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Optimized Information Hiding using Discrete Wavelet Transform and Genetic Algorithm

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***Abstract*—** With rapid advances in the field of communication and information sharing, Steganography – the art of secret communication has gained much attention in recent years. Communicating sensitive information through media like text, sound image and video without being noticed by intruder has become a challenge. Steganography deals with the development of efficient algorithms by a combination of variety of techniques to achieve imperceptibility. This article analyzes the effect of using the Discrete Wavelet Transform for hiding secret data and optimizing it using the genetic algorithm to achieve better results.

***Keywords*—** Spatial Domain, Transform Domain, Discrete Wavelet Transform (DWT), Genetic Algorithm, Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR).

I. INTRODUCTION

With the growth of internet, transmitting and sharing of information has become inevitable. In Steganography, the field of information hiding, many techniques are used to hide secret sensitive information.

Steganography methods can be categorized into spatial and transform domain methods. In Spatial domain methods secret data is directly embedding in the intensity of pixels [1]. The main focus of steganographic system is to embed content in cover media so as not to arouse an eavesdropper's suspicion [2]. Spatial domain methods include Least Significant Bit (LSB) Embedding, Pixel Value Differencing (PVD), and Random Pixel Embedding etc. The major advantages of spatial domain techniques are their simplicity and ease of implementation. However, the drawback is their vulnerability against attacks. Frequency domain methods embeds secret information in specific locations of the cover image after transformation thereby making it less vulnerable to attacks such as compression , cropping etc [3].

In frequency domain methods, the cover image is converted into frequency domain coefficients and then the secret message is embedded in these coefficients. The popular transforms used for embedding are the Fast Fourier

Transform, Discrete Cosine transform (DCT) and the Discrete Wavelet Transform (DWT).

Discrete Wavelet Transform

Wavelets are special functional base for signal decomposition [4]. Applying two dimensional wavelet transform represents an image in the four bands called LL, HL, HL and HH. The LL band contains low pass coefficients and three other bands represent high pass coefficients of the image, horizontal, vertical and diagonal features of the original image. Information related to edge components exists in high frequency section and the low frequency section is selected again for splitting the image into high and low frequency sections [5].

Figure 1 shows the process of 2D wavelet transform of an image of size M x N. The process of DWT transforms the image into A, H, V, D, the approximation, Horizontal, Vertical and Diagonal Coefficients.

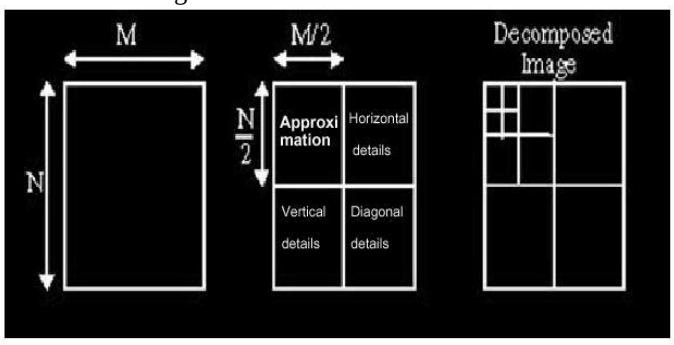

Figure 1. Decomposition Process of DWT

The sub band A includes the low pass coefficient and presents a soft approximation of the image. The other three sub bands show the horizontal, vertical and the diagonal details[6].

The Haar DWT is used in the proposed technique. Figure 2 shows the output of the 2D discrete wavelet transform. The Approximation (low-low) coefficeints is usually not used to conceal secret information, since human eyes are very sensitive to small changes in the low-low frequency. The rest of the coefficients contain high frequencies. Hence secret data will be hidden in these coefficients.

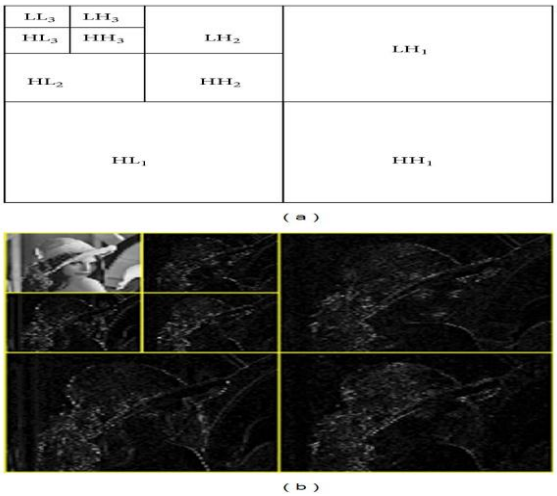

Figure 2: 2D DWT of Lena Image

Genetic Algorithm

Genetic Algorithm is a technique which mimics the genetic evolution as its model to solve problems. The given problem is considered as input and the solutions are found out according to a pattern. The fitness function evaluates every candidate solution most of which are chosen randomly. Evolution begins from a random set of entities and is repeated in the next generations. In the proposed algorithm GA is used to improve the image quality by selcting the best embedding positions.

