Steganography Based on Local Binary Pattern and Discrete Wavelet transformation

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Abstract: **In the upcoming years, information security has become an important part of one's life. Information security is no longer an option rather it has become the need of the hour. In this paper, Local Binary Pattern and D. Discrete wavelet transformation (DWT) has excellent Discrete Wavelet transformation in a combined manner is proposed.Discrete Wavelet transformation has excellent spatio-frequency localization properties which are used for image compression. Local Binary Pattern (LBP) operator is one of the most widely used approach for texture analysis. LBP algorithm revolves around the center pixel and its neighborhood pixels. Our approach includes combining these two algorithms for optimal result.**

Keywords- Information Security; Steganography; LBP; DWT

I. INTRODUCTION

Steganography is an art of writingsecret (hidden) information. The purpose of steganography is to keep the information hidden while not the fact that two parties are sharing the information with each other.Stego images should be imperceptible and statistically undetectable. Techniques for data hiding work either in frequency or spatial domain. The implementation of Spatial domain is easy to implement with low computation complexity and is fragile to common image processing and other attacks while the frequency domain is robust against common attacks and the computational cost is higher. Steganography is widely used in applications like
Copyright control, enhancingtheefficiency of image search engines, TVbroadcasting, smart

IDs (Photograph isembedded with the individual's details), safe circulation of confidential data, audio-video synchronization.
A steganography technique is proposed in this paper using local binary operator and discrete wavelet transformation. An image is divided into smaller cells and frequency coefficients of pixels are compared for calculating LBP patterns for these cells. To insert secret message one or more pixels' values are changed in the neighborhood. In existing technique [18,19] information is inserted in any coefficient, but in proposed technique data is embedded in most suitable position. The proposed scheme consists of all desirable properties of steganography including security, invisibility and obliviousness.
Following is how the paper organized: the brief description of related works are given in section II; then in section III basics of wavelet transformation, PSNR, SSIM and working of LBP algorithm is described. In section IV proposed scheme is illustrated. In section V experimental study and outcome are presented followed by results in section VI.

II.RELATED WORK

In today's era, when there is a rise in information exchange on Internet, secured data transmission has become a necessity. We have steganographic tools available like JSteg [2], F5 [30], Outguess [29], JP Hide Seek [2. In wavelet domain transformation , the secretinformation is embedded in resultant coefficients bearing high energy of DWT while the coefficients bearing low energy are kept unchanged in order to preserve image quality.DCT domain proposes many steganographic algorithms. Spatial frequency localization is offered in DWT which results in embedding of information which includes alteration of image locally thus resulting in better image steganography in wavelet domain as compared to the ones in DCT domain.Data hiding using vector quantization with single level Haar transform has been offered in Abdul Aziz and Pang [35].

Local binary operator which is used to calculate the local intensity of pixel contrast with that of its neighborhood pixels and thus have uses in applications like face recognition and texture classification. In addition to these, LBP is used in various other applications of biometrics like iris recognition, eye localization and fingerprint.Some important LBP operator characteristics include (1) simplicity of computations because of its discriminative power thus making the method very successful in many computer vision problems such as face analysis and motion analysis which were not regarded as texture problems.(3) Tolerance against illumination changes due to its non-varying nature against in monotonic gray-

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scale images. Ojala et al has proved that LBP is more efficient in comparing pixel contrast with its neighborhood using AGLD and multidimensional SGLD distribution.
In this paper we use LBP operator to embed a secret message in an image and measure the local intensity contrast.

III. BASIC METHODOLOGY

A. Transformation Of Wavelet

A signal can be decomposed into basic functions in Wavelet Transform. These basic functions are called wavelets. Unlike Fourier expansion, wavelet transform deals with both -time and frequency domain [19]. In Discrete Wavelet Transform(DWT), a discrete time signal is transformed into discrete wavelet representation.DWT uses two functions for this transformation, one is a Scaling function and the other is a wavelet function. Scaling function works as a low-pass filter, averaging the input. Wavelet function works as an high-pass filter, storing the difference and passing the sum. For DWT decomposition ofsignals, these functions are used for creating different frequency sub-bands of input signal. To produce outputs with multiple resolution, these functions are applied recursively. Many functions can be used as the wavelet function, such as – Biosplines, Symlets, Haar, Morlet [38] etc. In this paper Haar wavelet transform is used. For our input digital image,
Output is four sub-bands – LL (Low-Low), HH(High-High), HL(High-Low), LH (Low-High) where low-low refers to the application of two low pass filters, low-high the application of low-pass filter and then a high pass filter. Similarly, HL and HH can be explained. Let J(a,b) is an digital image of size 2P x 2P, i(p) and k(p) be the high-pass and low-pass filters respectively. The construction of sub bands is given by
Equation 1 –

