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Reversible Data Hiding Based on Improved Multilevel Histogram Modification of Pixel Differences

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Abstract

The technique of reversible data hiding recovers the original image without distortion from a stego-image after the hidden data have been extracted. In this paper, we modify Zhao et al.'s method to propose a reversible data hiding algorithm based on improved histogram modification of pixel differences. Experimental results show that our proposed scheme uses improved multilevel histogram modification of pixel differences to achieve large hiding capacity and keep distortion low. We alsoadopt a histogram shifting technique to prevent overflow and underflow. Performance comparisons with other existing schemes are provided to demonstrate the superiority of the proposed scheme.

Key Words: Reversible Data Hiding, Watermarking, Multilevel Histogram Modification

1. Introduction

With the rapid development of network technologies, the Internet has become an important part of the life for many people. Multimedia can be sent quickly by the Internet. However, it causes the problems of the information securities and multimedia copyright protections. Data hiding is a research topic for this problem. Data hiding is a technique that embeds secret information into host media to provide various purposes such as copyright protection, broadcast monitoring, authentication, and soon. Recently, reversible data hiding has attracted a lot of attention. Reversible data hiding can not only embed secret messages into images, but also can recover the original images after secret messages are extracted. Usually, it can be applied to the sensitive images, such as medical images, military images and legal documents which do not allow any damage. Available reversible data hiding techniques can be divided into spatial domain, transform domain and compressed domain methods. Most spatial domain reversible data hiding are developed based on two principles, i.e., difference expansion (DE) [1–4] and histogram modification [5–7]. The DE scheme modifies the relationships between two adjacent pixels. Under the predefined constraints that pixel values should lie between 0 and 255, by slightly adjusting the luminance value of adjacent pixels, data can be hidden into original image. The histogram-based scheme takes the whole image into account for performing data hiding, and it modifies the distribution of histogram of image tohide data. In the histogram-based data hiding, the number of pixels in the peak point is the maximal hiding capacity for the secret message to be embedded.

Histogram-based reversible data hiding technique was firstly presented by Ni et al. in [7,8], in which the message is embedded into the histogram bin. They utilize peak and zero points to achieve reversible data hiding with low capacity. Histogram modification based tech-

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*Corresponding author. E-mail: chingtanghsieh@gmail.com niques have been extended in [9,10]. However, those techniques all suffer from the unresolved issue represented by the need to memorize pairs of peak and zero points. In [11], Wl et al. use pixel differences to increase hiding capacity, and use a binary tree structure to eliminate the requirement tomemorize pairs of peak and zero points. In [12], Zhaoet al. propose a reversible data hiding scheme based on multilevel histogram modification of Pixel Differences. Its principle is to modify the histogram constructed based on the neighbor pixel differences instead of the host image's histogram as in [9]. Many peak points exist around the bin zero in this histogram due to the similarity of adjacent pixel values. Besides, many zero points exist in both sides of the histogram. This means that their scheme can highly raise the capacity of data hiding. In this paper, we improve Zhao et al.'s [12] multilevel strategy to provide more hiding capacity while keeping distortion low.

In recent years, the reversible data hiding techniques are also presented. As [13] to find a practical reversible data hiding scheme, Zhang presentedan iterative procedure to producethe optimal rule of value modification under a payload-distortion criterion. In [14], Qian et al. employed the modified JPEG stream to embedded secret message into the encrypted bitstream. And Hu et al. proposed reversible data hiding method based on the minimum rate criterion, which establishes the consistency between prediction-error histogram generated and secret data embedded to predict pixel in [15]. In this paper, we present a reversible data hiding method based on histogram. In experimental result, the capacity of our method improvement the average capacity 77.1% and 28.63% with Tai's and Zhao's method, and the cover image is also can be recovered.