The first part of this article analyzes the effect of using the Discrete Wavelet Transform while hiding different sized text messages inside images of different sizes. The second part optimizes the result obtained by combining Genetic Algorithm with Discrete Wavelet Transform.

The paper is organized as follows: Section II contain the related work in the field of steganography using DWT and Genetic algorithm, Section III elaborates the proposed work using DWT, Section IV discusses the result of DWT, Section V analyzes the use of Genetic Algorithm with DWT, Section VI deals with analysis of the results of DWT and GA , Section VII deals the comparison with other articles, Section VIII does the overall analysis of the research work.

II. RELATED WORK

In Hamad et al.'s work, a highly efficient algorithm that is capable of hiding miscellaneous data (text and images) using Haar wavelet. The cover image is resized to 512 x 512 and is separated into RGB planes. Wavelet transform is applied to the Red plane, Green plane is converted to binary vector and B plane is reshaped. The secret data is converted to binary vector. The secret text is hidden into the green layer. While embedding 107520 text letters the PSNR value is 51.30 dB and MSE is 0.8233 [7] .

Elham Ghasemi et al. in their work have proposed a high capacity steganography algorithm using a combination of wavelet transform and genetic algorithm. Frequency domain embedding is used to improve the robustness and optimal pixel adjustment is done using genetic algorithm to reduce the difference between the cover and the stego image. Gray scale images of size 512 x 512 are used as cover images and the messages to be embedded are randomly generated with the same length as the hiding capacity. The PSNR value got is 46.83 dB for the Lena image and 51.88 dB for the jet image [8].

In Prabakaran.G et al.'s article the cover image is divided into R, G, B planes and the Singular Value decomposition (SVD) using DWT is performed for the R component. The secret image is scrambled using the Arnold Transform. Both are added to get the fused image. For extracting the stego image, the alpha blending process is used to separate the secret and the cover image and the secret image is reconstructed using inverse DWT [9].

Shamimunnisabi et al. proposes a robust steganography using Integer Wavelet Transform and Genetic Algorithm. The article focuses on building a secure model that is RS-resistant and also maintains the image quality. Embedding is done in the Integer Wavelet coefficients of the cover image based on the genetic algorithm and pixel adjustment process [10].

Usha et al. has suggested a high capacity data embedding by using genetic algorithm. The search space for the GA is generated using the image data and an efficient fitness function is modeled for GA to evolve its solutions. Images of sizes 64 x 64, 128 x 128 and 512 x 512 and secret messages of sizes 26, 415 and 1024 bytes are used for experimentation. The PSNR value got is infinity in the case of 26 bytes and is in the range of 38 to 46 dB in other cases [11].

M.Vijay et al. has proposed a method using integer wavelet transform that maps integers to integers so that the embedded message can be recovered without loss. Embedding is done in the least significant bits of the Integer wavelet transform coefficients of the image. While extracting the inverse IWT is performed. Standard test gray scale images Lena, Barbara and Boat of size 512 x 512 is used for embedding. The PSNR values got are more than 40 dB

which suggests that the cover image quality is not degraded even after embedding the data [12].

Hemalatha et al. uses integer wavelet transform for hiding multiple secret images inside color cover image. The cover image used is of size 256 x 256 color image. Two gray scale images of 128 x 128 are the secret images. Embedding is done after converting the cover image into the YC_bC_r color space. The PSNR values of the stego images after embedding data are in the range of 44-45 dB which ensures a better image quality [13].

III. IMPLEMENTATION USING DISCRETE WAVELET TRANSFORM

For the implementation of secret message hiding using discrete wavelet transform MATLAB R2017a (9.2.0) is used. Cover image (Rose .bmp) of sizes 64 x 64, 128 x 128, 256 x 256 and 512 x 512 were used for embedding data and secret message text files of sizes varying from 1KB to 3 KB were used for 64 x 64 cover image and files of sizes 1 KB to 10 KB were used for cover image files of sizes 128 x 128, 256 x256, and 512 x 512.

In image processing, normalization is a process that changes the range of pixel intensity values i.e. bringing all data within a specific range. After normalizing the secret message it is encoded within the cover image. Encoding is the process of putting a sequence of characters, numbers into a specialized format for efficient transmission / storage. Fig. 3 shows the steps used for embedding data.

