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Hybrid Compression and DNA Sequence of Hyper Chaos System for Medical Image Steganography

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Abstract: Image Steganography is required in the medical field to protect the information of patients and sensitive data. The existing methods in image steganography have the limitation of lower quality of the image. In this research, the DNA sequence of hyperchaos system with hybrid compression methods of Discrete Wavelet Transform (DWT) and Neural Network is proposed for image Steganography. The medical images were used to test the performance of the developed method in terms of PSNR and MSE. The hybrid compression method improves the compression method and preserves the quality of the image in a hyper chaos system. The developed method shows that the hybrid compression method improves the quality of images in steganography. The proposed method has a 57.21 PSNR value for the cover image, DWT has a 45.26 PSNR value and Neural Network has a 44.26 PSNR value.

Keywords: Discrete wavelet transform, DNA sequence, Hyper chaos system, Image steganography, Neural network.

1. Introduction

Steganography is the process of hiding information within other data to transmit the data securely. Steganography hides secret data into host media to increase the security of the data and steganography provides secure communication for multimedia data [1]. Rapid development of intelligent mobile devices and network multimedia technology that capture, process and transmit images to provide an efficient and convenient way of communication, as widely used [2]. Image steganography hides the secret information in the cover image and its receiver recovers the secret information and the warder doesn't detect the presence of secret information. Embedding secret information in the cover image is commonly used in most steganography and has distortion. The steganalysis method is developed to measure embedded image quality based on the distortion of statistical features [3]. In a concealment system, steganography is a key technology. The steganography method has many common features related to and differs from watermarking [4]. In spatial domain steganography, a popular embedding method is Least Significant Bit (LSB). The statistical features of images are destroyed if LSB is adopted in the steganography method. Steganalyzer is easy to detect steganography. The LSB algorithm hides the least significant bit in each pixel channel in a given image [5].

Medical images are transmitted in networks conveniently for purposes of consultations, education, and research. Privacy protection and information security become greatly significant in medical image transmission on the Internet since the medical image has patients' personal information. Steganography is introduced to provide confidentiality and protection for medical images and this makes that patient information is undetectable [6, 7]. Commonly used steganography methods are Discrete Fourier Transform (DFT), Discrete Wavelet Transform (DWT), and Discrete Cosine Transform (DCT). The Reversible Data Hiding (RDH) with Differential Compression (DC) and other methods are applied for the encrypted image that has higher embedding capacity [8, 9]. The existing methods have lower efficiency in image steganography [10] and optimal selection of chaotic map improves the steganography performance. The objectives and contribution of the hybrid method were discussed below.

1. The hybrid method of DWT and NN model is proposed to perform effective compression and preserve the quality of the image. The hybrid method able to recognize the noise using NN model and compression is performed with avoiding the noise in the image.
2. Chen's hyper-chaotic system with DNA sequence model is proposed to improve the sensitivity of the encryption method. Encryption method efficiency is improved based on Quadratic Difference Expansion Algorithm.
3. Medical images were used to test the evaluation of the hybrid model in compression and steganography. The hybrid compression method has higher performance in steganography than existing methods.

This paper is organized as follows: Literature review of the existing works are presented in Section 2 and the proposed method is explained in Section 3. The result of the proposed method is given in Section 4, and the conclusion of this research work is given in Section 5.

2. Literature review

Medical images consist of sensitive information and this requires to apply secure steganography method to transmit the data. The existing methods in medical image steganography apply various techniques to improve the security of medical images. Some of the recent and notable researches in medical image steganography were reviewed in this section.

Ambika and Biradar, [11] applied Elephant Herding-Monarch Butterfly (EH-MB) method for medical image steganography for effective selection of pixels for embedding a secret message in the cover image. The EH-MB method applies cost function-based fitness function to measure pixel intensity, entropy, and edge for evaluating fitness. The 2-level DWT method was applied to convert the images into the frequency domain. The MATLAB in-built images were used to test the performance of the EH-MB method in steganography. The developed method reduces the distortion in the embedded images and preserves the quality of the images.

