Advancements in Reversible Data Hiding Techniques: A Review

Namita Tiwari1† and Abha Singh Sardar2††,
Maulana Azad National Institute of Technology, Bhopal, M.P., India

Summary
With the rapid advancement of communication through Internet, the information exchanged could be tampered intentionally or accidentally through unprivileged access. In the recent years, Reversible Data Hiding (RDH) has become an active research domain in the field of data hiding. In reversible data hiding, at the sender side, the bits which is to be concealed is embedded in the cover file (image) and at the receiver side, the hidden bits of data and the original cover media is extracted without any distortion. RDH is also referred as invertible or lossless data hiding. Nowadays with the increased popularity of outsourcing data to the cloud, it has become important to safe guard the privacy of data and enable the cloud server to easily manage the data at the same time. Reversible data hiding techniques solves the issue of the concealment of data. In this paper various techniques of reversible data hiding and their future scope is discussed.

Keywords:
Reversible Data Hiding, Reversible Data Hiding in Encrypted Images, lossless data hiding, invertible data hiding.

1. Introduction

The development in the study of personal computer brought a huge change in business, industry, education and science. A similar change also occurred in the area of networking and data communications. Advancement in technology has made it possible for data channels to carry more and faster signals. The rapid advancement of Internet, it has provided many facilities for human life lifestyle. People communicate with one another via texts, audio, and video. Sometimes the information shared between networks could be tampered or intercepted during the transmission. The ultimate goal of the network world is to transform the data and secure it from accidental/intentional unauthorized access, this is where the data hiding role comes into play. In past decades, data hiding has attracted quite a good number of researchers' attention [1], [2]. Data hiding concentrates on three basic factors: embedding capacity, imperceptibility, and unambiguousness. Embedding capacity is the amount of covert data that can be hidden in the cover media. Imperceptibility is the state of the marked media being perceptually indistinguishable after being embedded with the secret hidden information. Unambiguousness is the situation where the marked media could be easily distinguished by the receiver. There always happens to be a conflict between embedding capability and imperceptibility because more embedding leads to more distortion. The data hiding technique is split into non-reversible data hiding and reversible data hiding. The embedding capacity of non-reversible data hiding is high but the original cover media is destroyed whereas in RDH the embedding capability is low but the original cover media could be recovered. Some of the present data hiding schemes are not invertible, the presence of truncation error and round-off error in spread spectrum technique [3],[4],[5],[6] makes it non-reversible, because of the bit replacement without memory the least significant bit plane scheme [7],[8] is taken into account to be non-reversible and because of the quantization error quantization-index-modulation[9],[10] is rendered as invertible. RDH also links two data sets, a set belongs to the embedded information and another set belongs to the cover media data such that the cover media will be losslessly recovered once the hidden information has been extracted out [11], [12].According to the requirement, the hiding techniques can be robust, semi-fragile or fragile. Robust schemes are being used for proving ownership claims and fragile is being employed for multimedia content authentication. Robust schemes are ought to survive a good variety of friendly operations and malicious attacks, whereas the fragile watermarks are intolerable to malicious as well as content protective operations. Fragile schemes are supposed to report each potentially tampered region. RDH is considered to be a fragile technique. RDH strategies are often thought of as a method of semantic lossless compression [13], [14]. In RDH, some extra space is preserved for storing additional data by losslessly compressing the media. The term "semantic media" means that the compressed media should be close to the original media. Reversible data hiding techniques can be used to retrieve encrypted images to their pure state. These techniques have been generally classified into Compression-based, Histogram Shifting and Expansion based.

