Steganography of Data Embedding in Multimedia Images Using Interpolation and Histogram Shifting

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Abstract—**In this paper, we propose a data hiding scheme with high capacity in steganography. First of all, we improve the data hiding technique based one neighbor mean interpolation for increasing the image quality of a stego-image without losing any capacity. A stego-image is derived from a cover image which has embedded the secret data. A cover image is generated from an original image by using interpolating method. Secondly, we apply histogram shifting technique to embed more secret data. The difference tables between the cover image and the stego-image except pivot pixels are calculated to make a histogram at first. Then, we modify the histogram data in an embedding procedure, and construct a new stego-image with two levels data hiding method. Our scheme can not only provide better image quality of the stego-image, but also have a very high capacity compared with other data hiding schemes based on interpolation.**

Keywords- Data hiding; Steganography; Interpolation; Histogram shifting.

I. INTRODUCTION

In digital images, we embed secret data into pre-selected meaningful images called a cover image, and people are unable to visually detect any different. There are many schemes have been developed to perform efficient data hiding [1], [2], [3]. Chang et al. [4] proposed a reversible data hiding scheme based on side match vector quantization (SMVQ for short) for digital compressed images. It has two steps: extract the secret data and recover the original SMVQ compression codes. In their schemes, the receiver could not only get secret data but also recover the original image when receiving the stego-image. Later on, in 2008, Ni et al. [5] authored a robust lossless data hiding technique which could defend compression or other incidental alternation applied to the stego-image. According to their experimental results, it has the advantages of the high visual quality of stego-images, the data embedding capacity, and the ability to resist compression such as JPEG2000. In addition, Xuan et al. [6] applied histogram shifting technique to hide secret data in integer wavelets. Compared with other existing data hiding schemes developed in spatial domain, their scheme has larger embedding capacity under the same image quality.

In 2009, Jung and Yoo [7] proposed a data hiding scheme base on image interpolation. Initially, they selected a meaningful image called an input image. The cover image was generated through the input image by shrinking to half size and restoring to original size by using a special interpolation method named Neighbor Mean Interpolation (NMI for short). Jung-Yoo-scheme showed a good way in data hiding by interpolation, but we found a better way to improve the image quality and capacity. The details will be described as follows.

This paper proposes a data hiding scheme based on image interpolation and histogram shifting techniques. In the first stage, we enhance the image quality by comparing with the corresponding input image when generating the first stego-image. In the second stage, two histogram shifting operations are applied to embed more secret data. Both of these two stages are able to increase image quality and enlarge capacity comparable to the scheme suggested by the scheme in [7].

The remainder of this paper is organized as follows. In Section 2, we give the background to this proposal by mentioning related works such as interpolation and histogram shifting. Our proposed scheme is presented in Section 3. Experiment results are presented and discussed in Section 4. Finally, our conclusions are offered in Section 5.

II. RELATED WORKS

This section presents the review of some common interpolation methods, Jung-Yoo-Scheme, and the original data hiding technique based on histogram shifting.

A. Common interpolation methods

The interpolation is a method used to construct new data points within the range of a discrete set of given data points in numerical analysis. In digital image processing, interpolation is a good solution when we need to scale or resample an image. The theorems of image interpolations are described and analyzed in [9, 10]. Common image interpolation methods such as nearest neighbor interpolation (*NNI* for short), bilinear interpolation (*BI* for short), and Bicubic interpolation (*BCI* for short) are presented as follows.

(1) Nearest neighbor interpolation

NNI, also called zero order interpolation, is the method that directly assigned the closest reference pixel value to the new prediction pixel value. An example of applying *NNI* to scale up an image is shown in Figure 1.

