ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

Reversible Image Watermarking Using Adaptive Prediction Error Expansion & Pixel Selection

Pramod R Sonawane, K.B.Chaudhari
Department Of Electronics Engineering, University of Pune, India, University of Pune, India

Abstract* - Reversible image watermarking enables the embedding of copyright or useful information in a host image without any loss of information. Here we are proposing a novel technique to improve the embedding capacity i.e. reversible watermarking using an adaptive prediction error expansion & pixel selection. This work is an improvement in conventional PEE by adding two new techniques adaptive embedding & pixel selection. Instead of uniform embedding we adaptively embed one or two bits into the expandable pixels as per the regional complexity. Adaptive PEE can obtain the embedded rate up to 1.8 bits per pixel as compared to the 1 BPP of conventional PEE. As an intermediate step of prediction error expansion we also propose to select relatively smooth pixels and ignore the rough ones. In other words, the rough pixels may remain unchanged, and only smooth pixels are expanded or shifted. Also we get a more sharply distributed prediction error histogram and a larger proportion of prediction-errors in the histogram are expanded to carry hidden data. So the amount of shifted pixels is diminished, which leads to a better image quality.

Index Terms **– Reversible image watermarking, Adaptive prediction error expansion, Gradient adjusted prediction, Pixel Selection (PS).**

I. INTRODUCTION

Among different kinds of digital watermarking schemes, reversible watermarking has become a research hotspot recently. Compared with traditional watermarking, it can restore the original cover media through the watermark extracting process; thus, reversible watermarking is very useful, especially in applications dictating high Fidelity of multimedia content, such as military aerial intelligence gathering, medical records, and management of multimedia information. Visible watermarks are routinely added to digital images as a form of copy protection, but their presence essentially destroys the picture, obliterating information within altered pixels in a way that cannot be reversed. The system could be used for the authentication of military images. Inexpensive image editing software is now available that can be used to make essentially undetectable "photo realistic" changes to almost any photograph. In a military setting it is important to prevent unauthorized manipulation of digital images and to be able to demonstrate credibility and provenance. Digital watermarking has been widely used to protect the copyright of digital images. In order to strengthen the intellectual property right of a digital image, a trademark of the owner could be selected as a watermark and embedded into the protected image. The image that embedded the watermark is called a watermarked image. Then the watermarked image could be published, and the owner can prove the ownership of a suspected image by retrieving the watermark from the watermarked image. we can determine the ownership of the suspected image. The earliest reversible watermarking scheme was invented by Barton in 1997 in his paper 'Method and Apparatus for Embedding Authentication Information within Digital Data', after that no. of reversible watermarking methods have been reported in the literature. The Reversible watermarking algorithms are generally classified into following categories:

1) Reversible watermarking using data compression,
2) Reversible watermarking using difference expansion [4].
3) Reversible watermarking using histogram operation.
4) Reversible watermarking using integer transform [7].
5) Reversible watermarking using Prediction Error Expansion Method [5]

In the above techniques PEE becomes very much popular due to its potential to well exploit the spatial redundancy in natural images. Prediction Error expansion is an improved version of Tian's Difference Expansion PEE algorithm is developed by Thodi & Rodriguez [5] in 2007 in their paper of Expansion embedding techniques for reversible watermarking, where they propose prediction-error expansion, a new method for expansion embedding reversible watermarking. Prediction-error expansion combines the advantages of expansion embedding with the superior de correlating abilities of a predictor, resulting in a higher data-embedding capacity than with difference Expansion (DE).After that no. of PEE methods developed using different prediction algorithm.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

II. PREVIOUS WORK

In the Conventional PEE, first each pixel is predicted by using a prediction algorithm called Median Edge Detector (MED) [14],

$$\hat{x} = \begin{cases} \min(a, b), & \text{if } c \geq \max(a, b), \\ \max(a, b), & \text{if } c \leq \min(a, b), \\ a + b - c, & \text{Otherwise} \end{cases}$$

Where a, b, and c are the right, lower, and diagonal neighbors of x.

