High capacity image steganography using LSB with modified binary addition on RGB indicator

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Abstract. Steganography is the practice of hiding information in the code that makes up digital files and preventing unwanted people from knowing the existence of hidden information. High-capacity steganography techniques have been successfully performed using LSB with binary addition method, but the quality can be improved using LSB with modified binary addition. By using binary addition, message insertion can be done with two bits at once in one insertion process. For six examples of images, the message insertion process is carried out using the binary addition method and modified binary addition method with the use of 100% capacity or using all pixel values of the image. Then the SSIM, MSE, and PSNR values are calculated from each test result. This study shows that the modified binary addition method has better quality than the binary addition method. The test results show that the binary addition method produces average SSIM, MSE, and PSNR values respectively 0.971743, 9.711678, and 38.26588. Meanwhile, modified binary addition resulted in the values of 0.993287, 2.112745, and 44.88844. These results indicate that the modified binary addition method produces better quality than binary addition while maintaining high message capacity.

1. Introduction

Communication and information exchange has become much easier and faster but at the same time issues related to data security and confidentiality have become a major concern in today's era. Studies on data security have been conducted research [1-3]. In order to meet these information security needs, a number of covert and confidential communication techniques have been developed [4]. One of the techniques for data security is Steganography [5]. Steganography is the practice of hiding information in the code that forms digital files such as software and multimedia products such as text, music (in MP3 or WAV format), images or images, and digital video (VCD) while preventing unwanted sources from discovering the existence of communications. That is, data transmission is kept confidential between the communicating parties. This ensures that data protection is well maintained which is a necessity in any type of communication [6-7]. By using steganography, we can embed secret messages in unsuspecting information and send them without anyone knowing the whereabouts of the secret message [8].

One of the high-capacity steganography methods is LSB with binary addition. In this method, the original secret message is not directly inserted into the cover image but only modifies the pixel value in the cover image so that in the extraction process the pixel value will be calculated to find the original bit of the inserted message. In this method, two bits of the secret message can be inserted in one insertion process, so that the capacity of the cover image is twice that of the standard LSB. However, this method also has a weakness, namely the change in the pixel value of the cover image is larger using the LSB
standard. Therefore it is necessary to modify the binary addition process to reduce the difference in pixel value changes and improve the quality of the stego image.

The quality of the LSB method that uses binary addition still needs to be improved. To improve the quality of the stego image results by making modifications to the bucket class used in binary addition. This bucket class is modified so that each class has the same number of members, so that the maximum change in pixel value can be reduced.

2. Methods

The method used in this research is standard LSB, LSB with binary addition, and the proposed method uses LSB with modified binary addition. Least Significant Bit (LSB) is the simplest and most well-known method of image steganography. But vulnerable to various attacks. LSBs of various pixels can be grouped so that they form an array and secret binary messages can be embedded in the rightmost bit, so that distortion is minimum [9-10].

2.1. LSB with binary addition

LSB using binary addition is done by modifying the pixel value without inserting the target data directly. The target data insertion is carried out in two stages, firstly the adjusted value is placed in a special place. Then the binary addition is used to hide the data in the cover pixel. Any secret text characters to be embedded are converted to 7 bit ASCII characters before starting processing. Then determine the value of \( n \) which is the number of bits of the LSB pixel cover used for binary addition [11]. In this binary addition method \( n \) (\( n > 2 \)) bits of the LSB pixel cover are considered for binary addition. If the two LSB bits of the result of this addition are considered, the four combinations are 00, 01, 10, and 11. These combinations are related to the number of 1s in \( n \) bits used during binary addition [11].

2.1.1. Embedding of target data. For example, the string "01001110 ..." will be inserted and \( n = 4 \) LSB pixel cover for binary addition. Suppose that two target bits embedded in the closing pixel have an intensity value of \( 189_{10} (10111101_2) \). The 4 bit LSB of the 8 bit representation is \( 1101_2 \). Now binary addition is made between these 4 bits (1 + 1 + 0 +1 = 11) and the last two bits of this addition \( (11_2) \) are compared with the two target bits \( (01_2) \). This is not the same. So 4 bits \( (1101_2 \) or \( 13_{10} \) are replaced with the closest value of '01' and the result is \( 1000_2 \). Now \( 189_{10} \) \((10111101_2)\) is replaced by \( 184_{10} \) \((10111000_2)\). An example of this process can be seen in Figure 1.

