Performance of Reversible Image Watermarking Algorithm using Histogram Shifting under Noisy Conditions

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***Abstract*:** Image transfer leads to addition of unavoidable noise to the watermarked image. Sometimes malicious attacks also introduces noise to the image which replaces parts of the image deliberately by another pieceA method of lossless data hiding in images using integer wavelet transform and histogram shifting for gray scale images is proposed The method shifts part of the histogram, to create space for embedding the watermark information bits. The method embeds watermark while maintaining the visual quality well. The method is completely reversible. The original image and the watermark data can be recovered without any loss if noise is not introduced. Noise interference imparts difficulty in exact retrieval of the embedded watermark and the original image. . Effect of noise while extracting the watermark and reconstructing the original image is studied.

Keywords: Noise, Data Hiding, Histogram shifting, reversible watermarking , attacks ,watermark retrieval.

1. Introduction

The reversible watermarking algorithms are developed from the time it was suggested by its pioneers. Fridrich et al, Jun Tian and Ni et al are pioneers in the field.

Ni et al. [1] proposed an image lossless data hiding algorithm using pairs of zero-points and peak-points, in which the part of an image histogram is shifted to embed data. lossless data embedding algorithm based on the histogram shifting in spatial domain is proposed. J.Fridrich and M. Goljan suggested general methodologies for lossless embedding that can be applied to images as well as any other digital objects. The concept of lossless data embedding can be used as a powerful tool to achieve a variety of necessary tasks, including lossless authentication using fragile watermarks [2].

J. Tian calculates the differences of neighboring pixel values, and selects some difference values for the difference expansion (DE) for reversible data embedding as suitable pairs for data embedding. Pairs which do not affect the algorithm for lossless embedding and extraction are used and is indicated with the help of location map [3].

Xuan et al.[4] proposed the lossless embedding using the integer wavelet transform (IWT) and histogram medication using a threshold point for embedding limit. G. Xuan and Y. Q. Shi proposed a histogram shifting method for image lossless data hiding in integer wavelet transform domain. This algorithm hides data into wavelet coefficients of high frequency subbands. It shifts part of the histogram of high frequency wavelet subbands and embeds data by using the created histogram zero-point [5]. Chrysochos et al's scheme of reversible watermarking presents a method resistant to geometrical attacks [6].

Fallahpour M, Sedaaghi M proposes relocation of zeroes and peaks of the histogram of the image blocks of the original image to embed data in the spatial domain. Image is divided into varying number of blocks as required and the performance is analysed. [7]

Xianting Zenga,Lingdi Ping and Zhuo Li proposed scheme based on the difference histogram shifting to make space for data hiding. Differences of adjacent pixels are calculated by using different scan paths. Due to the fact that the grayscale values of adjacent pixels are close to each other, the various-directional adjacent pixel difference histogram contains a large number of points with equal values; data hiding space is obtained [8].

As a progress to this research domain, effect of noise on images is studied. Noise destroys the ability to retrieve the embedded watermark thereby resulting in loss of valuable information [9]. Various noises are introduced and the effect is examined by varying the intensities of each one of them. Noise removal from images plays a vital role in the success of various applications. These applications include optical character recognition, content-based image retrieval and hand-written recognition systems [10].

The formation causes of speckle noise in the reconstructed image and its characteristics are studied. Some conditions aggravate the speckle noise and is a kind of multiplicative noise in the reconstructed image [11].

2. Integer-To-Integer Wavelet Transforms

In conventional wavelet transform reversibility is not achieved due to the floating point wavelet coefficients we get after transformation. When we take the inverse transform the original pixel values will get altered.

When we transform an image block consisting of integer-valued pixels into wavelet domain using a floating-point wavelet transform and the values of the wavelet coefficients are changed during watermark embedding, the corresponding watermarked image block will not have integer values. When we truncate the floating point values of the pixels, it may result in loss of information and reversibility is lost. The original image cannot be reconstructed from the watermarked image.

