Journal of Information Hiding and Multimedia Signal Processing ©2015 ISSN 2073-4212
Ubiquitous International Volume **6**, Number **4**, July **2015**

Hybrid Color Image Steganography Method Used for Copyright Protection and Content Authentication

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Received September, 2014; revised March, 2015

Abstract. *In this paper, we proposed a hybrid image data hiding method used for watermarking applications in order to make sure the hidden dual watermarks survive after the image manipulation and enhancement processes. To achieve this goal, the proposed method is divided into two phases. In the first phase, the YCbCr color space is exploited, and, then, LSB techniques are used to embed the first level watermark bits in the YCbCr channel. In the second phase, the modification direction method is used to embed the second level watermark bits in the RGB channel. The experimental results confirmed that the proposed method resists most geometric attacks more effectively than Lusson et al.'s method. Therefore, the method is suitable for protecting the ownership of images and integrity of the potential tampered images.*

Keywords: Watermark, Steganography, Exploiting modification direction (EMD), Information hiding

1. **Introduction.** Image watermarking is a process of embedding information in images to protect the ownership of the images [1, 2, 3, 4], and steganography hides information into the image in an indiscernible way to transmit confidential data via cover media [5, 6]. Many watermarking methods have been proposed in the last decade with the aim of either proving image ownership or image content authentication.

In general, multi-purpose image watermarking applications can be realized. For example, we want to confirm the copyright of an image by using robust watermarking methods or to authenticate the integrity of an image's content by using fragile or semifragile watermarking methods. In the past ten years, there are many literatures that have discussed how to design hybrid watermarking methods to achieve dual purposes and enhance the robustness of the hidden watermark [7, 8, 9, 10, 11, 12]. A general solution to meet the above goals is to design hybrid strategies that embed two distinct watermarks into the host image.

In 2003, Shih and Wu [13] presented a watermark technique by combining the spatial and frequency domains to embed two distinct invisible watermarks into a host image to resist attacks. The dual watermarks are overlapped in a watermarked image. To embed the second-level watermark, pixel values which embedded former watermark bits are modified. Therefore, designing a dual watermarking method that reduces the distortion of the former hidden watermark and also resists malicious attacks is still under investigation. Moreover, many data hiding methods also focus on achieving reversible protection [14, 15, 16, 17]. Reversible data hiding methods can regain the original image after legal users remove the hidden data. In the dual watermarking method with the reversibility feature, if the later embedded watermark is legally removed, the former embedded watermark can be obtained easily. However, this leads to a shortcoming when the later embedded watermark is legally moved in that the image is protected only by a single watermark. Thus, it is urgent and necessary to design a hybrid image steganography method in which two embedded watermarks cannot be separately removed without affecting each other.

Some literatures [18, 19] have extended the hybrid watermarking method from grayscale images to color images. A model of a color image is an abstract mathematical model that describes the ways in which colors can be represented. Generally, an original image from RGB color space with three vectors (R, G, B) can be converted into YCbCr color space with the vectors (Y, Cb, Cr). In this paper, we utilized the relationship of changes from (R, G, B) vectors to (Y, Cb, Cr) vectors to embed our first watermark. Based on preprocessing, we designed a hybrid color image steganography method for YCbCr color images. First, a copyright watermark was embedded into the YCbCr color space of a host image. Then, a fragile watermark was embedded into the RGB color space of the same host image. The later watermark will not decrease the former watermark's quality significantly. Moreover, the hidden fragile watermark can be used to detect the tampered positions

The rest of the paper is organized as follows. Section 2 briefly introduces and discusses the Exploiting Modification Direction (EMD) method. In Section 3, our hybrid color image steganography method is described in detail. Experimental results are reported in Section 4. Finally, conclusions are presented in Section 5.

2. **Preliminaries.**

2.1. **Exploiting Modification Direction (EMD) Method.**

Zhang and Wang [20] proposed an exploiting modification direction method (EMD) in which only one grayscale value of each pixel in a pixel pair is modified when embedding a 5-ary secret number into a cover pixel pair. Their EMD method has the advantages of large hiding capacity, low image quality distortion and less execution time. Here, we describe the EMD embedding and extracting procedure, because the EMD method is used to embed the second watermark bits in our proposed method.

