HCWT: HYBRID CONTINUOUS WAVELET TRANSFORMED STEGANOGRAPHY FOR SECRET DATA SHARING

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ABSTRACT
Information security is one of the most important factors to consider when exchanging sensitive information between two parties. Cryptography and steganography are the two techniques used for this. Encryption encrypts information but reveals the existence of information. Steganography hides the actual existence of the information and makes the transmission invisible to anyone but the sender and receiver. In steganography, the confidential information sent is hidden by another carrier, making the confidential information invisible. Steganography can be applied to various file formats such as audio, video, text, and images. In this method of thrashing an image in a different image using the Hybrid Continuous Wavelet Transform (HCWT) process, HCWT combines WFT (Windowed Fourier Transform) and CWT (Continuous Wavelet Transform). HCWT uses an LSB method that converts data into various window shapes, converts high-frequency and low-frequency components into a bitstream, and hides the data bits in the last 3 bits of the carrier medium. We support. Due to data being embedded or hiding, the size of the cover media increases. Discrete Fourier Transform (DFT) is applied to reduce steganoImage file size. On the receiver side, secreted information is restored through Inverse HCWT. The evaluation result shows enhanced PSNR and lesser MSE with improved compression ratio, capacity, and security.

Keywords: - Steganography, CWT, Hybrid CWT, Data Security, DFT, Image Compression

1. INTRODUCTION
Multimedia and data security in IT industry are the most popular terms. With the innovation of digital information processing and the potential of the high-speed Internet, digital data communications are becoming commonplace, sending a large amount of data per second over the public and private network. It is essential to hide important data from intruders, as this sensitive data can be hacked by compromising the systems. Over the last decade, many data thrashing methods have been introduced to hide important information transmitted over unsecured channels [17] [18]. Therefore, steganography has occurred. The eventual goal of steganography is toughness, unrecognizably. In addition, you can recover hidden messages using the appropriate method without knowing the original cover media.
Many digital data formats, including text, images, audio, and video, can cover secret data bits [19] [20]. Image steganography is one of the most widely used methods for the popularity of images and can be rendered in camouflage mode. An image with embedded secret data is called a "cover image" or “carrier medium”. Confidential data should be embedded in the actual cover image without distortion or identifiable differences. The image obtained after embedding is called "StegoImage". The main goal of the steganography process is to keep communications secure and without advice to intruders through visual or statistical analysis. Performance evaluation of steganography systems needs to be evaluated in various aspects.
Various data formats cover secret data bits, including text, images, audio, and video [19] [20]. Image steganography is a security enhancement technique that is commonly accepted, and it is rendered in camouflage mode. An image with embedded sensitive information is a "cover image." Confidential

data should be thrashed in the actual cover image without distortion or identifiable differences. The image resulting after the data hiding is called `StegoImage.` Major goal of the steganography process is to maintain secure message sharing, and visual or statistical analysis does not give any hint to the intruder. Many factors need to be evaluated to find the efficiency of a steganography method in different ways.

a. Steganography

Steganography is the joining of two Greek words. They are are "steganos", which means hidden or secret, and "graphics" which means writing. Steganography means 'secret writes' and 'hiding data' in objects that no one can notice or recognize. Data can be thrashed in image files, audio files or video files. Encryption provides a certain level of protection and privacy. Steganography provides a additional cover of security for your data.

b. Types of Steganography

Image steganography: The image is used as an information carrier. The images can hold important secret data bytes because the data is embedded in pixels which is invisible to the human eye.

Text steganography: Textual steganography hides the data in a text paragraph. Hidden messages change between paragraphs, and you can use keys to get information (such as characteristics) from the text paragraph.

Audio steganography: Audio steganography hides the secret data in the audio signal. The human hearing system cannot able to identify the steganographic audio signal.

Image Steganography

Digital images are the safest way to send secret information over the network using steganography. The resolution of the image depends on the pixel. A pixel is a small area of light on the screen. A pixel is made up of three components. The three components are red, green, and blue (R, G, B). The depth of every pixel is 24 bits. The size of every element is 1 byte. Each color is made up by combining these three elements. The byte value is in the 0 to 255 range. Depending on the bit value, the color is displayed. The 0 value displays dark color, and 255 displays light color. The pixels count varies depending on the picture size. For example, the image size is 750 * 500, and the image is a collection of 3.75 million pixels. A pixel consists of three factors, every component being 8 bits in size. For example, 11111111 00000000 00000000 is a pixel bit, and the pixel color is red. The color of the pixels changes according to the RGB values.

