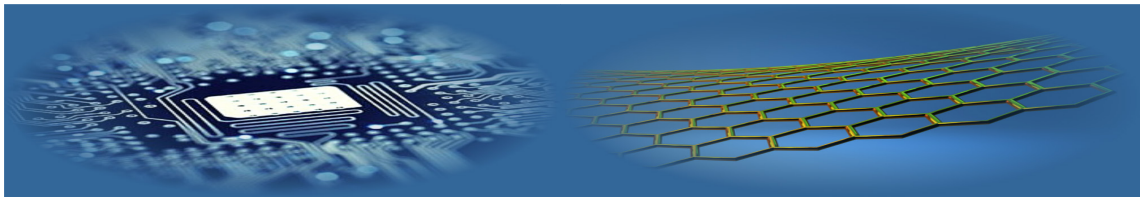

Image steganography algorithm based on edge region detection and hybrid coding

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Abstract

In this paper, a novel steganography algorithm based on local reference edge detection technique and exclusive disjunction (XOR) property is proposed. Human eyes are less sensitive towards intensity changes in the sharp edge region compared to the uniform region of the image. Because of this, the secret message bits have been embedded in the sharp regions by local reference pixels that are located in the edge blocks. The predefined sets of pixels are easily identified with less computational complexity in the stego image. The embedding algorithm improved in terms of security and capacity using bit plane dependent XOR coding technique that makes least possible alterations in LSB bits of edge pixels. The existing edge-based steganography techniques provide better imperceptibility but relatively limits the embedding capacity. The proposed method efficiently improves the embedding capacity with an acceptable range of imperceptibility and robustness. The simulation results evaluated using full reference image quality assessment method, it exhibits better embedding capacity (bpp) compared to existing steganography techniques retaining the values of PSNR and structural similarity (SSIM).

Key words

Steganography,
Edge detection,
Colour image,
XOR

1 Introduction

The exchange of information has increased rapidly in comparison with any other time in history. Because of the digitization of information, privacy and security have emerged as a serious issue. Encryption is presented as a solution in the early stages. Information can be easily shared through encryption on public networks, but additional bits are required. It is not very suitable for the low bandwidth insecure channel [1].

The alternate approach is steganography which overcomes all these shortcomings. It is capable of hiding a digital message in different media platform without revealing any noticeable presence [2]. Where cryptography protects the contents of a message, steganography can be called the defender of both the message and the communicating parties. This technique is based on the visual limitation of the human eye in which it tries to create some space in the image while maintaining the standards of human visual systems. It is quite popular in audio, image and video processing [3]. The image used for embedding secret message is called cover image, and the changed image which contains the hidden message is called stego image [4]. Like other data hiding techniques, the quality of steganography depends on three parameters namely capacity, imperceptibility, and robustness. These parameters depend on each other. So, it is not possible to get the optimum value of all the parameters simultaneously [5]. It is essential for an efficient steganography technique to achieve good embedding capacity while keeping the other parameters at the acceptable value.

It is divided into two parts that are the spatial domain and transform domain steganography both domains having its benefits and drawbacks [6]. The spatial domain provides good embedding capacity but shows weak performance against geometric attacks. LSB (least significant bit) and PVD (pixel value difference) are the traditional methods used in spatial domain steganography [7]. In 'k-bits' LSB substitution method, k-message bits are embedded into k LSB bits of the cover image pixels. Although the method is efficient, it creates a noticeable distortion that is detected by sample pair analysis [8]. Several adaptive techniques have been proposed to reduce such type of distortion where the choice of k- bits depends on the pixel intensity. This method increases the intensity of each pixel in irregular manner, but it can easily be detected by the histogram shift method. Techniques like LSB+ [9] and LSB++ [10] preserve the image histogram by adding some extra bits. Adjunctive redundant number system creates enough space for data embedding into the cover image by breaking into 13-bit planes (additional 5-bit planes) [11]. This method is also used very efficiently in colour image but has a weak performance against LSB steganalysis. Transform domain steganography provides better robustness but has less embedding capacity. It takes more computation time than a spatial domain. In this method, message bits are embedded into transform coefficient of the cover image. The discrete cosine transform (DCT), discrete wavelet transform (DWT) and integer wavelet transform (IWT) are quite popular in transform domain steganography [12]. Proposed paper is based on edge block detection and improved embedding technique, which is applied to greyscale as well as colour image. The remaining part of the paper is organized as follows: In Section 2 has a brief description of the strength and weaknesses of existing methods. Section 3-4, represent details of purpose method. Section 5 is all about its conclusion.

2 Review of literature

Along with a good embedding capacity, imperceptibility is an important issue for image steganography. It decreases with increase of message embedding bits in the cover image. So, the steganographer targets the scattered region of the cover image where the human visual system is less sensitive towards change. The sharp edge regions of the image are an ideal for message embedding. Wu and Tsai [13] proposed a steganography method called pixel- value differencing. The technique embeds the message bits according to the difference between consecutive pixels horizontally or vertically. The way to detect edge pixels of the cover image does not take into consideration all neighborhood pixels. The directional approach is easily identified by chi-square analysis method [14]. Despite these shortcomings, this method has been constantly revised and many improvements have been proposed. A new PVD method is proposed by Luo, Huang and Huang [15] that

is based on the Mielikainen algorithm and adaptive embedding. Edge pixels have been optimized based on the secret message length. In the partition of a pixel pair, the image is divided into non-overlapping blocks; then it is rotated by pseudo-random angles. This gives better PSNR and robustness compared to the previous method. Although due to lack of relationship between vertical and horizontal edge pixels, stego image (0.05bpp) is detected by difference histogram method.

Researchers are still interested in proper embedding location in the cover image used for imperceptible stego image. Edge and its neighborhood pixels are the best locations for it. There are so many well define edge detection technique, but it is difficult to get same edge pattern before and after embedding process [16]. So true message extraction is not possible. Canny edge detection performs much better than other edge detection techniques its Gaussian filter variance and the threshold value are used as reference parameters [17]. These parameters are used for extracting the edge pixels in stego image. Although this method does not provide enough embedding space in the cover image. Zero crossing, sboel and other first-order edge detection techniques do not perform better than canny. Chang and Le [18] propose a hybrid technique that is based on fuzzy logic and canny edge detection; that has been used for a color image and performs well in terms of embedding capacity. However, this method does not provide any detection technique for same edge pixel in stego image.

Modi, Islam and Gupta proposed a color image steganography technique based on canny edge detection and LSB matching. In this method, canny edge detection is applied to only one channel of the color image, which is used as a reference edge location for embedding purpose in other two channels. Extraction of same message bits is simple, and security also improved [19]. However, embedding capacity is relatively low because only two channels are used for embedding. This method is unable to achieve same edge pattern in all three channels of the color image. The structural image quality is not up to the mark. Blind image analysis also got very high score means its statistical parameter not preserved.

Al-Dmour and Al-Ani proposed a new edge detection method that is more suitable for steganography in which cover image is divided into 3×3 non-overlapping blocks for edge detection. Out of nine pixels, four corner pixels are used as a reference that is used for correct identification of edge blocks in Stego image. The difference between the horizontal pair, vertical pair and diagonal pairs of the reference pixel determines that whether it is an edge block or not. Only five pixels are used for embedding. Embedding technique is also very efficient and fast. This approach is tested on both spatial and transform domain, but a spatial domain has a better result in terms of data embedding capacity [7]. This technique provides good PSNR (48-51) with 0.7 bpp embedding capacity. The edge block used 45% of the pixels for edge detection. Many of pixels are not used in connected blocks in dense edge regions of the cover image.

Prasad and Pal proposed a colour image steganography technique based on pixel value differencing. In which conventional adjacent pixels is replaced with two overlapping blocks. These blocks are constructed with the paring of Red, Green, and Blue pixels. The threshold value is used to determine how much secret message bits can be embedded into RGB pixels. All pixels of the cover image is readjusted before creating stego image [20]. This method is used for the colour image only. This approach does not provide any protection against difference histogram steganalysis and RS steganalysis for high embedding capacity.

