# Embedding Data by Adjusting Pixel Pair Values

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***Abstract* —The proposal this paper provides is on the new data –hiding method based on pixel pair as an embedding unit. This method uses random values of a pixel pair as reference coordinate and search the coordinates in the pre-defined neighborhood set of this pixel pair as per given message digit. The message digit is then masked by replacing the pixel pair with newly searched coordinate. The highlight for this proposed method is that not only it is superior in performance compared to those of optimal pixel adjustment (OPAP) and diamond encoding (DE) but also secure under steganalysis. In addition this paper describes PPM method in RGB (color) image and the image quality is not only measured by Mean square error (MSE) but also by Peak signal to noise ratio (PSNR) and SSIM.**

***Index Terms*- pixel pair matching (PPM), exploiting modification direction (EMD), diamond encoding (DE), least significant bit (LSB), optimal pixel adjustment process (OPAP), adjustable pixel pair values (APPV).**

## I. INTRODUCTION

Data Hiding or Steganography is the art and science of hiding communication; a Steganographic system thus embeds hidden content in unremarkable cover media so as not to arouse an eavesdropper's suspicion [1]. The information-hiding process in a Steganographic system starts by identifying a cover medium's redundant bits (those that can be modified without destroying that medium's integrity) [2]. The embedding process creates a stego medium by replacing these redundant bits with data from the hidden message. Steganography goal is to keep its mere presence undetectable and should be capable of evading visual and statistical detection [3] while providing an adjustable payload [4].

In LSB steganography, the least significant bits of the cover media's digital data are used to conceal the message. LSB replacement flips the last bit of each of the pixel values according to message that needs to be hidden [5] and is vulnerable to steganalysis [6]. In 2004, Chan et al. [7] proposed a simple and efficient optimal pixel adjustment process (OPAP) method in their method, if message bits are embedded into the right-most r LSBs of an m- bit pixel, other m-r bits are adjusted by a simple evaluation. These methods are single pixel method.

Two methods Exploiting modification direction (EMD) method, Diamond encoding (DE) are data-hiding methods which employs two pixels as an embedding unit to conceal a message digit. In the year 2006, Zhang and Wang [8] [9] proposed an exploiting modification direction (EMD) method. In which each secret digit in a (2n+1)-ary notational system is carried by n cover pixels and, at most, only one pixel is increased or decreased by 1. In 2009, Chao et al. [10] proposed a diamond encoding (DE) method, it is the extension of the exploiting modification direction (EMD) embedding scheme. There are other data hiding method that considers security as a guiding principle for developing less detectable embedding schemes. Some data hiding methods takes group of pixel to hide data as Novel section-wise exploring modification direction method [11].

The proposed method offers lower distortion than DE by providing more compact neighborhood sets and allowing embedded digits in any notational system. Compared with the optimal pixel adjustment process (OPAP) method, the proposed method always has lower distortion for various payloads. Experimental results reveal that the proposed method [12] not only provides better performance than those of OPAP and DE, but also is secure under the detection of some well-known steganalysis techniques. Its extraction function is simple and it embeds more messages per modification and thus increases efficiency, with higher payloads also good quality of image is obtained with lower distortion.

## II. RELATED WORKS

In this section two existing methods OPAP and DE are briefly reviewed.

### A. Optimal Pixel Adjustment Process (OPAP)

Chan, et, al. (October, 2004) have proposed a simple and efficient method to reduce the distortion caused by LSB replacement. The OPAP method is described as follows [7]. Let the pixel value is $p$, the value of right most $r$ the LSBs value of $p$ is $p^{(r)}$. Let $p'$ be the pixel value after embedding $r$ message bit using LSB replacement method and $d$ be the decimal value of the $r$ message bits. OPAP have the following equation to adjust $p'$ so that embedding information can be minimized.

$$p'' = \begin{cases} p' + 2^r, & p^{(r)} - d > 2^{r-1} \text{ and } p' + 2^r \le 255 \\ p' - 2^r, & p^{(r)} - d < -2^{r-1} \text{ and } p' - 2^r \ge 0 \\ p', & \text{otherwise} \end{cases}$$

where, p'' denotes the result obtained by OPAP embedding. p' and p'' have same right most $r$ LSBs and the embedded data can be obtained directly from the right-most r LSBs.

