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Steganography Based on Image Compression Using a Hybrid Technique

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Abstract. *Information security is a crucial factor when communicating sensitive information between two parties. Steganography is one of the most techniques used for this purpose. This paper aims to enhance the capacity and robustness of hiding information by compressing image data to a small size while maintaining high quality so that the secret information remains invisible and only the sender and recipient can recognize the transmission. Three techniques are employed to conceal color and gray images, the Wavelet Color Process Technique (WCPT), Wavelet Gray Process Technique (WGPT), and Hybrid Gray Process Technique (HGPT). A comparison between the first and second techniques according to quality metrics, Root-Mean-Square Error (RMSE), Compression-Ratio (CR), Structural-Similarity-Index Metric (SSIM), Peak Signal-to-Noise Ratio (PSNR), and Normalized-Cross-Correlation (NCC) resulted in that can get a high-quality image using WGPT than that when using WCPT. So, it is combined with a multiwavelet transform to get the third technique, HGPT. The results are implemented using MATLAB, and they indicate that the HGPT hides the message image with the best quality metrics of PSNR = 84.05262 and a high compression ratio of 16 for embedded images, whereas 76.06046 and 16 for extracted messages. This technique can be used with AI and deep learning.*

Keywords: Steganography; image compression; WCPT; WGPT; HGPT

1. **Introduction.** Digital communication becomes an essential, and the Internet is efficient for digital communication, which is the most widely used. The data transmitted via the Internet are becoming in danger. So, continuing the data's secrecy is crucial if the data is personal or confidential. Steganography provides a good solution for these problems [1]. Hiding any secret message within the cover image is called image steganography. These images render as inputs to a steganography algorithm, which creates an embedded image that seems identical to the cover image but hides a secret message within its pixels [2]. Representing the images in a minimum number of bits without omitting any essential information from the original image is called image compression [3, 4]. It is important in enhancing the facilitating of images' transmission and storage [5]. Multiwavelet transform decomposes the image into 16 frequency sub-bands, capturing fine and coarse features [6]. Multi-wave and wavelet transforms are used on a larger scale for image analysis, providing more effective results. Multiple waves indicate energy compression efficiency [7]. The performance assessment can use image quality metrics, Mean-Square Error (MSE), SSIM, and PSNR [8].

2. **Related Work.** Rahman et al. [9] introduced a literature review of some steganographic technique features, classifying them into various domains, including spatial, adaptive, and transform. The paper covers necessary performance assessment measures PSNR and MSE. Abdullah et al. [10] employed the Discrete Wavelet Transform (DWT) to integrate transformation domain approaches with spatial domain techniques. The hiding image is extracted from the embedded image without needing the cover image. The technique minimizes noticeable distortion of the cover image while increasing embedding capacity. Biswas et al. [11] enhanced the resilience steganography of coverless images by combining DWT, pixel intensity averaging, and plane-slicing. Rahman et al. [12] presented replacing the least significant bit, which enhances the dependability of the image steganography by minimizing the error rate through the embedding process and ensuring that the concealing data remains invisible to the naked eye.

Raghavendra et al. [8] introduced a combination of LSB approaches and the Discrete Cosine Transform (DCT) to embed information in the medical images. The findings suggest that LSB steganography is a potential method for embedding safe data in medical imaging applications, as it often maintains image quality better than DCT. C. Yang and W. Wang [13] demonstrated how an ECG steganography technique uses standard deviation blocks, integer wavelet transform, LSB replacement, and coefficient alignment, improves the security of the patient's private data. The strategy outperforms in terms of SNR, and PSNR offers a greater payload capacity. Sao et al. [14] proposed dual images depending on adaptable data masking adapted to the secret bits. It calculates the frequencies of five-bit secret elements and then classifies them in a table to specify which criteria must be applied to the pixels of a cover image. Pan et al. [15] used the Arnold transform, and Hessenberg decomposition, and then a singular value decomposition was applied to process the hidden region, which is the area of the cover image that spans multiple wavelet sub-bands. Yousif et al. [16] presented a steganography technique for color images based on the YCbCr color space and a two-level DWT. The cover image is converted to YCbCr, and the Cb-band hides a grayscale image. The embedding process uses the horizontal sub-band based on a singular value decomposition of the secret image and the obtained horizontal sub-band of the cover image. PSNR and SSIM are used to evaluate the system's performance. Saidi et al. [17] focused on a counting-based secret sharing method to decrease the computational complexity of longer keys and develop a steganographic technique with efficient sharing. The process integrates counting by sharing with steganography and IWT. Alobaidi et al. [18] introduced an adaptive insertion strategy based on a Two-Dimensional Discrete Haar Filter (2D DHF). Using 2D DWT, the cover image is transformed into a wavelet and then analyzed in 2D DHF and 2D DCT. An adaptive algorithm minimizes the effect on the non-represented division of the cover images.