Kiruba and Sharmila, [12] applied FireFly Optimized hybridized Improved Seeker (FOIS) method for efficient image steganography. The FOIS method improves information security and protects medical images from cybercrimes. The pixel's optimal locations are effectively determined by the FOIS method in the cover image of spatial domains adaptively. The blocks of cover image and permutation combination were used to find several blocks. The developed method increases the quality and security of the images in transmission. Discrete Cosine Transform Coefficient of Least Significant Bits (LSB) and optimal pixel selection of each block are used for embedding a secret image. The developed method has higher performance compared to LSB, genetic algorithm, and particle swarm algorithm.

Koppu and Viswanatham, [13] applied 2D Logistic Chaotic Mapping (2DLCM) based on Self-Adaptive Grey Wolf Optimization (GWO) for image steganography. The Self-Adaptive GWO method selects the optimal chaotic system parameters for steganography. The Gaussian noise and salt and pepper noise were applied in the images to test the developed method of noise analysis. The CT, MRI and ultrasound images were used to test the performance of the developed method. The developed method performance was evaluated based on Chi-square test, quality of encryption, attacks, information entropy, adjacent pixel autocorrelation, histogram analysis and key sensitivity. The developed method performance was compared with conventional algorithms of GWO, genetic algorithm, and encryption-decryption method.

Jeevitha and Prabha, [14] applied DWT-based scrambling method for medical image steganography that extracts the edge maps from original images. The developed method consists of three phases: DWT level scrambling, edge map sequence generation and DWT plane decomposition. The edge map was estimated based on deriche edge detector method and this was similar in size to DWT-bit scales. Neighbor information was applied with DWT level scrambling and a strong correlation in neighboring pixel intensities weakens. The developed method has higher performance in terms of Unifed Average Hanged Intensity and Number of Pixel Change Rate.

Dash [15] applied multi-pass encryption method to scramble the pixels of image before hiding in steganography. The scramble mystery message is divided into two parts and uses the two duplicates of same cover image. The developed method has lower performance in preserving the quality of the image.

Yassin and Houby, [16] applied Integer Wavelet Transform (IWT) method for image steganography and high frequency bands of cover image were used to suppress secret message. Bands coefficients are labelled into six categories based Most Significant Bit (MSB) and coefficients from different bands related to same category. Embedding process starts from higher category and continue to next category based on number of coefficients. Encryption method is not used in the model to increases the security and quality of the images are degraded in the model.

Seenappa [17] applied DWT and IDWT to compress and decompress the stego image. The thresholding with morphological transform is applied for Region of Interest (RoI) segmented image in secret image. The DNA sequence with hyperchoatic system is applied for encryption and decryption of secret image. The stego image of secret and cover image was applied for embedding and extraction based on reversible watermarking.

Vivek and Gadgay [18] applied chaos method with enhanced mapping method to reduce computational complexity and fast encoding. Each pixel position of video frame is measured using Enhanced Least Significant Bit (ELSB) technique. Logistic and Henon mapping were applied to encrypt the video frame. The HEVC technique compress the input video frame and chaos with enhanced map for embedding secret video frame into cover image.

Juvvanapudi [19] applied IWT to transform the cover image into wavelet environment and Grey Wolf Optimization (GWO) method is applied to select the pixel in the image to embed the secret image in the cover image. Fitness function measures edge, pixel intensity and entropy of cover image in GWO to select the pixels in the image. Hybrid map of henon and logistic map were used with chaos encryption to encrypt the secret image.

Existing methods have the limitations of lower efficiency in preserving the quality of the images. Encryption and steganography performance were affected by the compression method. Existing DWT and IWT have lower efficiency in identify the noise in the images that affects the compression performance and quality of the image. The hybrid compression of DWT and NN is applied to identify the noise in the images and performs the compression effectively to preserve the quality of the image.

3. Proposed method

The block diagram of the proposed method is given in Fig. 1.

