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Generalized PVO base Reversible Data Hiding Using Firefly Algorithm

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Abstract Reversible data hiding scheme has presented in this paper for digital images on the basis of pixel value ordering, proposed a novel Generalized *PVO* base reversible data hiding using Firefly Algorithm *(GPVOFA)* The sequence of minimum and maximum pixels value has used to embed the secret data while predicted into multiple of pixels value for each block. The host image is divided into non-coinciding dynamic blocks size on the basis of quadtree partition while rough blocks are divided into larger size moreover, providing more embedding capacity used small flat blocks size and optimal location in the block to write the information. Our proposed method becomes able to embed adequate data into a host image with somewhat limited distortion. With rich experimental results also outperforms compare with other related preceding arts.

Keywords Reversible Data Hiding,Quadtree partition, Firefly Algorithm, Pixel value ordering.

1 Introduction

Data hiding has been extensively used in the fields of medical imaging, image authentication, military image, multimedia archive management satel-

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lite image, fingerprint, authentication, ownership fortification, data coloring in cloud and furtive communication. The main objective of data hiding is to embed the secret informations in host image (image, video, audio, text) while recover the embedded secret information and original image from stego image which is the main intention of Reversible Data Hiding *(RDH)*[1]. Until now an extensive range of *RDH* algorithms have been proposed.

Tian's proposed the Difference Expansion *(DE)*-based method to employ the pixels difference for embedding information's and gain higher data Embedding Capacity *(*EC) with little distortion as compared to earlier data hiding schemes [2,3]. There are three main extensions of *DE* method, first type emphases on generalization of *DE* into integer transform domain [4,5,6], the second scheme focus the size of location map in *DE* [7,8] while third kind change the difference value of prediction error [9,10].

Thodi and Rodrigues [9] proposed Predicted Error Expansion *(PEE)*- based method, while Hu et al.[11] improved above technique through reduction the size of location map. Further, Li et al.[12] improved Hu et al. technique though adaptive embedding of pixel selection in *PEE* and double-layered *PEE*-based technique have been proposed [13,14,15,16,17,18].

There is another significant work related to *RDH* [19,20,21], in which the low distortion of marked image is assured to alter each pixels value of prediction-error histogram by one while used top point of histogram to insert secret information. Currently a new research direction is opened, the name is high fidelity *RDH*. The advantage of the high fidelity *RDH* produces less embedding distortion. In the same domain Pixel Value Ordering*(PVO)* scheme is introduced by Li et al [22], which got a lot of exposure from the investigators. In their method first the cover image is divided into non overlapping blocks with the same size. After that the pixels are ordered by its value within a given block. As a result maximum pixel is computed by second largest pixel, while the minimum pixel is calculated by second smallest pixel. Finally prediction error is used for embedding data through *HS-PEE* technique. Moreover, many *RDH* schemes are proposed further for improving the embedding performance of *PVO*. Peng et al suggested an Improved Pixel Value Ordering *(IPVO)* method[23] for achieving high performance capacity. Where a relationship is considered namely, as relative location between maximum and second largest value. For embedding data bin *0* is used.

Later on, another approached *PVO-K*[24] is introduced to utilize bin *0*. The *PVO-K* yielded higher capacity as compared to *PVO* method, but this method was suffered from fixed and same size of block. However, adopting this method the bin selection is enhanced. To improve the image partition process another upgraded *PVO* scheme was proposed by Qu et al, and can be referred as *PPVO*[25], which take on the pixel by pixel embedding process rather than conventional block-by-block embedding procedure. In *PPVO* every pixel is calculated from its arranged content pixels. Additionally, for high embedding capacity achievement sliding window is used. Weng et al [26] proposed *PVO*-based adaptive method. This technique was not the same as compared to the earlier methods. In this method smooth blocks are partitioned into sub blocks with unknown size and the cover image has been divided by different size of blocks while flat image regions are partitioned into lesser blocks [27,28]. For embedding data adaptively the above all discussed schemes adopted the block complexity. But the block complexity fails when size of block is very small and the reason for this is insufficient data.

In this paper, a high-fidelity *RDH* technique is proposed based on new Generalized *PVO* base reversible data hiding using Firefly Algorithm *(GPVOFA)*. Proposed method have enough room space to embed more data in smooth block region due to minimum and maximum number of pixels value. The process of prediction and modification is held on minimum and maximum number of pixel blocks to embed the secret data into multiple bits while pixels value increased by one. We divided the smooth region of image into non-coinciding smaller size of blocks while rough region is divided into larger size of block and find best area in block using firefly algorithm moreover, each blocks to predict the second smallest value to predict its minimum value while the second largest value used to predict its maximum value. Furthermore, prediction error histogram and data embedding is implemented in each blocks. Our method performs well in addition the comparison with previous *PEE*- based techniques. The remaining paper part is ordered as follows. The related work and proposed scheme is introduce in section *2* in section *3* consecutively, comparison with the previous arts is shown in section *4* and conclusion is given in section *5*.

2 Related work

In this section, we briefly present the *PVO*-based *RDH* schemes.