This paper used WCPT, WGPT, and HGPT techniques to enhance the image-hiding process with high quality and compression. The WCPT and WGPT techniques are compared according to quality metrics. The finest technique, WGPT, is combined with multiwavelet to produce HGPT, which enhances the image-hiding, compression, and quality. This paper contains Sec. 3, which presents methods and materials of WCPT, WGPT, and HGPT; Sec. 4 focuses on results and discussion; and Sec. 5 provides the conclusions.

3. **Methods and Materials.** The block diagram of the proposed system is shown in Fig. 1.

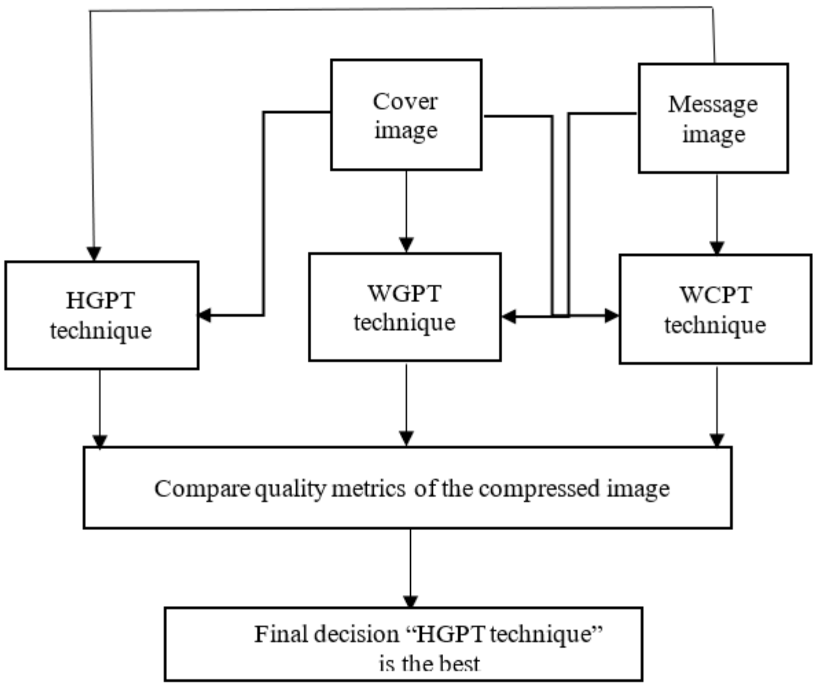

Figure 1. Block diagram of the proposed system

3.1. **WCPT technique.** The research aims to enhance the secrecy of the image by compressing it to conceal information and increase the difficulty of the force in perceiving it. This technique processes the color images without converting them to gray scale. In steganography, a message image is embedded into a cover image; therefore, cover and message images must be loaded.

1. Load the cover and message images, then read them. They are of different formats, such as PNG, JPG, and TIF and they are of different sizes; some are gray, while others are colored.
2. Resize them to a square size of 1024×1024, which is a power of 2, and then convert them to double precision for processing.
3. Decompose the cover image into 4 sub-bands using a Haar wavelet transform.
4. Choose the coefficients where the message image will be embedded. Generally, lower-frequency coefficients are preferred for embedding information because they are less likely to affect the perceived image quality.

5. Embed the message image into a LL sub-band; this is performed by adding the message image (after resizing it to the exact size of the LL sub-band and then scaling it by a scaling factor of $\alpha = 0.0625$, which is the best value that gives a better-embedded image, as shown in Fig. 2, where $\alpha = 0.001, 0.005, 0.01, 0.0625, 0.08, 0.1, 0.5, 1$) to the LL sub-band.

