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Reversible Data Hiding Based on Orthogonal Prediction Error Modification and Multilevel Histogram Shifting

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Abstract: In this study, a reversible data hiding for natural images are proposed. It exploits the technique of orthogonal prediction error modification and multilevel histogram shifting. The proposed orthogonal prediction error modification strategy uses the sets of basic pixels to predict the value of non-basic pixels. A histogram is constructed based on the sequences of prediction errors, and a multilevel histogram shifting mechanism is designed for embedding secret data. In decoder, the cover image pixels and secret data are perfectly recovered. The experimental results show the effectiveness of the proposed scheme. As more embedding levels are used in data hiding, the capacity can be enhanced to about 1.0 bit per pixel. Meanwhile, the visual quality can be achieved as larger than 30 dB.

Key words: Reversible data hiding, orthogonal prediction, multilevel histogram shifting

INTRODUCTION

Recently, the technique of reversible data hiding (Ahmed *et al*., 2010; Hong *et al*., 2009a; Li *et al*., 2011; Liu *et al*., 2010; Luo *et al*., 2011; Mohammad *et al*., 2011; Phadikar *et al*., 2007; Qureshi and Tao, 2006; Wang *et al*., 2008) has attracted increasing interests. Its key advantage is not only the secret data but also the host image can be accurately recovered in decoder. Because the reversibility of this technique, it plays an important role in some specific scenarios such as military, medical diagnosis, law enforcement and so on, where the cover images must be accurately reconstructed after data extraction.

Currently, research in reversible data hiding has become quite important. A lot of reversible data hiding schemes have been proposed in literatures. These schemes can be classified into frequency domain, compressed domain and spatial domain based schemes. Generally, the spatial domain schemes are the basis of other transform and compressed domain schemes; it can be divided into two effective ways to accomplish reversible data hiding categories. One is based on Difference Expansion (DE) and the other is based on histogram shifting.

Tian (2003) firstly proposed DE scheme. Its principle is to expand the differences of a pair of pixels and embed secret bits into the LSB of the expanded difference. Alattar (2004) developed Tian's method by using four neighboring pixels to carry more of secret data to improve the embedded capacity and image quality. Hong *et al*. (2009b) introduced a novel difference expansion scheme based on modification of prediction errors. This scheme firstly predicts pixel values and then obtains error values. Secret bits are embedded reversibly by modifying the values of prediction errors, which provides higher embedding capacity with better image quality.

Ni *et al*. (2006) proposed a reversible data hiding scheme based on the histogram shifting technique. In their scheme, the zero and peak points of an image histogram are shifted to vacate an empty bin for data embedding and achieved reversibility. Their scheme achieves low computational cost and high visual quality; however, the embedding capacity is low and mainly depends on the distribution of image histogram Li *et al*. (2010) a proposed histogram shifting scheme based on the Adjacent Pixels Differences (APD). This scheme employs the histogram of the pixel difference sequence to increase the embedding capacity. Zhao *et al*. (2011) proposed a reversible data hiding scheme based on multilevel histogram shifting, the differences histogram is constructed and employed multilevel histogram shifting mechanism for data embedding, and their method greatly improved the capacity. Generally, performance of a data hiding scheme is evaluated in terms of embedding capacity and the marked image quality. The DE based schemes can provide a higher capacity for secret data

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embedding, while the histogram shifting based schemes can obtain a better quality marked images. Nowadays, many efforts are committed to improving the overall performance.

Thodi and Rodriguez (2007) firstly combined the difference expansion and histogram shifting methods and proposed a new embedding method to improve the distortion performance and achieve reversibility. Although their method effectively improves the embedding capacity, the compressibility of the location map is undesirable for some images. Hong *et al*. (2010) designed a high capacity reversible data hiding scheme using orthogonal projection and prediction error modification, an orthogonal projection technique is used to compute the best weights for a predictor, so that prediction errors can be significantly reduced to achieve high capacity and better image quality.