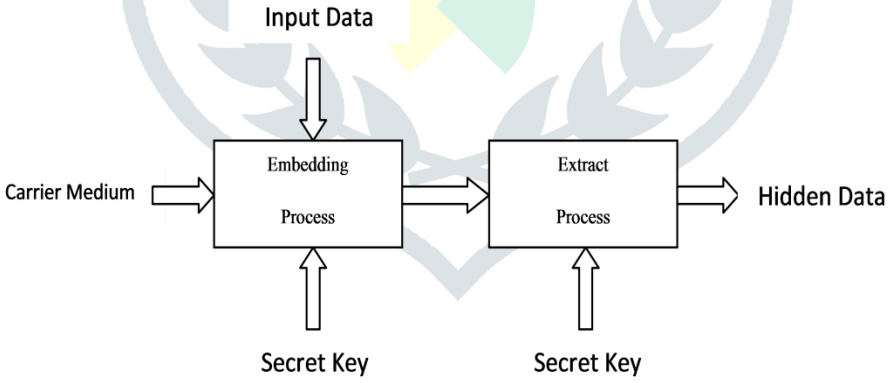

Fig. 1. LSB stego system

Secret messages embedded in the image are converted to bits according to the ASCII value. Depending on the steganography technique used, these data bits are stored in the image [3]. Steganography refers to the various high techs in which data is hidden in image files. This can be done by replacing the original data's redundant or less important bits. Fig. 1 shows a simple steganography system.

2. BACKGROUND STUDY

Kadhim, I. J., Premaratne, P., & Vial, peter J. [1] propose a new steganography approach based on confidential data hidden on the DTCWT subband of the carrier image. The secret data's high fidelity and low fidelity information are divided and thrashed in the equivalent high and low-occurrence DTCWT coefficients at the optimal match location. The flat, high-fidelity plane of the sensitive picture is separated into smaller patches, and a concentration map is used before discovering the optimal spot within the subband. Secret keys are created based on the thrashed location, and these keys are essential

to decoding the thrashed sensitive information on the receiving side. The effectiveness of different data samples at various resolutions has been benchmarked beside the latest approaches, and the results show better performance.

Liu, S., Liu, Y., Feng, C., Zhao, H., & Huang, Y [2] introduced a data security method for blockchain operation data that depends on HEVC video steganography. Data protection: The message is hidden in a 4x4 brightness QDST block after encryption, and matrix coding techniques are used to improve the proposed steganography algorithm's embedding ability and visual quality. The evaluation results prove the effectiveness of the projected method. In the future, we will investigate video steganography algorithms with improved performance and blockchain compatibility.

Pramanik, S., Samanta, D., Dutta, S., Ghosh, R., Ghonge, M., & Pandey, D [4] to hide the encrypted data in the carrier picture, we change the previous LSB technology and use a mapping feature that guarantees protected and sensitive image steganography leading to stego images. It combines cryptography and steganography, providing two levels of protection for sending sensitive messages over the network.

Q. Giboulot, P. Bas, and R. Cogranne [7] proposed a synchronized side-informed scheme synchronized in the image format area to minimize statistical detectability. It provides cutting-edge performance. It is done using a statistical model that tends to the correlation among the DCT coefficients and adds the most favorable steganography data with a covariance that is a scaled version of the carrier medium noise covariance. This process gives an apparent idea of why intra-block and inter-block dependencies improve performance, depending on your processing pipeline.

Onuma, K., & Miyata, S. [9] propose steganography using error correction code. The proposed technique enhances the data hiding ability without degrading the image quality. The proposed correlation-based steganography uses RS-code and sensitive data sharing methods. As a result, the data thrashing capacity can be enhanced eight times compared to without the RS code. However, ever since the compression resistance is not considered, there are still problems in practical use.