In conventional wavelet transform done as a floating-point transform followed by a truncation or rounding it is impossible to represent transform coefficients accurately. Information will be potentially lost through forward and inverse transforms.

In view of the above problems, an invertible integer-to-integer wavelet transform based on lifting is used in the proposed scheme. It maps integers to integers which are preserved in both forward and reverse transforms. There is no loss of information. Wavelet or subband decomposition associated with finite length filters is obtained by a finite number of primal and dual lifting followed by scaling.

3. Wavelet Histogram Shifting

Integer Wavelet transforms of the original image is taken. In the subband wavelet histogram data is to be embedded. In the histogram the horizontal axis(X) represents the wavelet coefficients value and the vertical axis(Y) represents the number of occurrence of the coefficients value. The wavelet histogram normally exhibits a Laplacian distribution nature with a peak point and sloping on either side. Peak in wavelet histogram is usually at coefficient value '0'

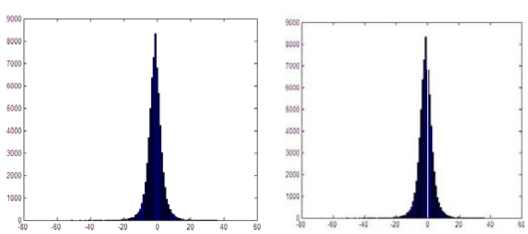
Embedding can be done on both the sides of the histogram to get the required embedding capacity.

Data embedding is done by modifying some of the coefficient values of the wavelet domain to it's neighboring value by shifting a portion of the histogram. This gives a good visual quality and thereby a better PSNR between original image and watermarked image.

To embed data we choose the peak point of the histogram and call it as P. Figure 1 shows a vacant point is created at Peak+1.This is done by shifting all points with value Peak+1 and above one position to the right. Now all the IWT coefficients are scanned and whenever a coefficient with value peak is encountered, '0' is embedded by leaving it as such and '1' is embedded by changing it's value to peak+1.This is repeated till all the points with value Peak are over. Then a new peak is created by shifting to the right and data is embedded as per the algorithm. We choose the peak point so that payload is maximized.

All the high frequency wavelet subbands can be utilized to get maximum capacity. The same process can be done on the left side of the histogram Peak to embed more watermark bits. A reverse algorithm is applied for extracting the watermark data.

After water mark bits are extracted, shifting is done towards the left each time after data extraction so that the original coefficient values are restored. This guarantees complete reversibility and the original image can be exactly reconstructed without loss.



(a) (b)

Figure 1 Illustration of wavelet Histogram, (a) Maximum point is at Peak, (b) Histogram with zero point created at peak +1

4. Proposed Method

4.1 Embedding Method

For the wavelet transformed image sub bands histogram is taken. Now we can start embedding using the following steps. For the selected sub band, set P = Peak of the histogram coefficients.

Create a zero point at P+1 so that no point in the histogram has the value P+1.To create the zero point shift all coefficients with value P+1 and above to one position right. This makes P+1 as P+2, and the original P+2 to P+3 and so on.

1. Now positions P and P+1 are chosen to embed data.
2. Read the n watermark bits W_b where 0<b<n-1.
3. Check W_b =0, then '0' is embedded in the coefficient with value P by leaving it unchanged as P.
4. Check W_b =1, then '1' is embedded in the coefficient with value P by changing it to value P+1.
5. Point P+1 gets slowly filled up depending upon the number of W_b bits with value 1.
6. Go to histogram of the other sub bands to be marked and repeat the same process.
7. While to- be- embedded watermark bits are still remaining, set P=Peak+2 and go to step1.Otherwise stop.