2.1 PVO-based reversible data embedding

In data embedding, the maximum alteration to pixel values is *1*, in case one or two bin in inner region. In inner region, the prediction-error are extended to carry the information and outer region, the prediction-error are moved besides after embedding while both regions are separated from each other.

$$P_{shifted} = \frac{\neq \{shiftedpixels\}}{\neq \{expandedpixels\}} \quad (1)$$

Where the number of shifted pixels Sc and Ss while EC (in terms of bits), the value of expected change in image is $0.5Sc+Ss$ [22,23]. First of all, divided the original image into equal non-coincided size of blocks. The value of block B consisting of n pixels $(B_1,...,Bn)$ in ascending order to obtain $(B(1),...,X(n))$ where, $1,...,n...1,...,n$ (one to one mapping) such that:$B(1) < ... < B(n), (i) < (j)$ if $B(i) = B(j)$ and $i < j$ moreover, used the second largest value $B(n-1)$ for prediction of maximum *B(n)*. The corresponding *PER* is,

$$PER_{max} = B_{\sigma(n)} - B_{\sigma}(n-1) \quad (2)$$

The histogram PER_{max}, the image *Lena* as an example of 2×2 sized blocks [29,30,31,32].

Peak point of the histogram consider larger than *1* bins of inner region as compare with outer section. For embedding data through *PEE*, The PER_{max} is altered I as,

$$PER_{max} = \begin{cases} PER_{max} & if \quad PER_{max} = 0, \\ PER_{max+b} & if \quad PER_{max} = 1, \\ PER_{max+1} & if \quad PER_{max} > 1, \end{cases} \tag{3}$$

Here $b\{0,1\}$ is embedded data bit hence, the maximum *B(n)* is changed to,

$$B = B_{\sigma(n-1)} + PER_{max} = \begin{cases} B_{\sigma(n)} & if \quad PER_{max} = 0, \\ B_{\sigma(n)+b} & if \quad PER_{max} = 1, \\ B_{\sigma(n)+1} & if \quad PER_{max} > 1, \end{cases} \tag{4}$$

The marked value of B is $(y_1, ..., y_n)$, *Y (n)* and $Y_i = B_i$ for every $i = (n)$ while the pixels value order will not change $B(1), ..., B(n-1)$, since the maximum *B (n)* either modified or upsurge. The prediction-error for a marked block value is $(Y_1, ..., Y_n)$.

$$PER_{max} = Y_{\sigma(n)} - Y_{\sigma}(n-1) \tag{5}$$

The image restoration and data extraction process is given below:

1- Data embedding has no alteration in blocks $if\ PER_{max} = 0$ while value is $(y_1, ..., y_n)$.

2- Hide the secret information in case $PER_{max} \epsilon \{1, 2\}$ where, the original values $(B_1, ..., B_n)$ and data embedding $B_i = y_i$ and $b = PER_{max} = 1$

3- The data embedding process, block is shifted $if\ PER_{max} > 2$ while other values $(B_1, ..., B_n)$, the number of P shifted that is defined in Eq. 1, further reformulated as given below,

$$P_{shifted} = \frac{\neq \{PER_{max} >\}}{\neq \{PER_{max \geq 1}\}} \tag{6}$$

PER_{max} is the prediction-error of original image defined in Eq. 2 for *PVO*-based embedding of dissimilar block sizes. The double-layered embedding[33], the context adaptive predictor and median-edge-detector *(MED)* [34,9] are two existing *PEE* embedding methods based on [35]. The four neighbors pixels is predicted [33] which performs well as compared to the previous arts in case of benchmark $P_{shifted}$. In addition, we can achieve better performance by using of larger blocks size and well exploit the spatial redundancy in cover images. By altering the maximum of a block size *PEE* embedding process can be implemented through the alteration of corresponding prediction-error

$PER_{min} = B(1) - B(2)$ by using a second least value *B(2)* which be able to use the prediction of minimum *B (1)*.

$$PER_{min} = \begin{cases} PER_{min} & if \quad PER_{min} = 0, \\ PER_{min-b} & if \quad PER_{min} = -1, \\ PER_{min-1} & if \quad PER_{min} < -1, \end{cases} \tag{7}$$

The marked image value *B(1)* according to the data bit $b(0,1)$ embedded two bits into blocks by using minimum and maximum pixels value to increase the *EC*. Moreover, embedded two bits in a block B when the conditions $B(n) - B(n-1) = 1 \quad and \quad B(1) - B(2) = -1$ are both satisfied. We used the flat blocks while leaving the coarse blocks and block *X's* complexity is measured through the difference between $B(n-1) - B(2)$ since the usage of flat blocks is more promising for data embedding[9].

If the block *B's* simplicity is smaller with predefined threshold T such as their complexities will be $B_1 - B_2 = 43 - 42 = 1, B_2 - B_4 = 1 = 119 - 117 = 2$ and $B_1 - B_4 = 154 - 153 = 1$. The capacity of $B(n-1)CX(2)$ is Contrast after data inserting however, reversibility of *PVO*-based embedding can be assured through utilizing of similar flat blocks

Furthermore, in *PVO k* embedding we cannot use the blocks that contain prediction-error of *0*, $P_n = P_n - 1$ as mentioned in earlier PVO-based approach. The second largest value can be taken for the prediction of maximum-ones in a block that contain $P_n = P_n - 1$ and $P_n - 1 > P_n - 2$. Generating a prediction-error $B = P_n - 1 \; P_n - 2 > 0$ and $P - 2$ can be used for the sake of prediction $P - 1$ and P_n. The maximum- pixels value $P_n - k + 1, ..., P_n$ is the main concern of $PVO - k$ method while conventional *PVO*-based data embedding and $PVO - k$ are similar in extraction process similarly, both schemes $PVO - k_1$ and $PVO - k_2$ for $K_1 = K_2$ can be used in dissimilar blocks. The data embedding into a given block, the $PVO - 1$ performing well as compared to $PVO - 2$ because the larger k produce more distortion during embedding phase.