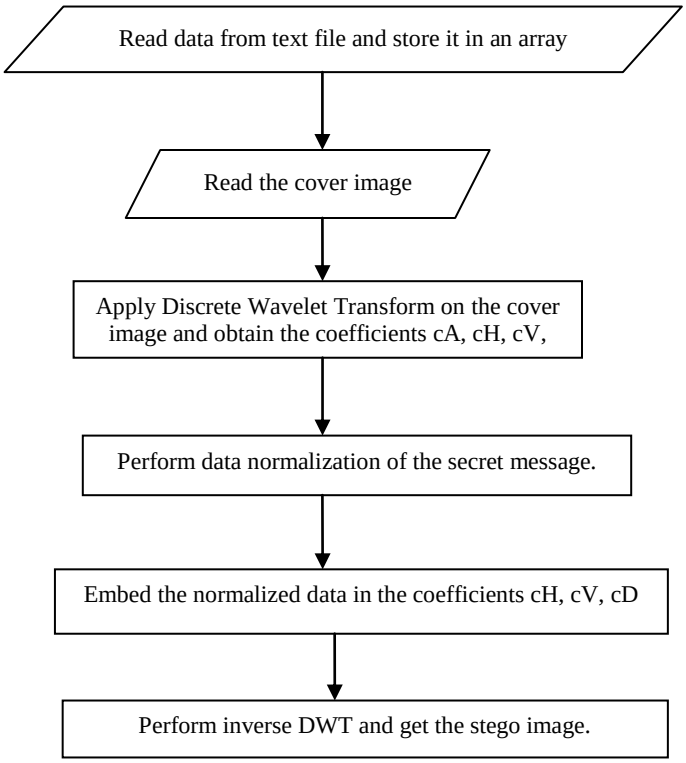

Figure 3. Embedding secret data using DWT.

Encoding Process

1. String message is converted into binary
2. Perform data normalization after finding the highest value.
3. Add all the binaries into the sub band after performing dwt.
4. Make embedded float matrix using inverse dwt and obtain the stego image.

Decoding Process

1. Apply dwt to the stego image.
2. Read the data from the sub bands.
   Write the secret data into a text file.

PERFORMANCE MEASURES

Mean Square Error (MSE)

The mean square error is calculated by finding the difference between pixel values in each position of the cover image and the image after embedding secret data i.e. the stego image. Equation (1) gives the formula for calculating the MSE

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(I(i,j) - I'(i,j))\,\wedge 2 \qquad \textbf{(1)}$$

Peak Signal to Noise Ratio (PSNR dB)

Peak Signal to noise ratio is calculated by calculating the pixel difference in each position of the original cover image and the image after embedding secret data i.e. the stego image. Equation 2 gives the formula for calculating PSNR that uses the MSE value in its denominator.

$$PSNR = 10\log_{10}\frac{255\,\wedge 2}{MSE}\,dB \qquad \textbf{(2)}$$

Structural Similarity Index Measure (SSIM)

The structural similarity index measure is used for measuring the image quality. SSIM is an image quality metric that assess the visual impact of the three characteristics luminance, contrast and structural aspects of an image.

The matlab function takes as parameters the two images and returns the index measure. Equation 3 shows the format of the ssim function available in matlab.

Ssimval = ssim (A, ref) **(3)**

Where A- is the image whose quality is to be measured and ref is the reference image against which quality is measured.

IV. RESULTS (DWT)

The following results were obtained while embedding secret data of different sizes in different sized cover images. For evaluating the proposed algorithm, performance measures such as Peak Signal to Noise Ratio (PSNR) which is represented in decibels (dB) and Mean Square Error (MSE) is used.

The cover images used are rose.bmp of various sizes 64 x 64, 128 x 128, 256 x 256 and 512 x 512. The secret message sizes are 1 KB to 3KB for embedding in 64 x 64 image and 1 KB to 10 KB for embedding in 128 x 128, 256 x 256 and 512 x 512 images. For comparison with other works using DWT Lena cover image of size 512 x 512 is also used for embedding 1KB to 10KB text.

Embedding Various Text Sizes inside Cover Image of different sizes using DWT

Figures 4 shows the sample images rose.bmp of sizes 64 x64, 128 x 128, 256 x 256 and 512 x 512 and Lena image of size 512 x 512 used for embedding and their Approximate, Horizontal, Vertical and Diagonal components got after performing **DWT** on the cover image.