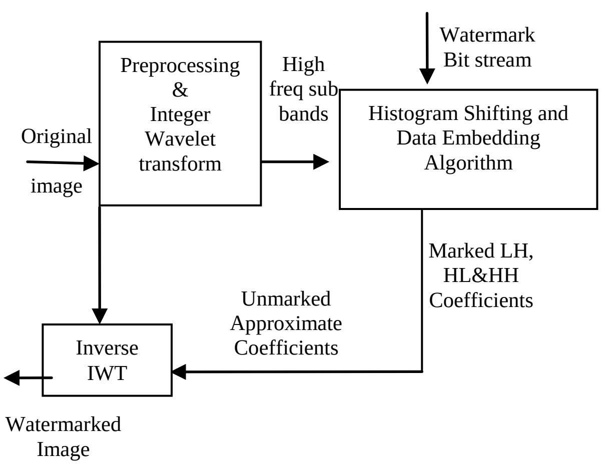


Figure 2 Embedding Method

Figure 2 Shows the original image is decomposed into it's sub bands using integer wavelet transform

After preprocessing IWT is used to ensure complete reversibility. The high frequency sub bands (horizontal, Vertical and Diagonal) are used for data embedding. Each sub band is used one after the other to meet the required embedding capacity. Watermark bits that forms the payload is embedded into these sub bands using the embedding algorithm. The low frequency unmarked approximate coefficients are then used along with the marked sub bands and Inverse IWT is taken to get the watermarked image.

4.2 Extraction Method

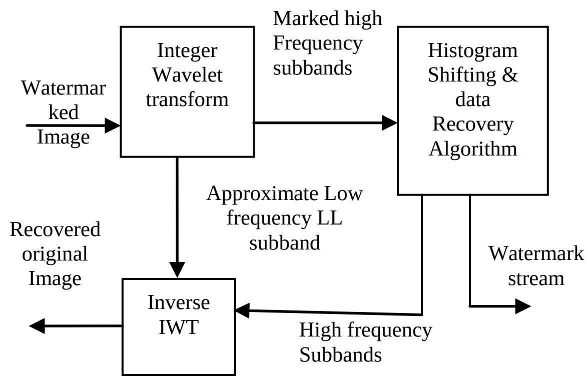


Figure 3 Extraction Method

The extraction method is shown in figure 3. Data extraction is the reverse process. Integer wavelet Transform is taken for the watermarked image. The watermarked high frequency sub bands are separated and using the Data extraction algorithm, the watermark bits are retrieved and the original sub bands are obtained. This is combined with the unmarked low frequency sub band to get the original image. This method is completely blind and reversible. Original image and the watermark data bits are obtained without any loss.

After wavelet decomposition of the watermarked image, histograms of the marked sub bands are taken. For the selected sub band, set Peak= Peak of the histogram coefficients.

1. P=Peak. Read the coefficients with value P and P+1.Whenever a coefficient with value P is read ,extract watermark bit as W_b =0 and leave P unaltered. Whenever a coefficient with value P+1 is read ,extract watermark bit as W_b =1 and change P+1 to P.
2. Shift all the coefficients with value P+2 and above one position to the left.

3. Go to histogram of the other marked sub bands and repeat the same process.
4. Set P = Peak+1.
5. While all watermark bits W_n are not extracted go to step1.Otherwise stop.

5. Image Noise

Image noise is generally regarded as an undesirable by-product during image transfer. These unwanted fluctuations became known as "noise" and they interfere in the extraction of watermark embedded in an image for authentication and security.
Noise is of various types. They are generally distributed in the whole image or part of the image. The types of noise which we have used for testing the algorithm are Salt Pepper noise, Gaussian noise, Speckle noise and Poisson noise.

Another category of disturbance arises due to the fact that part(s) of the image is intentionally altered by replacing it by another part. In this case also the embedded watermark as well as the reconstructed original image get disturbed and are not retrieved exactly as the original one.

5.1 Salt and Pepper Noise

It is a form of noise typically seen on images. It represents itself as randomly occurring white and black pixels. An effective noise reduction method for this type of noise involves the use of a median filter. Salt and pepper noise creeps into images in situations where fast transients, such as faulty switching occur.

