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# A Comparative Study of Reversible Watermarking Techniques

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**Abstract**: Reversible watermarking has fetched enormous attention of researchers in its domain in past decade as the need of recovering the original work image after extracting the watermark. There are many researches in this field are done and various techniques are available. So to choose which one is the best technique, a definite need arises to compare those techniques on some parameter like PSNR and others. This paper presents a comparative study of three basic robust techniques, which are Least Significant Bit (LSB), Difference Expansion (DE) and Reversible Contrast Mapping (RCM) technique. This work has been implemented through MATLAB.

**Keywords**: Reversible Watermarking, Difference Expansion (DE), Least Significant Bit (LSB), Reversible Contrast Mapping (RCM), PSNR (Peak Signal to Noise ratio), Processing Time.

## I. INTRODUCTION

The goals of the reversible watermarking are to protect the copyrights and recover the original image. The robustness, imperceptibility, higher embedding capacity, effectiveness, payload capacity, visual quality and the security are the basic criterion of the reversible watermarking. The reversible watermarking is especially suitable for the applications that require high quality images such as medical and military images. Reversible watermarking is also useful in remote sensing, multimedia archive management, law enforcement etc. It is a novel category of watermarking schemes. Reversible watermarking schemes have to be robust against the intentional or the unintentional attacks, and should be imperceptible to avoid the attraction of attacks and value lost. The robustness of the watermarked images against attacks has been verified on the parameters of PSNR (Peak Signal to Noise Ratio) and MSE (Mean Square Error) which show that the resulting quality of combination watermarking method is good than other techniques. Navnath Narawade et.al [3] describes a complete review of reversible watermarking techniques based upon the embedding capacity, PSNR and processing time. Nikhil Dalshania et.al [4] describes a comparative study of reversible watermarking techniques based on different parameters. Hence in previous works, there are various techniques are available for reversible watermarking. The challenge was to find which one is the best method robust to noise. In traditional reversible watermarking techniques, our main concern is to embed and recover the watermark and also restore the original image with minimum distortion. Our attempt here is to study three basic robust techniques and compare them on the basis of PSNR and processing time. The techniques we have studied here are difference expansion, reversible contrast mapping and least significant bit technique.

## II. METHODOLOGY

The main objective of the reversible watermarking technique for encrypted images is that we are able to embed data in encrypted images and then to decrypt the image and to rebuild the original image by removing the hidden data. Here we choose three basic robust techniques for reversible watermarking and compare them on parameter like MSE, PSNR and processing time.

### *A. LEAST SIGNIFICANT BIT (LSB)*

R. Aarthi et.al [5] proposed a modified LSB watermarking for image authentication that satisfies reversibility and improves embedding rate. The LSB scheme is based on pixel values; the process is simple to follow and uses binary values of the image to hide the secret image. The LSB technique works by replacing some of the information in a given pixel with information from the data in the image. While it is possible to embed data into an image on any bit-plane, LSB embedding is performed on the least significant bit(s).

The steps followed in LSB image watermarking are:

1) Select cover image.
2) Select information type for secret data as image or text.
3) Convert image pixels into binary values.
4) Hide the information in the LSB bit of the image using the parameter (standard deviation or mean) that results in high value.
5) Repeat the steps until image or text is hidden in image.

After getting the watermarked image, we need to create a matrix initialized with zeros, whose dimension is equal to the watermarked image. By XOR-ing each and every pixel of both the original and watermarked image, the result will be stored in the corresponding position in the newly created matrix. This matrix will also be sent to the extraction phase along with the watermarked image. During extraction the value of the newly created matrix will be checked. If it is 1, then watermarked image’s LSB of each pixel must be changed, else vice versa.

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Finally we could get back the original cover image. MSE and PSNR are calculated to compare the results with the existing approaches.

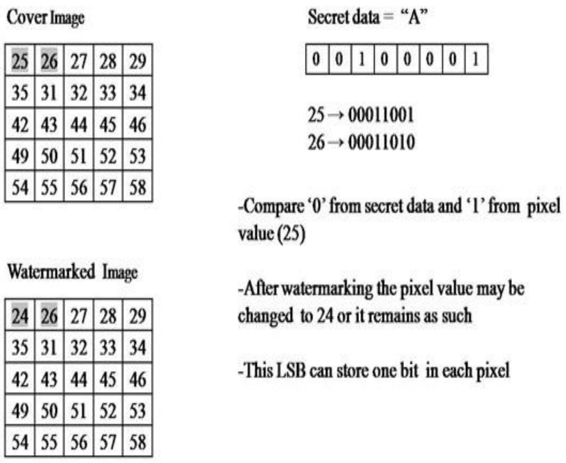


Fig. 2.1: An example of 1-bit LSB

For example, Figure 2.1 shows the 1-bit LSB which can store 1-bit in each pixel. If the cover image size is 256 x 256 pixel image, it can thus store a total amount of 65,536 bits or 8,192 bytes of embedded data

*B. DIFFRENCE EXPANSION*

Jun Tian [6] proposed a reversible data embedding using difference expansion which explores the redundancy in digital images to achieve very high embedding capacity and keep the distortion low. The difference expansion scheme is based on an integer transform defined on groups of two pixels. One bit of information is inserted into each transformed pixel pair, and then the inverse transformed is performed. A location map is necessary to identify the pairs of pixels where information was inserted.

