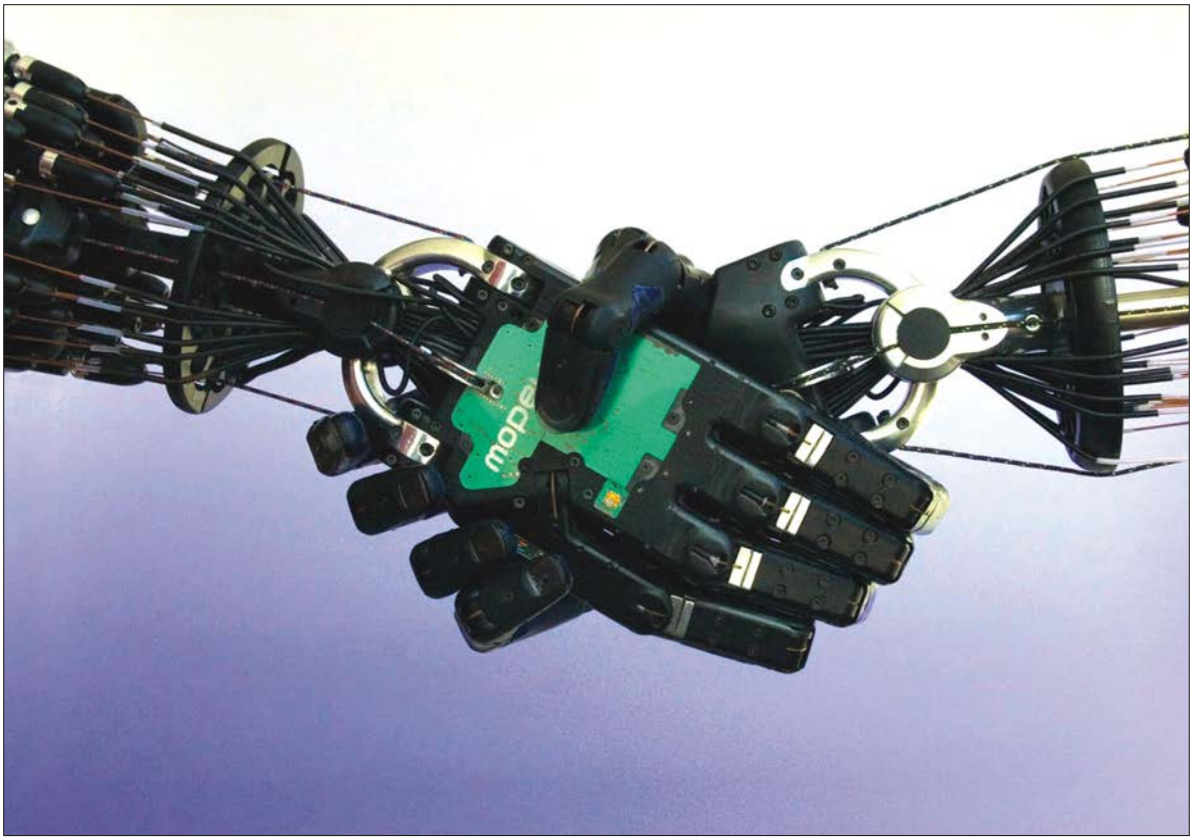

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Research Article

Reversible Secret Data Hiding Based on Adjacency Pixel Difference

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Abstract

Background: There have been discussed several data hiding techniques in an image which can embed the data in secret manner. However, after retrieving the secret data from an image, the original cover image information is not possible to be reconstructed. It is an important issue to have a lossless data hiding scheme which can reconstruct the original cover image without any loss after extracting the secret data. **Materials and Methods:** In this study a novel idea is introduced for lossless data hiding using adjacency pixel difference. **Results:** Here histogram is drawn for the pixel difference and secret bits are embedded only in the peak point of the histogram and tested on five gray scale cover images. **Conclusion:** In this method good amount of secret data can be embedded with high PSNR value.

Key words: Information security, lossless data hiding, reversible data hiding, histogram modification, histogram shifting

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Invertible data secreting is a highly protected technology to implant clandestine data into host picture indiscernibly and enable the host picture to be regained without any fault upon extraction of the implanted clandestine data which gives additional information to the embedded data. This technology is used in digital watermarking techniques where clandestine data and the image are very important.

Many reversible data hiding methodologies were developed in recent years. Difference between two adjacent pixels is used to embed data in difference expansion method[1]. A data can be hide using histogram shifting mechanism by Ni *et al.*[2]. The lossless compression method is used to create extra space to embed data by Celik *et al.*[3]. To improves the performance of reversible data hiding various technologies have been introduced by Luo *et al.*[4], Hong *et al.*[5] and Chang *et al.*[6]. Amplitudes of DCT coefficients are used to embed the data[7].

In order to increase the information security Zhang[8] proposed the lossless data hiding technique in an encrypted image. Zhang[9] separable lossless data hiding is introduced. Sorting and prediction method is used for lossless watermarking algorithm[10]. Ni *et al.*[11] scheme introducing a new embedding mechanism, which increases the data embedding capacity. In this method the image is divided into several numer of sub images and using pathwork theory for each sub image secret data are embeded.

Zeng *et al.*[12] are introduced new algorithm for reversible data hiding using arithmetic difference. The secret can be easily retreived based on the data distribution by Ni *et al.*[11] and Zeng *et al.*[12]. De Vleeschouwer *et al.*[13] and Kim *et al.*[14] showed better imperceptibility in their algorithm than Ni *et al.*[11] and Zeng *et al.*[12]. Zhao *et al.*[15] introduced a method called multilevel histogram modification. Huang and Chang[16] introduced algorithm based on quantized coefficients of Discrete Wavelet Transform (DWT).