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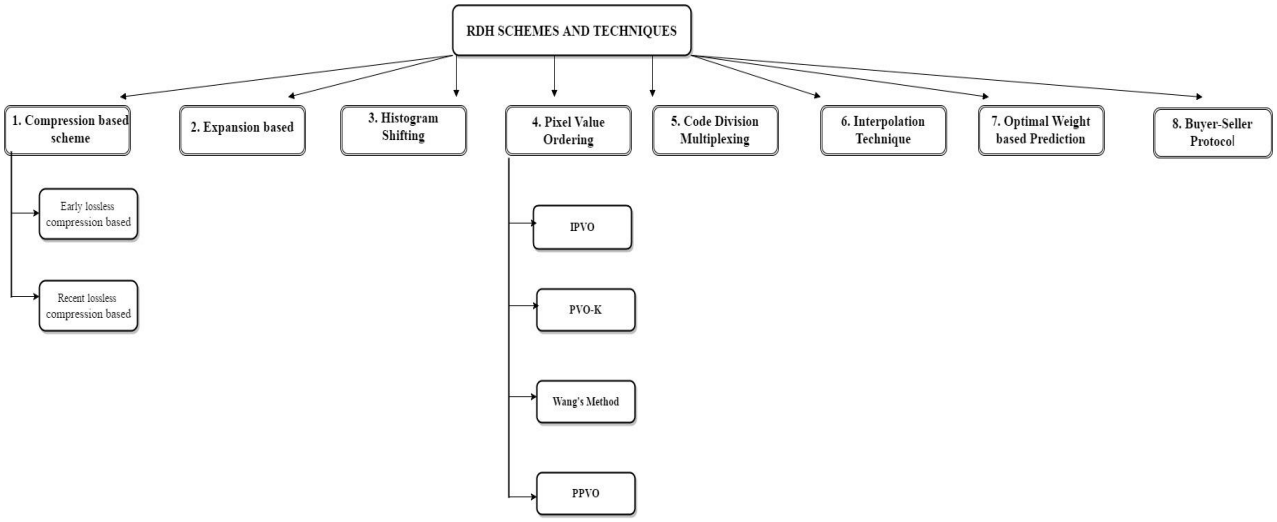

Fig. 1 Classification of RDH Techniques and schemes

Applications that utilize RDH include image authentication [15], where a RDH algorithm is applied to authenticate commonly used JPEG images, in this, among the adjacent blocks, differential histogram of the quantized coefficients is calculated and also the 64-bits authentication code is embedded by shifting the differential histogram during the JPEG compression. By reversing the shifting process, the embedded code is extracted. Medical image processing [16], Efficient maintenance of medical contents in an electronic format is crucial. Concerns are about confidentiality, authentication and availability. Authentication watermarking is meant to demonstrate the integrity and authenticity of the underlying data. Authentication watermarking represents a viable solution to authentication of medical images. Video error concealment coding [17], the transmission process in a network environment is error prone. Concealing the error is important for robust transmission of video. So RDH-based technique for the intra-frame error concealment is designed and by employing histogram modification technique, it is able to attain no quality degradation. Stereo image coding [18], Stereo images are pairs of images which are taken from the exact scene by considering a slight different viewpoint. Instead of a single image one should process a pair. Its storage space and the transmission bandwidth required may be twice larger than the traditional image applications. A straightforward solution to reduce the storage potential and the transmission bandwidth is the compression of each image frame. Compression-based methods have the drawback that once compressed; the actual matter of the stereo pair is no more available. In order to eliminate this drawback reversible watermarking is introduced, the information which is needed to recover one image is embedded in the other image by employing reversible watermarking.

This paper is summarized as, Section 2 includes RDH schemes/techniques, and section 3 includes the conclusion and future scope.

2. RDH Schemes and Techniques

As we know RDH is broadly divided into compression, difference expansion, and histogram shifting schemes which are also further divided into different techniques and are shown in Fig 1.

2.1. Compression-based schemes

The initial RDH schemes are based on lossless compression [19]-[27] which focused on high capacity embedding or fragile authentication. These schemes focus on releasing some space by losslessly compressing a subset S belonging to the original cover image, and then the saved space is utilized to save data. The embedding is performed by replacing S with the compressed form SC, and the message, and so the maximum embedding capacity becomes $S - s_c$. The performance is evaluated by the selected subset and the employed compression algorithm.

2.1.1 Early lossless compression based scheme

In [19], Friedrich et al., introduced two methods for lossless authentication watermarks. In the first method, lossless compression is done on the selected original LSB's of middle-frequency coefficients and in the same coefficients hash value of the complete image is inserted. In the second method, from the quantization table one quantization coefficient is selected and is changed to half of its value, and to keep the image appearance unchanged all respective coefficients in all blocks are multiplied by

two. In the modified coefficients simple LSB embedding is used which reversibly embeds the message or the hash value. In [21], Goljan et al. proposed the R-S scheme. In this technique, the original grayscale image is divided into disjoint groups, a discrimination function f is also defined which captures the smoothness of the group of pixels and categorizes them as Regular, Singular and Unstable. An invertible operation F called "flipping" is defined, which permutes the gray levels. Prior to the embedding operation, the groups are scanned and the status is losslessly compressed i.e. the RS-vector. In the compressed RS-vector, the message is being appended as bits and the resulting bits stream is embedded in the image. In [22], Xuan et al, proposed invertible data embedding technique. This technique makes use of the integer wavelet transform which maps integer to integer; and arithmetic coding, in the middle and high-frequency subbands. In the subbands the binary bits in the chosen bit-plane of the IDWT coefficients are losslessly compressed, a secret key function which keeps the data secret even after the algorithm is revealed and preprocessing which prevents possible overflow.