RELATED WORK

Hong *et al*. (2010). exploited the Orthogonal Projection Technique (OPT) to predict pixel values and modify the error values using the histogram shifting technique. In this method, the orthogonal projection technique is an weighted linear predictor. The value of current processing pixel p_j is predicted by a weighted sum of its three neighboring pixels, as shown in Fig. 1. And the prediction of p_j are computed as:

$$p_j = \sum_{i=1}^{3} n_i m_j^{(i)} \quad 1 \le j \le n \tag{1}$$

where, n is the weight of neighboring pixels $m_j^{(1)}$, $m_j^{(2)}$, $m_j^{(3)}$ of the current processing pixel p_j .

The best weights for an linear predictor which minimize the prediction error can be computed as:

$$m^{(k)} \cdot \left(p - \sum_{i=1}^{3} n_i m^{(i)} \right) = 0, \quad 1 \le k \le 3 \tag{2}$$

The above equation can be rewritten as the matrix form.

$$MM'N = Mp' \tag{3}$$

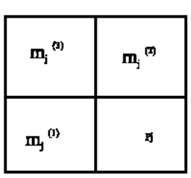

Fig. 1: The relationship of p_j and it's neighboring pixels

where, $M = [m^{(1)}, m^{(2)}, m^{(3)}]'$ and $N = [n_1, n_2, n_3]$. The weights N can be calculated as:

$$N = (MM')^{-1} Mp' \tag{4}$$

And then compute the predication value of p_j one by one according to Eq. 1 and 4. The histogram of prediction errors is shifted to embed secret data.

Zhao *et al*. (2011) proposed a reversible data hiding method based on multilevel histogram shifting and sequential recovery. The data embedding and data extraction is based on a multi level histogram shifting mechanism. A higher capacity is obtained using Zhao *et al*. (2011) method.

PROPOSED SCHEME

Generally, an integer parameter g named the embedding level in which the multilevel histogram shifting strategy is used to control the hiding capacity, a larger g indicates the more predicted errors provided, the more secret data can be embedded.

The method of Hong *et al*. (2010) was adopted to predict pixel values in residue image, and then the predication errors are achieved. Secret data is embedded into the histogram of prediction errors using histogram shifting. However, Hong *et al*. method only select one pair of peak bin and zero bins in the process of histogram shifting. As a result, the capacity is not excellent.

In this study, a novel multilevel histogram shifting strategy based on OPT was proposed. The more pairs of peak-zero points can be utilized; our method designed a multilevel histogram shifting mechanism for a large capacity data hiding.

Data embedding: Given a cover image I sized M×N and secret data S, the data embedding details are described as follows:

- **Step 1:** Compute weights N of linear predictor according to Eq. 4.
- **Step 2:** The first row and first column of I is selected as the basic pixel for predicted image I', the prediction values of the rest elements are computed according to Eq. 1. the predicted image I' can be obtained. Calculate the prediction errors e as:

$$e_{ij} = I_{ij} - I'_{ij} \quad 2 \le i \le m, 2 \le j \le n \tag{5}$$

- **Step 3:** Construct the histogram of these prediction errors with the exception of the first row and first column. Suppose the bins of histogram from left to right are denoted by $h_{-255}, h_{-254}\ldots h_{-1}, h_0, h_1\ldots h_{254}, h_{255}$. Given an integer parameter *g* named embedding level is used to control the embedding capacity, the multilevel histogram mechanism is exploited in the data embedding stage:
- **Step 4:** The prediction errors *e* is modified into the shifted differences e' ($2\le i\le M\times N$) as:

$$e_i' = \begin{cases} e_i + g + 1 & \text{if } e_i > g \\ e_i & \text{if } -g \le e_i \le g \\ e_i - g & \text{if } e_i < -g \end{cases} \quad (6)$$

- **Step 5:** Next, embed the secret data *s* into the shifted differences e', compute marked difference e''_i as:

$$e_i'' = \begin{cases} 2g + s & \text{if } e_i' = g \\ -2g - s + 1 & \text{if } e_i' = -g \\ e_i' & \text{if } e_i' = \pm g \end{cases} \quad (7)$$

- **Step 6:** Compute the capacity Cap (bit) as:

$$Cap = \begin{cases} h_0 & \text{if } g = 0 \\ \sum_{i=-g}^{g} h_i & \text{if } g > 0 \end{cases} \quad (8)$$

- **Step 7:** Generate the marked pixel $I_s(i, j)$ as:

$$I_s(i,j) = I'(i,j) + e''(i,j) \quad (9)$$

where, $2\le i \le m$, $2\le j\le n$.