In the EMD embedding procedure, the secret message is converted into a base-$(2n+1)$ numeral system before embedding the messages. The f function used in the embedding and extraction phases is defined as below:

$$f(p_1, p_2, ..., p_n) = \left[\sum_{i=1}^{n} p_i \times i\right] \bmod (2n+1) \tag{1}$$

where mod is the module operator, $p_1, p_2, ..., p_n$ are n pixels in the cover image, and p_i is the i^{th} pixel in the cover image.

Fig. 1 shows the embedding flowchart of the EMD method. The secret digital message d is a base-$(2n+1)$ number, which will be embedded into $(p_1, p_2, ..., p_n)$. If $d = f(p_1, p_2, ..., p_n)$ the cover image pixels $(p_1, p_2, ..., p_n)$ aren't changed to embed d; otherwise, $(p_1, p_2, ..., p_n)$ should be modified to at most one gray scale of each pixel to embed secret digital message d.

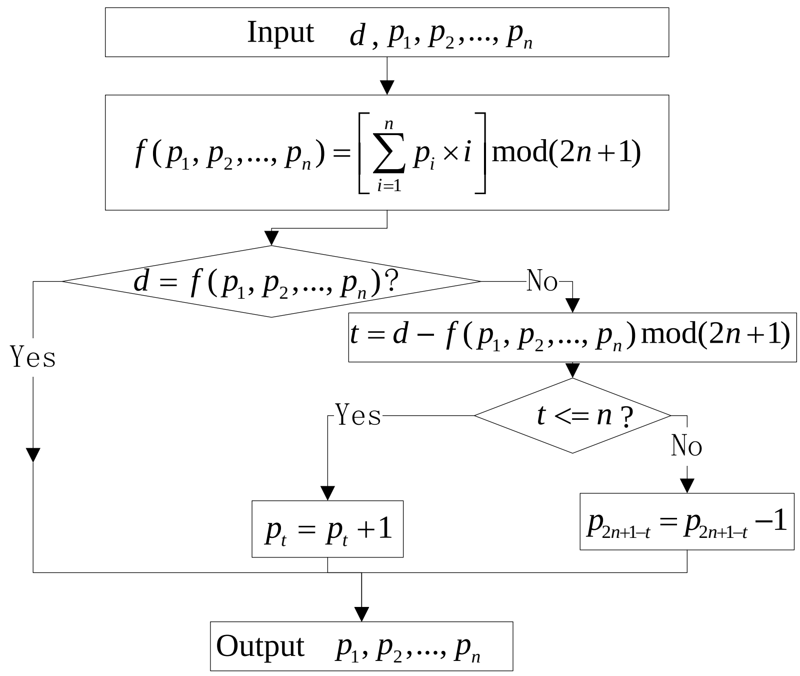


FIGURE 1. Flowchart of the embedding procedure in the EMD method

In the EMD extracting procedure, Equation (1) is used to easily extract the secret digital message. When the secret digits are extracted completely, they are concatenated and form the base-$(2n+1)$ numeral sequence of secret digits. Lastly these digits can be converted into the original binary secret message.

3. **The proposed method.**

In this section, the details of the embedding and extracting procedures of the proposed method are described.

3.1. **Embedding procedure.**

In this subsection, we introduce the details of the embedding procedure, which can be divided into two phases, i.e., the YCbCr color space watermark embedding phase and the RGB color space EMD watermark embedding phase. Fig. 2 shows the flowchart of our proposed two-level watermark embedding method.

The first level watermark is embedded into the YCbCr color space. We use a binary image on the behalf of copyright as the first level watermark and its size is smaller than the original image. For example, if the size of the original image were 512×512, the size of the first level watermark would be 64×64 The second level watermark is embedded into the RGB color space. We use the most significant bits of the R channel of the watermarked image generated by the first phase as the second level watermark to detect the tampered locations.

3.1.1. *YCbCr color space watermark embedding phase.*

In this phase, the LSB technique is employed to hide the first level watermark bits based on the exploitation of the YCbCr color spaces Fig. 3 shows the illustration of YCbCr color space watermark embedding phase.