In [26], Celik et al, presented a low-distortion, high-capacity, Type-II (information bits are embedded by modifying) lossless data embedding algorithm. Instead of the bit planes, this technique alters the lowest levels of the host signal to house the embedding data. This generalization gives a finer capacity-distortion granularity. The generalized LSB modifies the raw pixels values as the signal features. The recovery of the original media is performed by compression, transmission and recovering these features.

2.1.2 Recent lossless compression based scheme

In RDH, the payload's upper bound can be reversibly embedded in the cover image, for a given distortion constraint. The above problem has been resolved by Kalker and Willems [28], they developed a different RDH rate-distortion problem, and got the upper bound under a given distortion constraint Δ as shown in (1):

$$\rho_{rev}(A) = \max\{H(y)\} - H(x) \qquad (1)$$

where ρ_{revis} is the embedding capacity, x and y are the covers and marked sequence, and H is the entropy function. The distortion constraint is shown in (2):

$$\sum_{x,y} P_X(x) P_{Y/X}(y/x) D(x,y) \leq \Delta \qquad (2)$$

where, $P_{Y|X}(y|x)$ is the probability matrices and D(x, y) is the square error distortion. In [29]-[35] an asymptotic approach for the rate-distortion on lossless-compression RDH methods is discussed. All the above methods are improved variant of recursive code construction [28]. Recursive histogram modification (RHM) is practiced for lossless compression based scheme. Firstly, RHM solves the problem for estimating the optimal probability transition matrix $P_{Y|X}(y|x)$ and $P_{X|Y}(x|y)$.Secondly, RHM embeds the message recursively by dividing the cover sequence into disjoint blocks then modifies the histogram of each block. The capacity approaching codes minimize the embedding distortion for any cover sequence and given payload. Then the designers of RDH only need to concentrate on the formation of a cover signal having small entropy. For a short sized cover sequence, the perfect lossless compression of the cover signal cannot be achieved.

2.2 Expansion based

In [36]-[37], Tian proposed a RDH method of high capacity which was based on difference expansion (DE). In DE, to derive the difference values Haar wavelet transform have been applied to the cover media and then for reversible data embedding, the obtained difference values are expanded, to create vacancies. Steps of Tian's DE method:

- For a pixel pair (x_0, x_1), their integer average and difference is defined as

  $l = \lfloor (x_0 + x_1)/2 \rfloor$ and $h = x_1 - x_0$.

- Difference h is expanded to $h^* = 2h + m$, to embed 1 bit $m \in \{0, 1\}$ and keeping the integer average unchanged.
- On the basis of the newly produced difference value h^* and original integer average value l, the marked pixel pair is calculated. Pixel pair (y_0, y_1) is calculated as shown in (3):

$$\begin{cases} y_0 = l - \lfloor h^*/2 \rfloor \\ y_1 = l + \lfloor (h^* + 1)/2 \rfloor \end{cases} \qquad (3)$$

By reduction as shown in (4),

$$\begin{cases} y_0 = 2x_0 - \lceil (x_0 + x_1)/2 \rceil \\ y_1 = 2x_1 - \lceil (x_0 + x_1)/2 \rceil + m \end{cases} \qquad (4)$$

The original pixel pair (x_0, x_1) can be retrieved from the embedded bit m determined from the LSB of $y_1 - y_0$ as shown in (5).

$$\begin{cases} x_0 = l' - \lfloor h'/2 \rfloor \\ x_1 = l' + \lceil h'/2 \rceil \end{cases} \quad (5)$$

From the marked pixel pair, $l' = \lfloor (y_0 + y_1)/2 \rfloor$ and $h' = \lfloor (y_1 - y_0)/2 \rfloor$ are computed. By DE, one bit can be embedded in pixel pair so its embedding rate becomes 0.5 bpp. To handle the overflow/underflow problem, Tian adopted a location map which records the selected expandable locations.