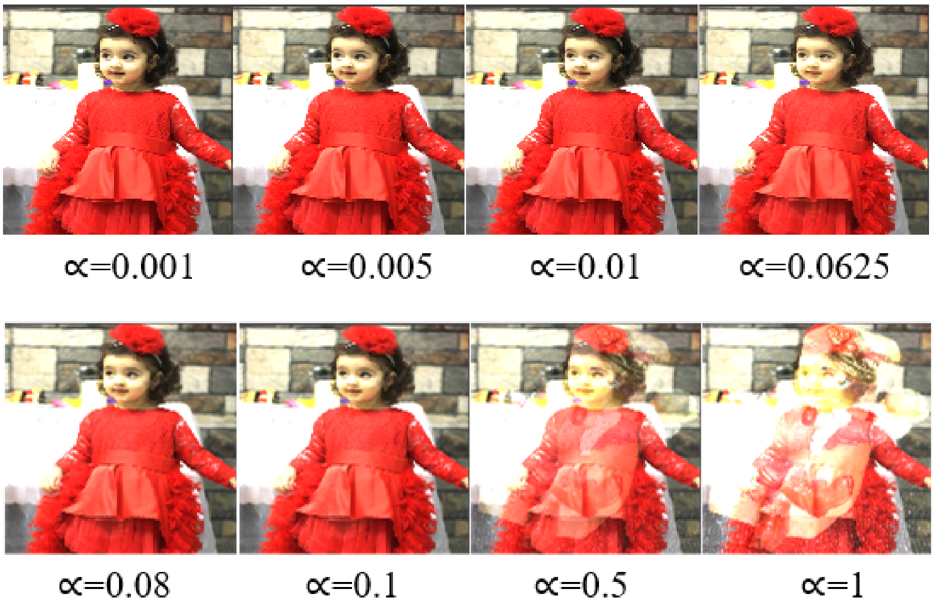

FIGURE 2. Message image after various scaling factors

6. Reconstruct the embedded image using the inverse wavelet transform on the embedded LL sub-band, then save it and read it to retrieve it.
7. To retrieve the message from the embedded image, perform wavelet decomposition on the message image to obtain the four sub-bands.
8. Extract the message from the embedded LL sub-band by multiplying it by the same scaling factor $\alpha = 0.0625$, then subtracting it from the LL sub-band of the message.
9. Reconstruct the message image using the inverse wavelet transform on the extracted image, then save it and read it to retrieve it.
10. Calculate the quality metrics using equations (1)–(5) [4, 7, 9, 19, 20, 21].

$$RMSE = \left[\frac{1}{KL} \sum_{i=1}^{K} \sum_{j=1}^{L} (u(i,j) - v(i,j))^2 \right]^{0.5} \tag{1}$$

where $v(i,j)$ is the cover or message image, $u(i,j)$ is the embedded image or extracted message, and K and L are the dimensions.

$$PSNR = 20 \log_{10} \left(\frac{255}{RMSE} \right) \tag{2}$$

$$SSIM = \frac{(2\mu_i\mu_j + c_1)(2\sigma_{ij} + c_2)}{(\mu_i^2 + \mu_j^2 + c_1)(\sigma_i^2 + \sigma_j^2 + c_2)} \tag{3}$$

where μ_i and μ_j are the mean intensities of i and j, respectively. σ_i, σ_j and σ_{ij} are the variances and covariance of i and j, respectively. While c_1 and c_2 are the stability variables; their value ranges from 0 to 1, and it should be nearly 1 for maximum performance.

$$NCC = \frac{\sum_{i=1}^{K} \sum_{j=1}^{L} (u(i,j) \cdot v(i,j))}{\sum_{i=1}^{K} \sum_{j=1}^{L} (u(i,j))^2} \tag{4}$$

$$CR = \frac{\text{Size before compression}}{\text{Size after compression}} \tag{5}$$

3.2. **WGPT technique.** This technique processes the color images and converting them to gray scale.

1. Load the cover and message images, then read them. They come in various sizes and formats, with some being gray and others being colorful.
2. Resize them to a size of 1024 × 1024, ensuring they are square and have a power of 2, then convert them to double precision.
3. Convert the cover and message images to grayscale if they are color.
4. Continue with the steps from 3 to 10 of WCPT.

3.3. **HGPT technique.** In this work, the WGPT technique has the best results compared to the WCPT technique. So, the hybrid technique is a multiwavelet-wavelet gray process technique which is used the converting of color images to gray images.

1. Load the cover and message images, then read them. They are of different sizes and formats; some are gray, while others are colored.
2. Resize them to a size of 1024 × 1024, ensuring they are square and have a power of 2, then convert them to double precision.
3. Convert the cover and message images to grayscale if they are color.
4. Decompose the cover image into 16 sub-bands using multi-wavelet transformation.
5. Choose the coefficients of the lower right sub-band of the LL sub-band because they are less likely to affect the perceived quality of the image.
6. Decompose this sub-band image into 4 sub-bands using a haar wavelet transform and choose the coefficients where the message image will be embedded.
7. Embed the message image into the LL sub-band; this is performed by adding the message image (after resizing it to the exact size of the LL sub-band and then scaling it by a scaling factor of $\alpha = 0.0625$, which is the best value that gives a better-embedded image) to the LL sub-band.
8. Reconstruct the embedded image using inverse wavelet transform on the embedded LL sub-band, save it, and read it to be retrieved.
9. To retrieve the message from the embedded image, perform wavelet decomposition on the message image to obtain the four sub-bands.
10. Extract the message from the embedded LL sub-band by multiplying it by the same scaling factor $\alpha = 0.0625$, then subtract it from the LL sub-band of the message.
11. Reconstruct the message image using the inverse wavelet transform on the extracted image, then save it and read it to retrieve it.
12. Calculate the quality metrics using Equations (1)–(5).

4. Results and discussion.

4.1. **Using WCPT technique.** Figures 3–5 illustrate the implementation of the WCPT on various combinations of cover and message images.