Accordingly, the PE is calculated by $e = x - \hat{x}$. We can then get the PE histogram which is a Gaussian-like distribution centered at 0

a) IF the PE belongs to the inner region, i.e., $e \in [-t, t]$, we take the watermarked pixel value as

$x^w = \hat{x} + e' = x + e + b$,

Where, $e' = 2e+b$

is the expanded PE, and $b \in \{0, 1\}$ is a watermark bit. As a result, one bit is embedded into this pixel.

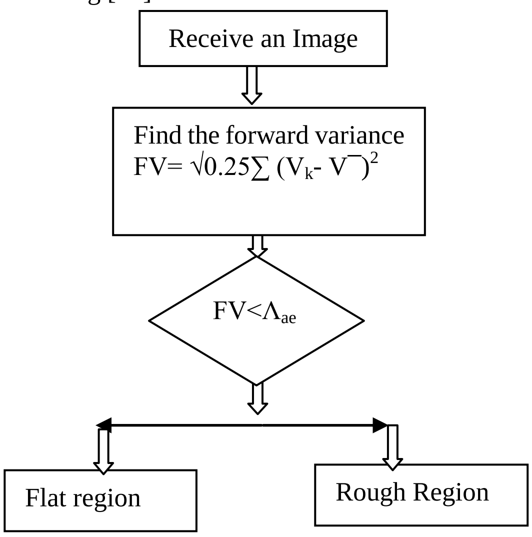
b) If the PE belongs to the outer region, i.e., $e \geq t$ or $e < -t$. In this case, the pixel does not carry any watermark bit and its value is simply shifted to get

$$x^w = \begin{cases} x + t, & \text{if } e \geq t \\ x - t, & \text{if } e < -t \end{cases}$$

Above "shift" manipulation is a characteristically process of reversible watermarking method, which guarantees recovering the original image. To minimize the distortion in PEE, the capacity-parameter is taken as the smallest integer such that the inner region can provide sufficient expandable pixels to embed the payload. To prevent overflow/underflow (overflow, in abbreviation), some pixels cannot be expanded or shifted. This means that the watermarked values should be restricted in [0,255].

III. PROPOSED METHOD

The proposed method combines the two new techniques adaptive embedding as well as pixel selection. First according to the optimal adaptive embedded threshold divide the image pixels into two regions. a) Flat region & Rough regions. Then embed 2 bits into the flat region pixels & embed only one bit into the rough region pixels. instead of embedding 1 bit into a pixel with large prediction-error, it is better to embed additionally 1 bit into an already embedded pixel whose original prediction-error is sufficiently small. This fact motivates us to exploit the pixels with relatively small prediction-errors. Based on this observation, unlike conventional PEE that uniformly embeds 1 bit into each expandable pixel, we turn to embedding more bits into expandable pixels located in flat regions. We call this adaptive embedding [13].



Prediction Algorithm:

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

The gradient variations of the neighboring Pixels are used for estimating the pixel value. The Gradient adjusted prediction (GAP) algorithm is operates on seven neighbors of the current pixel of a cover image $I_{i,j}$.
By Appling GAP algorithm for $I_{i,j}$, its predicted value $I^{\wedge}_{i,j}$ can be computed as, shown in fig.1

$d_h = |I_{i-1,j} - I_{i-2,j}| + |I_{i,j-1} - I_{i-1,j-1}| + |I_{i,j-1} - I_{i+1,j-1}|$

$d_v = |I_{i-1,j} - I_{i-1,j-1}| + |I_{i,j-1} - I_{i,j-2}| + |I_{i+1,j-1} - I_{i+1,j-2}|$

Where, d_h & d_v are vertical & horizontal gradients.
The GAP Predictor results in a new image with predicted pixels value [10].