In salt and pepper noise, pixels in the image are very different in color or intensity from the surrounding pixels. The defining characteristic is that the value of a noisy pixel bears no relation to the intensity of surrounding pixels. Generally this type of noise will only affect a small number of image pixels. When viewed, the image contains dark and white dots, so it is the termed salt and pepper noise.

5.2 Gaussian Noise

In Gaussian noise, each pixel in the image will be changed from its original value by a small amount. A histogram plot of the amount of distortion of a pixel value against the frequency, with which it occurs, shows a normal distribution of noise. While other distributions are possible, the Gaussian distribution is usually a good model, due to the fact that the sums of different noises tend to approach a Gaussian distribution according to central limit theorem.

The standard model of amplifier noise is additive, Gaussian, independent at each pixel and independent of the signal intensity, caused primarily by Nyquist noise also called thermal noise, including that which comes from the reset noise of capacitors Amplifier noise is a major part of the "read noise" of an image sensor, that is, of the constant noise level in dark areas of the image.

5.3 Speckle Noise

Speckle noise is a granular noise that inherently exists in and degrades the quality of the active synthetic aperture radar (SAR) images.

Speckle noise results from random fluctuations in the return signal from an object that is no bigger than a single image-processing element. It increases the mean grey level of a local area. Speckle noise in SAR is generally more serious, causing difficulties for image interpretation. It is caused by coherent processing of scattered signals received from multiple distributed targets.

Speckle noise in SAR is a multiplicative noise, and it is in direct proportion to the local grey level in any area .The signal and the noises are statistically independent of each other. The sample mean and variance of a single pixel are equal to the mean and variance of the local area surrounding that pixel.

5.4 Poisson Noise

Poisson noise or shot noise is a type of electronic noise. This occurs when number of electrons in an electronic circuit or photons in an optical device, is small enough to give rise to detectable statistical fluctuations in a measurement. It is important in telecommunications and image transmission. This type of noise follows a Poisson distribution, which is usually not very different from Gaussian noise.

In many cases, noise values at different pixels are modeled as being independent and identically distributed and hence uncorrelated.

Tests are conducted for both the cases where noise affects a portion of the image or the whole image. Experiments are conducted by introducing these noises at different amounts and area. Experiments are also conducted by replacing part of watermarked image by one or more icons. Different amount of noise is introduced on each image. The effect on the embedded watermark is studied by extracting the watermark from the noise affected image.

Results show how the embedded watermark gets affected by different noises.

6. Experimental Results and Discussion

6.1 Performance under normal condition

Experiments are conducted using different 512 X 512 gray scale images and different wavelets


(a)


(b)


(c)


(d)


(e)


(f)

Figure 4 Watermarked Image with payload (bpp) 0.4 (a)Sail Boat PSNR 37.05 dB, (b) Woman Dark Hair PSNR 45.03 dB, (c) Camera Man PSNR 48.65 dB, (d) Lena PSNR 37.89 dB, (e) Jet Plane PSNR 42.35 dB, (f) Lake PSNR 36.42 dB

Figure 4 shows image quality tested on different gray scale images after embedding around 1,00,000 bits.

Table 1 shows that cameraman image has a better embedding capacity than other images in the experiment. It also shows it has a better visual quality as far as Peak signal to noise ratio is concerned.

Figure 5 shows image quality tested on cameraman gray scale image after embedding different payload bits.

Figure 6 shows the image quality tested for different images using integer wavelet transform for different payloads using cdf2.2 wavelet .The sailboat image though has higher quality for the same payload compared to Lena image using lower payload, the image quality quickly falls down as payload is increased.

