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A new Data Embedding approach in digital images Using Adaptive Pixel Pair Matching

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Abstract —**This paper presents a novel data embedding method using adaptive pixel pair matching (PPM).it is a new Data hiding method which use the value of pixel pair as reference coordinate, and search a coordinate in the neighborhood set of this pixel pair as per the a given message digit. Then the pixel is replaced by the new coordinate to conceal the digit. Exploiting modification direction (EMD) and diamond encoding (DE) are two hiding methods based on PPM. The maximum capacity of EMD is 1.161 bpp. The proposed method offers much lower distortion than DE provides. It allows embedded digits in any notational system by providing compact neighborhood. Comparing with the optimal pixel adjustment process (OPAP) and DE method, the proposed method not only provides better performance but it also has low distortion for various payloads. It also secure the detection of some well-known steganalysis technique**

Index Terms—**Adaptive pixel pair matching (APPM), diamond encoding (DE), exploiting modification direction (EMD), least significant bit (LSB), optimal pixel adjustment process (OPAP), pixel pair matching (PPM).**

I INTRODUCTION:

Data hiding is a technique in which data is conceals into a carrier for conveying messages confidentially. Digital images are widely transmitted over the Internet; therefore, they often serve as a carrier for covert communication. Images act as a carrier for carrying date is known as cover image and images with embedded data are known as stego image. After embedding cover image will be modified and distortion occurs. a good data hiding method should be capable of statistical detection and evading visual while providing an adjustable payload.

The least significant bit substitution (LSB) is one of the popular embedding techniques used for data hiding. it is a easy to implement with low CPU cost However, in LSB embedding, the pixels with odd values and even values will be increased and decreased respectively by one or kept unmodified. Therefore, the imbalanced embedding distortion emerges and is vulnerable to steganalysis. In 2004, Chan *et al.* presented a simple and efficient optimal pixel adjustment process (OPAP) method to reduce the distortion caused by LSB replacement. In their method, if message bits are embedded into the right-most LSBs of an m bit pixel, other m-r bits are Adjust by a simple evaluation. If the adjusted result offers a smaller distortion, then these bits are either replaced by the adjusted result or otherwise kept unmodified.

In LSB and OPAP methods one pixel is assumed as an embedding unit, and conceals data into the right-most LSBs. Another group of data-hiding methods employs two pixels as an embedding unit to conceal a message digit s_B in a B-ary notational system. These data-hiding methods as pixel pair matching (PPM). In2006, [10] proposed an exploiting modification direction (EMD) method in 2004. Mielikainen's method is Mielikainen proposed an LSB matching method based on PPM. He used two pixels as an embedding unit. the first pixel of LSB is used for carrying one message bit, while a binary function is used to carry another bit. In Mielikainen's method, two pixels are carried by two bit. There is a 3/4 chance a pixel value has to be changed by one yet another 1/4 chance no pixel has to be modified. Accordingly, the payload is 1 bpp when MSE is $(3/4) \times (1^2/2) = 0.375$. the MSE obtained when LSB value is0.5. Zhang and Wang improved by EMD in which only one pixel from the pixel pair is changed one gray-scale unit and a message digit in a 5-ary notational system can be embedded. Therefore, the payload is (1/2) $\log_2 5=1.161$ bpp. LSB matching and EMD methods greatly improves the traditional LSB method in which a improved stego image quality can be achieved under the same payload. However, the maximum payloads of LSB matching and EMD are only 1 and 1.161 bpp, respectively. Hence, these two methods are not suitable for applications requiring high payload.

The embedding method of EMD and LSB matching offers no mechanism to increase the payload. In 2008, Hong [11] presented a hiding method based on Sudoku solution to obtain a maximum payload (1/2 $\log_2 9$ bpp. In 2009 Chao et al [12] presented a diamond encoding (DE) method used to improve the payload of EMD (Exploiting modification direction) and employed to generate diamond characteristic value (DCV). According to the DCV's neighborhood set embedding is done to alter the pixel pairs in the cover image. Chao used an embedding parameter to control the payload, in which a digit in a **B**-ary notational system can be concealed into two pixels, where $B=2k^2+2k+1$. If k=1, B=5, i.e. digits in 5-ary notational notation system and the resultant payload is equivalent to EMD. If k=2, B=13, if k=3, B=25.