3.1 Compression

3.1.1. Discrete wavelet transform

The DWT decomposes the signal based on mutual orthogonal with a set of wavelets. The mother wavelet and discrete wavelet are related, as given in Eq. (1), where ψ denotes mother wavelet, τ_0 denotes translation parameter that is greater than zero, s_0 denotes scaling parameter in the fixed set at a higher than 1, the m parameter of the integer is controlled by wavelet dilation, and the parameter k is wavelet translation, as given in Eq. (1).

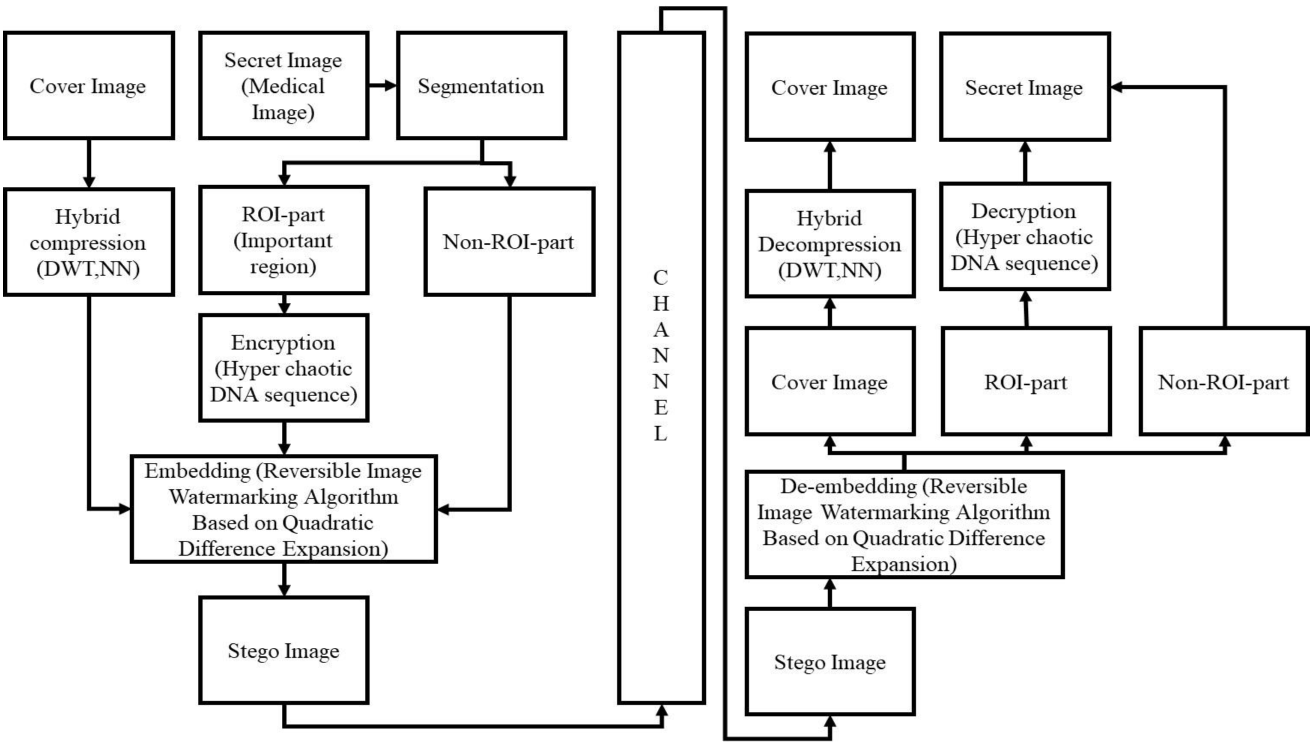


Figure. 1 The block diagram of the proposed method

$$\psi_{m,k}(t) = \frac{1}{\sqrt{s_0^m}}\psi\left(\frac{t-k\tau_0 s_0^m}{s_0^m}\right) \quad (1)$$

The DWT is measured from the original signal to obtain detail coefficient and approximation based on the high pass and low pass filtering. Each iteration process a decomposition level that provides one approximation coefficient and j detail coefficients from the selected decomposition level. The 2 decomposition levels and approximation are achieved based on the signal decomposition process using DWT tree structure. The high pass filter and a low pass filter are denoted as $h[n]$, and $h[n]$, the original input signal is denoted as $x[n]$.