1. Embedding a color message in the color cover image, then retrieving them as shown in Figure 2.
2. Embedding a gray message in the gray cover image, then retrieving them as shown in Figure 3.

3. Embed a color message in the gray cover image, then retrieving them as shown in Figure 4.
4. And so on with all images.

Figure 3. WCPT uses color messages and cover images

Tables 1 and 2 show the quality measurements of the WCPT technique for embedded and extracted images, respectively. The results are for different combinations of cover image and messages (color cover and message images, gray cover and message images, gray cover image and color message image), where image3g in the cover image and image3c in the message image indicated that image3 is gray in the cover image and image3 is color in message image. The results showed that the average NCC values are 0.9994 and 0.9929 for embedded and extracted images, respectively. Along with PSNR and RMSE values of 83.69734 and 75.30024 and 0.01846 and 0.0536 for embedded and extracted images, respectively.

Table 1. WCPT quality measurements of embedded images

Cover Image	RMSE	PSNR	SSIM	NCC	CR
Image1c	0.0084	89.6452	0.9997	0.9998	4
Image2g	0.0140	85.2082	0.9983	0.9998	4
Image3g	0.0147	84.7845	0.9979	0.9996	4
Image4c	0.0320	78.0278	0.9920	0.9986	4
Image5c	0.0232	80.8210	0.9957	0.9992	4
Average	0.01846	83.69734	0.9967	0.9994	4

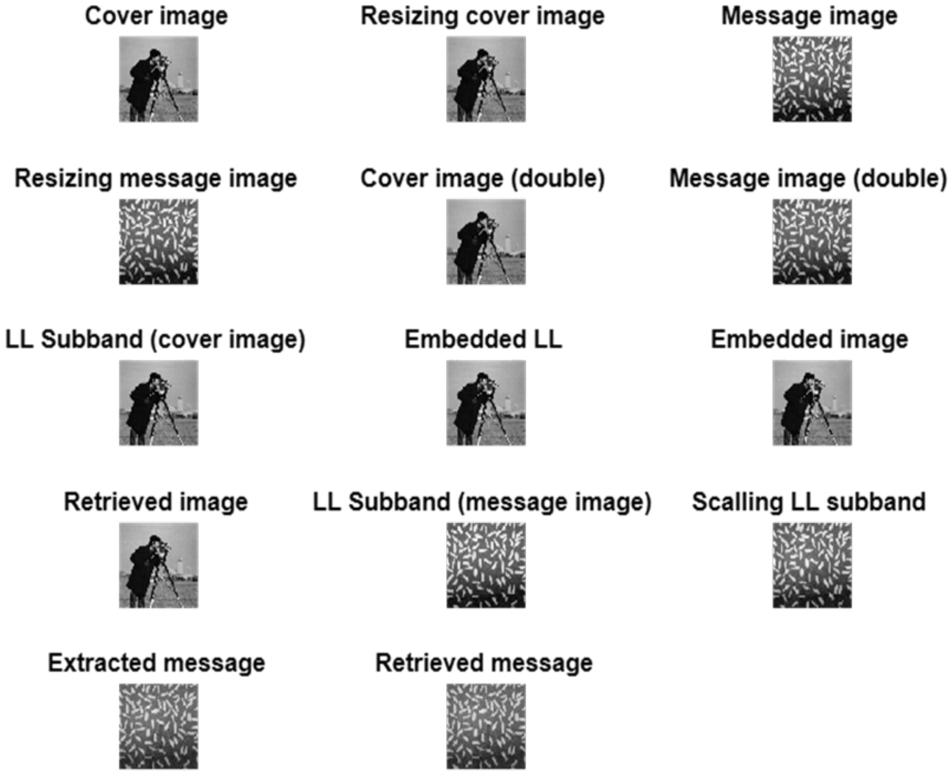

Figure 4. WCPT uses gray messages and cover images

Figure 5. WCPT uses color messages and gray cover images

4.2. **Using WGPT technique.** Figures 6–8 illustrate the implementation of the WGPT technique on various combinations of cover and message images.

Table 2. WCPT quality measurements of extracted images

Message Image	RMSE	PSNR	SSIM	NCC	CR
Image1c	0.0221	81.2430	0.9708	0.9995	4
Image2g	0.0261	79.7980	0.9581	0.9956	4
Image3c	0.0362	76.9566	0.9397	0.9944	4
Image4c	0.1183	66.6711	0.8192	0.9826	4
Image5c	0.0653	71.8325	0.9222	0.9923	4
Average	0.0536	75.30024	0.9220	0.9929	4

1. Embedding a color message in the color cover image, then retrieving them as shown in Figure 6.
2. Embedding a gray message in the gray cover image, then retrieving them as shown in Figure 7.
3. Embedding a color message in the gray cover image, then retrieving them, as shown in Figure 8.
4. And so on with all images.

