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REVERSIBLE WATERMARKING APPROACH FOR HEALTH INFORMATION SYSTEM

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Abstract
Health Information System [HIS] are gaining augmented acceptability and wide popularity as exchange of medical information and medical images between the healthcare centres are boosted up, which makes reversible watermarking emerge as an upcoming thrust area of research. This paper presents an efficient reversible approach for interleaving patient information in the form of Electro Cardio Graph [ECG] signal and hospital logo in the medical images. The proposed approach based on Discrete Wavelet Transform [DWT], utilizes the peak point of the difference image histogram for hiding the credentials of the corresponding patients. The superiority of the proposed approach is validated using 60 case studies of various modalities (CT, MRI, MRA and US) and comparing it with the spatial domain approach. Experimental results show that the histogram based approach using DWT gives high quality of watermarked image even after hiding the ECG signal encrypted with Adaptive Delta Modulation [ADM] and binary hospital logo. The high values of PSNR ensure the perceptual integrity, authentication of the patient's data and bandwidth reduction of the medical images as compared to the state of art methods.

Keywords:
DWT, Difference Image Histogram, ECG Signal, ADM

1. INTRODUCTION

HIS facilitate fast and easy access to medical data and also control its distribution and manipulation. Patient's vital information such as patients credentials, bio-signals are generally exchanged amongst the health care centres using unsecure network which may increase the risk of illicit access of patient information. To get the benefit of patient authentication with bandwidth reduction reversible watermarking approach is implemented to embed Hospital logo and ECG signal in medical image [1][2]. In reversible data hiding sender embeds the message to host image in lossless manner in such a way that the receiver would extract the message and get back the original image. Main significance of reversibility is original image would be retrieved completely with no alteration even after embedded information is extracted [3].

The reversible data hiding has been explored for authentication by Fridrich et al. [4,5] in JPEG domain using order 2 function to alter the quantization table for lossless embedding of one bit per DCT coefficients. Fridrich et al. also analysed RS method to embed bits into groups of pixels to offer high payload. De Vleeschouwer et al. [6] explored invertible algorithm which maps histogram of quantized values to the circle using circular interpretation of bijective transformation. The one bit of message is interleaved in respective orientation of the histogram of two groups of pixels and hence offers limited hiding capacity Difference expansion (DE) based invertible data hiding approaches are presented using Haar wavelet [7] and integer transform [8] to increase the efficiency of lossless compression.

Histogram based approaches are well known for distortion free data hiding techniques. Literature reports various histogram based technique in spatial and frequency domain like histogram modification based on difference statistics in spatial domain [9], block histogram in DWT domain is generated for same number of gray level and some pixels are moved to form some specific pattern to indicate watermark in gray level histogram distribution [10], blind invertible watermarking technique has been reported for medical images based on histogram shifting approach in wavelet domain. The binary watermark content are interleaved by selecting two threshold values as per the hiding capacity and by generating two zero points by shifting the starting and ending part of histogram thus binary data is hidden in the zero points and thresholds locations of the histogram [11]. Another researcher evaluated lossless data hiding scheme based on histogram shifting approach implemented using integer wavelet domain also, histogram modification technique is used to prevent underflow and overflow problems [12]. Multilevel invertible data hiding approach based on the difference image histogram modification is explored by free space creation by choosing peak points from histogram to insert messages [13]. All the reported techniques provides very less embedding capacity and moreover very few techniques are explored for medical image watermarking. Also the research is restricted for hiding binary logo or bit strings. The presented technique is evaluated for hiding dual hospital logo and ECG signal. For numerous serious diseases ECG signal plays crucial role for proper diagnosis hence, ECG signal is embedded to reduce transmission overhead. ADM technique is used to encrypt and compress the ECG signal as it gives better PSNR than other predictive techniques [14]. This paper presents histogram modification of difference images technique and also evaluated its performance in spatial and frequency domain for hiding multiple data like hospital logo and ECG signal.

The next section presents the technical details and algorithmic approach of hiding authentication credentials. Section 3 presents a performance evaluation of spatial domain and frequency domain (DWT-Histogram) approach. The paper concludes with discussion and conclusion.

