Comparison of n-LSB embedding approach in different color spaces

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Abstract. Today, secure communication is one of the biggest goals that people want to achieve. There are many different methods to ensure security in data communication. Steganography is one of the methods that can be used in secure data communication. In this study, n-LSB embedding method based on reducing the amount of distortion generated by the classical Least Significant Bit substitution method that we introduced in another study has been applied in both RGB color space and HSI, XYZ and YCbCr color spaces. In the embedding process, 3 message bits were embedded in each color channel. 7.94 kb data is embedded on 3 different cover images. The obtained results were compared with the PSNR criterion, which is the criterion of image quality evaluation, and it is seen that proposed n-LSB approach gives better results in HSI color space for 3 cover images. The highest PSNR value obtained was 83.907 dB.

Keywords: Image steganography, n-LSB embedding, Color spaces, Image quality.

1. Introduction
Secret message transmission technique, which contains hidden messages and no one can notice these messages except the sender and the receiver, is called “Steganography”. Even the person who is sent to him through Steganography will receive secret message only with his key. The purpose of steganography is to hide the existence of the message [1].

Steganography, which is the process of conveying information in the information or storing a confidential message in another message, is quite different from cryptography, which is a code of science. Cryptography is a method that can be accessed by the recipient only after they are subjected to a certain decryption method. Steganography prevents information from being accessed by other people by storing the information to be transmitted in other information. In Steganography, there must be a communication channel and a type of cover media where the message will be moved. However, cryptography is a communication method that uses a password to prevent the message from being exposed and does not care whether the communication is monitored and does not need to keep the privacy of the message. The greatest advantage of steganography by cryptography is that it is never known whether a person who sees the information has a secret message within the transmitted message. In other words, if today's advanced technologies are considered, there is a possibility of breaking the password no matter how strong it is, while steganography is not known and therefore does not attract attention. Steganography takes its power from “confidentiality”, while cryptography does this through the “encryption algorithm” [2-9].

Four types of media are generally used as cover media in steganography. These are text, images, audio and video. Since images are used more frequently in communication among people, studies on steganography have focused on the image.

In Steganography, text, image, audio and video types can be used as a message file, and also any digital file can be used.

Image steganography methods are divided into two main categories. These are spatial domain methods and frequency domain methods. In the spatial domain, the message file is embedded directly
in the pixels of the image. In the frequency domain, the image is first converted to frequency coefficients. The embedding operation is then done to these frequency coefficients. The LSB substitution method is one of the most basic methods in both domains.

This paper organized as follows: In Section 2, similar studies have been mentioned. In Section 3, LSB substitution method, n-LSB substitution method and color spaces have been mentioned. In Section 4, details and results of the study are given. In Section 5, the obtained results are evaluated and interpreted.

2. Related works
In our study [3], we proposed a new method to reduce the deformation resulting from the application of the classical LSB substitution method. We applied this method called n-LSB substitution in the 2 and 3-LSB substitution method. As a result of the tests performed, an increase of 6.6% was achieved according to the classical LSB substitution method in PSNR.

In another study we have done [4], the classical LSB substitution method has been tested in different color spaces. The cover image was transformed into RGB, HSI, YCbCr, XYZ and YIQ color spaces, and the stego images were compared according to the image quality evaluation criteria. The results showed that the highest PSNR values were obtained with HSI color space.

In [5], the most suitable color space for image steganography was investigated. They found that HSV color space from RGB, YCbCr, HSV and Lab color space is the most suitable color space for time complexity and image quality. They also proposed a new method of steganography using the HSV color space.

In [6], data hiding was performed by using LSB substitution method on RGB, YCbCr, XYZ, CMYK, YIQ and HSV color spaces. The resulting stego images were compared according to the image quality evaluation criteria and they claimed that the CMYK color space was the most suitable color space for embedding.