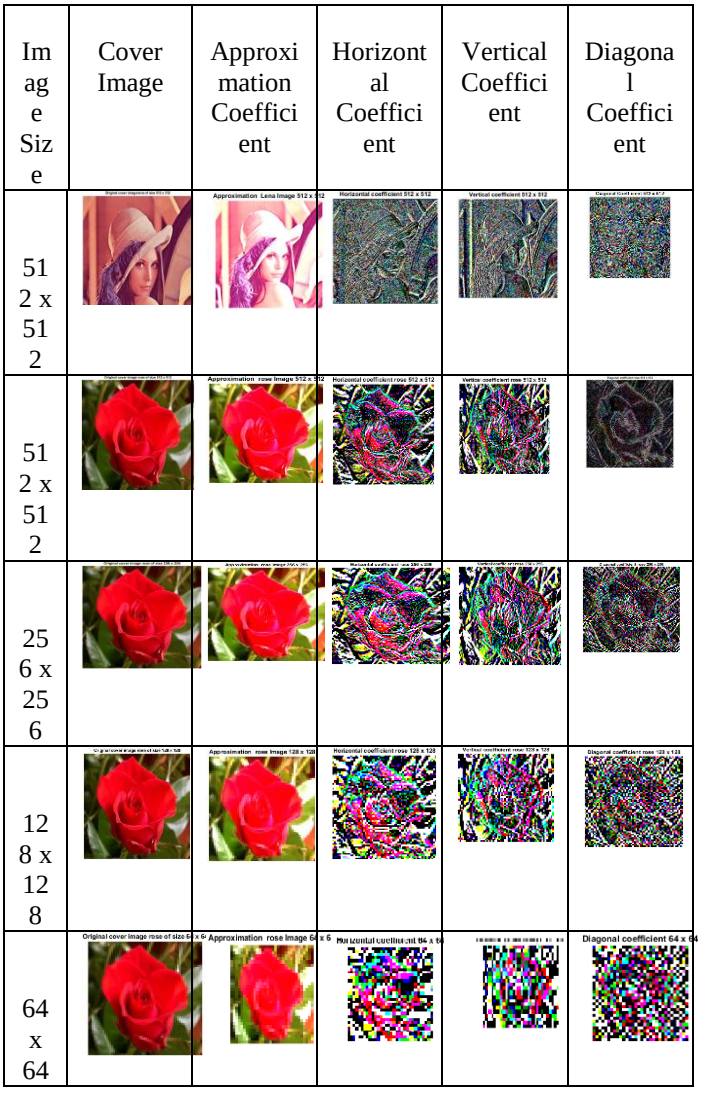

Figure 4. Sample images & A,H,V,D coefficients while using DWT

Table 1 shows the PSNR and MSE values while embedding data ranging from 1 KB to 3 KB inside a cover image of size 64 x64. Secret message size is considered only up to 3 KB since the size of the cover image is only 64 x 64. If more than 3 KB is embedded it will degrade the image quality. The PSNR value is in the range of 31 to 37 dB. Figure 5 shows the graphical representation of the PSNR and MSE values got while embedding in a 64 x64 cover image.

Table 1: Embedding in Rose. Bmp of size 64 x 64

Text File Size	PSNR	MSE
1 KB	37.198238	12.395287
2 KB	33.774134	27.268861
3 KB	31.05676	50.98053

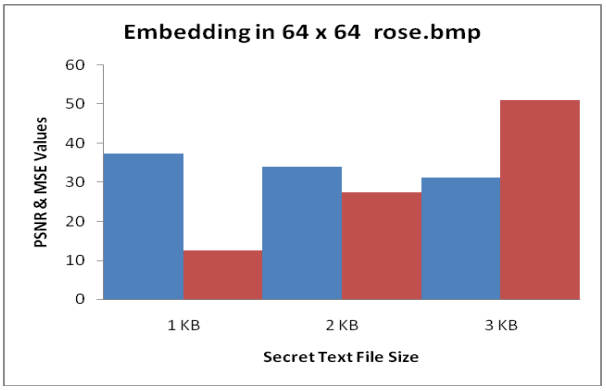

Figure 5. Comparison of MSE, PSNR values while embedding
1- 3 KB secret text inside 64 x 64 image using DWT.

Table 2 shows the PSNR and MSE values while embedding data ranging from 1 KB to 10 KB inside a cover image of size 128 x128. The PSNR value is in the range of 35 to 46 dB which is said to a reasonable value. Figure 6 shows the graphical representation of the PSNR and MSE values got while embedding in rose.bmp of size 128 x 128.