II RELATED WORK

DE increases the payload of EMD by embedding digits in a B-ary notational system and OPAP reduces the image distortion compared with traditional LSB method. These two methods provide a high payload while preserving an acceptable stego image quality.

Diamond Encoding

Chao et al. proposed a DE method in 2009 based on PPM. This method conceals a secret digit in a B-ary notational system into two pixels, where$B = 2k2 + 2k + 1 > 1$. The payload of DE is $(1/2)\log2(2k2 + 2k + 1)$ bpp. Note that when $k = 1$, DE Equivalent to EMD in which both methods conceal digits are in 5-ary notational system. The DE method described as follows.

Let the size *m* the bits cover image be M×M, message digits be S_B, where the subscript B represents S_B is in a B-ary notational system. First, the smallest integer is determined to satisfy the following equation:

$$\left\lfloor \frac{\boldsymbol{M\times M}}{\boldsymbol{2}} \right\rfloor \geq |\boldsymbol{S_B}|$$

Where $|S_B|$ denotes the number of message digits in a B-ary notational system. To conceal a message digit S_B into pixel pair *(x,y)*, the neighborhood set $\phi(x,y)$ is determined by

$$\phi(x,y = \{(\mathrm{a},\mathrm{b}) \mid |\mathrm{a}-\mathrm{x}| + |\mathrm{b}-\mathrm{y}| \leq \mathrm{k}\}$$

Where *ϕ(x,y)* represents the set of the coordinates' (a,b) whose absolute distance to the coordinate (*x*,*y*) is smaller or equal to k. A diamond function is then employed to calculate The DCV of (*x*,*y*) where $f(x,y) = \big((2k+1)x + y\big)\mathrm{mod}B$. After that, the coordinates belong to the set ϕ(*x*,*y*) are searched and DE finds a coordinate (*x′*,*y′*) satisfying f(*x′*,*y′*)=s_B and then (*x*,*y*) is replaced by (*x′*,*y′*) Repeat these procedures until all the message digits are embedded. In the extraction phase, pixels are scanned using the same order as in the embedding phased. The DCV value of a pixel pair (*x′*,*y′*) is then extracted as a message digit.

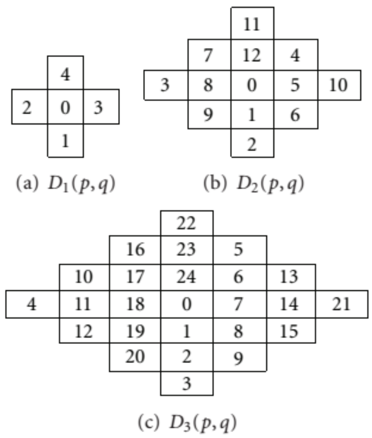

Fig.1. Diamond encoding patterns with k=1, k=2, and k=3

Here is a simple example. Let *k=3* and $(x\,,y) = (12{,}10)$, then $\mathrm{B} = 2\times 32 + 2\times 3 + 1 = 25.$ The neighborhood set ϕ (12,10) and its corresponding DCV values are shown in Fig. 1. If a digit in a 25-ary notational system 14_{25} needs to be embedded, then in the region defined by ϕ(12,10) .We find the value of DCV of (x',y')=(11,12)=14 Therefore, we simply replace

(12,10) by (11,12) and the digit is embedded. To extract the embedded digit, calculate $f(x',y') = f(11,12) = (7 \times 11 + 12)$result obtained as 14 which is an embedded digit

III, ADAPTIVE PAIR PIXEL MATCHING (APPM)

The basic idea of the PPM-based data-hiding method is to use pixel pair (x, y) as the coordinate, and search for the neighbor coordinate $(\mathrm{x}', \mathrm{y}')$ within a predefined neighborhood set ϕ(*x*,*y*) such that $f(x',y') = s_B$ where f is the extraction function and s_B is the message digit in a B-ary notational system to be concealed. Data embedding is done by replacing (x, y) with (x', y').

