# A Prediction-Based Adaptive Reversible Data Embedding Scheme

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***Abstract*—A reversible data embedding algorithm to adaptively hide a secret message is proposed. The embeddable location is determined by a variance threshold without a location map or overhead information. The proposed algorithm comprises three phases. In the preprocessing phase, the variance thresholds are generated to control the quantity of secret data bits and the image fidelity. In the embedding phase, each block composed of four cover pixels and is manipulated to overlap with blocks to determine a prediction error that arises from the difference between a cover pixel and the average value of its upper and left neighbors. Secret data then embedded in a cover pixel by adding them to the pixel prediction value plus the prediction error. In the extraction and recovering phase, the secret data are extracted in a manner similar to that in which they are embedded, and pixels can be restored to their original values. Experimental results show that the embedding capacity can be adjusted in the proposed scheme. Moreover, the embedding capacity exceeds that of other schemes and the image quality remains satisfactory.**

***Index Terms*—reversible data hiding, difference expansion, embedding capacity, image quality**

## I. INTRODUCTION

Reversible data hiding techniques conceal secret data into cover multimedia, yielding “stego multimedia.” When a user receives the stego multimedia, the private message can be extracted using an extraction procedure and the original multimedia can be totally restored by recovery procedure. In recent years, reversible information hiding techniques have been proposed [1-15] due to its widespread applications. They include difference expansion reversible information hiding, prediction-based reversible information hiding and histogram-based reversible information hiding.

In 2003, Tian proposed the difference expansion (DE) reversible information hiding technique [1]. However, some pixel pairs suffer from the overflow/underflow problem when data have been embedded. Accordingly, Tian’s scheme needs a location map to identify which pixel pair is embeddable. Consequently, the size of the location map is half that of the cover image and an efficient compression technique is required to compress the large amount of overhead information. If it was not this case, the pure payload, meaning the number of actual secret bits that can be carried by a cover image, would be small. The total pure payload that can be carried by the scheme of Tian is lower than 0.5 bit per pixel (bpp), which is quite limited. In 2004, Alatter proposed an integer transform method to enhance the hiding capacity of Tian’s scheme [2]. Alatter’s scheme enhanced the embedding capacity to 0.75 bpp but it does not satisfy the requirement of image distortion control. Subsequently, Kamstra *et al*. combined a wavelet technique and a sorting technique to control distortion [3]. In their scheme, the image quality was reasonably good at low hiding capacity. Kim *et al*. [4] and Hu *et al*. [5] proposed two enhanced methods to reduce the size of the location map and leave some space unoccupied by the overhead information to raise the hiding capacity. In 2004, Thodi *et al*. proposed a prediction-based reversible data hiding technique [6]. Thodi *et al*.’s scheme better exploits the correlation inherent in the neighborhood of a pixel and its capacity is several times larger than that of Tian’s scheme. However, their scheme is not effective enough to predict the pixels in the edge region, and requires a location map to help record the embeddable area. In 2009, Tseng and Hsieh proposed a novel prediction-based data hiding technique [7], which does not require a location map to help image restoration. Therefore, the performance of the scheme of Tseng and Hsieh in terms of image quality and hiding capacity is satisfactory.

To solve the overflow/underflow problem and enhance image quality, in 2006, Ni *et al*. proposed a reversible data hiding that uses the histogram technique [8]. This histogram-based scheme differs from above schemes that exploit the difference expansion technique or prediction


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technique. The scheme of Ni *et al*. firstly compiles original pixels to generate a pixel histogram. From that histogram, the most frequently appearing pixel, called the peak point, $p$, is denoted. Their scheme can find the pixel that never appear, called the zero point, $z$. The pixels whose ranges between $p+1$ and $z-1$ are increased by one. Finally, if the pixel equals to the peak point $p$ and secret message bit equals 1, the pixel is increased by 1; otherwise, if the pixel is equal to peak point $p$ and secret message bit equals 0, then the pixel is left unchanged. Accordingly, the scheme of Ni *et al*.'s scheme is very simple, and the stego-image quality is better than that obtained by the above technique. However, their hiding capacity is very low. Therefore, several scholars have devoted themselves to developing a lossless information hiding technique to increase the hiding capacity of histogram-based schemes [9, 10, 15].

