A Halftoning-Based Multipurpose Image Watermarking with Recovery Capability

Carlos Santiago-Avila, Mario Gonzalez-Lee, Mariko Nakano-Miyatake, and Hector Perez-Meana

***Abstract*—** Nowadays digital watermarking has become an important technique, because using computational tools, digital contents can be copied and/or modified easily. At the beginning, the digital watermarking has been used for either copyright protection purpose or content authentication purpose. However, in many situations both purposes (copyright protection and content authentication) are required to be satisfied at same time. The watermarking scheme that satisfies both purposes is called multipurpose watermarking scheme. In this paper, a novel multipurpose watermarking scheme is proposed, in which a self-embedding technique based on halftoning is used for content authentication and recovery purpose, and a binary pattern is embedded into the halftone image using quantization-based embedding method for copyright protection purpose. Experimental results show favorable performance of the proposed algorithm.

***Keywords*—** Halftoning, Multipurpose watermarking, Quantization method, Self-embedding.

I. INTRODUCTION

DIGITALIZATION of information provides a great benefit in reduction of storage space and its easy transfer using public network, such as Internet. However, on the other hand, it causes some serious problems, such as copyright violation and content alteration. For example, in July 2005 it was discovered that a number of Second World War files held at the National Archives contained some forged documents. An internal investigation found that the forgery took place of original one during or after the year 2000 [1].

Watermarking techniques are considered as alternative solutions for these problems, initially these techniques have been employed only for copyright protection of digital materials [2], and later fragile and semi-fragile watermarking techniques were introduced for authentication purpose [3,4]. Most of watermarking schemes are designed for only one purpose, either copyright protection [2,5,6] or content authentication [3,4], however in many situations, both purposes are required simultaneously to realize a reliable protection of digital contents. Recently multipurpose watermarking techniques, in which both purposes are accomplished at same time, have been proposed in the literature [7-11].

Carlos Santiago-Avila, Mario Gonzalez-Lee, Mariko Nakano-Miyatake, Hector Perez-Meana are with the Graduate and Research Section of the Mechanical and Electrical Engineering School of the National Polytechnic Institute of Mexico, Av. Santa Ana 1000, 04430, Mexico D.F., mnakano@ipn.mx.

In the multipurpose watermarking algorithm proposed by Zhu et al. [7], the original image is decomposed by DWT and then the robust watermark sequence is embedded lowest frequency subband (LL2), while the fragile watermark sequence is embedded into higher frequency subbands (LH2, HL2 and HH2). This algorithm detects successfully the tampered regions using fragile watermark. In [8], DCT-based multipurpose watermarking algorithm is proposed, in which the original image is decomposed into four sub-images using subsampling proposed by [12], and then two watermarks, corresponding to robust and semi-fragile, are embedded modifying the relationship between sub-images. Authors show very similar robustness degree of both watermarks against several attacks, it makes the purpose of each watermark unclear.

Authors of [9] proposed a multipurpose watermarking algorithm for color images, in which YCbCr color space is used. The robust watermark is embedded into DWT coefficients of middle frequency range of the luminance channel Y, while the fragile watermark is embedded into chrome channel. The experimental results show the robustness and fragility of both watermarks; however the algorithm doesn't have some mechanism to detect the tampered region. In [10], the bipolar watermark sequence is embedded using positive and negative modulations proposed by the cocktail watermarking technique [13] in DWT domain. Authors of [10] show the watermark robustness and tampered region detection capability. In [11], the authors proposed a multipurpose watermarking scheme using multistage vector quantization. From the original image two-stage vector quantization (VQ) are constructed and then the robust watermark is embedded using the first VQ, and the fragile watermark is embedded using the second VQ. The principal disadvantages of this method, a code book corresponded to two VQ stages and four secret keys must be saved to be employed in watermark detection stage. Authors of [14] proposed multipurpose watermarking algorithm for color halftone images, in which the robust and semi-fragile watermark are embedded into a color halftone image in place of general grayscale or color images. This method is very useful for printer and publishing application, where halftone images are used.

