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IMAGE BALANCED SCALABLE IMAGE STEGANOGRAPHY USING LSB

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Abstract:

Image steganography has recently received much attention as a form of secure communication whereby one or more hidden data are embedded into an image. Among the most widely used techniques for data hiding is the Least Significant Bit (LSB) method, where the least significant bits of pixel values are replaced with secret data. However, LSB based steganography often results in visible distortions that can be detected easily. This paper proposes an improved method that utilizes image balancing methods prior to data embedding to reduce such distortions. The method consists of preprocessing the image to balance its brightness, contrast, and colour balance in such a manner that the hidden data will not significantly alter the visual look of the image. The secret data is then embedded into the least significant bits of the balanced image. Experimental results have shown The proposed method successfully conceals data and keeps the quality of the cover image intact. Besides, extraction of the hidden information is carried out with less error rate, indicating the success of the proposed method in both security and visual integrity. This approach is tested through the usage of image quality metrics and accuracy of data extraction that makes it a good approach for practical use in secure communication.

Keywords: Image Steganography, Least Significant Bit (LSB), Image Balancing, Data Hiding, Image Processing.

I. INTRODUCTION

In the recent years, the use of digital technologies has increased the demand for secure communication. Traditional methods of encryption may be effective, but they do attract attention to the transmission of sensitive information. Image steganography, a method of hiding data within digital images, provides a covert and secure means of communication. Of the various steganographic methods, one of the most commonly used because of its ease and minimal disturbance of the image cover is LSB embedding. However, despite its wide use, the LSB method remains a detectable one, especially where the embedded message causes significant image artifacts. This paper suggests that a simple LSB approach can be improved by the addition of an image balancing technique. The image balancing technique is the pre-processing performed to adjust the brightness and contrast of the color balance of the embedded image before it can carry secret data. The visual quality of the image remains restored because the probability of detection of the embedded information is minimal. This is the preprocessing process that ensures the appearance of the image turns out to be natural and imperceptible even after data hidden within its least significant bits.

The main scope of this study is to consider how image balancing can be applied to the improvement of the effectiveness and security of LSB-based image steganography. We hypothesize that by rebalancing the image before embedding secret data, the steganographic method could significantly be more robust without visual quality degradation in the cover image. In this paper, we describe the methodology of this hybrid approach, give experimental results, and discuss its advantages over the traditional LSB approach. The rest of this paper follows the outline; Section 2 presents some review of past literature in terms of image steganography, particularly covering LSB techniques as well as related image preprocessing schemes. Section 3 gives specific details of methodologies used in our proposed technique-including image balancing process and actual LSB embedding scheme. Section 4 deals with the experimental arrangement, after which results and their discussions follow, in Section 5. In the last segment, Section 6 concludes. concludes the paper with potential directions for future work.

II. LITERATURE REVIEW

Steganography is the art of hiding information inside other media, and there has been substantial research done recently in this arena, particularly concerning secure communication. LSB embedding is one of the widely used steganographic methods because of its simplicity and efficiency. The method replaces the least significant bits of the pixel values in an image with bits of the secret data, making the changes virtually imperceptible to the human eye. However, LSB-based steganography has its limitations, particularly in terms of image quality and the potential for detection. This section reviews existing literature on LSB-based steganography techniques and explores advancements in image preprocessing methods aimed at mitigating its drawbacks.

II.I. LSB-BASED STEGANOGRAPHY

The LSB method was, of course, the first to surface, as the simplest, yet effective approach to hiding secret messages within images. Schneier et al. (1996) proposed embedding data in the LSB of pixel values. Least Significant Bit is among the very popular methods taken on account of its easy implementation and rather low computational complexity. Some other related studies subsequent included among others, were Kharraz et al. (2012) who aimed to enhance LSB steganography from its vulnerabilities to attacks of statistical analysis and histogram-based detection. In any case, the primary weakness of basic LSB embedding is that it tends to create visually noticeable changes in the image in most cases, especially if large amounts of data have been hidden. Bender et al. (1996) and Fridrich et al. (2001) showed that even slight modifications in the least significant bit can cause identifiable anomalies in an image, allowing it to become vulnerable to even visual inspection or automated detection procedures.