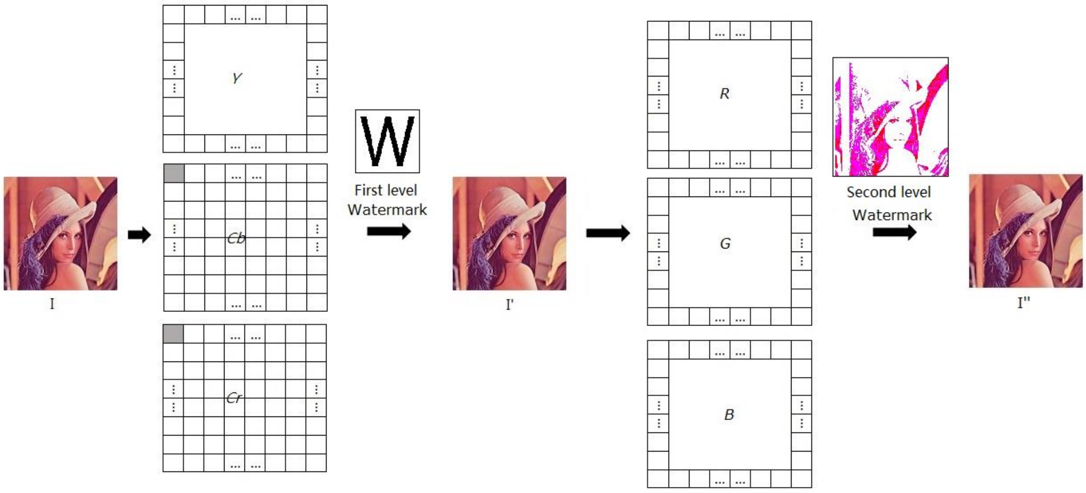


FIGURE 2. Flowchart of the embedding procedure in the EMD method

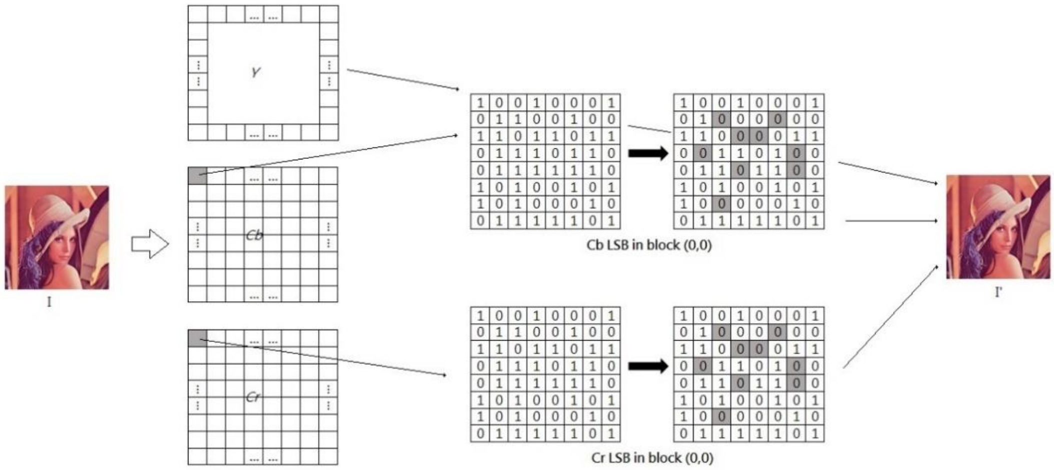


FIGURE 3. Illustration of YCbCr color space watermark embedding phase

The procedure of YCbCr color space watermark embedding phase is described by Algorithm 1.

Algorithm 1: YCbCr color space watermark embedding phase algorithm

Input: Color image I, which has the size of $H \times W$, the first level watermark binary image D, which has the size of $HD \times WD$ and a random positive integer seed S.

Output: First level watermark bits embedded image I'.

Step 1. Convert the original RGB image into YCbCr channel to get (Y, Cb, Cr) by Equation (2).

$$\begin{cases} Y = 0.299R + 0.587G + 0.114B \\ Cb = -0.172R - 0.339G + 0.511B + 128 \\ Cr = 0.511R - 0.428G - 0.083B + 128 \end{cases} \tag{2}$$

Using Equation (2), a pixel p_i in image I can be expressed as Equation (3).

$$p_i = (r_i, g_i, b_i) = (y_i, cb_i, cr_i) \tag{3}$$

Step 2. Extract the LSB values from Cb and Cr and mark the extracted LSB values with $(Cb)^0$ and $(Cr)^0$, respectively. We divide matrices $(Cb)^0$ and $(Cr)^0$ into series non-overlapping blocks with size of $h \times w = \lfloor \frac{H}{HD} \rfloor \times \lfloor \frac{W}{WD} \rfloor$. Then, the LSB values of each pixel

cb_i and cr_i in Cb and Cr is marked with $(cb_i)^0$ and $(cr_i)^0$. Count the number of zeroes and ones that exist in each block.