In PPM-based method, suppose a digit S_B is to be kept secret then the range s_B values lies between 0 and B-1,and coordinate has $(x',y') \in \phi(x,y)$ has to be found such that $f(x',y') = s_B$ Therefore, the range of $f(x,y)$ should lies between 0 and B-1, and each integer should occur at least. In the addition process, to reduce the distortion, the number of coordinates $\phi(x,y)$ in should be small. The best PPM method shall satisfy the following requirements: 1) There should be exactly B coordinates in $\phi(x,y)$. 2) The values of extraction function in these coordinates are mutually exclusive. 3) The design

The value of $\phi(x,y)$ and $f(x,y)$ significantly affect the stego image quality. The design of $\phi(x,y)$ and $f(x,y)$ must satisfy: all the values of $f(x,y)$ and $\phi(x,y)$ and the summation of the squared distances between all coordinates in $\phi(x,y)$and (x, y) has to be the smallest because in embedding (x, y) one of the coordinate is replaced by$\phi(\mathrm{x}, \mathrm{y})$. Let there are B coordinates in ϕ(x,y) i.e., digits in a B-ary notational system are to be kept secret, and the probability of replacing(x,y) by one of the coordinates in ϕ(x,y) is equivalent. The average of MSE can be obtained by averaging the summation of the squared distance between (x, y) and other coordinates in $\phi(\mathrm{x}, \mathrm{y})$. Thus, given a $\phi(\mathrm{x}, \mathrm{y})$, after embedding the expected MSE can be calculated by

$$\mathrm{MSE}_{\phi(x,y)} = \frac{1}{2B} \sum_{i=0}^{B-1} ((x_i - x)^2 + (y_i - \mathrm{y})^2)$$

Here we will propose an adaptive pixel pair matching (APPM) data-hiding method to provide better $\mathrm{f}(\mathrm{x}, \mathrm{y})$ and $\phi(\mathrm{x}, \mathrm{y})$ so that MSE get minimized. Data is then embedded by using PPM based on this f(x, y) and $\phi(\mathrm{x}, \mathrm{y})$ Let of ϕ(*x*,*y*) and *f*(*x*,*y*) should be capable of embedding digits in any notational system so that the B must be selected proper to achieve lower embedding distortion.

DE greatly improves the payload of EMD while preserving acceptable stego image quality. However, there are several issues. First, the payload of DE is determined by the selected notational system, which is restricted by the parameter; itself therefore, the notational system cannot be arbitrarily selected. For example, when is 1, 2, and 3, then digits in a 5-ary, 13-ary, and 25-ary notational system are used to embed data, respectively. However, DE will not support the embedding digits in a 4-ary (i.e., 1 bit per pixel) or 16-ary (i.e., 2 bits per pixel) notational system. Second, in $\phi(x,y)$ Diamond shape is defined by DE, which may have some unnecessary distortion whenk > 2. In fact, it is better other than diamond shape resulting in a smaller embedding distortion In section III-A we redefine ϕ(*x*,*y*) and *f*(*x*,*y*) based on that a new embedding method is proposed on PPM. The proposed method allows concealing digits in any notational system, and provides the even or same smaller embedding distortion than DE for various payloads.

A. *Extraction function and neighbor set.*

$f(\mathrm{x},\mathrm{y}) = (x + c_B \times \mathrm{y}) \bmod \mathrm{B}$

The solution of $\phi(x,y)$ *and* $f(x,y)$ is a discrete optimization problem

Minimize: $\sum_{i=0}^{B-1} (xi - \mathrm{x})\ 2 + (yi - y)2$

Subject to: $f(x_i, y_i) \in \{0,1\ldots\ldots,\mathrm{B}-1\}$

$f(\mathrm{x_i}, y_i) \neq f((x_i, y_{i)})$, if $i \neq j$

$$for\ 0 \le i,j \le B-1 \tag{1}$$

Given B is a integer and (x, y) integer pair, (1) can be solved to obtain a constant c_B and B pairs of (*xi*, *yi*). These B pairs of (x_i, y_i) are denoted by are denoted by $\phi_B(x, y)$ Note that $\phi_B(x,y)$ represents a neighborhood set of (x,y). Table I lists the constant c_B satisfying (1) for the payloads under 3 bpp. For a given *B*, it is possible to have more than one $c_B$and $\phi(x, y)$ satisfying (1). Table I only lists the smallestc_B.

