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Efficient Reversible Watermarking Using Differential Expansible Integer Wavelet Transform

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ABSTRACT : *Digital watermarking has been utilized widely to claim the ownership and to protect images from alternation. Reversible watermarking is having great importance as it provided original image and the embedded logo without any loss. This paper proposed reversible watermarking algorithm using integer wavelet transform to satisfy the reversibility requirement. Further difference expansion based lifting scheme is used to make algorithm fast. To show the robustness of algorithm, various attacks like noise, rotating/scaling an image and filtering to the watermarked image is employed. The extraction of original image against such attacks is quantified in terms of peak signal to noise ratio (PSNR).*
Keywords: *Differential Expansibility, Image watermarking, Interger to Integer Wavelet Transform,*

I. INTRODUCTION

Although watermarking was implemented long back, the digitization of images has expanded the watermarking concept using signal-processing applications. In digital watermarking, digital watermarks also referred as logos are embedded into digital images in such a way that the logos are invisible to the observer. Thus, it does not cause any degradation in the visual quality of an image. To claim ownership, the embedded logos are detected and extracted from the watermarked image. This paper presents new reversible watermarking based on wavelet lifting scheme. The Algorithm embeds a watermark in a lossless manner and extract it. If the watermark image is modified, it will not restore the exact original image.

II. LITERATURE SURVEYS

For the critical applications, i.e. low enforcement, in medical and military system, the restoration of images by extracting watermark without any distortion is important which is not possible in the conventional watermarking. Therefore, the reversible watermarking also has to satisfy all requirements of the conventional watermarking such as robustness, imperceptibility, and readily embedding and retrieving. Except for these requirements, reversible watermarking has to gratify the three additional requirements: (a) Blind: Some of the conventional watermarking schemes require the help of an original image to retrieve the embedded watermark. However, the reversible watermarking can recover the original image from the watermarked image directly. Therefore, the reversible watermarking is blind, which means the retrieval process does not need the original image. (b) Higher Embedding Capacity: The capable size of embedding information is defined as the embedding capacity. Due to the reversible watermarking schemes having to embed the recovery information and watermark information into the original image, the required embedding capacity of the reversible watermarking schemes is much more than the conventional watermarking schemes. The embedding capacity should not be extremely low to affect the accuracy of the retrieved watermark and the recovered image. (c) Reversibility: The original host image is perfectly recovered after the watermarked image passes the authentication process.

The steps of conventional watermarking and reversible watermarking are shown in figure 3.1. Both are similar except there is an additional function to recover the original image from the suspected image. Therefore, the reversible watermarking is especially suitable for the applications that require high quality images such as medical and military images.

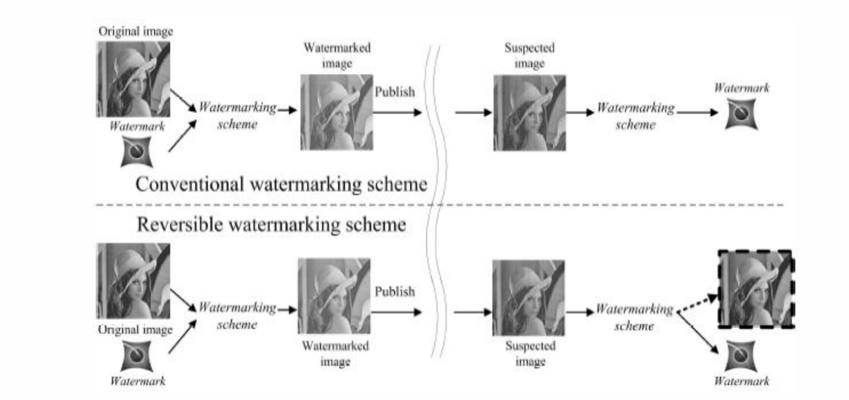

Figure 1 Flowcharts of conventional and reversible watermarking schemes

Medical imaging constitutes an important part of digital medical data. Clearly, the attacks that threaten digital medical information as a whole [1-2] would also apply to medical images. We note that medical practice is very strict with the management of medical data for the clinical, ethical and legislative reasons [3]. Thus in many cases it is often desirable that watermarking itself does not introduce any distortion to the medical images for the purpose of data authentication. Multimedia authentication inherits many characteristics of generic data authentication using cryptographic primitives, such as integrity verification, authenticity verification and non repudiation [4]. Therefore this paper proposes the reversible watermarking algorithm for retrieve images without any losses.