*B. Diamond Encoding (DE)*

This method conceals a secret digit in a B-ary notational system into two pixels, where B = $2k^2+2k+1$, k ≥ 1. The DE method described as follows.

Let the size of m 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 $k$ is determined to satisfy the following equation:

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

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

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

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) = ((2k+1) x +y) 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 procedure 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.

## III. THE PROPOSED METHODD

The basic idea of the proposed method, adjustable pixel pair value (APPV) is to use pixel pair (x, y) as the coordinate, and search for the neighbor coordinate (x', y') within a predefined neighborhood set ϕ(x, y) such that f(x', y') = $S_B$. Data embedding is done by replacing (x, y) with (x', y').where f is the extraction function and $S_B$ is the message digit in a B-ary notational system to be concealed.

To reduce the distortion, the number of coordinate's ϕ(x, y) in should be small. The best PPM method shall satisfy the following requirements:

1. There should be exactly B coordinates in ϕ(x, y).
2. The values of extraction function in these coordinates are mutually exclusive.
3. The design 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.

THREE MODULES:

•Extraction Function and Neighborhood Set
•Embedding Procedure
•Extraction Procedure

*A. Extraction Function and Neighborhood Set*

The value of extraction function f(x, y) and neighborhood set ϕ(x, y) significantly affect the stego image quality.

Extraction function: f(x,y) =(x + cB × y) mod B

The solution of ϕ(x,y) and f(x,y) is a discrete optimization problem

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

$$\text{Subject to: } f(x_i, y_i) \in \{0,1,\ldots,B-1\}$$
$$f(x_i, y_i) \ne f((x_i, y_i)), \text{ if } i \ne j$$
$$\text{for } 0 \le i, j \le B-1 \quad (1)$$

Given B and an integer pair (x, y), (1) can be solved to obtain a constant $C_B$ and B pairs of ($x_i$, $y_i$). These B pairs of ($x_i$, $y_i$) are denoted by are denoted by $\phi_B$ (x ,y).

TABLE I
LIST OF THE CONSTANT $C_B$ FOR 2≤B≤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 | | | | | |

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 ϕ(x, y) satisfying (1).

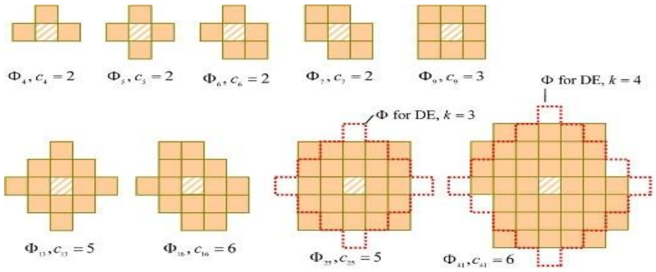


Fig.1. Neighborhood set (shaded region) for APPV

Fig.1 shows some representation of ϕ (x, y) and their corresponding $C_B$ satisfying (1), where the center $\phi_B$ (x, y) is shaded with lines.

*B. Embedding Procedure*

Embedding procedure is illustrated by the block diagram shown in Fig 2.