2. PROPOSED SCHEME

The framework of proposed interleaving approach is illustrated in Fig.1.

Wavelet subband is divided in 4×4 blocks and difference image is generated. Peak point of a histogram in difference image is used to create free space for hiding patient's credentials like hospital logo and ECG signal.

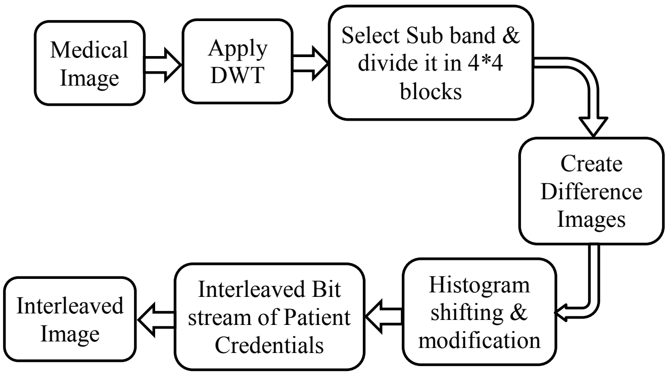
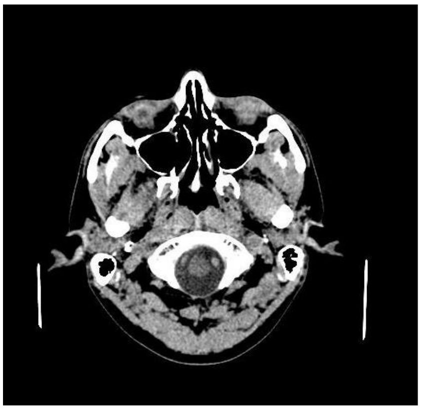
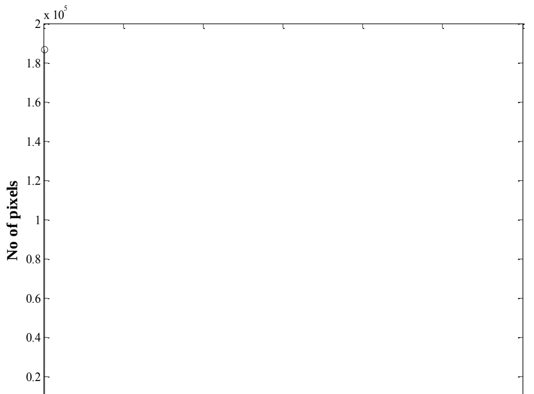


Fig.1. Proposed Architecture for Interleaving Patient Credentials

The histogram of digital image whose gray levels are in the range of 0 to L-1, is a discrete function $h(r_k) = n_k$, where r_k is the k^{th} gray level and n_k is the number of pixels in the image with gray level r_k. A normalized histogram is noted as $p(r_k) = n_k/n$, where k varies from 0 to $L - 1$ [19] as shown in Fig.2.



(a)



(b)

Fig.2. (a) Original medical image (b) Histogram of original medical image

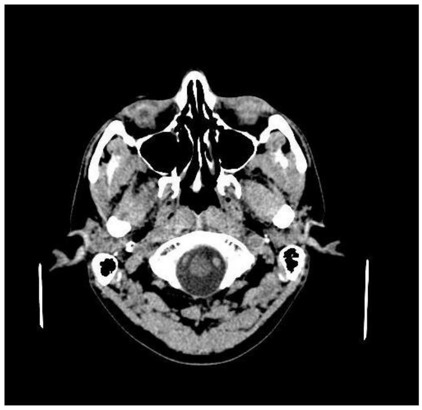
Frequency domain analysis has been performed using DWT. DWT gives multi-resolution representation which is effective to analyze content of an image. DWT localize the signal in spatiotemporal which is widely used by researchers. As the histogram vary as per the image so hiding a high payload will increase noticeable disturbance so to get the proper watermarking results wavelet domain is preferred as compare to spatial domain [11]. In the analysis of 2D-DWT, an image is decomposed into an approximation and three detail images [15]. The decomposition is done using Haar wavelet, as the dyadic rationality of the resulting coefficients with denominators of power 2 guarantees lossless reversibility of watermark coefficients. The Haar wavelet coefficients have the feature that, when changed using addition or subtraction of a multiple of 2^l, where l is the decomposition level, their inverse gives an image with integer pixel values; so any rounding operation will not alter the values of watermark bits [16].

