Intensity Adaptive LSB Method Applying a Revised Matching

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ABSTRACT
This paper proposes a new steganographic algorithm in spatial domain. A filtering method selects some color components of pixelsin BMP cover imagesfor embedding according to their Most Significant Bits(MSB) value. The components whose MSB value isgreater than a particular threshold,are qualified and the other ones will be skipped. This mechanism makes the retrieval of embedded message possible. Moreover, a matching technique ensures the most possible closeness of new intensity generated in embedding process to its original value.Performance of proposed method is evaluated by some measures namely MAE, MSE,LMSE,L^P-Norm, SNR, PSNR, and NCC according to which, proposed method offers up to 40% better results in some measures compared to two other methods; LSB and SLSB.

Keywords
Filtering, Intensity Adaptive LSB (IALSB), LSB Matching, LSB Plane, LSBSteganography,MSB, Performance Measure, SLSB, Spatial Domain, Threshold.

1. INTRODUCTION
In the age of computers and communications, data transmission through internet has made it possible to have afast access to data all over the world.In order to be able totransmit data securely against eavesdroppers, some techniques have been developed. Steganography is one of these techniques.

The word "Steganography" is originally derived from the Greek words steganos (covered) and graphy (writing) and literally means covered writing[1]. Using steganography, information is embedded in a medium such as image, audio, video, or text file called carrier in a way that it is not detectable by others[2]. Digital images are the most popular ones due to their variety and frequencyon the Internet. In image steganography secret information is embedded exclusively in images [3].The input image in which a secret message will be embedded is called cover image and the image containing the secret message is known as stego image[4].Another technique used in secret communications is Cryptography in which secret information is transformed to non-understandable form, but in steganography, no one knows about the existence of secret information transmitting between sender and receiver. Thus, steganographic algorithms provide more security in comparison to cryptographic approaches[5].

Oneof the major types applied in steganography is spatial domain. Spatial domain methods also known as image domain methods, substitution methods, or noise insertion methods,embed the secret message in the intensity of the cover image pixels. They work at level of LSBs. Firstup to the fourth LSB of the pixelmay besubstituted in the pixel with the bits of secret data by steganographer.Since only insignificant modifications are exerted in the embedding process, it is assumed that these changes will not be detected by an attacker. There is a trade-off between the embedding capacity (payload) and cover image distortion.Replacing more LSBs would cause more stego image distortion. Spatial domain methods benefit from simplicity andhigh payload capacity, but they are vulnerable against noise, lossy compression, image filters, cropping, and rotation. They also affect statistical properties of the image. BMP and GIF are the image formats that spatial domain methods work on[2],[5],[6], and [7].In this paper, the LSB and SLSB methodswill be reviewed and then a new steganographic technique and its two approaches will be introduced, investigated, and evaluated.

2. REVIEW OF RELATED WORKS
Two of fundamental inspiring steganographic methods to the new proposed method are as follows:

2.1. Least Significant Bit (LSB) Method
This technique is an instance of spatial domain methods. It is a simple, common approach whichplaces the bits of secret data at the LSB of the pixel in the cover image. Using a 24-bit BMP cover image, the LSB of red, green and blue (RGB) components participate in embedding process, since each of them is represented as a byte. In other words,it can store 3 bits of secret dataperpixel. While,for a GIF or 8-bit BMP file this value is equal to 1 bit per pixel. On average, around half of the LSBs in a cover image are needed to be modifiedto embed a secret message using the maximum cover size.

The distribution of embedding pixelsthrough the cover imagecan be contiguous or scattered. In the first approachalso known as sequential embedding, bits of secret message are embedded in the cover pixelsconsecutively. The location of first embedding pixel must be known for extraction of secret message.While,the second approachalsocalledrandom interval embedding uses a pseudorandom number generator (PRNG) to spread the secret data over the cover image in a rather random manner. Using a stego-key as a seed for a PRNG, a random sequence of indices is generated to determine the distance between two embedded bits pseudorandomly.The receiver can reconstruct the random sequence and extract the secret message byhaving access to the seedand knowledge of the PRNG [5],[7],[8],[9],[10].

Following [11], in this paper, in order to visualize the distributionof replacements and embedding colors and pixels in stego image,LSB plane is applied.Referring to the LSB plane and its guide, the modified pixels and components of the cover image in the stego image can be found correspondingly.