In 2007, Jin *et al*. proposed a novel reversible data hiding technique [11], which first divides the original image into several blocks, each of size. The scheme of Jin *et al*. explores the differences between the embeddable pixels and their neighboring pixels to determine an appropriate threshold, which can be used to identify which block can carry data because it contains no saturated pixels. Although the scheme of Jin *et al*. yields satisfactory image quality, its hiding capacity is not that high, and must be enhanced. In the same year, Thodi *et al*. combined a histogram technique and a prediction technique to achieve lossless information hiding [12]. The image quality and hiding capacity of the scheme of Thodi *et al*. are better than those of other schemes. However, Hong *et al*. in 2009 pointed out that the scheme of Thodi *et al*. is too complicated [13]. Hong *et al*. simplified the prediction scheme by generating a set of hiding rules. The image quality obtained by the scheme of Hong *et al*. is acceptable. However, the scheme generates saturated pixels. To solve the overflow/underflow problem, Hong *et al*. adopted a great quantity of overhead information. Recently, Wu *et al*. proposed a reversible data hiding technique to increase hiding capacity [14]. The scheme calculates variance among neighboring pixels of each block and sets a threshold to determine a smooth block which can embed more secret data. However, the scheme of Wu *et al*. has overflow and underflow problems. Therefore, extra information must be recorded to recover the original image.

The proposed scheme employs the variance strategy, which solves the problem of the low capacity of Hong *et al*.'s scheme and overcomes Wu *et al*.'s overflow/underflow problems. This scheme employs a variance threshold to determine which image blocks can be used to carry secret data and which can not. When the variance threshold is determined by the proposed variance strategy, the number of embeddable blocks exceeds those of the scheme of Hong *et al*., which only allows secret data to be embedded into the specific pixel whose difference value between the cover pixel and the predictive pixel is 0 or minus 1. This paper is organized as follows. Section II presents the proposed scheme in detail. Section III presents experimental results. Section IV draws conclusions.

## II. PROPOSED SCHEME

Clearly, the capacity of a reversible data hiding scheme can be increased by eliminating the need for a location map to embed/extract the secret message. The location-map-free scheme provides more space than other in which to hide more secret data without reducing the embeddable capacity to carry overhead information. The scheme of Hong *et al*. can extract a hidden message and preserve the stego-image quality with an average PSNR of 48.6 dB. Although that requires no location map, it must still address the problem of pixel overflow/underflow by storing extra information to point out what the original pixels are and their locations which data are embedded. The scheme of Hong *et al*. can not increase embedded capacity because the number of embeddable regions is limited: it embeds only secret data in the block whose prediction error should be 0 or -1. Since the number of such blocks is not that large, the embedding capacity of the scheme of Hong *et al*. is pretty low. This investigation proposes a novel reversible data hiding scheme that is based on prediction technique. This scheme has neither a location map nor overhead information. Moreover, the proposed scheme is superior to that of Hong *et al*. in terms of embedding capacity, and maintains the high quality of the stego-image.

For an edge block, the perceptible variation among pixels makes the variances of that edge block are larger. For such blocks, the difference expansion-based data hiding scheme (or the DE-based scheme for short) is not very suitable because the difference of blocks increases greatly extended when a secret value is added, significantly changing the pixel values. Pixel modification may yield pixel values that fall outside of the boundary of the pixel level, indicating that pixels within a block with huge variance commonly suffer from the overflow/underflow problem when secret data are embedded. This fact motivates the determination of a variance threshold in a preprocessing phase. This threshold can be used to determine whether a block is non-embeddable or embeddable and also to control the image quality.

