Improved Histogram Bin Shifting based Reversible Watermarking

Pasunuri Nagarju, Ruchira Naskar and Rajat Subhra Chakraborty

Dept. of Computer Science and Engineering
Indian Institute of Technology Kharagpur
Kharagpur, West Bengal, India – 721302
E-mail: rschakraborty@cse.iitkgp.ernet.in

***Abstract*—*Reversible watermarking* constitutes a class of fragile digital watermarking techniques that find application in authentication of medical and military imagery. Reversible watermarking techniques ensure that after watermark extraction, the original cover image can be recovered from the watermarked image pixel-by-pixel. In this paper, we propose a novel reversible watermarking technique as an improved modification of the existing *histogram bin shifting* technique. We develop an optimal selection scheme for the "embedding point" (grayscale value of the pixels hosting the watermark), and take advantage of multiple *zero frequency pixel values* (if available) in the given image to embed the watermark. Experimental results for a set of images show that the adoption of these techniques improves the peak signal-to-noise ratio (PSNR) of the watermarked image compared to previously proposed histogram bin shifting techniques.**

***Keywords*—digital image watermarking, histogram bin shifting, reversible watermarking.**

I. INTRODUCTION

Digital watermarking is a way of embedding information (i.e., watermark) in multimedia data (image, audio or video), such that the embedded watermark can be later retrieved from the watermarked data for the purpose of content protection or authentication. In this work we concentrate on grayscale image watermarking. Reversible watermarking is a special kind of digital watermarking which enables exact retrieval of the original image (termed the "cover image") from the watermarked image along with embedded watermark. These reversible watermarking algorithms find applications in many domains where distortion-free recovery of the original image after the watermark extraction is of utmost importance, e.g. in medical, legal and military applications.

Several classes of reversible watermarking techniques have been proposed previously [1–7]. Among these, *histogram bin shifting* constitute a class of techniques which are simple to implement but very effective. The common feature of the different variants of the basic technique is to take advantage of a pixel value for which there are no corresponding pixels in the image. For example, in a 8–bit grayscale image, with the pixel values being unsigned integers in the range [0,255], often there is no pixel with the grayscale value 255. Such a pixel value is often termed a *zero point*.

There are several advantages of the histogram bin shifting technique, perhaps the most significant among them being that there is no need to store the *location map*, a piece of additional information needed to retrieve the original image, if the image has at least one zero point. The distortion characteristics (PSNR vs. embedded watermark size) of the watermarked image is superior compared to many of the existing reversible watermarking techniques. Additionally, the computational overhead of the algorithm is less compared to most proposed reversible watermarking techniques.

However, there are a few disadvantages of the histogram bin shifting based schemes, namely, the embedding capacity is less compared to most other reversible watermarking technique; the PSNR is almost independent of watermark length; and the proposed variants do not take the advantage of having multiple zero points in the given image to increase the PSNR ratio. These are the shortcomings that we strive to overcome in this work, through the adoption of the following techniques:

- In previously proposed variants of the histogram bin shifting based technique, the pixels with the most common grayscale value ("peak point") determined the pixels that are to be used to embed the watermark. In contrast, we select the embedding point not to be always the peak point, but a variable point capable of accommodating the given watermark, and minimum pixel count away from the zero point. This reduces the number of pixels to be shifted to embed the watermark, so that the distortion of the watermarked image with respect to the original image is less. This improves the PSNR for a given watermark.
- We choose the optimal zero point if multiple zero points are present in the image to further enhance the distortion characteristics of the image.

The rest of the paper is organized as follows. In Section II, we provide an overview of the general histogram bin shifting technique through a description of the technique proposed in [2]. In Section III, we describe our proposed scheme in detail. We present experimental results in Section IV and comparison of our proposed scheme with the original histogram bin shifting based scheme of [2]. Finally, we conclude in Section V.

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II. BACKGROUND

A. Watermark Embedding Procedure

For a given (grayscale) image, a histogram to represent the number of pixels for each pixel value in the range [0,255] is constructed. Consider a histogram as shown in Fig. 1(a). From the histogram, the zero point (pixel value whose frequency is zero) is $b = 7$ and peak point (pixel value whose frequency is maximum) is $a = 2$. Then all the pixels between peak point $a = 2$ and zero point $b = 7$ are shifted by one position towards zero point as shown in Fig. 1(b). So, the modified frequency of pixel value 3 will be zero and this used for embedding the watermark. If in a given image there is no zero point, the pixel value with the lowest frequency is chosen as the zero point.