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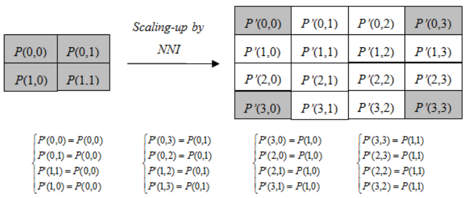

Figure 1. Scaling-up by *NNI*

(2) Bilinear interpolation

BI which is also called *first order interpolation* is the method that applies three times linear interpolation and refers four adjacent pixel values to predict new pixel values. Given that we have four referencing neighboring pixels including an original pixel $P(0,0)$ in a $n \times n$ block, the method of how to predict a new pixel value $P(a,b)$ by *BI* is illustrated in Fig. 2, where a and b represent the vertical and horizontal distances to original pixel and $0 < a,b < n$.

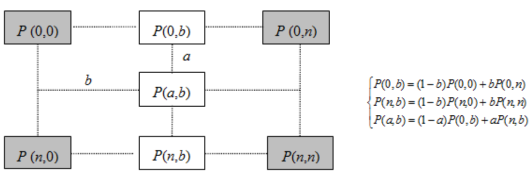

Figure 2. Predict a new pixel by *BI*

(3) Bicubic interpolation

BCI is similar to *BI* but add the neighbor referencing neighboring pixels to sixteen pixels. It contains a kernel function k which is shown in Eq. (1). For computing original pixel P to target pixel P', the formula is described as Eq. (2) where a, b are the vertical and horizontal distances to corresponding neighboring pixels.

$$k(x) = \begin{cases} 1 - 2|x|^2 + |x|^3, & 0 \le |x| \le 1 \\ 4 - 8|x| + 5|x|^2 - |x|^3 & 1 \le |x| \le 2 \\ 0 & otherwise \end{cases} \tag{1}$$

$$P'_{i,j} = \sum_{p=-1}^{2} \sum_{q=-1}^{2} P_{i+p,j+q} k(q-b) k(a-p) \tag{2}$$

B. Jung-Yoo-Scheme

Jung and Yoo proposed a data hiding scheme based on interpolation method in 2009 [7]. They select a meaningful image as an input image at first, and then shrink it to half size to be an original image. The neighbor mean interpolation (*NMI* for short) which first proposed by Jung and Yoo is used to generate a cover image from an original image.

In embedding phase of Jung-Yoo-scheme, the secret data are embedded into the differences which calculated by a pivot pixel value and the remainder pixel values in a block with size of 2×2. The differences d are computed by the pivot pixel value being subtracting the other pixel values in one block respectively, and the numbers n are represented how many secret bits embedded in a pixel value. The secret bits s are bit sequences including n bits which are transformed to decimal numbers and directly added to corresponding pixel values in the cover image. On the other hand, the extraction procedure is described as the inverse steps of embedding phase. At first, generate the cover image by *NMI* and the pivot pixel values in the stego-image, and then produce s by restoring d and n. The secret data comprise by s in sequence.

C. A data hiding technique based on histogram shifting

Ni et al. proposed a reversible data hiding technique based on histogram in 2006 [8]. The histogram is generated by the amounts of each selected image's pixel values. The peak and minimum/zero point represent the max and fewest amounts of pixel values of the histogram needed to enter in extraction phase. In order to minimize the number of pixel affected, minimum/zero point must choose the point which is closest to peak point. A target block is the interval between peak point pixel value and minimum/zero point pixel value from the histogram.

III. Our Proposed Scheme

In this section, we propose a data hiding scheme with high capacity in three procedures. At first, we improve Jung-Yoo-scheme in embedding procedure to increase image quality in Section 3.A. Next, the proposed embedding procedure using histogram shifting is illustrated in Section 3.B. Finally, extraction of all secret data is described in Section 3.C.

