Enhanced Data Security and Integrity using Contourlet Transform for Medical Images

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Abstract

Objective: The objective of this framework is to analyze the security, compression ratio and integrity by using segmentation algorithm and transformation to extract the tumor region from MRI brain image and to observe its performance metrics. Methods/Statistical Analysis: This paper offers a futuristic healthcare solution to encompass of segmenting the ROI using Bhattacharya coefficient algorithms and successively applying the modified EMD steganography method centered on contourlet transform. This framework also challenges to verify the integrity of ROI using SHA-1, precisely senses any variation in ROI, furthermore, it ensures robustness of the entrenched data in non-region of interest and mends ROI perfectly for investigation. Lastly the whole image is encrypted with modified Logistic map encryption in order to afford overall security. Findings: This work recapitulates the contrast of distinct embedding algorithms viz. Least Significant Bit - Discrete Cosine Transform (LSB-DCT) and no-shrinkage F5-Integer Wavelet Transform (nsF5-IWT) with Improved Exploiting Modification Direction-Contourlet Transform (IEMD-CT) for embedding processes. The performance analysis of integrity check during transmission is verified using Secure Hash Algorithm 1 (SHA-1). Experimental endings deliberate Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM), Mean Square Error (MSE), Bit Error Rate (BER), Signal to Noise Ratio (SNR) as performance metrics and found the effectiveness of the proposed framework over conventional methods. Application/Improvements: This framework can be exploited in telemedicine applications in order to obtained with meticulousness in tumor location for effective healthcare services.

Keywords: Brain Tumor, Confidentiality, Contourlet Transform, Integrity, MRI Image, Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index Measure (SSIM), Tumor Extraction

1. Introduction

Telemedicine plays an imperative role in transmitting the patient medical images and data between the end users. The increase in demand for medical facilities and subsequently medical expenses will too upsurge. To overcome the addressed issues, many researchers are doing research on telemedicine applications using communication technologies for healthcare services. With some modifications in healthcare scenario investigates the medical schemes based on portable monitoring device using communication technologies. Moreover, it is significant to make clear that the medical information has not been altered while transmitting through networks. Therefore, for proper analysis on the receiver side, the data integrity of ROI is the major limitation. Mostly fuzzy models characteristically use thresholding methods to progress the non-enhanced region of the tumor. After the image has been segmented, the patient medical information is to be embedded inside RONI using an appropriate transform.

Directional selectivity is the major shortcoming of wavelet transformation since it affords an image...
representation with local frequency range of spatial scales and hence, it does not signify 2D singularities efficiently which in turn will create artifacts on the boundaries of the restored image. In another work, the author has presented ridge let transform in which boundaries are characteristically curved relatively than straight and ridge lets only cannot produce effectual demonstration\(^3\). In\(^4\), the author has well-defined the curvelet transform directly through frequency allocating without using ridge let. In frequency domain, the images are sampled on the quadrangular lattice, such that the implementation of the curvelet transforms in discrete domain is very challenging. In\(^5\), the author exploits contourlet transform coefficients to choose contour regions of the medical image schemes. This transform can competently estimate a contour region at several smooth resolutions whereas in the frequency domain, the contourlet encompasses of directional and multi-scale decomposition using filters which provides directionality and anisotropy.

Though security is the major concern for transmitting the medical image and it is too simple for the hackers to alter the images during transmission through public networks. Hence, it is critical to provide security for the patient images to avoid some illegal changes. Three major security issues are noticed, namely integrity, authenticity, and confidentiality. Digital watermarking method changes the bits in the pixel in an imperceptible way in order to embed patient information inside the medical image\(^6\). Owing to embedding the data in an image causes a change which is not accepted. Apart from security aspects, the steganography structure is categorized by invisibility, capacity and robustness. Watermarking method has been implemented in frequency and spatial domain\(^7\). In\(^8\), the author has proposed an ROI based watermarking technique in which three watermarks are generated for different purposes. This method is very complex and might fail in case of any modification.