- **Step 8:** Repeat Steps 1-7, the marked image I_s is obtained

Data extraction and Image recovery: In this process, the details of the data extraction and image recovery are described as follows:

- **Step 1:** Initialize the first row and first column of the marked image I_s as left-and-top-most one of the recovered cover image I
- **Step 2:** Compute the predicted values I_{ij}' of the recovered cover image I according to the following Equation:

$$I'(i+1, j+1) = \text{round}(n_1 I_s(i-1, j) + n_2 I_s(i, j-1) + n_3 I_s(i-1, j-1)) \quad (10)$$

where, round (●) represents rounding the element to the nearest integers. and $1\le i\le m-1$, $1\le j\le n-1$.

- **Step 3:** Compute marked difference e'' as:

$$e'' = I_s - I' \quad (11)$$

- **Step 4:** Obtain the embedding level *g* from the encoder. Calculate the original error e as:

$$e = \begin{cases} e'' - g - 1 & \text{if } e'' > 2\times g + 1 \\ c & \text{if } e'' \in \{2\times c, 2\times c + 1\}, c = 0,1,\ldots,g \\ -c & \text{if } e'' \in \{-2\times c, -2\times c + 1\}, c = 1,\ldots,g \\ e'' + g & \text{if } e'' < -2\times g \end{cases} \quad (12)$$

- **Step 5:** Retrieve the Cth round secret data, C represents rounds of the secret data extraction. The secret data s is recovered as:

$$s = \begin{cases} 0 & \text{if } e'' = 2\times g \text{ or } e'' = -2\times g + 1 \\ 1 & \text{if } e'' = -2\times g \text{ or } e'' = 2\times g + 1 \end{cases} \quad (13)$$

- **Step 6:** The recovered pixels I(i, j) can be computed as:

$$I(i,j) = I'(i,j) + e(i,j) \quad (14)$$

- **Step 7:** Repeat Steps 1-6. In this way the original image I is reconstructed and secret data s are extracted accurately

EXPERIMENTAL RESULTS AND COMPARISONS

As shown in Fig. 2, six 512×512 gray level natural images are selected as test image. The secret data is binary sequences generated by pseudo-random number generator.

Our scheme is compared with Hong *et al*. (2010) method, As the results shown in Table 1, 2.The Tables list the capacity and PSNR values of Hong *et al*.'s method and the proposed scheme with *g* = 1, ….9. Hong *et al*.'s method only provides one pair of peak-zero bins in histogram shifting but our scheme exploits the multilevel histogram shifting of many pairs of peak-zero bins. Obviously, our scheme can provide a higher capacity than Hong *et al*.'s method.

The six marked images obtained by our scheme and Hong *et al*. scheme are shown in Fig. 3-8. All results demonstrate the capacities are improved in our scheme, the average PSNR value is larger than 30 dB even when *g* = 9. As human eyes are not sensitive to distortions when PSNR>30 dB, the visual quality of the marked images are acceptable.

Table 1: Comparison of PSNR and capacity for Hong *et. al*'s method and our method on Elaine, Goldhill, Couple images

Method	g	Elaine		Goldhill		Couple	
		Cap	PSNR	Cap	PSNR	Cap	PSNR
Cap Hong *et al.*'s method		17773	51.13	19496	51.06	26840	51.04
	1	49566	44.62	57699	44.65	74064	44.82
	2	78406	40.92	91949	41.06	114317	41.41
	3	104026	38.52	121367	38.77	147438	39.27
	4	126670	36.79	146152	37.15	172767	37.81
Our method	5	146730	35.49	166901	35.94	191426	36.74
	6	164128	34.48	183577	35.02	205528	35.93
	7	179657	33.67	197384	34.28	215975	35.28
	8	192871	33.01	208411	33.69	224020	34.76
	9	203984	32.47	217427	33.20	230171	34.32