3 Proposed method

The neighbourhood pixels around the edge are a suitable place for steganography. There are many techniques have been available for edge detection, but it is difficult to retrieve same edge pixel from stego image without any reference. The purpose of this technique is to embed pixels which can be easily identified in the stego image. The technique is applied equally on grayscale as well as monochrome image. This technique is used independently on red green blue channels of the colour image. The process is started by dividing the grayscale image into nxn non-overlapping blocks. The corner pixels of the blocks are used as a reference pixel, which remains unchanged during the embedding process. The rest pixels in the block are used for embedding. The Corner pixels of a block determine whether this block is a neighbour of the cover image's edge or not. The absolute difference between corner pixels in the neighbouring blocks of the cover

image's edge is more than any other blocks. If the absolute difference between this corner pixels is greater than the observed threshold value, then the block is called an edge block or otherwise called non-edge block. The following steps are required for calculating edge pixels in the cover image.

- The cover image is divided into non-overlapping blocks.
- The Corner pixels of blocks are arranged according to their intensity.
- The absolute difference $\left(|\max int ensity - \min int ensity|\right)$ of corner pixels is calculated in each block.
- Absolute difference (d) is compared with threshold value (Th).
- Calculate the edge blocks in the entire image which has contained higher absolute difference than threshold value (d>th).
- Number of edge pixels = Number of edge blocks x (n^2-4).

The number of edge pixels is controlled by selection of threshold value. In spite of increasing the length of secret message bits, the number of edge pixels has to be also increased, which is possible only with the decrease in the threshold value.

Proposed paper is based on square 4x4 non-overlapping blocks where 4 corner pixels are used as a reference pixels and rest of 12 pixels are used for message embedding. The rest of the process is done according to the steps given above shown in Figure 1.

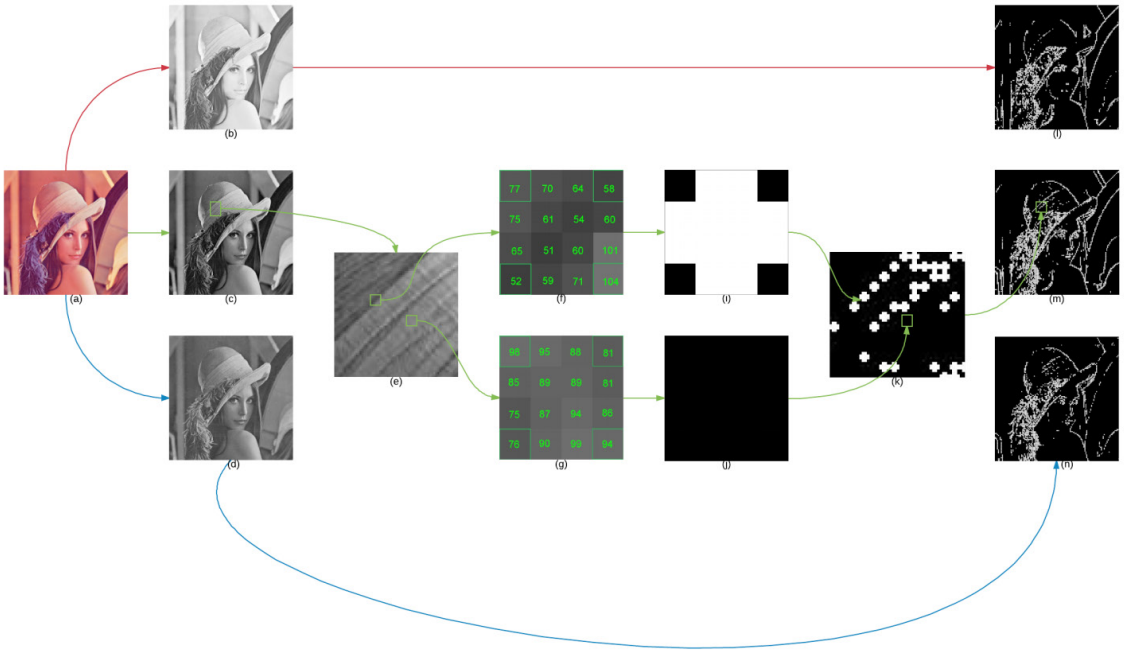

FIGURE 1 (a) Input colour cover image, (b) Red channel image, (c) Green channel image, (d) Blue channel image, (e) zoom area from the cover image green channel, (f) Random 4×4 block from edge region, (g) Random 4×4 block from smooth region, (h) Binary form of detected edge block (white represent the selected pixel for embedding), (i) Binary form of detected non edge block(no embedding), (j) Embedding regions in zoomed area(Th=40), (k) Embedding regions in red channel image(Th=40), (l) Embedding regions in green channel image(Th=40), (m) Embedding regions in blue channel image(Th=40)

The number of edge pixels on a certain threshold value depends upon the image details and textures. Usually threshold value lies between 6 to 120. If the threshold value is less than 6 the edge pixels start to be located in smooth regions of the cover image and for greater than 120 the number of edge pixels starts decreasing rapidly.

The embedding process is based on hybrid XOR technique. It is based on a choice of five or three edge pixel bits. The proposed methods are mentioned in the picture. The process of embedding secret message bits explained by following steps:

- Four lsb bits are extracted from the non-reference pixels of the edge blocks.
- The last two LSB bits of all edge pixels are kept in Group A and rest of two LSB

bits are kept in Group B.

- Five bits p_1, p_2, p_3, p_4, and p_5 are selected from Group A then it is converted into four new hybrid bits k_1, k_2, k_3, and k_4 according to Table 1.
- Then compare it with four message bits m_1, m_2, m_3, and m_4 according to the Table 2. Update these altered bits into group A again according to Figure 3.

Similar steps are applied for group B in the following ways:

- Three bits p_1, p_2, and p_3 are selected from Group B then it is converted into two new hybrid bits k_1 and k_2 according to Table 1.
- Then compare it with two message bits m_1 and m_2 according to the Table 3. Update these altered bits into group B again.

The message extraction process starts with an evocation of threshold value from the stego image shown in Figure 10. The same process is used for colour stego image by breaking into 3 RGB planes shown in Figure 2. The extraction process is initiated by the following steps:

- All edge pixels are identified with the help of extracted threshold value.
- The last two LSB bits of all edge pixels are kept in Group A and rest of two LSB bits are kept in Group B.
- Five bits q_1, q_2, q_3, q_4 and q_5 are selected in order from Group A, from which four message bits m_1, m_2, m_3, and m_4 are extracted according to table 1.
- Three bits q_1, q_2, and q_3 are selected in order from Group B, from which two message bits m_1 and m_2 are extracted according to Table 1.