In\(^9\) the author has proposed blind region based lossless watermarking technique with tamper detection and localization. This algorithm detects the tamper region effectively and thus sustaining the complete ROI. Furthermore the obtained PSNR values for reconstructing image are within 40 dB. Even though this technique affords better security, but the quality of the image is very poor. In\(^10\), the author has suggested an efficient embedding technique using JPEG algorithm. Owing to the arbitrary variety of no shrinkage f5 (nsf5), the DCT coefficients gets altered easily with smaller magnitude. In\(^11\), the author has proposed an enhanced embedding technique for exploiting modification direction (EMD), which ensures a better embedding capability and better PSNR. The motivation behind this algorithm is in every secret digit, a \((2n+1)\) - ary notational scheme can be conceded through solitary cover pixel. The technique achieves twice of the capacity than the conventional EMD method.

Various signature patterns were demonstrated to provide security for data as well as image under convinced complications. A verification system based on off-line signature on a displacement technique has been proposed by the author in\(^12\). The displacement tasks are extracted for any pair of signatures. However the enactment of the proposed technique is solely based on the average error rate. In\(^13\), the author has offered digital signature algorithms in which the ROI is extracted by the use of hash algorithm. Finally an encryption technique has been used to ensure a second level of security.

Data Encryption Standard (DES) and Advanced Encryption Standard (AES) are intended by diffusion properties and better confusion\(^14\). These algorithms are generally originated in chaotic behavior which is sensitive to performance parameters. In\(^15\) a modified substitution-diffusion cryptosystems has been proposed. Due to arithmetic and logical operation, diffusion effect is habituated in substitution phase. Additionally the efficiency of the encryption is increased owing to additional rounds required and it is not resistance to homogeneous attack. In\(^16\), the author has proposed an algorithm which produces ensures chaotic behavior using a single secret-key, different convolution are involved to rearrange the location of the pixels and some sequences are used to confuse and diffuse the image pixels values. The concert shows that it provides high security, speed of encryption is high and strong robustness but attains a good encryption effect over encryption errors and then it consequently guarantees a high range of security. Considering all the above facts into account, the significance or the need for an integrated framework ensuring both reliability and security were felt. Consequently, the major focus of this work is to offer enhanced medical data security without compromising reliability.

The proposed work is structured as surveys: Section I surveys the introduction and literature survey in detail. Section II comprises of the projected framework. The investigational outcomes and argument are presented in section III. Lastly the section IV completes this paper.
2. Proposed Framework

The proposed work encompasses of different sections to accomplish Bhattacharyya coefficient segmentation, improved EMD data embedding technique, confidentiality and integrity using SHA-1 as presented in flowchart Figure 1. Initially the brain tumor image is segregated into region of interest (ROI) and non-region of interest (NROI) using the segmentation technique. Then the patient medical information is embedded along with a hash function to secure the ROI in the original image. By using Bhattacharyya coefficient segmentation the tumor detection is performed. The high frequency components are alienated using contourlet transform to embed patient medical information. And the cropped tumor image (ROI) obtained from Bhattacharyya method is exposed to hash algorithm for ensuring integrity. Finally, by using modified logistic map algorithm the image is encrypted and then communicated Figure 1. On the other end, the image has been decrypted and recovers the details of ROI in the original image. Then the integrity of ROI is validated at the receiver end to avoid data mismatch. From the analysis, it is concluded that the projected framework affords good visual perception in terms of PSNR and MSE and also ensures integrity in receiver side by means of hash values, which enables misdiagnosis at the Physician end in a telemedicine scenario. The overall process is accomplished by four phases, which is deliberated in detail successively.