Jun Tian presented wavelet based reversible watermarking algorithm where they utilized binary representation of wavelet coefficients to embed watermark [5]. Similarly a slantlet transform has been used in [6] and coefficients are modified to embed watermark. They tested robustness against JPEG compression. To provide more robustness, after embedding watermark, an encoding method is used and semi blind watermarking algorithm is proposed [7]. However, encoding and decoding algorithm increases computational complexity. Khalid Edris et al [8] proposed the improvement in the algorithm where combination of prediction technology, histogram shifting and sorting technology is used. The limitation is that the method is against the human visual system. Three stages expansion scheme for reversible watermarking is proposed in [9] ti improve the classical two stage reversible watermarking algorithm.

This paper proposed the robust reversible watermarking algorithm, In the proposed method, integer wavelet transform is used to obtain lossless recovery from embedded image. Convolution-based filtering consists in performing a series of dot products between the two filter masks and the extended 1-D signal. This implementation is non-polyphase and suffers from inefficient hardware utility, low throughput and perfect reconstruction is not guaranteed. Therefore lifting based scheme is used which required fewer coefficients and hence low memory. It also enable lossless compression. Further difference based invertible integer wavelet transform is used to provide robustness to the various attacks.

III. BACKGROUND USED IN PROPOSED APPROACH

Initially an image divided into square block. Then a wavelet transform using lifting scheme is calculated over each block.To embed the watermarked image pixel, the expansibility of each wavelet coefficient is checked. Therefore, this section introduced lifting based wavelet transform and criterion to check its expansibility.

(a) Lifting based Wavelet transform: In wavelet transform, a signal to be analyzed is decomposed into low frequency and high frequency for the various numbers of levels. To perform the forward DWT the standard uses a one-dimensional (1-D) sub band decomposition of a 1-D set of samples into low-pass and high-pass samples. Low-pass samples represent a down-sampled, low-resolution version of the original set. High pass samples represent a down-sampled residual version of the original set, needed for the perfect reconstruction of the original set from the low-pass set. The DWT can be irreversible or reversible.

Lifting-based filtering consists of a sequence of very simple filtering operations for which alternately odd sample values of the signal are updated with a weighted sum of even sample values, and even sample values are updated with a weighted sum of odd sample values, as shown in figure 2. To get smooth coefficient, lifting scheme is used. For smooth coefficient division by two is needed. The lossless version of wavelet is calculated as follows.

$$s(x, y) = (e(x, y) + [\,predict \quad (o, x, y)] - v(x, y) / 2 \qquad (1)$$

$$d(x,y) = o(x,y) - [predict\ (s,x,y)] \quad (2)$$

v is either 0 or 1, is chosen such that $(e(x,y) + [predict\ (o,x,y)] - v(x,y)$ is even. The inverse of the transform is