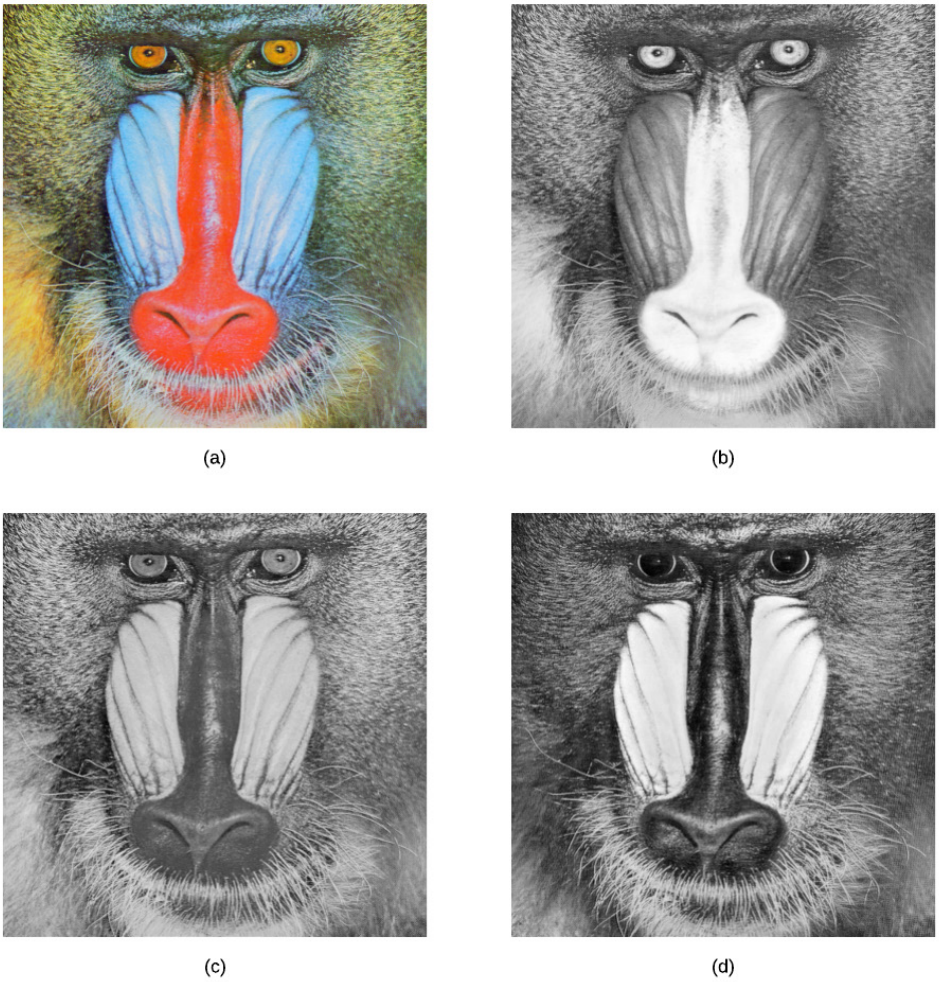

FIGURE 2 (a) Cover Image (Mandrill.tiff, 512×512×3), (b) Red channel of Cover Image, (c) Green channel of Cover Image, (d) Blue channel of Cover Image

TABLE 1 Method of Embedding and Extraction process

	Group A	**Group B**
Numbers of bits used for embedding	Bit array from 1st and 2nd LSB planes of edge pixels	Bit array from 3rd and 4th LSB planes of edge pixels
Embedding processes	$k_1 = p_1 \oplus p_2$ $k_2 = p_3 \oplus p_4$ $k_3 = p_1 \oplus p_3$ $k_4 = 1 \oplus p_S$	$k_1 = p_1 \oplus p_2$ $k_2 = p_2 \oplus p_3$
Extraction process	$m_1 = q_1 \oplus q_2$ $m_2 = q_3 \oplus q_4$ $m_3 = q_1 \oplus q_3$ $m_4 = 1 \oplus q_S$	$m_1 = q_1 \oplus q_2$ $m_2 = q_2 \oplus q_3$

4 Experimental results

To evaluate the efficiency of the proposed steganography algorithm, four standard tests are used that are based on full reference image quality assessment. In which two of them are deterministic approach, and other two are statistical approach. The experimental results are shown of all parameters with the different threshold value and embedding capacity.

Embedding capacity is an average estimate that shows how many message bits per pixel have been hidden in the cover image. It is computed according to Eq.1.

$$Embedding\ capacity(E) = \frac{Total\ no.\ of\ embedded\ massage\ bits(T)}{Total\ no.\ of\ pixels\ in\ \mathrm{cov}er\ image(C)} bpp \tag{1}$$

PSNR is a dimensionless standard matric-based measurement that is used for full reference image quality assessment. It is defined in logarithmic scale so its value changes nonlinearly for image distortion. According to the human visual system, it is challenging to differentiate between a cover image and stego image above a limiting PSNR value (35). That is determined as the following Eq.2.

$$PSNR = 10\log_{10}\left(\frac{MAX^2}{MSE}\right), \tag{2}$$

where MSE (mean square error) between the cover image and stego image that is defined as

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left[I(i,j) - k(i,j)\right]^2, \tag{3}$$

where $I(i,j)$ and $k(i,j)$ is the pixel intensity of cover and Stego image, m and n are the width and height of the cover image. As the stego image reaches closer to the cover image, the value of MSE decreases and PSNR increases [21].

The structural similarity index (SSIM) [22] measures the similarity between the cover image and the stego image regarding local luminance, contrasts and spatial structure. The similarity of the luminous distribution over two small image patches x and y can be defined by the product of the two means divided by the sum of their squares defined by Eq. 4.

$$l(x,y) = \frac{2\mu_x\mu_y + C_1}{\mu_x^{\ 2} + \mu_y^{\ 2} + C_1}, \tag{4}$$

where μ represents arithmetic means of the luminance intensity over an image patch. That is located in the range of 0 to 1 and becomes equal to 1 represents both patches have the same mean luminance. The similarity of the luminance contrasts of two small image patches x and y can be defined by the product of the two standard deviations divided by the summative squares defined by Eq.4.

$$c(x,y) = \frac{2\sigma_x\sigma_y + C_2}{\sigma_x^{\ 2} + \sigma_y^{\ 2} + C_2} \tag{5}$$

where σ represents a standard deviation of

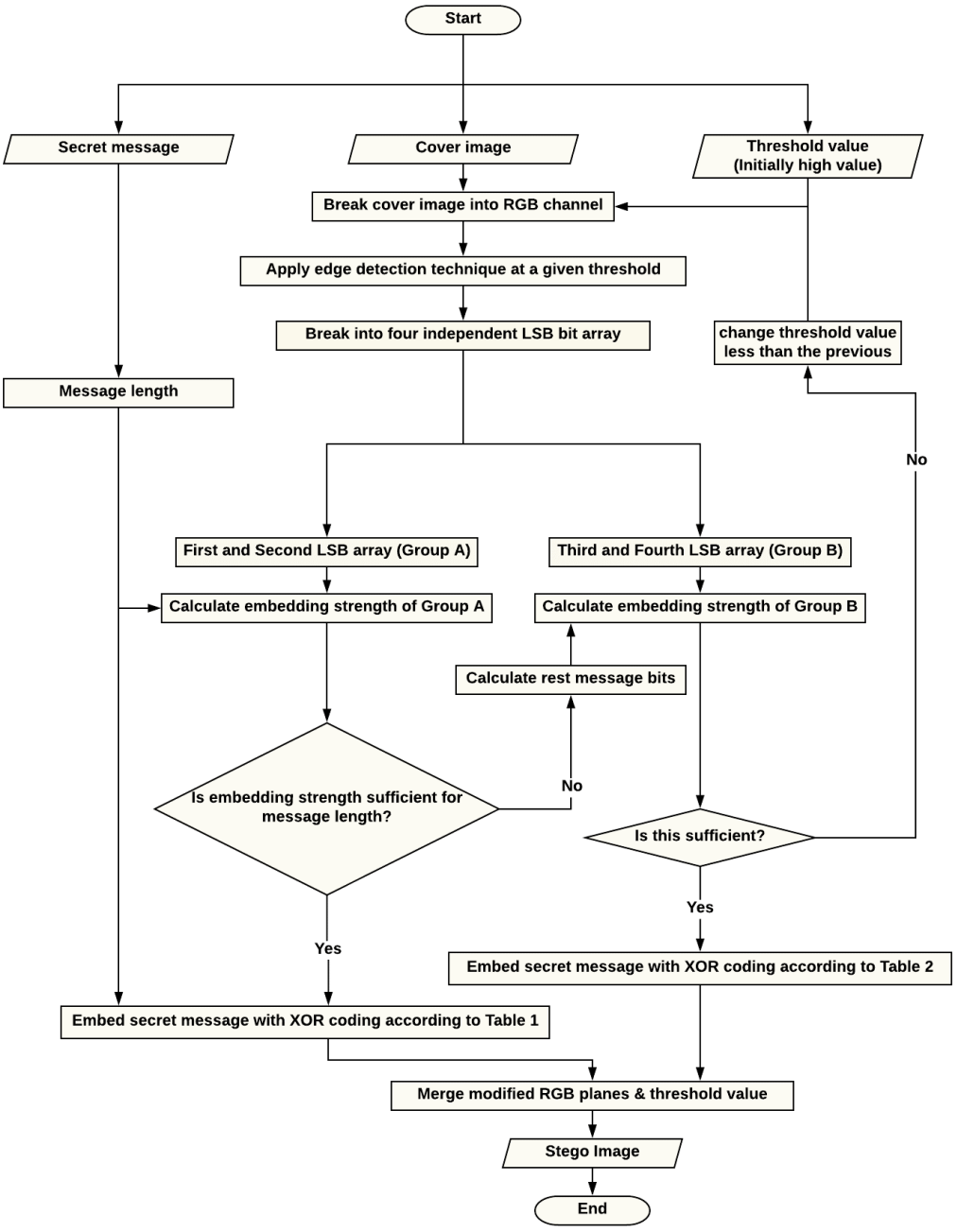

FIGURE 3 Data embedding process in spatial domain

luminous intensity of an image patch. C is in the range of 0 to 1 and becomes equal to 1 when both patches have the same contrast. The covariance of x and y reflects the tendency of two image signals vary together, that is taken as a measure of the structural similarity of the two patches.