$$\begin{cases} LL_{(x,y)}=\Sigma_{a,b} i(m-2n)i(o-2p)J(m,o) \\ LH_{(x,y)}=\Sigma_{a,b} i(m-2n)k(o-2p)J(m,o) \\ HL_{(x,y)}=\Sigma_{a,b} k(m-2n)i(o-2p)J(m,o) \\ HH_{(x,y)}=\Sigma_{a,b} k(m-2n)i(o-2p)J(m,o) \end{cases} \qquad (1)$$

Where x, y, P€Z^+, m, o€Z,2P+1<=m-2n<=0, -2P+1<=o-2p<=0.DWT decomposition of digital image is first level of Haar transformation.

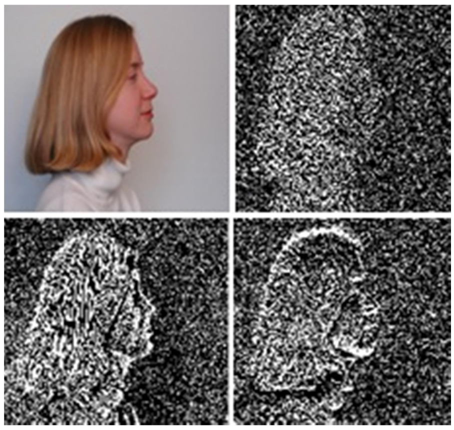

Fig1.images produced after using DWT decomposition

The image is reconstructed by inverse Haar transform. Functions for inverse DWT[23] :

$$\begin{cases} \Sigma_{m,o} i(m-2n)i(o-2p)LL_{(x,y)} \\ \Sigma_{m,o} i(m-2n)k(o-2p)\,LH_{(x,y)} \\ \Sigma_{m,o} k(m-2n)i(o-2p)\,HL_{(x,y)} \\ \Sigma_{m,o} k(m-2n)i(o-2p)\,HH_{(x,y)} \end{cases} \qquad (2)$$

Where x, y, P€Z^+, m, o€Z, -2P+1<=m-2n<=0, -2P+1<=o-2p<=0. Every wavelet transformation scales downsize of sub band by factor of 4.

B. LBP Operator

LBP operator is calculated by measuring the difference in the grey-scale values of center coordinate and its neighboring coordinates in a local region. With the grey-scale value of center pixel as threshold, neighboring pixels are given values 1 or 0. 1 if value is larger than threshold, 0 otherwise. For N neighbors within D distance (radii) LBP number (V) is given by –

$$V = \sum_{n=0}^{N-1} S(\text{gn} - \text{gc}) \times 2^n \qquad (3)$$

Where, gc is gray-scale value of the center pixel, gn the gray-scale value of neighboring pixel n and S(x) is the sign function.

$$S(x) = \begin{cases} 1\ , & \text{if } x \geq 0 \\ 0, & \text{or else} \end{cases} \qquad (4)$$

C. Peak Signal to Noise Ratio(PSNR)

Many criterions are there to measure the quality of digital images. One of them is PSNR [19]. PSNR is given by –

$$\text{PSNR} = 10\log_{10}[max(u(i,j))^2 / MSE]$$

$$\text{MSE} = \frac{1}{m*n} \sum_{i=1}^{m} \sum_{j=1}^{n} [\, u(i,j) - v(i,j)]^2$$

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u(i,j) and v(i,j) refers to similar pixel position as in the original images as well as in the embedded image.
Smaller the PSNR value, higher the distortion.