MATERIALS AND METHODS

Literature survey: Ramaswamy and Arumugam[17] introduced a new lossless data hiding algorithm using adjacency pixel difference. The embedding algorithm steps are given below:

- Scan the grayscale image
- Find the pixel difference 'd_i' for each adjacency pair as follows in Eq. 1:

$$d_i = \begin{cases} p_i, \text{ if } i = 0 \\ |p_{i-1} - p_i|, \text{ otherwisw} \end{cases} \quad (1)$$

- Find the peak difference 'PP'
- If d_i >PP the shift pixel value by 1 as follows in Eq. 2:

$$newp_i = \begin{cases} p_i, \text{ if } i = 0 \text{ or } d_i < PP \\ p_{i+1}, \text{ if } d_i > PP \text{ and } p_i \geq p_{i-1} \\ p_{i-1}, \text{ if } d_i > PP \text{ and } p_i < p_{i-1} \end{cases} \quad (2)$$

- If d_i = PP, change the pixel value according to the secret bit [0,1] according to Eq. 3:

$$\text{After emb}p_i = \begin{cases} p_i, \text{ if secret bit is } 0 \\ p_{i+1}, \text{ if secret bit is } 1 \text{ and } p_i \geq p_{i-1} \\ p_{i-1}, \text{ if secret bit is } 1 \text{ and } p_i < p_{i-1} \end{cases} \quad (3)$$

In this proposed method the host image is divided in to several 2×2 sub images. Then adjacency pixel difference is calculated for each block. From this difference peak point is calculated. The payload capacity is based on the peak point level. If the peak point is high then payload capacity is also high. This algorithm retrieves the secret without any loss and the image is also recovered with no distortion.

Proposed scheme: An efficient reversible data hiding method is proposed using histogram shifting is given in Fig. 1. Here adjacency pixel difference is used for embedding. Neighbouring pixel in an image is highly correlated. Hence, maximum adjacency pixel difference is nearly zero as shown in Fig. 2a. Let us consider 'd' is the peak point of the histogram and add 'n' with each difference which have value greater than 'd' and this is called histogram shifting, where 'n' value is 3 for 2 bits embedding and for 3 and 4 bits embedding 'n'

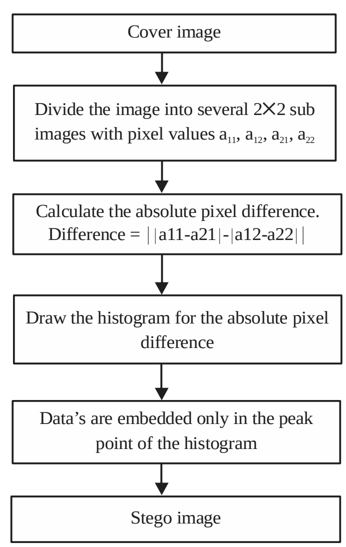

Fig. 1: Proposed method

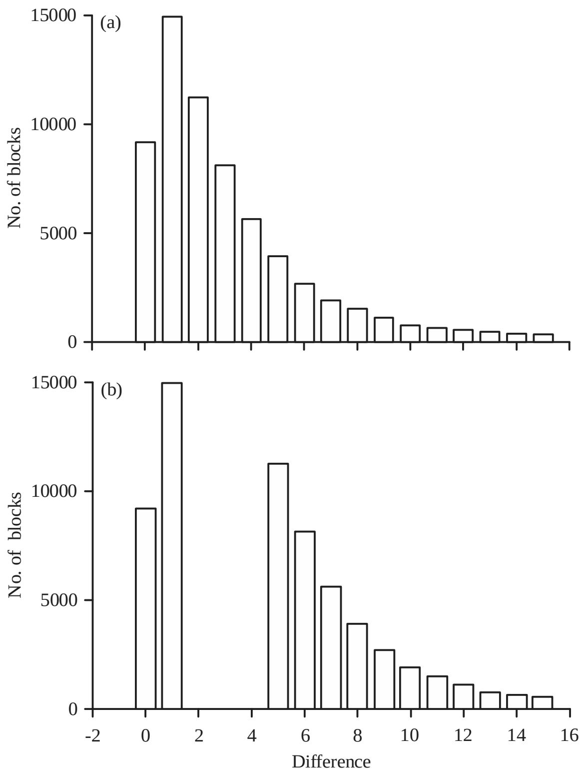

Fig. 2(a-b): (a) Histogram for absolute difference and (b) Histogram after shifting

values are 7 and 15, respectively. Equation 1 and Fig. 2b show the histogram shifting. Histogram shifting algorithm and embedding algorithm are given in this study. Data retrieving and image reconstruction is reverse process of the data embedding and histogram shifting in Eq. 4:

$$\text{Difference} = \begin{cases} \text{difference} + n, & \text{difference} > d \\ \text{difference}, & \text{otherwise} \end{cases} \quad (4)$$

Histogram shifting

- Separate the cover image into several 2×2 sub images as:

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$$

- Loop for all sub images
  - Temp1 = $|a_{11}-a_{21}|$
  - Temp2 = $|a_{12}-a_{22}|$
  - Difference = |Temp1-Temp2|
- End loop
- Draw the histogram for the difference value
- Let 'd' is the peak point of the histogram
- Loop for all sub images
  - Temp1 = |a11-a21|
  - Temp2 = |a12-a22|
  - If(|Temp1-Temp2|>d)
    - If(|Temp1|>|Temp2|)
      - if(a11>a21)
        - a11 = a11+3
      - else
        - a21 = a21+3
    - else
      - if(a12>a22)
        - a12 = a12+3
    - else
      - a22 = a22+3
- End loop

Embedding algorithm:

- Loop for all sub images
  - Temp1 = |a11-a21|
  - Temp2 = |a12-a22|
  - If(Temp1|-|Temp2|is equal to 'd')
    - if(secret to be embedded is "00")
      - Do nothing
    - Else if(secret to be embedded is "01")
      - if(a11>a21)
        - a11 = a11+1
      - else
        - a21= a21+1
    - Else if(secret to be embedded is "10")
      - if(a11>a21)
        - a11=a11+2
      - else
        - a21= a21+2
    - Else if(secret to be embedded is "11")
      - if(a11>a21)
        - a11= a11+3
      - else
        - a21 = a21+3
  - If(|Temp1|-|Temp2|is equal to '-d')
    - if(secret to be embedded is "00")
      - Do nothing
    - Else if(secret to be embedded is "01")
      - if(a12>a22)
        - a12 = a12+1
      - else
        - a22 = a22+1
    - Else if(secret to be embedded is "10")
      - if(a12>a22)

        - a12 = a12+2
    - else
        - a22 = a22+2
  - Else if(secret to be embedded is “11”)
    - if(a12>a22)
        - a12 = a22+3
    - else
        - a22 = a22+3
- End Loop

RESULTS AND DISCUSSION

This new lossless data hiding algorithm based on adjacency pixel difference was implemented using jdk1.6. The cover Lena image size 512×512 is given in Fig. 3a. The resultant stego image after embedding is given in Fig. 3b. The recovered image after extracting the secret image is given in Fig. 3c. The corresponding histogram of cover, stego and recovered image of Lena is given in Fig. 3d-f, respectively and observed no difference in histogram level.

The baboon cover and stego images are given in Fig. 4a and b, respectively and recovered baboon image is given in Fig. 4c. Figure 4d-f are shown their corresponding histograms and found to be intact for all the cases original, stego and recovered cover object.

Babara cover, stego and recovered images are given in Fig. 5a-c, respectively and those corresponding histograms are given in Fig. 5d-f, respectively and found to be intact for all the cases original, stego and recovered cover object.

The cameraman cover and stego images are given in Fig. 6a and b, respectively and recovered cameraman image is given in Fig. 6c. Figure 6d-f are shown their corresponding histograms and found to be intact for all the cases original, stego and recovered cover object.

Gold Hill cover and stego images are given in Fig. 7a and b, respectively and recovered Gold Hill image is given in Fig. 7c. Figure 7d-f are shown their corresponding histograms and found to be intact for all the cases original, stego and recovered cover objects.

The man cover and stego images are given in Fig. 8a and b, respectively and recovered man image is given in Fig. 8c. Figure 8d-f are shown their corresponding histograms found to be intact for all the cases original, stego and recovered cover object. The boat cover and stego images are given in Fig. 9a and b, respectively and recovered boat image is given in Fig. 9c.

The butterfly cover and stego images aregiven in Fig. 10a and b, respectively and recovered butterfly image is given in Fig. 10c. Figure 10d-f are shown their corresponding histograms.