3.1.2. Artificial neural network

The ANN method shows the effective performance in the non-linear analysis of input data in prediction and classification. The ANN model shows significant performance in non-linear analysis. Multi-layer of Neural architecture consists of many neurons connected to the previous layer and this is a parallel computation model. The ANN is inspired by the Human nervous system and the learning process is based on networks analysis and pattern learning. The forward process and backpropagation are two computational processes in a neural network. Activated network layers flow forward direction in the forward process of input signals i.e., input to output. The backward parameter is the error correlation step based on bias term and connection weight. The bias term and connection weight are estimated based on error correlation. The gradient descent rule is applied by backpropagation to minimize network error in classification. The forward and backward processes are applied repeatedly to achieve desired results. Various model is developed based on the neural Net model and neural network.

Artificial Neural Network with three-layered feed-forward network is discussed for better understanding. The training pattern are carried out for the input signal and the weight value is multiplied in the next layer. The weighted signal is added with each bias term and the suitable activation function to develop hidden layer output. The error value is used to weight outputs and output neurons summed up. The input and output layers based on the aforementioned process are explained as follows.

Input Unit: $o_1^1 = y$
Hidden Units: $o_i^2 = f(net_i), i = 1, \ldots, I$
$net_i = y.w_i^1 + B_i$, where f is the sigmoid activation function.

Output Unit: $N(y) = \sum_{i=1}^{I}(w_i^2.o_i^2) = \sum_{i=1}^{I}(w_i^2.f(w_i^1.y + b_i))$.

3.2 Hyper chaotic system

The diffusion structure of Chen's hyper chaos system provides more sensitive values in encryption that increases the random of encryption. Chen's hyper-chaotic system of hyper chaotic sequences is applied to encrypt the image. Eq. (2) provides Chen's hyper-chaotic system.

$$\begin{cases} \dot{x} = a(y-x) \quad ; \\ \dot{y} = -xz + dx + cy - q \quad ; \\ \dot{z} = xy - bz \quad ; \\ \dot{q} = x + k \quad ; \end{cases} \quad (2)$$

In Eq. (2), the system parameters are a, b, c, d, k, when $a = 36, b = 3, c = 28, d = 16$ and $-0.7 \leq k \leq 0.7$, four chaotic sequences is used to generate a hyper chaotic state of Chen's hyper-chaotic system. The Lyapunov exponents are 1 = 1.552, 2 = 0.023, 3 = 0, 4 = −12.573 with parameters values $a = 36, b = 3, c = 28, d = 16$ and $k = 0.2$. Two positive Lyapunov exponents are present in hyper-chaos method and system prediction time is lesser than the chaotic system and also safer than the security algorithm of chaos. Runge-Kutta method of four order is applied to solve equation from sequence x, y, z, q. The integer part and decimal part of hyper-chaotic sequences are reserved to get a better effect and get four sequences.

3.2.1. DNA sequence

Four nucleic acid bases of DNA sequence are T (thymine), G (guanine), C (cytosine), and A (adenine), where complementary are G and C, and complementary are A and T. The binary complementary are 0 and 1, complementary are 00 and 11, also complementary are 01 and 10. There are 24 kinds of coding methods that are applied to encode 00, 01, 10 and 11 using four bases A, C, G and T. The complement rule of Watson-Crick is satisfied by only eight kinds of coding methods.

The color image is encoded based on DNA code and three channels are present in the color image: Red, Green and Blue. The DNA sequence is expressed as each pixel for channel image of 8-bit that length is 4. The 173 Red channel image for the first-pixel value and DNA encoding rule 1 is applied to convert it into binary sequence [10101101] and get DNA sequence $[CCTG]$. The DNA sequence is decoded based on DNA encoding rule 1 and obtained a binary sequence [10101101]. The same DNA sequence is decoded based on DNA encoding rule 2 and obtain binary sequence [01011110] and it is a simple way of encryption.