V, G. A., & Devanagavi, G. D. [10] propose the RandomBitSelect algorithm. The proposed technique handles pixel value bits in an image. The appeal of this RandomBit selection algorithm is that it gives the user the option of providing the user with an input from 1 to 4 that determines the data thrashing. The higher value specified by the user, the larger the embedded ability. If the user-specified value is 2, 2 bits of the pixel value are changed with the data bits. This methodology uses a color image as carrier medium and text as secret data. Text messages are transformed to bits and replaced with carrier medium bits.

Venugopal, E., Ranganathan, S., Velmurugan, V., & Hailu, T. [11] Presents a modified CNN-based Stegoanalyzer for images obtained through the application of steganography with proprietary key insertion. The proposed design transplants fewer turns with much larger channels into the final folding layer and gradually widens. You can manage large images and small payloads. The modified CNN leads to a related number of highlights (256), but with two tomahawks, there are twice as large folding layers and fewer information images. Note that the sharing activity is placed on two layers. The whole is a traditional neural scheme with the simplest structure. It is a single income layer consisting of two Softmax neurons. It is in sharp contrast to what CNN had planned in the past.

Indrayani, R. [13] the visual spectrogram evaluation showed no major variation among LSB and modified LSB methods. However, there are differences between the original audio and the spectrogram of the eight modified methods. Of the 8 WAV format audio cover media methods, the most recommended is the LSB + 5 method, which has a large steganography capacity and minimizes the risk of deterioration.

3. HYBRID CONTINUOUS WAVELET TRANSFORM

Steganography is a method for thrashing sensitive data in a regular non-sensitive file or data to keep away from its discovery. Then the hidden information is gathered at the receiver end. The Hybrid Continuous Wavelet Transform is the combination of WFT and CWT. The HCWT increases the error rate and proives a better output than previous methods.

INPUT IMAGES

The input images are carriers and secret images. Image files are most commonly used to pass secrets because they are easy to send during communication and have a large capacity for embedding messages. The purpose of steganography is to embed the sensitive data in the cover so that no one but the sender and the intended recipient knows it is the secret data. First, read the cover image that hides another image.

WINDOWED FOURIER TRANSFORM

The 2-D WFT and 2-D inverse WFT are presented as

$$Sf(u,v,\xi,\eta) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)g(x-u,y-v)exp(-j\xi x - j\eta y)dxdy, \quad -1$$

$$f(x,y) = \frac{1}{4\pi^2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} Sf(u,v,\xi,\eta)g(x-u,y-v) \times exp(j\xi x + j\eta y)d\xi\, d\eta\, du\, dv, \quad -2$$

Where the assumption unit j =$\sqrt{-1}$ and the window function g(x, y) is a regulated Gaussian method described as

$$g(x,y) = \frac{1}{\sqrt{\pi\sigma x\sigma y}}\exp\left(-\frac{x^2}{2\sigma^2 x} - \frac{y^2}{2\sigma^2 y}\right), \quad -3$$

where sx and sy are the Gaussian function's standard deviations(SD) in x and y directions. In WFT, the segment j and filtered fringe model can be discussed as

$$\varphi(x,y) = tan^{-1}\left[\frac{\text{Imf(x,y)}}{\text{Ref(x,y)}}\right], \quad -4$$

$$f(x,y) = \frac{1}{4\pi^2}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \overline{Sf}(u,v,\xi,\eta)g(x-u,y-v) \times exp(j\xi x + j\eta y)d\xi\, d\eta\, du\, dv, \quad -5$$

The essential frequency component is gathered from the filtered spectrum by regulating x and Z

$$\overline{Sf}(u,v,\xi,\eta) = \begin{cases} Sf(u,v,\xi,\eta) & if\ |Sf(u,v,\xi,\eta)| \geq thr, \\ 0 & if\ |Sf(u,v,\xi,\eta)| \leq thr. \end{cases} \quad -6$$