Fig. 2 shows some representation of $\phi(x,y)$ and their corresponding c_B satisfying (1), where the center $\phi_B(x,y)$ is shaded with lines. Note that, in DE, assuming k=3 and k=4, respectively, embeds digits in the 25-ary and 41-

ary notational systems. We also depict the $\phi(x, y)$ of DE when setting k=3 and k=4 in Fig. 2.

TABLE I
LIST OF THE CONSTANT c_B FOR $2 \leq B \leq 64$

c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}	c_{12}	c_{13}	c_{14}	c_{15}	c_{16}	c_{17}	c_{18}
1	1	2	2	2	2	3	3	3	3	4	5	4	4	6	4	4
c_{19}	c_{20}	c_{21}	c_{22}	c_{23}	c_{24}	c_{25}	c_{26}	c_{27}	c_{28}	c_{29}	c_{30}	c_{31}	c_{32}	c_{33}	c_{34}	c_{35}
4	8	4	5	5	5	5	10	5	5	5	12	12	7	6	6	10
c_{36}	c_{37}	c_{38}	c_{39}	c_{40}	c_{41}	c_{42}	c_{43}	c_{44}	c_{45}	c_{46}	c_{47}	c_{48}	c_{49}	c_{50}	c_{51}	c_{52}
15	6	16	7	7	6	12	12	8	7	7	7	7	14	14	9	22
c_{53}	c_{54}	c_{55}	c_{56}	c_{57}	c_{58}	c_{59}	c_{60}	c_{61}	c_{62}	c_{63}	c_{64}					
8	12	21	16	24	22	9	8	8	8	14	14					

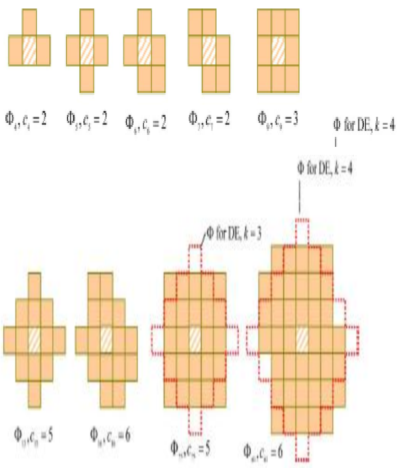

Fig. 2. Neighborhood set(shaded region) for APPM

The four corners of the diamond shape cause larger MSE but we selects more compact region for embedding, and thus less distortion can be obtained.

B. *Embedding Procedure:*

Let the cover image is of size $M \times M$, S is the message bits to be concealed and the size of S is$|S|$. First we calculate the minimum value of B so that all the message bits can be embedded. Then, message digits are linearly concealed into pairs of pixels. The brief procedure is listed as follows.

Input: Cover image I of size $M \times M$ conceal bit stream S, and key K_r.

Output: Stego image I', C_B ϕ_B (x,y) and K_r .

1. Calculate the minimum B satisfying $\lfloor M \times M/2 \geq S_B \rfloor$ and Convert S into B-ary notational system S_B.
2. Solve the discrete optimization to find C_B and$\phi_B(x, y)$.
3. In the region $\phi_B(0,0)$, record the coordinate ($\hat{x}_i$,$\hat{y}_i$). Such that $f(\hat{x}_i ,\hat{y}_i)$ = i, $0 \leq i \leq B - 1$
4. Construct a non repeating random embedding sequence Q using a key Kr.
5. To embed a message digit S_B, two pixels (x,y) in the cover image are selected with respect of embedding sequence Q, and calculate the modulus distance [14]

$d = (sB - f(x, y)) \bmod B$ Between $f(x, y)$ and s_B then replace (x,y) with $(x + \hat{x}_d, y + \hat{y}_d)$.

6. Repeat the above 5 steps until all the message digits get embedded.

In real time applications, we can solve all c_B and $\phi_B(x, y)$ at once. With the knowledge of c_B and $\phi_B(x, y)$, there is no need to perform Step 2.