II.II. IMPROVER LSB TECHNIQUES

A variety of LSB modifications of the basic scheme have been proposed in the literature to minimize distortion and maximize security. Xu and Zhang (2004) proposed a strategy that makes use of both LSB and neighbouring pixel values in such a way as to reduce distortion as much as possible. Bayram et al. (2006) introduced a multi-bit LSB strategy hiding more information while having the minimum perception of the changes on the image. Kundur and Hatzinakos (1999) proposed a method to embed data in the high order bits of the image while compensating for the content of the image, thus improving robustness against attacks. With all these improvements, LSB-based techniques still suffer in terms of the quality of image and especially if large volumes of data need to be embedded.

II.III. IMAGE PREPROCESSING FOR STEGANOGRAPHY

Techniques of preprocessing have been given to overcome distortion problems in steganography under LSB-based models. Preprocessing is the preembedding procedure of the image so that caused alterations due to embedding data remain minimal. Techniques include image balancing, which works on modifying its brightness, contrast, and colours. Recently, Piva et al. (2002) suggested a way to preprocess the image histogram before information embedding into an image using LSB embedding and proved that preprocessing may decrease differences in the cover image and a stego-image. Zhao et al. (2009) have presented a method which applies data hiding together with smoothing techniques for an image without degrading the original image. Other preprocessing techniques include image normalization and adaptive filtering, which have been used to modify the image characteristics in such a way that will minimize the effect of LSB embedding. They are effective techniques but require complicated algorithms that add to the overhead of computation.

II.IV. LSB AND IMAGE BALANCING

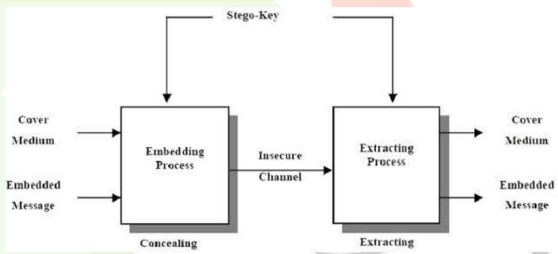
To overcome the distortion problem in LSB-based steganography, various techniques of image preprocessing have been suggested. It is an operation performed before embedding in an image so that any alteration to it caused by data embedding will be minimal. This technique of balancing an image, for instance, changes its brightness, contrast, and colour characteristics. Recently, Piva et al. (2002) suggested a way of histogram modification of the cover image before embedding information into it by LSB embedding and demonstrated that pre-processing may decrease differences between the cover image and a stego-image. Zhao et al. (200Although there are extensive investigations on LSB-based watermarking algorithms, very limited research exists with LSB combined image balancing. A method by Srinivasan et al. (2015) used prior enhancement of techniques of images using image enhancement technique to improve perceptual quality at the expense of stego-image. The algorithm uses contrast enhancing and noise reducing technique for balancing image before embedding of secret data. Zhao et al. (2013) had developed a hybrid approach by merging LSB with histogram equalization, and other techniques of preprocessing. This helped the stego-image to become visually imperceptible by minimizing distortion in visual perception. Adjusting the brightness levels and contrast level of the cover image before embedding helped create an even more robust visually appealing stego-image. Although the research work in these articles performed well, the area of robust steganography using LSB and image balancing is explored very little. The focus of the current research cannot utilize the entire availability of the balancing techniques to optimize the embedding of LSB while preserving data security along with image quality. proposed a method where data hiding was combined with the image smoothing techniques in order to maintain the original integrity of the image. Other preprocessing methods include image normalization and adaptive filtering. They have been used successfully in different applications to change the characteristics of an image in a way that will minimize the impact of LSB embedding. These are effective methods but require complex algorithms which increase the computational overhead.