3 Proposed Schemes

We proposed a novel *GPVOFA* scheme for digital image based on pixel value ordering to write the secret information in largest and second largest pixels value on digital image. The value of k will be greater than *2* in smooth region in that case we cant use both schemes $PVO - 1$ and $PVO - 2$ for larger *EC* similarly, additional distortion will be produce due to more alteration in pixels value. We determined the optimal thresholds and built the location map for a specified block size $n_1 \times n_2$ moreover, before data embedding the cover image has distributed into non-coinciding dynamic blocks size on the basis of quadtree partition while rough blocks are divided into larger size and flat block into smaller size in image. The overflow and underflow can occur in some block *"0", "1", "254", and "255"* if the block pixels value is same. The block location is recorded as *"2"*, otherwise block location will be *"1"* while other blocks kept same location and recorded as *"0s"* value .

3.1 Quadtree image partition

Quadtree partition is extensively used in image compression, image coding and many others image processing field[36, 37, 38], its tree data structure where original image portions is recursively distributing into non overlapping four sub block regions, displayed in Figure. 1. Quadtree partition, the original image is divided into block A with block size is $2^m \times 2^m$ where (m define as positive integer) furthermore, if the block A is fulfilled the predefined condition then the block A is divided into further four non-coinciding blocks with $2m-1 * 2m-1$ size otherwise stop division process for current block. The same operation is performed for each sub smaller block separately and stop the partition process for current block when $m_0 \leq 1$ condition is true, for example: the image Lena with size 512×512 , $p \geq T$ is pre-define condition where p and T describe the difference value of image block for any two pixels.

The sender side compute the optimal location of block in cover image to find out the optimal value. The image is partition before data embedding based on optimal value while process is similar on receiver side besides extracted the embedded data and recover the cover image losslessly. In preceding PVO-based schemes [22, 23] to select the smooth region based on noise level in the block as well as in proposed scheme for image partition to set the judgment condition based on block complexity. Optimal location of block is denoted as r while the value of r is same before and after data embedding in given block to confirm the reversibility.

Presume block A with block size is $2^m \times 2^m$ where (m define as positive integer) further block A is divided into non-coinciding blocks $\{A_1, A_2, A_3, ., A_m\}$, moreover, mining optimal region for block A using firefly algorithm as follows. In 2007 xin Xin-She Yang developed Firefly optimization Algorithm at Cambridge University[39, 40, 41, 42].

$$r_{ij} = \parallel z_i - z_j \parallel = \sqrt{\sum_{q=1}^{d} (z_{iq} - z_{jq})^2} \tag{8}$$

The i and j represent distance between two fireflies at the position of z where $z_{i,q}$ is the i^{th} firefly's of q^{th} component on spatial coordinate z_i. The i firefly attracted to one more brighter firefly j movement is determined as

$$Z_i = Z_i + \Omega o \quad e^{-\beta r_{i,j^2}} (z_j - z_i) + \alpha(rand - 1/2) \tag{9}$$

Where α is randomization parameter, rand is random number , we taken $\alpha \epsilon [0, 1]$ and Ωo is *1*.

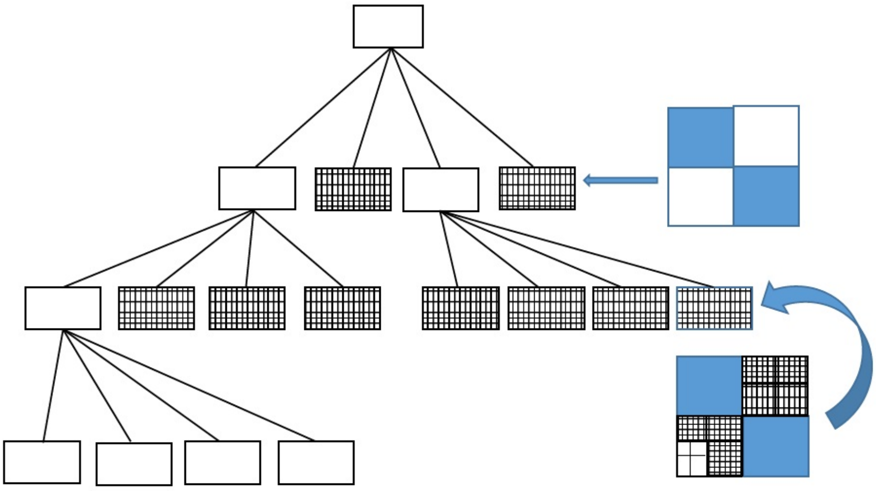

Fig. 1 Block partion using quadtree

3.2 Embedding scheme.

Case 1: The block skipped from embedding procedure which block *LM (H)* is equal to *2*.