For example, if there is an original RGB image I with $H \times W = 512 \times 512$ pixels and the first level watermark image D with $HD \times WD = 64 \times 64$ pixels, Equation (2) is used to convert the RGB channel of original image I into the YCbCr channel. After converting the original image, three matrices (Y, Cb, Cr) are obtained. Then, the LSB values of each pixel in Cb and Cr are extracted, respectively. After that, the converted original image is divided into several, non-overlapping blocks sized $h \times w = 8 \times 8$. Finally, the number of values "0" and "1" in each $(Cb)^0$ or $(Cr)^0$ block is counted. For instance, Fig. 4 shows a block in $(Cb)^0$ that is sized 8×8 and contains 36 and 28 numbers of "1" and "0," respectively.

1	0	0	1	0	0	0	1
0	1	1	0	0	1	0	0
1	1	0	1	1	0	1	1
0	1	1	1	0	1	1	0
0	1	1	1	1	1	1	0
1	0	1	0	0	1	0	1
1	0	1	0	0	0	1	0
0	1	1	1	1	1	0	1

FIGURE 4. Example of a 8×8 block in $(Cb)^0$

Step 3. Transform the first level watermark binary image D into the binary bit stream $D = d_1, d_2, \cdots, d_{(h \times w)}$.

Step 4. Use random positive integer seed S to generate embedding strength parameters $s_1, s_2, \cdots, s_{(h \times w)}$. Here $s_1, s_2, \cdots, s_{(h \times w)}$ are random positive integers that will be used in different blocks. They are selected by considering the balance between robust and watermarked image quality.

Step 5. If all blocks are embedded watermark bits, goto Step 7; otherwise, goto Step 6.

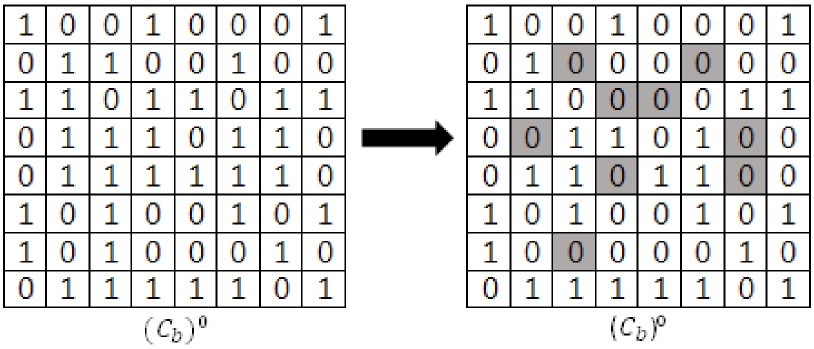
Step 6. For the i^{th} block, if the watermark bit $d_i = 0$, randomly select a $(cb_i)^0$ in $(Cb)^0$ and set it to "0" until the number of zeroes in $(Cb)^0$ is equal to $1/2 \times h \times w + s_i$. If the embedded watermark bit $d_i = 1$, randomly select a $(cb_i)^0$ in $(Cb)^0$ and set it to "1"until the number of ones in $(Cb)^0$ is equal to $1/2 \times h \times w + s_i$. The procedure is the same as that performed on $(Cr)^0$ to strengthen the embedded watermark.

Step 7. Use Equation (4) to convert the watermarked YCbCr data back to the RGB data to get the stego-image I'. Finally, the first level watermark bits embedded image I' is output.

$$\begin{cases} R = Y + 1.371(Cr - 128) \\ G = Y - 0.698(Cr - 128) \\ B = Y + 1.732(Cb - 128)) \end{cases} \tag{4}$$

Fig. 5 shows the case in which a secret bit 0 is embedded to the $(Cb)^0$ block in Step 6 when $s_i = 5$.