The Fig.3 shows wavelet decomposition of an image which gives four sub bands that is Approximation (LL), Horizontal (HL), Vertical (LH) and Diagonal (HH). The Table.1 illustrates the energy distribution of CT image in its approximation and detail sub-bands using single level Haar DWT. The sub-band is selected based on energy which is calculated using Eq.(1).

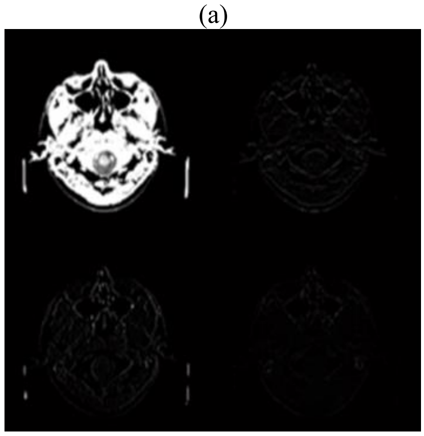
$$E_r = \frac{1}{P_r \cdot Q_r} \sum_i \sum_j \left| e_r(i,j) \right| \quad (1)$$

where, r denotes the detail and the approximation sub-bands at each levels. DWT sub-bands coefficients are e_r and P, Q is their corresponding dimensions.

The Table.1 shows that horizontal subband, which consists of more energy than vertical and diagonal. Watermark embedding in horizontal subbands provide more robustness as their energy compaction make them strong for attacks [17]. In presented technique HL band is used to hide encrypted ECG and hospital logo. Histogram of wavelet high frequency subbands coefficients has Laplacian distribution and high frequency sub bands has less impact of disturbance on Human Visual System (HVS)[11].



(a)



(b)

Fig.3. (a) Medical image (b) Single level DWT Image

Table.1. Energy of sub-bands of a 1-level DWT of a CT image

Sub-band	Level 1
Approximation	43.0816
Horizontal detail	2.8310
Vertical detail	2.7738
Diagonal detail	0.667

2.1 ECG SIGNAL ENCRYPTION USING ADM

With Adaptive delta modulation is used to encrypt the ECG signal. Our earlier research presents an algorithm which encrypts 16 bit ECG signal to 1 bit. This algorithm efficiently reduces memory utilization and enhances PSNR when tested on set 20 images of different modalities [14]. In ADM, the present and predicted samples $y(k)$, $\tilde{y}(k)$ are compared. The comparator output $c_q(k)$ is $\pm\Delta$, where Δ is the step size. Positive or negative step size is determined by [20][14].

$$c_q(k) = \begin{cases} +\Delta & y(k) \geq \tilde{y}_q(k) \\ -\Delta & y(k) < \tilde{y}_q(k) \end{cases} \quad (2)$$

The variable step size controller in ADM modifies the gain by factor K depending on previous and current values of $c_q(k)$, The gain $t(k)$ changes as follows:

$$t(k) = \begin{cases} t(k-1) \times K & c_q(k) = c_q(k-1) \\ t(k-1)/K & c\varepsilon_q(k) \neq c_q(k-1) \end{cases} \quad (3)$$

The new predicated sample is expressed as:

$$\tilde{y}_q(k) = \tilde{y}_q(k\text{-}1) + t(k\text{-}1)c_q(k\text{-}1) \quad (4)$$

The $c_q(k)$ is encrypted 1 bit output which is embedded in an medical image which reduces the bandwidth relatively as 16 bit signal gets encrypted in 1 bit. The Fig.4(a)-Fig.4(c) shows the original ECG signal, encrypted signal using ADM and reconstructed signal.