Case 2: If *LM (H)* is equal to one in block then residual pixels used to embed the secret bit, using Eq. 10. Increase the pixels value by one if the value of b is equal to *1* moreover, no alteration will occur in pixels value if the value of b will be zero.

$$B'_{\lambda(i)} = \begin{cases} B_{\lambda(i)} & if \quad i = 1, \\ B_{\lambda(i)} + b_{i-1} & if \quad i = 2, 3, ..., n_1 \times n_2, \end{cases} \tag{10}$$

Case 3: If a block $LM(H)$ is equal to zero in location map then we get $H(B_1, B_2, ..., B_{(u_1 \times u_2)})$ while the pixel value gained in blocks
$B_\lambda(B_{\lambda(1)}, B_{\lambda(2)}, ..., B_{\lambda(u_1 \times u_2)})$ in ascending order,
$B_{\lambda(u_1 \times u_2 - k - L}) < B_{\lambda(u_1 \times u_2 - k - L + 1}) = ... = B_{\lambda(u_1 \times u_2 - k)} < B_{\lambda(u_1 \times u2 - k + 1)} = ... = B_{\lambda(u_1 \times u_2)}$ assumed the maximum pixels *(K)* $B_{\lambda(u_1 \times u_2 - k + 1}) = B_{\lambda(u_1 \times u_2 - k + 2})$ $... = B_{\lambda(u_1 \times u_2}), B_{\lambda(u_1 \times u_2 - k - L + 1})B_{\lambda(u_1 \times u_2 - k - L + 2}) = ... = B_{\lambda(u_1 \times u_2 - k})$ in second maximum pixels. Compute the maximum prediction error in Eq. 11.

$$d_{max} = B_{\lambda(u_1 \times u_2 - k + 1)} - B_{\lambda(u_1 \times u_2 - K)} \tag{11}$$

Case 3.1 The maximum pixels value will be increased by one and not used to write the secret data if d_{max} value is greater than one, using Eq. 12.

$$B'_{\lambda(i)} = B_{\lambda(i)} + 1 \tag{12}$$

Case 3.2 The maximum pixels value used to write the secret data if d_{max} is equal to one. The maximum value will not be alter in case the value of b_r is zero moreover, maximum value is increase by one when the value of b_r is one, in Eq. 13,

$$\begin{cases} B'_{\lambda(i)} = B_{\lambda(i)} + b_{i-n_1 \times n_2 + K} + 1, \\ B'_{\lambda(j)} = B_{\lambda(i)} + 1, \end{cases} \tag{13}$$

3.3 Extraction scheme.

The image is distributed into non-coinciding blocks size same as in section 3.1 and process the further blocks to recover the secret data in succeeding steps.

Case 1: There will be no change in original blocks and does not use to hide the secret information if $LM(H)$ is equal to *2*.

Case 2: We extract the secret information just in case the location map in blocks $LM(H)$ is equal to one,

Using Eq. 14 compute the prediction error, pixels value will not change to extract the secret information $H_{i-1} = 0$ if $d_i = 0$,

Using Eq. 15 decreased the pixels value and extract the secret data $b_{i-1} = 1$ just in case $d_i = 1$,

$i\epsilon\{2, 3, ..., u_1 \times u_2\}, x_{\lambda(1)} = B'_{\lambda(1)}$.

$$d_i = B'_{\lambda(i)} = B'_{\lambda(i)} \tag{14}$$

$$B_{\lambda(i)} = \begin{cases} B'_{\lambda(i)}, b_{i-1} = 0 \quad if \quad d_i = 0, \\ B'_{\lambda(i)} - 1, b_{i-1} = 1 \quad if \quad d_i = 1, \end{cases} \tag{15}$$

Case 3: Arrange the pixels value in ascending order in case the location map of block *LM(H)* is equal to *0*, $H'_{\lambda}(B'_{\lambda(1)}, B'_{\lambda(2)}, ..., B'_{\lambda(u_1 \times u_2)})$, Presume that,

$B'_{\lambda(u_1 \times u_2 - R - S - T)} < B'_{\lambda(u_1 \times u_2 - R - S - T + 1)} = ... = B'_{\lambda(u_1 \times u_2 - R - S + 1)} = ... = B'_{\lambda(u_1 \times u_2 - R)} < B'_{\lambda(u_1 \times u_2 - R + 1)} = ... = B'_{\lambda(u_1 \times u_2)}$

Assumed that M_1, M_2, M_3 is maximum pixels value,

$M_1 : B'_{\lambda(u_1 \times u_2 - R + 1)} = B'_{\lambda(u_1 \times u_2 - R + 2)} = ... = B'_{\lambda(u_1 \times u_2)}$;

$M_2 : B'_{\lambda(u_1 \times u_2 - R - S + 1 -)} = B'_{\lambda(u_1 \times u_2 - R - S + 2)} = ... = B'_{\lambda(u_1 \times u_2 - R)}$;

$M_3 : B'_{\lambda(u_1 \times u_2 - R - S - T + 1)} = B'_{\lambda(u_1 \times u_2 - R - S - T + 2)} = ... = B'_{\lambda(u_1 \times u_2 - R - S)}$;

$d_1 \geq 1$ and $d_2 \geq 1$ prediction error if the value of $T \neq 0$, compute the prediction error using Eq. 16

$$\begin{cases} d_1 = B'_{\lambda(u_1 \times u_2 - R + 1)} - B'_{\lambda(u_1 \times u_2 - R)}, \\ d_2 = B'_{\lambda(u_1 \times u_2 - R - S + 1)} - B'_{\lambda(u_1 \times u_2 - R - S)}, \end{cases} \tag{16}$$