Where 'thr' is a predetermined value to smother noise. For the WF ridges method, local frequencies ox and oy, and phase j can be described as

$$[\omega x(u,v), \omega y(u,v)\ ] = \arg\max_{\xi,\eta} |\ Sf(u,v,\xi,\eta)|, \quad -7$$

$$\varphi(u,v) = tan^{-1}\begin{Bmatrix} ImSf[u,v,\omega x(u,v),\omega y(u,v)] \\ ReSf[u,v,\omega x(u,v),\omega y(u,v)] \end{Bmatrix} + \omega x(u,v)u + \omega y(u,v)v. \quad -8$$

CONTINUOUS WAVELET TRANSFORM

The WFT results are applied to the CWT. The CWT is a formal (that is, non-numeric) tool that provides an overrepresentation of the signal by continuously varying the wavelet transform and scaling parameters. In CWT, the logical function is wavelet `ψ`. CWT evaluates the signal to the wavelet's shifted and compressed or stretched versions. Stretching or compressing a function is collectively called expansion or scaling and corresponds to the physical term of scaling. Get the function of two variables by comparing the signal to the wavelet at different scales and positions. The representation of one-dimensional data is redundant from the two-dimensional data. CWT is a complex value function of range and spot if the wavelet is complex. If the signal is real, CWT is a real-valued function of scale and position. For value parameters á > 0 and spot b, the CWT is:

$$CWT(á, b; f(t), \Psi(t)) = \int_{-\infty}^{\infty} f(t)\ \frac{1}{\sqrt{á}}\ \ \Psi^*\left(t - \frac{b}{á}\right) dt \qquad -9$$

Here the * indicates the difficult conjugate. Not only do the scale and position values affect the CWT coefficient, but the choice of wavelet also affects the value of the coefficient. By constantly changing the values of the level factor a and the spot factor b, the cwt coefficient CWT (á, b) can be found.

HYBRID CONTINUOUS WAVELET TRANSFORM

The hybrid CWT combines the window Fourier transform and the continuous wavelet transform. The Window Fourier Transform creates a window on the cover and input images. The CWT then compares the signal to the wavelet's shifted and compressed or stretched versions. Stretching or compressing a function is collectively called expansion or scaling and corresponds to the physical term of scaling. Get the function of two variables by comparing the signal to the wavelet at different scales and positions. Fig. 2 shows the process flow of steganography with HCWT embedded. Fig. 3. Describes the process of extracting data from a steganographic image file.