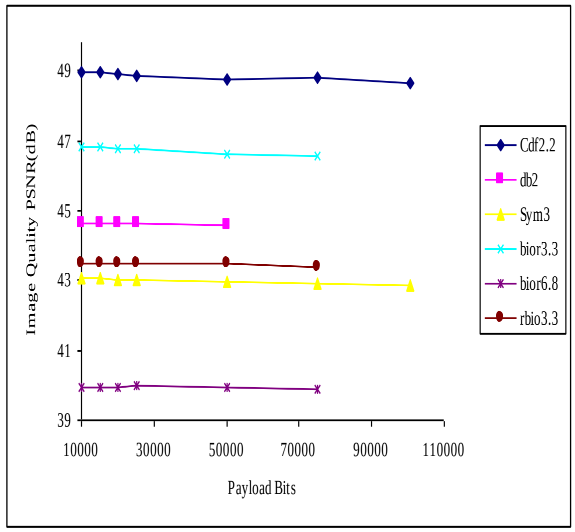


Figure 5 shows image quality tested on cameraman gray scale image for different payload bits.

Table 1 Image Quality Tested for Different Grayscale Images for each payload using Cdf2.2 wavelet

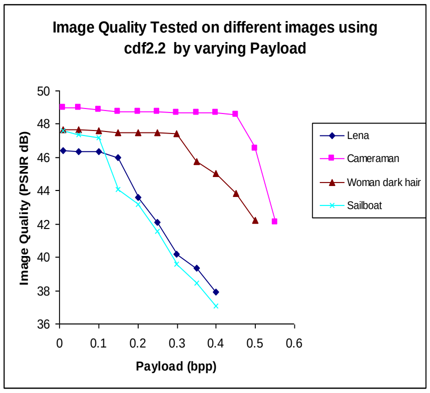


Figure 6 Image Quality Tested on Different Images Using cdf 2.2 by Various Payload (bpp)

Table II Comparison of performance of various wavelet families on Cameramen for different payload size

Payload Bits	cdf2.2 PSNR (dB)	db2 PSNR (dB)	sym3 PSNR (dB)	bior3.3 PSNR (dB)	bior6.8 PSNR (dB)	rbio3.3 PSNR (dB)
10000	48.96	44.63	43.05	46.85	39.93	43.50
15129	48.95	44.62	43.04	46.81	39.93	43.49
20164	48.91	44.61	43.03	46.78	39.93	43.48
25281	48.86	44.60	43.02	46.76	39.99	43.47
50176	48.75	44.56	42.93	46.61	39.94	43.46
75076	48.78	xxx	42.90	46.55	39.86	43.36
100489	48.67	xxx	42.83	xxx	xxx	xxx

Table II shows image quality tested for different payloads on the same image using different wavelets.Cdf2.2.performs better than other wavelets for the same payload. Image quality quickly changes when different wavelets are used. Performance in embedding measured using peak signal to noise ratio shows that bior6.8 has the minimum quality. The embedding capacity also varies when using different wavelets using different wavelets when the image is decomposed using db2 embedding stops in about 50,000 bits whereas cdf2.2 continues to embed over one lakhs bits. The same is illustrated in the graph.

Experiments were conducted on various 512x512 grayscale images to study the performance of various wavelets on the embedding algorithm. For a fixed payload of 25,000 bits embedded and tested, db1 performs best as shown in the table III. Bior6.8 has the minimum quality. A variation of about 10db in Peak signal to noise ratio exists while changing the wavelet family used for decomposing the original image for embedding. Also PSNR between the original image and the watermarked image varies depending on the image when using the same wavelet for decomposition.

Table III Image Quality Tested for Different Grayscale Images for fixed payload of 25000 bits

Wavelets	Lena PSNR (dB)	Cameraman PSNR (dB)	Woman Dark Hair. PSNR (dB)	Sail Boat PSNR (dB)
db1	47.56	48.32	49.37	48.85
cdf2.2	46.34	46.58	48.87	47.59
bior3.3	45.37	45.53	46.75	46.38
sym2	44.62	44.98	44.60	44.83
db3	42.35	42.51	42.14	42.44
sym3	41.12	41.16	43.02	42.51
rbio3.3	41.09	41.32	43.51	42.87
rbio6.8	40.45	40.79	40.48	40.66
bior6.8	39.88	40.40	39.99	40.24