3.2.1.1. DNA sequences based on XOR algebraic operation

The researchers presented with the DNA sequence of some algebraic and biology operations such as XOR operation with DNA computing development. The DNA sequence of XOR operation is performed based on traditional XOR in binary and DNA encoding method of eight kinds and exist eight kinds of XOR, DNA rules.

The key image and original image are fusion in XOR operation. For example, adopt one type of XOR operation to XOR DNA sequence of $[AGCT]$ and $[CTGA]$ and result sequence is $[CCTT]$. The XOR operation is reflexive and gets a sequence of $[AGCT]$ by XOR sequence of $[CATT]$ and $[CTGA]$ under XOR operation. Every column or row of one base is unique and the XOR operation result is unique. The XOR operation rule is used in this research to scramble the original image of pixel values.

3.3 Quadratic difference expansion algorithm

Adjacent pixel pair of difference expansion algorithm performs integer transform on any pixel pair $P = (x, y)$ in the image to obtain difference h and mean l. The h and l are inversely transformed and the original pixel pair values of x and y is losslessly recovered.

Eqs. (3) and (4) are positive transform:

$$l = \left\lfloor \frac{x+y}{2} \right\rfloor, \tag{3}$$

$$h = x - y \tag{4}$$

Eqs. (5) and (6) are inverse transform:

$$x' = l + \left\lfloor \frac{h'+1}{2} \right\rfloor, \tag{5}$$

$$y' = l - \left\lfloor \frac{h\prime}{2} \right\rfloor \tag{6}$$

The 1-bit left shift is carried out to obtain h and the least significant bit is embedded with watermark b , is difference expansion, and mathematical expression is $h' = 2h + b$.

The watermark information is embedded using difference expansion to obtain pixel value causes pixel overflow and inverse transform is used to obtain x' and y' that is limited in the range of [0, 255] and is not reversible. This is necessary to limit h' in Eq. (7).

$$|h'| = \min(2(255 - l), 2l + 1) \tag{7}$$

The watermarking algorithm of difference expansion applied pixel pairs difference to perform watermark embedding and has a limited capacity of embedding.

The difference transform and difference expansion are used to perform quadratic watermark embedding which is used to generate pixel pair (x', y') to improve watermark embedding capacity and visual quality. Eqs. (8) to (10) is applied for a specific process.

$$l' = \left\lfloor \frac{x'+y\prime}{2} \right\rfloor \tag{8}$$

$$h'' = x' - y' \tag{9}$$

$$h''' = \left\lfloor \frac{h\prime\prime}{2} \right\rfloor + b \tag{10}$$

Eqs. (11) and (12) is applied in inverse transform.

$$x'' = l' + \left\lfloor \frac{h'''+1}{2} \right\rfloor \tag{11}$$

$$y'' = l' - \left\lfloor \frac{h\prime\prime\prime}{2} \right\rfloor \tag{12}$$

The watermark embedding is used to generate watermarked image based on linear difference expansion and the original image is returned from the quadratic difference expansion.

4. Results

This research proposes hybrid compression method and DNA sequence of hyper chaotic system. The proposed method is evaluated on various performance metrics to test the performance in steganography. The hybrid compression of DWT and Neural Network (NN) was used in the proposed method. The sample input, cover and compressed images are shown in Fig. 2 and sample extracted and recovered images are shown in Fig. 3. Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Structural Content (SC), Normalized Cross Correlation (NCC), Average Difference (AD), and Normalized Absolute Error (NAE) were evaluated from the hybrid compression method.

The sample images of ROI, encrypted, extracted, and decrypted images are shown in Fig. 4.