2. Related Works

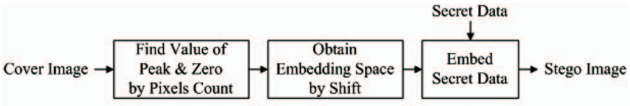
2.1 Ni et al.'s Method

In [7], Ni et al. first presented the histogram-based reversible data hiding technique to embed secret messages in host image. The pixels of host image were counted by image scan. They employ these counts to generate host histogram. In secret messages embedding, their method finds a pair of count that called peak and zero point in maximum and zero counts. When the pair of counts was found, this method scans host image and modifies pixels which next to peak count pixels to make histogram shift from peak to zero point. In the same scan, the present method also modifies the peak count pixels by secret messages. Finally, the extract and recovery key were saved. The operating and flow-chart as (1) and Figure 1(a) show. Where o and s mean original and stego image. And msg, $peak$ and $zero$ are secret messages, peak and zeros point separately. The flow-chart Figure 1(b) shows the secret messages extract and host image recovery. The secret messages were extracted when scan to pixels value as peak and next to peak. And the host image recovered when the pixels between peak and zero point.

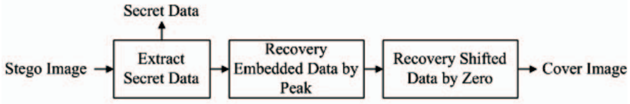
$$s(x,y)\begin{cases} o(x,y)+msg & \text{if } o(x,y)=peak \\ o(x,y)+1 & \text{if } zero>peak \,\&\, peak<o(x,y)<zero \\ o(x,y)-1 & \text{if } zero<peak \,\&\, zero<o(x,y)<peak \end{cases} \tag{1}$$

2.2 Tai et al.'s Method

In [11], Tai et al. presented and employed inverse S order on difference base histogram in reversible data hiding. In histogram base reversible data hiding, the capacity is improved very significance than Ni's method by inverse S order. In method, they utilize their proposed which called inverse S order to make host image from 2-D image matrix to a 1-D vector. The histogram d_i is calculated by the distance of neighborhood vector as (2). Where v_i is ith value in original 1-D vector, sd_i is shifted vector.



(a) Embedding flow-chart



(b) Extracting flow-chart

Figure 1. Ni et al. proposed method.

$$d_i = \begin{cases} v_i & \text{if } i = 1 \\ |v_{i-1} - v_i| & \text{otherwise} \end{cases} \tag{2}$$

$$sd_i = \begin{cases} d_i & \text{if } i = 1 \text{ or } d_i < P \\ d_i + 1 & \text{if } d_i \geq d_{i+1} \text{ and } d_i > P \\ d_i - 1 & \text{if } d_i < d_{i+1} \text{ and } d_i > P \end{cases} \tag{3}$$

$$d'_i = \begin{cases} sd_i & \text{if } i = 1 \text{ or } sd_i \neq P \\ sd_i + b & \text{if } d_i \geq d_{i+1} \text{ and } sd_i = P \\ sd_i - b & \text{if } d_i < d_{i+1} \text{ and } sd_i = P \end{cases} \tag{4}$$

$$v'_i = \begin{cases} d'_i & \text{if } i = 1 \\ d'_i + b & \text{if } d_i \geq d_{i+1} \\ d'_i - b & \text{if } d_i < d_{i+1} \end{cases} \tag{5}$$

The peak point P is determined from pixels distance that counted highest. As pixel distance is larger than P, the presented method modifies 1 value for this pixel as histogram shifting sd_i. The operation as function (3) shows. In embedding, the secret messages b are embedded as (4) operate. Finally, after (5) function operating, the stego image is generated by inverse S order.

2.3 Zhao et al.'s Method

In [12], a method based on difference histogram was proposed by Zhao et al. Their method combined Tai's inverse S order and embedding level (EL) to advance embedding capacity. First, Zhao et al. make image from 2-D image to 1-D vector by inverse S order. Then difference histogram is calculated by neighborhood vector as (6). After difference histogram calculation, apositive integer which is called embedding level (EL) is selected and inputted in embedding operation.

In embedding operation, the processing is different when EL is equal and bigger than zero. In EL equal to zero, the method modifies the pixels of difference histogram as shifting by (7). Then the secret messages are embedded in this position that is shifted before by (8). In EL bigger than zero, the modification as (9) and (10) shifts difference histogram and embeds secret messages. When this level finished, the EL was decreased a level by method. Then the embedding operation processes continually until secret data is finished or capacity is full. Finally, as (11) makes embedded vector to stego vector and resizes to 2-D image by inverse S order.

In secret messages extracting and host image recovery, the secret messages and the host image are extracted and recovered by inverse operation.