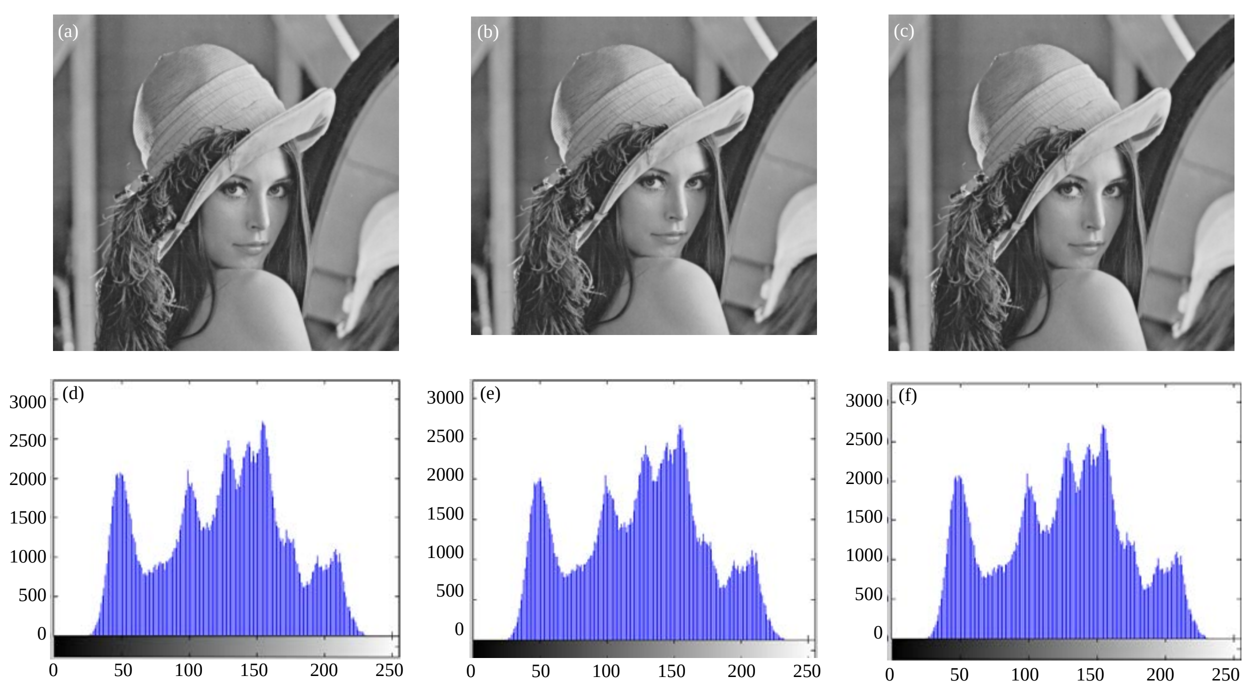

Fig. 3(a-f): (a) Original Lena, (b) Stego Lena, (c) Recovered Lena, (d) Histogram of original Lena, (e) Histogram of stego Lena and (f) Histogram of recovered Lena

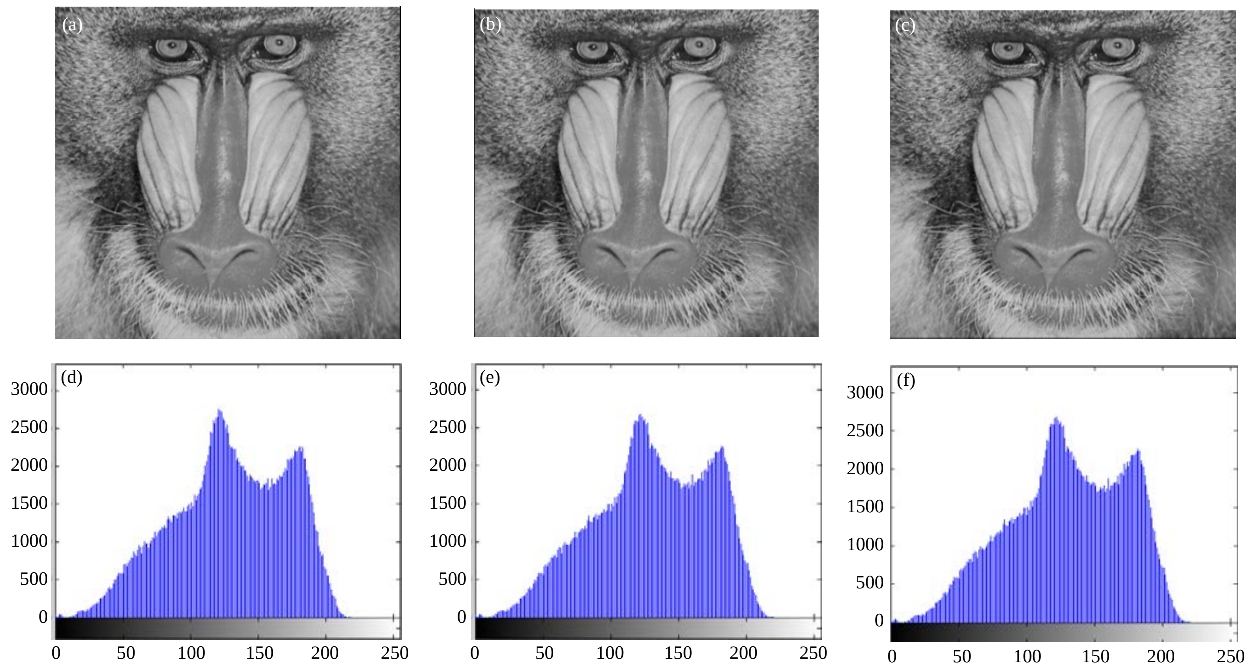

Fig. 4(a-f): (a) Original baboon, (b) Stego baboon, (c) Recovered baboon, (d) Histogram of original baboon, (e) Histogram of stego baboon and (f) Histogram of recovered baboon