2.2.1 Integer- to-Integer Transformation (IT)

DE can be viewed as a kind of Integer Transformation and is first of its kind in RDH. In [38], Alattar projected a new scheme of generalizing DE from the viewpoint of IT. By generalizing difference expansion from pixel pair to pixel block of arbitrary size, Alattar improvised Tian's method. The embedding rule of Alattar method are shown in (6):

$$\begin{cases} y_0 = 2x_0 - \left\lfloor \frac{2\sum_{i=0}^{n} x_i + \sum_{i=1}^{n} m_i}{n+1} \right\rfloor + \left\lfloor \frac{\sum_{i=0}^{n} x_i}{n+1} \right\rfloor \\ y_1 = 2x_1 - \left\lfloor \frac{2\sum_{i=0}^{n} x_i + \sum_{i=1}^{n} m_i}{n+1} \right\rfloor + \left\lfloor \frac{\sum_{i=0}^{n} x_i}{n+1} \right\rfloor + m_1 \\ y_n = 2x_n - \left\lfloor \frac{2\sum_{i=0}^{n} x_i + \sum_{i=1}^{n} m_i}{n+1} \right\rfloor + \left\lfloor \frac{\sum_{i=0}^{n} x_i}{n+1} \right\rfloor + m_n \end{cases} \quad (6)$$

where $(x_0, x_1, \ldots, x_n) \in Z^{n+1}$, $(y_0, y_1, \ldots, y_n) \in Z^{n+1}$, and $(m_1, \ldots, m_n) \in (Z_2)^n$ they represent the cover image's pixel block size $n+1$, marked pixel block and secret data to be embedded respectively. Clearly, n bits can be embedded in $n+1$ pixels and it is possible to increase the embedding rate to 1 bpp with this transformation. In [39], Coltuc and Chassery have proposed a method on reversible contrast mapping. It is an IT of integer pairs. This method is efficient in respect of computational complexity as compared to DE because it doesn't require additional lossless data compression. In [40], Weng *et al* proposed a method which is established on invariability of the sum of pixel pairs and pair wise difference adjustment. Weng *et al* further improved DE by taking into account the magnitude of different values of two different ITs of pixel pair. In [41], Wang *et al* also generalized DE by employing a new IT. This method showed that the embedding rule of DE can be redeveloped by transforming the integer pair. In [42], Coltuc contemplated a new IT scheme called low-distortion transformation which embeds one bit into a pixel quad. The impact that the location map had on embedding performance was reduced. In case of the IT based schemes, as a result of a less efficient, the average value of the block is used to predict each pixel within the block. For larger data embedding IT-based RDH is more efficient.

2.2.2 Prediction Error Expansion

In [43] and [44], Thodi and Rodriguez proposed prediction error expansion (PEE) for the first time. Later on this technique has been accepted by many authors [45]-[60]. PEE uses pixel indicator instead of difference operator as the de-correlation operator as used in difference expansion. This technique exploits the spatial redundancy in natural images. The local correlation of larger neighborhood is used in PEE instead of considering the correlation of two adjacent pixels as done in difference expansion (DE). In the case of DE and PEE the common characteristic is the expansion based embedding operation. In this, the difference value and the prediction error is expanded respectively for embedding secret bits by difference expansion. By DE, only one bit can be embedded in a pixel pair so its maximum embedding rate is 0.5 bpp. In the case of PEE, one bit can be embedded in a pixel so maximum embedding rate of 1 bpp can be achieved.

2.2.3 Adaptive Embedding

Kamstra and Heijmans [61], proposed the first adaptive RDH scheme which is based on sorting and difference expansion. The Tian's method [DE] for information embedding has been improved where the pixel pairs have been sorted just as the local variance. The difference value of the integer average value of two pixels in a pair alone is altered. On the part of computing the local variance for sorting the pixel pairs, the encoder and decoder can utilize the embedding invariants. The pair is assumed to be located in a flat image region, if the local variance of a pixel pair is small and so the pair could be expanded with small difference value. The location map can be visibly compressed by sorting as compared to the original DE method. In [48],[52], [54], [56], [57], [62]-[68] authors suggested that by combining adaptive embedding scheme with other reversible methods, i.e. sorting or pixel-selection with prediction error expansion, can drastically improve the embedding capacity. On the side of obtaining a better cover medium, adaptive embedding makes use of the smooth image pixels and then it modifies the generated cover medium hence implementing reversible data embedding. Adaptive embedding gives a better performance enhancement.