Let $x' = x + \hat{x}_d$ and $y' = y + \hat{y}_d$. If an overflow or underflow problem occurs, that is, $(x', y') < 0$ or $(x', y') > 255$ then in the neighborhoods of (x, y). Find a nearest (x'', y'') such that $f(x'', y'') = s_B$.This can be obtained by solving the optimization problem.

Minimize $(x - x'')^2 \div (y - y'')^2$

Subject to $f(x'', y'') = s_B$,$0 \leq x'', y'' \leq 255$

We use a simple example to illustrate the embedding procedure. Let the cover image of size 512 × 512 with embedded requirement of 520 000 bits. The minimun B satisfying $(512 \times 512 \times log_2 B)/2 \geq 520\,000$ bits. The minimun B satisfying $(512 \times 512 \times log_2 B)/2 \geq 520\,000$ is 16; therefore , we choose the 16-ary notational system as the embedding base. After the notational system is known, $c_{16} = 6$ and $\phi_{16}(x, y)$can be obtained by solving(1). The $16(\hat{x}_i, y_i)$ in ϕ_{16} (0,0) such that $f(\hat{x}_i, \hat{y}_i) = i, 0 \leq i \leq 15$ are recoded. The neighbour set $\phi_{16}(0.0)$ such that $(\hat{x}_I, \hat{y}_i)$, where $0 \leq i \leq 15$, are shown in Fig. 3. suppose a pixel pair (10,11) that is to be conceal a digit 1_{16} in 16-ary notational system. The modulus should lies between 1_{16} I and $f(10,11)$ is $d = (1 - 12) \bmod 16 = 5$ and $(\hat{x}_5, \hat{y}_5) = (-1,1)$; therefore, we replace (10,11) by (10-1,11+1) = (9,12).

C. *Extraction Procedure*

To obtained the embedded message digits, pixel pairs are scanned in the same order as in the embedding procedure. The message digits the values of extraction function of the pixel pair.

Input: stego image I', c_B ,$\phi(x, y)$, and K_r.

Output: secret bit stream s

1. Construst the embedding sequence Qusing the key Kr.

2. Select two pixels (x', y') from the embedding sequence Q.
3. Calculate $f(x',y')$ the result is the embedded digit.
4. Repeat the above step 2 and step 3 until the message digits are extracted.
5. The message bits can be obtained by converting the extracted message digits into a binary bit stream.

From the above example. Consider the scanned pixel pair be $(x',y') = (9,12)$. The embedded digits in 16-ary notational system can be extract by calculating $f(9,12) = (9 + 6 \times 12 \bmod 16 = \mathrm{I}_{16}$.

IV. QUALITY ANALYSIS AND EXPERIMENTAL RESULT

Image distortion generally occurs when data is embedded because the pixel value is modified. We use MSE to measure the image quality

$$MSE = \frac{1}{M \times M} \sum_{i=0}^{M} \sum_{j=0}^{M} (p_{i,j} - p'_{i,j})^2$$

Where $M \times M$ denotes the image size, $p_{i,j} - p'_{i,j})^2$ represents the pixel value of the original image and the stego image, A smaller MSE denotes that the stego image has better image quality.

A. *Analysis of Theoretical MSE:*

In this section we exmain the average of MSE of LSB. OPAP, DE and APPM so that the stego imagequality obtain from each method can be theoritically measured. When data are embedded using *r* LSBs of each pixel, each bit value 0 or 1 has equal probaality. The squared error caused by embedded bit in the LSB is (1/2) $(2^{i-1})^2$; therfore the average MSE of embeddeding *r* LSB is given by

$$MSE_{\mathrm{LSB}} = \frac{1}{2} \sum_{i-1}^{r} (2^{(i-1)^2} = \frac{1}{6} (4^r - 1) \qquad (2)$$

Now we analyse the average MSE of OPAP when *r* message bits are embedded in every pixel. suppose the original pixel value be υ and the stego pixel value be υ". then the probablity of $|\upsilon - \upsilon"| = 0$ or $|\upsilon - \upsilon"| = 2^{r-1}$ is $1/2^r$; the probability of $|\upsilon - \upsilon"|$ to be within the range $[1, 2^{r-1} - 1]$ is $1/2^r$. Therefore , the average MSE caused by embeddimg *r* bits is

$$\mathrm{MSE_{OPAP}} = \frac{1}{2^r} (2^{r-1})^2 + \frac{1}{2^{r-1}} \sum_{i=1}^{2^{r-1}-1} i^2 = \frac{1}{12} (4^r + 2) \qquad (3)$$

Note that when r=1, OPAP and LSB have the same value of MSE. In other words, OPAP cannot reduce the distortion caused by LSB embedding at 1 bpp.