This scheme usually generates some small values to represent the features of the original image. Then, we expand (enlarge) the generated values to embed the bits of watermark information. The watermark information is usually embedded in the LSB parts of the expanded values. Then the watermark image is reconstructed by using the modified values.

The steps are:
1. Take two adjacent pixel values x and y.
2. Find difference and average values of pixels.

$$a = \frac{x+y}{2} \qquad (1)$$

$$d = x - y \qquad (2)$$

3. Then we expand 'd' into its binary form and add watermark bit 'w' right most significant bit to get 'd'.

4. Reconstructed the image using 'a' and 'd', we get the watermarked image.

The similar process is required to be followed for the lossless recovery of the original image and the watermark. MSE and PSNR are calculated to compare the results with the existing approaches.

*C. REVERSIBLE CONRAST MAPPING (RCM)*

Dinu Coltuc et.al [7] proposed a very fast watermarking by reversible contrast mapping (RCM). It provides high data embedding bit-rate at a low mathematical complexity. The RCM scheme is based on a simple integer transform defined on pairs of pixels. RCM is perfectly invertible, even if the least significant bits (LSBs) of the transformed pixels are lost. The data space occupied by the LSBs is suitable for data hiding. The basic RCM watermarking scheme was introduced in which a modified version that allows robustness against cropping is proposed. The control of distortions introduced by the watermarking is investigated as well. The mathematical complexity of the RCM watermarking is further analysed, and a very low cost implementation is proposed.

*Marking*: The marking proceeds as follows:

1) Partition the entire image into pairs of pixels (for instance, on rows, on columns, or on any space filling curve)
2) For each pair
a) If and if it is not composed of odd pixel values, transform the pair using the (1), set the LSB of to "1," and consider the LSB of as available for data embedding.
b) If and if it is composed of odd pixel values, set the LSB of to "0," and consider the LSB of as available for data embedding.
c) If , set the LSB of to "0," and save the true value.

3. Mark the image by simple overwriting the bits of the watermark.
A different marking procedure is used in which a map of transformed pairs and the sequence of LSBs for all non transformed pairs are first collected. Then, the entire image LSB plane is overwritten by the payload and by the collected bit sequences. The slightly modified procedure proposed in this which provides robustness against cropping. The location map of the entire image is replaced by the LSB of the first pixel of each pair showing if the pair was transformed or not. Let us further consider that the saved LSB of a non transformed pair is embedded into the available LSB of the closest transformed pair. Thus, all the information needed to recover any original pixel pair is embedded into the pair itself or very close to it. In the case of cropping, except for the borders where some errors may appear, the original pixels of the cropped image are exactly recovered together with the embedded payload. For pixel pairing on row or column direction, there are no problems of synchronization. Some control codes should be inserted in the payload to validate watermark integrity.

*Detection and Original Recovery*: Watermark extraction and exact recovery of the original image is performed as follows:
1. Partition the entire image into pairs of pixels.
2. For each pair

a) If the LSB is "1," extract the LSB of and store it into the detected watermark sequence, set the LSBs of, to "0," and recover the original pair by inverse transform.


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b) If the LSB of is "0" and the pair with the LSBs set to "1" belongs to , extract the LSB of , store it into the detected watermark sequence, and restore the original pair as with the LSBs set to "1".

c) If the LSB of is "0" and the pair with the LSBs set to "1" does not belong to, the original pair is recovered by replacing the LSB of with the corresponding true value extracted from the watermark sequence. MSE and PSNR are calculated to compare the results with the existing approaches.

*D. PSNR and MSE*

The simplest, oldest and most widely used technique to quantify image/video signal quality is the mean squared error (MSE). Mathematically it is defined as:

$$\text{MSE} = \frac{1}{\text{MN}} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (u - v)^2$$

Where, two images u and v having size M×N, one of them is the noisy (watermarked) approximation of the other (original) one.