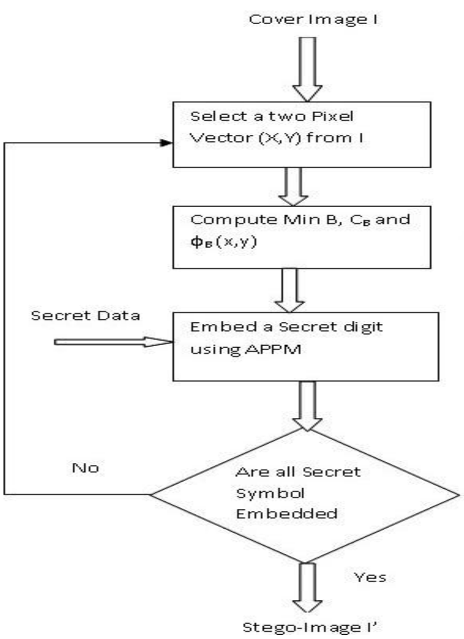


Fig.2. Data embedding process

The detailed steps of the proposed method are discussed below. The cover image is of size $M \times N$ , S is the message bits to be concealed and the size of S is $|S|$.

*Step 1*: Calculate Minimum B so that all the message bits can be embedded

$$(M \times M \times \log_2 B)/\ 2 \geq \text{No. of bits to hide}$$

*Step 2*: Then $C_B$ and $\phi_B$ (x,y) are obtained by solving discrete optimization

*Step 3*: In the data embedding procedure, the original image is segmented into a number of non overlapping two pixel blocks. Then, we can select each block from top-down and left-right in turn for data embedding process

*Step 4*: Calculate the modulus distance between digit and extraction function

$$d = (S_B - f(x,y)) \bmod B, \text{ between } f(x, y) \text{ and } S_B$$

*Step 5*: Replace (x, y) with (x+ x̂d ,y+ ŷd) = (x', y')

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

*C. Extraction Procedure*

Extraction procedure is illustrated by the block diagram shown in Fig 3.

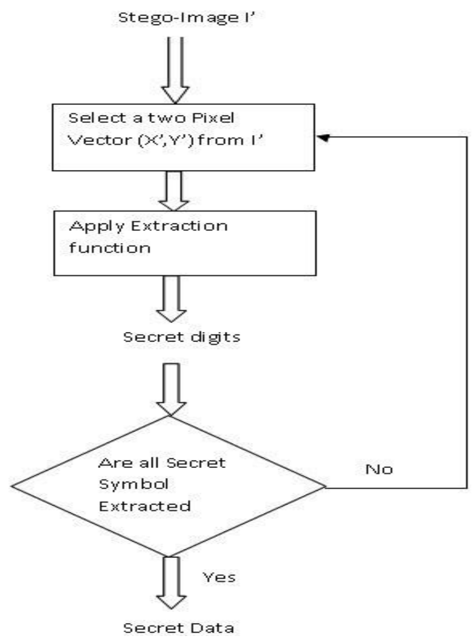


Fig.3. Data extraction process

To obtain the embedded message digits, pixel pairs are scanned in the same order as in the embedding procedure. Then extraction function is applied to scanned pixel pair to obtain the embedded message digits. The message bits can be obtained by converting the extracted message digits into a binary bit stream.

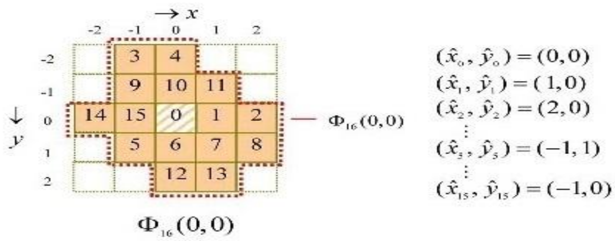


Fig.4. Neighborhood set $\phi_{16}(x, y)$ and $(\tilde{x}_i, \tilde{y}_i)$, where $0 \le I \le B-1$

Example: B= 16, $C_B$ = 6 and Neighborhood set are given in Fig.4.

Suppose a pixel pair (10, 11) that is used to conceal a digit $1_{16}$ in 16-ary notational system. The modulus distance is d = (1-12) mod16= 5.Digit5 is represented by pixel pair $(\tilde{x}_5, \tilde{y}_5) = (-1, 1)$. Therefore, we replace (10, 11) by (10-1, 11+1) = (9, 12).