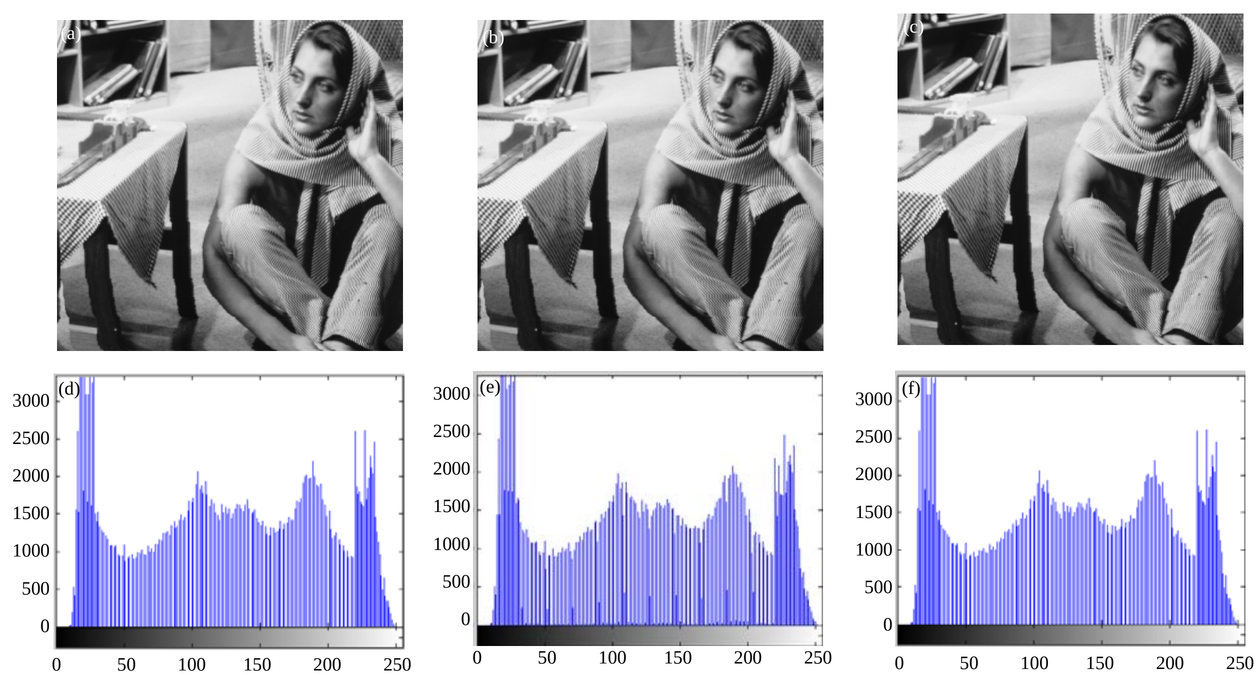

Fig. 5(a-f): (a) Original Barbara, (b) Stego Barbara, (c) Recovered Barbara, (d) Histogram of original Barbara, (e) Histogram of stego Barbara and (f) Histogram of recovered Barbara

The road cover and stego images are given in Fig. 11a and b, respectively and recovered road image is given in Fig. 11c. Figure 11d-f are shown their corresponding histograms.

The manwoman cover and stego images are given in Fig. 12a and b, respectively and recovered manwoman image is given in Fig. 12c. Figure 12d-f are shown

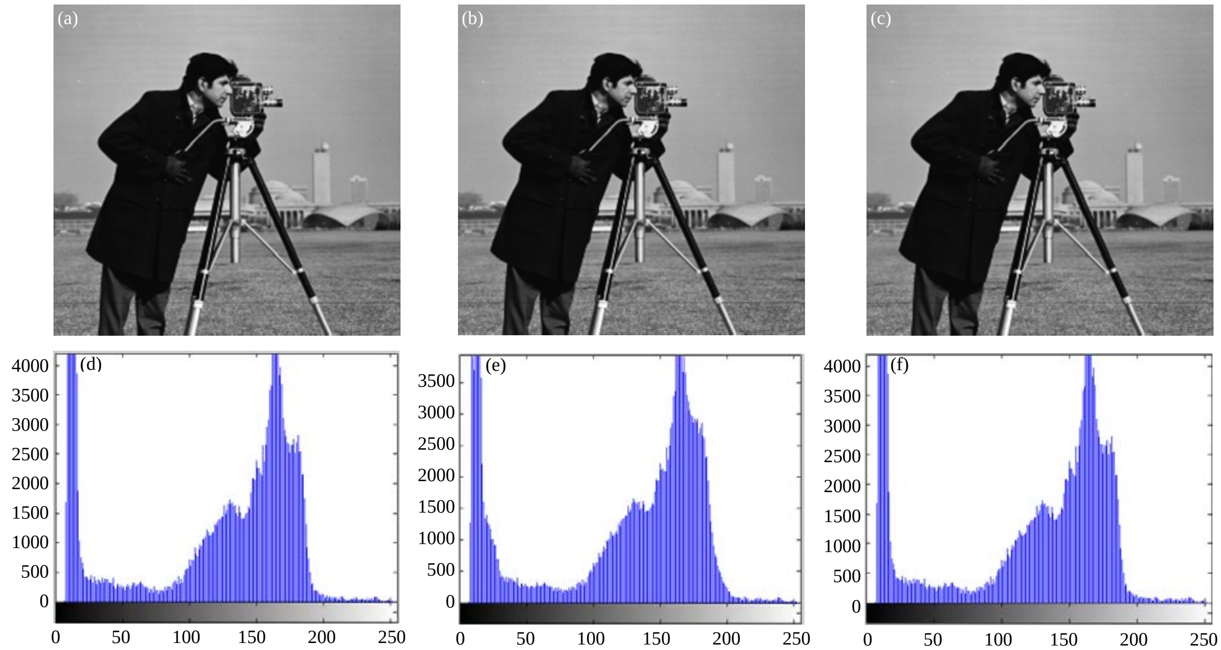

Fig. 6(a-f): (a) Original cameraman, (b) Stego cameraman, (c) Recovered cameraman, (d) Histogram of original cameraman, (e) Histogram of stego cameraman and (f) Histogram of recovered cameraman