$$s(x,y)=\frac{\acute{o}_{xy}+C_3}{\acute{o}_x\acute{o}_y+C_3} \tag{6}$$

The overall similarity index between the patches x and y is defined as the product of luminance, contrasts and structural similarity components as Eq.7.

$$SSIM=\frac{\left(2\mu_x\mu_y+C_1\right)\left(2\sigma_{xy}+C_2\right)}{\left(\mu_x{}^2+\mu_y{}^2+C_1\right)\left(\sigma_x{}^2+\sigma_y{}^2+C_2\right)} \tag{7}$$

where μ_x and μ_y are the average of x and y, σ_x and σ_y are the variance of x and y, σ_{xy} is the covariance of x and y, C_1 and C_2 are the

TABLE 2 Embedding conditions for Group A

Condition	Action to be taken
$m_1 = k_1 \quad m_2 = k_2 \quad m_3 = k_3 \quad m_4 = k_4$	No change required
$m_1 = k_1 \quad m_2 = k_2 \quad m_3 = k_3 \quad m_4 \neq k_4$	Complement p_5
$m_1 = k_1 \quad m_2 = k_2 \quad m_3 \neq k_3 \quad m_4 = k_4$	Complement p_1 and p_2
$m_1 = k_1 \quad m_2 = k_2 \quad m_3 \neq k_3 \quad m_4 \neq k_4$	Complement p_1, p_2 and p_5
$m_1 = k_1 \quad m_2 \neq k_2 \quad m_3 = k_3 \quad m_4 = k_4$	Complement p_4
$m_1 = k_1 \quad m_2 \neq k_2 \quad m_3 = k_3 \quad m_4 \neq k_4$	Complement p_4 and p_5
$m_1 = k_1 \quad m_2 \neq k_2 \quad m_3 \neq k_3 \quad m_4 = k_4$	Complement p_3
$m_1 = k_1 \quad m_2 \neq k_2 \quad m_3 \neq k_3 \quad m_4 \neq k_4$	Complement p_3 and p_5
$m_1 \neq k_1 \quad m_2 = k_2 \quad m_3 = k_3 \quad m_4 = k_4$	Complement p_2
$m_1 \neq k_1 \quad m_2 = k_2 \quad m_3 = k_3 \quad m_4 \neq k_4$	Complement p_2 and p_5
$m_1 \neq k_1 \quad m_2 = k_2 \quad m_3 \neq k_3 \quad m_4 = k_4$	Complement p_1
$m_1 \neq k_1 \quad m_2 = k_2 \quad m_3 \neq k_3 \quad m_4 \neq k_4$	Complement p_1 and p_5
$m_1 \neq k_1 \quad m_2 \neq k_2 \quad m_3 = k_3 \quad m_4 = k_4$	Complement p_2 and p_4
$m_1 \neq k_1 \quad m_2 \neq k_2 \quad m_3 = k_3 \quad m_4 \neq k_4$	Complement p_2, p_4 and p_5
$m_1 \neq k_1 \quad m_2 \neq k_2 \quad m_3 \neq k_3 \quad m_4 = k_4$	Complement p_2 and p_3
$m_1 \neq k_1 \quad m_2 \neq k_2 \quad m_3 \neq k_3 \quad m_4 \neq k_4$	Complement p_1, p_4 and p_5

TABLE 3 Embedding conditions for Group B

Condition	Action to be taken
$m_1 = k_1 \quad m_2 = k_2$	No change required
$m_1 = k_1 \quad m_2 \neq k_2$	Complement p_3
$m_1 \neq k_1 \quad m_2 = k_2$	Complement p_1
$m_1 \neq k_1 \quad m_2 \neq k_2$	Complement p_2

variables to stabilize the division with weak denominator. When comparing two images, the structural similarity index is computed locally within a sliding window that moves a pixel by pixel across the image resulting in a structural similarity index map. Structural similarity index score of the entire image is then computed by averaging the structural similarity index map across the image. The above measurements are only valid for greyscale cover image and stego image. Hassan and Bhagvati extend this method for colour image structural similarity [23].

The Feature Similarity Index (FSIM) [24] is much better than SSIM in term of local image quality assessment. It is based on the human visual system, which is sensitive to low-level features where the phase of its frequency components is congruent. It has combined the feature of phase congruency (PC) and gradient magnitude (GM). Both are complementary to each other. The original publications of FSIM are used for the grayscale image. FSIM is calculated between stego and cover image. The measure of similarity for $PC_1(x)$ and $PC_2(x)$ are define as Eq.8.

$$S_{PC}(X) = \frac{2PC_1(X)PC_2(X) + T_1}{PC_1^2(X) + PC_2^2(X) + T_1} \tag{8}$$

where $T_1 0$. The measure of similarity of GM values for $G_1(x)$ and $G_2(x)$ are define as Eq.9.

$$S_G(X) = \frac{2G_1(X)G_2(X) + T_2}{G_1^2(X) + G_2^2(X) + T_2} \tag{9}$$

where T_1 and T_2 0 and it depends upon the dynamic range of phase congruency and gradient magnitude values. Both constant $T_1 = 0.85$ and $T_2 = 160$ are fixed in this quality measurement. Multiply $S_{PC}(X)$ and $S_G(X)$ values for every location for measurement of similarity. FSIM is define for monochrome cover image and stego image is defined as Eq.10.

$$FSIM = \frac{\sum_{x\in\Omega} S_L(X) PC_m(X)}{\sum_{x\in\Omega} PC_m(X)} \tag{10}$$

Zhang, Mou and Zhang [24] proposed the

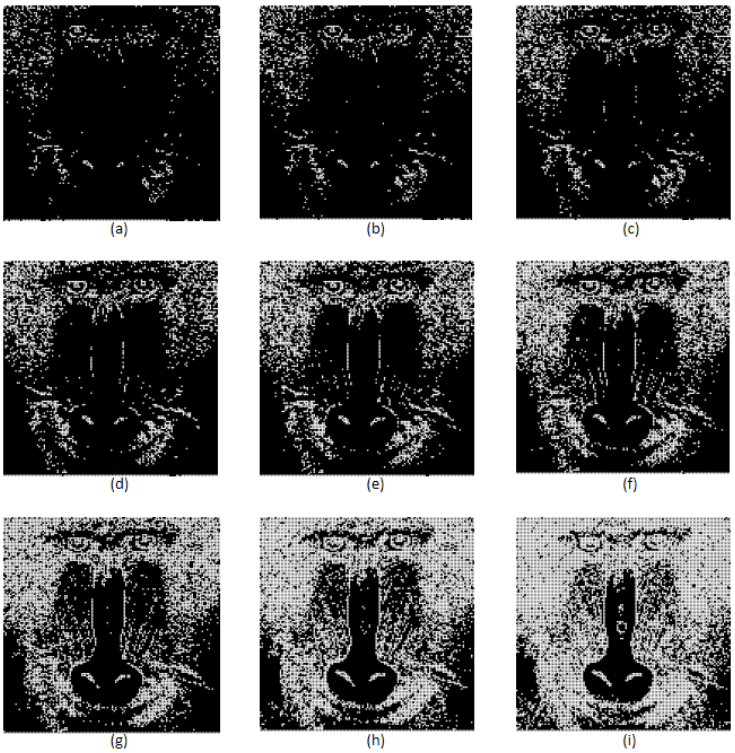

FIGURE 4 (a) edge of red channel using Th=105, (b) edge of red channel Th=95, (c) edge of red channel Th=85, (d) edge of red channel Th=75, (e) edge of red channel Th=65, (f) edge of red channel Th=55, (g) edge of red channel Th=45, (h) edge of red channel Th=35 (i) edge of red channel Th=25