The LSB plane of sequential LSB method on the Pepper.bmp cover image with the secret message mentioned in section 4andreplacing 3 bit/pixel is as follows:

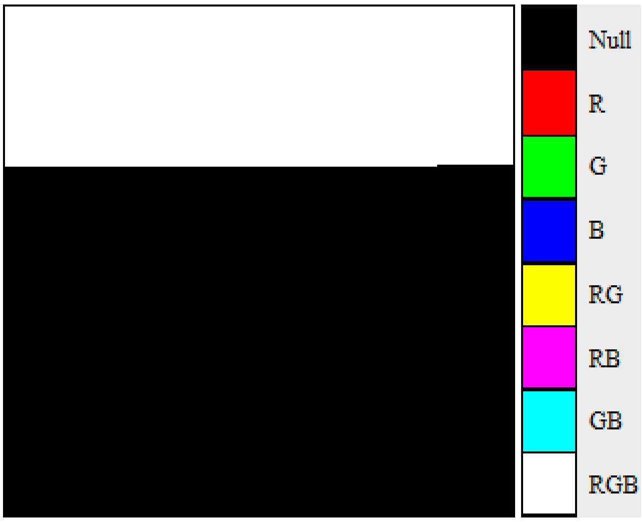


Figure 1.LSB plane of sequential LSB method

As shown in the Figure 1, sequential LSB method starts from the beginning and embeds the secret bits in all components of the pixels consecutively until the whole message is covered.

2.2. Selected Least Significant Bit (SLSB) Method

Itbelongs to spatial domain group[12].Many of spatial domain steganographic algorithms embed secret information in the LSB of all red, green, and blue(RGB) colors of the 24-bit cover pixels that may lead to major distortions. These distortions may not be detectable by human eye, but they will be detected by some statistical analyses such as RS[13]and Sample Pairs[14]. As a solution, SLSB algorithm selects one color out of three (RGB) applying a preliminary Sample Pairs analysis[15] by which a color that offersmore diversity and consequently less considerable changes is selected [12], [15].

After color selection, SLSB algorithmfilters the cover image (evaluatively) using an edge detection filter such as Laplace, Prewitt, Roberts, Sobel, or more likely Roque filter[12],[16],[17]and embeds the secret data in the areas that achieve a better ratein filtering process.The filter employs most significant bits of the pixels andleaves less significantones for embedding.This ensures that the embedded information be retrievable. That is to say, in extracting process, reapplication of the filter will choose the same pixels and components selectedfor the concealing process[12].

According to[12] andfollowing[18] and [19],in order to havethe final color closest to the original color, LSB Matching techniquecalculates the distance between the steganographic and original color. If it is greater than a certain threshold determined by the number of bits to hide, the color is decremented to get a final color closest to its origin.

Applying a histogram analysis to the SLSB method’s stego image reveals that there are only changes in the histograms of illumination and the color selected by the algorithm as the optimal color of embedment[12].

The LSB plane of SLSB method on the Pepper.bmp cover image with the secret message mentioned in section 4 and replacing 3 bit/pixel (3 bits of selected color) is as follows:

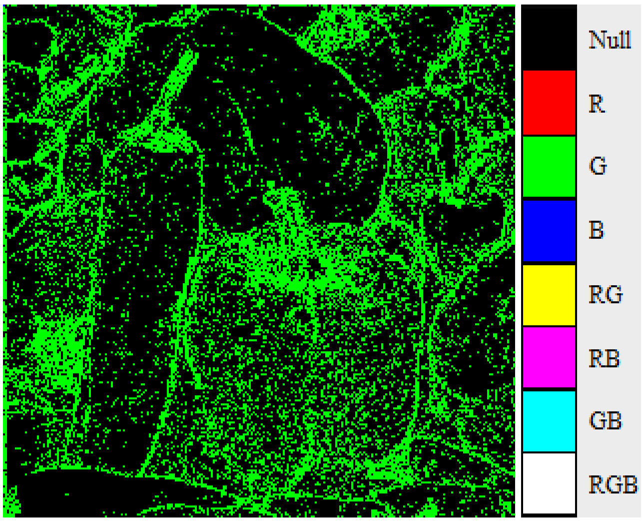


Figure 2.LSB plane of SLSB

According to the Figure 2, SLSB algorithm has selected the green color of pixels emphasizing on the edges for embedding.