Case 3.1: Using Eq. 17 decreased the pixels value by one and no secret data will be embed if $d_1$is greater than *2*.

$$B_\lambda(i) = B'_{\lambda(i)-1, i\epsilon\{u_1 \times u_2 - R+1}, \quad u_1 \times u_2 - R + 2, ..., u_1 \times u_2\} \tag{17}$$

Case 3.2: Decreased the pixels value by one in M_1 as well as M_2 besides embed the data if d_2 is equal to *1* and $d_1 < 2$, using Eq. 18.

$$B_\lambda(i) = B'_{\lambda(i)-1, i\epsilon\{u_1 \times u_2 - R-S-T+1}, u_1 \times u_2 - R - S - T + 2, ..., u_1 \times u_2\} \tag{18}$$

The pixels from the regions $M_1 \quad and \quad M_2$ to extract the secret information's $S(H) = b_i | bi\epsilon 0, 1.i = 1, 2, ..., R + S$ using Eq. 19

Extract the secret information if b_i is equal to zero and decrease the pixels value by one if D_i is equal to 2 moreover, extract the secret information if $H_i = 0$, while pixels value will not alter in case $D_i = 1$ using Eq. 20

$$\begin{aligned} D_i = B'_{\lambda(i)} - B'_{\lambda(u_1 \times u_2 - R-S)}, \\ i\epsilon\{u_1 \times u_2 - R - S + 2, ..., u_1 \times u_2, \\ u_1 \times u_2 - R - S - T + 2, ..., u_1 \times u_2\} \end{aligned} \tag{19}$$

$$B_{\lambda(i)} = \begin{cases} B'_{\lambda(i)}, b_i = 0 \quad if \quad d_i = 1, \\ B'_{\lambda(i)} - 1, b_i = 1 \quad if \quad d_i = 2, \end{cases} \tag{20}$$

Case 3.3: The region M_1 is use to embed the secret information $if d_1 \leq 2$ and $(d_2 \geq 2 || T = 0$. Extract the secret information from regions M_1 while decreased the pixels value by one from regions M_1 and M_2 using Eq. 21

Extract the secret information if b_i is equal to one and decrease the pixels value by one if D_i is equal to *2*. Extract the secret information if $B_i = 0$ moreover, pixels value will not be alter if D_i is equal to one, recover the original pixels using Eq. 22.

$$D_i = B'_{\lambda(i)} - B'_{\lambda(n1 \times n2 - R)}, i\epsilon\{n_1 \times n_2 - R + 1, n_1 \times n_2 - R + 2, ..., n_1 \times n_2\} \tag{21}$$

$$B_{\lambda(j)} = B'_{\lambda(j)} - 1$$

$$B_{\lambda(i)} = \begin{cases} B'_{\lambda(i)}, b_i = 0 \quad if \quad d_i = 1, \\ B'_{\lambda(i)} - 1, b_i = 1 \quad if \quad d_i = 2, \end{cases} \tag{22}$$

where, $j\epsilon\{u_1 \times u_2 - R - S + 1, u_1 \times u_2 - R - S + 2, ...,$
$n_1 \times n_2\} and \quad i\epsilon\{u_1 \times u_2 - R + 1, u_1 \times u_2 - R + 2, ...,$
$u_1 \times u_2\}$

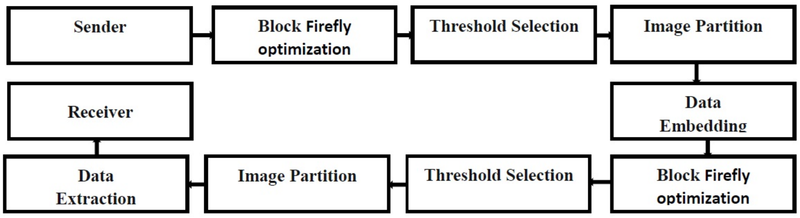

Fig. 2 Work Flow of Proposed Method

3.4 Data embedding and extraction procedures

The following steps to write and extract data from cover image shown in Figure. 2.
Step 1. original image is allocated into non coinciding block $u_1 \times u_2$ using lossless compression algorithm to established a location map.
The biased efficient lossless compression algorithm as follow,
The bitstream $x \epsilon \{0,1\}^n$ as well as $c \epsilon [0, 1/2]$, is c-biased if $1-c$ fraction of ones is smaller. the efficient compression algorithm, the C is positive constant that is less than 1/2 where C is bit-stream. Actual the aim of lossless algorithm is to gain more space for data embedding [43,44,45]. Proposed algorithm is better compressed size and performance well as compared with binary arithmetic algorithm.

Input: C-baised bitstream, where $B = (B_1, B_2, B_3, ..., B_n) \epsilon \{0,1\}^n$
$f_s(X)$ got compressed bit-stream.
1- The *n-bit* strings set in ordinal number d and x compute with exactly K ones.
2- (k, d) of binary representation output where $\lceil log_2 n \rceil$ bits k put in first $f_c(B)$ for extraction algorithm *(EA)*;
Input: n and $f_c(B)$ $B \epsilon \{0,1\}^n$ obtained the original bit-stream as follow,
1- Compute (n, k, d) from $f_c(B)$ value.
2- (n, k, d) where B is reconstructed
The *m-bit* binary string as k ones *n-bit* string are encoded by using binary arithmetic coding algorithm where,

$$m = \lceil log_2 e \rceil + \lceil log_2 [(\frac{e}{k})^k (\frac{e}{e-k})^{e-k}] \rceil \tag{23}$$

m-bit binary string as k ones *n-bit* string encoded by using proposed compression algorithm where,

$$m' = \lceil log_2 e \rceil + \lceil log_2 (\frac{e}{k}) \rceil \tag{24}$$

Step 2. Embed the secret data when $LM(H) = 1$ and skip when $LM(H) = 2$ while increase $LM(H) = 0$ and embed the secret data on maximum and minimum pixels value of location.

