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Reversible Data Hiding using Spiral Order Technique in Medical Images

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***Abstract*—Reversible data hiding is a technique of hiding secret and sensitive data in some multimedia cover medium. Both the hidden data and cover medium (image, video and audio) can be retrieved from stego image without any loss. A highly efficient reversible data hiding technique and histogram modification technique for medical images are proposed in this paper. Spiral order technique is used to locate the embedding area and a Histogram modification technique is used for embedding the hidden data. Based on the experimental results it is proved that the proposed method produces good visual quality stego and reconstructed image in terms of MSE, PSNR and SSIM with good embedding capacity. The proposed method is used for various medical images and recent reversible data hiding techniques to recover in comparison.**

Keywords—Reversible data embedding, Medical image, Reversible data hiding

I. INTRODUCTION

In current trends, applications that require secure communication of information have increased significantly triggering the interest of researchers in information security. Consequently, steganography has become an active and energetic research field and it is the process of hiding secret information in cover media with the ability of extracting the data either lossy or lossless. Generally, image steganographic techniques use an image as a cover media and they can be classified into two major categories. The functioning in spatial domain that embeds secret information directly into the image pixels of the original image was considered first. The second one is using the frequency domain to embed secret information into the transformed coefficients resulting from one of the famous transforms such as Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT).

Lossless reversible data hiding is a kind of data hiding technique whereby the original image and hidden data can be recovered exactly. Being lossless makes this technique suited for medical and military applications. Data hiding can be done in either spatial or frequency domain. Generally, the spatial domain methods offer high embedding capacity, but at the cost of low imperceptibility. However, some spatial domain methods offer good imperceptibility and embedding capacity while compromising the robustness and complexity. On the other hand, frequency domain methods are robust, but with a low embedding capacity. As the confidential data is hidden into the high-frequency coefficients of the transform while leaving the low-frequency coefficients unaltered, it offers very good stego image quality. The method is slower compared to the spatial domain algorithms as it is not easy to compute.

The pixel values are changed straight to embed the confidential data in spatial domain schemes. The existing spatial domain techniques can be divided into six streams based on the embedding method used. They are i) Difference Expansion (DE) based schemes; this scheme discovers an additional storage capacity by finding the redundancy in the image content. To reversibly embed a payload into digital images DE method is used ii) In Histogram shifting based methods the histogram based reversible information hiding earned quality because of its easy implementation. The selected luminance is effectively made as blank by a purposeful shift in the host image histogram and it gives space for reversible information hiding. Also the embedding size is raised by properly choosing the suitable luminance value [9]. iii) Prediction based schemes; as a replacement for using feature elements in the spatial domain, used a predictor to make feature elements in the field of prediction errors. Modification of Prediction Errors (MPE) method uses the idea of histogram-shifting method to hide information in the field of prediction errors. The computational complexity is O(mn) where m and n are the aspects of the image matrix, which is slightly more efficient than Ni et.al algorithm [10]. iv) Interpolation based methods; Jung &yoo et al developed an interpolation method which is a novel lossless data hiding method that scales up the neighbours mean by interpolation. The low time complexity and high-performance computing are the two advantage of this method. This method embedded secret payload with nearly imperceptible modification [12]. v) Robustness based methods; this system is depending on patchwork theory, permutation scheme and the delivery features of pixel groups. JPEG2000/JPEG compression was good because of robust stego image and had no salt-and-pepper noise. Though, the embedding size was only 1,024 bits and image quality did not exceed 38 dB [13]. vi) Human Visual System (HVS) based methods hide the data into the host image with consideration of the HVS.

II. LITERATURE REVIEW

FA Chin-Chen Chang et.al proposed a technique to hide more data by using the characteristics of pixel difference and prevent overflow and underflow problems they presented a histogram shifting method[1]. Neminath et.al utilized the histogram of images to develop a watermarking technique that exhibits a good fidelity [2]. Osamah Al-Qershi et.al proposed a region of interest (ROI) based data hiding in medical images and is shown to be tamper resistant [3]. Wei-Liang Tai et.al proposed a scheme which uses a histogram modification to perform reversible data hidingThey used a binary tree structure to find the solution. By using pixel difference distribution method they obtain a large hiding spacebutlow distortion. To prevent overflow and underflow the histogram shifting technique was used [4]. A recent advancement in the spatial domain methods is the utilization of luminance values of an image proposed by Jamal Hussein [5] which exhibited good tolerance towards JPEG compression and rotation attacks.

