport	36,539	48.79	72,968	43.12	107,953	39.88	141,537	37.50	175,794	35.72
Avion	63,685	49.44	123,714	43.67	180,306	40.21	235,021	37.90	287,832	36.05
Baboon	21,025	48.50	42,537	42.78	64,035	39.36	85,742	37.04	106,793	35.19
Boat	36,119	48.79	72,453	43.11	108,080	39.88	141,842	37.63	174,487	35.82
Man	47,569	49.10	93,264	43.25	136,895	39.95	179,205	37.54	218,320	35.77
Peppers	47,099	49.01	93,283	43.17	139,581	39.93	184,863	37.70	229,887	35.92
Toy	66,124	49.45	128,431	43.70	188,065	40.24	245,867	37.98	302,537	36.14
Village	40,937	48.88	80,773	43.02	121,498	39.89	159,229	37.58	194,637	35.85
Woman	43,243	48.95	85,417	43.09	125,875	39.79	165,408	37.38	203,593	35.58
Average	45,909	49.02	90,450	43.24	133,702	39.94	175,509	37.61	215,963	35.80



(a) (b)

Figure 6: Multi-layer embedding with several scheme: (a) Lena;(b) Baboon

$$MSE=\left(\frac{1}{MN}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}(I_{(i,j)}-I'_{(i,j)})^2\right), \qquad (15)$$

where $I_{(i,j)}$ and $I'_{(i,j)}$ indicate the pixel values of the original image and the stego-image of size $M \times N$.

Table 1. shows the result of the hiding capacity and image distortion between several schemes and the proposed scheme.

In Li et al.'s scheme, we utilized the APD_2. In Hong's scheme, the embedding level was set to 0 and the threshold value TH was set to ∞. In Tsai et al.'s scheme, NPD_1 is used.

The hiding capacity of the proposed scheme is 56,747 bits that is amount of larger than other schemes in Lena image. In the average value, the hiding capacity of the proposed scheme was 45,909 bits. This is also larger than other schemes. The image distortion of the proposed scheme is 49.02 dB. It is better than Li et al. and Hong's scheme. However, the image distortion of the proposed scheme is decreased by 1.27 dB compared to Tasi et al.'s scheme. When the $PSNR$ value is over 30 dB, the image distortion is invisible by the human visual system (HVS). Thus, the image distortion of the proposed scheme is over 48 dB, and it's to give a good performance.

Table 2. shows the result of hiding capacity (bpp) and image distortion ($PSNR$) of the proposed scheme with multi-layer embedding in several images. Figure 6. shows the comparison results of the hiding capacity (bpp) and image distortion ($PSNR$) of the proposed scheme and other schemes with multi-layer embedding in the Lena and Baboon images. At first embedding, the proposed scheme shown a good performance in the hiding capacity and image quality. When several times embeds using multi-layer embedding, the hiding capacity and image quality of the proposed scheme is to give a good performance better than other scheme with an exception of Li et al.'s scheme.

5. CONCLUSIONS

We proposed a novel reversible data hiding scheme based on histogram shifting using edge direction (ED) predictor.

At ED predictor, weighted edge direction of adjusted pixels is used, and all of cases edge direction are used.

In the proposed scheme, embedding and extraction procedures were classified by odd and even columns for using ED predictor. Because of divided image by odd and even columns, the proposed scheme used two point pairs. When an even line was embedded, its procedure used modified pixels. However, the proposed scheme shown a good performance.

In our experimental results, the hiding capacity and image quality of the proposed scheme is superior to other schemes. When several times embeds using multi-layer embedding, the image quality of the proposed scheme was poorer than Li et al's scheme. However, the hiding capacity and image quality of the proposed scheme is to give a good performance better than other scheme with the exception of Li et al.'s scheme.

6. ACKNOWLEDGMENTS

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