Subsection A will present the preprocessing phase the variance threshold is set. Subsection B introduces in detail, the secret data embedding phase. Subsection C presents the data extraction and image restoration phase. This subsection also presents the embedding capacity ratio.

### A. Preprocessing Phase

Preprocessing is to calculate the variances of each individual block, and one proper variance chosen as a threshold. The threshold is determined to avoid the overflow/underflow problem. After the embedding of secret data, this threshold controls the quality of the stego-image. No secret data are embedded into blocks with a larger variance to preserve the quality of the image without distortion, preventing the overflow/underflow problem.

| | | |
|---|---|---|
| $I(i-1, j-1)$ | $I(i-1, j)$ | $I(i-1, j+1)$ |
| $I(i, j-1)$ | $I(i, j)$ | $I(i, j+1)$ |

Block $B(i, j)$ by bold Block $B(i, j+1)$ by gray-color

Figure 1. Pixels of four-bit block

For convenience, the following notations are used. The cover image is denoted $I$ and has size $M \times N$, where $M$ is the image length and $N$ is the image width. $I(i, j)$ stands for a cover pixel in the $i$th row and the $j$th column, $0 \le i \le M-1$ and $0 \le j \le N-1$. $I'$ stands for the stego-image. $I$ and $I'$ are divided into overlapping blocks of $2 \times 2$ pixels. Let $B(i, j)$ denote a block that has four pixel values, $I(i, j)$, $I(i, j-1)$, $I(i-1, j)$ and $I(i-1, j-1)$ and these four are located at the bottom right, the bottom left, the top right-upper and the top left, respectively, as shown in Fig. 1. In Fig. 1, two overlapping blocks are also displayed. The variance of $B(i, j)$ is denoted by $Var(B(i, j))$. For simplicity, $a$, $b$ and $c$ are used in the names of three pixels, $I(i, j-1)$, $I(i-1, j)$ and $I(i-1, j-1)$, which are the neighbors of pixel $I(i, j)$ in block $B(i, j)$. For each block $B(i, j)$, a prediction value $\hat{x}$ will be calculated from $a$, $b$ and $c$ using (1). The difference between $I(i, j)$ and $\hat{x}$ is called a prediction error and denoted as $e$. $S$ denotes the secret message that is to be embedded and $S = \{s_1, s_2, ..., s_l\}$, where $l$ is the length of the secret message and $s \in [0, 1]$. After the preprocessing phase, a variance threshold $T$ is determined.

The following preprocessing steps are implemented.

*Step 1*: Starting with $i = 1$ and $j = 1$, calculate the prediction value $\hat{x}$ using (1), where $a = I(i, j-1)$, $b = I(i-1, j)$ and $c = I(i-1, j-1)$. Furthermore, set $T$ to be $\infty$.

*Step 2*: Obtain the prediction error $e$ using the function $e = I(i, j) - \hat{x}$.

*Step 3*: Calculate the expansion of $I(i, j)$ using the functions $I(i, j) = \hat{x} + 2 \times e$ (expansion and embedding of 0) and $I(i, j) = \hat{x} + 1 + 2 \times e$ (expansion and embedding of 1).

*Step 4*: Check whether $I(i, j)$ (regardless of whether 0 or 1 is embedded) is more than 255 or less than 0, recode the variance of $B(i, j)$, calculated from $a$, $b$ and $c$ using the function $Var(B(i, j)) = [(a-v)^2 + (b-v)^2 + (c-v)^2]/3$, where $v = (a+b+c)/3$. If the variance $Var(B(i, j))$ is less than $T$, then the value of $T$ is replaced with the new variance value.

*Step 5*: Repeat Step 1 to Step 4 in raster-scan order from $i = 1$ and $j = 1$ to $i = M-1$ and $j = N-1$ to get feasible $T$ is the threshold that will be used in the embedding phase.

After $T$ is determined, the overflow and underflow problems are considered. Therefore, the overflow/underflow problem does not arise when the secret data are embedded, and no location map is required.