Payload (bpp)	Lena PSNR (dB)	Camera man PSNR (dB)	Woman Dark Hair. PSNR (dB)	Sail Boat PSNR (dB)
0.1	46.3338	48.8519	47.5824	47.2015
0.15	45.9927	48.7678	47.5095	44.0572
0.2	43.6043	48.7591	47.5146	43.1822
0.25	42.1267	48.7421	47.4691	41.5522
0.3	40.1725	48.7014	47.4321	39.5865
0.35	39.3304	48.6990	45.7253	38.4327
0.4	37.8965	48.6552	45.0346	37.0477
0.45	xxx	48.5825	43.8402	xxx
0.5	xxx	46.5234	42.2365	xxx
0.55	xxx	42.1261	xxx	xxx

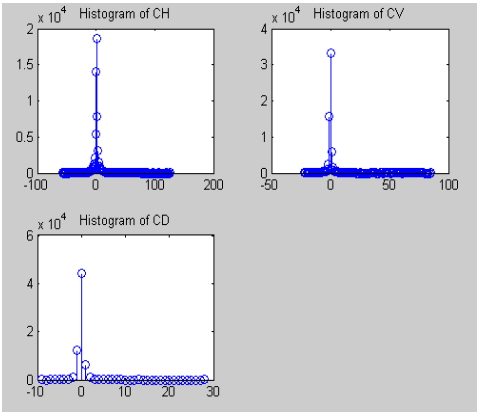


Figure 8 Histogram of Cameraman Image after IWT

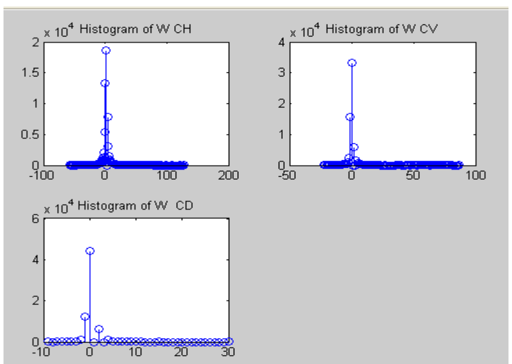


Figure 9 Histogram of Watermarked Cameraman Image

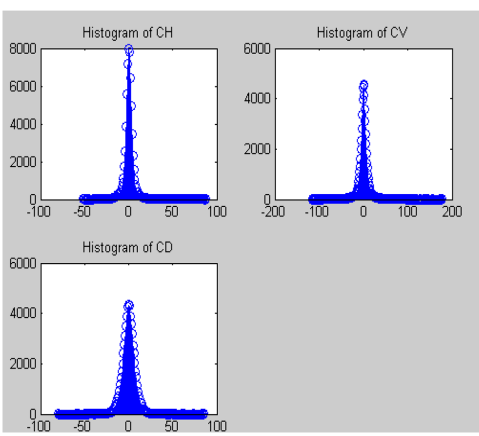


Figure 10 Histogram of Sailboat Image after IWT

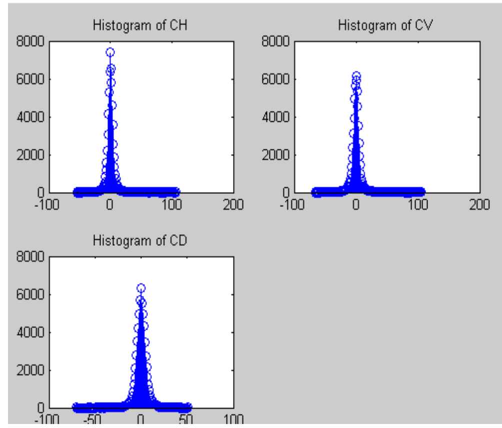


Figure 11 Histogram of Lena Image after IWT

Histogram of wavelet transformed cameraman image shows more number of coefficient values at peak point compared to Lena image and sailboat. This influences the embedding capacity. Cameraman image has higher embedding capacity compared to Lena or sailboat image. This is illustrated in figure 8, 10 and 11. Figure 9 shows the watermarked cameraman image wavelet histogram. This shows the shifted positions of the histogram points due to shifting and embedding.