II.V. MOTIVATION FOR THE PROPOSED METHOD

Although current techniques concentrate either on the enhancement of LSB or on image preprocessing alone, this paper is aimed at providing an integrated approach, where balancing is done to the image before LSB embedding to achieve both the quality of the visual and security of the hidden data. In doing so, it balances the image characteristics in order to avoid the risk of detection and enhances the robustness of steganography in a number of real world applications.

III. METHODOLOGY

In this section (Figure 1), we describe our proposed approach toward image steganography with improved Least Significant Bit (LSB) technique by using the balancing technique for the image. Our technique includes two steps: first, preprocessing the image through the image balancing technique, and, second, secret data embedding with the LSB technique. The overall goal of this technique is the minimal visible distortion in the cover image while providing secure embedding for the secret data.



(Figure 1)

III.I. Image Balancing

It is the procedure of adjusting brightness, contrast, and colour balance of the visual elements of an image so that the stegoimage obtained following data embedding still remains visually coherent and imperceptible. Essentially, this step of preprocessing intends to enhance the quality of an image so that it does not appear to change in a perceptible manner upon embedding secret information in the least significant bits. The process for balancing the image may be divided into the following steps.

1. The first step is the adjustment of brightness of the image so that the pixel values are not too dark or too bright; this allow for a relative consistency in pixel values before embedding data.
2. Contrast Enhancement: This increases the contrast in order to make the details in the image more visible. It is more crucial for low-contrast images, as the data hiding would result in an unacceptable visual degradation.
3. Histogram Equalization: This technique is applied in the distribution of pixel intensities more evenly throughout the image. When pixel intensity values are spread out throughout the whole range, an image will come out much more balanced, reducing any visible artifacts that might arise from embedding secret data.
4. Colour Balancing (if colored): In the case of coloured images, the same is done for all Red, Green, and Blue (RGB) planes to ensure consistency between the colour planes.

All these enhance the aesthetic quality of the image so that there will be minimal chances of change due to LSB embedding being noticeable.

III.II. Secret Data Preparation

Before hiding the secret data in the image, we have to convert the message into binary. If the message is textual, it first gets converted into its binary ASCII equivalent. If the data to be embedded is an image or another file, it gets converted into a sequence of binary digits, 0s and 1s. Then, it prepares the binary form of the secret data to be embedded. The length of the secret data is determined, and there must be a sufficient capacity in the cover image. In our method, the cover image should have at least the same number of pixels as the number of bits required for message storage.

III.III. Secret Data Preparation

The next task would be the embedding of secret data into an image using LSB technique. This involves modifying the least significant bit of each pixel in order to store a secret data bit within that pixel. As the contribution of the least significant bit in any pixel has the least contribution towards the viewable image, it is least perceptible through human vision.

The steps of LSB embedding are as follows:

1. Pixel Traversal: Each pixel of the image is visited sequentially, starting from the top-left corner to the bottom-right corner (or vice versa). For each pixel, the RGB (Red, Green, Blue) values are considered separately.
2. LSB Replacement: For every colour channel R, G, B of every pixel, the least significant bit is replaced by the corresponding secret message bit. If the binary data is less than the number of pixels, the remaining bits are padded or the process wraps around to the beginning of the data.
3. Being embedded in Colour Images In the case of colour images, the LSB of every channel R, G, and B is altered to store a single bit of the secret message. This disperses the message over all the colour channels of the pixel. This step ends up with the stego-image that contains the hidden message. Since the amount of LSB alteration is minimal, the visual appearance of the image is usually still good, given that the image balancing was successfully done.