$$e(x,y) = 2s(x,y) - [predict\ (o,x,y)] + v(x,y) \quad (3)$$

$$o(x,y) = d(x,y) + [predict\ (s,x,y)] \quad (4)$$

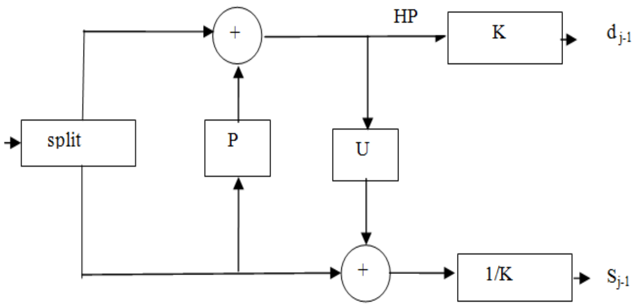

Figure 2 Lifting based filtering Method

Haar wavelet's property like symmetry, orthogonality and compact support, provides lossless data compression. Therefore Haar filter is utilized in thesis to implement the lifting based wavelet transform so that the reversible watermarking can be obtained without any data loss. Of course, this is true when the decompressed image values are not clipped when they fall outside the full dynamic range. Traditional wavelet transform implementations require the whole image to be buffered and the filtering operation to be performed in vertical and horizontal directions. While filtering in the horizontal direction is very simple, filtering in the vertical direction is more cumbersome. Filtering along a row requires one row to be read; filtering along a column requires the whole image to be read. The line-based wavelet transform overcomes this difficulty, providing exactly the same transform coefficients as the traditional wavelet transform implementation. However, the line-based wavelet transform alone does not provide a complete line-based encoding paradigm for JPEG 2000. A complete row-based coder has to take also into account all the subsequent coding stages up to the entropy coding. Below table 1 describe the Haar filter coefficients utilized in lifting scheme.

Table 1 Haar analysis and synthesis filter coefficient

	Analysis Filter coefficient		**Synthesis Filter coefficients**	
I	Low-pass filter	High-pass filter	Low-pass filter	High-pass filter
0	0.5	0.5	0.5	0.5
±1	0.5	-0.5	-0.5	0.5

One of the elegant features of the lifting scheme is that the inverse transform is a mirror of the forward transform. In the case of the Haar transform, additions are substituted for subtractions and subtractions for additions. The merge step replaces the split step.

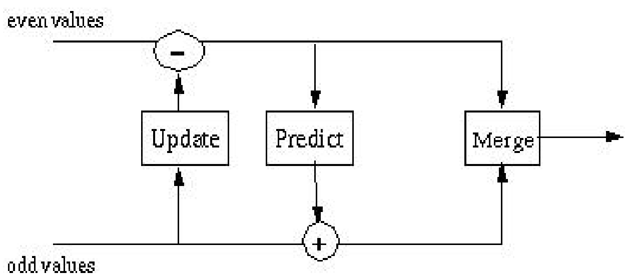

Figure 3 Lifting Scheme based inverse wavelet transform

(b) Integer to Integer Wavelet decomposition: Conventional wavelet transform is not applicable to the re¬versible watermarking scheme since it does not guarantee the re¬versibility. the con¬ventional wavelet transform is, in practice, implemented as a floating-point transform followed by a truncation or rounding since it is impossible to represent transform coefficients in their full accuracy: information can potentially be lost through for¬ward and inverse transforms. To avoid this problem, an invert¬ible integer-to-integer wavelet transform based on lifting is used in the proposed scheme [10].

For example, the integer-to-integer wavelet transform that approxi¬mates Haar wavelet is given by

$$d_k^1 = c_{2k}^0 - c_{2k+1}^0 \tag{5}$$

$$C_k^1 = C_{2k+1}^0 + INT\left({d_k^1}/{2} \right) \tag{6}$$

Here, Int(x) is an arbitrary rounding function, which may have different interpretations. For example, Int(x) can be the integer that is nearest to x;,or Int(x) may be any integer that satisfies x-1<Int(x)≤x ,etc. If all entries in the original signal {ck0} are integer, those in both {ck1} and {dk1} are integers after eq.1. From equation 5 and 6, we can also easily obtain the following integer reconstruction algorithm.

$$C_{2k+1}^0 = C_k^1 - INT\left({d_k^1}/{2} \right) \tag{7}$$

$$c_{2k}^0 = d_k^1 + c_{2k+1}^0 \tag{8}$$

IV. PROPOSED REVERSIBLE WATERMARKING ALGORITHM

The proposed algorithm is described in three parts: (1) Calculation of difference expansion scheme on wavelet coefficients (2) Watermark Embedding process and (3) Watermark extracting process. So the major steps involve for this algorithms are Embedding Process: in which the watermark is embed in a original image such a way that watermark is not visible to the users, Extracting Process: in which the watermark and the original image should be recovered.