A. Improvement of Jung-Yoo-scheme in embedding procedure

In Jung-You-scheme, the secret data is embedded to the differences of a pivot pixel value and remainder pixel values in a 2×2 pixel block, and the lengths of embedded secret data are the log values of the differences. The embedding procedure uses only addition without referring to the input image pixel values, and it leads to reduce the image quality between input image and stego-image. We improve the defect by comparing input image pixel values in embedding procedure. Suppose the middle stego-image MS is generated by the cover image C after embedding secret data sd, and the cover image with the size of $2m \times 2m$ is constructed from the corresponding input image I. For a pixel $MS(i, j)$, the modified embedding rule is shown in Eq. (3) below.

$$MS(i,j) = \begin{cases} C(i,j) - sd, & if \;\; I(i,j) < C(i,j) \\ C(i,j) + sd, & if \;\; I(i,j) \ge C(i,j) \end{cases} \tag{3}$$

B. Proposed embedding procedure using histogram shifting

Based on the study in the literature [8], an embedding procedure using histogram shifting is applied in our scheme. After MS is generated, we calculate the difference table D by Eq. (4).

$$D(i,j) = C(i,j) - MS(i,j) \tag{4}$$

Because of the average operation in interpolation, the values of $D(i, j)$ are located between −128 and 128. We generate the amount of values histogram $H_D(k)$, k=−128, −127,…,0, 1,…,128, by D except the values of corresponding positions of pivot pixels, and find the max peak point M_P and the second peak point S_P. The algorithm to produce the paired zero points M_z and S_z are shown as follows:

Zero Point Producing Algorithm

Input: M_p, S_p
Output: M_z, S_z
If $M_p > S_p$
  For k = 127 to M_p + 1
    If $H_D(k)$!= 0
      $M_z = k + 1$
    End If
  End For
  For k = -127 to S_p - 1
  If $H_D(k)$!= 0
    $S_z = k - 1$
  End If
  End For
Else
  For k = -127 to M_p - 1
    If $H_D(k)$!= 0
      $M_z = k - 1$
    End If
  End For
  For k = 127 to S_p + 1
    If $H_D(k)$!= 0
      $S_z = k + 1$
    End If
  End For
End If

Since M_P, S_P, M_z, and S_z have been generated, we defined the H_{Ds} and H_{De} which mean a histogram after shifting process and a shifted-histogram after embedding secret data respectively. Consider that sb_d stands for the dth secret bit in all embedding secret bits, the proposed embedding procedure by histogram shifting is given as follows:

Embedding Algorithm Using Histogram Shifting

Input: M_p, S_p, M_z, S_z,, sb
Output: H_{De}
If $M_p > S_p$
  Generate H_{Ds} by shifting all values between M_p +1 and M_z -1 to the right for 1 unit and all values between S_P -1 and S_z +1 to the left for 1 unit.
Else
  Generate H_{Ds} by shifting all values between M_p -1 and M_z +1 to the left for 1 unit and all values between S_P +1 and S_z -1 to the right for 1 unit.
End If
For each value V_i(i = 1, 2, …, $3m^2$) in H_{Ds}
  If $M_p > S_p$
    If $V_i = M_p$ and $sb_d = 1$
      $V_i = M_p + 1$
      $d = d + 1$
    ElseIf $V_i = M_p$ and $sb_d = 0$
      $d = d + 1$
    ElseIf $V_i = M_s$ and $sb_d = 1$
      $V_i = M_s - 1$
      $d = d + 1$
    ElseIf $V_i = M_s$ and $sb_d = 0$
      $d = d + 1$
    End If
  Else
    If $V_i = M_p$ and $sb_d = 1$
      $V_i = M_p - 1$
      $d = d + 1$
    ElseIf $V_i = M_p$ and $sb_d = 0$
      $d = d + 1$
    ElseIf $V_i = M_s$ and $sb_d = 1$
      $V_i = M_s + 1$
      $d = d + 1$
    ElseIf $V_i = M_s$ and $sb_d = 0$
      $d = d + 1$
    End If
  End If
End For
Return H_{De} by calculating the amount of values V

After H_{De} have been produced, we renovate D by referencing to H_{De} to generate the new difference table ND. The stego-image S is constructed by Eq. (5).

$$S(i, j) = C(i, j) - ND(i, j) \tag{5}$$

C. The extraction procedure

In this sub-section, the extraction procedure of our scheme is presented. It can be describe as inverse processes of embedding procedure between a stego-image and a cover image. The proposed ***Extraction Algorithm Using Histogram Shifting*** (***EAUHS*** for short) is also given below. We describe whole extraction procedure step by step as follows:

Input: stego-image S, M_p, S_p, M_z, S_z
Output: secret data sd, secret bits sb
Step 1: Restore the cover image C using pivot pixel values of S and interpolating method.
Step 2: Calculate the difference table D by Eq. (6).

$$D(i, j) = C(i, j) - S(i, j) \tag{6}$$

Step 3: Generate the amount values histogram H_D by D except the values of corresponding positions of pivot pixels.
Step 4: Apply ***EAUHS*** to produce sb and the histogram H_o modified from H_D by inputting the parameters M_p, S_p, M_z, and S_z which originated from the embedding procedure.
Step 5: Construct the original difference table D_o which is exactly the same as ND (mentioned in Section 3.2) by referencing to D and H_o.
Step 6: Restore the middle stego-image MS by Eq. (7).

$$MS(i, j) = C(i, j) - D_0(i, j) \tag{7}$$

Step 7: Extract secret data sd by Eq. (8).

$$sd = | C(i, j) - MS(i, j)| \tag{8}$$

Extraction Algorithm Using Histogram Shifting

Input: H_D, M_p, S_p, M_z, S_z
Output: H_o, secret bits sb
If $M_p > S_p$
  For each value V_i(i = 1, 2, …, $3m^2$) in H_D
    If $V_i = M_p$
      $sb_d = 0$
      $d = d + 1$
    ElseIf $V_i = M_p + 1$
      $sb_d = 1$
      $d = d + 1$
      $V_i = V_i - 1$
    ElseIf $V_i = M_s$
      $sb_d = 0$
      $d = d + 1$
    ElseIf $V_i = M_s - 1$
      $sb_d = 1$
      $d = d + 1$
      $V_i = V_i + 1$
    End If
    If $V_i > M_p$ +1 and $V_i \leq M_z$
      $V_i = V_i - 1$
    Elsef $V_i < S_P$ -1 and $V_i \geq S_z$
      $V_i = V_i + 1$
  End for
Else
  For each value V_i(i = 1, 2, …, $3m^2$) in H_D
    If $V_i = M_p$
      $sb_d = 0$
      $d = d + 1$
    ElseIf $V_i = M_p - 1$
      $sb_d = 1$
      $d = d + 1$
      $V_i = V_i + 1$
    ElseIf $V_i = M_s$
      $sb_d = 0$