In following formulas, v_i is resizing from 2-D original image to 1-D vector by inverse S order. d_i is calculated by neighborhood vector. w is secret message. EL means embedding level. The vector that is shifted and embedded is sd_i and d'_i respectively.

$$d_i = \begin{cases} v_1 & \text{if } i = 1 \\ v_{i-1} - v_i & \text{otherwise} \end{cases} \tag{6}$$

$$sd_i = \begin{cases} d_1 & \text{if } i = 1 \\ d_i & \text{if } d_i \leq EL \cap i > 1 \\ d_i + 1 & \text{if } d_i > EL \cap i > 1 \end{cases} \tag{7}$$

$$d'_i = \begin{cases} sd_1 & \text{if } i = 1 \\ sd_i + w & \text{if } sd_i = EL \cap i > 1 \\ sd_i & \text{if } sd_i \neq EL \cap i > 1 \end{cases} \tag{8}$$

$$sd_i = \begin{cases} d_1 & \text{if } i = 1 \\ d_i & -EL \leq d_i \leq EL \cap i > 1 \\ d_i + EL + 1 & d_i > EL \cap i > 1 \\ d_i - EL & d_i < -EL \cap i > 1 \end{cases} \tag{9}$$

$$d'_i = \begin{cases} sd_1 & \text{if } i = 1 \\ sd_i & \text{if } sd_i \neq EL \cap i > 1 \\ 2 \times sd_i + w & \text{if } sd_i = EL \cap i > 1 \\ -2 \times sd_i - w + 1 & \text{if } sd_i = -EL \cap i > 1 \end{cases} \tag{10}$$

$$v'_i = \begin{cases} d'_1 & \text{if } i = 1 \\ d'_{i-1} - d'_i & \text{otherswise} \end{cases} \tag{11}$$

3. Proposed Method

In this section, we present a reversible data hiding method that modified from [12]. The first of all, 1-D vector is obtained as [11,12] by inverse S order. To avoid overflow and underflow in embedding, the vector elements that may overflow and underflow are checked by embedding level (EL) as shown in formula (12). Where V_i is the ith elementof 1-Dvector V that is cover image by inverse S scan, v_i is the ith element of vector v that is modified, I_{MAX} and I_{MIN} are maximum and minimum energy of image. EL is embedding level. The processing shows as Figure 2. When the vector is modified, the modification position is compressed by run-length, than saved and embedded after secret data embedded.

Then we calculate difference histogram as formula (6). The difference histogram is shown as Figure 3. In Zhao's method [12], they only shift right bar which bigger than zero. Our present modifies their formula to (13) via 2's complement. When shifting, our method moves the value with conditionas (13). Figures 4 and 5 are two samples that the shifting EL is equal to 0 and 2, respectively. In secret messages embedding, the formula (14) embeds secret messages in 1-D vector. Where p_1 is first value in vector, d_i as (7) is calculated by neighborhood element, d_i' and d_i'' are vectors thatis shifted and embedded, separately. When a level of EL embedding is finished, the EL is checked with zero. As EL is bigger than zero, it would decrease a level, and then embed secret messages by formula (14), recursively. Until EL is equal to zero or all secret messages is embedded, the step of embedding is end. Figures 6 and 7 show the embedding in EL is equal to 0 and 2, individually. The stego image is generated from 1-D vector resizing to 2-D image through inverse S order after formula (11) operation.

In secret messages extracting and recovery operation, the method employs formula (15) and (16) to extract secret messages and recover original vector separately

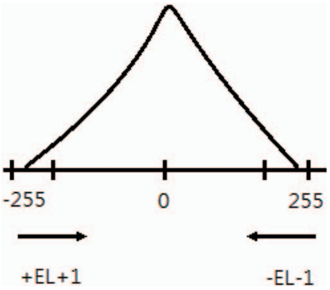


Figure 2. The processing of over/underflow avoid.

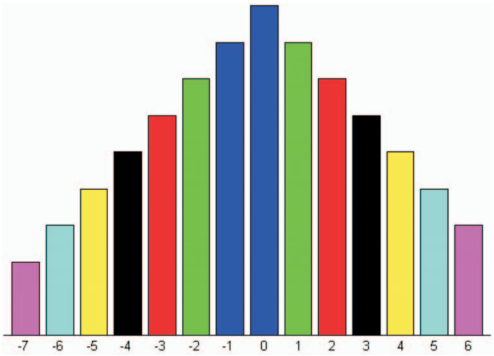


Figure 3. An example of difference histogram.