(a) Difference expansion scheme: Let l and h are the wavelet coefficients obtained using Haar wavelet transform.

$$l = \left\lfloor \frac{x+y}{2} \right\rfloor, h = x + y \tag{9}$$

Symbol └ ┘ is the floor function meaning "the greatest integer less than or equal to". The inverse transformation of eq. 9 is,

$$x = l + \left\lfloor \frac{h+1}{2} \right\rfloor, y = l - \left\lfloor \frac{h}{2} \right\rfloor \tag{10}$$

As grayscale values are bounded in [0,255], we have

$$0 \le l + \left\lfloor \frac{h+1}{2} \right\rfloor \le 255, 0 \le l - \left\lfloor \frac{h}{2} \right\rfloor \le 255 \tag{11}$$

Which is equivalent to

$$|h| \le \min(2(255 - l), 2l + 1) \tag{12}$$

Then, the process of embedding watermarking using difference expansion is described as follows:

(b) Embedding Process: The block diagram of embedding process is shown below. Assume that the original image is a grayscale image with 256 colors and size of 512X512 pixels.

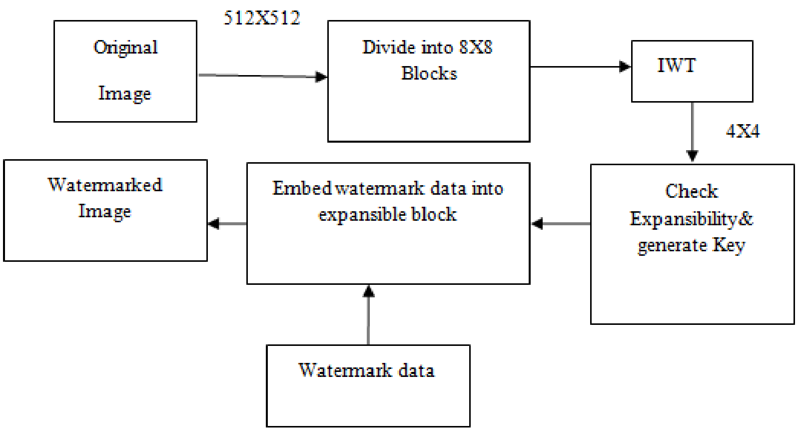

Figure 4 Watermark Embedding Process

Step 1: We first split the original image which is to be watermarked, into many non-overlapping small blocks with 8 X 8 pixels in a scan-line order. For convenience, let us assume that the image has 256 gray levels and 512 X 512 pixels. Thus, we will get 4096 small blocks.
Step 2: for every block, it is decomposed by 1-level IWT (Integer Wavelet Transform), and produces a low frequency sub-band LL1, which is a 4x4 matrix, as shown in Fig. 5

b1			
	b6		
		b11	
			b16

Figure 5 The pixel array graph of the block

Step 3: If the pair of values (b1, b6) and (b1, b16) all are expandable, then we use '1' to stand for the attribute, else '0' is used to represent the attribute. Expansibility is checked as explain in section 4.1.
Step 4: According to expansibility of each block a 4096 bit secret key is generated composed by '0' and '1'.
Step 5: Watermark is embedded in the corresponding block where key is 1. Calculating the average li and difference hi for the ith pair of pixels, denoted as (xi, yi) by using equations 3 for both the pair of pixels of ith block.
Step 6: Calculate $h_i' = 2h_i + w_i$, where is the corresponding bit of watermark.
Step 7: Calculating new ith pair of pixels (xi',yi') after embedding watermark using eq. 12.
Step 8: Repeat the former steps until both pixel pairs of each ith block.
Step 9: Construct new coefficients using new (xi', yi')
Step 10: Find inverse IWT of each block and rearrange 8x8 blocks to get watermark image.