	j-1	j	j+1	j+2
i-1	u_1	u_2	u_3	
i	u_4	$I_{i,j}$	v_1	x
i+1	v_2	v_3	v_4	
i+2	y	z		

$$\widehat{I}_{i,j} = \begin{cases} v_1 & \text{if } d_v - d_h > 80 \\ \frac{(v_1 + I'_{i,j})}{2} & \text{if } d_v - d_h \in (32, 80] \\ \frac{(v_1 + 3I'_{i,j})}{4} & \text{if } d_v - d_h \in (8, 32] \\ I'_{i,j} & \text{if } d_v - d_h \in [-8, 8] \\ \frac{(v_3 + 3I'_{i,j})}{4} & \text{if } d_v - d_h \in [-32, -8) \\ \frac{(v_3 + I'_{i,j})}{2} & \text{if } d_v - d_h \in [-80, -32) \\ v_3 & \text{if } d_v - d_h < -80 \end{cases}$$

fig.1

Then find out the prediction error

$P_{i,j} = I_{i,j} - I^{\wedge}_{i,j}$

Adaptive Embedding & Pixel Selection:
step1)
Find out the Capacity parameter (t) according to capacity and one gets the so-called inner region and outer region. Finally, each pixel of inner region is expanded to carry 1bit, and pixels of outer region are shifted to eliminate ambiguity. Here, expanding or shifting a pixel means to expand or shift its prediction-error in the prediction-error histogram select the capacity parameter t €{1,2...255}
See the fig.2
Step 2) now by using the capacity parameter divide the flat region pixels & rough region pixels into expandable pixels & shift able pixels.

Flat region pixels $J_f(t)$

Expandable pixels   shift able pixels.

Rough region pixels $J_r(t)$

Expandable pixels   shift able pixels.

Overflow pixels: $O(t) = (J_f - E_f(t) - S_f(t)) U (Jr - Er(t) - Sr(t))$ therefore we can say that image pixels are divides into 5 parts. Each pixel of $E_f(t)$ can be expanded to carry 2 bits without overflow, whereas 1 bit for the pixel of Er(t). The pixels in O(t) cannot be expanded or shifted, and they will remain unchanged in data embedding. So, if taking t as the capacity-parameter, the amount of data bits that can be embedded is $2|E_f(t) + Er(t)|$.
The capacity parameter t can be select in such a way that it can provide enough expandable pixels to embed the data

$2|E_f(t) + Er(t)| \geq N_C + 60 + 18\, O(t)$

Where N_C is a capacity & 18 bits are required to record one overflow location.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

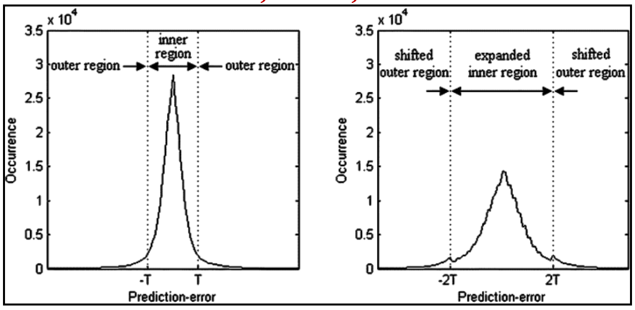


Fig.2

Step 3) Determine Pixel Selection threshold level Λ_{PS}

As an intermediate step of PEE, we propose to select relatively smooth pixels (i.e., pixels located in smooth area) and ignore the rough ones. In other words, the rough pixels may remain unchanged, and only smooth pixels are expanded or shifted. For that we have to find out pixel selection threshold level. We select the pixels whose forward variances satisfy FV < Λ_{PS}, where Λ_{PS} is a threshold, and then we utilize these pixels for data embedding while ignoring the others. By this strategy, only smooth pixels are expanded or shifted, and rough ones are unchanged. For an appropriate, the predictor works better with selected pixels and the prediction-error histogram derived from selected pixels is more concentrated than the original as shown in fig.3 As a result, a larger proportion of prediction-errors in the histogram are expanded to carry hidden data, and we get a smaller N_S,