3. Materials and methods

3.1. Least significant bit substitution method
The LSB (Least Significant Bit) means the bit that, if changed, makes the least change in an image pixel. In other words, converting the LSB from 0 to 1 or from 1 to 0 will cause the least distortion on the cover image relative to other bits. Therefore, the basis of data hiding algorithms is mostly based on LSB substitution [1-9].

Just as the LSB of a pixel can be changed, the least significant 2 bits or the least significant 3 bits can be changed. During embedding for this, the next 3 bits of message file is changed to the last 3 bits of the cover image pixel. As a result, the amount of data that can be embedded on the image is increasing, as the distortion on the image is relatively increased.

3.2. n-LSB substitution method
The n-LSB method, proposed in [3], is based mainly on reducing the distortion that occurs in the classical LSB method (Figure 1). This process is done as follows:
First, the message file is embedded on the cover image using the classic 3-LSB (or 2-LSB) substitution method. After embedding, the cover and stego image pixels are compared one by one. The difference values must be between -7 and 7 in decimal. If the difference is between -4 and 4, no action is taken on the related pixel. If the difference is 5, 6, or 7, the first 1 encountered from the 4th bit is converted to 0. That is, decimal number 8 is subtracted from the related pixel. If the difference is -5, -6, or -7, the first 0 encountered from the 4th bit is converted to 1. That is, the decimal number 8 is added to the related pixel. As a result of these operations, there will be no loss of information since the first 3 bits of the pixels have not changed [3].
Each bit of message file is directly inserted to LSB of each channel of each pixel. The last bit of each pixel of the stego image is merged and the message file is obtained.

On the receiver side, since there is no operation to change the first 3 bits on the stego image, the message information will be extracted according to the classical 3_LSB substitution method.

The flowchart of proposed n_LSB substitution method was given in figure 2.

**Figure 1.** LSB substitution method.

**Figure 2.** n_LSB embedding algorithm.

- C[i]: Cover Image (RGB)
- S[i]: Stego Image (RGB)

if C[i]-S[i] > 0
if C[i]-S[i] < 0
if (n+2)th bit of S[i] is set 1 and the operation is terminated.
if (n+1)th bit of S[i] is set 0 and the operation is terminated.
if (n+2)th bit of S[i] is set 0, then the operation is terminated.
if 8th bit of S[i] is set 1 and the 3rd, 4th, 5th, 6th, 7th bit of S[i] is set 0, then the operation is terminated.
No changes are made to S[i].
No changes are made to S[i].

if (n+2)th bit of S[i] equals 0
if (n+1)th bit of S[i] equals 1
if (n+2)th bit of S[i] equals 0
if 8th bit of S[i] equals 1
if 8th bit of S[i] equals 0
if (n+1)th bit of S[i] equals 0
if (n+1)th bit of S[i] equals 1
if (n+2)th bit of S[i] equals 1
if 8th bit of S[i] equals 0
if 8th bit of S[i] equals 1

The 8th bit of S[i] is set 0 and the 3rd, 4th, 5th, 6th, 7th bit of S[i] is set 1, then the operation is terminated.
The 8th bit of S[i] is set 0 and the 3rd, 4th, 5th, 6th, 7th bit of S[i] is set 1, then the operation is terminated.
3.3. Color spaces
Due to the high variety of colors, the need for grouping these colors is emerged. In order to group and standardize these colors, the concept of color space has emerged. Each color space has its own structure to describe the color set [7].

In this study, the classical and n-LSB method is applied to HSI, XYZ and YCbCr color space as well as RGB color space. These color spaces to RGB color space conversion formulas are given in (1), (2), (3), (4), (5) and (6).

\[
I = \frac{1}{3}(R + G + B) \tag{1}
\]

\[
\theta = \cos^{-1}\left[\frac{(R-G)+(R-B)/2}{\sqrt{(R-B)^2+(R-B)(G-B)}}\right] \tag{2}
\]

\[
H = \begin{cases} 
\theta & B \leq G \\
360 - \theta & B > G 
\end{cases} \tag{3}
\]

\[
S = 1 - \frac{3}{R+G+B}[\min(R,G,B)] \tag{4}
\]

\[
\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.412453 \\ 0.212671 \\ 0.019334 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{5}
\]

\[
\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 77/256 \\ -44/256 \\ 161/256 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{6}
\]

3.4. PSNR
Image quality can be divided into two main classes: objective and subjective quality. Subjective quality methods are based on qualitative human perception. Objective quality methods are based on mathematical algorithms. Objective quality methods are designed with the human vision system in mind. Objective methods need to have a high connection with subjective quality methods in order to be useful [8].