Step 3. After embedding the secret information, the remaining blocks of cover image record the embedding location. Embed the extra information in cover image while using the above algorithm to compressed the location map.

Step 1. Extract the compressed location map with secret data further decompressed the location map to get *LM*. According to desirable size of block divided the image into non overlapping blocks.

Step 2. Extract the secret information when $LM(B) = 1$ and skip when $LM(B) = 2$ while increase $LM(B) = 0$ and extract the secret data on maximum and minimum pixels value of location. After extract the secret information, to process the all residual blocks to extract extra information.

4 Experiments

4.1 Analysis of Proposed Method

We evaluated the five grayscale image as cover image in our proposed scheme. Comparison between different methods is based on relationship between the quality of camouflaged image and *EC*. When *EC* has increased then the quality of image declined gradually in different data hiding schemes but also *EC* and quality of image graph is change in different image. For example, the comparison between two images Airplane and Baboon in terms of *EC* when the capacity of image enlarged from *5000* to *14,000* bits then the quality of image among Airplane and Baboon is greater than Baboon. The quality of image is change in those blocks there are more sensitivity and higher *EC* due to more smooth blocks i.e., Airplane image. In previous history Lin et al.[46] proposed the difference image histogram and exposed that there is a large possibility that the neighbor's pixels in an image have same pixels value. According to this investigation the difference between two neighbored pixels can be the value of difference image and highest number of pixels tends around *0*. Higher *EC* and *PSNR* in smooth region have maximum contiguous pixels that have analogous pixels values that upturn the *PSNR* and *EC*, shown in Figure. 3. Maximum *EC* of baboon image i.e., *14,000* bits. Smooth region of block can hide more data as compare with rough block as well as *Lena* image we can hide *20,000* to *30,000* bits of secret information as compared with Baboon image while *EC* of smooth region the Airplane image is *52,000* bits which is more than Baboon image.

4.2 Special Blocks Handling

The overflow/underflow problem in traditional methods that use to handle these modified pixel to record two bits that is the reason to increase the size of location map. The overflow/underflow may occur in proposed technique in following range of pixels value $"0,""1,""254,"and\quad"255."$ Record the location to construct a map of modified pixels by using the safe range of boundary

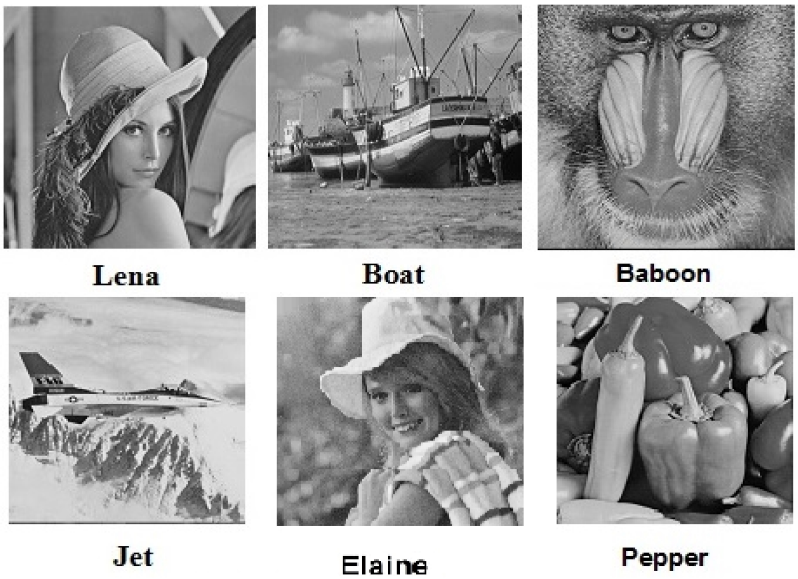

Fig. 3 The test stego images

pixel values. The distinct block size dramatically act the performance of *EC* however, the larger block size improve the quality of image and gain least *EC* due to reduce the relevance of blocks pixels value Similarly, smooth area of image have great correlations between other pixels for the reason that we have partition smooth area into smaller blocks while rough area have partition into larger region in the image. Proposed *GPVOFA* method used dynamic block strategy while selective region of image is used to gain more *EC* as compare with other *PVO* method.

4.3 Performances Comparison

In this section we compared our *GPVOFA* method with *PVO*[22], *IPVO*[23], PVOK[24], PPVO[25], Wang et al. [26] and Li et al.[27] methods with dynamic block size of five grayscale image are used in our experiment. The performance of *GPVOFA* method is successfully enhanced the *EC* and low distortion as compared with other schemes moreover, the quality of image is affected in some degree of camouflaged image for the reason that *GPVOFA* method emphases to gain maximum *EC* of cover image, shown in Figure 5.