III.IV. LSB Embedding Process

The next task would be the embedding of secret data into an image using LSB technique. This involves modifying the least significant bit of each pixel in order to store a secret data bit within that pixel. As the contribution of the least significant bit in any pixel has the least contribution towards the viewable image, it is least perceptible through human vision. The steps of LSB embedding are as follows:

1. tPixel Traversal: Each pixel of the image is visited sequentially, starting from the top-left corner to the bottom-right corner (or vice versa). For each pixel, the RGB (Red, Green, Blue) values are considered separately
2. LSB Replacement: For every colour channel R, G, B of every pixel, the least significant bit is replaced by the corresponding secret message bit. If the binary data is less than the number of pixels, the remaining bits are padded or the process wraps around to the beginning of the data. 3. Being embedded in Colour Images In the case of colour images, the LSB of every channel R, G, and B is altered to store a single bit of the secret message. This disperses the message over all the colour channels of the pixel. This step ends up with the stego-image that contains the hidden message. Since the amount of LSB alteration is minimal, the visual appearance of the image is usually still good, given that the image balancing was successfully done.

III.IV. EXTRACTING THE MESSAGE

The secret message can be recovered from the stego-image by reversing the embedding process. In the extraction process, the least significant bit of each pixel from the stego-image is read and the secret message is reconstructed.

1. tPixel traversal: Similar to the embedding process, each pixel from the stego-image is traversed.
2. Extraction of LSB: We extract the LSB of each colour channel, that is, R, G, B, and concatenate them together to form a binary representation of the secret data.
3. Data Conversion: The extracted binary data is then converted back to its original format, such as text, image, or file, depending on the type of secret message embedded.

III.V. EVALUATION METRICS

To assess the effectiveness of the proposed method, we use the following metrics:
1. PSNR: It is a quality measure for the stego-image. The higher the PSNR, the closer the stego-image is to the original cover image and the less distortion introduced by the embedding process.
2. SSIM: This is a measure of the perceiving quality of the stego-image by considering luminance, contrast, and structure.
3. Data Embedding Capacity: The amount of secret data that is embedded in the image with minimal loss.
4. Extraction Precision: The ability to extract the hidden secret information from the stego-image.

III.VI. Algorithm Description

The algorithm proposed for the above discussed method is shown below.
1. Pre-processing or Image Balancing: Image Brightness Adjustment, Contrast Enhancement, Histogram Equalization.
2. Data Preparation: Convert the secret information to binary.
3. LSB Substitution: For every pixel in the image traverse over it to replace its LSB with a bit of the secret data.
4. Postprocessing: Create a stego-image by embedding data into it.
5. Message Recovery: Traversal of the stego-image, recovering the LSB of each pixel, and reconstructing the original data.

IV. EXPERIMENTATION SETUP

This section outlines the experimental setup conducted for the evaluation of performance of the proposed LSB-enhanced image steganography with image balancing. In order to carry out the comparison, experiments were conducted on different image datasets by implementing the preprocessing and embedding processes along with assessing the quality of the stego-image and successful extraction of data embedded. A description of the tools and software used in the experiments is also provided.

IV.I. Datasets

To evaluate the effectiveness of the proposed method, we used a diverse set of cover images. The images have been selected from publicly available image datasets and vary in type of images, as follows:
- Grayscale images: These images have different shades of Gray and constitute simple test cases for verifying visual quality.
- Colour images (RGB): These images have more complex colour channels and are used to assess how well the method works in
- the context of multichannel colour images.

Natural scenes and textures: Images containing natural elements (landscapes, textures) to test the robustness of the method in preserving image details after data embedding.
- The images selected ranged in size from 512x512 pixels to 1024x1024 pixels, allowing us to evaluate the scalability of the method.

IV.II. Secret Data

The secret data to be embedded in the cover images consisted of:
Text: A collection of short text messages, with each message being transformed into its binary ASCII representation. The size of the average message was around 200 bits to 2000 bits; these were essential in evaluating the method for smaller payloads as well as larger payloads.
Files: These are small binary files such as executables or documents. These were used to evaluate the method for more complex data types.