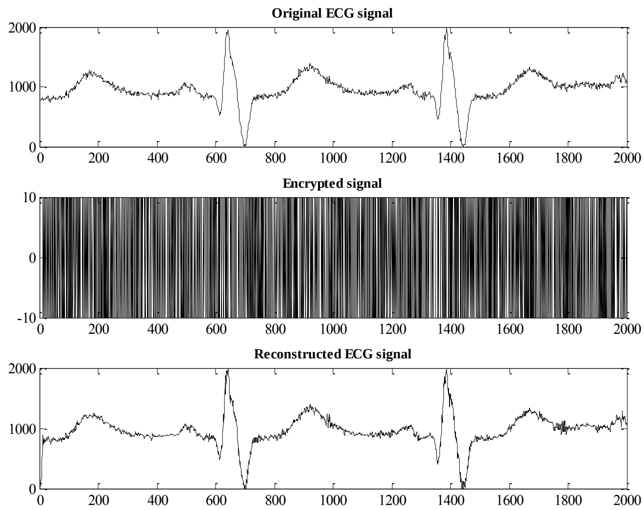


Fig.4. ECG Encryption using ADM (a) ECG signal (b) ADM encrypted signal (c) Extracted ECG signal

2.2 ALGORITHMIC STETPS

1. Initialize user-defined variables:
   - Initialize $F(m,n)$ as host image.
   - Initialize w with selected watermark.
   - Initialize $D(l,k)$ as difference image
   - Initialize $R(m,n)$ as watermarked image
   - Select peak value as P_K.

   Note: Embedding process has been applied by considering $O(a,b)$ has size 4×4 and $Z(l,k)$ and $S(l,k)$ has size 4×3 and $R(a,b)$ has size 4×4
2. Perform 1 level DWT on host image $F(m,n)$ to get LL, LH, HL, HH sub bands.
3. Select HL sun band of size $(m/2,n/2)$ for watermark embedding based on calculated energy values
4. Divide the HL sub-band into 4×4 blocks which is noted as $O(a,b)$.
5. Generate difference image $D(l,k)$ of size $[a\times(b\text{-}1)]$ for each block by taking difference of adjacent columns as follow

```
for i = 1:1:a
    for j = 1:1:b-1;
        D(l,k))=abs(O(i,j) - O(i,j+1));
    end
end
```

6. Plot histogram of difference image $D(l,k)$ and record the peak value as P_K for each block.
7. Perform histogram shifting on each block of difference image $D(l,k)$ to get the modified image $S(l,k)$ by comparing peak value P_K with coefficient of difference image $D(l,k)$. If the value of $D(l,k)$ is greater than the peak value P_K then add one in the value of $D(l,k)$ to get the coefficient of $S(l,k)$ otherwise keep the value of $D(l,k)$ as it is in $S(l,k)$ as shown below:

```
for i = 1:1:l
    for j = 1:1:k;
        if D(i,j)>P_K
            S(i,j)=D(i,j)+1;
        else
            S(i,j)=D(i,j);
        end
    end
end
```

8. Obtain watermark bit stream w from Logo and encrypted ECG signal.
9. Embed the watermark bits w into each block of modified image $S(l,k)$ by comparing pixel value of $S(l,k)$and peak point P_K. If pixel value of $S(l,k)$ is same as P_k then add w into $S(l,k)$ to generate modified difference image $Z(l,k)$. Otherwise keep $S(l,k)$ value as it is.

```
for i = 1:1:l
    for j = 1:1:k
        if S(i,j) == P_K
            Z(i,j) = S(i,j) + w;
        else
            Z(i,j)=S(i,j);
        end
    end
end
```

10. Generate watermarked image block $R(a,b)$ by comparing $O(a,b)$ and $Z(l,k)$.

Case 1. First column of watermarked image block $R(a,1)$ is obtained by comparing first two columns of $O(a,b)$.