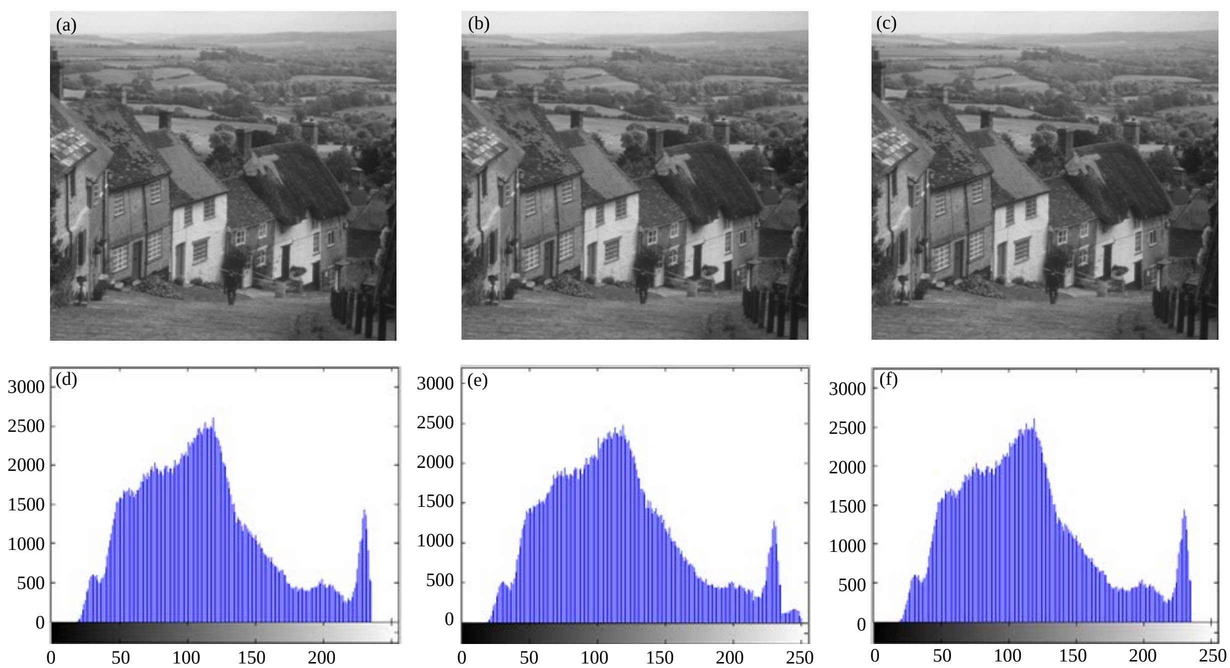

Fig. 7(a-f): (a) Original Gold Hill, (b) Stego Gold Hill, (c) Recovered Gold Hill, (d) Histogram of original Gold Hill, (e) Histogram of stego Gold Hill and (f) Histogram of recovered Gold Hill

their corresponding histograms and found to be intact for all the cases original, stego and recovered cover objects.

This new lossless data hiding algorithm based on adjacency pixel difference method embedding capacity is superior as compared with other method is shown in Table 1. Pepper (512×512) offer good capacity and PSNR. Butterfly host image (512×512) offer low capacity, the stego object offer a favorable PSNR value for steganography and comparable with baboon (512×512)[2,17].

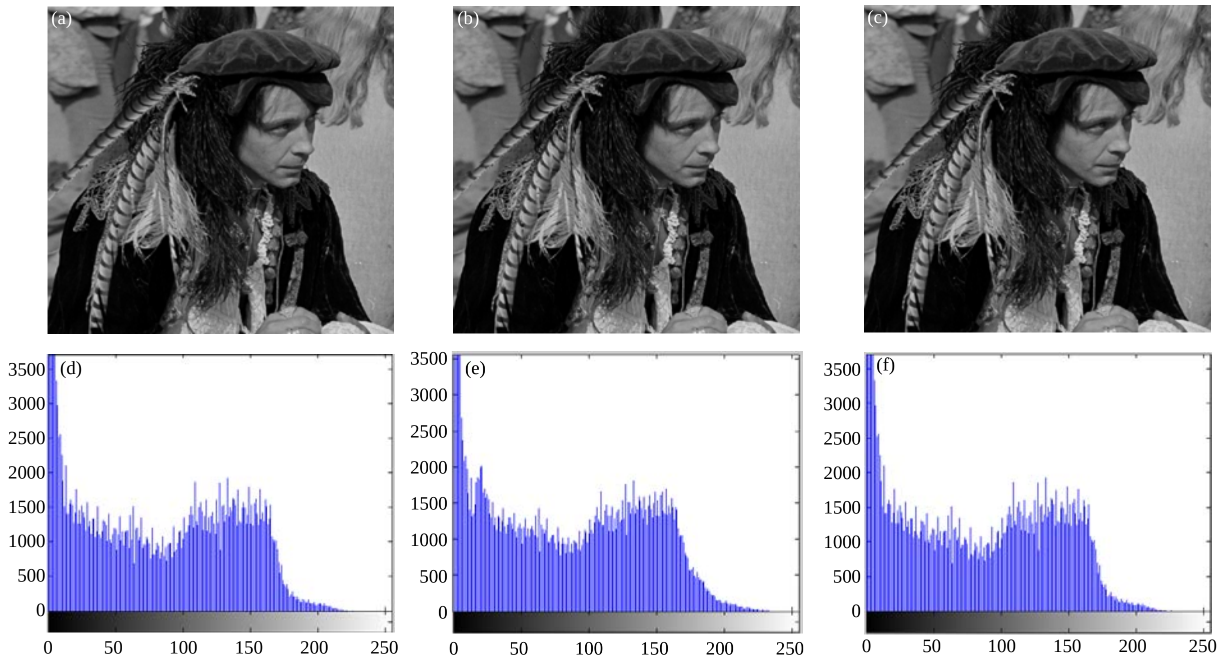

Fig. 8(a-f): (a) Original man, (b) Stego man, (c) Recovered man, (d) Histogram of original man, (e) Histogram of stego man and (f) Histogram of recovered man