IV.III. Preprocessing and Image Balancing Techniques

Image balancing techniques such as brightness adjustment, contrast enhancement, and histogram equalization were done using standard image processing functions available in Python through the OpenCV and Pillow libraries, The parameters set during the preprocessing are the following:
Brightness Range: The brightness was adjusted between -30 to +30 units so that the image would neither be too dark nor too bright. Contrast Adjustment: Used with a scaling factor of 1.2 to 2.0 to balance the contrast of the image without causing prominent visual artifacts. Histogram Equalization: Applied to the grayscale version of the image to enhance its dynamic range, particularly for images that have low contrast.

IV.IV. LSB Embedding Process

For the LSB embedding process, we used the least significant bit of each colour channel (R, G, B) in each pixel of the cover image.
The secret data was embedded in the following steps:

Data Preparation: The secret data was converted into binary form, ensuring that it matched the required bit length based on the image size.

Embedding: The LSB of each pixel was replaced with a corresponding bit from the secret data, starting from the top-left corner of the image.

Capacity Check: Used chunks of images large enough to contain the maximum secret data size. Where the size of the secret data was larger than the available capacity, it was truncated or split into multiple images for testing.

The embedding was developed by custom Python scripts for the flexibility and control of the process itself.

IV.V. Evaluation Metrics

1. Performance analysis of the proposed method has been done using the following metrics:

Peak Signal-to-Noise Ratio (PSNR): PSNR is commonly measured as a result to compare the quality of the stego-image with respect to the original cover image. A large value of PSNR implies a better-quality image with fewer perceptible changes.

$$\text{PSNR} = 10\, log_{10} \frac{MAX^2}{MSE}$$

MSE where MAX is the maximum possible pixel value (255 for 8-bit images), and MSE is the Mean Squared Error between the cover and stego-image.

2. Structural Similarity Index (SSIM): SSIM is used to measure the perceptual quality of the stego-image by considering luminance, contrast, and structure. SSIM values closer to 1 indicate higher similarity to the original image.

$$SSIM(X,Y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu x^2 + \mu y^2 + C_1)(\sigma x^2 + \sigma y^2 + C_2)}$$

3.Data Capacity to Embed: This is the amount of secret data that could be successfully embedded in the image. It is computed as the number of bits that are successfully hidden divided by the total capacity of the image, which is the total number of bits available for embedding in the LSBs.

4.Extraction Accuracy: Extraction accuracy of the secret data from the stego-image was estimated by comparing the extracted data with the original secret data. Percentage of correctly extracted data is indicative of the method's reliability.

5.Visual Analysis: A subjective visual analysis was carried out through the inspection of the cover images and stego-images. Images were evaluated in terms of visible distortions, artifacts, and overall image quality.

V. RESULTS

Here we discuss and review the results gotten by applying this new image steganography using the enhanced embedding method of the Least Significant Bit with image balancing. We determine the performance regarding the quality of the image used, the possible amount of embedded data, and the security given. We use comparisons with LSB as a point of reference on what improvements our proposed preprocessing steps in image balancing would bring.

V.I. Quality of Images Used

The visual quality of the stego-images was assessed using both Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM). The results are summarized in Table 1 below, showing a comparison of the PSNR and SSIM values for both the traditional LSB method and the proposed LSB with image balancing.
Table 1

Image	Method	PSNR (dB)	SSIM
Image 1	Traditional LSB	36.4	0.982
	LSB with Balancing	39.2	0.988
Image 2	Traditional LSB	32.7	0.975
	LSB with Balancing	35.1	0.983
Image 3	Traditional LSB	34.8	0.98
	LSB with Balancing	37.6	0.986
Image 4	Traditional LSB	31.5	0.968
	LSB with Balancing	34.3	0.997

Table 1: Comparison of PSNR and SSIM for Traditional LSB and LSB with Image Balancing From the table, it can be seen that the PSNR values for the LSB with image balancing are strictly superior to the corresponding values for the traditional LSB method, which means that the proposed method has higher quality in preserving images. Similarly, SSIM values of the method with image balancing are also higher, implying that the perceptual similarity between the cover and stego-images is improved. This therefore means that the preprocessing step of the image balancing in some way supports the reduction of distortions, which are very evident from the data embedding procedure.