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        d = d + 1
      ElseIf V_i = M_s + 1
        sb_d = 1
        d = d + 1
        V_i = V_i - 1
    End If
    If V_i < M_p -1 and V_i ≥ M_z
        V_i = V_i + 1
    ElseIf V_i > S_P +1 and V_i ≤ S_z
        V_i = V_i - 1
  End for
End If
Return sb and H_o calculated from the amount of values V
```

IV. Experimental Results

In this section, capacity and image quality are presented and compare with Jung-Yoo-scheme (2009) via the observations of experiments for input images, Family, Lena, Toys, Peppers, Zelda, and Sailboat. The six input images are all 8-bit grayscale images with size of 512×512. Secret data and bits are randomly generated and composed of bits "0" and "1". The peak signal-to-noise ratio (PSNR) is used to measure the image quality of input image, middle stego-image, and stego-image.

Table 1 shows the comparison on PSNR of middle stego-image and stego image with Jung-Yoo-scheme. According to the experimental results, our proposed embedding procedure has better image quality rather that Jung-Yoo-scheme. Both stages in our embedding procedure are able to enhance image quality. The improved effect in histogram shifting embedding stage comes from the feature of difference table. After improved embedding stage, most of pixel values of middle stego-image will be located between cover image and input image. When we shift histogram to both sides, it leads the pixel values closer to input image.

Table 2 shows the enhancement of capacity by proposed embedding scheme, and most of the capacity increases more than 1.5 times. Figure 3 displays the change of histogram of Pepper's difference table after embedding secret bits. We can observe that the difference values highly concentrate on the peak point that represents a high capacity in embedding stage by histogram shifting. On the other hand, the more difference values concentrate on the peak point, the fewer amounts of values which will be shifted in embedding stage. It results in the effect that increases image quality in histogram shifting embedding stage is not obvious.

V. Conclusions

In this paper, we have proposed a data hiding scheme with high capacity and good image quality. In our proposed scheme, we improve the image quality by referencing the input image at first, and then increase the embedding capacity by using modified histogram shifting algorithm. The experimental results exhibit that the PSNR and payload are higher than the previous works. It represents that our scheme can provide better image protection and more data hiding capacity with the same size of cover and stego images.

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References

[1] R.Z. Wang, C.F. Lin, and J.C. Lin, "Hiding data in images by optimal moderately-significant-bit replacement," *Electronics Letters*, vol. 36, no. 25, pp. 2069–2070, 2000.

[2] C.C. Thien and J.C. Lin, "A simple and high-hiding capacity method for hiding digit-by-digit data in images based on modulus function," *Pattern Recognition*, vol. 36, no. 12, pp. 2875–2881, 2003.

[3] C.H. Tzeng, Z.F. Yang, and W.H. Tsai, "Adaptive data hiding in palette images by color ordering and mapping with security protection," *IEEE Transactions on Communications*, vol. 52, no. 5, pp. 791–800, 2004.

[4] C.C. Chang, W.L. Tai, and C.C. Lin, "A reversible data hiding scheme based on side match vector quantization," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 16, no. 10, pp. 1301–1308, 2006.

[5] Z. Ni, Y.Q. Shi, N. Ansari, W. Su, Q. Sun, and X. Lin, "Robust Lossless Image Data Hiding Designed for Semi-Fragile Image Authentication," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 18, no. 4, pp. 497–509, 2008.

[6] G. Xuan, Q. Yao, C. Yang, J. Gao, P. Chai, Y. Q. Shi, and Z. Ni, "Lossless data hiding using histogram shifting method based on integer wavelets," in *Proceedings of the 5th international conference on Digital Watermarking*, Berlin, Heidelberg, 2006, pp. 323–332.

[7] K.H. Jung and K.Y. Yoo, "Data hiding method using image interpolation," *Computer Standards & Interfaces*, vol. 31, no. 2, pp. 465–470, 2009.

[8] Z. Ni, Y.Q. Shi, N. Ansari, and W. Su, "Reversible data hiding," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 16, no. 3, pp. 354–362, 2006.

TABLE I. PSNR comparison with Jung-Yoo-scheme.

Input Image	Jung and Yoo's	Improved embedding	After histogram shifting embedding
Family	32.55	34.39	34.48
Lena	31.88	33.57	33.68
Toys	28.81	30.09	30.19
Peppers	30.47	31.65	31.77
Zelda	34.25	35.11	35.11
Sailboat	28.09	29.47	29.62

TABLE II. Capacity comparisons with Jung-Yoo-scheme.

Scheme / Input image	*Jung and Yoo's*		*Proposed*	
	Capacity (bits)	Payload (bpp)	Capacity (bits)	Payload (bpp)
Family	238829	0.91	375039	1.43
Lena	185567	0.71	334389	1.28
Toys	164753	0.63	321168	1.23
Peppers	182603	0.70	332152	1.27
Zelda	147981	0.56	307579	1.17
Sailboat	257876	0.98	388056	1.48

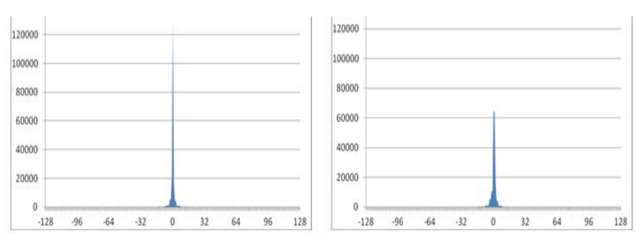

Figure 3. The histogram of Peppers' difference table.