2.3 Histogram Shifting

In [69] and [70], Ni et al proposed the histogram shifting method for the first time. In this approach, a histogram is first obtained, and then reversible data embedding is performed by altering the generated histogram. In the

following way, for a given integer a, the covert data is embedded into the cover media I to get the marked media J which is shown in (7).

$$J_{i,j} = \begin{cases} I_{i,j} - 1, & if\ I_{i,j} < a \\ I_{i,j} - m, & if\ I_{i,j} = a \\ I_{i,j}, & if\ I_{i,j} > a \end{cases} \quad (7)$$

where to be embedded bit is $m \in \{0,1\}$ and (i,j) represents the pixel coordinate in the cover media. In this scheme the PSNR of the marked media versus the original one is 48.13 dB since every pixel value is modified by at most 1. In the interest of maximizing the capacity, the integer a can be taken as the histogram peak. The embedded data can be extracted and the original media could be restored on the decoder side. By following the steps:

- If $J_{i,j} < a - 1$, then there is no hidden data in the pixel, and the original value is $J_{i,j} + 1$.
- If$J_{i,j} \in \{a-1, a\}$, the pixel carries secret data and the embedded bit is
$$m = a - J_{i,j}.$$
- If$J_{i,j} > a$, the pixel remains unchanged during embedding operation.

In [71], Fallahpour and Sedaagi proposed block-based histogram shifting in which instead of using the whole image, histogram shifting should be applied to image blocks. In this technique, the cover media is first divided into multiple blocks. Then, the histogram is produced for individual divided blocks and then for data embedding, Ni et al's histogram shifting is applied. With a reduced embedding distortion, the embedding size can be increased. In [72], Lee et al, proposed a new technique which uses the difference histogram. In this approach an improved performance is obtained since the spatial correlation of natural image is exploited. Since the difference histogram has Laplacian-like distribution and has higher peak points so it is treated to be better for RDH. In [73], X.Li proposed a general construction for designing the HS-based RDH. This included many previous schemes as special cases. In this technique, the cover image is split into non-overlapping blocks and each block contains n pixels. By counting the recurrence of each divided block a n -dimensional histogram is generated. In the final stage the data embedding is done by modifying the n-dimensional histogram. The pixel blocks are elements of Z^n which is split into disjoint sets. The expansion based on predefined embedding function method is accustomed to carry the secret data in one set and based on the predefined shifting function; the other set is simply shifted and is done to create free spaces which ensure reversibility.

2.4 Pixel Value Ordering

In [74], Li et al, proposed a PVO (Pixel Value Ordering) method. In this approach, pixel values are ordered in a block-wise manner and then the prediction error is calculated by employing the second-largest/smallest pixel value for predicting the largest/smallest pixel value. "1" and "-1" are chosen as peak points for embedding the secret data since after ordering the variance between the adjacent pixels is smaller. Before embedding the secret data, pixels must be processed, to avoid the overflow/underflow issue. If the pixel is "0"/"255" then the value must be increased/decreased by one. Then the position of pixels in location map is to be recorded, otherwise, the pixel value is kept unchanged.

To embed the secret data, a block B of size $n_1 * n_2$is taken. In the current processed block the pixels need to numbered and sorted as to get a sequence $B\left(x_{\pi(1)}, x_{\pi(2)}, \dots, x_{\pi(n_1 * n_2)}\right)$ .Then the second largest/smallest pixels are used for predicting the largest/smallest pixel value. The two prediction errors are calculated from (8). If the maximal prediction error is "1" or the minimal prediction error is "-1", the secret information can be embedded in the largest/smallest pixels which is given by the formula (9) and (10).

$$\begin{cases} d_{max} = x_{\pi(n_1 * n_2)} - x_{\pi(n_1 * n_2 - 1)} \\ d_{min} = x_{\pi(1)} - x_{\pi(2)} \end{cases} \quad (8)$$

$$x'_{\pi(n_1 * n_2)} = \begin{cases} x_{\pi(n_1 * n_2)} & if\ d_{max} = 0 \\ x_{\pi(n_1 * n_2)} + b & if\ d_{max} = 1 \\ x_{\pi(n_1 * n_2)} + 1 & if\ d_{max} > 1 \end{cases} \quad (9)$$

$$x'_{\pi(1)} = \begin{cases} x_{\pi(1)} & if\ d_{min} = 0 \\ x_{\pi(1)} - b & if\ d_{min} = -1 \\ x_{\pi(1)} - 1 & if\ d_{min} < -1 \end{cases} \quad (10)$$