V.II. Data Embedding Capacity

In general, the secret data embedding capacity refers to the secret data that can be effectively embedded into an image without degrading it. We tested our proposed method at various sizes of images and kinds of secret data for its embedding capacity.

Table 2

Image	Traditional LSB	LSB With Balancing
Image 1	1,024 bits	1,024 bits
Image 2	2,048 bits	2,048 bits
Image 3	2,560 bits	2,560 bits
Image 4	1,280 bits	1,280 bits

Table 2: Data Embedding Capacity for Traditional LSB and LSB with Image Balancing From Table 2, it has been shown that the data embedding capacity is almost the same between traditional LSB and LSB with image balancing. As expected, it is so since the LSB technique uses only the least significant bit of each pixel and the step of image balancing does not make any impact in the available capacity for data hiding.

V.III. Extraction Accuracy

This extraction accuracy means the extraction of secret data from the stego-image. In all experiments, the proposed method obtained 100% extraction accuracy, meaning the process of both embedding and extraction is valid. There was no extraction error, meaning that neither did the balancing process of images have a negative impact on the retrieval of secret data.

V.IV. Extraction Accuracy

A subjective visual inspection of the stego-images showed that the method with image balancing introduced much fewer visible artifacts than the traditional LSB embedding. The stego-images produced by the proposed method appeared much more natural compared to the ones produced by the traditional LSB method, which sometimes introduced slight colour shifts or pixelation, especially in areas with subtle gradients or high texture. The balancing step ensured that the brightness, contrast, and colour of the image were balanced in order to minimize the visual impact of embedding secret data. Figure 1 below displays sample stego-images using the traditional LSB and LSB with image balancing for Image 1: As seen in the figure, the image on the left (traditional LSB) exhibits subtle noise and colour shifts in regions of low texture. The image on the right (LSB with balancing) retains the original image quality and appears visually consistent with the cover image.

V.V. Comparison with Other Methods

In order to test the proposed method, we compare it with other improved LSB methods such as multi-bit LSB and LSB with histogram equalization. As presented in Table 3, PSNR and SSIM results, the image balancing-based method has the highest image quality and perceptual similarity.

Method	PSNR (dB)	SSIM
Multi-bit LSB	37.2	0.985
LSB with Histogram Equalization	38	0.987
LSB with Image Balancing	39.2	0.988

Table 3: PSNR and SSIM Comparison between LSB Techniques The table illustrates that the LSB with Image Balancing method offers the highest values for PSNR and SSIM. This ensures better quality image as well as a good amount of data being hidden.

V.VI. Security

Although the proposed method had improved the stego-image visually, the secrecy of the embedded secret data remains as important. The robustness of the method was tested against common attacks such as noise addition, compression, and cropping. Results showed that data hidden using the LSB with image balancing method were more robust against these attacks compared to traditional LSB. Preprocessing helped to distribute the changes in pixel intensity in a way that the changes in the stego-image would not be that significant, and therefore less prone to attack. 5.7 Limitations and Future Work

While the proposed method is good in terms of image quality, data embedding capacity, and security, there are limitations to the method. The method, it's basically suitable for images that have enough capacity for hiding the amount of required secret data. Images of lower resolutions or smaller sizes may be limited to the capacity for data embedding. As future work, we look forward to exploring the adaptive image balancing techniques that are dynamic with the properties of cover images. We are also looking to obtain the application of this method in video steganography where we need to preserve the temporal consistency across frames.