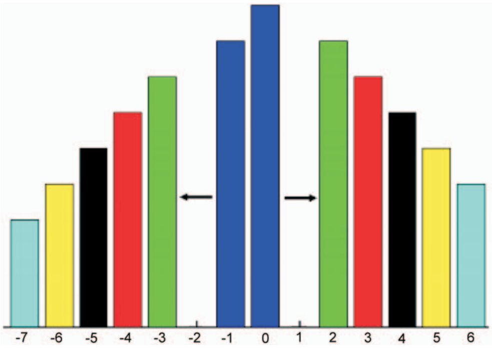


Figure 4. Shifting when EL = 0.

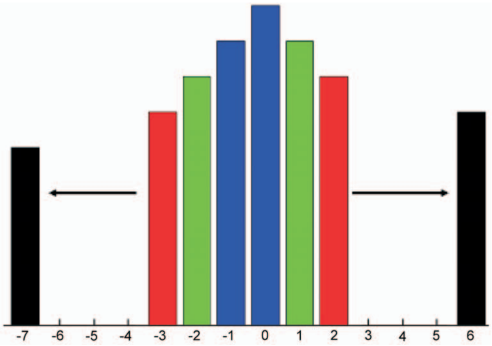


Figure 5. Shifting when EL = 2.

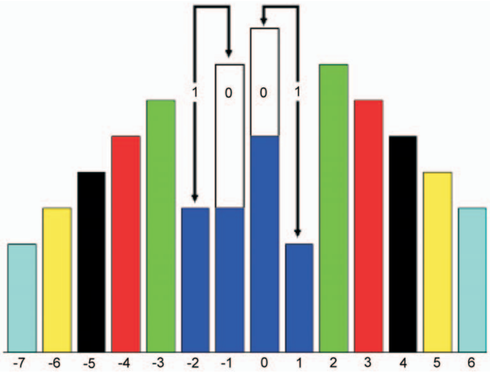


Figure 6. Embedding when EL = 0.

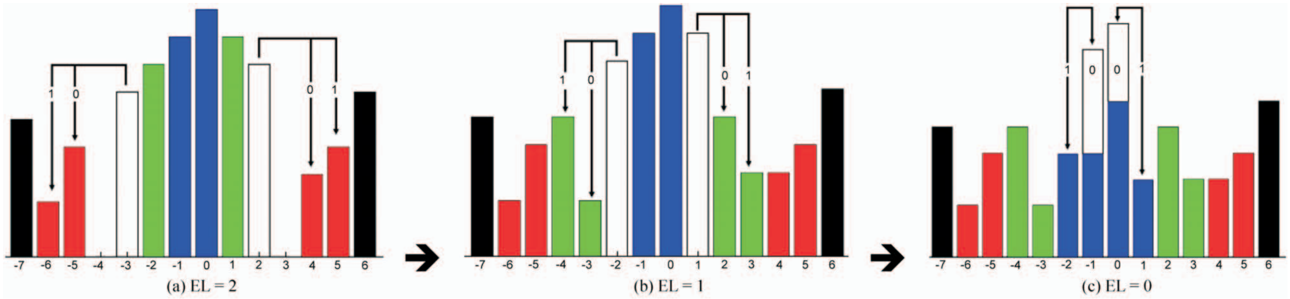


Figure 7. Embedding when EL = 2.

as the different histogram of stego image is computed. Where *tEL* means the embedding level from 0 to *EL*.