2.1 Segmentation Phase

In\textsuperscript{17}, the authors have suggested a Bhattacharyya coefficient segmentation algorithm to identify brain tumor from the brain Magnetic Resonance Imaging (MRI). In this framework, a Bhattacharyya coefficient algorithm benefits enormously due to its fast, automatic and error free segmentation technique that bounds the list of issues by limiting a rectangular box, adjacent to the brain tumor region in a Medical image\textsuperscript{18}. To retrieve the medical information from the MRI image, BC segmentation is applied to find out the tumor region.

The Bhattacharyya coefficient is

\[ BC(a, b) = \sum_i \sqrt{a(i) + b(i)} \]  

Using Equation 1, BC segmentation has been accomplished for six distinct MRI brain tumor images which is shown in Figure 2 and Figure 3 proves that the segmented ROI in MRI images.

Figure 1. Flowchart Representation of the Proposed Integrated Framework.

Figure 2. (a),(b),(c),(d),(e) Bhattacharyya coefficient based segmentation output for six different MRI brain images.

Figure 3. (a) Input Image (b) Segmented Image (c) Extracted ROI.
2.2 SHA-1 algorithm

After identifying the tumor using a Bhattacharya coefficient algorithm, the tumor region is hashed using a SHA-1 algorithm to ensure integrity between the transmitter and receiver. SHA-1 hashing functions are commonly hired in several security applications and protocols. In the hash value has been calculated using MD5 for the region of interest of medical image. Input information is deliberated as a sequence of zero's and one's where the magnitude of the data is the input sequence. The resolution of information padding is to produce padded information of magnitude equal to several of 512 bits. The reason behind the SHA-1 algorithm is the evolution of data as 'n' number of 512-bit chunks when computing the message digest. The detailed algorithm can be referred from.

2.3 Contourlet Transform

In conventional transforms like integer wavelet, Fourier transform, etc. the main challenge is to capture the geometry of image edges from the discrete sequence of data. Hence, distinctly transforms like curvelets, was initially developed in both time domain and frequency domain. Using non-separable filter banks, a multi resolution domain and multi direction extension are developed using filters in such a way that wavelets were constructed. This encompasses more flexible and it captures geometric properties of an image using curved fragments called contourlet. It has recapitulated filter banks that involves amandate of N processes for N number of pixels. In contourlet transform, two filters, namely Laplacian pyramid stage with “9-7” filters and directional filter bank with“23-45” biorthogonal filters must be used to ensure the better outcomes for patient medical images. The number of decomposition phase in the directional filter bank is twice at every improved scale and it is almost identical to five at the improved level. In these circumstances, the similar detail Wj has been shared by wavelet and the contourlet transforms. The dissimilarity is that for every detail coefficients of wavelet transform Wj is signified by three diverse directions, whereas in the contourlet transform it is characterized by more directional features. Figure 4 shows a representation of CT medical image using contourlet transform. It is noticed that contourlet transform matches by both in different directions and position of image in order to represents significant coefficients.

2.4 Improved EMD Embedding Process

Exploited Modification Direction (EMD) technique conceals the patient information and hash value into a cover image. Two phases are involved to accomplish huge pay-
loads. Initially the pixels are defined as gray scale values in a cluster, namely \( C_1, C_2, C_3, \ldots, C_n \) and segregate the values into equal loads with size \( m \).

Let \( \{b_1, b_2, \ldots, b_n\} = \left\{ \frac{C_1}{m}, \frac{C_2}{m}, \ldots, \frac{C_m}{m} \right\} \) \quad (3)

Equation (3) signifies a group of pixels. Using the number sets \( \{b_1, b_2, \ldots, b_n\} \), the extraction function \( f' \) is obtained by Equation (4)

\[
f'(b_1, b_2, \ldots, b_n) = \left[ \sum_{i=1}^{n} (i*b_i) \right] \mod(2n + 1)
\]

The cover image pixels remains as it is when the secret digit \( d = f' \) function of a cluster. If the \( d \neq f' \) then

\[
s = (d - f') \mod(2n + 1).
\]

If \( s \) is smaller than \( n \) which may increase \( g_s \) by \( m \) otherwise, decreases \( C_{2n+1-s} \) by \( m \).