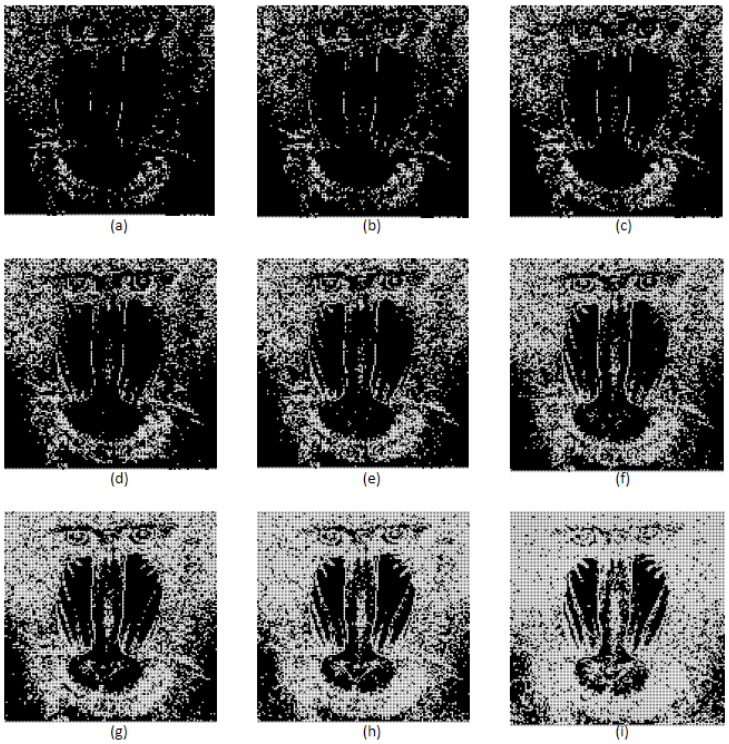

FIGURE 5 (a) edge of green channel using Th=105, (b) edge of green channel Th=95, (c) edge of green channel Th=85, (d) edge of green channel Th=75, (e) edge of green channel Th=65, (f) edge of green channel Th=55, (g) edge of green channel Th=45, (h) edge of green channel Th=35, (i) edge of green channel Th=25

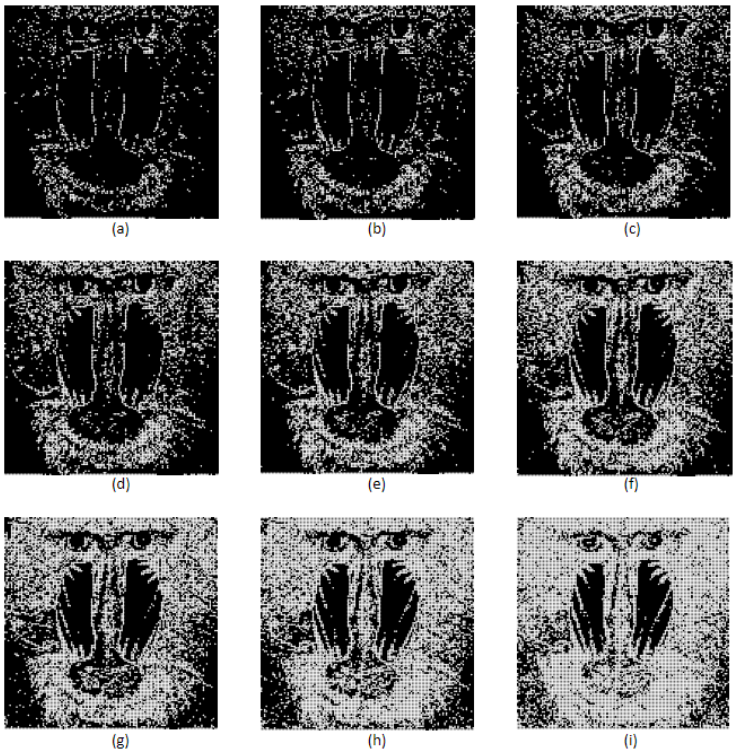

FIGURE 6 (a) edge of blue channel using Th=105, (b) edge of blue channel Th=95, (c) edge of blue channel Th=85, (d) edge of blue channel Th=75, (e) edge of blue channel Th=65, (f) edge of blue channel Th=55, (g) edge of blue channel Th=45, (h) edge of blue channel Th=35, (i) edge of blue channel Th=25

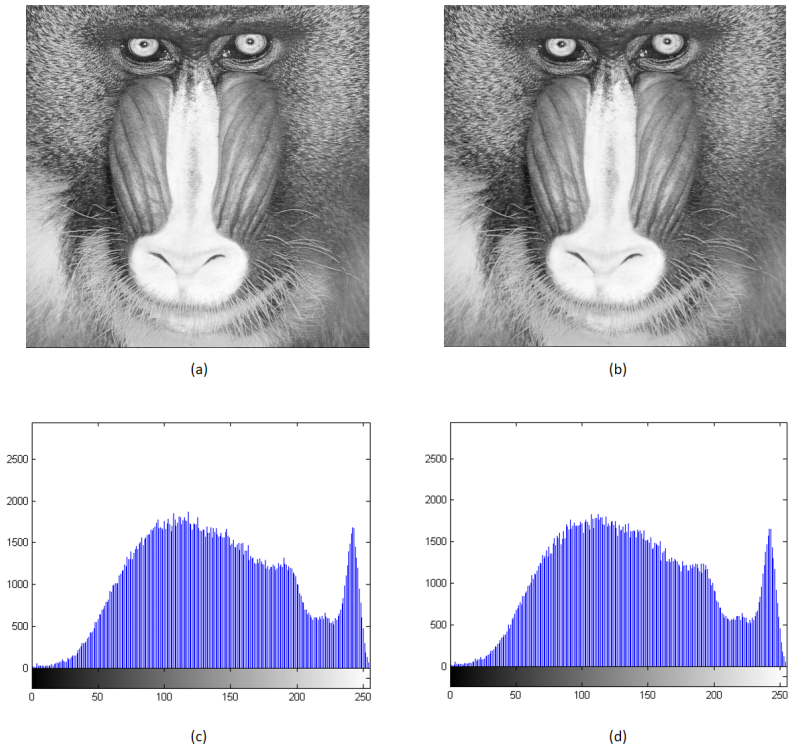

FIGURE 7 (a-b) Red channel of colour stego Image(Th=25) and cover Image and (d-f) Histogram of the corresponding Red channel of colour stego Image(Th=25) and cover Image