Fig. 9(a-c): (a) Original boat, (b) Stego boat and (c) Recovered boat

Table 1: Hiding capacity for 512×512 grayscale image and image distortion

	Ni *et al.*[2]	Ramaswamy and Arumugam[17]	Proposed study	
Host image (512×512) grayscale	Embedding capacity in bits	Embedding capacity in bits	Embedding capacity in bits (n = 15)	PSNR (dB)
Lena	2618	40740	59960	32.1060
Baboon	2759	16465	21532	31.0643
Cameraman	2905	37885	26214	35.1509
Barbara	2405	41327	45056	31.6926
Gold Hill	2618	35022	45184	31.6440
Pepper	-	-	92512	34.0774
Airplane	-	-	74908	32.6930
Car	-	-	67788	32.5577
Boat	-	-	63988	32.1641
Manwoman	-	-	46276	31.6586
Man	-	-	41936	31.5927
Road	-	-	35372	31.3829
Butterfly	-	-	21880	31.8579

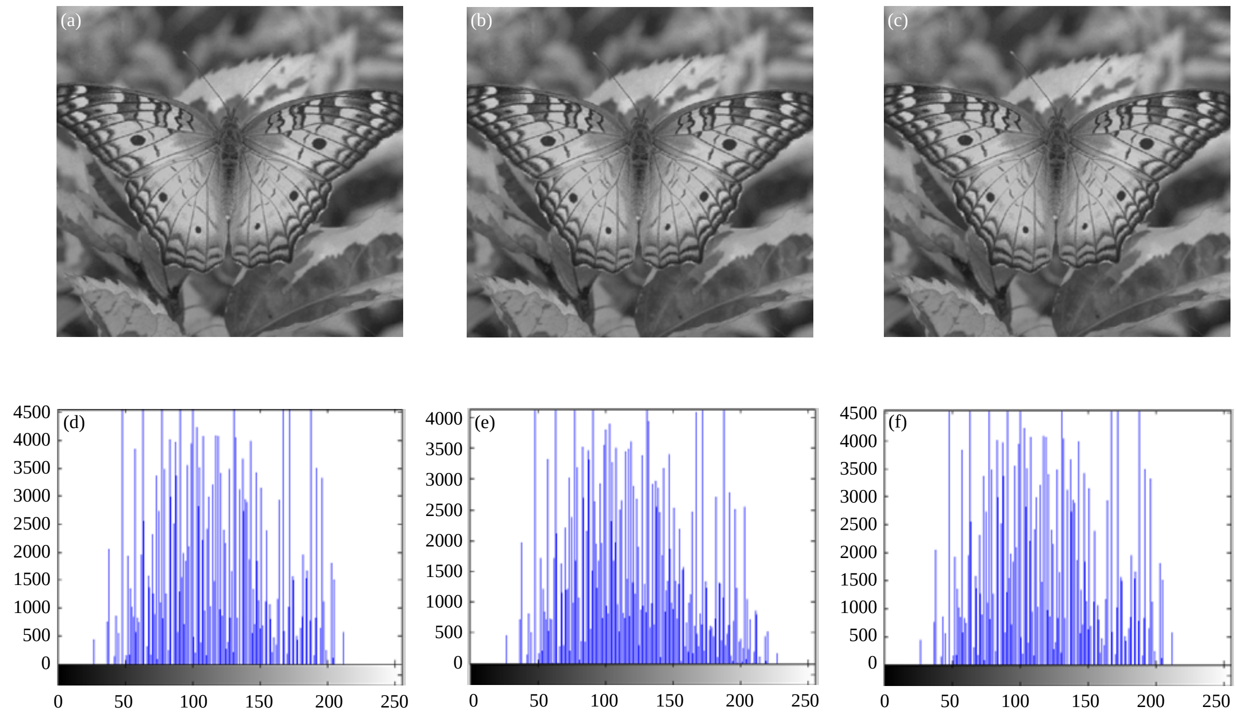

Fig. 10(a-f): (a) Original butterfly, (b) Stego butterfly, (c) Recovered butterfly, (d) Histogram of original butterfly, (e) Histogram of stego butterfly and (f) Histogram of recovered butterfly