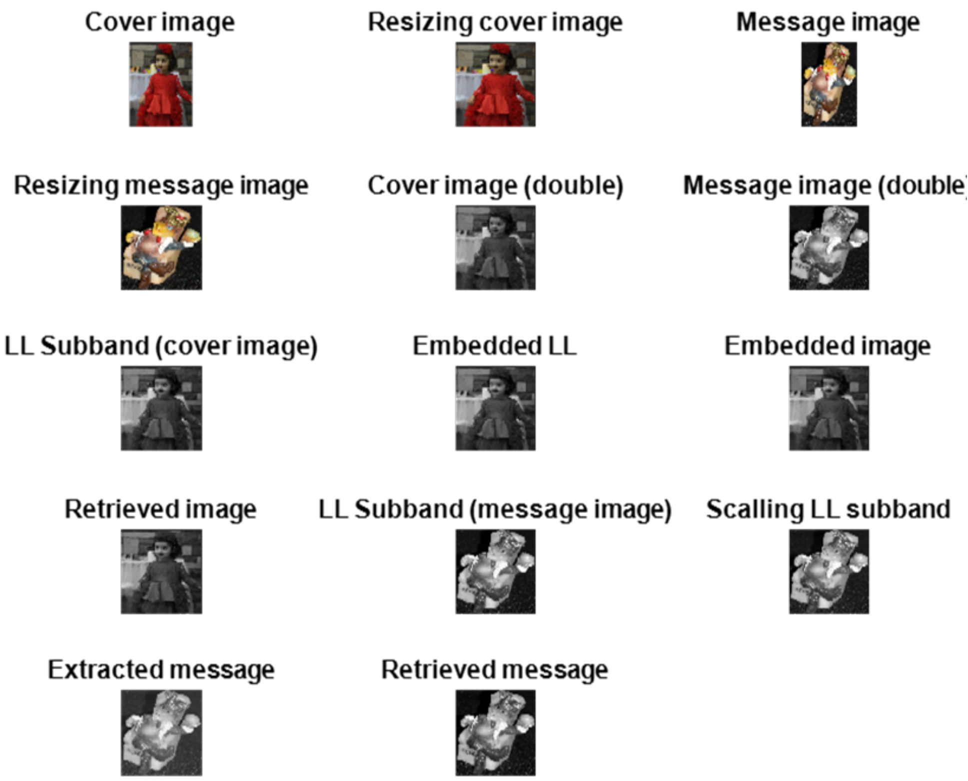

Figure 6. WGPT uses color messages and cover images

Tables 3 and 4 show the quality measurements of the WGPT technique for embedded and extracted images, respectively. The best results are obtained by image1 in both embedded and extracted images, which are color images with the lowest RMSE and highest PSNR, SSIM, and NCC. On the other hand, when comparing the WCPT and WGPT techniques, the average values of PSNR, SSIM, and NCC in the embedded and extracted images of the WGPT technique are greater than those of the WCPT technique and have less RMSE. The results obtained using the WGPT technique are more outstanding than