One of the most used objective quality method is Peak Signal to Noise Ratio (PSNR). The PSNR formula is given in (7). In (7), MSE is the average of the square of the difference between the original image and the stego image. The difference between the images decreases as the PSNR value increases.

\[
PSNR = 20 \log_{10}\frac{255}{\sqrt{MSE}} \tag{7}
\]

4. Results and discussion
In this study, we aimed to investigate the effect of the n-LSB method on different color spaces, which we have proposed in a previous study. Experiments have been done on RGB, HSI, XYZ and YCbCr color spaces. 3 different images were used as cover image. The resolutions of the images used are; 225x225, 229x220 and 350x348. All images are in “.bmp” format. The message file is 7.94 kB plain text. No compression or encryption is done before the message file is embedded. The embedding process is done in pixel-by-pixel format so that each pixel has the last 3 bits.
Initially, the message file was hidden using the n-LSB method on the image named “Lena” at a resolution of 225x225 pixels. Then, this cover image was transformed into HSI, XYZ and YCbCr color spaces, and embedding was performed using n-LSB method. The obtained cover and stego images are given in figure 3.

The message file was hidden using the n-LSB method on the image named “Baboon” at a resolution of 229x220 pixels. Then, this cover image was transformed into HSI, XYZ and YCbCr color spaces, and embedding was performed using n-LSB method. The obtained cover and stego images are given in figure 4.

Finally, the message file was hidden using the n-LSB method on the image named “Tiger” at a resolution of 350x348 pixels. Then, this cover image was transformed into HSI, XYZ and YCbCr color spaces, and embedding was performed using n-LSB method. The obtained cover and stego images are given in figure 5.

After embedding, all stego and carrier images obtained were subjected to PSNR analysis. The PSNR values obtained are given in Table 1.
| Image        | Color Space | PSNR (dB) |
|--------------|-------------|-----------|
| Image 1 “Lena” | RGB        | 49,7006   |
|             | HSI         | 80,1997   |
|             | XYZ         | 78,7413   |
|             | YCbCr       | 49,7126   |
| Image 2 “Baboon” | RGB     | 49,4791   |
|             | HIS         | 80,0773   |
|             | XYZ         | 78,7411   |
|             | YCbCr       | 49,7260   |
| Image 3 “Tiger”    | RGB       | 53,3519   |
|             | HSI         | 83,9074   |
|             | XYZ         | 82,5740   |
|             | YCbCr       | 53,6346   |

When we examine Table 1, the highest PSNR value in 3 cover images was obtained with HSI color space. With the XYZ color space, a PSNR value close to this value was obtained. In the 3 cover images, the worst PSNR value was obtained with RGB color space. The highest PSNR obtained was 83.9074 dB.

5. Conclusion
In this study, the success of the n-LSB substitution method we introduced in a previous study was tested in different color spaces. The message file was hidden on 3 different cover images using the n-LSB substitution method. PSNR values of obtained stego images and cover images, which are one of the image quality evaluation criteria, were calculated. According to the results, the HSI color space gave the best result in the whole cover images. The lowest PSNR value was obtained by RGB color space. When we compare the results with the results of our another study, which we tested the classical LSB substitution method on different color spaces, it was observed that the HSI color space gave the best results, similarly. In future studies, the proposed n-LSB method can be applied in the frequency domain techniques and the results can be examined.

6. References
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