Fig. 5 (a) shows a block that contains 28 zeroes and 36 ones before embedding. Fig. 5 (b) shows that the block carries a watermark bit 0 and contains 37 zeroes and 27 ones when $s_i = 5$.



(a) (b)

Figure 5. Embedding a secret bit 0 into a $(Cb)^0$ block in Step 6

3.1.2. *RGB color space EMD watermark embedded phase.* In this phase, the exploiting modification direction method [20] is used to embed the second watermark. The RGB color space watermark embedding phase algorithm is described in Algorithm 2.

Algorithm 2: RGB color space watermark embedding phase algorithm

Input: The first-level watermark bits embedded color image I' sized $H \times W$

Output: The second level watermark bits embedded image I''

Step 1. Extract the most significent bit of I' as the second level watermark image D' and transform D' into a 4-based notational system $d'_1, d'_2, \cdots, d'_{\frac{H\times W}{2}}$.

Step 2. Separate the pixels of I' into two pixel pairs.

Step 3. If all pairs of I' are have watermark bits embedded, goto Step 6; otherwise, select a pair of unembedded pixels (p_i, p_{i+1}), where i is an odd number that ranges from 1 to $H \times W$, and goto Step 4.

Step 4. Use the EMD embedding phase (Fig. 1), where $n = 2$, to embed a 4-based integer $d'_{[\frac{i+1}{2}]}$ into (p_i, p_{i+1}) of I'. Goto Step 3.

Step 5. Output the second level watermark bits embedded image I''.

3.2. **Extracting procedure.** In this section, we introduce the details of the extracting procedure. The watermark extracting phase algorithm is described as Algorithm 3.

Algorithm 3: RGB color space watermark extracting phase algorithm

Input: Watermark bits embedded color image I'' sized $H \times W$, blocksize $h \times w$

Output: Authenticated Image *Result* and first level watermark D_{ex}, sized $H/h \times W/w$

Step 1. Extract the most significent bit of I'' as the second level watermark image D''_{ex} and transform D''_{ex} into 4-based notational system ${d_{ex}}''_1, {d_{ex}}''_2, \cdots, {d_{ex}}''_{\frac{H\times W}{2}}$.

Step 2. Separate the pixels of I'' into several pairs with each pair having two neighboring pixels.

Step 3. Select a pair of unembedded pixels $(p''_i, p''_{(i+1)})$ in I'', where i is an odd number that ranges from 1 to $H \times W$, goto Step 4. If all pairs of I'' are selected, goto Step 5;

Step 4. Using Equation (1), where n=2, extract the secret digit ${d_{ex}}'_{\lfloor\frac{i+1}{2}\rfloor}$ from (p''_i, p''_{i+1}). Goto Step 3.

Step 5. Compare the ${d_{ex}}''_1, {d_{ex}}''_2, \cdots, {d_{ex}}''_{\frac{H\times W}{2}}$ and ${d_{ex}}'_1, {d_{ex}}'_2, \cdots, {d_{ex}}'_{\frac{H\times W}{2}}$, and use Equation(5) to compute the authentication result $\{result_1, result_2, \cdots, result_{\frac{H\times W}{2}}\}$.

$$result_j = \begin{cases} 0, & if\ {d_{ex}}'_j \neq {d_{ex}}''_j \\ 1, & if\ {d_{ex}}'_j = {d_{ex}}''_j \end{cases} \tag{5}$$

where $j = 1, 2, \cdots, \frac{H\times W}{2}$.

Step 6. Use row major order to construct vector $\{result_1, result_2, \cdots, result_{\frac{H\times W}{2}}\}$ to H-row $\frac{W}{2}$-colomn matrix $Result$ and output it.

Step 7. Image I'' is converted into YCbCr channel to get three matrices (Y'', Cb'', Cr'') by Equation (2).

Step 8. Extract the LSB values in Cb'' and Cr'' and mark them as $(Cb'')^0$ and $(Cr'')^0$. Divide matrices $(Cb'')^0$ and $(Cr'')^0$ into series non-overlapping blocks with sizes of $h \times w$. Next, calculate the numbers of "0" and "1" in each $(Cb)^0$ or $(Cr)^0$ block, and use Equation (6) to extract the bits of first level watermark d_{ex}.

$$d_{ex} = \begin{cases} 0, & if\ number\ of\ zeros\ \geq\ number\ of\ ones \\ 1, & if\ number\ of\ zeros < number\ of\ ones \end{cases} \tag{6}$$

Step 9. After all blocks of $(Cb'')^0$ and $(Cr'')^0$ are extracted, matrix D_{ex} is constructed.