Table 2: Embedding in Rose.bmp of size 128 x 128

Text File Size	PSNR	MSE
1 KB	46.139548	1.581705
2 KB	41.635394	4.462117
3 KB	40.479904	5.822238
4 KB	39.715223	6.943174
5 KB	38.910471	8.356671
6 KB	37.0189	12.917853
7 KB	36.839148	13.463735
8 KB	36.163253	15.730955
9 KB	36.082082	16.027736
10 KB	34.966423	20.722305

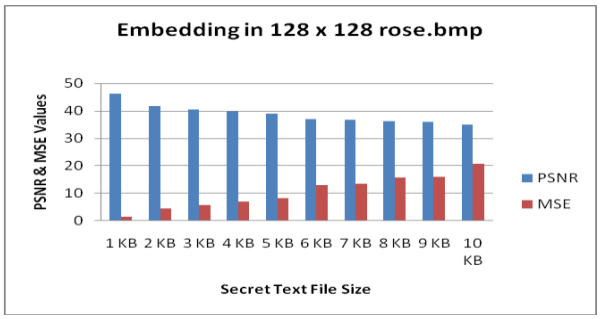

Figure 6. Comparison of MSE, PSNR values while embedding
1 – 10 KB secret text inside 128 x 128 image using DWT.

Table 3 shows the PSNR and MSE values while embedding data ranging from 1 KB to 10 KB inside a cover image of size 256 x256. The PSNR value is in the range of 45 to 58 dB. Any image having a value greater than 40 dB is said to be of very good quality which means that even after embedding 10 kb of data the quality of the image is high. Figure 7 shows the graphical representation of the PSNR and MSE values got while embedding in rose.bmp of size 256 x 256.

Table 3: Embedding in Rose.bmp of size 256 x256

Text File Size	PSNR	MSE
1 KB	58.377754	0.094472
2 KB	55.471431	0.184475
3 KB	51.3636	0.475029
4 KB	49.939524	0.659368
5 KB	46.920229	1.321471
6 KB	46.513927	1.451068
7 KB	46.443348	1.474842
8 KB	45.98773	1.637975
9 KB	45.892814	1.674168
10 KB	45.062942	2.026685

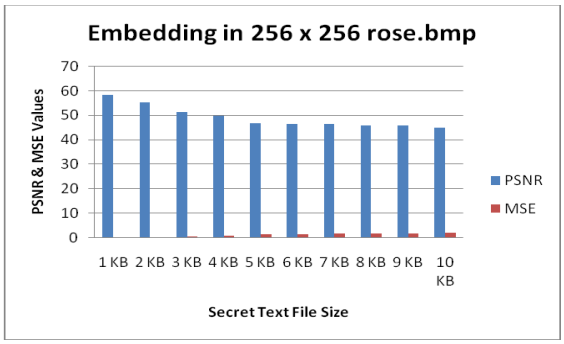

Figure 7. Comparison of MSE, PSNR values while embedding
1 – 10 KB secret text inside 256 x 256 image using DWT.

Table 4 shows the PSNR and MSE values while embedding data ranging from 1 KB to 10 KB inside a cover image of size 512 x 512. The PSNR value is in the range of 56 to 70 dB which means that even after embedding 10 kb of data the quality of the image is high with a value of 56dB.

Figure 8 shows the graphical representation of the PSNR and MSE values got while embedding in rose.bmp of size 512 x 512. Since the image size is more the effect of embedding even 10kb data is not felt by the viewer. The image quality is very high with a value of 70dB while embedding 1 KB data.

Table 4: Embedding in Rose.bmp of size 512 x 512

Text File Size	PSNR	MSE
1 KB	69.737387	0.006908
2 KB	66.523832	0.014478
3 KB	62.784455	0.034248
4 KB	62.082894	0.040252
5 KB	60.826322	0.053759
6 KB	59.412864	0.074438
7 KB	58.963625	0.08255
8 KB	57.956442	0.104097
9 KB	57.484119	0.116056
10 KB	56.168203	0.15713

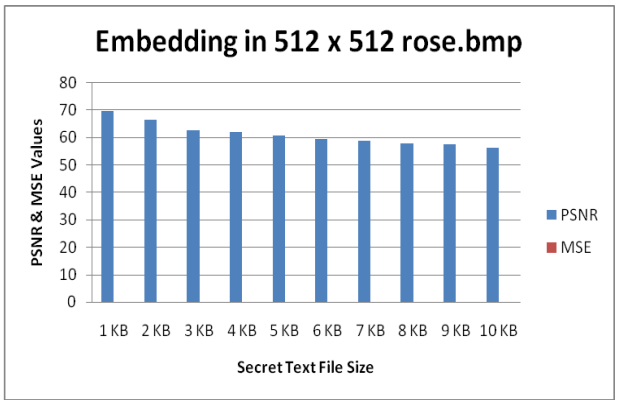

Figure 8. Comparison of MSE, PSNR values while embedding
1 – 10 KB secret text inside 512 x 512 image using DWT.