The order of B is unchanged since the largest pixel value always increased and the smallest pixel value decreased. Hence the secret data can be extracted and the original pixels can be recovered. The prediction errors are calculated according to (8) then the secret data can be retrieved from (11) and (12). For replacing the pixels the location map is needed.

$$x_{\pi(n_1\times n_2)} = \begin{cases} x'_{\pi(n_1 * n_2)} & if\ d_{max} = 0 \\ x'_{\pi(n_1 * n_2)} - 1, b = 1 & if\ d_{max} = 2 \\ x'_{\pi(n_1 * n_2)}, b = 0 & if\ d_{max} = 1 \\ x'_{\pi(n_1 * n_2)} - 1 & if\ d_{max} > 2 \end{cases} \quad (11)$$

$$x_{\pi(1)} = \begin{cases} x'_{\pi(1)} & if\ d_{min} = 0 \\ x'_{\pi(1)} + 1, b = 1 & if\ d_{min} = -2 \\ x'_{\pi(1)}, b = 1 & if\ d_{min} = -1 \\ x'_{\pi(1)} + 1 & if\ d_{min} < -2 \end{cases} \quad (12)$$

2.4.1 Improved Pixel Value Ordering (IPVO)

The main issue of IPVO is solving the overflow/underflow problem. The embedding process between the largest and smallest pixels is the same. In this, only the embedding and data extraction in largest pixels are proposed. In IPVO the prediction error "0" is also taken into consideration which means the secret message can be embedded in prediction errors which are equal to "0" or "1". Calculation of prediction error is given by (13), the embedding process is given by (14) and recovery of pixel values is given by (15).

$$\begin{cases} d_{max} = x_u - x_v, \\ u = \min\big(\pi(n_1 * n_2), \pi(n_1 * n_2 - 1)\big), \\ v = \max\big(\pi(n_1 * n_2), \pi(n_1 * n_2 - 1)\big), \end{cases} \quad (13)$$

$$x'_{\pi(n_1 * n_2)} = \begin{cases} x_{\pi(n_1 * n_2)} + b & if\ d_{max} = 1 \\ x_{\pi(n_1 * n_2)} + 1 & if\ d_{max} > 1 \\ x_{\pi(n_1 * n_2)} + b & if\ d_{max} = 1 \\ x_{\pi(n_1 * n_2)} + 1 & if\ d_{max} < 0 \end{cases} \quad (14)$$

$$x_{\pi(n_1 * n_2)} = \begin{cases} x'_{\pi(n_1 * n_2)} - 1, b = 1 & if\ d_{max} = 2\ or - 1 \\ x'_{\pi(n_1 * n_2)} - 1 & if\ d_{max} > 2 \\ x'_{\pi(n_1 * n_2)}, b = 0 & if\ d_{max} = 0\ or\ 1 \\ x'_{\pi(n_1 * n_2)} - 1 & if\ d_{max} < -1 \end{cases} \quad (15)$$

2.4.2 PVO-K

Like IPVO, PVO-K was proposed to utilize the prediction error "0". In the matter of PVO-K, the k same largest/smallest pixels are anticipated as a single unit for embedding secret information. With K largest pixels in the block, the ordered sequence becomes as shown in (16):

$$x_{\pi(1)} \le \cdots \le x_{\pi(n_1 * n_2 - K)} < x_{\pi(n_1 * n_2 - K + 1)} = \cdots = x_{\pi(n_1 * n_2)} \quad (16)$$

Prediction error of largest pixel is computed as (17):

$$d_{max} = x_{\pi(n_1 * n_2 - K + 1)} - x_{\pi(n_1 * n_2 - K)} \quad (17)$$

The embedding and data extraction process are same as (9)-(12).