For extraction consider the scanned pixel pair be (9, 12). Embedded digits can be extracted by calculating f (9, 12) = (9+6×12) mod 16=$1_{16}$.

## IV.QUALITY ANALYSIS AND EXPERIMENTAL RESULTS

Image distortion occurs when data are embedded because pixel values are modified. We use relative MSE, Peak signal to noise ratio (PSNR) and SSIM to measure the image quality.

### *A. Relative Mean Square Error (RMSE)*

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

Here, the symbols $p$(i, j) and $p'$ (i, j) represent the pixel values of the cover image and stego-image in the position (i, j) respectively. Smaller the RMSE better the image quality.

*Analysis of Theoretical MSE:*

In this section, we analyze the relative MSE of LSB, OPAP, DE, and APPV so that the stego image quality obtained from each method can be theoretically measured.

$$\text{RMSE}_{\text{LSB}} = \frac{1}{2}\sum_{i=1}^{r}(2^{i-1})^2 = \frac{1}{6}(4^{r} - 1)$$

$$\text{RMSE}_{\text{OPAP}} = \frac{1}{2^r}(2^{r-1})^2 + \frac{1}{2^{r-1}}\sum_{i=1}^{2^{r-1}-1} i^2 = \frac{1}{12}(4^r + 2)$$

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

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

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

$$\text{RMSE}_{\text{APPV}} = \frac{1}{2B}\sum_{i=0}^{B-1}((x_i - x)2 + (y_i - y)^2))$$

for $(x_i, y_i)$ ε $\phi$(x,y)

Let us take an example, B =16, from Table I $C_B$ is 14 then the relative MSE is calculated by the averaged squared distance

$$\text{RMSE}_{\text{APPV(B= 16)}} = \frac{1}{2\times 16}(1\times 4 + 2\times 4 + 4\times 4 + 5\times 3)$$

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

Taking different payloads MSE is calculated theoretically to obtain table below. Table II reveals that the MSE of APPV is smaller than those of LSB and OPAP in all payloads [12]

TABLE II
MSE COMPARISON OF THE PROPOSED METHID WITH LSB AND OPAP

| Payload (bpp) | LSB | OPAP | APPV | RMSE improvement over OPAP |
|---|---|---|---|---|
| 1 | 0.500 | 0.500 | 0.375(C4 = 2) | 0.125 |
| 2 | 2.500 | 1.500 | 1.344 (C16= 6) | 0.156 |
| 3 | 10.500 | 5.500 | 5.203 (C64=14) | 0.297 |
| 4 | 42.500 | 21.500 | 20.518 (C256=92) | 0.982 |

The comparison of theoretical MESs under various payloads for APPM and DE is shown in table III. From the table we see that MSE of APPM is smaller than DE.

TABLE III
MSE COMPARISON OF THE PROPOSED METHOD WITH DEMETHOD

| Base B | bpp | DE | | APPV | | RMSE Improvement |
|---|---|---|---|---|---|---|
| | | k | RMSE | CB | RMSE | |
| 5 | 1.161 | 1 | 0.4 | 2 | 0.4 | 0 |
| 13 | 1.850 | 2 | 1.077 | 5 | 1.077 | 0 |
| 25 | 2.322 | 3 | 2.080 | 5 | 2.000 | 0.080 |
| 41 | 2.679 | 4 | 3.415 | 6 | 3.341 | 0.074 |
| 61 | 2.965 | 5 | 5.082 | 8 | 4.902 | 0.180 |
| 85 | 3.205 | 6 | 7.082 | 10 | 6.847 | 0.235 |
| 113 | 3.410 | 7 | 9.416 | 31 | 9.071 | 0.345 |
| 145 | 3.590 | 8 | 12.083 | 22 | 11.890 | 0.193 |
| 181 | 3.750 | 9 | 15.083 | 39 | 14.519 | 0.564 |
| 221 | 3.894 | 10 | 18.416 | 26 | 17.787 | 0.629 |