3. NEW PROPOSED METHOD; INTENSITY ADAPTIVE LEAST SIGNIFICANT BIT (IALSB)

3.1. Description

Proposed method; IALSB is an instance of spatial domain group.Following [12], this method applies an evaluative highintensity filter to the components of the cover pixels and embeds the secretinformation in the areas that are qualified according to the filter. That is to say,the secret information is embedded in the LSB of the components whose MSB value aregreater than a particular threshold. This mechanism ensures the retrievability of embedded information. After embedment, a matching technique is appliedto moderate the new generated color toward its origin. The first bit adjacent to the least significant bit or bits would change in favor of closing new generated color to its originand lead to less visibility of stego image distortions. According to the description of new proposed method, the components (bytes) of the cover pixels are structured as follows:

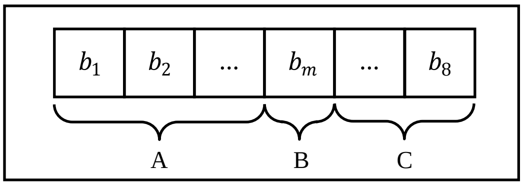


Figure 3. Color structure in IALSB

Section A of the Figure 3 is most significant bits section which will be evaluated in the filtering step. This part will never be modified to ensure the secret information retrieval. Section B of the Figure 3is the matching bit which may be modified to moderate the distortions generated in embedding step. The last part; Section C of the Figure 3 includes least significant bit or bits that carry the secret information. The certain indices of MSB and matching sections (A and B respectively) are dependent to the number of the bits that section C employs. Applying more LSBs for embedding will push the sections A and B to the left part of the color. For example, considering b_7 and b_8 as section C, the section B includes b_6 and consequently section A consists of b_1, b_2, b_3, b_4, and b_5. The flow of embedding process is as Figure 4 shows.

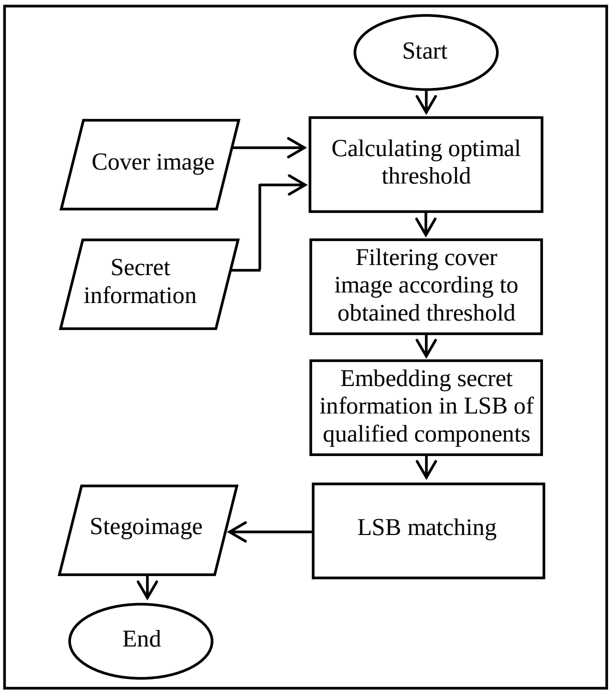


Figure 4. The flow of embedding process

3.2. Calculating a Particular Threshold

Proposed method applies a particular threshold to determine the pixels and components participate in embedding process. The components whose MSB valueisgreater than the threshold are qualified for embedding the secret information.According to [20], assuming k as the number of color components needed to embed secret message:

$$k = \left\lceil \frac{l}{n} \right\rceil \qquad (1)$$

where$l$ is the length of the secret bit stream (secret message in bits) and n is number of LSB used per component for embedding. To obtain the optimal thresholdof $m$covercomponents, the MSB value of all $m$components should be sorted in descending order. According to the equation (1), the k^{th}element of the sorted MSBs refers to the optimal threshold. The illustration is as follows:

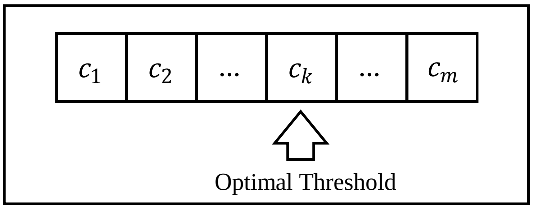


Figure 5.Optimal threshold determination $(c_i \geq c_{i+1})$

The figure 5 illustrates the determination of optimal threshold;$c_k$from the sorted MSBs $(c_i \geq c_{i+1})$. This is the maximal possible threshold which ensures embedding of the secret message with the most scatter through the cover image. Applying a threshold greater than $c_k$will cause whole the secret message not be embedded fully, and using a threshold smaller than c_k will cause the secret message not be scattered mostly through the cover image.