(c) Watermark extraction: The block diagram is shown in fig.6. The steps are given below:
Step 1: The watermarked image is firstly split into 8X8 many non-overlapping small blocks with pixels in a scan-line order.
Step 2: According to secret key, the expansible blocks is decomposed by 1-level wavelet lifting scheme, for pair of pixels (b1,b6) and (b11,b16) of low frequency sub-band LL1, the following procedures are adopted to extract watermarking extraction:
1. Calculate the average and difference of the pair of pixels.

$$l' = \left\lfloor \frac{x' + y'}{2} \right\rfloor, h' = x' - y' \tag{13}$$

2. Extract watermarking:

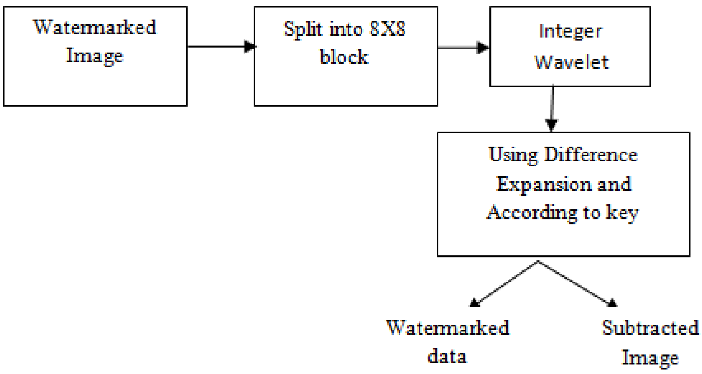

Figure 6 Extraction process of watermarked image

$$w = LSB(h'), h_0 = \left\lfloor \frac{h'}{2} \right\rfloor \tag{14}$$

3. Restore the original pixel values back using eq. 14.

$$x_0 = l' + \left\lfloor \frac{h_0 + 1}{2} \right\rfloor, y_0 = l' - \left\lfloor \frac{h_0}{2} \right\rfloor \tag{15}$$

After the restoring the original pixel finds the inverse IWT to the subtracted image, which is similar to the original image. The result according to this algorithm is shown in fig. 7.

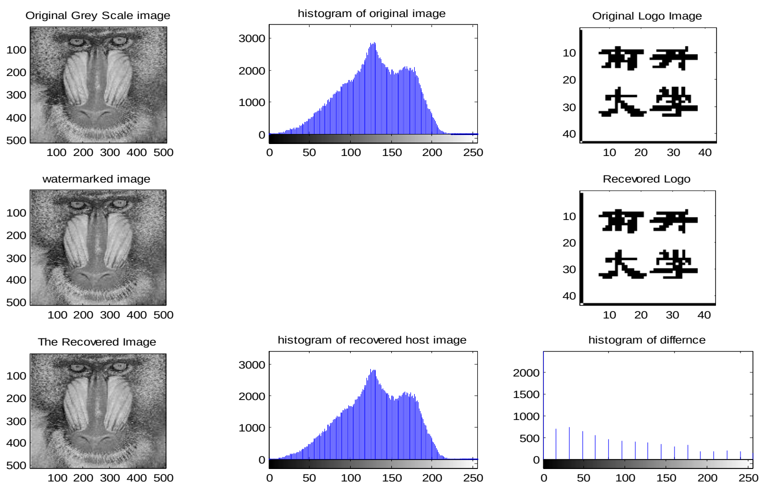

Figure 7 (Left) Original Image, watermarked image and recovered image (Middle) Comparison of Histograms of original and recovered image (Right) Original and recovered watermark image and histogram difference