2.4.3 Wang's Method

In [75], Wang proposed a dynamic block division scheme. This method flexibly selects the block sizes for different regions and so the smooth regions can be used for embedding the secret data. First, the cover data is split into $4 * 4$ sized blocks. A method is required to judge the complexity of each block. The complex parameters cannot be changed after performing the embedding operation so that the reversibility is maintained. A complex feature which is the difference between the second largest and second smallest pixel is chosen and is called NL (Noise Level). Two thresholds $T1$ and $T2$ $(-1 \le T_2 \le T_1 \le 255)$ are set. The blocks are processed just as the following cases:

- Case 1: If $NL > T_1$,the block is examined to be a rough block. The blocks are unsuitable for embedding secret data.
- Case 2: If$T_2 < NL \le T_1$, the block is examined to be normal block. The block is smooth and is considered for embedding the secret data.

- Case 3: If$NL \leq T_2$, the block is examined to be a flat block. In this situation the $4 * 4$ block is divided into $2 * 2$ to embed the secret data.

2.4.4 PPVO

For embedding secret information the pixels in the smooth regions cannot be efficiently utilized in schemes PVO, IPVO, PVO-K and Wang's since two bits of secret data are embedded at most in a block. PPVO uses a sliding window concept instead of the non-overlapping blocks, to fully utilize individual pixel of the image and during the secret information being embedded only the target pixel is changed in the sliding window. Except for the target pixel value, the largest and smallest pixel values are selected. One bit of secret data can be veiled if the index pixel value corresponds to the largest or smallest pixel value. One bit of secret data can also be hidden if all the pixel values in the sliding window are equal including the target pixel value. PPVO also suffers from overflow/underflow problem which is to be solved first by PVO method. Then all the pixels in the sliding window except the target pixel are to be sorted in ascending order to attain an ordered sequence $\left(x_{\pi(1)}, x_{\pi(2)}, \dots, x_{\pi(n-1)}\right)$ .The following cases needs to be considered to handle the target pixel,

- Case 1: If$x_{\pi(1)} \neq x_{\pi(n-1)}$, the target pixel $x_t$is modified and the secret data $b \in \{0,1\}$ is embedded by (18).
- Case 2: If $x_{\pi(1)} = x_{\pi(n-1)}$, the pixels in the sequence are all equal and is denoted by VC, to embed secret message target pixel is modified as (19)

$$x'_t = \begin{cases} x_t + b, if\ x_t = VC = 254 \\ x_t - b, if\ x_t = VC < 254 \\ x_t - 1, if\ x_t < VC \\ skip, if\ x_t > VC \end{cases} \quad (18)$$

The secret data is extracted and the cover pixel values are recovered by (1) and (20).

$$x_t = \begin{cases} x'_t + 1, & if\ x'_t < x'_{\pi(1)} \\ x'_t, b = 0, & if\ x'_t = x'_{\pi(1)} \\ x'_t + 1, b = 1, & if\ x'_t = x'_{\pi(1)} - 1 \\ x'_t - 1, & if\ x'_t > x'_{\pi(n-1)} \\ x'_t, b = 0, & if\ x'_t = x'_{\pi(n-1)} \\ x'_t - 1, b = 1, & if\ x'_t = x'_{\pi(n-1)} + 1 \\ skip, if\ x'_t > x'_{\pi(1)}\ or\ x'_t < x'_{\pi(n-1)} \end{cases} \quad (19)$$

$$x_t = \begin{cases} x'_t, b = 0 & if\ x'_t = VC = 254 \\ x'_t, b = 1, & if\ x'_t = VC = 253 \\ x'_t, b = 0, & if\ x'_t = VC < 254 \\ x'_t + 1, B = 1 & if\ x'_t = VC < 253 \\ x'_t + 1, & if\ x'_t < VC \\ skip, & if\ x'_t > VC \end{cases} \quad (20)$$

Table 1: difference between PVO techniques

	PVO	***IPVO***	***PVO-K***	***Wang's method***	***PPVO***
Block Type	Fixed block	Fixed block	Fixed block	Sliding window	Dynamically divide
Peak Points	"1" or"-1"	"0" and "1" (or "-1")	"1" and "-1"	"0" and "1"(or "-1")	"0"
number of bits that can be embedded into a 4 * 4 sized block	8	8	8	8	9