3.3. LSB Matching

According to [21], in the LSB replacement, if the secret bit does not match the cover LSB, then LSB matching adds +1 or -1 is to the correspondingpixel value randomly. Statistically, generated asymmetry artifacts can be avoided.

In this work, LSB matching has been adapted for any arbitrary number of LSB. As illustrated in the Figure 3, a matching bit (b_m) is considered for each component of the cover pixels adjacent to LSB section. This bit may be changed in order to moderate the distortion generated by embedment of secret message. Following[12], [18], [19],and [21], the b_m will be valued as follows:

$$b_m = \begin{cases} 1 & |c - c'| > |c - c''| \\ 0 & |c - c'| < |c - c''| \\ 1 \text{ or } 0 & Otherwise \end{cases} \qquad (2)$$

where c is the original value of the cover component, c' is the stego value of the component considering $b_m$as zero, and c" is stego value of the component considering b_m as one. As equation (2) expresses, matching bit(b_m)of each component will be set to a valuewhich minimizes the difference between the original and stego value of that color component.

3.4 Two Approaches for Proposed Method

The proposed method can be applied in two approaches. First approach is employing all colorsof the cover pixels for embedding. It benefits from high payload capacity, but it may cause some distortions due to modification of all components in some cover pixels. This approach can be named *Multi-color IALSB*.

Applying Multi-color IALSB, in aM×N pixel 24-bit cover image, the optimal threshold is the k^{th}(k from (1)) element of 3MNdescending sorted MSBs of all cover components.

The LSB plane of Multi-color IALSB approach on the Pepper.bmp cover image with the secret message mentioned in section 4 and replacing 3 bit/pixel (if all 3 components are qualified) is as follows:

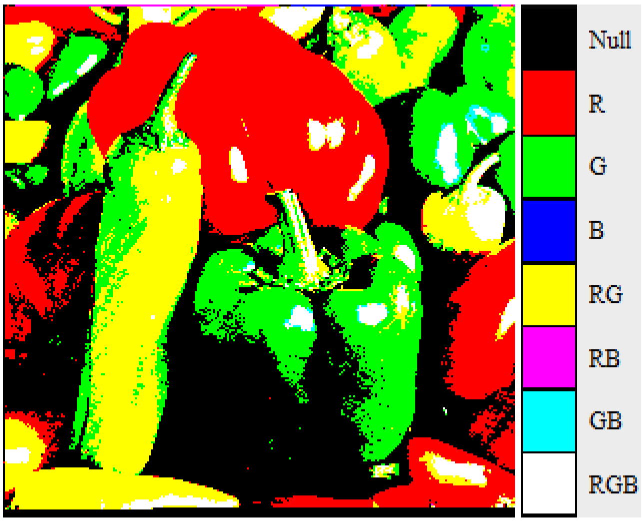


Figure 6.LSB plane of Multi-color IALSB

According to the Figure 6, the secret message is embedded in various components of the pixels. In some pixels, individual red or green components are used for embedding. In some others, combinations of components are employed. Referring to the LSB plane guide, yellow pixels state that only the red and green components of corresponding pixels have MSB values greater than the applied threshold and due to this contain secret information, but their blue components contain no embedment. White pixels of the LSB plane state that corresponding pixels in stego image contain embedment in their all red, green, and blue components, because bright pixels contains high intensity of RGB. On the other hand, in the black pixels none of components are qualified to be employed in the embedment.

Second approach is employing one of the colorsout of three which consequently leads to lower distortion and payload.This approach can be called *Single-color IALSB*[12].

The target color in Single-color IALSBwill bethe one which has the most qualified components applying the corresponding local optimal threshold.According to [12] and [15], more frequency of qualified components leads to less considerable changes.Applying Single-color IALSB, the local optimal threshold for one colorin a M×N pixel 24-bit cover image is obtained by selecting the k^{th} (k from (1)) element ofMN descending sorted MSBs ofthe same color.

After color selection, all remaining steps of embedding are the exerted to the components of selected color.