*Peak-signal-to noise-ratio (PSNR)* is used to quantify the visual distortion made by watermarking process as well as different attack operations. The PSNR is a popular index term to evaluate the difference between the pre-processing image and the post-processing image. Mathematically for an 8 bit gray scale image it is defined as:

$$\text{PSNR} = 10 \log_{10} \left( \frac{255^2}{\text{MSE}} \right)$$

Where: 255 is the maximum possible pixel of the image. Here for 8 bit image, it is 255. A larger value of PSNR (in dB) means that the watermarked image has a better quality.

## III. RESULT

The best technique should have low MSE, high PSNR and very low processing time. We have compared all the above techniques based on MSE, PSNR and processing time. The results are shown below.

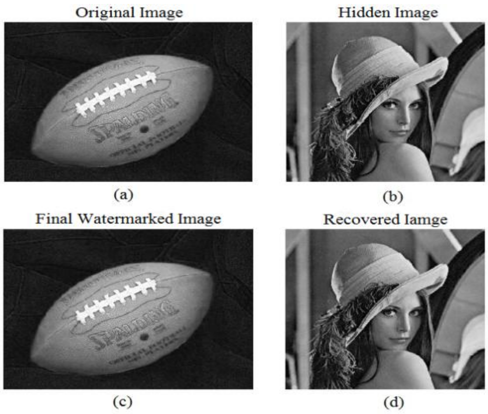


Fig. 3.1(a-d): Least Significant Bit (LSB) method

The LSB method is based on pixel value modification and is simple to understand, easy to implement and results in stegno images that contain hidden data yet appear to be of high visual fidelity. It results high PSNR (for 1st bit or LSB bit position) which helps the data from loss. It leads to MSE (Mean square error) which helps the images from degradation.

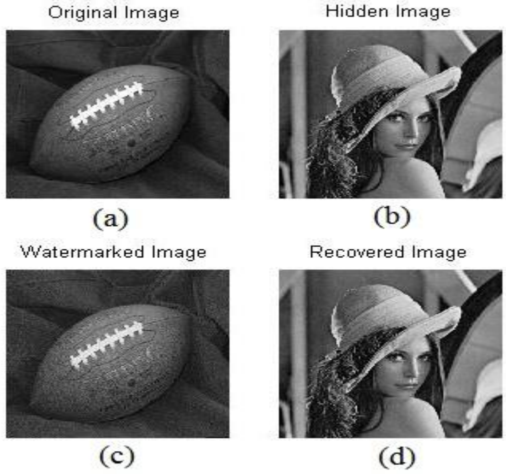


Fig. 3.2(a-d): Difference Expansion (DE) method

The DE method has moderate MSE and PSNR because most of the bits available for embedding are used for saving header information and location map. This method is also weak in robustness and processing time because the destroyed location map will cause mismatching.

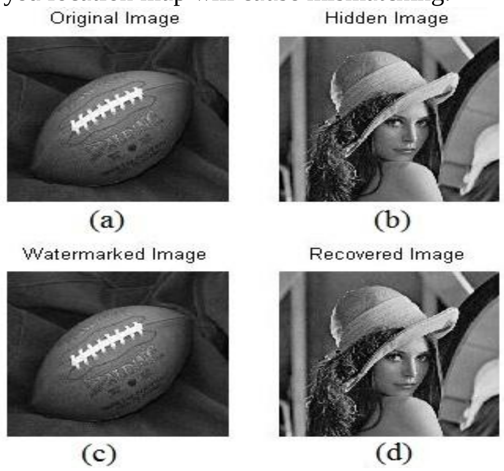


Fig. 3.3(a-d): Reversible Contrast Mapping (RCM)

The RCM method works on pairs of pixels. It's PSNR, processing time and complexity is considerably low. It provides robustness against cropping.

| Method | MSE | PSNR | Processing Time |
|---|---|---|---|
| LSB | 0.50 | 51.12 | Very low |
| DE | 42.46 | 32.69 | High |
| RCM | 4756.61 | 10.64 | Low |

Table 3.1: Comparative table of techniques

The result shows that the LSB method has low MSE which helps the image from degradation and high PSNR which helps the data from loss. Its processing time is also


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very low as compare to other two techniques. Hence we can say that it is the best and simple technique.

## IV. CONCLUSION AND FUTURE SCOPE

In this paper we have introduced three basic techniques for reversible watermarking of digital images, as well as touching on the limitations and possibilities of each. The three types are analysed and compared based on MSE, PSNR and processing time and the result shows that the LSB method is the best and simple technique as compared to the other two techniques because the higher the PSNR, the better the quality of the compressed or reconstructed image is obtained. For the future, we will try to improve these methods by increasing the payload, visual quality and security. To overcome various limitations of existing techniques we will be considering the human visual system (HVS) while embedding the secret information and try to increase the PSNR as high as possible.

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