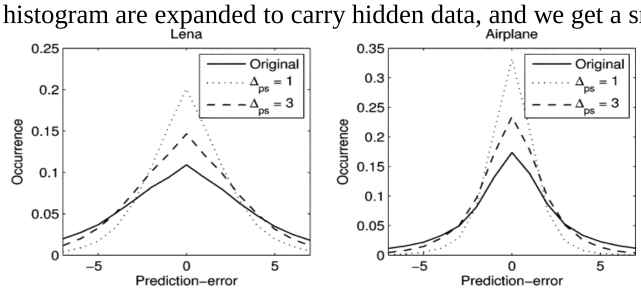


Fig.3

As we compare between conventional PEE and the PEE with pixel selection as shown in Fig. 4. From this figure, we can say that significant improvement is there.

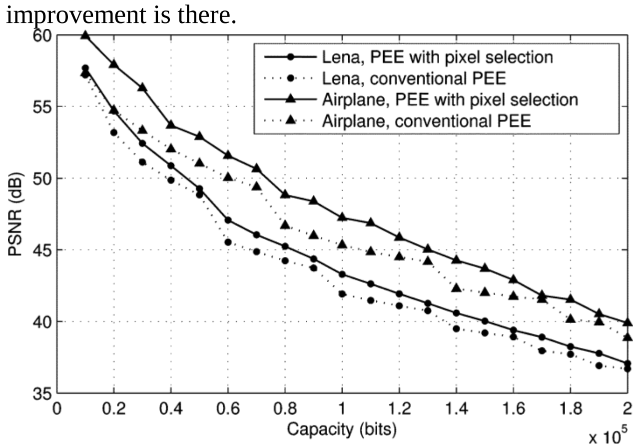


Fig.4

Now determine the smallest s i.e. T_{CP} such that the smooth expandable pixels $E_F(T_{CP}, s)$ U $E_r(T_{CP}, s)$ are capable to embed a payload

$2|E_F(T_{CP}, s)| + |E_r(T_{CP}, s)| \geq N_C + 60 + 18\, O(T_{CP})$

Where, $s \in \{0,1,\ldots 255\}$ & $E_F(T_{CP}, s) = \{(i,j) \in E_F(T_{CP}): C_{i,j} \leq s\}$

$E_r(T_{CP}, s) = \{(i,j) \in E_r(T_{CP}): C_{i,j} \leq s\}$

In the above equations Ci,j is the maximum value between $FV_{i,j}$, $BV_{i,j}$ & $G_{i,j}$ As we have seen $FV_{i,j}$ is called as forward variance. $BV_{i,j}$ is called backward variance & is defined as $BV_{i,j} = \sqrt{\tfrac{1}{4}\sum(u_k - u')^2}$

& $G_{i,j} = |v' - u'|$ i.e. The gap between forward pixels & backward pixels.

Step 4)

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

Pixel Selection & Adaptive Embedding [13]:

First we consider the boundary pixels are unchanged hence there watermarked value will be equal with their original value. Embed the message into image J (image without considering the boundary pixels) by scanning the image from left to right & from top to bottom. We have to embed the data simultaneously while we are performing the pixel selection procedure. Calculate the watermarked value $I^{W}_{i,j}$ by using the pixel selection criteria.