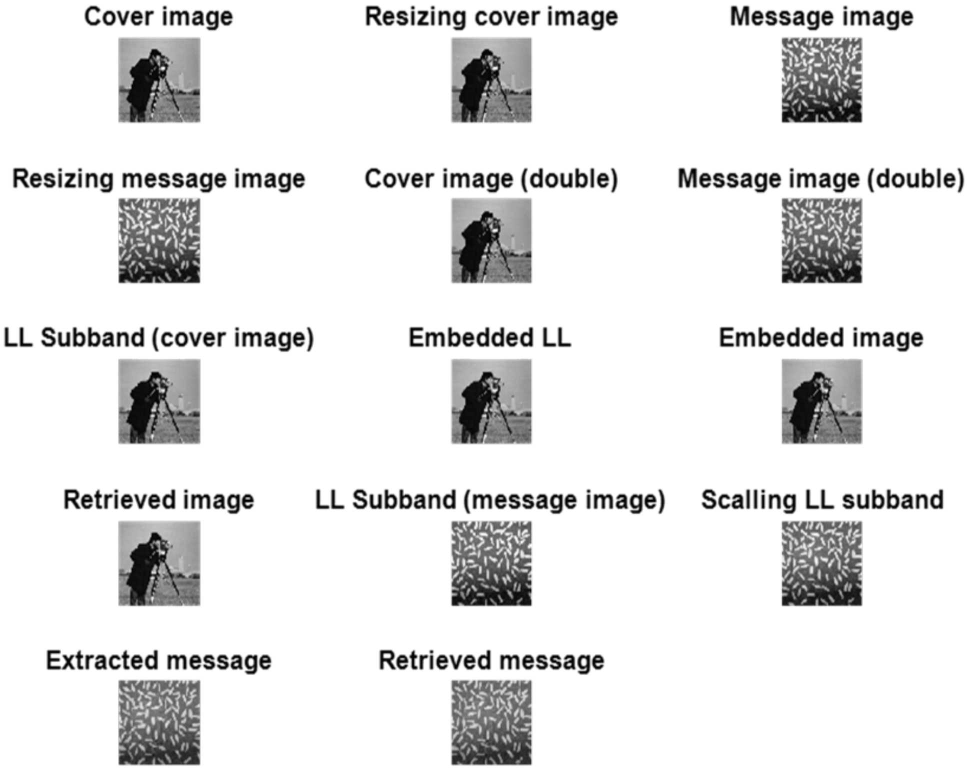

Figure 7. WGPT uses gray messages and cover images

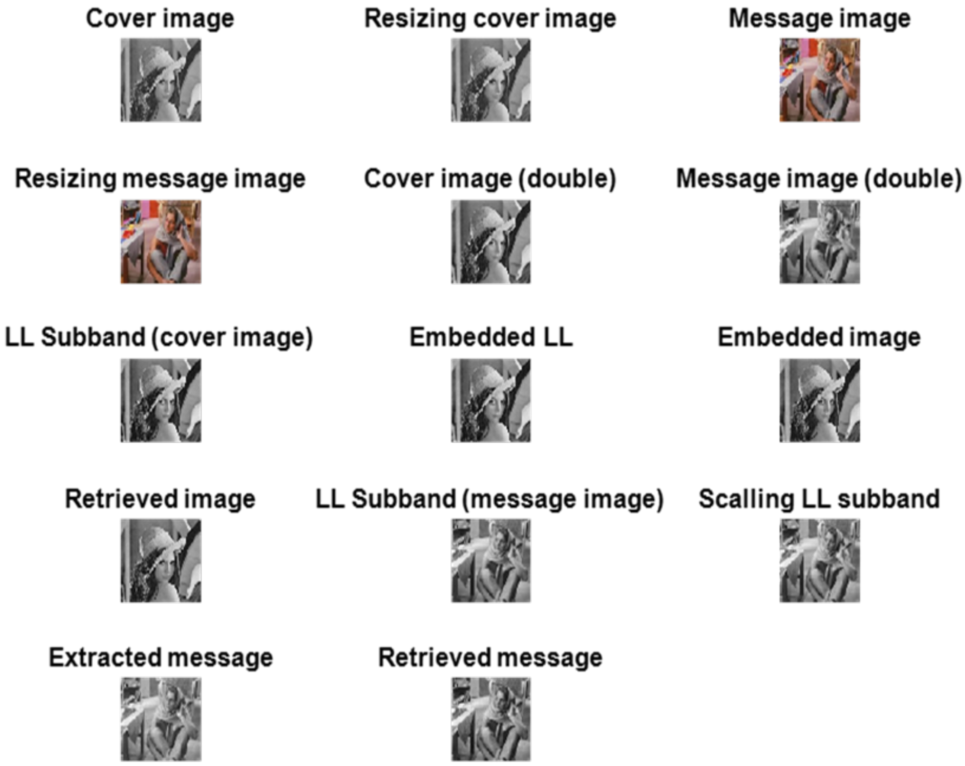

Figure 8. WGPT uses color messages and gray cover images

those obtained using the WCPT technique, indicating that the method has yielded high-quality measurements. The two techniques have a CR value of 4.

Table 3. WGPT quality measurements of embedded images

Cover Image	RMSE	PSNR	SSIM	NCC	CR
Image1c	0.0137	85.3964	0.9999	0.9998	4
Image2g	0.0146	84.8437	0.9983	0.9996	4
Image3g	0.0147	84.7845	0.9979	0.9995	4
Image4c	0.0242	80.4545	0.9927	0.9989	4
Image5c	0.0179	83.0737	0.9950	0.9993	4
Average	0.01702	83.71056	0.9968	0.9994	4

Table 4. WGPT quality measurements of extracted images

Message Image	RMSE	PSNR	SSIM	NCC	CR
Image1c	0.0316	78.1371	0.9745	0.9990	4
Image2g	0.0363	76.9327	0.9381	0.9965	4
Image3c	0.0362	76.9566	0.9297	0.9944	4
Image4c	0.0679	71.4934	0.8592	0.9824	4
Image5c	0.0382	76.4895	0.9122	0.9926	4
Average	0.04204	76.00186	0.9227	0.9930	4

4.3. **Using HGPT technique.** Figures 9–11 illustrate the implementation of the HGPT technique on various combinations of cover and message images.

1. Embedding a color message in the color cover image, then retrieving them, as shown in Figure 9.
2. Embedding a gray message in the gray cover image, then retrieving them as shown in Figure 10.
3. Embedding a color message in the gray cover image, then retrieving them, as shown in Figure 11.
4. And so on with all images.

Tables 5 and 6 indicate the implementation of the HGPT technique for embedded and extracted images.