![Figure 1](image.png)

**Figure 1.** Example the insertion process with a binary addition.

2.1.2. Extraction of target data. On the receiving side first the length of the string and the number of bits \( (n > 2) \) involved for binary addition is extracted then the hidden target data is extracted using binary addition. During each iteration, the first pixel intensity is converted to an 8-bit binary form. Then the binary addition is carried out between the LSB \( n \) \((n > 2)\) and the two bits of the binary addition are obtained. For example, the extracted \( n \) value is 4 and the stego pixel value is \( 184_{10} \) \((10111000_2)\). The 4 bit LSB of \( 101111000_2 \) is \( 1000_2 \). Now the last bit of the binary addition \( 1000_2 \) is \( 01 \) \((1 + 0 + 0 + 0 = 01)\). \( 01 \) This is the extracted target secret bit on the receiving side. This process can be seen in Figure 2.
2.2. LSB with modified binary addition

The method proposed in this study uses LSB with modified binary additions. The algorithm designed in this method consists of an embedding algorithm, an extraction algorithm, and an algorithm for creating a modified bucket class table which is a refinement of the bucket class table in binary summation. The bucket class table in binary addition is generated from the binary addition method which adds bit 1 of a binary number with a maximum bit length of 8 bits taken from the pixel value. Then this method will group the numbers 0 to 255 into four bucket classes, namely classes 00, 01, 10, and 11.

The bucket class in the binary addition method has a weakness, namely the uneven number of members of each class and a maximum pixel value change of 7. To correct this, the proposed method uses modified binary addition by modifying the bucket class table.

Suppose \( x \) is a pixel value from 0 to 255, then to determine the class of the \( x \) value uses equation (1).

\[
C_x = \left( x - \left( \frac{x \mod 16}{4} - \frac{x \mod 4}{4} \right) \right) \mod 4
\]  

(1)

If \( C_x \) produces 0 then \( x \) will enter class 00, if \( C_x \) produces 1 then \( x \) will enter class 01, if \( C_x \) produces 2 then \( x \) will enter class 10, and if \( C_x \) produces 3 then \( x \) will enter class 11. Table 1 shows the bucket class table obtained based on the calculation of equation (1).

| Bucket Class | Class members                                                                 | Number of Members |
|--------------|-------------------------------------------------------------------------------|-------------------|
| 00           | 0, 5, 10, 15, 16, 21, 26, 31, 32, 37, 42, 47, 48, 53, 58, 63, 64, 69, 74, 79, 80, 85, 89, 95, 96, 101, 106, 111, 112, 117, 122, 127, 132, 133, 138, 143, 144, 149, 154, 159, 160, 165, 170, 175, 176, 181, 186, 191, 192, 197, 202, 207, 208, 213, 218, 223, 224, 229, 234, 239, 240, 245, 250, 255, 258, 263, 268, 273, 278, 283, 288, 293, 298, 303, 308, 313, 318, 323 | 64                |
| 01           | 1, 6, 11, 12, 17, 22, 27, 28, 33, 38, 43, 44, 49, 54, 59, 60, 65, 70, 75, 76, 81, 86, 91, 92, 97, 102, 107, 108, 113, 118, 123, 124, 129, 134, 139, 140, 145, 150, 155, 156, 161, 166, 171, 172, 177, 182, 187, 188, 193, 198, 203, 204, 209, 214, 219, 220, 225, 230, 235, 236, 241, 246, 251, 252 | 64                |
| 10           | 2, 7, 8, 13, 18, 23, 24, 29, 34, 39, 40, 45, 50, 55, 56, 61, 66, 71, 72, 77, 82, 87, 88, 93, 98, 103, 104, 109, 114, 119, 120, 125, 130, 135, 136, 141, 146, 151, 152, 157, 162, 167, 168, 173, 178, 183, 184, 189, 194, 199, 200, 205, 210, 215, 216, 221, 226, 231, 232, 237, 242, 247, 248, 253 | 64                |
| 11           | 3, 4, 9, 14, 19, 20, 25, 30, 35, 36, 41, 46, 51, 52, 57, 62, 67, 68, 73, 78, 83, 84, 89, 94, 99, 100, 105, 110, 115, 116, 121, 126, 131, 132, 137, 142, 147, 148, 153, 158, 163, 164, 169, 174, 179, 180, 185, 189, 195, 196, 201, 206, 211, 212, 217, 222, 227, 228, 233, 238, 243, 244, 249, 254 | 64                |

In Table 1, each class has the same number of members so that it is more evenly distributed. The maximum pixel value change in this method is 3. The minimum pixel value change will result in a higher stego image quality.