$$v_i = \begin{cases} V_i - EL - 1 & \text{if } V_i + EL + 1 > I_{MAX} \\ V_i + EL + 1 & \text{if } V_i - EL - 1 < I_{MIN} \end{cases} \quad (12)$$

$$d'_i = \begin{cases} p_1 & \text{if } i = 1 \\ d_i & \text{if } -EL - 1 \le d_i \le EL,\ i > 1 \\ d_i + EL + 1 & \text{if } d_i > EL,\ i > 1 \\ d_i - EL - 1 & \text{if } d_i < -EL - 1,\ i > 1 \end{cases} \quad (13)$$

$$d''_i = \begin{cases} p_1 & \text{if } i = 1 \\ d'_i & \text{if } -EL - 1 < d'_i < EL,\ i > 1 \\ 2 \times EL + w & \text{if } d'_i = EL,\ i > 1 \\ -2 \times EL - 1 - w & \text{if } d'_i = -EL - 1,\ i > 1 \end{cases} \quad (14)$$

$$w = \begin{cases} 0 & \text{if } d''_i = 2 \times EL, & i > 1 \\ 0 & \text{if } d''_i = -2 \times EL - 1, & i > 1 \\ 1 & \text{if } d''_i = 2 \times EL + 1, & i > 1 \\ 1 & \text{if } d''_i = -2 \times EL - 2, & i > 1 \end{cases} \quad (15)$$

$$d_i = \begin{cases} d''_i - EL - 1 & \text{if } d''_i > 2 \times EL + 1, & i > 1 \\ d''_i + EL + 1 & \text{if } d''_i < -2 \times EL - 2, & i > 1 \\ tEL & \text{if } d''_i = 2 \times tEL \text{ or } d''_i = 2 \times tEL + 1, & i > 1 \\ -tEL - 1 & \text{if } d''_i = -2 \times tEL - 1 \text{ or } d''_i = -2 \times tEL - 2, & i > 1 \end{cases} \quad (16)$$

4. Experimental Result

In experimental, the cover images we employed as Figure 8. The size of images is 512 × 512 and gray-level. And wecompare our method result with others by capacity andquality.

In capacity comparing, we employ bit per pixel (bpp) as shown in (17). And in quality, PSNR (18) is used to compare between methods.
Where P_e is embedded pixel count, P_{total} is total pixel of image, I_{MAX} is max value of pixel, and *MSE* is mean square error as shown in (19).

$$bpp = \frac{P_e}{P_{total}} \quad (17)$$

$$PSNR = 10 \times \log_{10} \frac{(I_{MAX})^2}{MSE} \quad (18)$$

$$MSE = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} (o(i,j) - s(i,j))}{m \times n} \quad (19)$$

Figures 9 and 10 shows the comparing with other

(a) Aerial (b) Lena (c) Airplane

(d) Car (e) Barbara (f) Golden Hill

Figure 8. Experimental images.

methods in capacity and PSNR, individual. In Figure 9 comparing with capacity, our method bpp of images is higher than other methods. With Kim's method, the average bpp increase 77.1 percent. With Zhao's method, our method advantage 28.63 percent in average bpp. And with Tai's method, our method capacity is higher in images that are smoothing as (a), (b), (c) and (d) in low EL, and the average bpp only decrease 2.46 percent. As Figure 10 quality comparing, the stego image in Tai's method is the lowest with others. Although our method is lower than methods of Kim and Zhao, the average quality PSNR with their methods is less under 3 dB. And the stego image is not noticed in our method directly.

5. Conclusions

In this paper, we presented a novel reversible data hidingto gain the capacity by modifying Zhao's method.