Table 5. HGPT quality measurements of embedded images

Cover Image	RMSE	PSNR	SSIM	NCC	CR
Image1c	0.0143	85.0241	0.9991	0.9999	16
Image2g	0.0142	85.0850	0.9989	0.9997	16
Image3g	0.0140	85.2082	0.9987	0.9996	16
Image4c	0.0223	81.1647	0.9934	0.9987	16
Image5c	0.0165	83.7811	0.9985	0.9994	16
Average	0.01626	84.05262	0.99772	0.99946	16

The results illustrate that the HGPT technique achieves effective compression (CR = 16) with better image quality for embedded and extracted images. However, their PSNR, SSIM, and NCC average values are higher than those of WCPT and WGPT. Thus, using the HGPT technique enhanced the performance of image steganography by increasing capacity and robustness for hiding information and improved image compression by increasing the compression ratio. Tables 7 and 8 compare the proposed techniques for embedded and extracted images, respectively. These tables show that the HGPT technique used for embedded images or extracted images has the lowest value of RMSE and

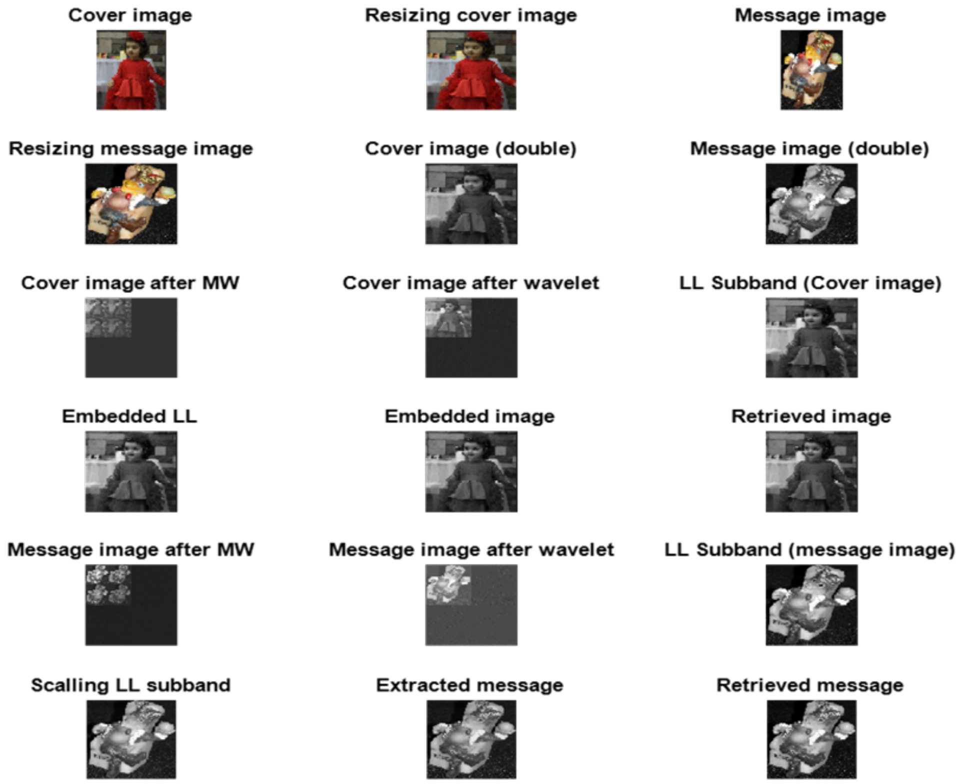

Figure 9. HGPT uses color messages and color cover images

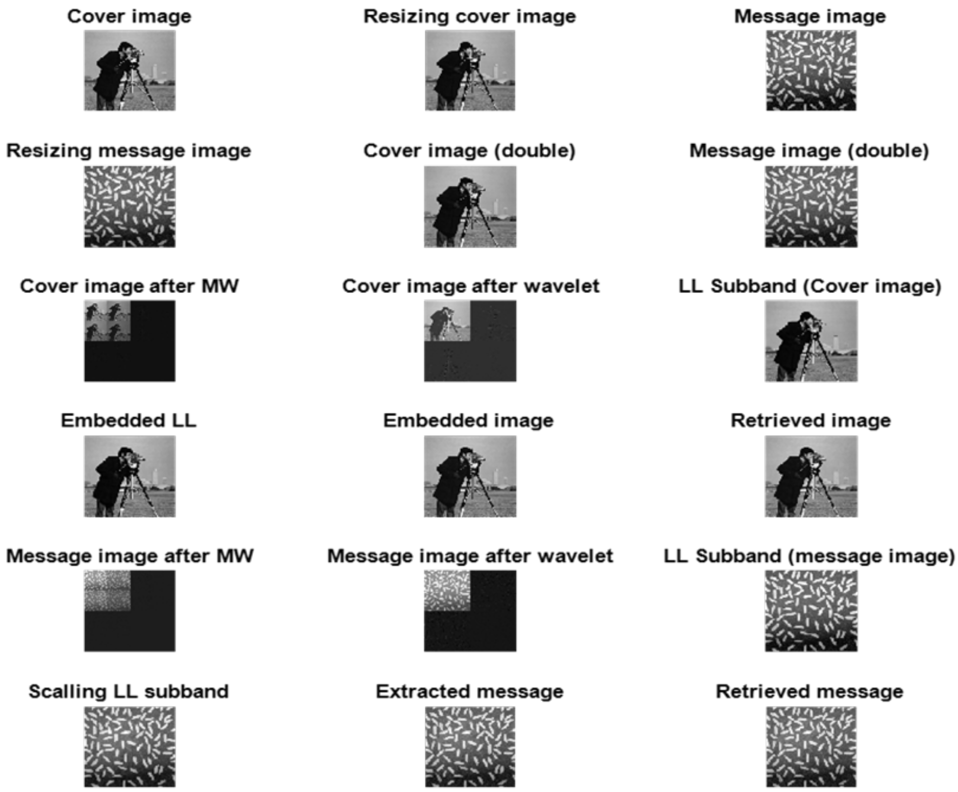

Figure 10. HGPT uses gray message and gray cover images

the higher values of PSNR, SSIM, and CR. This means that the image quality after compression using this technique is more efficient than WCPT and WGPT. Because the

Figure 11. HGPT uses color messages and gray cover images

Table 6. HGPT quality measurements of extracted images

Message Image	RMSE	PSNR	SSIM	NCC	CR
Image1c	0.0302	78.5307	0.9850	0.9997	16
Image2g	0.0368	76.8138	0.9604	0.9986	16
Image3c	0.0384	76.4442	0.9824	0.9957	16
Image4c	0.0601	72.5533	0.8164	0.9845	16
Image5c	0.0406	75.9603	0.9401	0.9873	16
Average	0.04122	76.06046	0.93686	0.99316	16

multi-wavelet possesses more than one scaling function, it has a large degree of freedom and is likely to perform better in image processing applications than a scalar wavelet [4].

Table 7. Comparison between the proposed techniques for embedded images

Technique type	RMSE	PSNR	SSIM	NCC	CR
WCPTav	0.01846	83.69734	0.9967	0.9994	4
WGPTav	0.01702	83.71056	0.9968	0.9994	4
HGPTav	0.01626	84.05262	0.99772	0.99946	16

Table 9 compares embedded image quality metrics with those from previous research. The proposed technique's PSNR, CR, and SSIM results indicate a better-quality image because they are higher than those in other research.