D. *Structural Similarity Index (SSIM)*

Similarity between the original image A and output image B can be measured by index SSIM [23]. For identical images, threshold value is 1. Magnitude ranges between -1 and 1.

$$SSIM = \begin{cases} I(H,H') = \dfrac{2\mu_H\mu_{H'} \quad + C_1}{\mu_H^2 + \mu_{H'}^2 + C_1} \\ c(H,H') = \dfrac{2\sigma_H\sigma_{H'} + C_2}{\sigma_H^2 + \sigma_{H'}^2 + C_2} \\ s(H,H') = \dfrac{\sigma_{HH'} + C_3}{\sigma_H\sigma_{H'} + C_3} \end{cases}$$

where, the first term I , is for comparison of luminance which represents the closeness of the two images' mean luminance (Hand H'). This factor is maximum and equal to 1 only when H= H'. C, is the contrast comparison function which compares the contrast of the two images. Here, the measurement of contrast is done by standard deviation H_d H'.This term is maximum and equal to 1 only if H= H'. S,is the structure comparison function which compares the correlation coefficient of the two images H and H'.

IV. PROPOSED LOCAL BINARY PATTERN STEGANOGRAPHY TECHNIQUE IN WAVELET DOMAIN

Two images are taken; one is the cover image which can be in any format like jpeg, png etc. and other is the embedded image (secret data) that is taken in bits. Now, Discrete Wavelet Transformation is applied on the cover image to obtain 4 sub-bands namely : high-high (HH), low-low(LL),high-low(HL), low-high(LH). Out of HH, LH, HL one of the band is chosen and is further divided into blocks of n*n. Then, using Boolean functions LBP patterns are calculated on frequency coefficients in the sub-band chosen and secret message is embedded by adjusting one and more pixels in the local region.

A. *Local Region Definition (X,Y)*

pc is defined as coefficient that represent the center coordinate and pn as coefficient that represent neighborhood coordinates. Therefore, (X, Y) can be represented as the following:

pn={ pi|0,….b…..,D-1} (7)
qn={ qi|qi =|pi-pc|,i=0,…,D-1}(8)

rn={ ri | ri = sign(pi-pc),i=0,…..,D-1} (9)

The sign function used in equation 9 maps to equation 4. Therefore, the local region (X,Y) is divided in 3 sections which are represented in Figure 2 for (X=8,Y=1).pn is the matrix of X pixels in Radius Y.qn is the matrix that is calculated by subtracting neighborhood coordinate values with the center coordinate value and rn is the sign matrix of binary terms. The Boolean function f(rn) is represented as:

f(rn) =r0 ⊕ r1 ⊕… rn-1 (10)

⊕ the exclusive OR (XOR) used in equation 10 and f(rn) is both associative and communicative. So if any circular bit shift in sign then function rn doesn't not change equation 10.

B. *Algorithm for Embedding Proposed*

Message is hidden by changing values of f(rn) in local region (X.Y). changes in f(rn) by changing rn. The modifications are made to the coordinate that has the smallestvalue in qn for embedding data, therefore the quality of image is not much affected and hence it concludes that f(rn) is kept equal to the embedded bit in the block.

The embedding algorithm is sequentially defined in the following manner:

1. The cover image is made to pass through a 2D Single stage Haardiscrete wavelet transformation to obtain high frequency coefficients in lower level bands that will be generated. The output obtained is four sub-bands' matrices namely HH, LL, LH, HL.
2. Every character in the data is transformed into set of 8 bits for the purposed of embedding.
3. Randomly a sub-band is selected namely LH and it is divided into blocks (X,Y) and pn,qn,rn are calculated. Now, assuming z is one of the bit to be embedded. In each block if f(rn) = x then, no change is made else one coordinate value is changed so that f(rn) becomes equal to the value of z.

p3	p2	p1
p4	pc	p0
p5	p6	p7

q3	q2	q1
q4		q0
q5	q6	q7

r3	r2	r1
r4		r0
r5	r6	r7

fig 2. Local Region (X=8, Y=1) divided in parts: p8 coordinate matrix, q8 magnitude matrix, r8 sign matrix

If (z=1 and f(rn)=0) or (z=0 and f(rn)=1), then

Select qi=min (qn)
If ri=1
pi=pi-qi
Else
pi=pi+qi
end
end

Thus, encoded sub-band is obtained.

4. Now, another sub-band is chosen namely HH is selected at random and the procedure in Step 3 is repeated using HH band.
5. Inverse DWT is applied on all four sub-bands to obtain our final image i. e Stego image.

C. Extraction Algorithm

1. From embedding procedure Step 1 is repeated to find the coefficients of the four sub-bands namely HH, LL, HL, and LH.
2. The values of f(rn) is calculated for the two bands that were selected.
3. If f(rn)=1 then bit embedded z=1 else z=0
   thus, length of the message is obtained from HH and secret message is obtained from sub-band LH.