If there is any modification in the bucket number \( m \), then the secret digit is embedding again. The two-stage embedding scheme has been used to perform \( m+1 \) operation for every stego pixels. In this algorithm, \( n/2 \) digits in the \( 5 \)-ary notational system and one in the \( (2n+1) \)-ary notational system, signifying \( (n/2) \log_5(2n+1) + \log_2(2n+1) \) bits, are entrenched into \( n \) concealment value of pixels. Consequently, the entrenching proportion \( R' \) is given as

\[
R' = \frac{(n/2) \log_5(2n+1) + \log_2(2n+1)}{n} = 2R
\]

From Equation 5, implies that the embedding rate is doubled than that of the original EMD entrenching algorithm.

### 2.5 Modified Logistic Map Encryption

Finally, a distinct security enactment has been made to make sure of high level security for the image and embedded data. In this proposed work, encryption is performed using chaotic map to ensure security during transmission. Chaotic map encryption comprises of two independent phases, namely substitution and diffusion. Affording to certain transformations, all the pixels in an image are permutated without altering the values. To split the correlation between neighboring pixels in an image, there are \( n \) rounds of permutation, where \( n \) is greater than unity. At the end of the phase, every value of the pixel is substituted by a new one in the same image. Thus the confusion arises in this phase. Conversely the values of the pixels never changed and the histogram is similar as that as without transformation. Subsequently, the range of the pixel are altered in the circulation phase consecutively, such that, a small variation in a pixel values extents over the whole medical image. The entire substitution and diffusion system \( S \) replicates for \( m \) stretches \( (m \geq 1) \) to accomplish a suitable level of encryption. To enrich the level of security still, the limitations dominant the permutation and the diffusion must be different in consecutive sequences. This is attained by a circular key maker with an initial secret key as response. The substitution and diffusion phase of the chaotic map encryption is illustrated in Figure 5.

Figure 5 displays the improved encryption process. The dissemination proportion is enhanced and the better security is sustained in less encryption sequences. The speed of the complete encryption is promoted. In the improved substitution phase, the iteration result of 3D chaotic map is intended conferring to the new position of the pixel using the equation (6). Nevertheless, before rearranging the coefficients of pixels, diffusion consequence is introduced with the preceding Permuted pixel values. Arithmetic operation are involved in the algorithm which provides the best simulation outcomes.

Thus the unique value of the pixel is given by

\[
v_i = c_{xy} \left[ (p_i + v_{i-1}) \mod L, LSB_3 (v_{i-1}) \right]
\]

Where \( p_i \) is the current value of pixel.

\( L \) is the conceivable gray levels.

\( v_{i-1} \) is the \( (i-1) \)th pixel after encryption

\( C_{xy}[s, q] \) denotes right cyclic shift

To examine the efficiency of encryption, the relationships among two adjacent values of the pixels are estimated in different directions. Two steps are involved to find out the correlation between the two pixels. Initially, choose \( P \) sets of two horizontal neighboring pixels randomly then estimate the relationship between the coefficient \( r_{uv} \) of
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For the arbitrary image, the data of the two encrypted images are dissimilar in nature. This infers that encryption can meritoriously segregate the neighboring pixels in the original image. As the illustration, the correspondence disseminations of dual level neighboring pixels of the original image and the encrypted image are attained by the modified chaotic logistic map encryption is shown in Figure 6 respectively.

Figure 6. Correlation analysis of two horizontal adjacent pixels.