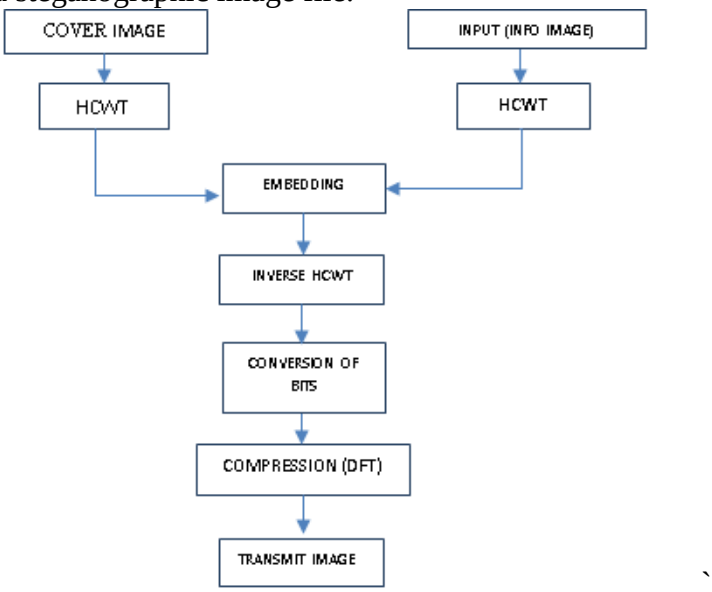

Fig 2. Flowchart of HCWT Embed Process

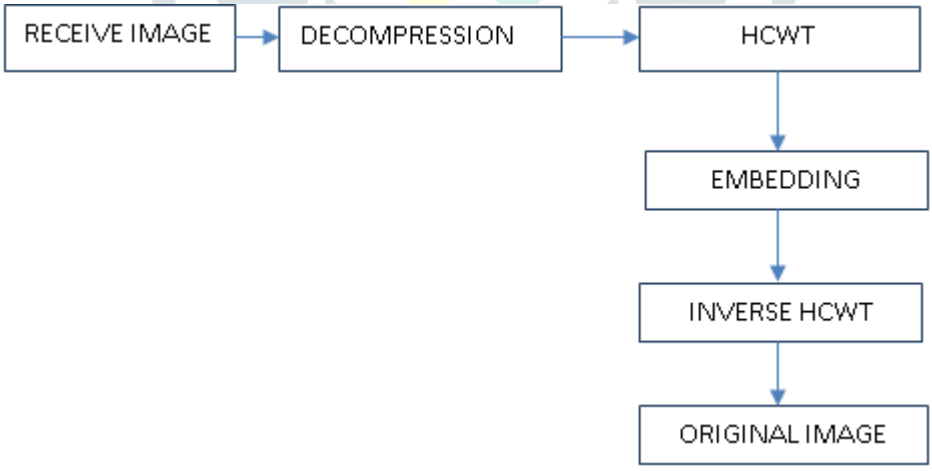

Fig 3. Flowchart of HCWT Extract Process

ALGORITHMS

HCWT: Combination of Windowed Fourier Transform and Continuous Wavelet transform
Embedding
Compression &Decompression

Algorithm for HCWT:

1. Find Fourier transform of B-Spline window
2. Find Fourier transform of an input image
3. Shift B-spline window spectrum with index 1
4. Multiply the shifting result to Fourier transform of an input signal to calculate the co-efficient.
5. Inverse transform of the object to generate the row of the transform matrix equivalent to a constituent frequency 'n'
6. Repeat the above steps for the whole matrix.

EXPECTATION MAXIMIZATION ALGORITHM

Choosing a threshold calculation method is a major issue with the wavelet transform method. In general, threshold calculations are performed using the mean value and can be found using the expected value maximization algorithm. The EM is used to get the highest probability parameter of the statistical method. These methods contain latent variables and strange parameters and recognized data observations. It is easier to formulate the model by assuming the presence of missing values or additional unobserved data points between the data.

DISCRETE FOURIER TRANSFORM

Discrete Fourier transform (DFT) is the most important tool in the digital data processing. You can use DFT to reduce and compress your data. The basis of this invention is the Fast Fourier Transform (FFT), which calculates the DFT with minimized processing time. Several toolbox features, together with Z-domain frequency response, spectral and cepstrum study, and some filter design and implementation features, include the FFT.

The MATLAB has default functions fft and ifft for computing the Discrete Fourier Transform or its inverse. The two functions implement the relationship between the input series y and its transformed version Y (Discrete-Time Fourier transform at evenly spaced frequencies around a unit circle). The DFT is applied individually to every A x B block to characterize an image in the frequency field, giving real and assumption components. The zero's are removed by applying the Matrix Minimization algorithm. This process reduces the data signal and delivers the compressed output data.

4. RESULTS AND DISCUSSION

The implementation of the HCWT steganography method on the JPEG format image cover media and image format input data is done using MATLAB. Several testing techniques, namely Peak Signal Noise to Ratio (PSNR), MSE, and compression Rate, are evaluated. The testings are done with various size of input and carrier medium files. The data compression after the steganography improves the performance while transferring over the network.

Cover Image (Size in KB)	Secret Image (Size in KB)	StegoImage (Size in KB)	MSE	PSNR
858	421	532	0.51	55.43
891	438	549	0.85	58.44
937	438	561	0.92	51.72
942	537	632	0.98	57.43
979	574	649	1.15	68.74
985	536	695	1.37	59.91

TABLE 1. HCWT EVALUATION

Table1 describes various Image Metrics like Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), and evaluated data compression values. The value of MSE lies between 0.51 to 1.37 and the PSNR value between 51.72 to 59.91. The performance of PSNR values and the MSE values sample is shown in the Line Graph. Fig. 4, Fig.5, and Fig.7 show the excellent performance ratio by using HCWT.

Mean Square Error (MSE)

MSE is a degree of exceptional of an estimator. Derived from the rectangular Euclidean distance, its miles a positive value reduces the zero mistake tactics. Suppose a random sample of length n from population X1, ... Xn. For example, a sample unit is selected for replacement. That is, n pulls. The usual estimator for μ is the sample mean.