The LSB plane of Single-color IALSB approach on the Pepper.bmp cover image with the secret message mentioned in section 4 and replacing 3 bit/pixel (3 bits of selected color) is as follows:

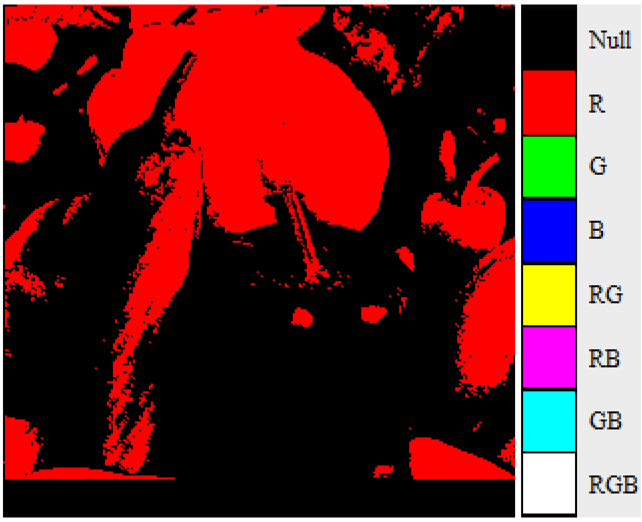


Figure 7.LSB plane of Single-color IALSBapproach

The figure 7 expresses that the red color of the cover pixels is the one which has the most frequent qualified components. The secret message is embedded in the high intensity red components whose MSB values greater than the corresponding threshold.

4. EXTRACTION PROCESS

Extraction process of the secret information is started with calculating the threshold used in embedding process. Using stego key including l and$n$ (from (1)),k is obtainable[20]. The threshold will be the k^{th} element of the stego image MSBssorted in descending order knowing that the stego MSBs are not changedin the embedding process. Having the stego image, the stego key (l and$n$ from (1)), and the obtained threshold, the secret information can be extracted by filtering the stego image. In Single-color IALSB extraction process, all steps are performed by using local optimal threshold of the selected color.

The$n$ (from (1)) LSB of qualified components in filtering process make the secret bit stream consecutively. The flow of extraction process is shown in Figure 8.

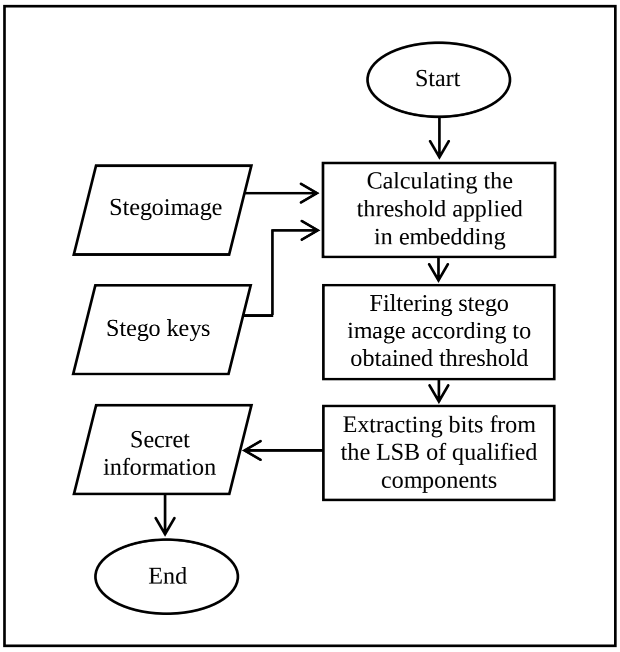
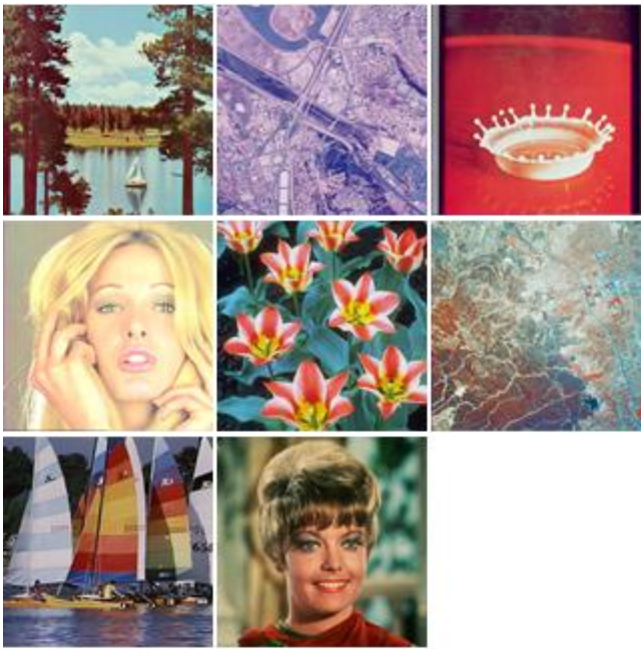