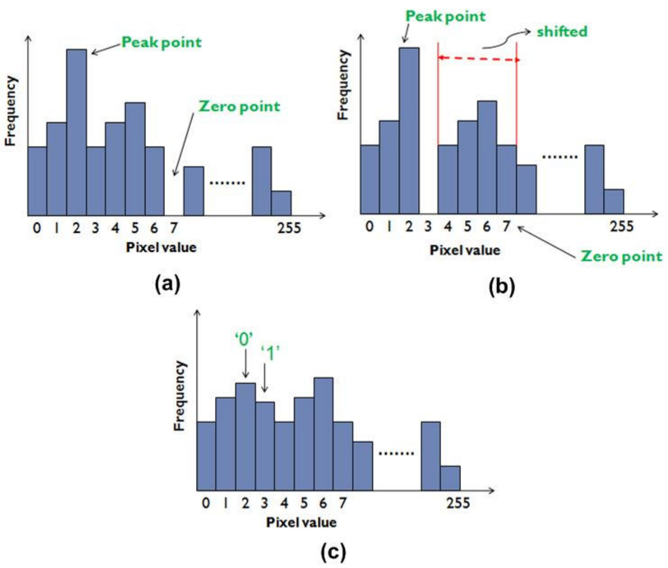

Fig. 1. Histogram bin shifting proposed by Ni. et. al [2]. (a) Histogram before shifting with peak point = 2 and zero point = 7; (b) Histogram after shifting the pixels; (c) histogram after watermark embedding.

Consider all pixels of the cover image with value equal to the peak point value. If '1' is the watermark bit to be inserted, then the pixel value is incremented or decremented depending on the relative position of the zero point. The pixel value is incremented if the zero point lies to right side of the peak point in the frequency histogram, and decremented if the zero point lies to left side of peak point. On the other hand, if the watermark bit to be embedded is '0', then the pixel value is left unchanged. In the given example, whenever pixel value 2 is encountered and if '1' is the watermark bit to be embedded, then the pixel value is incremented by 1. Otherwise, if '0' is the watermark bit to be embedded, the pixel value (i.e., 2) is unchanged. For the given example, the histogram after watermark insertion is shown in Fig. 1(c).

B. Watermark Extraction Procedure

During extraction, each pixel (e.g., pixel value = x) of the watermarked image is considered in same order as the embedding process. If the zero point lies to right side of peak point and x is equal to $a + 1$ (where a is the peak point), then x is decremented by 1. On the other hand, if the zero point lies in left side of peak point and x is equal to $(a - 1)$, x is incremented by 1. In effect, if $x \in (a,b]$ (where b is the zero point) and if the zero point lies to right side of peak point, then x is decremented; if $x \in [b,a)$ and if the zero point lies to left side of peak point, then x is incremented. Thus, for the example given in Fig. 1, whenever a pixel with grayscale value 3 is encountered, the retrieved watermark bit is inferred to be '1', and if a pixel with grayscale value 2 is encountered retrieved watermarked bit is inferred to be '0'. And if a pixel with grayscale value $\in$ (3,7] is encountered, then the pixel value is decremented.

III. PROPOSED SCHEME

In this section, we describe the proposed technique.

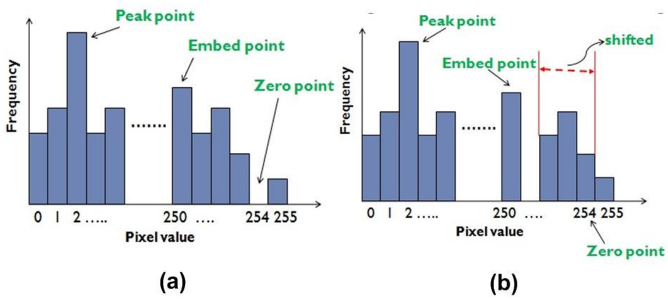

Fig. 2. Example of histogram before and after shifting the pixels in our proposed scheme: (a) Histogram before shifting with peak point = 2, embed point = 250 and zero point = 254; (b) Histogram after shifting the pixels.

A. Proposed Watermark Embedding Procedure

From the previous discussion, it should be evident that in existing histogram bin shifting algorithms, the distortion of the watermarked image with respect to the original image depends on the number of pixels between the peak point and zero point of the image [2]. Here, the peak point acts as the "embed point", i.e. the pixel value used to embed the watermark. Hence, it should be possible to reduce the distortion by reducing the number of pixels between the embed point and the zero point by choosing an appropriate embed point. In our proposed scheme, from the obtained histogram we find the zero point. Then, we choose a pixel value as the embed point (not necessarily the peak point) such that its frequency is greater than or equal to the watermark size (i.e., number of bits in the watermark to be embedded), and additionally, the number of pixels between the chosen pixel value and zero point must be minimum. If there is no zero point in the given image, then the grayscale value which corresponds to the minimum number of pixels is chosen as the zero point, as in the case of existing histogram bin shifting schemes.