### *B. Embedding Phase*

The secret data $s_k$, where $k$ is the number of secret data in sequence. The stego-image is $I'$, and $I'(i, j)$ represents pixel of $I'$ with coordinates ($i$, $j$). Embedding is performed as follow.

*Step 1*: $I'(i, j)$ equals $I(i, j)$ when $i = 0$ or $j = 0$.

*Step 2*: Starting with $i = 1$ and $j = 1$, calculate the average $v$ using the function $v = (a+b+c)/3$, where $a = I(i, j-1)$, $b = I(i-1, j)$ and $c = I(i-1, j-1)$.

*Step 3*: Calculate the variance $Var(B(i, j)) = [(a-v)^2 + (b-v)^2 + (c-v)^2]/3$ from $a$, $b$ and $c$. Check whether $Var(B(i, j)) < T$, calculate the prediction value $\hat{x}$ using (1). Otherwise, $I'(i, j)$ equals $I(i, j)$ and go to Step 6.

*Step 4*: Compute the prediction error $e$ between $I(i, j)$ and prediction value $\hat{x}$, $e = I(i, j) - \hat{x}$.

*Step 5*: Embed the secret data $s_k$ in pixel $I'(i, j)$ in the stego-image with the function $I'(i, j) = \hat{x} + s_k + 2 \times e$.

*Step 6*: Repeat Step 1 to Step 5 in raster-scan order from $i = 1$ and $j = 1$ to $i = M-1$ and $j = N-1$.

*Step 7*: Transfer the secret data are embedded in the stego-image $I'$ and the variance threshold value $T$ to the receiver.

After the embedding procedure is conducted, the secret data are embedded into a stego-image without any additional information or the need to generate a location map.

In the above embedding phase, one secret bit is carried by one cover pixel, but not the cover pixels in the first row and column of image. Therefore, the pixel values in the first row or first column of the original image will remain unchanged and no secret data will embedded in term, because they are used for image recovery. Accordingly, the maximum embedding capacity of the proposed scheme will not exceed $(M-1) \times (N-1)$ bits. More than one variance thresholds are used to increase embedding capacity. Let $T_{one}$ be a variance threshold that is used to determine whether a cover pixel can carry one secret bit. $T_{two}$ is another variance threshold that is less than $T_{one}$: $T_{two} < T_{one}$. $T_{two}$ is used to determine which cover pixel can carry two secret bits at a time. To enhance the embedding capacity, the proposed scheme firstly calculates the variance $Var(B(i, j))$ of a given overlapping block $B(i, j)$. Fig. 2 reveals that if the variance $Var(B(i, j))$ is less than $T_{two}$, then two secret bits are embedded into the cover pixel $I(i, j)$; if the variance $Var(B(i, j))$ is greater than $T_{two}$ and is less than $T_{one}$, then a secret bit is embedded into cover pixel $I(i, j)$; otherwise, cover pixel $I(i, j)$ remains unchanged, because no data can be embedded. Suppose each pixel in a cover image can carry two secret bits at a time; the embedding capacity is then increased $2\times(M-1)\times(N-1)$ bits. However, the variance threshold $T_{two}$ does not exist in every image.

### C. Extraction and Recovering Phase

This subsection shows the extraction and recovering part. After the stego-image $I'$ and the variance threshold $T$ have been received, embedded location can be calculated with $T$ without the need for any information. The receiver can easily extract the secret data and recover the original image. The extraction and recovering algorithm is as follows.

*Step 1*: Restore the original pixel $I(i, j)$ by the stego pixel $I'(i, j)$, when $i=0$ or $j=0$.

*Step 2*: Starting with $i=1$ and $j=1$, calculate the average value $v$ using the function $v=(a+b+c)/3$, where $a=I'(i, j-1)$, $b=I'(i-1, j)$ and $c=I'(i-1, j-1)$.