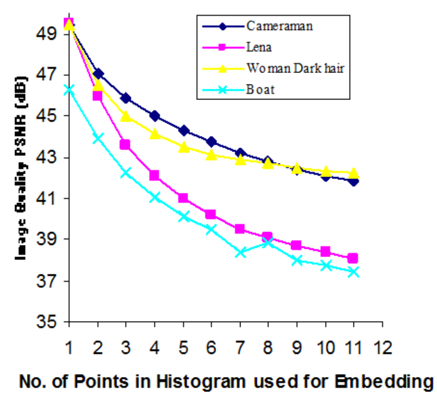


Figure 12 Image Quality Tested by using different number of embedding points in histogram

Image quality is tested using different number of embedding points in histogram to embed the watermark data. Each coefficient value can embed watermark bits equal to the number of occurrence of that point in the wavelet histogram. Figure 12 shows image quality decreases as we use more and more points in the histogram for embedding data. With lesser payload fewer points are used and we get more image quality for the watermarked images.

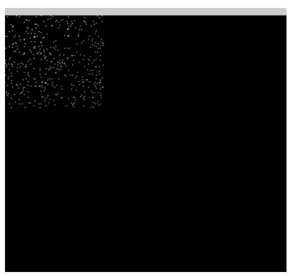
6.2 Performance under Noisy Conditions

6.2.1 Noise affecting part of an Image

a) Embedded Watermark

(b) Recovered Elaine Image showing noise in a corner.

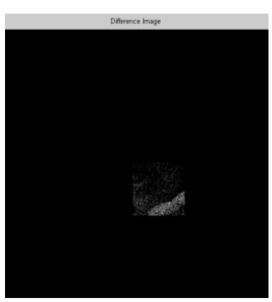
(c)Extracted atermark



(d) Difference Image

Figure 13 10% Salt Pepper Noise in image part

Fig 13 shows salt pepper noise affecting a corner of the Elaine image. The recovered image also shows visual artifacts because of the noise. The extracted watermark is also not retrieved as the original embedded watermark.



(a) Recovered Image (b)Difference Image

d) Embedded Watermarked (c) Extracted Watermark

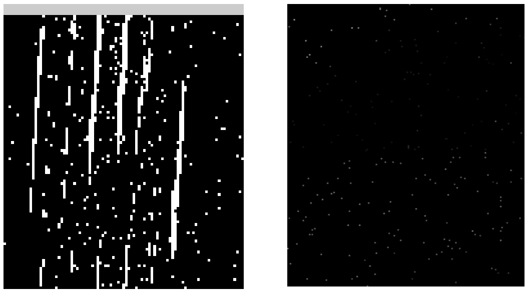
Figure 14 10% Gaussian Noise in image part

Fig 14 illustrates similar effect because of added Gaussian noise in part of the Elaine image

6.2.2 Whole Image

Noise affects either part of the image or the whole image. Fig 15 shows how salt pepper noise throughout the boat image disturbs the recovered image as well as the extracted watermark.