Almost all multipurpose watermarking schemes contain tamper detection capability and also some of them can locate the tampered region in an accurate manner, however there isn't any multipurpose scheme with tampered region recovery capability.

In this paper a novel multipurpose watermarking algorithm with tampered region recovery capability is proposed, in which two different kinds of watermark sequences, corresponded to semi-fragile and robust watermarks are embedded into an image. The image can be grayscale or color version. In the case of color image, firstly RGB color space is transformed to YCbCr color space. The semi-fragile watermark sequence is a halftone version of the original grayscale image (luminance channel Y for the color image), which is generated by the error diffusion halftoning method [15]. This watermark sequence is embedded for authentication and recovery purpose. The robust watermark sequence is a binary bit sequence generated by owner's secret key or binary owner's logotype, which is embedded for copyright protection purpose into the halftone image generated previously. To evaluate tamper detection and recovery capability of the proposed algorithm, some objects are superimposed into the watermarked image. To evaluate the robustness of the second watermark sequence, the watermarked image is compressed by JPEG compression with different quality factors.

The remainder of this paper is organized as follows. In Section II, generation methods of the first and second watermark sequences used in the proposed algorithm are mentioned. In Section III, the proposed multipurpose watermarking algorithm is described in detail. The simulation results and conclusions are given in Section IV and V, respectively.

II. Watermark Generation

A. Semi-Fragile Watermark Sequence

The first watermark sequence is a semi-fragile watermark generated by halftoning method from the original grayscale image or the original luminance channel Y of the color image. The halftoning techniques are conversion methods from a grayscale image into a binary image, keeping similar image quality for Human Visual System (HVS). Until now several halftoning methods have been proposed, among them error diffusion halftoning method is considered as effective one from visual quality and low computer complexity points of view. Fig. 1 shows a block diagram of the error diffusion halftoning method.

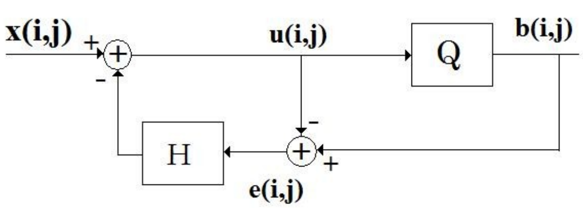


Fig. 1 Block diagram of the error diffusion halftoning method.

In Fig. 1, Q is the quantization process, which converts a grayscale pixel value into a binary value using a predefined threshold value *Th*. This process is given by

$$Q(u(i,j)) = \begin{cases} 0 & u(i,j) < Th \\ 1 & u(i,j) \geq Th \end{cases} \quad . \qquad (1)$$

The notation H of the figure is a 2D filter whose coefficients indicate a quota of the diffused error for each neighbor of the (i,j)-th pixel. In the proposed watermarking algorithm, the Floyd-Steinberg error diffusion method is employed to carry out the halftoning, however any error diffusion method, such as Jarvis and Stuscki, can be used. The filter coefficients of Floyd-Steinberg method is given by Fig. 2.

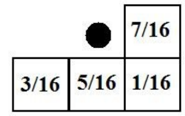
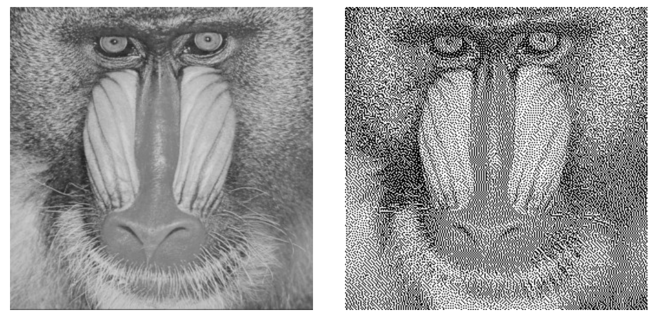


Fig. 2 Filter coefficients of the Floyd-Steinberg method [15].