V. IMPLEMENTATION USING DISCRETE WAVELET TRANSFORM AND GENETIC ALGORITHM

Genetic Algorithm is combined with discrete wavelet transform to optimize the embedding position selections. The selection, crossover and mutation are performed before embedding the secret data. Figure 9 shows the flowchart depicting the process of embedding secret data using a combination of genetic algorithm and discrete wavelet transform.

The population is initialized and then selection is done to find the best pair of individuals for crossover which is set as 0.60. Mutation is performed with a very small probability of 0.05. The objective function is used to estimate the fitness value of an individual.

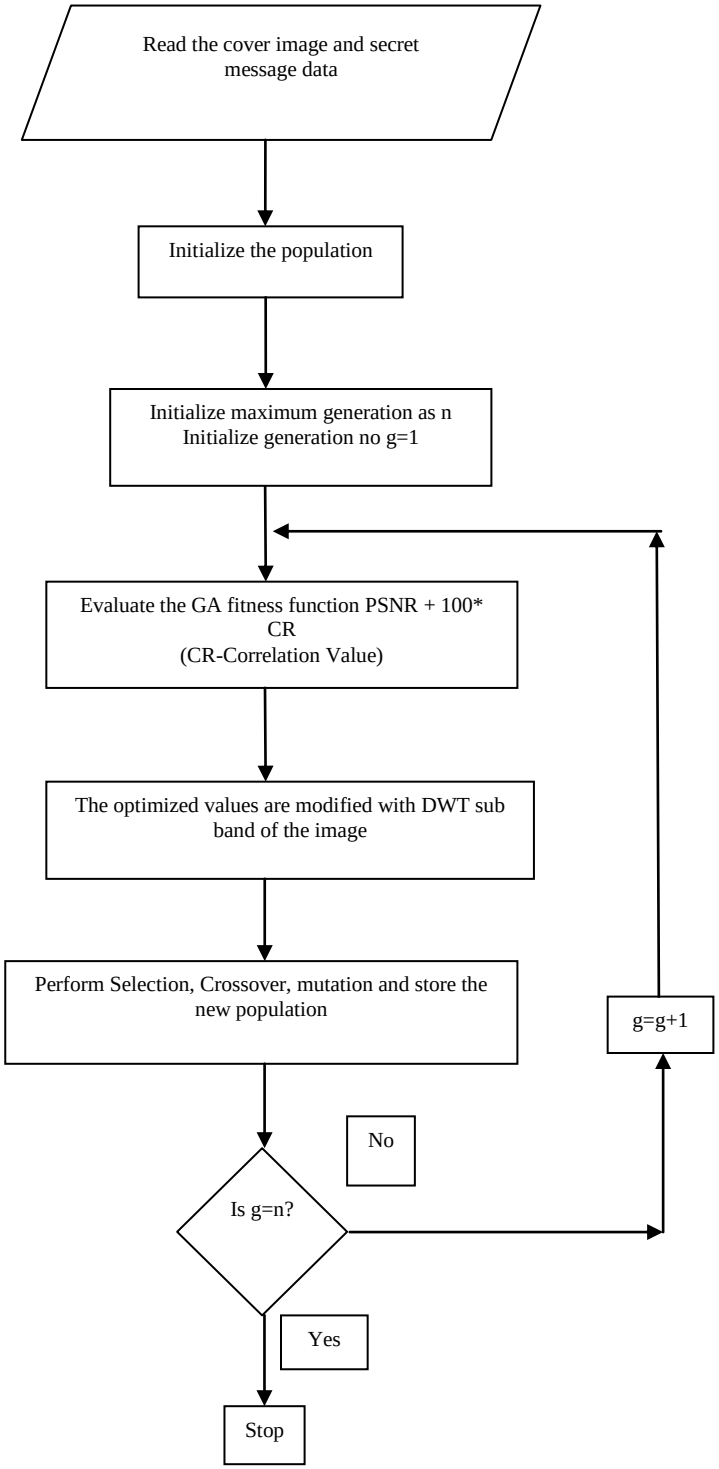

Figure 9. Embedding using DWT and GA

VI. Results Discussion (DWT & GA)
Embedding Text of Various Sizes inside Cover Images of different sizes using DWT and GA.

Table 5 shows the PSNR and MSE values got while embedding secret data of sizes ranging from 1KB to 3 KB inside an image of size 64 x 64.

Table 5: Embedding in Rose.bmp of size 64 x 64

Text File Size	PSNR	MSE
1 KB	37.21082	12.35944
2 KB	33.82161	26.97236
3 KB	31.05876	50.95703

Figure 10 shows the graphical representation of the values of table 5.