Chin Feng Lee et.al has put forward reversible data hiding technique utilizing a vector quantization compression code and is able to restore the original image without any distortion [6]. Seung-Won Jung et.al proposed an algorithm, toadaptively adjust each pixel without affecting HVS characteristics to perform data embedding. The Just Noticeable Difference (JND) values werecalculated in all the pixel, and the calculated values are utilized to resolve the embedding level. The distortion due to data embedding can be fully reduced by pixel level alteration [7].

Rajkumar Ramaswamy et.al presented a histogram modification technique which works by findingthenearest pixels differencesinstead of simple pixel values. The nearest pixels are highly correlated which helps to achieve payload capacity. The payload capacity is high in the gray scale images [8]. The reversible data hiding technique that was used to modify the histogram was proposed by Ni et.al thatuses either the peak and zero point or minimal point of the image histogram.

Reversible techniques are well suited for hiding data in medical images as distortion of image pixels due to data hiding in irreversible methods will lead to wrong diagnosis. Generally, payload capacity and embedding time complexity play a vital role in determining the efficiency of data hiding algorithms. Most of the above proposed methods achieve either one parameter compromising the other one. A new hiding technique based on reversibleinformationin medical images has been proposed. The novelty of our proposed method is achieving high payload capacity with less embedding time, thereby outperforming similar methods. Payload capacity is one of the metrics for assessing the efficiency of any information hiding algorithm.

III. Proposed Method

The proposed method has been developed for confidential images and data hiding in medical images is concentrated. Generally, medical images having no data at background region, so the intensity values of background region are few keeps running of 0's (in grayscale image) which can be utilized for information hiding. Aninnovativemethod for confidential images that uses reversible data hiding technique is proposed which uses spiral order technique and histogram modification for data embedding. This technique, being reversible, is convenient for hiding information into a medical image, satellite image etc. In medical image hiding, both the hidden information and the cover image are recoveredwith no loss at the receiver side. This is very crucial for diagnosis in medical applications. The two stages involved in the proposed method are

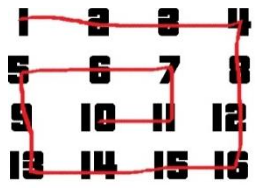
1. Information hiding pre processing using the Spiral order technique.
2. Histogram modification.

A. Information hiding Pre- processing using the spiral order technique

Hiding operation is performed by reading the cover image and data to be hidden at first. The cover image matrix is converted into a vector using spiral order technique as a first step in the data hiding procedure. After that positions for hiding the data in the converted vector are to be found out. Spiral order technique executes the following four steps until all the pixel values are retrieved.

1. Take the first row from the remaining rows.
2. Take the last column from the remaining columns.
3. Take the last row from the remaining rows.
4. Take the first column from the remaining columns.

The process of spiral order technique is shown in Fig. 1(a) and Fig. 1(b).



(a)

(b)

Fig. 1. Spiral order technique (a) Image matrix, (b) Vector retrieved using Spiral order technique

B. Histogram Modification

After retrieving the spiral ordered vector, the pixel differences between the adjacent pixels are calculated. In general the neighbouring pixels in images are highly correlated, so the pixel difference values taken between adjacent pixels have a distribution that is packed near zero. The peak point of this distribution is the most frequently occurring pixel difference value. In histogram modification, pixels are modified in three ways depending on whether the pixel difference is greater or lower than the peak point.

Algorithm for embedding message bits

Let us consider grayscale image A with N number of pixels with Ai and Yi denoting the grayscale values of i^{th} pixel, before and after modification respectively.

- Read the image and convert into a vector (A) in spiral order as shown in Fig. 1(a).
- The pixel difference Di between the pixel Ai and Ai-1 is calculated using equation (1).

$$Di = \begin{cases} Ai & if\ i = 0 \\ |\,Ai\text{-}1\text{-}\ Ai\,|, & otherwise \end{cases} \quad .....(1)$$

- Find out the peak point PP from the pixel differences
- If Di>PP then shift each pixel by 1 using equation (2)

$$Yi = \begin{cases} Ai & if\ \ i = 0\ or\ Di < PP \\ Ai + 1,\ if\ \ Di > PP\ and\ Ai \geq Ai\text{-}1 \\ Ai - 1,\ if\ \ Di > PP\ and\ Ai < Ai\text{-}1 \end{cases} \quad .....(2)$$

- If Di=PP, modify the pixel Ai according to the hidden message bit B [0, 1].

$$Yi = \begin{cases} Ai + B, \ if \ \ Di = PP \ and \ Ai \geq Ai\text{-}1 \\ Ai - B, \ if \ \ Di = PP \ and \ Ai < Ai\text{-}1 \end{cases} \quad .....(3)$$

The stego image is thus created by executing the above five steps for all the pixels Ai, 1⩽i⩽N.

a. Recover the hidden data and cover image

As done in the embedding processthe Stego image is read in the spiral order. A bit ‘1’ is extracted if a pixel with its grayscale value (PP+1) is encounteredand a bit ‘0’ is extracted if a pixel with its grayscale value PP is encountered,.After the extraction of the message bits, the original pixel values are restored and the original image is reconstructed.