### *B. Peak Signal to Noise Ratio (PSNR)*

Peak Signal to Noise ratio (PSNR) is another parameter commonly used to measure the quality of image. This ratio is often used as a quality measurement between the original and compresses image. Higher the PSNR better is the quality of the compressed or reconstructed image.

$$\text{PSNR} = 10*\log_{10}(255^2/(\text{MSE})$$

TABLE IV
PSNR COMPARISON OF THE PROPOSED METHOD WITH OPAP and DE

| Test Images | OPAP | DE | APPV |
|---|---|---|---|
| Leena | 49.1 | 50.1 | 52.0 |
| Baboon | 49.0 | 50.2 | 52.1 |
| Plane | 49.1 | 50.1 | 52.7 |

| | | | |
|---|---|---|---|
| Sawara | 49.1 | 50.1 | 53.4 |
| Nature | 49.0 | 50.0 | 52.2 |
| Cameraman | 49.1 | 50.1 | 52.3 |

Table IV shows comparison of PSNR among OPAP, DE and APPV on various test images with embedding payload=36000 bits. It also reveals that the PSNR of proposed method is higher than other existing methods.

*C. The structural similarity (SSIM)*

SSIM index is a method for measuring the similarity between two images. The SSIM metric is calculated on various window of an image. The measure between two windows X and Y of common size is

$$SSIM(X,Y) = \frac{(2 * \mu_X * \mu_Y + C_1)(2\sigma^2{}_{XY} + C_2)}{(\mu^2{}_X + \mu^2{}_Y + C_1)(\sigma^2{}_X + \sigma^2{}_Y + C_2)}$$

Where, $\mu_x$ is the average of x

$\mu_y$ is the average of y

$\sigma^2_x$ is the variance of x

$\sigma^2_y$ is the variance of y

$\sigma^2_{xy}$ is the covariance of x and y

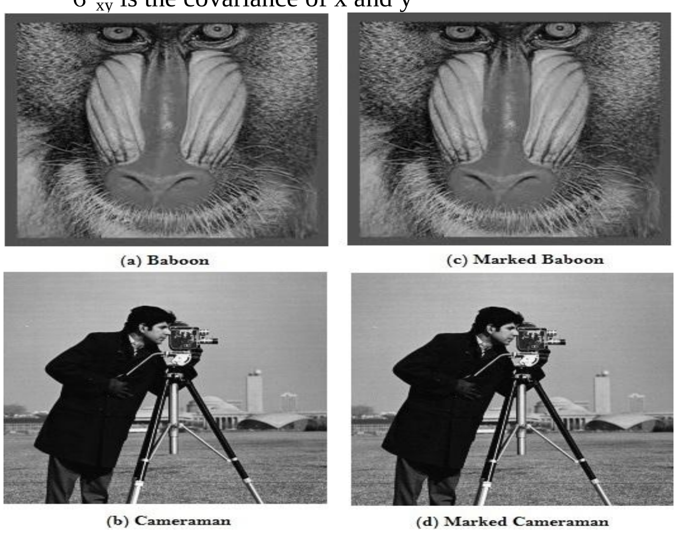


Fig.5. Test image (a) – (b) and stego image (c) – (d)