The proposed method performance without compression techniques for various performance metrics is given in Table 1. This shows that the proposed method provides considerable performance without the compression method. The proposed

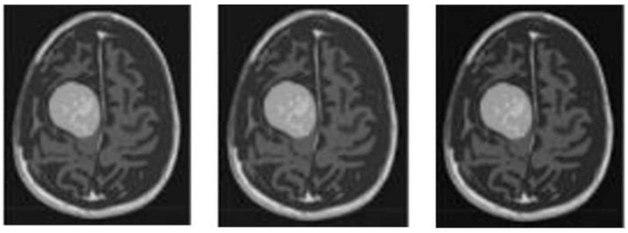


Figure. 1 The sample input, cover and compressed image

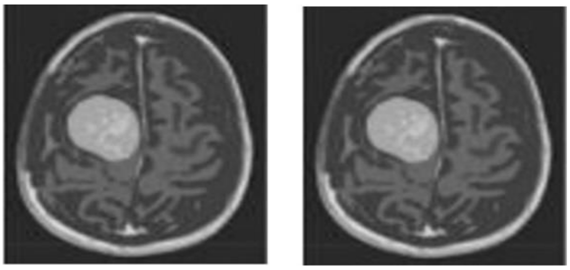
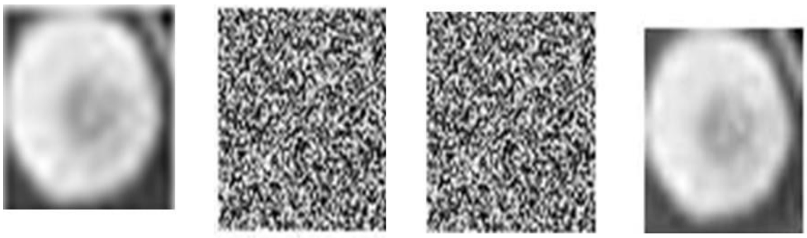


Figure. 2 Extracted and recovered image



(a) (b) (c) (d)

Figure 3. Sample images (a) ROI, (b) Encrypted, (c) Extracted, and (d) Decrypted

Table 1. Performance of proposed method without compression

	PSNR (dB)	NCC	MSE	AD	SC	NAE
Cover Image	57.217	0.99457	0.12579	0.0092143	0.99517	0.0065746
Secret Image	99.005	0.99982	0.0014863	0.0082634	0.99088	0.0095503

Table 2. Performance of the proposed method

	PSNR (dB)	NCC	MSE	AD	SC	NAE
Cover Image	46.29	0.9911	1.54	0.00688	0.07665	0.99645
Secret Image	99	0.9909	0.0094833	0.00124	0.00489	0.99657

method error value is low for both cover and secret images. The cover image has a 57.21 dB PSNR value and the Secret image has a 99.005 dB PSNR value.

The performance of the proposed method for the cover image and secret image is shown in Table 2. This shows that the proposed method has higher efficiency with compression in steganography. The hybrid compression method of the DWT and NN model improves the performance of the steganography. The proposed method has a 99 dB PSNR value for secret images and the proposed method without compression has 99.005 dB PSNR.

The proposed method with and without compression for cover and secret images is shown in Fig. 5. The proposed method with compression has a higher PSNR value compared to without compression method. The proposed method with compression has a higher PSNR value for both cover and secret images. The hybrid DWT and Neural Network method improve the performance of compression in steganography.

The proposed method MSE value with and without compression in image steganography is shown in Fig. 6. This shows that the proposed method with compression has a lower MSE value compared to the proposed method without compression. The DNA sequence of the hyperchaos method and hybrid DWT and Neural Network compression preserves the quality of the image.

The proposed method compression and individual DWT and NN compression for various metrics are shown in Table 3. As the hybrid compression method effectively handles the noises in the pixel, this reduces the error values in pixel that significantly reduces MSE and NAE value. The value of NCC, AD, and SC also increases in the hybrid compression method than single compression. The proposed hybrid compression method has higher image quality and lower error value compared to the individual method in image steganography. The proposed method has 0.12 MSE, DWT has 1.937, and Neural Network has 1.083 MSE.

The proposed hybrid compression PSNR is compared with DWT and Neural Network compression, as shown in Fig. 7. This shows that the hybrid compression method has a higher PSNR value than individual methods. The hybrid compression method has a 57.21 dB PSNR value for the cover image, DWT has a 45.26 dB PSNR value and Neural Network has a 44.26 dB PSNR value.