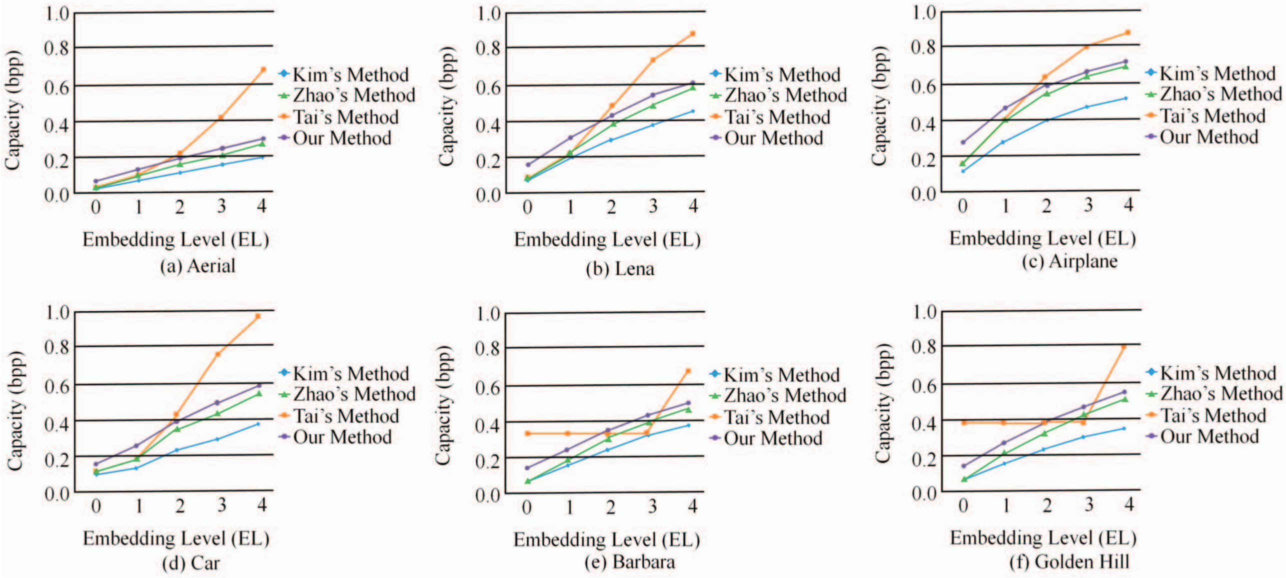


Figure 9. Comparing with other methods in capacity.

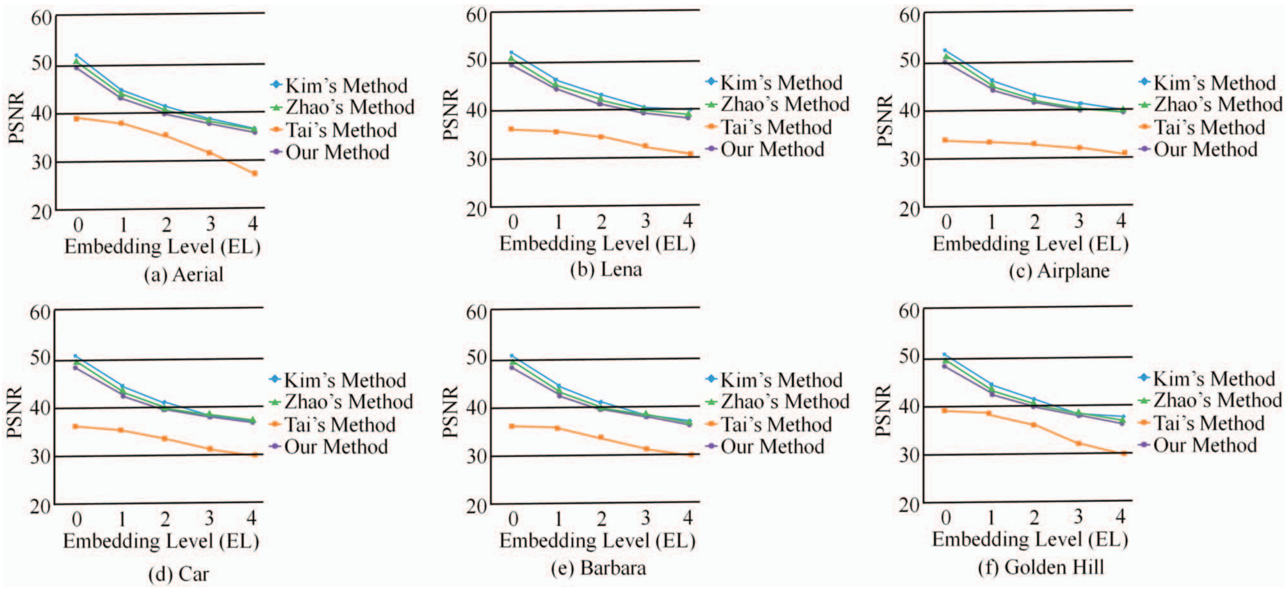


Figure 10. Comparing with other methods in PSNR.

In quality, our method PSNR is only less under 3 dB in comparing with the methods of Tai and Zhao. However in capacity, we advantage the average capacity 77.1% and 28.63% with Tai's and Zhao's method. And in cover image overflow and underflow processing, we proposed a formula to adapt EL method easily.