If the coefficient of first column $O(a,1)$ is less than or equal to coefficient of second column $O(a,2)$ then keep the value of first column $O(a,1)$ as it is in the watermarked marked image $R(a,1)$, otherwise $R(a,1)$ is modified as addition of the coefficient value of $O(a,2)$ to $Z(a,1)$

Case 2. Second column of watermarked image is $R(a,2)$is obtained by comparing first two columns of $O(a,b)$.

If the coefficient of first column $O(a,1)$ is less than or equal to coefficient of second column $O(a,2)$ then modify $R(a,2)$ by adding the value of $O(a,1)$ with $Z(a,1)$, otherwise keep the coefficient value of $O(a,2)$ in $R(a,2)$.

Case 3. Remaining columns are obtained as follows

i) $R(a,3)$ is obtained by comparing the values of $O(a,2)$ and $O(a,3)$. If the pixel value of $O(a,2)$ is less than or equal to the pixel value of $O(a,3)$ then $R(a,3)$ is obtained by adding the value of $R(a,2)$ to $Z(a,2)$, otherwise subtract the value of $Z(a,2)$ from $R(a,2)$ to obtain $R(a,3)$.

ii) $R(a,4)$ is obtained by comparing the values of $O(a,3)$ and $O(a,4)$. If the pixel value of $O(a,3)$ is less than or equal to the pixel value of $O(a,4)$ then $R(a,4)$ is obtained by adding the value of $R(a,3)$to $Z(a,3)$ otherwise subtract the value of $Z(a,3)$ from $R(a,3)$) to obtain $R(a,4)$.

The steps are briefed as follows

```
for i = 1:1:a
  for j = 1:1:b
    if(j == 1)
      if(O(i,j) <= O(i,j+1))
        R(i,j)=O(i,j);
      else
        R(i,j) = O(i,j+1)+Z(i,j);
      end
    elseif(j == 2)
      if(O(i,j-1) <= O(i,j))
          R(i,j) = O(i,j-1) + Z(i,j-1);
      else
          R(i,j) = O(i,j);
      end
    else
      if(O(i,j-1) <= O(i,j))
        R(i,j) = R(i,j-1) + Z(i,j-1);
      else
        R(i,j) = R(i,j-1) - Z(i,j-1);
      end
    end
  end
end
```

11. Perform IDWT to get watermarked image $R(m,n)$.

12. Extraction of watermark, host image is done in reverse way.

In this process, peak value acts like a secret key which will improve the security aspect similar way which is highlighted by N_i [18].

The Fig.5 and Fig.6 illustrates an example for hiding a bit streams and recover the original image after extracting the bit streams using mentioned algorithm.

140	139	138	135
142	141	143	145
145	149	150	153
115	122	124	127

(a) DWT Image O_b

1	1	3
1	2	2
4	1	3
7	2	3

(b) Difference Image D_b

1	1	4
1	3	3
5	1	4
8	3	4

(c) Modified Difference Image D_b'

1	2	4
1	3	3
5	2	4
8	3	4

(d) Hidden Difference Image D_b''

140	139	137	133
142	141	144	147
145	150	152	156
115	123	126	130

(e) watermarked image M_b

Fig.5. Example of the Hiding steps for bit stream 0101

140	139	137	133
142	141	144	147
145	150	152	156
115	123	126	130

(a) Watermarked Image M_b

1	2	4
1	3	3
5	2	4
8	3	4

(b) Difference Image MD_b

1	1	4	1
1	3	3	1
5	1	4	5
8	3	4	8

(c) Modified Difference Image MD_b'

1	1	3
1	2	2
4	1	3
7	2	3

(d) Reconstructed Difference Image RD_b''

140	139	138	135
142	141	143	145
145	149	150	153
115	122	124	127

(e) Recovered image RO_b

Fig.6. Example of extracting steps for bit stream 0101

3. EXPERIMENTAL RESULTS

The experimentation is carried out on different medical imaging modalities like MRI, MRA, CT, and US with each set containing 20 images of size 512×512 pixels. The algorithm interleaves hospital logo of size 90×90 and heart rate signal (ECG) of size 2000 bytes in the medical image. Quality measures like PSNR, Normalized mean square error (NRMSE), and Mean Structural Similarity Index Metrics (MSSIM) are used to evaluate the efficacy of the algorithm in terms of imperceptibility and similarity of original and watermarked image. Robustness of the algorithm is checked by using various attacks like, rotating, sharpening, blurring, and salt and pepper noise.