*Step 3*: Calculate the variance $Var(B'(i, j))=[(a-v)^2+(b-v)^2+(c-v)^2]/3$ from $a$, $b$ and $c$. Check whether $Var(B'(i, j))<T$, calculate the prediction value $\hat{x}$ using (1), as shown in Subsection B. Otherwise, restore pixel $I(i, j)$ by the stego pixel $I'(i, j)$, and go to Step 7.

*Step 4*: Calculate the prediction error $e$ between $I'(i, j)$ and the prediction value $\hat{x}$, where $e=I'(i, j)-\hat{x}$.

*Step 5*: Extract the secret data $s_k$ from the prediction error $e$ using the function $s_k = e \bmod(2)$.

*Step 6*: Recover the pixel $I(i, j)$ using the function $I(i, j)=\hat{x}+(e-s_k)/2$.

*Step 7*: Repeat Step 2 to Step 6 with raster-scanning order from $i=1$ and $j=1$ to $i=M-1$ and $j=N-1$.

*Step 8*: Image $I$ is restored into its original image and the secret data have been extracted.


Figure 2. Range of variance between $T_{two}$ and $T_{one}$

## III. EXPERIMENTAL RESULTS

This section summarizes the experimental results related to the proposed scheme and compares that scheme with previous reversible data hiding schemes. In the experiments, eight standard images are used as test images, as shown in Fig. 3. They are grayscale images and have size 512×512. Image quality is commonly evaluated by measuring the peak signal-to-noise ratio (PSNR), which is the difference ratio between original image and stego-image. Generally, determining the difference between cover image and the stego-image by naked eye is difficult when the PSNR of the image exceeds 30 dB. Let $I(i, j)$ and $I'(i, j)$ be the pixel values of an original image of size $M$ by $N$ and the corresponding stego-image, respectively. The PSNR is defined as

$$\text{PSNR} = 10\log_{10}\frac{255^2}{\text{MSE}}, \text{ where}$$

$$\text{MSE} = \frac{1}{M\times N}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}(I(i, j)-I'(i, j))^2.$$

Fig. 4 compare of the image quality and embedding capacity achieved using the proposed scheme and other reversible schemes for eight test images, where "bpp" means the bits per-pixel. From Figs. 4(a)-(f), the proposed scheme yields quite stable image distortion which means while the embedding rate is increasing, the proposed scheme maintains a stable degree of image quality without causing a great change. However, for the other schemes of interest, the image distortion gets a great descent while the embedding capacity arises. With a capacity ratio more than 0.47 bpp, the proposed scheme has better performance and preserves pleasing visual quality.

Table I presents the result concerning PSNR and capacity of the first embedded phase. A binary random number string is used as the secret data to compare the embedded results with the other schemes. In Table I, "EC" means the embedded capacity and the symbol "—" means that the secret message cannot be embedded. Table I shows that the average embedded capacity of proposed scheme is 2.6 times that of the others schemes. The proposed scheme indeed lifts the embedding capacity more than other schemes do, the stego-image cannot be distinguished from the original by human vision, the proposed scheme has a lower PSNR although. From Table I, the capacity of the scheme of Ni *et al.* is too low, even though PSNR is high. The experimental results concerning the proposed scheme show that the worst cases of low capacity in terms of the embedded bits are associated with the Pepper and Baboon images. We have a few observations to make on the occurrence of both images. The Baboon image is complex, whereas the

Pepper image is smooth with limited grayscale pixels. The proposed variance strategy cannot easily determine a feasible threshold value for both images to carry secret bits without causing the overflow/underflow problem. Therefore, pixel shrinking is an artifice to overcome this problem of low embedding capacity. Extreme pixel values (also called saturated pixels) may invoke overflow or underflow problem after the secret data are embedded. The low embedding capacity that is associated with such images as Baboon or Pepper is caused by extreme pixels whose values are close to 0 or 255. This property requires a small variance threshold to be chosen to avoid the underflow/overflow problem after secret data are embedded. However, a small variance threshold results in a low embedding capacity. In the proposed scheme, to increase the embedding capacity, the shrinkage of the left end of the pixel histogram is exploited by increasing $\delta$. Assume $\delta = 5$, such that the pixel values of smaller than 5 will be treated as five. This invokes some extra overhead. The overhead information will be treated as part of the secret message and be embedded into the cover image. Table II shows the adjusted embedding capacity, the increased embedding capacity and the amount of extra recorded information. In Table II, the values of the shrinkage parameter $\delta$ are less than 20. Accordingly, 23 bits are required to record each extreme pixel; 18 bits are required to record the coordinates of the pixel and 5 bits are required to record the original pixel value.