$FV_{i,j} < T_{pst,}$ and $BV^{W}_{i,j,}, G^{W}_{i,j} \leq Tpst + Tcp$ ---(1)

Case 1) If the above equation is satisfies (i,j) € Ef(Tcp)& embed 2 bits b € {0,1,2,3} into the pixel :

$Iwi,j= Ii,j +3|Pi,j| +b$

Case 2) If equation 1 satisfies & (i,j) € Sf(Tcp), then shift the pixel value

$$Iwi,j= \begin{cases} Ii,j +3\ |Tcp/3| & \text{if } Pi,j \geq |Tcp/3| \\ Ii,j -3\ |Tcp/3| & \text{if } Pi,j < -|Tcp/3| \end{cases}$$

Case 3) If equation 1 satisfies (i,j) € Er(Tcp) then embed 1 bits b € {0,1} into the pixel :

$Iwi,j= Ii,j +|Pi,j| +b$

Case 4) If equation 1 satisfies & (i,j) € Sr(Tcp), then shift the pixel value,

$$Iwi,j= \begin{cases} Ii,j + |Tcp| & \text{if } Pi,j \geq Tcp \\ Ii,j - |Tcp| & \text{if } Pi,j < - Tcp| \end{cases}$$

Case 5) otherwise

$Iwi,j = Ii,j$

Therefore we are embedding the data into the pixels, satisfying case 1 & case 3, we are shifting the values of pixels, satisfying case 2 & case 4. & the remaining pixels remain unmodulated.

Step 4-A) Embedding of Auxiliary information & Overflow locations.

Step 5) Extraction Procedure:

The Extraction procedure is exactly reverse of embedding procedure & it is relatively simple.

a) Extract Auxiliary Information and Overflow Locations- By reading LSBs of the first 60 pixels of J , determine T_{AET} ,T_{CP}, T_{PST}, $|O(T_{CP})|$ & the end location.

b) Extract the Sequence S_{LSB} and Restore a Part of Image From the end-location, in the reverse raster-scan-order, repeat the following process a) and b) until the sequence is extracted. Assume that the current pixel is (i,j)

a) Compute the prediction $I\^{}_{i,j}$, forward-variance $FV_{i,j}$, backward variance $BV^{w}_{i,j}$ from recovered pixels & unprocessed watermarked pixels. These values will be exactly same as that of in embedding process.

Here consider $P^{w}i,j= I^{w}_{i,j} - I'_{i,j}$.

b) Recover the original pixel value & extract the hidden data by using following procedure. As $T'cp= Tcp/3$

case1) If equation 1 satisfies & (i,j) €∕Ó (Tcp), & If FVi,j < Taet , $P^{w}i,j$ € [-4T´cp , 4T´cp], the embedded data i.e. 2 bits is $b= | P^{w}_{i,j} |-4| P^{w}_{i,j} /4|$, then the original value of pixel is ,

$Ii,j= I^{w}_{i,j} - 3| P^{w}_{i,j} /4|- b$

.

Case 2) If If FVi,j < Taet , $P^{w}i,j$ € [-∞, -4T´cp] U [4T´cp, ∞], then the original value of pixel is ,

$$I_{i,j}= \begin{cases} I^{w}_{i,j} - 3T'cp & \text{if } P^{w}_{i,j} \geq 4T'cp \\ I^{w}_{i,j} + 3T'cp & \text{if } P^{w}_{i,j} < - 4T'cp \end{cases}$$

Case 3) If FVi,j ≥ Taet and , $P^{w}i,j$ € [-2Tcp , 2Tcp], the Embedded data i.e. 1 bits is

$b= | P^{w}_{i,j} | - 2| P^{w}_{i,j} /2|$

then the original value of pixel is ,

$Ii,j= I^{w}_{i,j} - | P^{w}_{i,j} /2|- b$

Case 4) If FVi,j ≥ Taet , $P^{w}i,j$ € [-∞, -2Tcp] U [2Tcp, ∞], then the original value of pixel is ,

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

$$I^{w}_{i,j} - Tcp \qquad \text{if } P^{w}_{i,j} \geq 2Tcp$$

$$I_{i,j} = \qquad I^{w}_{i,j} + Tcp \qquad \text{if } P^{w}_{i,j} < -2Tcp$$

Then we have to extract the embedded message & restore the remaining part of image
Finally the message is extracted & the original image is recovered.