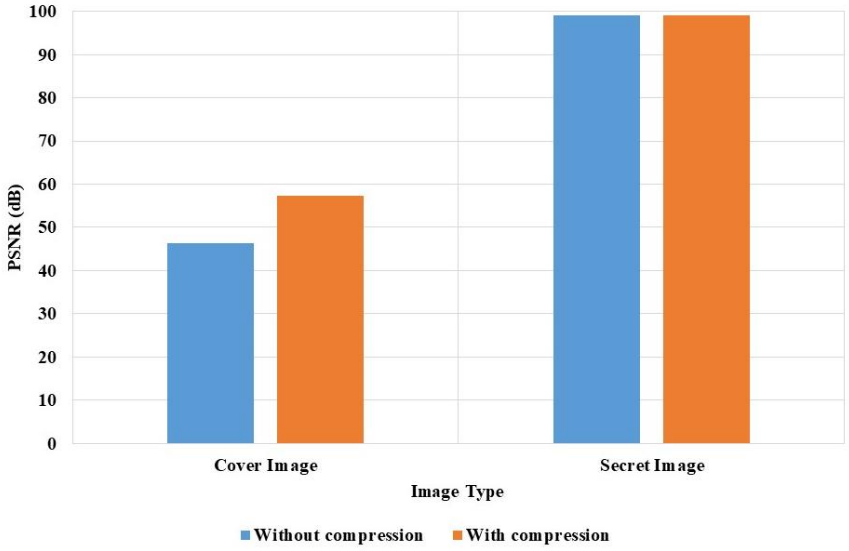


Figure. 4 PSNR value of cover and secret image with and without compression

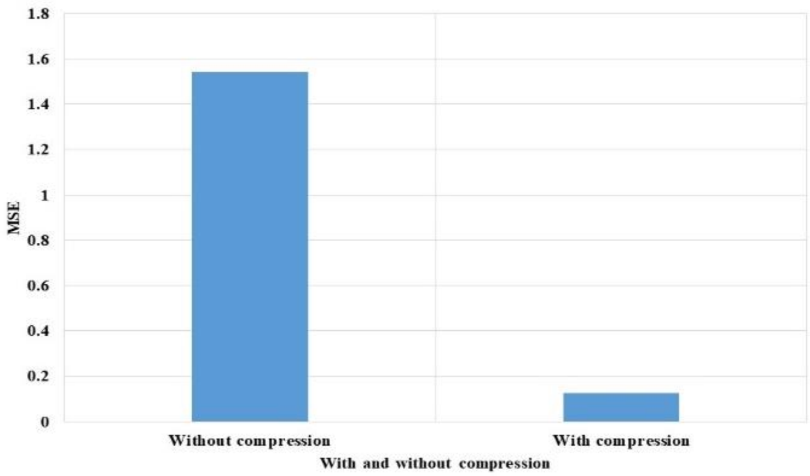


Figure. 5 The proposed method MSE value with and without compression for a cover image

Table 3. Performance metrics of proposed method with compression method

Methods	PSNR (dB)	NCC	MSE	AD	SC	NAE
DWT	45.268	0.99327	1.9377	0.082403	0.99545	0.010556
NN	44.268	0.98437	1.08347	0.093423	0.99604	0.090647
Hybrid compression	57.217	0.99457	0.12579	0.0092143	0.99517	0.0065746

4.1 Comparative analysis

The proposed method is compared with the existing method in image steganography in terms of PSNR and MSE.

The proposed method is compared with the existing EH-MBO [11] method in image steganography, as shown in Table 4. This shows that the developed method has higher performance than the existing EH-MBO technique. The developed method has the advantages of hybrid compression and the DNA sequence of the hyper chaos method improves security.