4. **Experimental results.** The method proposed in this paper was implemented in MATLAB, and image "Lena" was chosen as the cover image to carry the binary watermark image sized 64×64. We implemented Lusson et al.'s method and the proposed method by using MATLAB R2013a software, which works on an Intel® Core™ i7 processor.

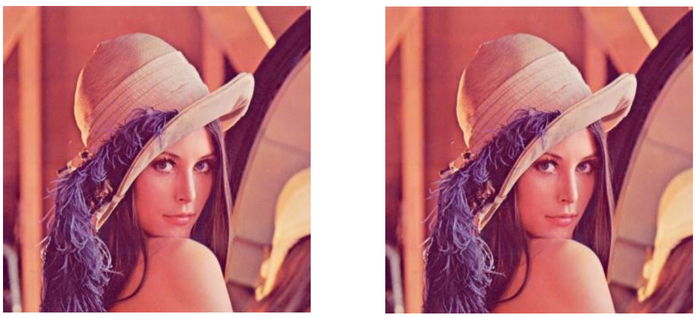
The peak signal-to-noise ratio(PSNR) was used to evaluate the quality of the watermarked color image. The $PSNR$ of an $H \times W$ color image is defined as Equation (7):

$$PSNR = 10 \times \log_{10} \frac{255^2 \times 3}{MSE(R) + MSE(G) + MSE(B)}. \tag{7}$$

The MSE is defined as Equation (8):

$$MSE = \frac{1}{H \times W} \sum_{i=1}^{H} \sum_{j=1}^{W} (x_{ij} - \overline{x_{ij}})^2. \tag{8}$$

Here, x_{ij} denotes the original pixel value, and $\overline{x}_{ij}$ denotes the pixel value of a watermarked image. Fig. 6 shows the watermarked image generated by the proposed method with the image "Lena".



(a) (b)

Figure 6. Watermarked image generated by the proposed method with the image "Lena": (a) "Lena" after embedding the first level watermark ($PSNR$ = 46.90dB); (b) Image of (a) after embedding the second level watermark ($PSNR$ = 45.75dB)

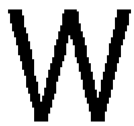
The normalized correlation coefficient (NC) was used to evaluate the similarity between the original watermark and the extracted watermark. The NC is defined as Equation (9):

$$NC(D, D_{ex}) = \frac{\sum_{i=1}^{H}\sum_{j=1}^{W} D(i,j)D_{ex}(i,j)}{\sqrt{\sum_{i=1}^{H}\sum_{j=1}^{W} D(i,j)^2}\sqrt{\sum_{i=1}^{H}\sum_{j=1}^{W} D_{ex}(i,j)^2}} \tag{9}$$

Five attacks were performed on the watermarked image, and the comparisons between our method and Lusson et al.'s method are shown below. Moreover, the detection performance of the proposed method on collage attack also is demonstrated at the end of this section.

4.1. **Filtering attacks.** The simulation was conducted such that the watermarked images were attacked by MATLAB's filtering attack with a ratio of 0.05. Table 1 compares the results obtained by our method and Lusson et al.'s method.

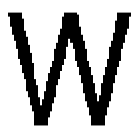
TABLE 1. Results of filtering attack with a ratio of 0.05 for our method and Lusson et al.'s method

Lusson et al.'s method [19]	PSNR (dB)	NC	The proposed method	PSNR (dB)	NC
	72.82	0.99		Reversible	1

Since our method is reversible, the original image can be reconstructed after the hidden watermark has been extracted. Therefore, the reconstructed image is exactly the same as the original image, which is clearly superior to Lusson et al.'s method.

4.2. **Noise addition attacks.** In noise addition attacks, the watermarked images are attacked by MATLAB's Salt and Pepper noise attack with a ratio of 0.02. Table 2 compares the results of our method with that of Lusson et al.