ECG samples are taken from database (MIT-DB) [21]. Performance of the algorithm is also tested on spatial domain and results are tabulated. The PSNR is important quality measure which generally consider as efficient numerical measure of image distortion and it is very useful in medical applications calculated as,

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \tag{5}$$

where, MSE is mean square error.

Also, NRMSE is computed to check alteration in the original image contents, given as:

$$NRMSE(\%) = \sqrt{\frac{\sum_{I=1}^{M}\sum_{J=1}^{N}\left(Q(I,J) - Q'(I,J)\right)^2}{\sum_{I=1}^{M}\sum_{J=1}^{N}\left(Q(I,J)\right)^2}} \times 100 \tag{6}$$

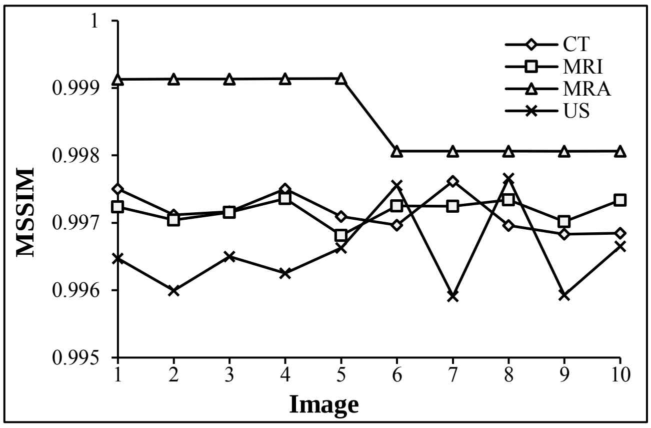
Lin et al. [13] has implemented multilevel data hiding technique, for first level data hiding using general images (Lena, Baboon etc.) 48.67dB PSNR is achieved also author claims as number of level increases PSNR drastically decreases to 23.53 dB however; for medical images multilevel hiding is not suitable. The tabulated experimental results show that even though hiding capacity is increased perceptual integrity does not hamper as PSNR values are above 50 dB in both spatial and frequency domain approach.

Table.2. Quality Measures for different Medical Image Modalities

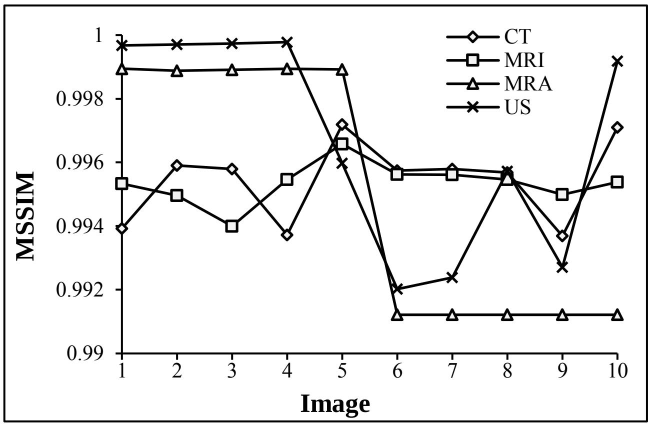
Quality Measure	Technique	Hospital Logo + ECG			
		MRI	**MRA**	**CT**	**US**
PSNR	DWT-Histogram	54.93	55.42	55.02	53.42
	Histogram	58.34	57.69	56.99	58.33
NRMSE (%)	DWT-Histogram	0.92	0.60	0.55	1.32
	Histogram	0.61	0.52	0.44	0.79

DWT-histogram approach is more suitable than the histogram approach as the histogram differ as per the image and hiding a high payload will increase noticeable disturbance [11], which is not desirable in medical image watermarking. Also, the spatial domain that is only histogram approach is fragile in nature so DWT based histogram approach is preferred.