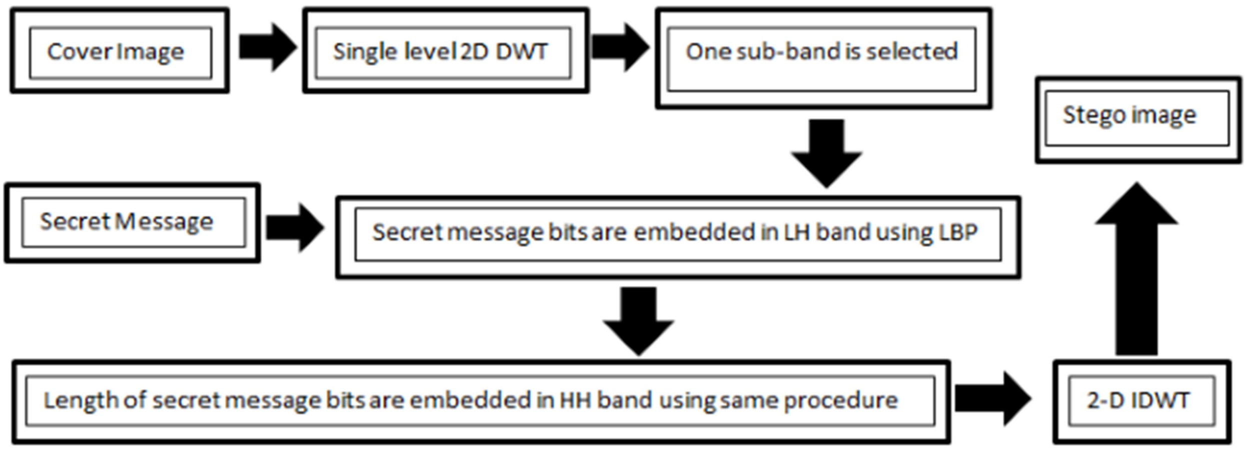

Fig 3. Embedding in Cover Image using LBP algorithm

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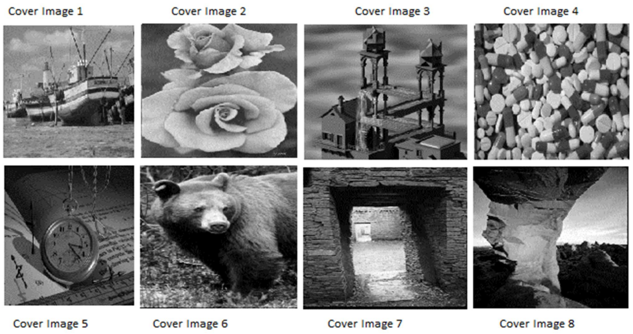

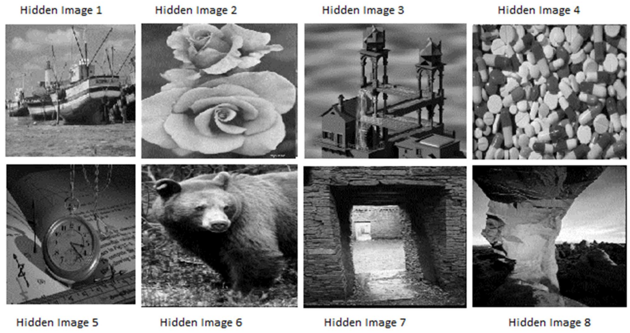

V. EXPERIMENTAL STUDY

The study has been conducted on images taken from [3,4,5,6,7,8,9,10] . 480x480 8-bit grayscale images were experiment upon during the study and are embedded with secret information of different sizes shown in figures 4 and 5.

PSNR and SSIM values of a variety of steganographic images is depicted in table 1. Table 1 shows comparison between the proposed method and simple substitution in wavelet domain. Graphical results are shown in fig. 6 .

VI. CONCLUSION

The idea proposed using this paper is the concept of data embedding using LBP in wavelet domain. LBP operator uses spatial frequency localization to embed secret information in the coefficients of high energy sub band. To maintain the quality of Stego image, we use minimum number of coefficients for embedding. Images from [3,4,5,6,7,8,9,10]
were experimented upon to study and compare the PSNR and SSIM values. Results conclude that the proposed method gives higher PSNR and Similarity index values.