Figure 8. The flow of extraction process

5.EXPERIMENTAL SETUP

To evaluate the new proposed approaches, twenty frequently-used 512×512 24-bitBMP cover images, whose sizes are 786,486 bytes namely Baboon.bmp, Barbara.bmp, Boats.bmp, Cove.bmp, Earth.bmp, F16.bmp, GoldHill.bmp, House.bmp, Lena.bmp, Monarch.bmp, Oakland.bmp, Peppers.bmp, Sailboat.bmp, San-Diego.bmp, Splash.bmp, Tiffany.bmp, Tulips.bmp, Woodland- Hills.bmp, Yacht.bmp, and Zelda.bmp are selectedwhose thumbnails are as follows respectively:



The plain text considered as secret message in the experiments is[14]cut in the length of 31,072 bytes.
For investigating the LSB and IALSB methods, an application is developed to implement the methods and obtain the experimental results. For SLSB method and the related results, [16] is applied.

6. PERFORMANCE EVALUATION AND RESULTS

In order to evaluate the quality of the stego images compared to the cover images, following measures are applied[7],[12],[16],[20],[22], and[23]:

$$Mean\ Absolute\ Error\ (MAE) = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left|X_{ij} - Y_{ij}\right| \quad (3)$$

$$Mean\ Square\ Error\ (MSE) = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(X_{ij} - Y_{ij}\right)^2 \quad (4)$$

$$L^p\ Norm = \left(\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(\left|X_{ij} - Y_{ij}\right|\right)^p\right)^{1/p} \quad (5)$$

$$Laplacian\ Mean\ Square\ Error\ (LMSE) = \sum_{i=1}^{M}\sum_{j=1}^{N}\left(L(X_{ij}) - L(Y_{ij})\right)^2 \Big/ \sum_{i=1}^{M}\sum_{j=1}^{N}\left(L(X_{ij})\right)^2 \quad (6)$$

where $L(X_{ij}) = X_{i+1,j} + X_{i-1,j} + X_{i,j+1} + X_{i,j-1} - 4X_{ij}$ (7)

$$Signal-to-Noise\ Ratio\ (SNR) = \sum_{i=1}^{M}\sum_{j=1}^{N}{X_{ij}}^2 \Big/ \sum_{i=1}^{M}\sum_{j=1}^{N}\left(X_{ij} - Y_{ij}\right)^2 \quad (8)$$

$$SNR\ (dB) = 10\ log_{10}(SNR) \quad (9)$$

$$Peak\ Signal-to-Noise\ Ratio\ (PSNR) = MN\ (\max X_{ij})^2 \Big/ \sum_{i=1}^{M}\sum_{j=1}^{N}\left(X_{ij} - Y_{ij}\right)^2 \quad (10)$$

$$PSNR\ (dB) = 10\ log_{10}(PSNR) \quad (11)$$

$$Normalized\ Cross\ Correlation\ (NCC) = \sum_{i=1}^{M}\sum_{j=1}^{N}X_{ij}Y_{ij} \Big/ \sum_{i=1}^{M}\sum_{j=1}^{N}{X_{ij}}^2 \quad (12)$$

$$Normalized\ cross\ correlation\ (NCC) = \sum_{i=1}^{M}\sum_{j=1}^{N}X_{ij}Y_{ij} \Big/ \sqrt{\left(\sum_{i=1}^{M}\sum_{j=1}^{N}{X_{ij}}^2\right)\left(\sum_{i=1}^{M}\sum_{j=1}^{N}{Y_{ij}}^2\right)} \quad (13)$$