213	216	218	220	236	234	236	234
235	236	234	225	223	223	232	233

Algorithm for Extraction

- The message bit B can be extracted from:

$$B = \begin{cases} 0, \ if \ \ |Yi - Ai - 1| = PP \\ 1, \ if \ \ |Yi - Ai - 1| = PP + 1 \end{cases} \quad .....(4)$$

- The Pixel values Ai of the original image can be reconstructed by using equation (5)

$$Ai = \begin{cases} Yi + 1, \ if \ \ |Yi - Ai - 1| > PP \ and \ Yi < Ai\text{-}1 \\ Yi - 1, \ if \ \ |Yi - Ai - 1| > PP \ and \ Yi > Ai\text{-}1 \\ Yi, \quad otherwise \end{cases} \quad .....(5)$$

The flow diagram of the proposed method is shown in Fig. 2.

213	215	217	219	235	234	236	234
235	236	234	226	224	223	231	233

b. An example of embedding and extraction process

Let A be the part of an original image as shown below

$$A = \begin{bmatrix} 213 & 215 & 217 & 219 \\ 226 & 224 & 223 & 235 \\ 234 & 233 & 231 & 234 \\ 236 & 235 & 234 & 236 \end{bmatrix}$$

The pixel differences of the adjacent pixels are

1	2	3	4	5	6	7	8
213	2	2	2	16	1	2	2
9	10	11	12	13	14	15	16
1	1	2	8	2	1	8	2

It can be noted that the peak point is 2 being the most frequently occurring pixel differences. As the number of occurrences of 2 in the vector iseight, the embedding capacity of the image is eight bits and these embedding bits are randomly selected using random permutation. Let the embedding message (B) be 11100010. After embedding the bits using equation 4 and equation 5, the modified pixels (Y) are

The part of a stego image is shown below

$$Y = \begin{bmatrix} 213 & 216 & 218 & 220 \\ 225 & 223 & 223 & 236 \\ 234 & 233 & 232 & 234 \\ 236 & 235 & 234 & 236 \end{bmatrix}$$

The stego image is converted into spiral ordered vector at first in the extraction process. The spiral ordered vector of stego image ‘Y’ is

Reconstructed image from spiral order is

$$Reconstructed\ Image\,(RI) = \begin{bmatrix} 213 & 215 & 217 & 219 \\ 226 & 224 & 223 & 235 \\ 234 & 233 & 231 & 234 \\ 236 & 235 & 234 & 236 \end{bmatrix}$$