IV. CONCLUSION

Here, PEE technique is further investigated and an efficient reversible watermarking scheme is presented using Adaptive prediction error expansion & pixel Selection. Unlike conventional PEE which embeds data uniformly we adaptively embed 2 bits into each expandable pixel of flat regions and 1 bit into that of rough regions. Adaptive PEE can achieve an ER as high as 1.8 BPP. As an intermediate step of PEE, we proposed to select relatively smooth pixels (i.e., pixels located in smooth area) and ignore the rough ones. It can embed larger payloads with less distortion.

REFERENCES

[1] J. B. Feng, I. C. Lin, C. S. Tsai, and Y. P. Chu, "Reversible watermarking: Current status and key issues," Int. J. Netw. Security, vol. 2, May 2006.

[2] M. U. Celik, G. Sharma, A. M. Tekalp, and E. Saber, "Lossless generalized- LSB data embedding," IEEE Trans. Image Process., vol. 14, no. 2, Feb. 2005.

[3] Z. Ni, Y. Q. Shi, N. Ansari, and W. Su, "Reversible data hiding," IEEE Trans. Circuits Syst. Video Technol., vol. 16, no. 3, Mar. 2006.

[4] J. Tian, "Reversible data embedding using a difference expansion," IEEE Trans. Circuits Syst. Video Technol., vol. 13, no. 8, Aug. 2003.

[5] D. M. Thodi and J. J. Rodriguez, "Expansion embedding techniques for reversible watermarking," IEEE Trans. Image Process., vol. 16, no.3, Mar. 2007.

[6 W. Hong, T. S. Chen, and C. W. Shiu, "Reversible data hiding for high quality images using modification of prediction errors," J. Syst. Softw., vol. 82, no. 11, pp. Nov. 2009.

[7] A. M. Alattar, "Reversible watermark using the difference expansion of a generalized integer transform," IEEE Trans. Image Process., vol. 13, no. 8, Aug. 2004.

[8] S. Lee, C. D. Yoo, and T. Kalker, "Reversible image watermarking based on integer-to-integer wavelet transform," IEEE Trans. Inf. Forensics Security, vol. 2, no. 3, Sep. 2007.

[9] X. Chen, X. Li, B. Yang, and Y. Tang, "Reversible image watermarking based on a generalized integer transform," in Proc. IEEE ICASSP, 2010,

[10] M. Fallahpour, "Reversible image data hiding based on gradient adjusted prediction," IEICE Electron. Express, vol. 5, no. 20, 2008.

[11] L. Luo, Z. Chen, M. Chen, X. Zeng, and Z. Xiong, "Reversible image watermarking using interpolation technique," IEEE Trans. Inf. Forensics Security, vol. 5, no. 1, Mar. 2010

[12] P. Tsai, Y. C. Hu, and H. L. Yeh, "Reversible image hiding scheme using predictive coding and histogram shifting," Signal Process., vol. 89, no. 6, Jun. 2009.

[13] Xiaolong Li, Bin Yang, and Tieyong Zeng," Efficient Reversible Watermarking Based on Adaptive

Prediction-Error Expansion and Pixel Selection", IEEE Tran. on image processing, vol. 20, no. 12, dec 2011

AUTHOR BIOGRAPHY

Pramod Sonawane received the B.E.degree in E&Tc from Pune University, India in 2009, Pursuing M.E. degree in Microwave Engg. From AISSMS COE, Pune University, India. Currently, he is lecturer at Pimpri Chinchwad College of engineering, University of Pune. His research interests are image processing & Reversible image watermarking.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

Kirtee Chaudhari received the B.E.degree in Electronics from Mumbai University, India, M. E. degree in Electronics from Dr. B.A.M.U. Aurangabad, Pursuing Ph D in College of Engineering, Pune University, India. Currently, she is Assistant Professor at AISSMS COE, Pune University, India. Her research interests are speech processing & signal processing.