2.5 Code Division Multiplexing

In [76], a novel code division multiplexing (CDM) based RDH technique is presented. The covert information is denoted by totally different orthogonal spreading sequences and embedded into the cover media. The

original image is fully retrieved once the information is extracted precisely. The Walsh Hadamard matrix is used to get orthogonal spreading sequences, by which the data will be overlappingly embedded while not being intrusive, and the multilevel information embedding may be applied to enlarge the embedding capability. Most components of individual spreading sequences are reciprocally cancelled after they are overlappingly embedded, that maintains the image in sensible quality even with high embedding payload. A location-map free technique is bestowed to secure lots of extra space for data embedding, and also the overflow/underflow downside is resolved by shrinking the distribution of the image histogram on each ends. Experimental results presents that the CDM can achieve the best performance at the moderate-to-high embedding capacity. This algorithm continues to be fragile as any malicious invasion might cause errors within the decryption of the information hiding media.

2.6 Interpolation Technique

In [77], a secret message embedding approach based on interpolation error expansion is proposed. This technique embeds a large amount of covert information into the cover images with least visible modifications. Besides it is a kind of difference expansion (DE). But it differs from most DE approaches in two fields. First, instead of using inter-pixel difference or prediction error to embed data it uses interpolation error. Second, instead of shifting the bits it expands the differences by addition. This technique does not need location map to identify the expanded interpolation errors. Interpolation errors are to be more expandable than the prediction errors or inter-pixel differences. The advantages include the preservative expansion to be smaller since every pixel is altered at most by 1. Without sacrificing the embedding size it guarantees a high image quality.

2.7 Optimal Weight Based Prediction

In [78], the optimum rule of value modification underneath a pay-load distortion criterion is found by using a repetitive method, and a feasible RDH approach is projected. The secret information, together with the auxiliary data which is employed for content recovery, is taken by the variation between the actual pixel-values and the corresponding values estimated from neighbors. In agreement with the optimum value transfer rule, the estimation errors are modified. The host image is split into a variety of subsets and therefore the auxiliary data of a subset is embedded into the estimation errors within the next subset. In the matter of smooth host images, the projected scheme considerably outperforms the previous RDH strategies.

2.8 Buyer-Seller Protocol

In [79], a secure buyer-seller watermarking protocol is proposed which includes just two participants, a seller, and a buyer. This scheme is rest on the idea of secret sharing. In order to track piracy in the digital media, a watermark is embedded which comprises of two parts, one secret detail generated by the seller and one by the buyer. As neither is aware of the precise watermark, the client cannot remove the watermark from the watermarked media; at an equivalent time, the vendor cannot fabricate piracy to allege an innocent. In this proposed method no third party is involved so the issue of a seller conspiring with a third party to deceive the buyer is avoided, namely the conspiracy problem. This method resolves the anonymity problem, conspiracy problem, piracy tracing problem, customer's rights problem and the unbinding problem. There are three sub-protocols for the secure buyer-seller watermarking protocol:

- Registration protocol
- Watermarking protocol
- Identification and arbitration protocol

3. Conclusion and Future Scope

In this paper, we presented an active research domain of digital data hiding techniques. The lossless compressibility decides the reversibility of RDH images. We discussed eight RDH techniques, to which the G-LSB of early compression based scheme gives a fine scalability and the recent lossless compression based scheme minimizes the embedding distortion. It also comprises of the future work for short cover sequence. The difference expansion scheme gives a higher embedding capacity with low distortion. The adaptive embedding strategies improve the reversible embedding performance by taking into account the properties of local image such as sorting and embedding-location selection. It perhaps can be integrated into many RDH methods to obtain an improved performance. Histogram shifting is an actively explored topic in RDH. For getting a performance enhancement, instead of using the spatial domain embedding, the transform domain embedding makes a large difference. PVO based methods give a good quality of stego-image by accurately predicting the values and then ordering the pixel values. The characteristics of different PVO methods: IPVO, PVO-K, PPVO and Wang's method were discussed. The PPVO gives a higher embedding size of 9 bits for a 4×4 block. The future work in PVO based RDH techniques include, improving the embedding size. Code division multiplexing gives high embedding capability with low level of distortion. The future work involves elimination of the errors caused in the decoding

stage due to malicious attacks. Interpolation technique gives a high image factor without compromising with the embedding size. Optimal weight based prediction achieves a good payload-distortion performance. The future work could explore a better performance by making the estimation errors close to zero, and combining this scheme with different data images. The buyer-seller protocol successfully resolves the conspiracy problem. The future work could include the exploration in elimination of the buyer's assistance to resolve the dispute in piracy.

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