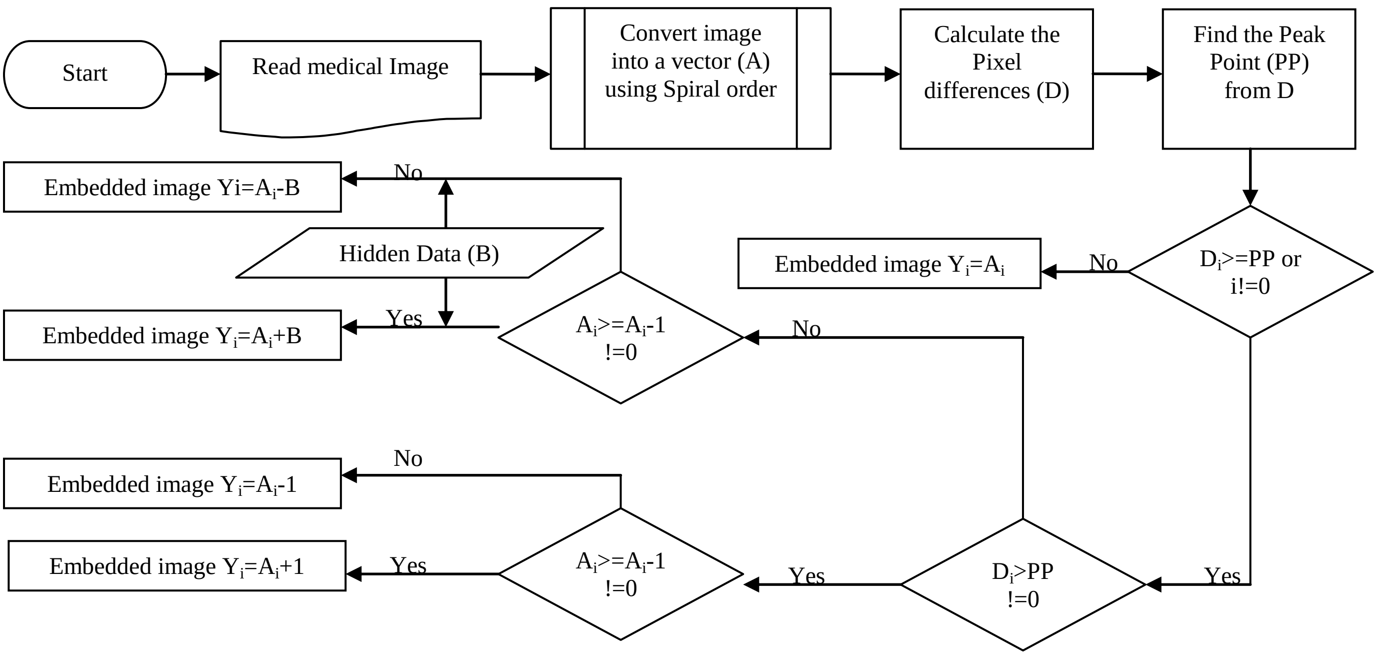


Fig. 2. Flowchart of embedding message bits

IV. Performance Metrics

The existing methods and the proposed method performance are compared based on encoding time and embedding capacity, where embedding capacity is equal to the total number of pixels at the peak point (PP)

The quality of the stego image is assessed by measuring the standard metrics, Mean Square Errors (MSE) and the Peak signal-to-noise ratio (PSNR) between the original images. Bits per pixel (bpp), specifies the number of bits used to represent a pixel.

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[A(i,j)-Y(i,j)]^2 \qquad .....(6)$$

Where A is the original image and Y is the stego image. The PSNR (in dB) is defined as

$$PSNR = 10\log_{10}\left(\frac{Max(A)^2}{MSE}\right) \qquad .....(7)$$

$$BPP = \frac{Embedding\ Capacity}{Total\ number\ of\ Pixels} \qquad .....(8)$$

Structural SIMilarity (SSIM) is a parameter that reflects image degradation as perceived change in structural data and it is a perception based model. It is calculated using equation (9).

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \qquad .....(9)$$

μ is average, σ is variance and c1 and c2 are two variables to stabilize the division with weak denominator.

V. Experimental Results

The proposed method is examined using medical images of size512x512 (grayscale and RGB). Embedding capacity and encoding time of the proposed method are compared with existing method in Table 1. Existing method [8] is a recent reversible data hiding method in literature which is used for comparing the performances of the proposed method.

TABLE I. Comparison of the performance metrics of the proposed and existing methods

Medical Image	Embedding Capacity		Encoding Time (in seconds)	
	Existing method [8]	*Proposed method*	*Existing method [8]*	*Proposed method*
X-ray	181072	181171	1.32	1.24
CT Scan	171791	173714	1.36	1.26
PET	211178	211402	1.45	1.35
MRI	171590	172070	1.36	1.32
Ultrasound	176359	177992	1.32	1.29

Embedding capacity varies with different medical images. It is evident from Table 1 that the proposed method achieves higher payload capacity with a gain range of 100-3000 bits over existing method. It is also worth noting that the proposed method takes less encoding time than existing [8] method.

The graphical representation of the performance comparison of proposed and the existing method in terms of embedding capacity and embedding time are shown respectively in Fig. 3 and Fig. 4.

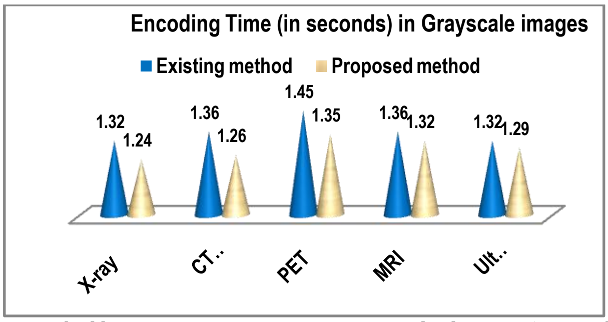


Fig. 4.Embedding Time Comparison in various medical images (Grayscale)

Table 2. demonstrates that the proposed method produces better quality stego images which is revealed by the quality parameters PSNR and SSIM, thereby achieving high imperceptible one of the key factors of the information security. Furthermore, the proposed method has achieved SSIM closer to 1, which indicates high similarity to original image.