where M and N are the number of pixels in the vertical and horizontal dimensions of cover imagerespectively. X_{ij} is the intensity value of a cover pixel whose coordinates are (i, j)in row and column respectively and Y_{ij} refers to the intensity value of corresponding pixel in stego image[7].
Note that the measure (12); NCC from[7],[12], [16], and[22], which is a normalized measure,in some experiments returns some values greater than 1. Due to this, (13) is employed as well from [23] whose results are smaller than or equal to 1.
The results of experiments are represented in two tables in order to be categorized based on the number of embedding colors and bits they apply per pixel (payload). Multi-color IALSB may apply three colors and 3, 6, or 9 LSB per pixel which is comparable toLSB method. On the other hand, Single-color IALSB which uses one color and 1, 2, 3 LSB per pixel (in the selected color), is comparable to SLSB method.The results are as follows:

Multi-color IALSB vs. LSB		MAE	MSE	L3-Norm	LMSE	SNR (dB)	PSNR (dB)	NCC from (12)	NCC from (13)	Average bit/pixel
3 b/p	LSB	0.4736992	0.9464504	1.2861368	0.001556	52.606876	57.103834	0.9998858	0.9999959	3
	Multi-color IALSB	0.4745405	0.7554602	1.1176865	0.001481	53.618729	58.115686	0.9991522	0.9999963	1.895
6 b/p	LSB	0.572603	2.486775	2.2967699	0.0036694	48.412885	52.909843	0.9997619	0.9999905	6
	Multi-color IALSB	0.5308876	1.5229263	1.7377534	0.0029843	50.633689	55.130647	0.9994318	0.9999923	3.4635
9 b/p	LSB	0.8214569	7.5324951	4.2587979	0.0114103	43.606074	48.103032	0.9997076	0.9999722	9
	Multi-color IALSB	0.7287823	4.1776619	3.059052	0.008169	46.309189	50.806147	0.9998003	0.9999789	5.115

Table 1. Performance measures of Multi-color IALSB versus LSB (Average of 20)

Single-color IALSB vs. SLSB		MAE	MSE	L3-Norm	LMSE	SNR	PSNR	NCC from (12)	NCC from (13)	Average bit/pixel
1 b/p	SLSB	0.4736994	0.4737059	0.7795451	0.0017118	55.612718	60.109676	0.9999049	0.9999959	1
	Single-color IALSB	0.4725033	0.4725033	0.7788751	0.0014428	55.623761	60.120719	0.9994731	0.9999961	1
2 b/p	SLSB	0.5238035	0.9100225	1.2232723	0.0032069	52.777581	57.274539	0.9999476	0.9999922	2
	Single-color IALSB	0.5199331	0.8962461	1.2139305	0.0028191	52.84385	57.340808	0.9995667	0.9999924	2
3 b/p	SLSB	0.7281796	2.5072136	2.1831904	0.0082947	48.376699	52.873657	0.999879	0.9999784	3
	Single-color IALSB	0.7131233	2.3936398	2.1301713	0.0067849	48.580295	53.077253	0.9997569	0.9999794	3

Table 2. Performance measures of Single-color IALSB versus SLSB (Average of 20)

The measures (3), (4), (5), and (6)represent the difference and distance between cover image and stego image. Thus, higher value of these measures implies to more distortions of stego image compared to cover image. As shown in the Tables 1 and 2, proposed approaches represent better results supplied by MAE, MSE, L^3Norm, and LMSE for all number of embedding bits except the one highlighted by red color. Oppositely, the measures (8), (9), (10), (11), (12), and (13) indicate the similarity between cover image and stego image. Therefore, higher value of these metric implies to less distortion of stego image in comparison to cover image. As represented in the Tables 1 and 2, proposed approaches give better results supplied by SNR, PSNR, and NCCs for all number of embedding bits.

7. CONCLUSION

Proposed method presents a new simple type of scatter of secret data over the cover image in two approaches. The secret information can be tunably embedded in the high intensity colors and components of the cover image which cause the modifications be a small proportion of original intensity values and consequently, less distortion of stego image. Multi-color LSB benefits from variable number of embedding component and bit per pixel which makes extraction procedure more undiscoverable to attackers.Two approaches of IALSB specially Single-color IALSB, can be robust against statistical analysis due to modification of only one color of cover pixels and leaving the two others unchanged[12]. Investigating the robustness of proposed method against to steganalyses, applying a steganographic or cryptographic approach to transmit the stego key, and applying a compression method to compress the secret message which leads to less distortion of stego image versus cover image can be considered asfuture works.

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