(a) Lena

(b) Airplane

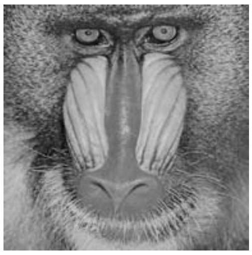
(c) Gold

(d) Zelda

(e) Girl

(f) Boat

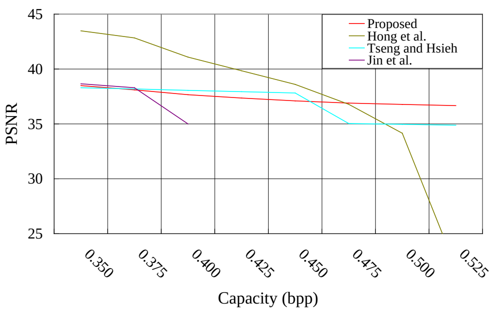
(g) Pepper



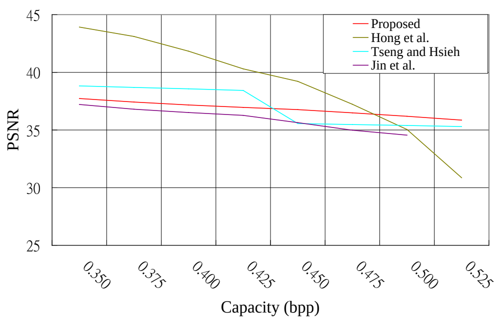
(h) Baboon

Figure 3. Test images

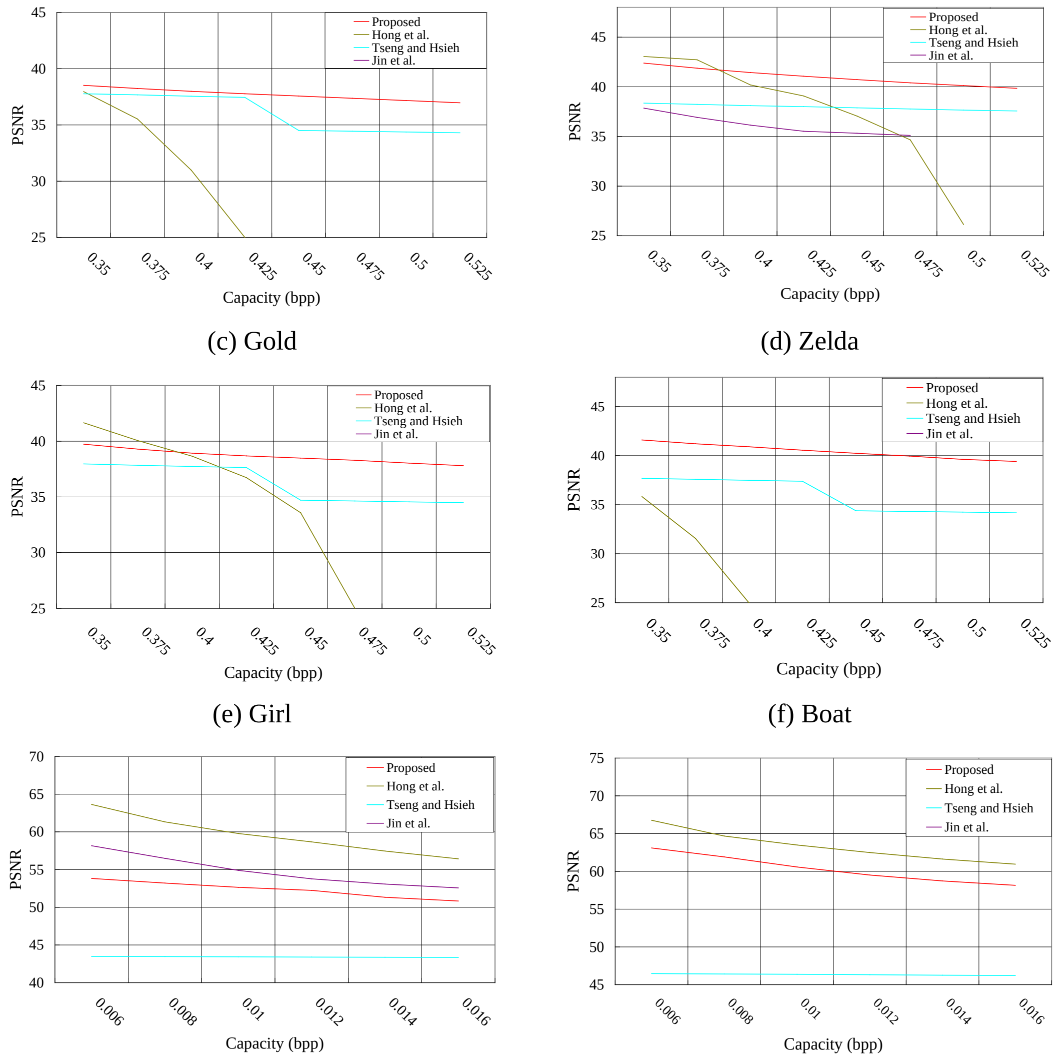
In the proposed scheme, more than one variance threshold is used to increase embedding capacity. Two variance thresholds $T_{one}$ and $T_{two}$, where $T_{two} < T_{one}$, are determined and applied to ensure that a cover pixel carries one secret bit or two secret bits at once. Suppose that each pixel in a cover image can carry two secret bits at a time; the embedding capacity is lift to $2 \times (M-1) \times (N-1)$ bits. However, not every image can meet the condition that a variance threshold $T_{two}$ can exist such that two secret bits can be hidden at a time. Table III shows the results of embedding two secret bits. However, only four images Lena, Airplane, Gold and Zelda have a variance threshold $T_{two}$ to embed two secret bits at a time.




(a) Lena




(b) Airplane




(c) Gold (d) Zelda

(e) Girl (f) Boat

(g) Baboon (h) Pepper

Figure 4. Performance comparison of results obtained using proposed scheme and with other reversible schemes using various test images. (a) Lena; (b) Airplane; (c) Gold; (d) Zelda; (e)Girl; (f) Boat; (g) Baboon; (h) Pepper.

Table I.
Comparison of the proposed scheme with those of Ni *et al.*'s scheme, Jin *et al.*'s scheme, Tseng and Hsieh's scheme and Hong *et al.*'s scheme in terms of stego-image quality as well as embedding capacity