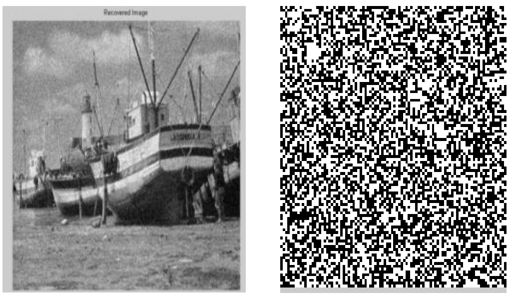
(a) Original image (b)Recovered Image



(c)Extracted Watermark

d) Difference image showing salt pepper noise

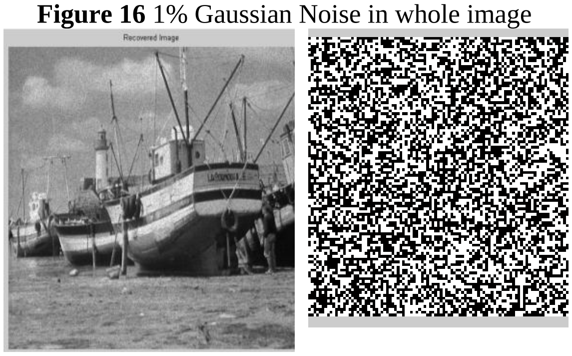
Figure 15 1% Salt Pepper Noise in whole image



(a) Recovered Image

(b) Extracted Watermark

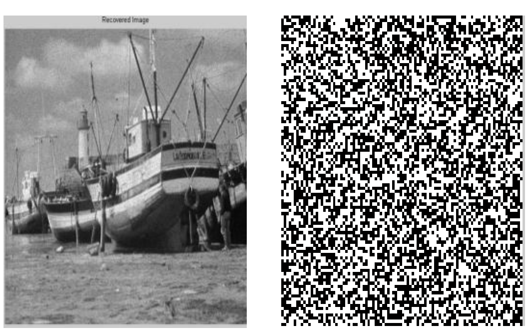
Figure 16 1% Gaussian Noise in whole image



(a) Recovered Image

(b) Extracted Watermark

Figure17 1% Speckle noise in whole image



(a) Recovered Image

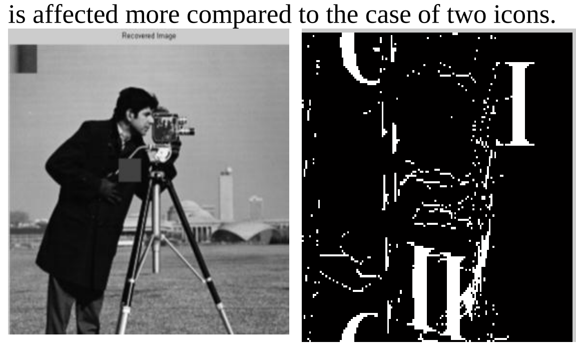
(b)Extracted Watermark

Figure18 1% Poisson noise in whole image

Figure 16-18 shows similar effect caused by Gaussian noise, speckle noise and poisson noise in the whole boat image. The extracted watermark is also distorted.

6.2.3 Image Tampered using Icons

Sometimes part of the watermarked image is replaced intentionally with a different part. This also disturbs the reconstructed original image and the extracted watermark. Fig 19 shows cameraman image tampered in two places .One at the corner of the image and the other near the hand of the cameraman. The reconstructed original image illustrates the same. Fig 20 shows boat image tampered with three icons.The extracted watermark is affected more compared to the case of two icons.



(a) Recovered Image

(b) Extracted Watermark

Figure19 Cameraman Image tampered with two icons

(a) Recovered Image

(b) Extracted Watermark

Figure19 Boat Image tampered with three icons

7. Conclusion

Reversible image watermarking using histogram shifting method was done and tested using different images. Embedding capacity not only varies from image to image, it also varies for various wavelets .The wavelet histogram is used foe embedding as it has a Laplacian like distribution and embedding can be done on both sides of the histogram to embed more data. More image quality is achieved for the same payload compared to other reversible watermarking methods. Images with more number of points on the wavelet histogram peak can embed more data. This is a blind watermarking method. Original image and the embedded data are extracted exactly without any loss because our method is completely reversible if noise is not added to the watermarked image. In the presence of noise the embedded watermark is not exactly recovered. The effect of various noise interference in extracting the watermark and reconstructing the original image is studied.

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Author Biographies

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