After obtaining the embed point and the zero point, the embedding procedure is same as that of existing histogram bin shifting techniques. All the pixels between the embed point and the zero point are shifted by one position towards the zero point and the watermark bits are inserted into the image as described in Section II.A. Note that with the increase of watermark size, the peak point itself may be the chosen as the embed point.

Consider an example as shown in Fig. 2. Here, if we choose the peak point (i.e., grayscale value 2) to embed the watermark, the number of pixels needed to be shifted will be more; however, if we choose an appropriate embed point as shown, the number of pixels needed to be shifted will be less, and thus improving the PSNR. Using Multiple Zero Points

The distortion can be reduced further by choosing the optimal zero point, if multiple zero points are present in a given image. For each zero point, we find the corresponding embed point. Then, provided the embed point frequency is sufficient to host the watermark, for each pair of embed point and zero point we calculate the number of pixels between them. We choose a pair (embed point and zero point) which has minimum number of pixels between them among all the pairs. This ultimately decreases the distortion of the watermarked image with respect to the original image.

B. Proposed Watermark Extraction Procedure

The watermark extraction is same as that of original histogram bin shifting [2] as described in Section II B, the only difference being that in our proposed scheme instead of the peak point, the embed point is used for extracting watermark. In the given example in Fig. 2(a), whenever a pixel with grayscale value 251 is encountered, the retrieved watermarked bit is inferred to be ‘1’, and if a pixel with grayscale value 250 is encountered then the retrieved watermarked bit is inferred to be ‘0’. If a pixel with grayscale value ∈ (250,254] is encountered, then the pixel value is decremented.

IV. RESULTS

The proposed scheme was implemented in MATLAB. To test the performance of the proposed scheme, we applied it to standard image processing test images, shown in Fig. 3. The performance was measured in terms of distortion (PSNR, in dB) of the cover image vs. the watermark embedding rate expressed in bits-per-pixel (bpp). We have also compared the performance of our scheme with that of the existing histogram bin shifting technique [2]. The comparison results have been shown in Fig. 4. Fig. 4 shows that for lower bpp values, the PSNR obtained by our scheme is higher compared to the existing histogram bin shifting [2]; but as the watermark size increases the PSNR obtained by the two schemes converge. However, even at higher bpp values, for all the test images, our scheme was never inferior to the scheme proposed in [2].