DWT based histogram modification approach offers good imperceptibility as average PSNR value is greater than 53dB and NRMSE value is less than 1.5% as indicated in Table.2.



(a) DWT-Histogram technique

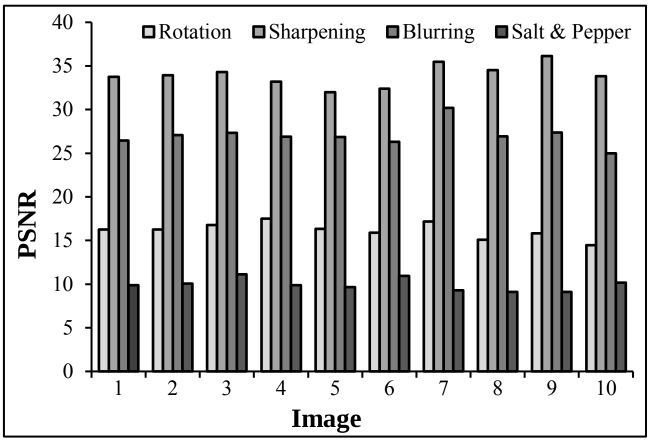


(b) Histogram Technique

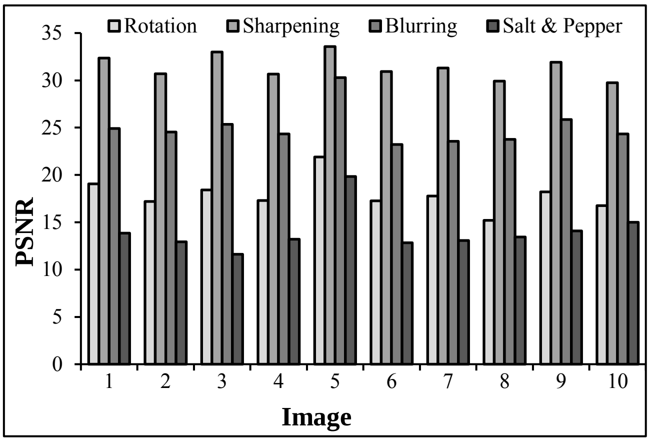
Fig.7. MSSIM Plot for medical image modalities

The Fig.7 demonstrates the plot of MSSIM values of watermarked image for different modalities which clarifies that watermarking image is almost similar with original image as value is nearest to 1. The Fig.8 showcases the effect of attacks. The graphical result shows that the algorithm is sustained for blurring and sharpening attacks as compare to other attacks as

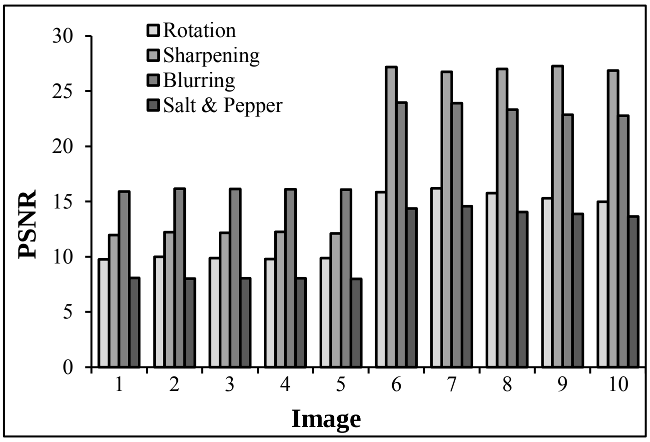
PSNR is not much hampered. The Fig.9 illustrates that the nature and the shape of the histogram are preserved even after interleaving the patients' credentials which shows of both original and watermarked image is similar and hence perceptual integrity is preserved using DWT-Histogram. Subjective analysis has been done by taking experts opinion and our approach preserves medical diagnosis details as well.