The results indicated that the proposed technique HGPT hides the message image with the best quality metrics and compression ratio. Fig. 12 shows samples of cover and message images.

Table 8. Comparison between the proposed techniques for extracted images

Technique type	RMSE	PSNR	SSIM	NCC	CR
WCPTav	0.0536	75.30024	0.9220	0.9929	4
WGPTav	0.04204	76.00186	0.9227	0.9930	4
HGPTav	0.04122	76.06046	0.93686	0.99316	16

Table 9. Comparison of the embedded image quality metrics with previous researches

Comparison	Technique used	PSNR	CR	SSIM
[1]	Image steganography using histogram modification and wavelet transform	35.4219	-	-
[3]	Grayscale image compression using adaptive pixel-based technique	44.1232	12.6909	-
[4]	Comparison hybrid techniques with mixed transform using quality and compression metrics	53.5303	-	-
[15]	Image steganography with double matrix decomposition based on multi-region coverage and wavelet transform	49.5106	16	0.99389
Proposed technique	HGPT	84.05262	16	0.99772

(a) Samples of cover images

(b) Samples of message images

Figure 12. Samples of cover and message images

5. **Conclusion.** The security of the message information has been given more attention nowadays [23]. This research presented steganography based on image compression using dual techniques that combine wavelet and multiwavelet transforms. It is an advanced method for securely performing data perception by balancing masking accuracy and data size while maintaining image accuracy and compression effectiveness. The presented technique achieves discreet detail, preserving the original image's characteristics. Firstly, WCPT and WGPT are compared according to quality metrics, and then the best technique, WGPT, is combined with multiwavelet to produce HGPT. Combining

various frequency conversions improves performance by simultaneously creating different frequency factors. The HGPT hides the message image with the best quality metrics, including a PSNR of 84.05262 and a high compression ratio of 16 for embedded images, and 76.06046 and 16 for extracted message images. Therefore, it achieves average PSNR, SSIM, NCC, and CR values that are greater than those of WCPT and WGPT. Thus, it enhances the performance of image steganography by increasing capacity and robustness for hiding information while also improving image compression by increasing the compression ratio.

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