Figure 3 shows an example of halftone image generated using Floyd-Steinberg error diffusion method together with its original grayscale image.



(a) (b)

Fig. 3 (a) Original gray-scale image, (b) halftone image.

The halftone image is a binary image (1 bit/pixel) and it can be considered as a compressed version of the original grayscale image (8 bits/pixel). Therefore using halftone image as the semi-fragile watermark sequence, the tampered region can be detected and also the original version of the region can be estimated. This technique is known as self-embedding watermarking.

B. Robust Watermark Sequence

The second watermark is the robust watermark sequence, whose purpose is the copyright protection. This watermark sequence consists of binary bits, representing owner's logotype or generated randomly using owner's secret key. For example, we used 8x8 binary pattern related to the ownership, which is shown by Fig. 4.

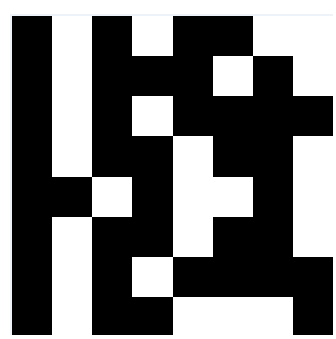


Fig. 4 Binary watermark pattern related to ownership.

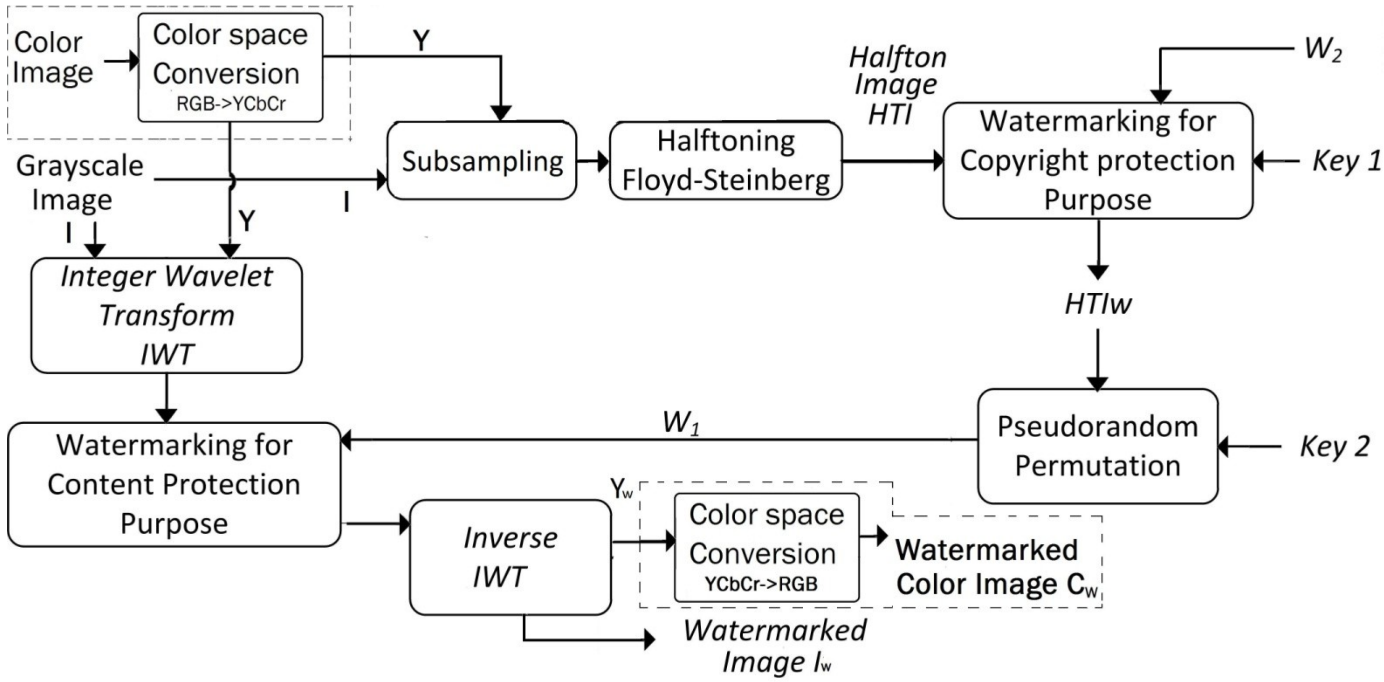


Fig. 5 Proposed watermark embedding process

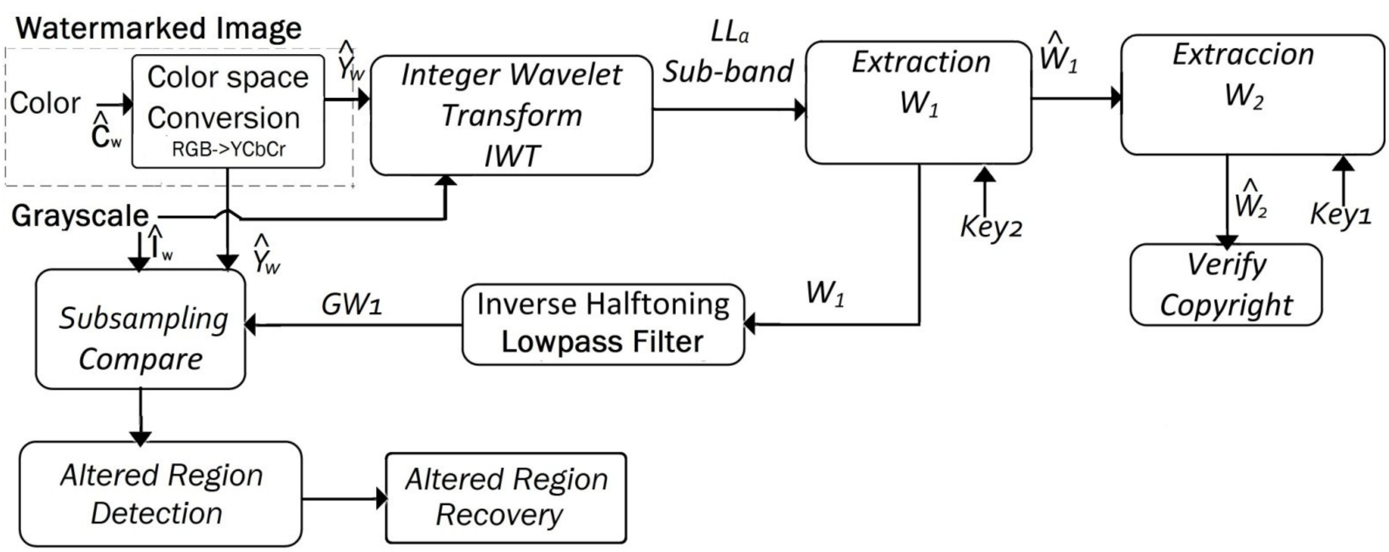


Fig. 6 Proposed authentication and recovery processes

The binary pattern in Fig. 4 represents 8 letters "IPNESIME" concatenating vertically the 8 bits ASCII codes of 8 letters. Considering watermark robustness, the watermark sequence generated randomly under a distribution N(0,1) can be better sequence. The optimal watermark length from robustness and imperceptibility points of view is analyzed later.