| Image | Ni *et al.*'s scheme | | Jin *et al.*'s scheme | | Tseng and Hsieh's scheme | | Hong *et al.*'s scheme | | Proposed scheme | |
|---|---|---|---|---|---|---|---|---|---|---|
| | PSNR (dB) | EC (bits) | PSNR (dB) | EC (bits) | PSNR (dB) | EC (bits) | PSNR (dB) | EC (bits) | PSNR (dB) | EC (bits) |
| Lena | 53.85 | 2,908 | 41.86 | 62,659 | 42.14 | 69,698 | 48.75 | 67,562 | 35.35 | 242,311 |
| Airplane | 53.24 | 9,002 | 39.29 | 63,889 | 42.64 | 68,901 | 48.78 | 71,275 | 33.36 | 256,378 |
| Gold | 51.06 | 2,683 | 38.27 | 65,025 | 41.89 | 67,268 | 48.59 | 50,752 | 35.57 | 212,718 |
| Zelda | 53.32 | 2,565 | 43.46 | 65,025 | 41.77 | 79,568 | 48.71 | 64,766 | 37.67 | 253,344 |
| Girl | 55.22 | 3,739 | 40.65 | 65,025 | 42.01 | 67,731 | 48.68 | 60,263 | 35.51 | 255,675 |
| Boat | 53.13 | 5,614 | 46.08 | 43,822 | 41.87 | 69,817 | 48.57 | 48,449 | 38.03 | 178,762 |
| Baboon | 50.32 | 2,936 | 49.70 | 17,070 | 41.84 | 39,133 | 48.37 | 25,893 | 50.83 | 4,241 |
| Pepper | 50.05 | 2,905 | — | — | 42.01 | 78,095 | 48.66 | 58,292 | 57.94 | 4,503 |
| Avg. | 52.52 | 4,044 | 42.76 | 54,645 | 42.02 | 67,526 | 48.64 | 55,907 | 40.53 | 175,992 |

Table II.
Experimental results of adjusted cover image with first embedding phase

| Image | Original EC (bits) | After adjusted EC (bits) | $\delta$ value | Recorded pixel numbers | Extra record data (bits) | Pure payload (bits) | Increased EC (bits) | PSNR (dB) |
|---|---|---|---|---|---|---|---|---|
| Baboon | 4,241 | 95,747 | 17 | 186 | 4,278 | 91,469 | 87,228 | 34.18 |
| | | 95,760 | 18 | 237 | 5,451 | 90,309 | 86,068 | 34.18 |
| | | 95,775 | 19 | 292 | 6,716 | 89,059 | 84,818 | 34.18 |
| Pepper | 4,503 | 132,609 | 9 | 2,828 | 65,044 | 67,565 | 63,062 | 41.65 |
| | | 132,837 | 10 | 3,769 | 86,687 | 46,150 | 41,647 | 41.57 |
| | | 133,044 | 11 | 4,746 | 109,158 | 23,886 | 19,383 | 41.46 |

Table III.
Experimental results with two-bit data embedded

| Image | One-bit secret data | | Two-bit secret data | | Increased two-bit capacity (bits) | Increased ratio (%) | Decreased PSNR ratio (%) |
|---|---|---|---|---|---|---|---|
| | PSNR (dB) | Capacity (bits) | PSNR (dB) | Capacity (bits) | | | |
| Lena | 35.35 | 242,311 | 35.17 | 248,056 | 5,745 | 2.37 | 0.51 |
| Airplane | 33.36 | 256,378 | 33.12 | 271,646 | 15,268 | 5.96 | 0.72 |
| Gold | 35.39 | 212,718 | 35.06 | 219,911 | 7,193 | 3.38 | 0.93 |
| Zelda | 37.30 | 253,344 | 31.82 | 408,450 | 155,106 | 61.22 | 14.69 |
| Avg. | 35.35 | 241,188 | 33.79 | 287,016 | 45,828 | 18.23 | 4.21 |

## IV. CONCLUSIONS

A simple reversible data hiding scheme based on Hong, *et al.*'s prediction method [13] by using a feasible variance that does not depend on a location map is proposed to restore stego-image back to their original form. A feasible variance threshold is present to prevent the overflow/underflow problem. When an image block with pixels has large variance, that block is not adopted to embed secret data. The proposed scheme not only successfully increasing the embedding capacity but also reducing the image distortion because secret data are hidden in smooth blocks. The scheme benefits from the fact that requires no location map because it uses the variance threshold to determine which blocks can be used to carry data. The experimental results show that the embedding capacity of proposed scheme is two to four times than those of other schemes, and that the proposed scheme still maintains high visual quality. Furthermore, without the need for a location map, the embedding and extracting procedures are simple and efficient.

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