The presentation of *GPVOFA* and *PVO-K* methods the usage of different block sizes is significant that improve the *EC* of digital image hence, different blocks size $2\times2, 2\times3, 3\times3, 3\times4, 4\times4$ tested respectively likewise, "Lena" and "Airplane" image the block extent will distress the expansion of *EC* conversely, it will boost up the image quality, display in Figure.3 4, 5. *GPVOFA* method use the diverse blocks and remarkably enhanced the *EC* of cover image while

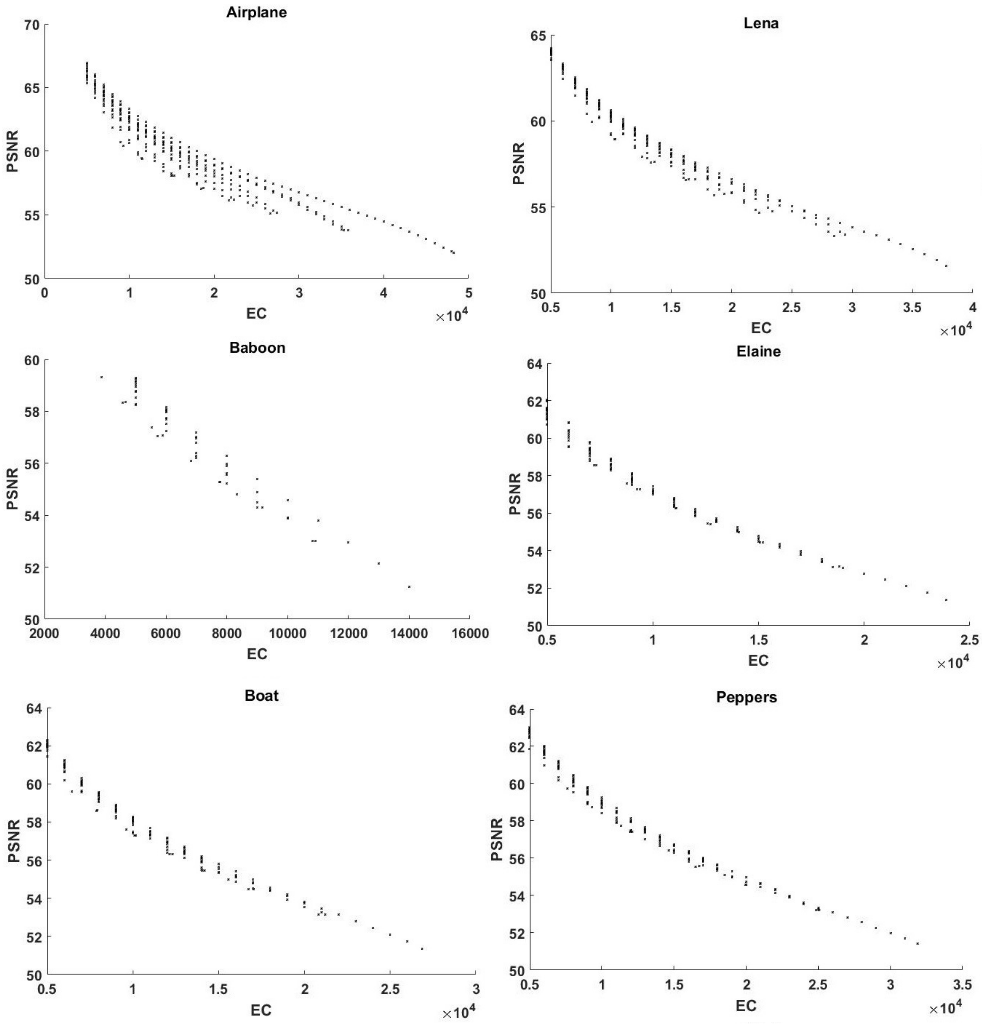

Fig. 4 Evaluation with reverence of *EC* and *PSNR* with different block size of following images

capacity of *PVO-K* method can change the *K* bits by embedding one bit of secretive data where each pixel is modify by *1*. *GPVOFA* method embed the outsized capacity of information into *K* bits (*K* largest- pixels *1-2 K* value for each pixels) and second-largest pixels value is revised by one in small block size while embed the secretive data, smallest-pixels value is shifted to original value.

The average *EC* of *GPVOFA* method is more than *PVO*[22], *IPVO*[23], PVOK[24], PPVO[25], Wang et al. [26] and Li et al.[27] methods, exposed in Table. 1. Quality of image is suffer if the significant improvement of *EC* in s-mooth area of image, that approximately more than *50000* bits is optimum *EC*