For the complete reversibility the histogram of original and recovered image should be same i.e. the difference between this two histogram should be null. But from the fig 7 (lower right) we can see that resultant histogram after taking the difference between original image histogram and recovered histogram contains some random datas i.e. we are not getting complete reversibility. The reason for this is that, when it is performed an inverse IWT on the modified wavelet coefficients, this leads to invalidation of reversibility. So, in order to achieve complete reversibility of the algorithm, some measures must be adopted. Here, the method we used is described as follows: In the procedure of confirmation the location of embedding, a restriction is given to the coefficients of sub-band, that is, b1, b6, b11, and b16 should satisfy the condition:
max (b1, b6, ,b11, b16) $\leq \alpha$ and max (b1,b6,b11, b16)$\leq \beta$
Where α and β are pre-defined constants.

V. SIMULATION RESULTS

To verify performance of the proposed algorithm, following image database and parameters are used.
1. Original Images : The propose algorithm is tested on grayscale images having size of 512X512 and 8 bits/pixels like (1) Leena (2) Baboon (3) Barabra (4) Peppers (5) Goldhill

2. Watermark Image: Binary watermark having size of 47X47 as shown below is used in the proposed model.

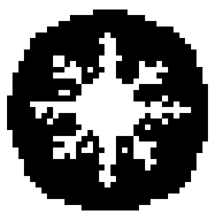

Figure 8 Watermark image used to embed

3. Wavelet Coefficients: As suggested, to obtain perfect reconstruction using integer wavelet transform, the coefficients upper and lower limits are used i.e. α=200, β=90

4. Mean Square Error (MSE): It is measured as the average of square of error introduce. It is defined as,

$$MSE = \left(\frac{\sum_{r=0}^{M-1} \sum_{c=0}^{N-1} \{ I(r,c) - I1(r,c) \}^2}{MN} \right) \quad (16)$$

Where, M x N is size of image. I(r,c) and I1(r,c) denotes row element "r" and column element "c" of Original and Watermarked image.

5. Peak Signal to Noise Ratio (PSNR): It is a ratio of maximum signal power to noise power.
PSNR = 10 log (2552 / MSE) (17)

6. Similarity Factor: It is a form of normalized correlation.

$$SF = \left(\sum_{r=0}^{M-1} \sum_{c=0}^{N-1} f(r,c) * f'(r,c) \Big/ \sum_{r=0}^{M-1} \sum_{c=0}^{N-1} f^{2}(r,c) \right) \quad (18)$$

The proposed scheme is used for the Leena, Baboon, Barbara, Peppers and Gold hill images with 512x512x8 bits and with watermark of 47X47 binary images. The upper bound of coefficient in sub band LL 1 is α=200 and β=90.