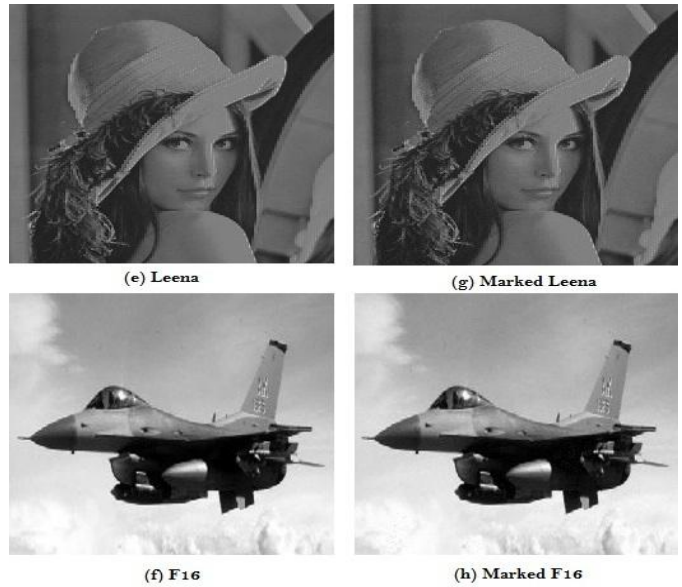


Fig.6. Test image (e) – (f) and stego image (g) – (h)

This section presents and analyzes the experimental results by using the proposed method. To evaluate the performance of our new scheme, in our experiments, we have used about 20 images with size 256 × 256. Our evaluation starts with the four well-known images Baboon, Cameraman, Leena Airplane, which are shown in Figures 5(a)–(b) and 6(e)–7(f). Figures 5(c)–6(d) and 6(g)–6(h) are the stego-images produced by APPV where B=16 was set. The generated stego-images show that they contain no artifacts that can be identified by human eyes. So from Fig.5 and 6 we can say that our method is capable of evading visual. We compare ours scheme with other existing well-known data hiding methods.

Fig.7. Cover image and stego image under various RMSE (a) cover image (b) stego image,MSE =1.315 (c) stego image,MSE = 1.319 (d) stego image ,MSE = 1.312.SIMM=0.998

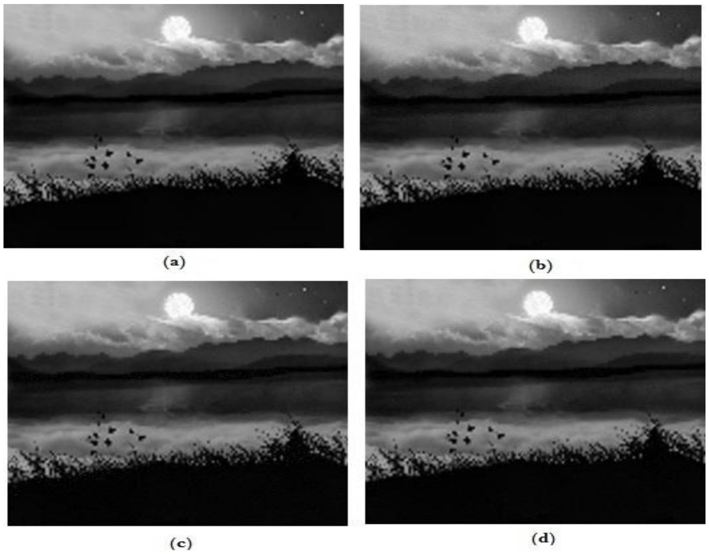

Fig.8. Cover image and stego image under various RMSE and PSNR (a) cover image (b) OPAP stego image,MSE =2.6461 (c) DE stego image,MSE = 2.0132 (d) stego image ,MSE = 1.7184, SSIM= 0.988

Fig 7 and 8 shows randomly generated message digits are embedded on cover image to generate stego image of different existing methods and their different MSEs and PSNR. From the fig 7 and 8 we can see that the RMSE of the proposed method APPV is smaller than other existing methods like OPAP and DE and also its PSNR is higher compared to existing method.

APPV is also applied to RGB (color) Image. In RGB format more number of message digits can be embed without destroying the image quality.

In addition, the proposed scheme is secure against the well known steganalysis scheme Horizontal and Vertical Difference Histogram (HVDH) [15].

## V. CONCLUSION

The proposed method offers lower distortion than other methods by providing more compact neighborhood sets and allowing embedded digits in any notational system. Two pixels are scanned as an embedding unit and a specially designed neighborhood set is employed to embed message digits with small distortion and better image quality. The method not only provides better performance but also is secure under steganalysis techniques with adjustable embedding capacity.

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