Table 2: Comparison of PSNR and capacity for Hong *et al.* (2009a,b) method and our method on Airplane, Frog, Barbara images

Method	g	Airplane		Frog		Barbara	
		Cap	PSNR	Cap	PSNR	Cap	PSNR
Hong *et al.* (2009a,b) method		40134	51.04	8570	51.03	22419	50.84
	1	106550	45.19	23739	44.34	64773	44.58
	2	151229	42.10	35901	40.41	100892	41.10
	3	180210	40.21	46770	37.74	128470	38.87
	4	199139	38.89	57624	35.75	148250	37.26
Our method	5	212023	37.91	69473	34.18	162534	36.01
	6	221034	37.14	81498	32.91	173118	35.00
	7	227748	36.51	93280	31.84	181220	34.14
	8	232811	35.98	103508	30.93	187790	33.39
	9	236813	35.53	115580	30.15	193291	32.73

Fig. 2(a-f): Test images (a) Elaine (b) Goldhill (c) Couple (d) Aerial (e) Frog (f) Barbara

Fig. 3(a-b): Visual quality comparison for two methods: (a) Marked Elaine images obtained by Hong *et al.*'s method (17773 bits hidden, 51.13 dB) and (b) Marked Elaine images obtained by our method with $g = 9$ (203984 bits hidden, 32.47 dB)

Fig. 4(a- b): Visual quality comparison for two methods: (a) Marked Goldhill images obtained by Hong *et al.*'s method (19496 bits hidden, 51.06 dB) and (b) Marked Goldhill images obtained by our method with g = 9 (115580 bits hidden, 33.20 dB)

Fig. 5 (a-b): Visual quality comparison for two methods: (a) Marked Couple images obtained by Hong *et al.*'s method (26840 bits hidden, 51.04 dB) and (b) Marked Couple images obtained by our method with g = 9 (230171 bits hidden, 34.32 dB)

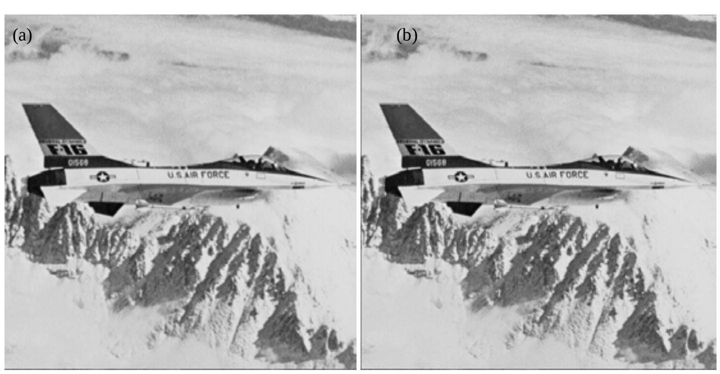

Fig. 6 (a-b): Visual quality comparison for two methods: (a) Marked Airplane images obtained by Hong *et al.*'s method (40134 bits hidden, 51.04 dB) and (b) marked Airplane images obtained by our method with g = 9 (236813 bits hidden, 35.53 dB)

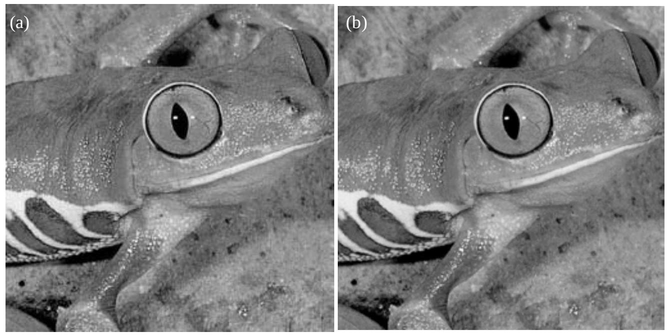

Fig. 7(a-b): Visual quality comparison for two methods: (a) Marked Frog images obtained by Hong *et al.*'s method (8570 bits hidden, 51.03 dB) and (b) marked Frog images obtained by our method with g = 9 (115580 bits hidden, 30.15 dB)