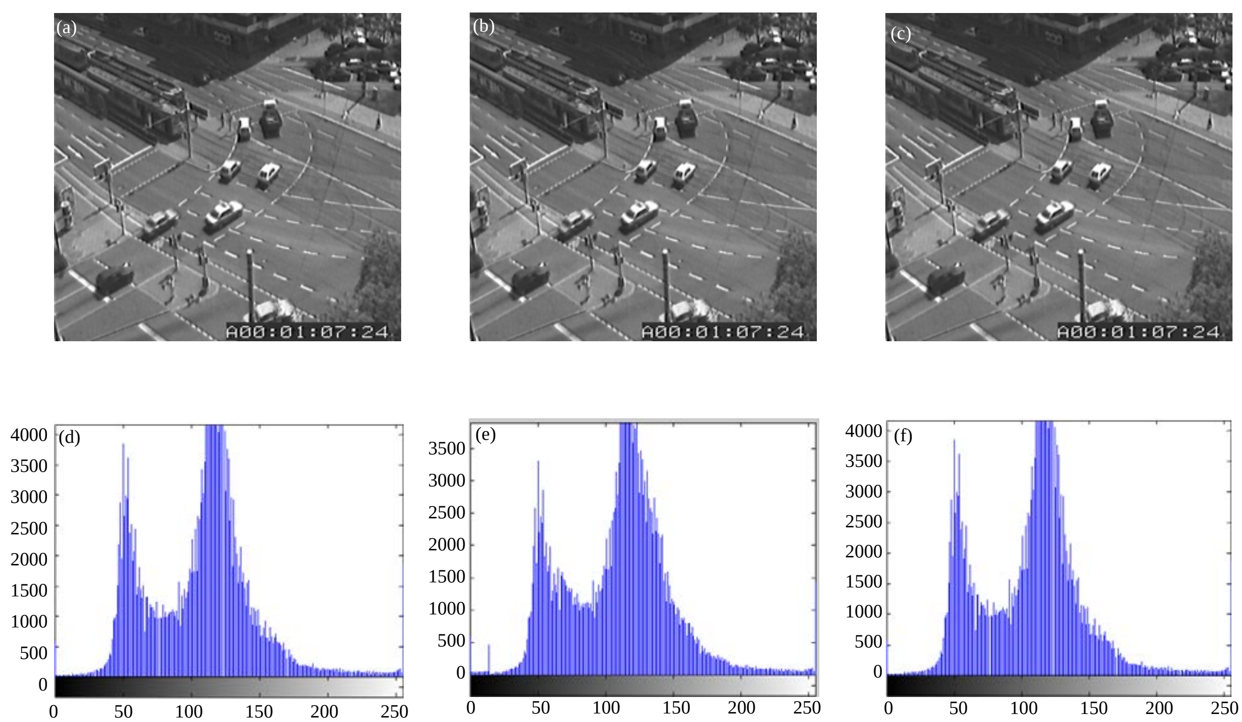

Fig. 11(a-f): (a) Original road, (b) Stego road, (c) Recovered road, (d) Histogram of original road, (e) Histogram of stego road and (f) Histogram of recovered road

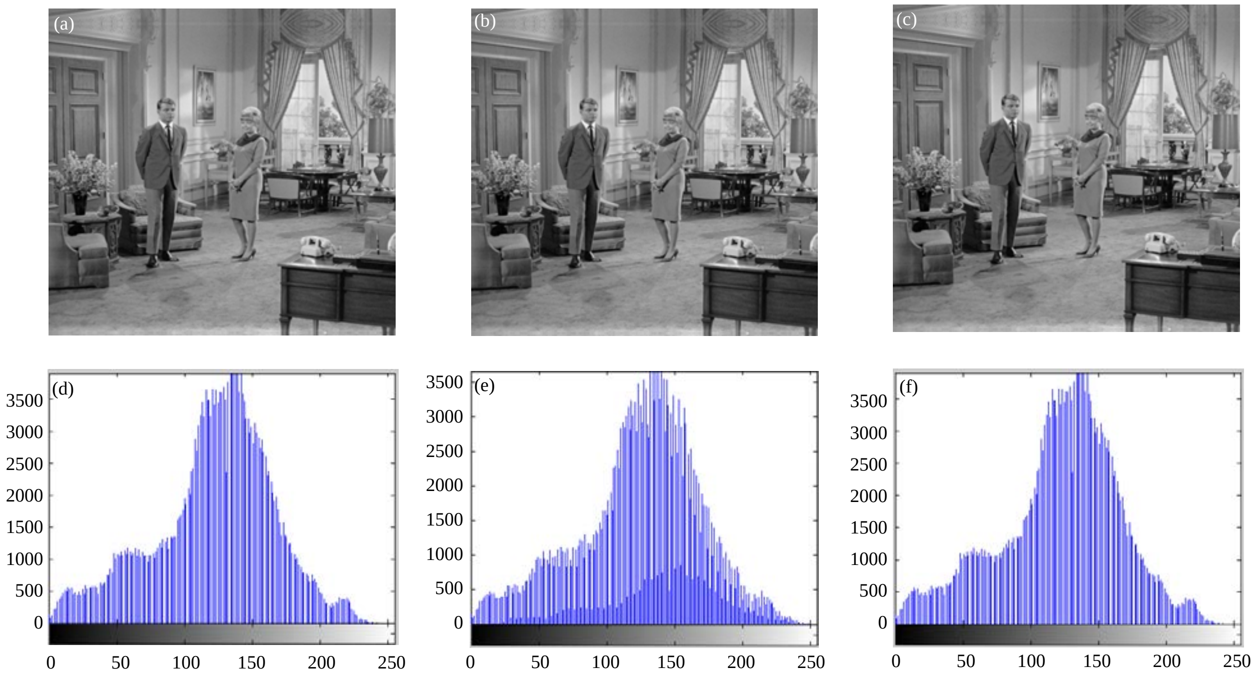

Fig. 12(a-f): (a) Original manwoman, (b) Stego manwoman, (c) Recovered manwoman, (d) Histogram of original manwoman, (e) Histogram of stego manwoman and (f) Histogram of recovered manwoman

CONCLUSION

This study gives an overall view about the reversible data hiding technique using histogram modification. This can be achieved by calculating the difference between two neighbouring pixels. Except the edge pixels almost all neighbouring pixels are extremely correlated, this will help to embed huge quantity of secret data when compare to the older ones. For full lossless data retrieving and image recovery is possible to share the peak difference value from the histogram. This technique is successfully compiled and executed using jdk1.8. In the years to come, this powerful algorithm will find a wide range of applications. One such instance is the direction of video sequences where each sequence can be separated into single frames. In each frame this method suggests to apply the same lossless data hiding technique and combine those frames to get the original.

SIGNIFICANCE STATEMENT

- Reversible secret data embedding based on histogram modification technique is proposed and executed using jdk1.8
- Histogram for the absolute pixel difference is calculated and embedding is done only at the peak points
- Full lossless data retrieving and image recovery is achieved
- The PSNR and embedding capacity is improved and comparison is done with the existing methods

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