3. Results and Discussion

This section shows the simulation results of the proposed technique. Then analyze the results based on SSIM, MSE and PSNR calculations, and based on the capacity of the media coverage. The testing is done on six images from different resolutions i.e., 16x16 pixel, 32x32 pixel, 64x64 pixel, 128x128 pixel, 256x256 pixel, and 512x512 pixel from images airplane, baboon, lena, peppers, sailboat, and tiffany. The analysis was carried out based on the embedding of text messages and using all pixel values. Some examples of the results from the test database are shown in Table 2.
Table 2. Comparison Result of Cover Image and Stego Image.

| Name / Resolution | Cover Image | Stego Image | Stego Image | Stego Image |
|-------------------|-------------|-------------|-------------|-------------|
|                   |             | LSB Standard | LSB with Binary Addition | LSB with Modified Binary Addition |
| Airplane / 16 × 16 pixel | ![Airplane Cover Image](image1) | ![Airplane LSB Standard](image2) | ![Airplane LSB with Binary Addition](image3) | ![Airplane LSB with Modified Binary Addition](image4) |
| Baboon / 32 × 32 pixel | ![Baboon Cover Image](image5) | ![Baboon LSB Standard](image6) | ![Baboon LSB with Binary Addition](image7) | ![Baboon LSB with Modified Binary Addition](image8) |
| Lena / 64 × 64 pixel | ![Lena Cover Image](image9) | ![Lena LSB Standard](image10) | ![Lena LSB with Binary Addition](image11) | ![Lena LSB with Modified Binary Addition](image12) |
| Peppers / 128 × 128 pixel | ![Peppers Cover Image](image13) | ![Peppers LSB Standard](image14) | ![Peppers LSB with Binary Addition](image15) | ![Peppers LSB with Modified Binary Addition](image16) |
| Sailboat / 256 × 256 pixel | ![Sailboat Cover Image](image17) | ![Sailboat LSB Standard](image18) | ![Sailboat LSB with Binary Addition](image19) | ![Sailboat LSB with Modified Binary Addition](image20) |
| Tiffany / 512 × 512 pixel | ![Tiffany Cover Image](image21) | ![Tiffany LSB Standard](image22) | ![Tiffany LSB with Binary Addition](image23) | ![Tiffany LSB with Modified Binary Addition](image24) |

Now the image quality of the output stego images is analyzed by MSE, SSIM, and PSNR. Mean Square Error determines image quality. For good image quality, the Mean Square Error value must be minimal [12]. It is calculated as in equations 2 [13].

\[
MSE = \frac{1}{N \times M} \sum_{i=1}^{N} \sum_{j=1}^{M} [f_1(i,j) - f_2(i,j)]^2
\]  

Structural Similarity Index Metric (SSIM) is used to evaluate the similarity between the cover image and the stego image. The results of the SSIM value are limited in the range between 0 and 1. If the SSIM value is close to 1, it indicates the stego image is the same as the cover image and has high quality [14]. It is calculated as in equation 3.

\[
SSIM(x, y) = \frac{(2\mu_x \mu_y + \epsilon_1)(2\sigma_{xy} + \epsilon_2)}{(\mu_x^2 + \sigma_x^2 + \epsilon_1)(\mu_y^2 + \sigma_y^2 + \epsilon_2)}
\]  

The Peak Signal to Noise Ratio (PSNR) is used to measure the quality of stego image compared to the cover image. Higher PSNR indicates that the reconstruction of the image is of higher quality. PSNR is considered good enough to hide information if it exceeds the 40 dB threshold [15]. It is calculated as in equation 4.

\[
PSNR = 20 \times \log_{10} \frac{255^2}{\sqrt{MSE}}
\]
Stego image quality testing results can be seen in Figures 3 to 5. These tables and graphs show the values of MSE, SSIM, and PSNR at 100% message capacity usage.

![Mean Square Error (MSE) for 100% capacity usage](image1)

**Figure 3.** Mean Square Error (MSE) for 100% capacity usage.

![Structural Similarity Index Metric (SSIM) for 100% capacity usage](image2)

**Figure 4.** Structural Similarity Index Metric (SSIM) for 100% capacity usage.

According to graphs in figures 3 to 5, we can see that the MSE value of the modified binary addition method is smaller than the binary addition method, this indicates a smaller error rate. The SSIM value of the modified binary addition method is greater than the binary addition, this indicates that the quality of the resulting stego image has a higher degree of similarity. The PSNR value of the modified binary addition method is higher than the binary addition and greater than 40 dB, indicating that the quality is quite good.
4. Conclusion
The application of modified binary addition to the steganography technique using the Least Significant Bit (LSB) method can affect the number of messages inserted in the cover image. By implementing this method, the message capacity can be doubled from the standard Least Significant Bit (LSB) method, because there are two message bits that can be inserted in one insertion process. The application of modified binary additions can also affect the SSIM, MSE, and PSNR values which indicate the quality of the message insertion process into the cover image. The test results show that the binary addition method produces average SSIM, MSE, and PSNR values respectively 0.971743, 9.711678, and 38.26588. Meanwhile, modified binary addition resulted in the values of 0.993287, 2.112745, and 44.88844. These results indicate that the modified binary addition method produces better quality than binary addition while maintaining high message capacity.

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