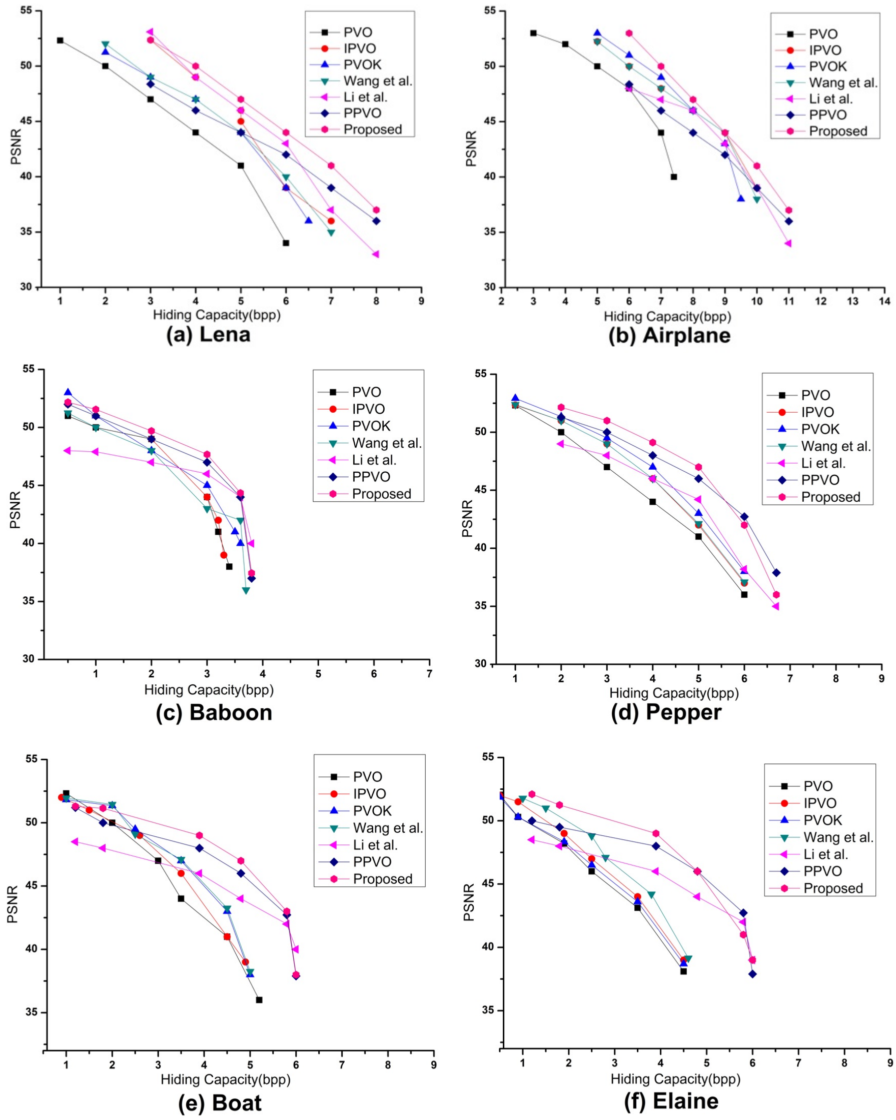

Fig. 5 Evaluation of *GPVOFA* methods with other techniques

of image Airplane but also sustained the quality of image in *GPVOFA* scheme. Furthermore, *GPVOFA* method have exceptional performance in terms of *EC* and maintaining the quality of stego-image as compared with *PPVO* and Li et al. methods. *PPVO* method got high 44000 *EC* but comparatively low *PSNR* while Li et al. got *44000 EC* and got low *PSNR* 48.37 db as well as *GPVOFA* got high 44000 *EC* and got highest *PSNR* 53.10 db as compare with both technique in image "Lena".

Table 1 Evaluation of *GPVOFA* performances comparison with other methods Li et al.*PVO*[22], Peng et al. *IPVO*[23], Xu et al.*PPVO*[25], Ou et al. PVOK[24], Wang et al. [26] and Li et al.[27] (C represent embedding capacity)

Method	Lena		Boat		Baboon		Jet		Pepper		Elaine	
	C	PSNR	C	PSNR	C	PSNR	C	PSNR	C	PSNR	C	PSNR
PVO[22]	32000	52.32	24000	52.00	13000	51.75	38000	53.12	28000	52.05	21000	52.05
IPVO[23]	38000	52.35	26000	51.80	13000	51.80	52000	52.50	30000	52.00	24000	52.00
PPVO[25]	44000	51.25	29000	51.20	15000	51.50	69000	50.95	33000	51.30	28000	50.00
PVOK[24]	37000	52.02	26000	51.82	13000	52.00	47000	52.24	31000	51.92	23000	51.87
Wang's[26]	38000	52.15	26000	51.95	13000	51.85	52000	52.00	30000	52.00	25000	51.78
li[27]	44000	48.37	30000	49.00	15000	49.90	66000	48.13	36000	48.67	28000	49.17
Proposed	44000	53.10	27000	51.91	14000	52.18	52000	52.72	31000	52.02	24000	52.10

Several *RDH* schemes support the multilevel embedding strategy that continuously embed the secret data to use new cover image again after embedding the data while increase the *EC* to optimal level in camouflaged image. *GPVOFA* method the secret data assume as *0* and *1* that generated randomly to use smallest and largest pixels values to embed the secret data in blocks. Moreover, split the previous smallest and largest pixel value after embed the secret data and subsequent level will be split again to increase the *EC* step by step but in this case camouflaged image quality also will be decreased gradually.

5 Conclusions

In this paper a novel Generalized PVO base reversible data hiding using Firefly Algorithm *GPVOFA* scheme has presented for digital images, In our scheme we have established a pixel based compressed location map size is reduce to compute the each block while a block that have underflow /overflow skip from embedding procedure furthermore, decrease only smooth area of image that was the reason to gain high EC and increase rough block area of image that maintained the quality of image. The maximum and minimum pixels values with multilevel embedding strategy has also used to embed the secret data that significantly improved the *EC* and sustain the quality of image as compared to preceding works. Future work we will try to increase the *EC* and sustain the high quality of image.

Declarations

Competing interests
The authors declare that they have no competing interests.

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