References

[1] Alattar, A. M., "Reversible Watermark Using Difference Expansion Ofquads," *IEEE Int'l Conf. on Acoustics, Speech and Signal Processing*, Vol. 3, pp. 377–380 (2004). doi: 10.1109/ICASSP.2004.1326560

[2] Alattar, A. M., "Reversible Watermark Using the Difference Expansion of a Generalized Integer Transform," *IEEE Trans. Image Process*., Vol. 13, No. 8, pp. 1147–1156 (2004). doi: 10.1109/TIP.2004.828418

[3] Thodi, D. M. and Rodriguez, J. J., "Expansion Embedding Techniques for Reversible Watermarking," *IEEE Trans. Image Process*., Vol. 16, No.3, pp. 721–730 (2007). doi: 10.1109/TIP.2006.891046

[4] Tian, J., "Reversible Data Embedding Using a Difference Expansion," *IEEE Trans. Circuits Syst, Video Technol*., Vol. 13, No. 8, pp. 890–896 (2003). doi: 10.1109/TCSVT.2003.815962

[5] Coltuc, D. and Chassery, J. M., "Very Fast Watermarking by Reversible Contrast Mapping," *IEEE Signal Process. Lett*., Vol. 14, No. 4, pp. 255–258 (2007). doi: 10.1109/LSP.2006.884895

[6] Kim, H. J., Sachnev, V., Shi, Y. Q., Nam, J. and Choo, H. G., "A Novel Difference Expansion Transform for Reversible Data Embedding," *IEEE Trans. Information Forensics and Security*, Vol. 3, No. 3, pp. 456–465 (2008). doi: 10.1109/TIFS.2008.924600

[7] Ni, Z., Shi, Y. Q., Ansari, N. and Su, W., "Reversible Data Hiding," *IEEE Trans. Circuits Syst, Video Technol*., Vol. 16, No. 3, pp. 354–362 (2006). doi: 10.1109/TCSVT.2006.869964

[8] Ni, Z., Shi, Y. Q., Ansari, N. and Su, W., "Reversible Data Hiding," IEEE Proceedings of ISCAS'03, Vol. 2, pp. II-912–915 (2003). doi: 10.1109/ISCAS.2003.1206123

[9] Fallahpour, M. and Sedaaghi, M. H., "High Capacity Lossless Data Hiding Based on Histogram Modification," *IEICE Electron. Exp*., Vol. 4, No. 7, pp. 205–210 (2007). doi: 10.1587/elex.4.205

[10] Lee, S. K., Suh, Y. H. and Ho, Y. S., "Reversible Image Authentication Based on Watermarking," *Proc. IEEE Int. Conf. Multimedia Expo, Toronto*, on Canada, pp. 1321–1324 (2006). doi: 10.1109/ICME.2006.262782

[11] Tai, W. L., Yeh, C. M. and Chang, C. C., Reversible Data Hiding Based on Histogram Modification of Pixel Differences, *IEEE Transactions on Circuits and Systems for Video Technology*, Vol. 19, No. 6, pp. 906–910 (2009). doi: 10.1109/TCSVT.2009.2017409

[12] Zhao, Z. F., Luo, H., Lu, Z. M. and Pan, J. S., "Reversible Data Hiding Based on Multilevel Histogram Modification and Sequential Recovery," International Journal of Electronics and Communications (AEU), In Press, Corrected Proof, March (2011). doi: 10.1016/j.aeue.2011.01.014

[13] Zhang, X. P., "Reversible Data Hiding with Optimal Value Transfer," *IEEE Transactions on Multimedia*, Vol. 15, No. 2, pp. 316–326 (2013). doi: 10.1109/TMM.2012.2229262

[14] Qian, Z. X., Zhang, X. P. and Wang, S. Z., "Reversible Data Hiding in Encrypted JPEG Bitstream," *IEEE Transactions on Multimedia*, Vol. 16, No. 5, pp. 1486–1491 (2014). doi: 10.1109/TMM.2014.2316154

[15] Hu, X. C., Zhang, W. M., Li, X. L. and Yu, N. H., "Minimum Rate Prediction and Optimized Histograms Modification for Reversible Data Hiding," *IEEE Transactions on Information Forensics and Security*, Vol. 10, No. 3, pp. 653–664 (2015). doi: 10.1109/TIFS.2015.2392556

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