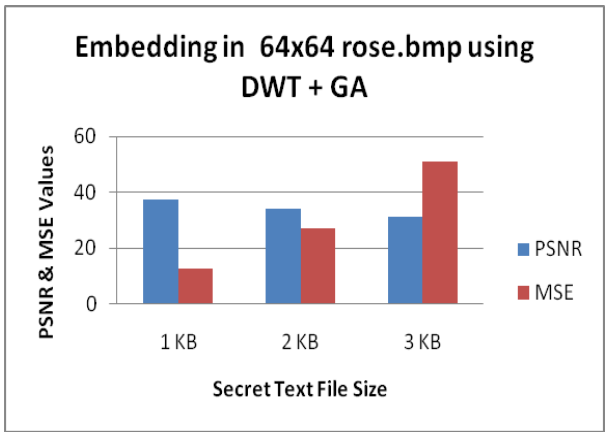

Figure 10. Comparison of MSE, PSNR values while embedding 1 – 3 KB secret text inside 64 x 64 image using DWT and GA.

Table 6 shows the PSNR and MSE values got while embedding secret data of sizes ranging from 1KB to 10 KB inside an image of size 128 x 128.

Table 6: Embedding in Rose.bmp of size 128 x 128

Text File Size	PSNR	MSE
1 KB	46.13982	1.581605
2 KB	41.69249	4.403842
3 KB	40.48344	5.817494
4 KB	39.71551	6.942722
5 KB	38.91232	8.353106
6 KB	37.0189	12.91785
7 KB	36.83917	13.46368
8 KB	36.16466	15.72588
9 KB	36.08471	16.01826
10 KB	34.90249	21.02962

Figure 11 shows the graphical representation of the values of table 6.

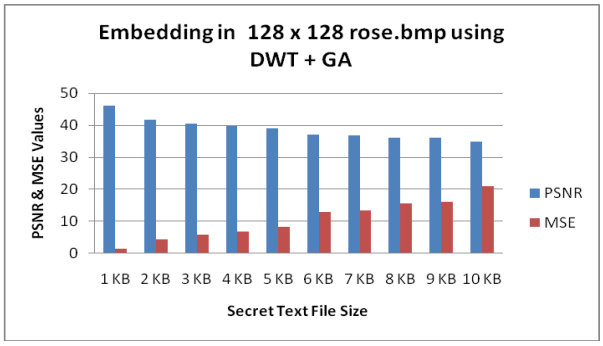

Figure 11. Comparison of MSE, PSNR values while embedding
1 – 10 KB secret text inside 128 x 128 image using DWT and GA.

Table 7 shows the PSNR and MSE values got while embedding secret data of sizes ranging from 1KB to 10 KB inside an image of size 256 x 256.

Table 7: Embedding in Rose.bmp of size 256 x 256

Text File Size	PSNR	MSE
1 KB	58.40766	0.093824
2 KB	55.48786	0.183778
3 KB	51.38875	0.472287
4 KB	49.94196	0.658998
5 KB	46.92149	1.321086
6 KB	46.53937	1.442593
7 KB	46.44869	1.473029
8 KB	45.99139	1.636595
9 KB	45.89414	1.673657
10 KB	45.08621	2.015854

Figure 12 shows the graphical representation of the values in table 7.

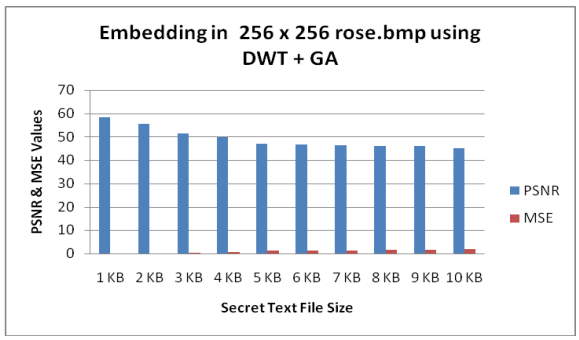

Figure 12. Comparison of MSE, PSNR values while embedding
1 – 10 KB secret text inside 256 x 256 image using DWT and GA

Table 8 shows the PSNR and MSE values got while embedding secret data of sizes ranging from 1KB to 10 KB inside an image of size 512 x 512.

Table 8: Embedding in Rose.bmp of size 512 x 512

Text File Size	PSNR	MSE
1 KB	69.835478	0.006754
2 KB	66.55693	0.014368
3 KB	62.79162	0.034192
4 KB	62.17082	0.039446
5 KB	60.825105	0.053774
6 KB	59.41824	0.074346
7 KB	58.96748	0.082477
8 KB	57.95644	0.104097
9 KB	57.48412	0.116056
10 KB	56.16739	0.15716

Figure 13 shows the graphical representation of the values of table 8.