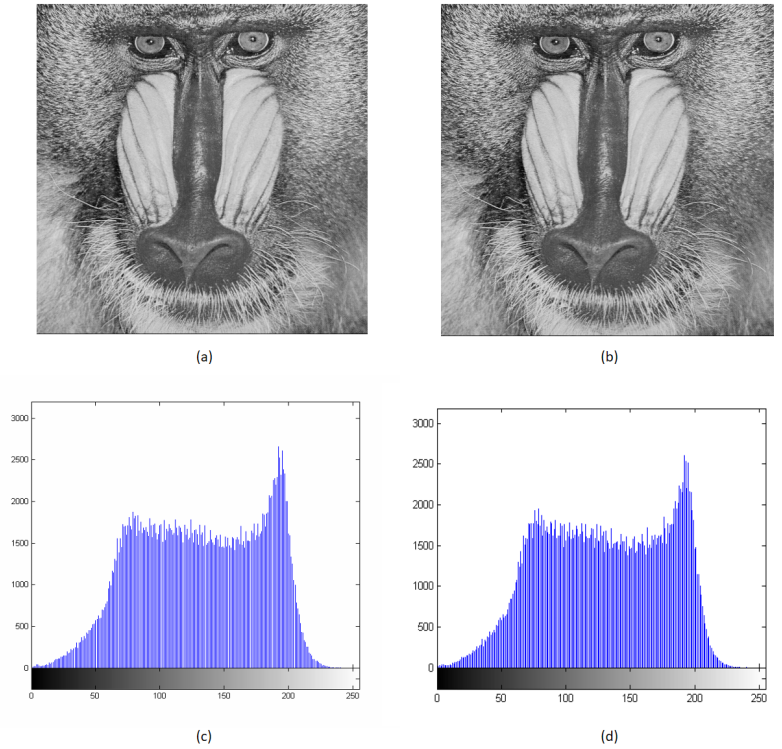

FIGURE 8 (a-b) Green channel of colour stego Image(Th=25) and cover Image. and (d-f) Histogram of the corresponding Green channel of colour stego Image(Th=25) and cover Image

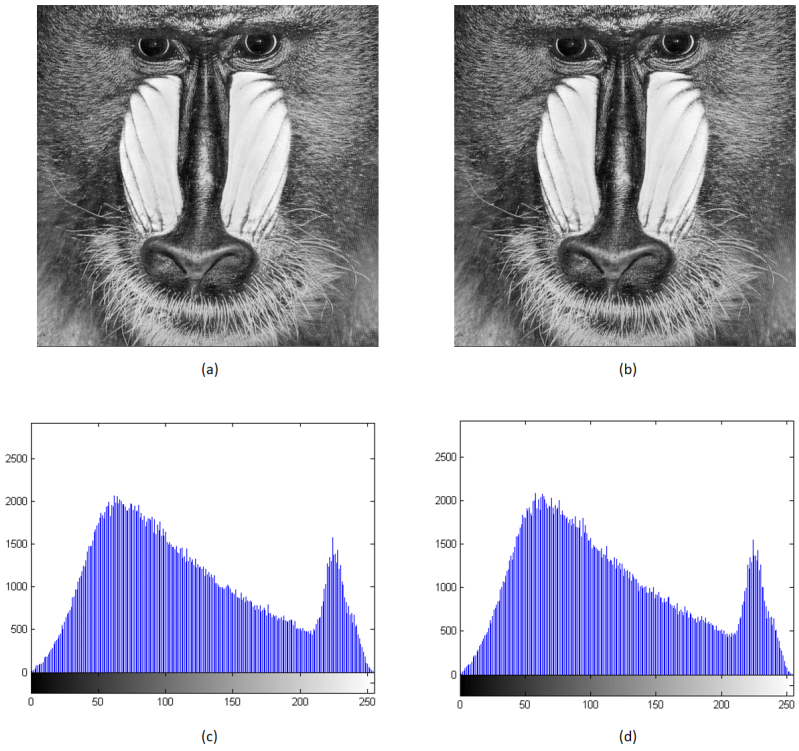

FIGURE 9 (a-b) Blue channel of colour stego Image(Th=25) and cover Image. and (d-f) Histogram of the corresponding Blue channel of colour stego Image(Th=25) and cover Image

generalized method for the colour image named as FSIMc. That is defined in YIQ Colour space where Y channel represents luminance while other channels represent chromatic information. Chromatic feature similarity is defined as

$$S_I(X) = \frac{2I_1(X)I_2(X)+T_3}{I_1^2(X)+I_2^2(X)+T_3} \tag{12}$$

$$S_Q(X) = \frac{2Q_1(X)Q_2(X)+T_4}{Q_1^2(X)+Q_2^2(X)+T_4} \tag{13}$$

$$S_2(X) = S_I(X)S_Q(X) \tag{14}$$

where $T_3>0$, $T_4>0$, both constant T_3 and T_4 are fixed in our quality measurement $T_3=T_4=200$ and both components (I and Q) have same dynamic range. $S_2(X)$ is chrominance similarity measure and overall feature similarity index measurement (FSIM) is given as Eq.15.

$$FSIM_C = \frac{\sum_{x\in\Omega} S_L(X)\left[S_C(X)\right]^{\lambda} PC_m(X)}{\sum_{x\in\Omega} PC_m(X)} \tag{15}$$

The above-mentioned quality assessment parameter demonstrates the performance of proposed method. For comparison, existing methods PVD [13], IPVD [16], AE-LSB [25], and N-bpp [7] are also simulated. All simulation has been implemented in MATLAB 2013a and tested with McGill, Barcelona, and SIPI image database. Colour image (Mandrill. tiff, 512×512×3) has been used to show for detailed analysis at different threshold value and embedding capacity. The evaluation of the proposed method has been computed by 1500 images from the image database. The results of the proposed method have been presented separately for grayscale image and colour image. The results are not connected to any particular image. There may be slight changes with different set of images.

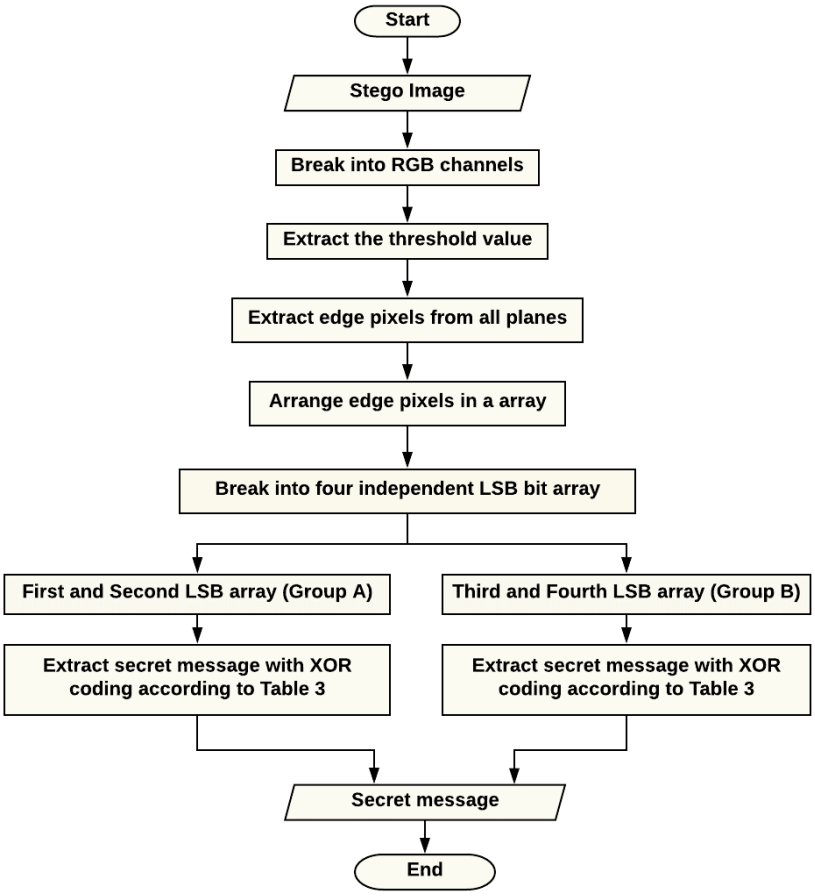

FIGURE 9 (a-b) Blue channel of colour stego Image(Th=25) and cover Image. and (d-f) Histogram of the corresponding Blue channel of colour stego Image(Th=25) and cover Image