3. Investigational Analysis and Discussion

The proposed work is compared with two different embedding schemes, namely NSF5-IWT and LSB-DCT for medical imaging modalities like CT and MRI images. On the whole, the performance metrics such as MSE, PSNR and Structural Similarity Index (SSIM) were calculated. The outcome of the projected work achieves better results in all the constraints. This is due to the point that the contourlet based technique performs well since it decomposes the image effectively by approximating a contour at several level resolutions. Furthermore, it provides directionality by which it delivers better PSNR in the received image. From Table 1 it is shown that there is an increase in PSNR value of 58.7 dB to 64.82 dB, the MSE value decreases from 0.0963 to 0.0432, SSIM value also upturns from 0.9765 to 0.9967 for MRI brain tumor images when associated by Integer wavelet based steganography. Whereas for CT images the PSNR value rises from 60.04 dB to 64.72 dB, MSE value also reduces from 0.0376 to 0.0177 when compared with Integer wavelet based steganography. Finally, the SSIM value of IWT based steganography accomplishes the value of 0.9832, whereas the proposed scheme deals a high value of SSIM 0.99 which is obviously designated in Table 1. The average PSNR value is improved as 6.264 dB and 9.1 dB which are attained through the framework for CT and MRI images correspondingly over NSF5 entrenching algorithm.

Table 2. shows that, two distinct algorithms, namely NSF5-IWT and LSB-DCT is compared with the proposed scheme in terms of payload. The performance metrics such as MSE, PSNR and SSIM are computed. The analysis designates that the proposed work accomplishes a considerable progression in all the aspects consistently. This is owing to the fact that the enhanced EMD algorithm associates different pixel clusters to suggest more entrenching directions with small deviation of the image pixels than that of the EMD algorithm. By selecting the appropriate combination of pixel clusters, the competence of embedding and the superiority of visual perception of the cover image is improved. From the obtained results, it is settled that when the payload is 0.02 bpc, there is an upsurge in PSNR value from 58.72 dB to 64.82 dB and when the payload is 0.04 bpc, there is an intense enhancement in PSNR value from 55.73 dB to 62.15 dB. Then, the MSE value diminishes from 0.0414 to 0.0175 and from 0.478 to 0.0185 when the payload is 0.02 and 0.04 respectively. Finally, the SSIM value for IWT based embedded technique achieves the value of 0.9741, while the proposed work affords a high value of SSIM (average of 0.99) which is clearly directed in the Table 2. Last but not least, the experimental results demonstrated that contourlet based steganography perfectly renovates the original signal without conceding the superiority of the original image.

Table 3. illustrate the performance analysis of integrity check during transmission. The exploratory conclusions are consummate with two image modalities like CT and MRI images. For different kinds of images, the implication of the involved parameters like Bit error rate, integrity analysis were analyzed for the proposed technique during the data communication over an unsecured passage. This is due to the fact that secure hash algorithm have gained great accomplishment in ensuring that information remains unchanged and provide robustness in real time scenarios. From the attained outcome, it concludes when the signal to noise
Table 1. Performance investigation of distinct embedding methods

| S.no | Image type       | LSB-DCT       | NSF5-IWT       | Proposed       |
|------|------------------|---------------|----------------|----------------|
|      |                  | PSNR | SSIM | MSE  | PSNR | SSIM | MSE  | PSNR | SSIM | MSE  |
| 1    | MRI Brain image  | 50.7 | 0.87976 | 0.0872 | 61.8 | 0.9845 | 0.0349 | 65.70 | 0.9982 | 0.0166 |
| 2    |                  | 48.81 | 0.84673 | 0.0963 | 58.7 | 0.9765 | 0.0432 | 64.82 | 0.9967 | 0.0168 |
| 3    |                  | 46.13 | 0.81734 | 0.1061 | 57.1 | 0.9711 | 0.0498 | 64.78 | 0.9952 | 0.0157 |
| 4    |                  | 46.71 | 0.80121 | 0.1305 | 55.6 | 0.9681 | 0.0509 | 62.76 | 0.9854 | 0.0129 |
| 5    |                  | 45.21 | 0.78281 | 0.2915 | 54.7 | 0.9672 | 0.0562 | 61.22 | 0.9801 | 0.0289 |