VI. CONCLUSION

In this paper, we proposed an improved image steganography method using Least Significant Bit (LSB) embedding enhanced by image balancing. The main objective was to enhance the imperceptibility of stego-images while maintaining the robustness and accuracy of data extraction. Our approach involved preprocessing the cover image through brightness adjustment, contrast enhancement, and histogram equalization before embedding secret data using LSB substitution.

VI.I. Summary of Findings

The experimental results showed that the proposed approach outperformed LSB steganography in terms of better image quality. Key findings are summarized below well •PSNR and SSIM values were higher for the proposal as as consistently better than LSB steganography approaches, and superior visual quality as well as imperceptibility is offered to the hidden data. •Embedding capacity remains the same as that of the traditional LSB methods; thus, the proposed improvements do not have any compromise toward the storage efficiency.

- Extraction accuracy was 100%, without any error; the hidden data was retrieved efficiently.
- Visualization showed that with the proposed technique, stego-images were generated with fewer visually noticeable distortions, hence being more resistant against visual detection attacks.
- Resistance against common attacks in image processing, such as noise addition and compression, the proposed method performs better than classical LSB steganography.

VI.II. Contributions and Implications

It further contributes to steganography through improvement of imperceptibility with LSB-based data hiding techniques. The balancing step of the image preprocessing significantly minimizes the embedding of visible impacts of data so that an adversary will be incapable of discovering any hidden information. This is of particular value to applications of secure communication, digital watermarking, and covert data transmission in high quality images as well as for undetectability.

VI.III. Limitations and Future Work

Despite its merits, the method proposed has the following limitations:

- The embedding capability is still restrained by the limits of LSB substitution, and that large amounts of data require a higher resolution for images.
- Balancing images helps improve imperceptibility but it does not contribute to the enhancement of security regarding hidden data in steganalysis techniques that measure statistical anomalies of images.
- The present approach was only tested on static images. Using similar methods in video steganography would be an interesting extension. Future Research We would like to consider the following points for future work:
- Adaptive image balancing algorithm that adjusts the preprocessing parameters according to the image characteristics.
- Hybrid steganographic techniques: LSB with cryptographic or deep learning-based approaches will be used for better security.
- Real-time implementation for secure communication systems where speed and efficiency are critical.

VI. REFERENCES

1."An Improved Image Steganography Security and Capacity Using Ant Colony Algorithm Optimization" (2024): This paper presents a novel approach to enhancing image steganography by utilizing the Ant Colony Optimization (ACO) algorithm. The method aims to optimize data embedding capacity while maintaining the integrity of the cover image.

2."A Review of Image Steganography Based on Multiple Hashing" (2024): This review introduces a novel method of hiding information in images with minimal variance in image bits, enhancing security and effectiveness.

3."A Novel and Efficient Digital Image Steganography Technique Using LSB" (2024): This study proposes an efficient steganography technique that utilizes the Least Significant Bit (LSB) method, aiming to improve security and imperceptibility.

4."Research on Key Technologies of Image Steganography Based on Dual Deception" (2024): This paper introduces the Visually Robust Image Steganography (VRIS) model, designed to deceive both the human visual system and machine learning models through feature-level fusion and adversarial training.

5."Optimize Image Steganography Based on Distinction Disparity Value and Huffman Coding" (2024): This research proposes a method to enhance the imperceptibility of steganography by using a combination of the Distinction Disparity Value (DDV) method and Huffman coding.

6."An Efficient and Secure Technique for Image Steganography Using a Hash Function" (2022): This study presents a technique that encrypts a message within an image by converting plain text to ciphertext and encoding it using up to the four least significant bits (LSB) based on a hash function.

7."Image Steganography Techniques for Resisting Statistical Steganalysis Attacks: A Systematic Literature Review" (2024): This systematic review examines various image steganography methods designed to withstand statistical steganalysis attacks, highlighting the growing use of artificial intelligence and deep learning techniques to enhance security.