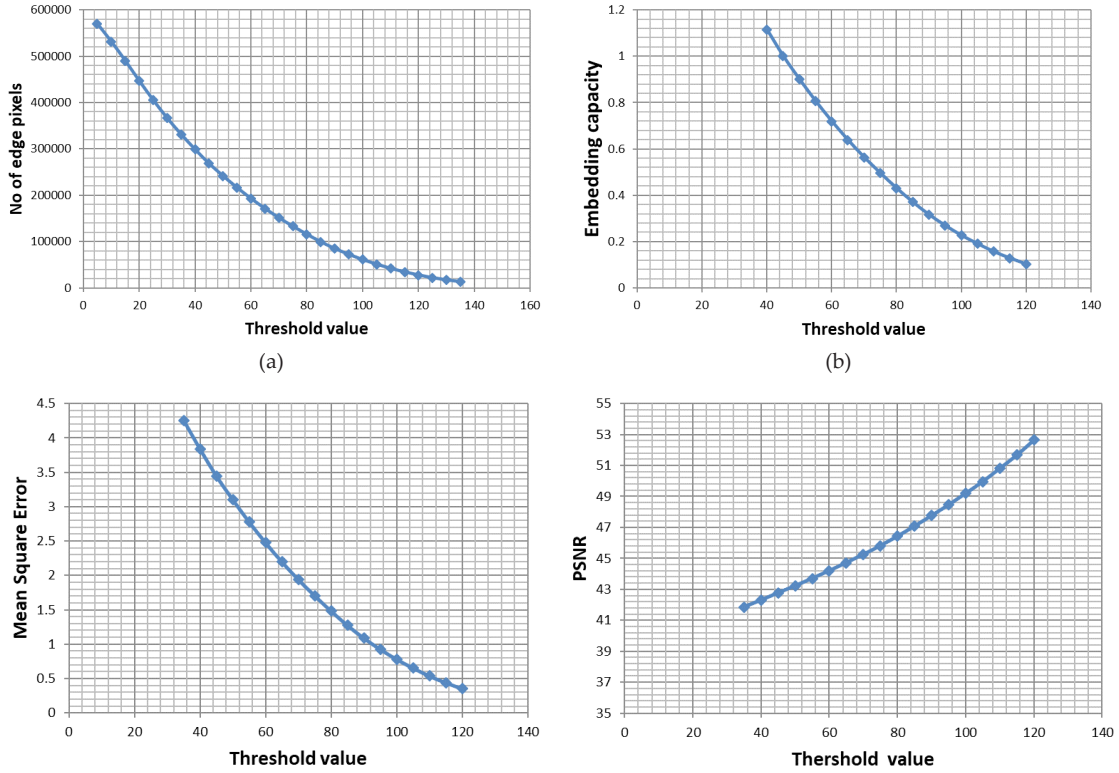

FIGURE 11 (a) Number of Edge pixels. (b) Embedding capacity (c) Mean square error (d) Peak signal to noise ratio (PSNR) with respect to threshold value tested on 24-bit (Mandrill.tiff, 512×512×3) colour image for proposed algorithm

TABLE 4 Full reference image quality assessment of proposed method in spatial method tasted over grey image database

Embedding capacity	Method	MSE	PSNR	SSIM	FSIM
	PVD [13]	0.4591	52.5119	0.9994	0.9993
	IPVD [16]	0.2720	53.7851	0.9992	0.9991
0.1	AE-LSB [25]	0.4092	52.0114	0.9995	0.9995
	N-bpp Edge-XOR [7]	0.2883	53.5325	0.9997	0.9997
	Proposed method	**0.1406**	**56.6504**	**0.9998**	**0.9998**
	PVD	1.1687	47.4537	0.9989	0.9987
	IPVD	0.6632	49.9145	0.9988	0.9986
0.25	AE-LSB	1.0244	48.0261	0.9991	0.9990
	N-bpp Edge-XOR	0.6895	49.7452	0.9992	0.9992
	Proposed method	**0.3277**	**52.9766**	**0.9995**	**0.9994**
	PVD	2.1040	44.9004	0.9978	0.9978
	IPVD	1.2302	47.0011	0.998	0.9981
0.45	AE-LSB	1.8380	45.4874	0.9982	0.9984
	N-bpp Edge-XOR	1.2576	47.1353	0.9984	0.9987
	Proposed method	**0.6110**	**50.2707**	**0.9991**	**0.9990**
	PVD	2.7775	43.6943	0.997	0.9971
	IPVD	1.8326	45.5002	0.9978	0.9979
0.65	AE-LSB	2.3867	44.3528	0.9974	0.9979
	N-bpp Edge-XOR (2016)	1.6664	45.9131	0.9977	0.9984
	Proposed method	**0.8891**	**48.6414**	**0.9988**	**0.9988**

The number of edge pixels in independent colour channels of a cover image at different threshold values is shown in Figure [4-6]. Figure 11(a) shows that at the threshold value has been decreased from 105 to 25, the number of edge pixels increased rapidly around the edges of cover image. The variation of Edge pixels, embedding capacity, mean square error, and PSNR with respect to the threshold value is shown in Figure 11[b-d].

The proposed scheme achieves a value of PSNR at 0.65bpp as 48.64. Whereas PVD, IPVD, AE-LSB, and N-bpp schemes achieve as 43.69, 45.50, 44.35, and 45.91 respectively shown in Table 4. The comparison is also presented in Figure 12 (a). From this figure, it is observed that the proposed method provides better PSNR than N-bpp and IPVD methods in terms of embedding capacity. The N-bpp method utilize 5 pixels out of 9 pixels for embedding, but the proposed method utilizes all the 9 pixels in a 33 block. The proposed scheme for color image steganography achieves a value of PSNR at 0.80bpp as 44.68. Whereas N-bpp [7] and color PVD [20] schemes achieve as 42.22, and 40.78 respectively. The comparison is also presented in Figure12 (b). It is observed that the proposed scheme achieves a much higher embedding capacity for the approximate close PSNR.

To study the structural stability of the presented steganography scheme, SSIM and FSIM parameters have been examined on different values of embedding capacity. Proposed scheme achieve 0.9988 SSIM while PVD, IPVD, AE-LSB, and N-bpp schemes achieve 0.9970, 0.9978, 0.9974 and 0.9977 respectively at 0.65 bpp embedding capacity. The difference between the structural similarity lies between 0.0004 to 0.001 shown in Table 4. This small difference is also considered as a significant improvement in the structural quality of the Stego image. The presented technique provides better structural stability than others. The reason is that the technique has been used to hide in the particular regions of the cover image. Group A provides 40%-bit errors against 80% embedding, whereas in group B provides only 33%-bit errors against 67% embedding. On the basis of per 5 bits maximum 3 and average 1.75 bits are altered in the Group A. During simulation, it has been found that the average bit error per 5 bits always less than 1.75 bits and its value lies between 1 to 1.2. Group B performs much better regarding

TABLE 5 Full reference image quality assessment of proposed method in spatial method tasted over Color image database

Embedding capacity	Method	MSE	PSNR	SSIM	FSIM
	N-bpp Edge-XOR [7]	0.5121	51.0376	0.9998	0.9996
0.1027	Color PVD [20]	0.6496	50.0041	0.9996	0.9995
	Proposed method	**0.2938**	**53.4505**	**0.9999**	**0.9997**
	N-bpp Edge-XOR	1.2584	47.1325	0.9995	0.9995
0.2695	Color PVD	1.7233	45.7671	0.9994	0.9992
	Proposed method	**0.7369**	**49.4569**	**0.9996**	**0.9993**
	N-bpp Edge-XOR	2.2734	44.5641	0.9991	0.9989
0.4956	Color PVD	3.1329	43.1713	0.9989	0.9987
	Proposed method	**1.3548**	**46.8121**	**0.9992**	**0.9989**
	N-bpp Edge-XOR	3.8965	42.2241	0.9985	0.9984
0.8066	Color PVD	5.4243	40.7874	0.9982	0.998
	Proposed method	**2.2087**	**44.6894**	**0.9987**	**0.9984**
	N-bpp Edge-XOR	5.1648	41.0003	0.9982	0.9981
1.0008	Color PVD	7.2887	39.5043	0.9979	0.9978
	Proposed method	**2.7365**	**43.7589**	**0.9984**	**0.9983**
	N-bpp Edge-XOR	6.9846	39.6894	0.9978	0.9978
1.236	Color PVD	10.1726	38.0565	0.9975	0.9974
	Proposed method	**3.4049**	**42.8098**	**0.998**	**0.9982**

bit errors and always got less than 0.75 bits. Because of that, the third or fourth LSB planes of the cover image got very little change. The method provides an additional one-bit plane for embedding in comparison with N-bpp.