In DE method, consider that the probability of selecting a coordinate(x_i , y_i) in the diamond shape $\phi(x,y)$ to replace the pixel pair (x,y) is the same. Therefore, the average MSE on embedding digits in a B-ary notational system is

$$MSE_{DE} = \frac{1}{2B} \sum_{i=0}^{B-!} ((x_i - x)^2 + (y_i - y)^2)$$

$$= \frac{1}{2B} \sum_{y=0}^{k} \sum_{x=y-k}^{k-y} (x^2 + y^2) + \sum_{y=1}^{k} \sum_{x=y-k}^{k-y} (x^2 + y^2)$$

$$= \frac{k(k+1)(k^2+k+1)}{3+6k(k+1)} \qquad (4)$$

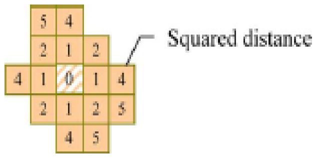

Fig.4. Calculation of the theoretical averaged MSE for APPM with $B = 16$

where k is the embedding parameter of DE. For embedding digits in a B-ary notational system using APPM, assume that the probablity of replacing (x,y) with each (x',y') in $\phi_B(x,y)$ is identical. With the knowledge of $\phi_B(x,y)$, the average MSE can be ovtained by

$$\mathrm{MSE_{APPM}} = 1/2B \sum_{i=0}^{B-1} ((x_i - x)^2 + (y_i - y)^2) \text{ for } (x_i, y_i) \in \phi(x,y) \qquad (5)$$

For example, the ϕ_{16} (x,y) that allows conceal digits with the 16-ary notational system is shown in Fig.4. The squared of the distance between $(x_i, y_i) \in \phi_{16}(x,y)$ and the center position in $\phi_{16}(x,y)$ are marked in the corresponding positions. The average MSE is then estimated as average square distance

$$\mathrm{MSE}_{\mathrm{APPM}\ (B=16)} = \frac{1}{2\times16} (1 \times 4 + 2 \times 4 + 4 \times 4 + 5 \times 3$$

$$= \frac{43}{32} = 1.344$$

LSB and OPAP applied in every pixel of the cover image as an embedding unit, *r* bit can be embedded into each pixel. Therefore, the payload is *r* bpp. For the PPM-based embedding method, a payload with *r* bpp is equal to embedding $2r$ bits for every two pixel , which is equal to concealing digits in a 2^r-ary notational system. Because DE does not allow embedding digits exactly in a 2^{2r}-ary notational system. We campare the MSE of APPM with OPAP and LSB first. The result are depicted in Table II. Note that the result listed in the Table II are obtained by using (2)-(5), i.e. the theoretically value of MSE. A similar result can also be obtained if these method is applied in nature images.

SIMULATION RESULTS:

Original Image

BY USING LSB

Stego image

BY USING OPAP

Stego Image

BY USING DIAMOND ENCODING

Stego image

ADAPTIVE PIXEL PAIR MATCHING

Stego image

Methodology	**BER**	**MSE**
LSB	0	5.1285
OPAP	0	2.6659
Diamond Encoding	0	2.0417
APPM	0	1.3123

V CONCLUSION

This paper proposed a simple and effectual data embedding method based on PPM. Two pixels are scanned as a embedding unit and a specially designed neighbor set is employed to embed message digits with a smallest notational system. APPM allows users to select digits in any notational system for data embedding for achieving better image quality. The proposed method provides a lower distortion than DE. The proposed method resolves the low payload problem in EMD. It provides smaller MSE as compared with OPAP and DE. APPM does not produce artifacts in stego images and steganalysis results are similar to those of the cover images. It provides secure communication under the detection of some well-known steganalysis techniques.

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$(3/4) \times (1^2/2) = 0.375$