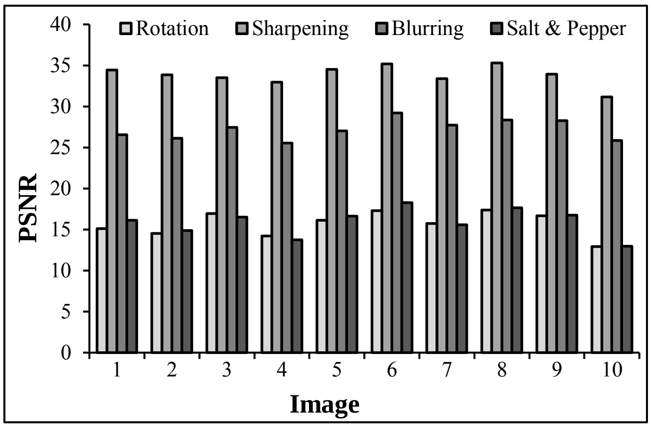
(a) DWT - Histogram: CT Modality



(b) DWT - Histogram: MRA Modality

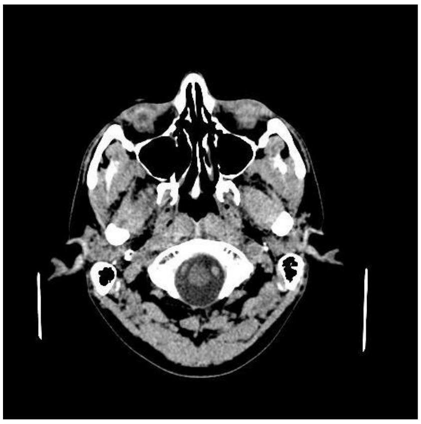


(c) DWT - Histogram: MRI Modality

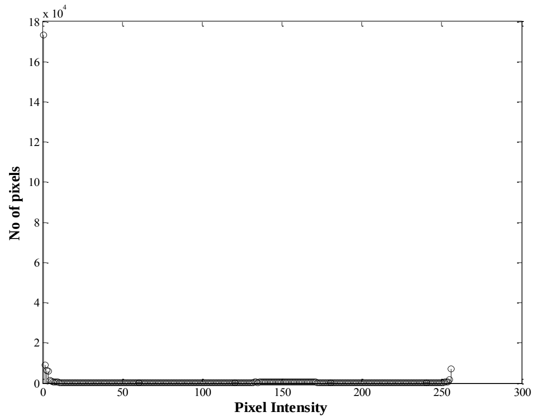


(d) DWT - Histogram: US Modality

Fig.8. PSNR of medical images after applying various attacks



(a)



(b)

Fig.9. (a) Watermarked Image (b) Histogram of Watermarked image

4. DISCUSSION AND CONCLUSION

Histogram based invertible technique is implemented for medical image authentication using histogram modification and shifting in wavelet domain. Patient's credentials like ECG signal encrypted using ADM and hospital logo is interleaved in medical image. The technique is proved to be competent as it preserves the diagnostic details of medical image. Perceptual integrity of an image is preserved as PSNR value is above 50dB even though the hiding capacity is increased. It is necessary to compare and contrast the proposed work with the state of art methods. The state of art methods use DWT [11] but the methods have achieved less PSNR and have been able to hide only limited size data. As already discussed, Lin et al. explores the use of multilevel reversible data hiding approach [13]. The reported approach successfully achieves the increase in the hiding capacity. However, the PSNR of the image is hampered with the increase in the level. It is highly imperative to preserve the PSNR in case of the medical images. Moreover, it is also of paramount importance to validate the efficacy of the algorithm for various attacks that are likely to have an adverse effect on the PSNR. The reported studies do not consider or address this fact. The algorithm presented in this paper is reversible and additionally achieves acceptable hiding capacity without compromising on the values of PSNR. It is also necessary to emphasise that the obtained results are robust and withstand the general attacks on an image and are therefore superior as compared to the state of art methods. The high values of PSNR ensure the perceptual integrity, authentication of the patient's data and bandwidth reduction of the medical images as compared to the state of art methods. Our further work aims to incorporate tamper detection as the further enhancement in the proposed study.

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