The histogram of the cover image and stego

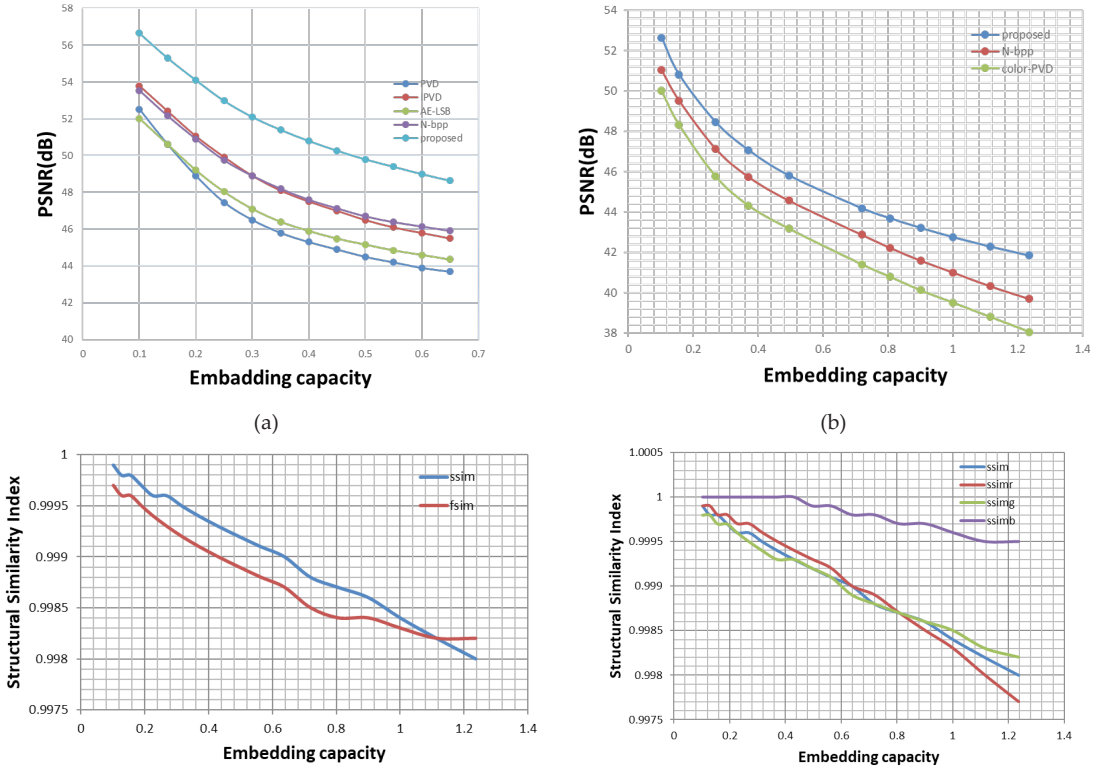

FIGURE 12 (a) Peak Signal to noise ratio (PSNR) with respect to embedding capacity tasted on grey scale image database for PVD, IPVD, AE-LSB, N-bpp, and purposed method. (b) Variation of PSNR with respect to embedding capacity tasted on colour image database for N-bpp, colour PVD, and purposed algorithm. (c) Variation of Structural similarity index (SSIM) and Feature similarity index (FSIM) with respect to embedding capacity tested on greyscale image database for proposed algorithm. (d) Variation of Structural similarity index of 3 colour channels and overall similarity index with respect to embedding capacity tested on colour image database for proposed algorithm

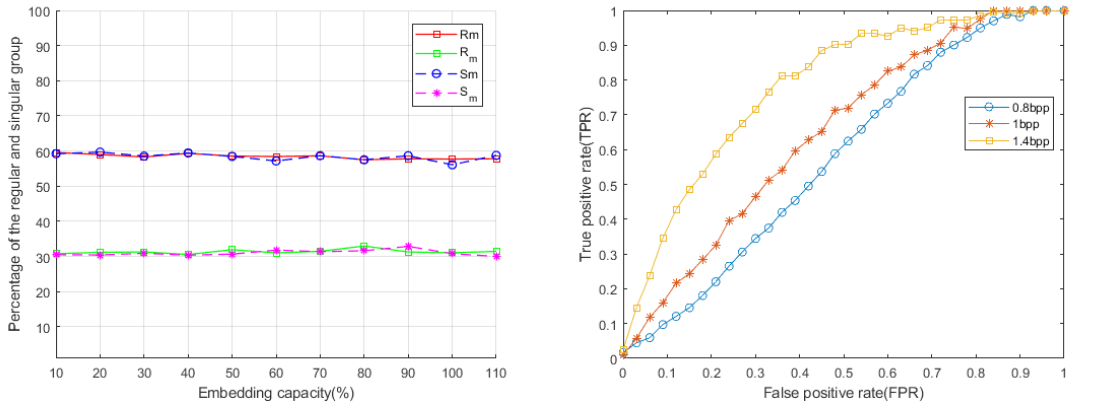

FIGURE 13 (a) RS diagram of stego image (Mandrill.tiff, 512×512×3) the x-axis denotes the embedding capacity and the y axis denotes the relative percentage of regular and single group with mask. (b) ROC curve for the proposed method with 80%, 100%, and 140% embedding capacity. The x-axis represents false positive rate (FPR) and y-axis represent true positive rate (TPR) respectively

image is shown in Figure [7-9]. The figure shows a high degree of similarities. This shows that the proposed steganography technique is quite capable of preserving the histogram. Regular and singular (RS) steganalysis method is very effective to identify the hidden message in LSB based steganography [5]. The security of the proposed technique has been evaluated by this method. During this experiment, two masks have been used. The result of the RS method for the stego image is shown in the percentage of R and S according to the Figure 13(a). It shows that are very close to each other and their percentage value also stable with increasing embedding capacity up to 1bpp. The Receiver operating characteristic (ROC) is shown in Figure 13(b). In which the detection probability of 80%, 100% and one 140% embedding capacity of the stego image has been analysed. It can be clearly seen that the proposed method is quite robust against the RS steganalysis.

5 Conclusions

This paper presents an improved steganography technique on the basis of HVS system that is less sensitive to changes in the sharp edge regions. Here, non-overlapping blocks are used for the edge regions detection that can be easily identified through local reference pixels present in the modified monochrome image. An improved XOR technique has been used for message embedding. It is able to make change according to the strength of LSB planes and provide minimum bits alteration in the cover image. This algorithm has been tested on the different set of image databases. We conclude that the average PSNR is approximately 43 and SSIM is 0.998 on the 1.25 bpp embedding capacity. This represents a capable steganography technique. The algorithm can be applied into the grey image as well as a colour image.

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Ethics

I have used MATLAB 2013a for my research which is a simulation software. Our Institute (NIT Uttarakhand) have a server licence for this software, as well as some databases are used for result discussion that is also publicly available. I have not done any work for which I need ethical permission.

Funding

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Data accessibility

I have used three image databases that are publicly available on the Internet.

McGill image database. (http://tabby.vision.mcgill.ca/html/browsedownload.html)

Barcelona image database. (http://www.cvc.uab.es/color_calibration/Database.html)

SIPI image database. (http://sipi.usc.edu/database/database.php?volume=misc)

Competing interests

The authors declare no competing interests.

Authors' contributions

Kumar Gaurav (K.G.) and Umesh Ghanekar (U.G.) have designed the study. K.G. has collected all image databases for analysis. K.G. analysed the data. K.G. and U.G. have written this manuscript. U.G. and K.G. gave final approval for publication.

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