TABLE II.Performance analysis of the proposed method using image quality metrics

Medical Image	MSE	PSNR	BPP	SSIM
X-ray	0.6538	49.98	0.6911	0.9945
CT Scan	0.6224	50.19	0.6627	0.9917
PET	0.5144	51.02	0.8064	0.9848
MRI	0.6266	50.16	0.6564	0.9921
Ultrasound	0.633	50.12	0.6792	0.9917

For color images (RGB), the embedding capacity is three times more than grayscale image embedding capacity. The results are tabulated in table 3 and it is evident that in terms of embedding capacity and encoding time the proposed method outperforms the existing method.

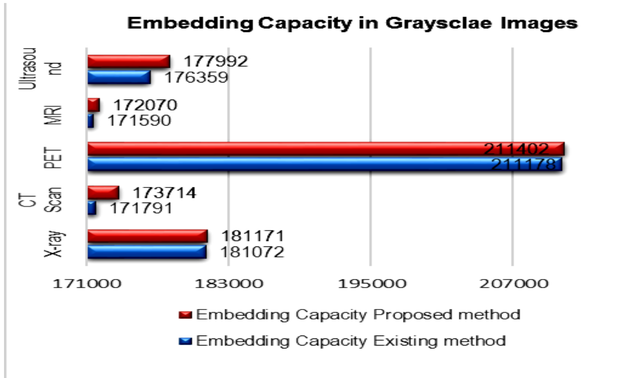


Fig. 3.Comparison of Embedding Capacity in various medical images (Grayscale)

The visual comparison of original and reconstructed images are shown in table 4 and table 5 which demonstrates the excellent performance of the proposed method in terms of quality and imperceptible.

TABLE III. EMBEDDING CAPACITY OF RGB IMAGES OF SIZE 512X512

Medical Image		Embedding Capacity				Encoding Time (in seconds)			
		Existing method[8]		*Proposed method*		*Existing method[8]*		*Proposed method*	
X-ray	R	174103		176905		1.30		1.29	
	G	174853	523765	178045	532282	1.37	4.06	1.24	3.89
	B	174809		177332		1.39		1.36	
CT Scan	R	187768		188413		1.33		1.26	
	G	188738	565592	189373	567471	1.35	4.07	1.33	3.98
	B	189086		189685		1.39		1.39	
PET	R	194467		199903		1.41		1.37	
	G	192199	567054	197597	584515	1.40	4.35	1.37	4.00
	B	180388		187015		1.54		1.26	
MRI	R	162745		163609		1.27		1.26	
	G	171430	502542	171946	504402	1.32	4.97	1.35	3.91
	B	168367		168847		1.38		1.30	
Ultrasound	R	177295		177943		1.33		1.30	
	G	176863	531067	177334	532752	1.56	4.25	1.44	4.01
	B	176909		177475		1.36		1.27	

TABLE IV. VISUAL COMPARISON OF MEDICAL IMAGES (GRAYSCALE)

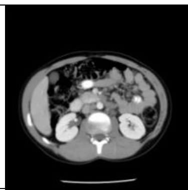
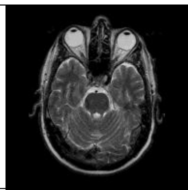
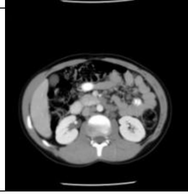
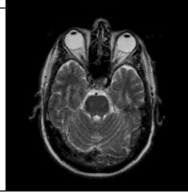
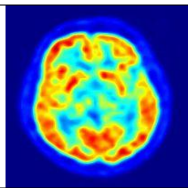
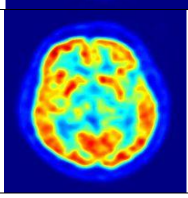
Medical Image	X-ray	CT Scan	PET	MRI	Ultrasound
Original image					
Reconstructed image					

TABLE V. VISUAL COMPARISON OF MEDICAL IMAGES (RGB)

Medical Image	X-ray	CT Scan	PET	MRI	Ultrasound
Original image					
Reconstructed image					

VI. CONCLUSION

In this proposed method, an efficient reversible technique is presented by considering the differences among neighbouring pixels for data hiding rather than simple pixel values. The advantages of the proposed method over similar existing methods are (i) embedding capacity is higher than other method. (ii) Good visual clarity stego and reconstructed images (iii) encoding time is less. In RGB images, each color plane has its own embedding capacity, and hence the ratio of the payload capacity of the RGB images and the grayscale images is approximately 3:1.Being a reversible technique, this method stands a good choice for secured transmission of confidential patient data hidden within medical images.

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