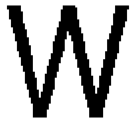
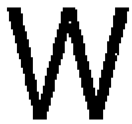
TABLE 2. Results of Salt and Pepper noise attack with a ratio of 0.02 for our method and Lusson et al.'s method

Lusson et al.'s method [19]	PSNR (dB)	NC	The proposed method	PSNR (dB)	NC
	71.98	0.99		Reversible	1

4.3. **Resize attacks.** In resize attacks, the experimental results showed various degrees of resize percentage, ranging from 10 to 50%. Table 3 provides the watermark survival results of our method and Lusson et al.'s method.

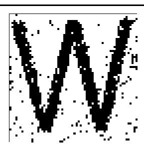
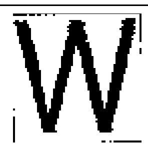
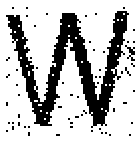
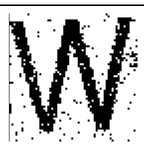
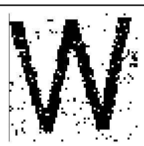
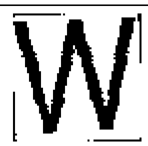
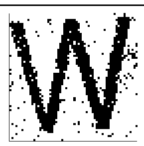
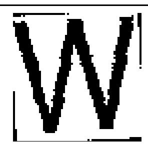
In the resize attacks, first, we reduced the size of the watermarked image by 10 to 50%. Then, we restored the watermarked image to its original size. Table 3 shows that the hidden watermark is not reversible when the image was resized up to 30%, while the NC of the extracted watermark using the proposed method still reached 0.99.

TABLE 3. Watermarksurvival results after resize attack with various degrees of resize percentage between our method and Lusson et al.'s method

Degrees	Lusson et al.'s method [19]	PSNR (dB)	NC	The proposed method	PSNR (dB)	NC
10%		71.06	0.97		Reversible	1
30%		67.21	0.96		81.27	0.99
50%		62.92	0.95		71.27	0.99

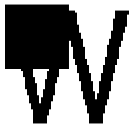
4.4. **Rotation attacks.** In rotation attacks, the experimental results showed the situations from 1 to 3 degrees. And comparison results between our method and Lusson et al.'s method are given in Table 4.

TABLE 4. Watermark survival results after rotation attacks from 1 to 3 degrees between our method and Lusson et al.'s method

Degrees	Lusson et al.'s method [19]	PSNR (dB)	NC	The proposed method	PSNR (dB)	NC
1		60.25	0.95		63.78	0.98
1.5		59.22	0.94		60.90	0.96
2		58.57	0.93		59.80	0.95
2.5		58.17	0.93		58.83	0.94
3		57.91	0.92		58.00	0.92

4.5. **Cropping attacks.** In cropping attacks, the results showed different cropping degrees. Although the PSNRs of the proposed method were smaller than those of Lusson et al.'s method, the visual quality of our method was still better than that of Lusson et al.'s method. The experimental results are given in Table 5.

TABLE 5. Watermark survival results in different degrees for cropping attacks between our method and Lusson et al.'s method.

Degrees	Lusson et al.'s method [19]	PSNR (dB)	NC	The proposed method	PSNR (dB)	NC
10%		63.01	0.98		59.11	0.94
25%		58.83	0.94		55.92	0.87

4.6. **Detection performance of collage attack.** The experimental results for the collage attack of the image "Lena" are shown in Fig. 7. Fig. 7(a) shows the result after modifying the watermarked image, and Fig. 7(b) shows the detecting result of the modified area by marking it in black. Comparing Figs. 7(a) and 7(b), it is clear that the proposed method can identify areas that have been subjected to a collage attack.

(a) (b)

FIGURE 7. Collage attack with "Lena" and the authentication results: (a) tampered watermarked image; (b) authentication result of attacked image

5. **Conclusions.** Our aim was to use image steganography technology to design a hybrid data hiding method for watermarking applications. The proposed method uses the YCbCr color spaces and the EMD method to embed dual watermarks. The experimental results demonstrated that the proposed hybrid data hiding method can efficiently resist most geometric and processing attacks. In other words, the hidden watermarks with the proposed method can survive after image manipulation and enhancement processes. Therefore, the method can be used for protecting the ownership of images and the integrity of the potential tampered images.

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