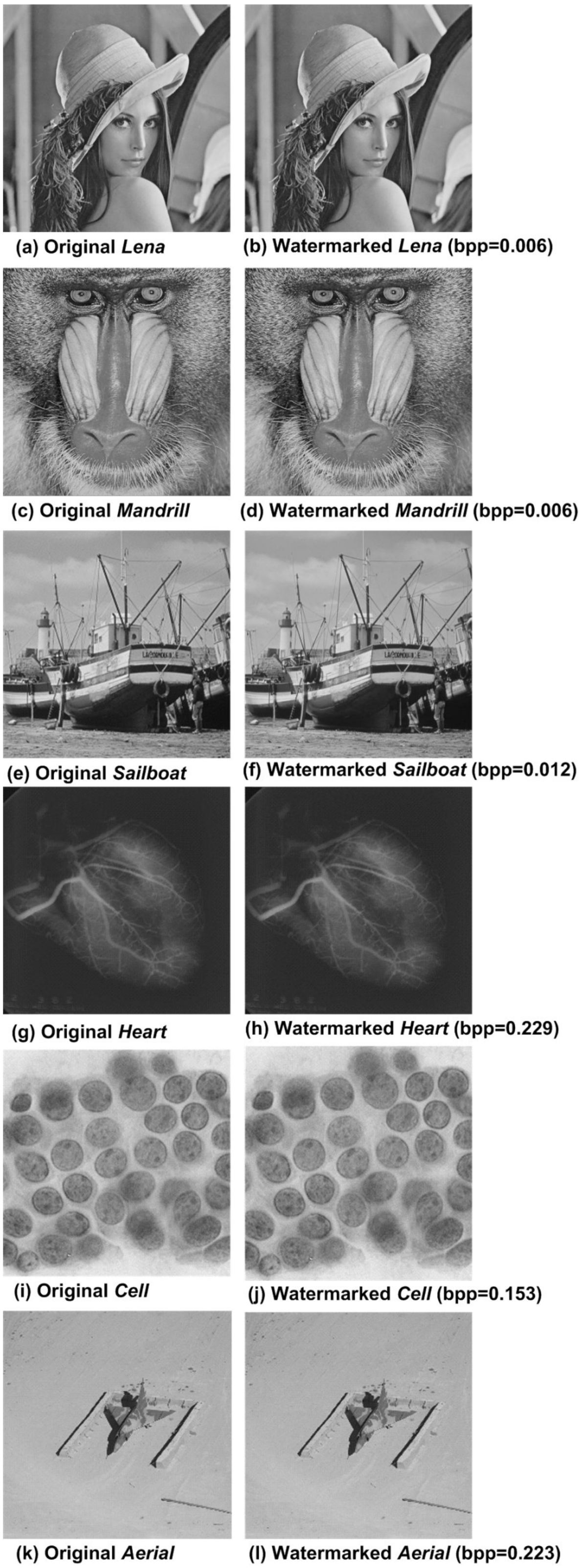

Fig. 3. Original and watermarked for 512X512 images for different watermark sizes in bits-per-pixel (bpp).

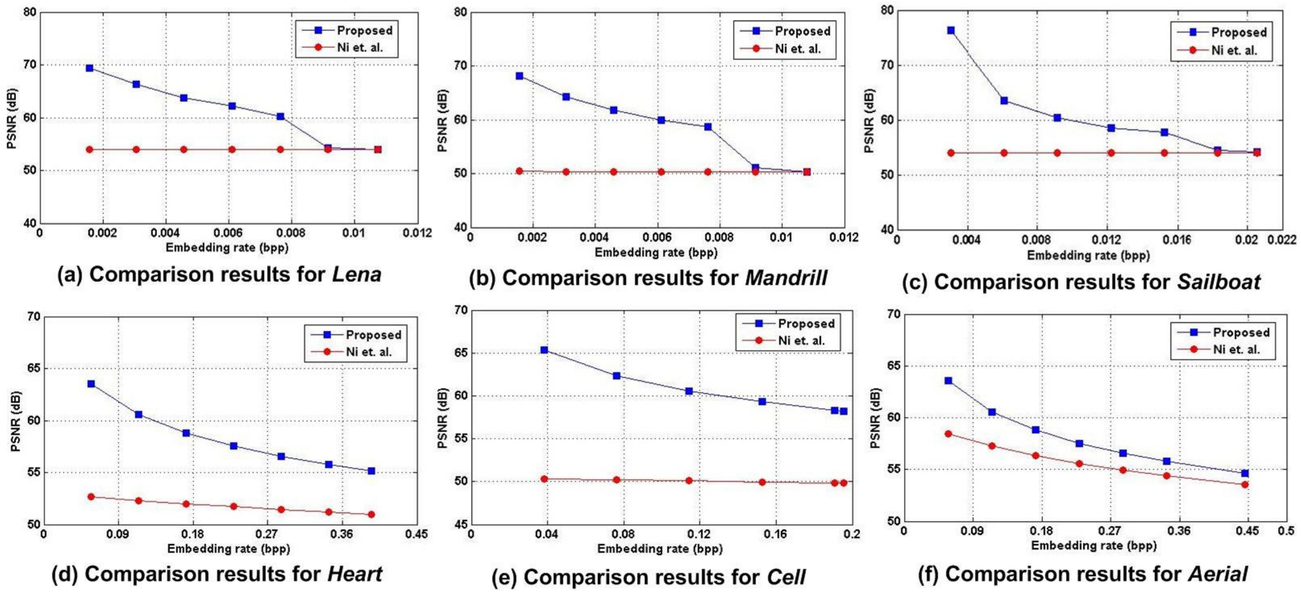

Fig. 4. Capacity vs. distortion characteristics comparison results for six different images.

V. CONCLUSION

Histogram bin shifting is a reversible watermarking technique, well–known for its computational simplicity. In this paper, we have proposed an improved histogram bin shifting technique to minimize the cover image distortion, depending on the size of the watermark embedded. The improvement is brought about in the proposed scheme by optimal embedding point selection in the cover image frequency histogram. We also take advantage of multiple zero points (if present) in an image. This process considerably reduces the number of pixels to be shifted while embedding the watermark. These enhancements considerably reduce the cover image distortion, as shown by our experimental results.

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