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \qquad -10$$

It has a mean square error with an expected value (undistorted) equal to the true mean μ.

$$MSE(\bar{X}) = E\left[(\bar{X} - \mu)^2\right] = \left(\frac{\sigma}{\sqrt{n}}\right)^2 = \frac{\sigma^2}{n} \qquad -11$$

Where σ^2 is the population variance, for a Gaussian distribution, is the best-undistorted estimator (the lowest MSE estimator of all undistorted estimators), but not for a uniform distribution. Figure 4 shows the reduced error rate for Stegano Image.

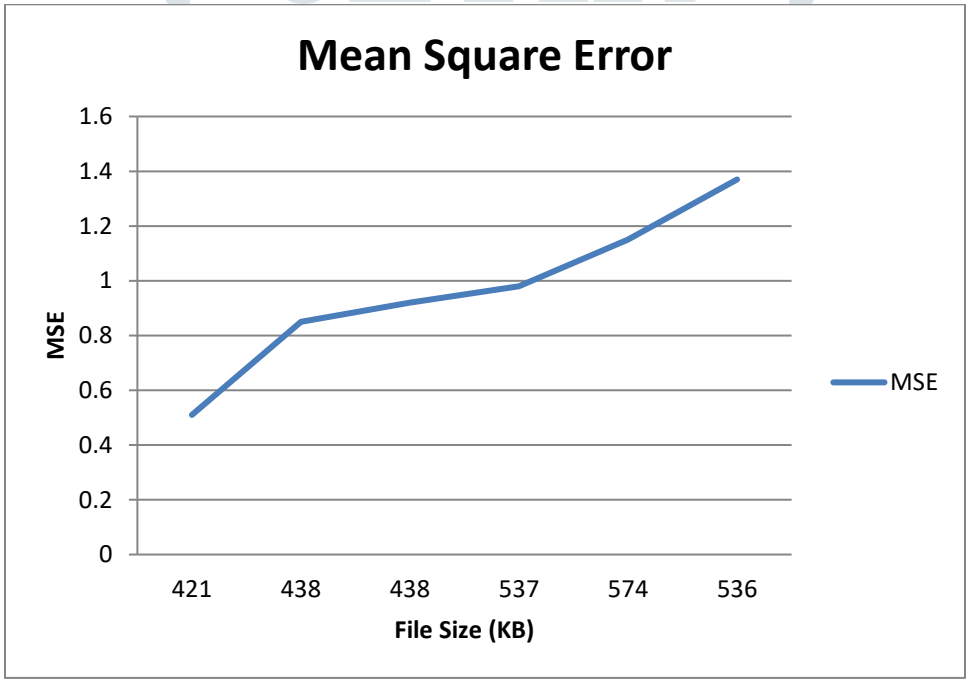

Fig 4. MSE Evaluation

Peak Signal Noise to Ratio (PSNR)

PSNR is an important test used to evaluate the changes in image quality after an experience with steganography technology. The main indicator of PSNR is the presence of noise level. The PSNR value was found by comparing the data strength between the input image and stegoimage. A high PSNR value specifies the good quality of an image, and a low value specifies the poor quality of an image. Table 1 shows the test results of cover media with various file sizes that hide secret messages by changing the LSB.

$$PSNR = 10 *^{10} \log\left(\frac{\sum_{i=1}^{m} x_1^2}{\sum_{i=1}^{m}(x_1 - x_0)^2}\right) \qquad -12$$