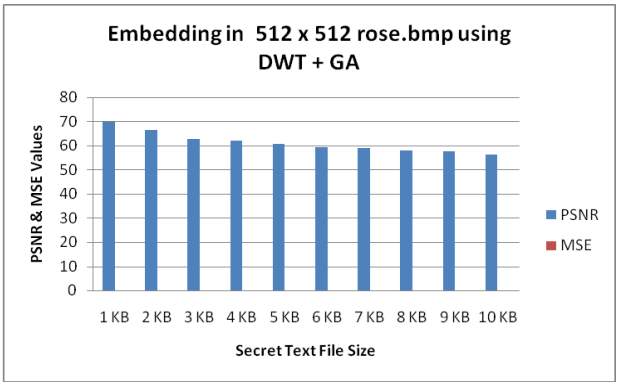

Figure 13. Comparison of MSE, PSNR values while embedding
1 – 10 KB secret text inside 512 x 512 image using DWT and GA

Comparison of PSNR values of DWT and DWT + GA while embedding 1KB to 10 KB secret text inside a cover image of size 512 x 512.

The following section deals with the comparison of the PSNR values got while embedding 1 KB to 10 KB data using DWT and DWT + GA into the cover image of size 512 x 512 and is shown in Table 9. There is a slight increase in the PSNR values while using DWT +GA.

Table 10 shows the comparative values while embedding in Lena image of size 512 x 512 using DWT and then with DWT +GA. In the case of the Lena image there is a much larger difference between the two.

Table 9: PSNR Comparison while embedding in Rose.bmp of size 512 x 512

Text File Size	PSNR	
	DWT +GA	DWT
1 KB	69.835478	69.737387
2 KB	66.556933	66.523832
3 KB	62.79162	62.784455
4 KB	62.17082	62.082894
5 KB	60.825105	60.826322
6 KB	59.418243	59.412864
7 KB	58.96748	58.963625
8 KB	57.956442	57.956442
9 KB	57.484119	57.484119
10 KB	56.167388	56.168203

VII. COMPARISON WITH OTHER RELATED ARTICLES

For Comparison with other implementations Lena cover image of sixe 512 x 512 is taken and the PSNR and MSE values are compared and it is found that our method yields a better result in some situations and there is no improvement in some cases.

Table 10: PSNR Comparison while embedding in Lena.bmp size 512 x 512

Text File Size	PSNR	
	DWT +GA	DWT
1 KB	64.134361	63.874723
2 KB	60.753602	60.753602
3 KB	57.829564	57.829564
4 KB	57.048740	57.022854
5 KB	55.457364	55.472243
6 KB	54.108975	54.108975
7 KB	53.744205	53.739027
8 KB	52.932910	52.932035
9 KB	52.695311	52.695311
10 KB	51.897403	51.897403

Comparison of PSNR values and DWT + GA while embedding 1KB to 10 KB secret text inside a cover image of size 512 x 512 with other methods.

Table 11 lists the comparative values while using a payload of size 1000, 2000 and 4000 bytes. The proposed method is compared with three other papers are compared for the PSNR and the MSE values. The Proposed method definitely shows a better PSNR value for the same cover image of the same size of 512 x 512. The highlighted values in the table definitely shows that the proposed method i.e. the DWT as well as the combination of DWT and GA gives better results than the other methods suggested by [14][15][16].

Table 11: Comparative values with other articles while embedding in Lena image of size 512 x 512

Payload Bytes /KB	Metrics	Lai Method [14]	Reddy Method [15]	Seyyed Method [16]	Proposed DWT	Proposed DWT +GA
1000 / 1 KB	PSNR	56.62	42.4	62.12	**69.737**	**69.835**
	MSE	0.163	7.42	0.04	**0.006**	**0.006**
2000 / 2 KB	PSNR	53.38	38.7	59.18	**66.523**	**66.556**
	MSE	0.337	15.672	0.079	**0.014**	**0.014**
4000 / 4 KB		50.12	34.97	56.24	**62.082**	**62.17**
	MSE	0.7	35.932	0.115	**0.04**	**0.04**

VIII. DISCUSSION OF RESULTS

The results of the implementation of steganography using discrete wavelet transform and optimization of the peak signal to noise ratios using genetic algorithm clearly highlights the effect of hiding various sized text messages inside various cover images. The comparison of the proposed methods with other DWT methods clearly shows that the proposed method gives a better PSNR value and better image quality than other methods.

CONCLUSION

This paper has analyzed in detail the effect of embedding different sizes of secret messages in different sized cover images using discrete wavelet transform and optimization using genetic algorithm. The quality of the message after embedding is measured using PSNR and MSE value and is found to give better results than the compared methods. This method can be enhanced in future by including the measure of checking the robustness against attacks after embedding.

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