The DWT-NN model and existing steganography models were compared in Figure and Table. The DWT-NN model has higher performance in terms of PSNR in image steganography due to NN model

Table 4. Proposed method comparative analysis

Methods	PSNR (dB)	NCC	MSE	AD	SC	NAE
EH-MBO [11]	42.1776	0.876386	9.892831	0.177657	22.33333	0.996657
Proposed	57.217	0.99457	0.12579	0.009214	0.99517	0.006575

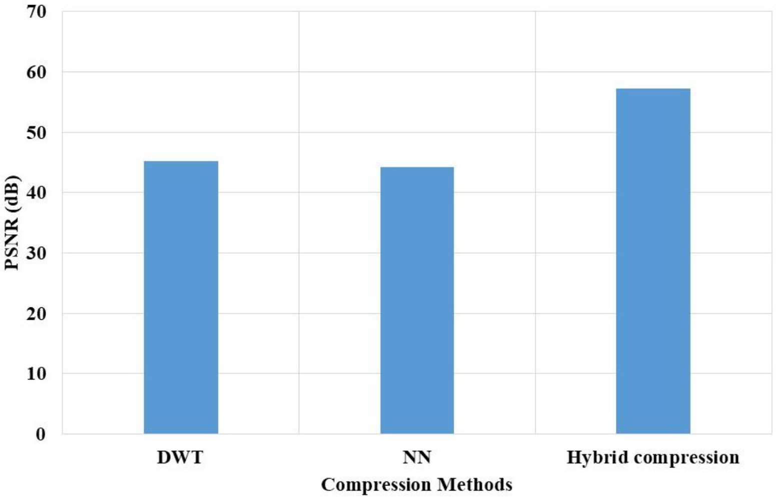


Figure. 6 PSNR value of proposed method with and without compression

Table 5. PSNR performance of Proposed method and existing methods

Methods	PSNR (dB)
EH-MBO [11]	42.1776
Multi-pass [15]	47.1
IWT [16]	46.04
Choas encryption [18]	35.42
GWO [19]	53.02
DWT-NN	57.217

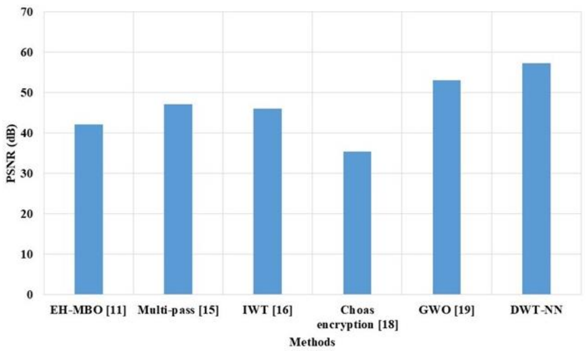


Figure. 7 PSNR value of proposed and existing methods

identify the noise and removed in the compression to preserve the quality of the image. Existing methods have lower efficiency in handling the noise in the image. The GWO [19] has considerable performance and this method easily struck local optima.

5. Conclusion

Image steganography is required in the medical image to improve the security of the model. The existing methods in image steganography have the limitations of lower efficiency in preserving the quality of the image. In this research, the DNA sequence of the hyperchaos model with the hybrid compression method of DWT and Neural Network is proposed for image steganography. The medical images were used to test the performance of the proposed method in steganography. The hybrid compression method improves the steganography performance and also has higher efficiency than the existing methods in preserving quality. The developed method has 0.12 MSE, DWT has 1.937, and Neural Network has 1.083 MSE. The proposed method's future work involves applying chaos-based algorithm to improve the sensitivity of the model.

Notations

Notation	Description
a, b, c, d, k	system parameters
B	Bias
f	sigmoid activation function
h	Difference
$h[n]$	high pass filter
j	approximation coefficient
k	wavelet translation
l	Mean
m	wavelet dilation
o	Neurons
P	Pixel pair
s_0	scaling parameter
w	Weight
$x[n]$	original input signal
x', y'	Inverse transform
y	Label
τ_0	translation parameter
ψ	mother wavelet

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

The paper background work, conceptualization, methodology, dataset collection, implementation, result analysis and comparison, preparing and editing draft, visualization have been done by first and third author.

The supervision, review of work and project administration, has been done by second author.

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