Fig. 8 (a-b): Visual quality comparison for two methods: (a) Marked Barbara images obtained by Hong *et al.*'s method (22419 bits hidden, 50.84 dB) and (b) Marked Barbara images obtained by our method with g = 9 (193291 bits hidden, 32.73 dB)

CONCLUSIONS

This study proposes a novel reversible data hiding scheme based on orthogonal prediction modification (OPT). OPT technique can obtain the best weights of a predictor. As a result, the most prediction errors also are concentrated around zero. The multilevel histogram shifting strategy can provide higher embedding capacity is compared with one level histogram shifting method. Experimental results show our proposed method outperforms Hong *et al.*'s method. Therefore, our method is efficient.

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REFERENCES

Ahmed, M.A., M.L.M. Kiah, B.B. Zaidan and A.A. Zaidan, 2010. A novel embedding method to increase capacity and robustness of low-bit encoding audio steganography technique using noise gate software logic algorithm. J. Applied Sci., 10: 59-64.

Alattar, A.M. , 2004. Reversible watermark using the difference expansion of a generalized integer transform. IEEE Trans. Image Process., 13: 1147-1156.

Hong, W., J. Chen and T.S. Chen, 2009a. Blockwise reversible data hiding by contrast mapping. Inform. Technol. J., 8: 1287-1291.

Hong, W., T.S. Chen and C.W. Shiu, 2009b. Reversible data hiding for high quality images using modification of prediction errors. J. Syst. Software, 82: 1833-1842.

Hong, W., T.S. Chen, Y.P. Chang and C.W. Shiu, 2010. A high capacity reversible data hiding scheme using orthogonal projection and prediction error modification. Signal Process., 90: 2911-2922.

Li, C.H., Z.M. Lu and Y.X. Su, 2011. Reversible data hiding for Btc-compressed Images based on bitplane flipping and histogram shifting of mean tables. Inform. Technol. J., 10: 1421-1426.

Li, Y.C., C.M. Yeh and C.C. Chang, 2010. Data hiding based on the similarity between neighboring pixels with reversibility. Digital Signal Process., 20: 1116-1128.

Liu, Z., X. Sun, Y. Liu, L. Yang, Z. Fu, Z. Xia and W. Liang, 2010. Invertible transform-based reversible text watermarking. Inform. Technol. J., 9: 1190-1195.

Luo, H., Z. Zhao and Z.M. Lu, 2011. Joint secret sharing and data hiding for block truncation coding compressed image transmission. Inform. Technol. J., 10: 681-685.

Mohammad, N., X. Sun and H. Yang, 2011. An excellent Image data hiding algorithm based on BTC. Inform. Technol. J., 10: 1415-1420.

Ni, Z., Y.Q. Shi, N. Ansari and W. Su, 2006. Reversible data hiding. IEEE Trans. Circ. Syst. Video Technol., 16: 354-362.

Phadikar, A., B. Verma and S. Jain, 2007. Region splitting approach to robust color image watermarking scheme in wavelet domain. Asian J. Inform. Manage., 1: 27-42.

Qureshi, M.A. and R. Tao, 2006. A comprehensive analysis of digital watermarking. Inform. Technol. J., 5: 471-475.

Thodi, D.M. and J.J. Rodriguez, 2007. Expansion embedding techniques for reversible watermarking. IEEE Trans. Image Process., 16: 721-730.

Tian, J., 2003. Reversible data embedding using a difference expansion. IEEE Trans. Circ. Syst. Video Technol., 13: 890-896.

Wang, H., X. Sun, Y. Liu and Y. Liu, 2008. Natural language watermarking using Chinese syntactic transformations. Inform. Technol. J., 7: 904-910.

Zhao, Z., H. Luo, Z.M. Lu and J.S. Pan, 2011. Reversible data hiding based on multilevel histogram modification and sequential recovery. AEU-Int. J. Electron. Commun., 65: 814-826.