Random sub bands are selected for data hiding in this method. Extensions to this method can further be proposed to study RGB images.

ORIGINAL IMAGE	SECRET MESSAGE CAPACITY	PROPOSED FRAMEWORK		SIMPLE SUBSTITUTION	
		PSNR	SSIM	PSNR	SSIM
I1:cover image 1 480x480	1920	71.6516	1	42.4928	0.9947
	1280	75.6517	1	44.2434	0.9968
	640	81.4013	1	47.2288	0.9988
I2:cover image 2 480x480	1920	69.9116	1	55.897	0.9989
	1280	71.7060	1	57.2025	0.9993
	640	76.3711	1	59.8627	0.9998
I3:cover image 3 480x480	1920	73.2707	1	48.0462	0.9982
	1280	77.7416	1	48.3501	0.9986
	640	83.7795	1	49.6316	0.9993
I4:cover image 4 480x480	1920	71.1847	1	44.5468	0.9983
	1280	73.2538	1	47.1028	0.999
	640	76.1476	1	50.7248	0.9997
I5:cover image 5 480x480	1920	76.6368	1	43.4889	0.995
	1280	78.5907	1	45.1945	0.9969
	640	82.4999	1	48.1683	0.9989
I6:cover image 6 480x480	1920	65.7927	0.9999	47.4794	0.9984
	1280	67.6059	1	48.8519	0.9989
	640	71.6104	1	51.9506	0.9997
I7:cover image 7 480x480	1920	62.7222	0.9999	44.8757	0.9976
	1280	63.6065	0.9999	46.8662	0.9988
	640	65.354	1	50.2458	0.9996
I8:cover image 8 480x480	1920	64.6346	0.9999	41.1331	0.9945
	1280	69.091	1	42.8754	0.9968
	640	72.818	1	45.6152	0.9987

able 1:comparison between the proposed method and simple substitution in wavelet doman

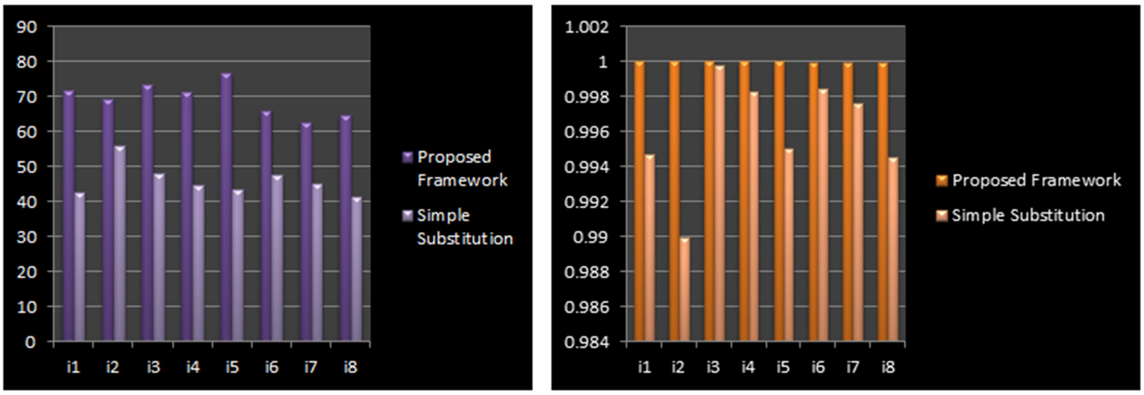

fig 6:results of value comparison of PSNR and SSIM of the proposed method and the substitution

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[3] Fishingboat.Courtesy of the Signal and Image Processing Institute at the University of Southern California.

[4]Black Bear. Copyright photos courtesy of Robert E. Barber, Barber Nature Photography (REBarber@msn.com) .

[5]Pocket Watch on a Gold Chain. Copyright image courtesy of Kevin Odhner(jko@home.com).

[6]Pills. Copyright photo courtesy of Karel de Gendre.

[7]Brandy rose. Copyright photo courtesy of Toni Lankerd.

[8]Skyline Arch. Copyright photo courtesy of Robert E. Barber, Barber Nature Photography (REBarber@msn.com).

[9]Always running, never the same.... Copyright image courtesy of JaimeVivesPiqueres (jaime@ctav.es).

[10]Pueblo Bonito. Copyright photo courtesy of Robert E. Barber, Barber Nature Photography (REBarber@msn.com) .

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