III. Proposed Multipurpose Watermarking

The block diagrams of the watermark embedding and extraction process of the proposed multipurpose watermarking algorithm is shown by Figs. 5 and 6, respectively. If the original image is color image, firstly RGB color space is converted into YCbCr color space, using the conversion matrix given by

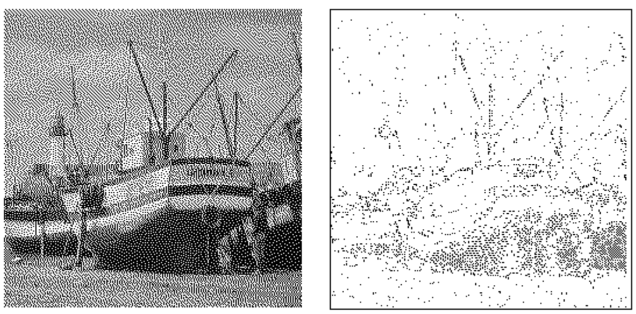
$$\begin{bmatrix} Y \\ Cb \\ Cr \\ 1 \end{bmatrix} = \begin{bmatrix} 0.2990 & 0.5870 & 0.1140 & 0 \\ -0.1687 & -0.3313 & 0.5000 & 0.5 \\ 0.5000 & -0.4187 & -0.0813 & 0.5 \\ 0 & 0 & 0 & 1 \end{bmatrix}. \quad (2)$$

This process is shown by dotted box in Figs. 5 and 6. The robust and semi-fragile watermark sequences are embedded in luminance channel Y, and the chrome channels are saved to generate watermarked color image.

A. Robust Watermark Embedding

The original grayscale image I or original luminance channel Y of color image are sub-sampled to reduce size to ¼ of the original image. The robust watermark sequence is embedded into the halftone image *HTI* generated from the sub-sampled original grayscale image or the luminance channel Y. Some watermarking algorithms that the watermark sequence is embedded into the halftone images, have been proposed in the literature [14,16,17]. Considering that the halftone image is a type of binary images, also some data hiding techniques for binary images [18, 19] can be adapted to our proposed algorithm. From the security, imperceptibility and blind extraction requirements, the data hiding method proposed by Wu [18] is employed to embed the robust watermark sequence W_2.

Firstly from the halftone image *HTI*, "flippable" pixels are located. A "flippable pixel" is defined that the pixel of binary image can be flipped (changing black to white or vice versa) without causing any visual degradation to the binary image [18]. To determine the "flippable" pixels, smoothness and connectivity into a window of size 3x3 of the binary image are measured. Fig. 7 shows the halftone image and its "flippable" pixels.



(a) (b)

Fig. 7 (a) Halftone Image, (b) Detected "flippable" pixels of (a).

Once "flippable" pixels are detected, using the secret key (key1 in Fig. 5), these pixels are permuted using random permutation method for security and imperceptibility purpose. The permuted "flippable" pixels are segmented into LxL blocks of NxN pixels, as shown by Fig. 8. Here the number of blocks corresponds to the length of the robust watermark sequence W_2.

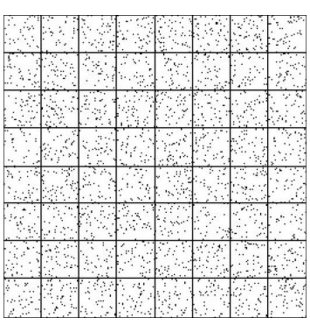


Fig. 8 Segmentation of the permutated flippable pixels.

The watermark embedding is performed forcing the number of black pixels per block to be odd or even times of the quantization step size Q_r, depending on the watermark bit value, which can be formulate as

$$NB_w = \begin{cases} 2kQ_r & \text{if } w_2(i) = 0 \ \& \ (2k-1)Q_r \le NB < (2k+1)Q_r \\ (2k+1)Q_r & \text{if } w_2(i) = 1 \ \& \ 2kQ_r \le NB < 2(k+1)Q_r \end{cases}, \qquad (3)$$

where NB and NB_w are numbers of black pixels in i-th block before and after quantization, respectively, and $w_2(i)$ is i-th bit of the robust watermark sequence W_2. After all watermark bits were embedded, the number of black pixels of each block (Fig. 8(b)) is modified, and then using key1, the modified "flippable" pixels are returned to their original coordinates in the halftone image to obtain the watermarked halftone image HTI_w. Fig. 9 shows the original halftone image and watermarked one.