Table 2. Performance investigation of payload in distinct steganography based transforms

| S.No | Payload (bpac) | LSB-DCT | NSF5-IWT | Proposed |
|------|---------------|---------|----------|----------|
|      |               | PSNR | SSIM | MSE  | PSNR | SSIM | MSE  | PSNR | SSIM | MSE  |
| 1    | 0.01          | 50.3 | 0.81689 | 0.0864 | 61.8 | 0.9869 | 0.0559 | 65.16 | 0.9974 | 0.0171 |
| 2    | 0.02          | 47.3 | 0.81673 | 0.0935 | 58.72 | 0.9741 | 0.0414 | 64.82 | 0.9971 | 0.0175 |
| 3    | 0.03          | 45.5 | 0.81646 | 0.0921 | 57.14 | 0.9710 | 0.0344 | 63.70 | 0.9951 | 0.0178 |
| 4    | 0.04          | 44.1 | 0.81630 | 0.1263 | 55.73 | 0.9681 | 0.4788 | 62.15 | 0.9936 | 0.0185 |
| 5    | 0.05          | 43.3 | 0.81605 | 0.1967 | 54.72 | 0.9653 | 0.513  | 61.23 | 0.9813 | 0.0198 |

Table 3. Performance analysis of integrity check mechanism during transmission

| S.NO | Image type |IFFT size| No of carriers| Amplitude clipping (db)| SNR (db)| Bit Error Rate| Integrity analysis |
|------|------------|---------|---------------|------------------------|---------|---------------|--------------------|
| 1    | MRI Images | 32      | 10            | 3                      | 20      | 0.000000      | Matched            |
| 2    | CT Images  | 32      | 10            | 3                      | 15      | 0.000000      | Matched            |
| 3    | CT Images  | 32      | 10            | 3                      | 10      | 0.000624      | Matched            |
| 4    | CT Images  | 32      | 10            | 3                      | 5       | 0.010109      | Not matched        |
| 1    | CT Images  | 32      | 10            | 3                      | 20      | 0.000000      | Matched            |
| 2    | CT Images  | 32      | 10            | 3                      | 15      | 0.000000      | Matched            |
| 3    | CT Images  | 32      | 10            | 3                      | 10      | 0.000224      | Matched            |
| 4    | CT Images  | 32      | 10            | 3                      | 5       | 0.001144      | Not matched        |
ratio (SNR) is 20 dB, 15 dB the receiver hash values matches with the transmitter hash value which make sure of integrity with closely zero error rate, while when the SNR decreases below 5 dB, the receiver hash function does not match with the transmitter hash function which does not promote integrity at the receiver end for both MRI and CT images as obvious from Table 3.

4. Conclusion

This proposed work aspires to set forth a secure structure for efficient telemedicine applications. In this projected work BC segmentation algorithm, EMD embedding technique, SHA-1 as a hash function and logistic map encryption algorithm are together used to hide patient diagnostic data in a medical image. Once it originates into the real time scenario, data integrity of ROI is significant for perfect diagnosis. A spontaneous algorithm for brain tumor segmentation is employed to obtain the ROI region in order to provide proof of legitimacy in the region of interest, a hash function of ROI is calculated by the incomes of SHA-1. Subsequently the calculated hash function is concealed in the MRI image along with the patient medical information by using contourlet transform based steganography technique to sustain the superiority of the medical image. Later, a modified logistic map encryption algorithm is employed in mandate to ensure a second phase of security before transmission. Finally the encrypted image is transmitted over the Rayleigh channel to explore the robustness of the MRI image. Moreover, at the receiver side, the image is decrypted and segmented into ROI and NROI region. Ensuing, the embedded information and hash function is recovered from the stego image and ROI is checked with recovered transmitter hash function and the calculated ROI in receiver side. This is done to achieve data reliability check. The sequence of sections in the projected work affords an improved image quality by the incomes of PSNR, MSE and also integrity checking in the region of interest by means of hash function, which comforts to improve misdiagnosis at the doctor end in telemedicine consequences.

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