x0 = peak signal carrier medium before steganography

x1 = peak signal carrier medium after steganography

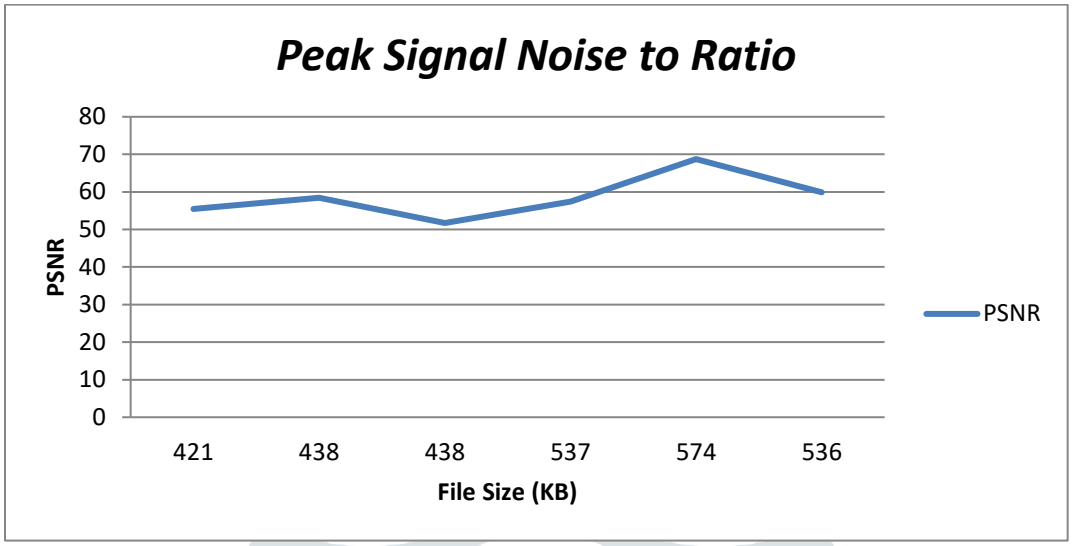

Fig. 5 PSNR Evaluation

Fig. 5 illustrates a PSNR evaluation of the stegano image. The PSNR value represents the quality of an image.

Fig 6. StegoImage File Compression

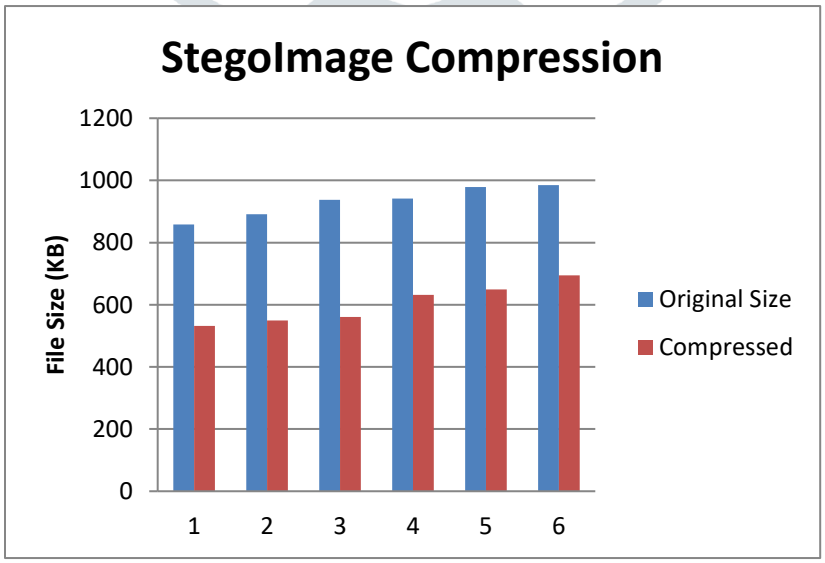

Fig 7. StegoImage File Compression Bar Chart

Experimental results are shown here to demonstrate the effectiveness of the proposed compression technique. The proposed HCWT was implemented in MATLAB. Fig. 6 and Fig. 7, explore the compression ratio of an image. In this, the stegano image had been compressed and sent to the destination. Then, the compressed steganoImage was decompressed and extracted to find the hidden information in the carrier medium.

5. CONCLUSION

This paper introduces a hybrid method of data security using steganography. The HCWT is used with an expectation-maximization algorithm to find the threshold and LSB masking technique. The hybrid continuous wavelet transform produces a window model of the carrier and input images. It compares the signal to the wavelet's shifted and compressed or stretched version. This process provides a way to hide the digital data in the carrier image by regulating the thresholds from the EM algorithm. The embedding point is recognized and filled with the LSB bits by applying the threshold from the calculated detail factor. This method has a high payload capacity, has little effect on statistical characteristics, and has enhanced PSNR and MSE values.

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