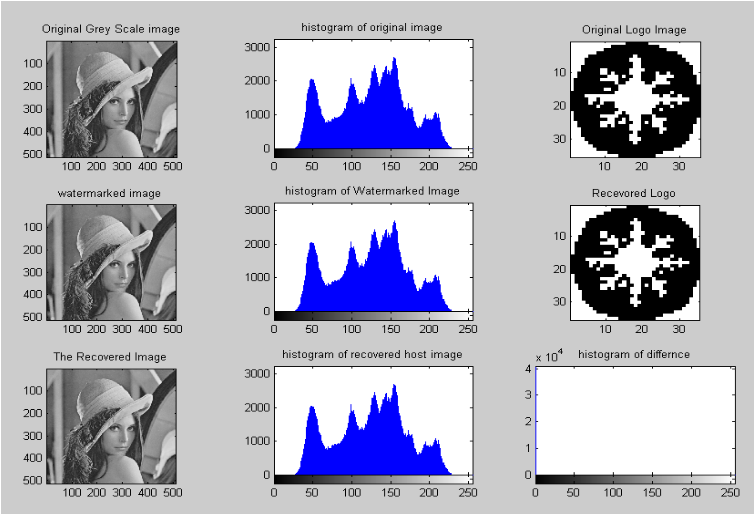

Figure 9 Simulation results for image Lenna.jpg

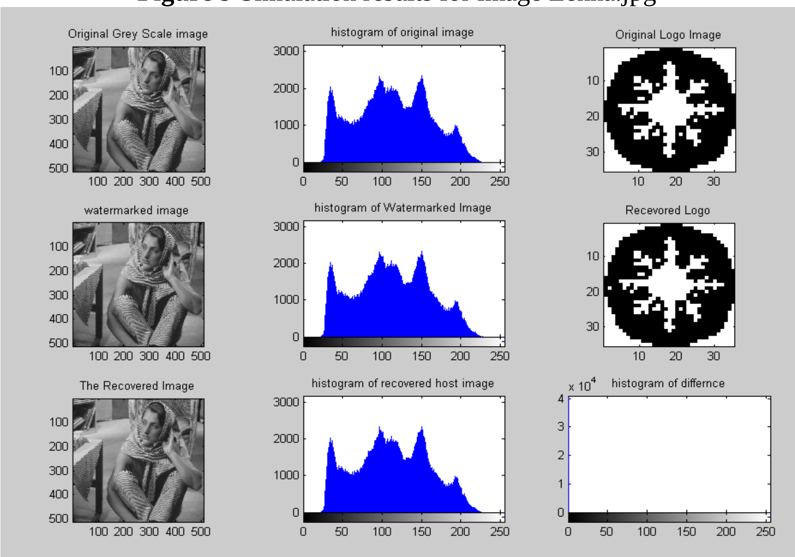

Figure 10 Simulation results for image Barbara.jpg

Table 2: Simulation results against various attacks

Image	MSE	PSNR(dB)	SF
Lenna	0.6924	49.7274	1.000
Baboon	1.2604	47.1255	1.000
Barbara	1.6436	45.9727	1.000
Peppers	0.6043	50.3176	1.000
Gold Hill	1.6830	45.8698	1.000
Images with Gaussian noise			
Leena + Gaussian Noise	0.3261	52.9963	0.950
Babbon + Gaussian Noise	1.2847	47.042	0.982
Barbara + Gaussian Noise	0.5961	50.3771	0.874
Peppers + Gaussian Noise	0.2478	54.1896	0.900

Gold Hill + Gaussian Noise	0.6495	50.0046	0.991
Images with Impulsive noise			
Lenna + Impulsive noise	0.9162	48.5105	0.997
Baboon + Impulsive noise	1.9214	45.2946	0.999
Barbara + Impulsive noise	1.1942	47.3598	0.999
Peppers + Impulsive noies	0.8077	49.0578	0.998
GoldHill + Impulsive noise	1.2561	47.1405	0.999
Image Rotation by 30^o			
Lenna	125.3000	27.1512	0.804
Baboon	121.8767	27.27159	0.813
Barbara	124.7886	27.16905	0.798
Peppers	112.9444	27.60215	0.690
Gold Hill	117.0497	27.44709	0.760
Image Scalling			
Lenna	17.9508	35.5899	0.997
Baboon	52.1365	30.9593	0.982
Barbara	31.6213	33.1310	0.987
Peppers	18.6075	35.4339	0.997
Gold Hill	27.9596	33.6654	0.993

VI. CONCLUSION

In this paper, a new reversible watermarking algorithm is proposed, which use difference based on image wavelet lifting scheme. Sub-band LL1 is used to embed watermark data based on reversible algorithm. Experiments results shows different attacks like Gaussian noise with a zero mean and very low variance, salt and pepper noise of 0.5%, rotating and scaling. In the meantime, if watermarked image is not modified, after extracting watermark, we can restore the image exactly same as the original one, this is especially valuable for some critical applications such as digital watermarking systems in the area of medical and military imaging and remote sensing.

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