(a) (b)

Fig. 9 (a) Original halftone image, (b) Watermarked halftone image.

The step size Q_r controls the watermark imperceptibility and robustness, a larger Q_r gives higher robustness against several attacks, however the quality of the watermarked halftone image can be degraded [18]. Also the watermark length determines the upper limit of Q_r, because the number of blocks is equal to the watermark length and if the number of blocks is increased, each block size is decreased and as consequence, number of "flippable" pixels/block is decreased. Fig. 10 shows the relationship between watermark length and average upper limit of step size Q_r for several halftone images of size 256 x 256. Fig. 10 indicates that more adequate watermark length LxL is 64 (8x8) or 256 (16x16).

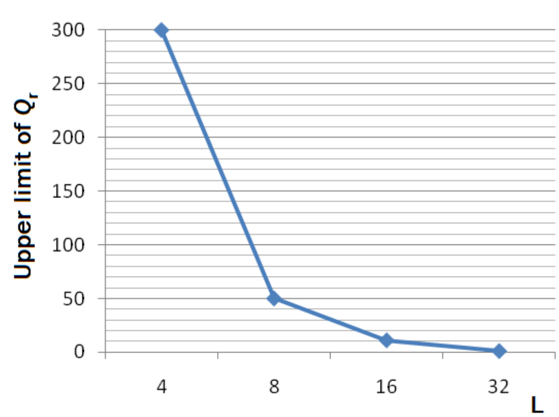


Fig. 10 Relationship between watermark length(LxL) and upper limit of sep size Q_r .

B. Semi-fragile Watermark Embedding

Once the watermarked halftone image is obtained, it becomes a semi-fragile watermark W_1 for authentication purpose. This watermark sequence is embedded into the coefficients of the lowest sub-band LL of the Integer Wavelet Transform (IWT) domain. The IWT and inverse IWT have a lossless property, since the coefficient's values obtained by IWT and pixel value obtained by inverse IWT from IWT coefficients are integers [20]. This property contributes to low bit error rate (BER) of the extracted watermark sequence. To decompose the original grayscale image or original luminance channel Y, the integer version of the Haar transform is used, which is given by

$$\begin{aligned} d_{1,l} &= s_{0,2l+1} - s_{0,2l} \\ s_{1,l} &= s_{1,l} + \lfloor d_{1,l}/2 \rfloor \end{aligned} \quad , \qquad (4)$$

where s_0 is the original image and s_1, d_1 are low-pass and high-pass coefficients, respectively after a first level wavelet decomposition. Sub-index l indicates raw or column index of pixel. The equation (4) is applied consecutively to row vectors and column vectors of the image.

The first level decomposition by IWT is carried out to the original grayscale image and then four sub-bands (LL, LH, HL and HH) are obtained as shown by Fig. 11. The lowest sub-band LL is used for the watermark embedding.

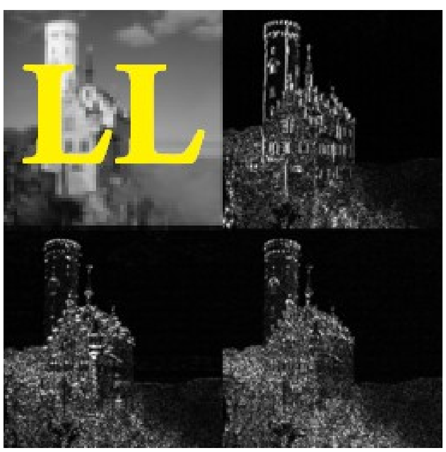


Fig. 11 Four sub-bands obtained by first level decomposition of IWT .

The watermark embedding method is given by (5), which is the same quantization method used in the robust watermark embedding process. The step size Q_s used in this embedding process is 9, which value is determined empirically taking account of watermark imperceptibility and robustness.

$$LL(i)_w = \begin{cases} 2kQ_s & \text{if } w_1(i) = 0 \ \& \ (2k-1)Q_s \le LL(i) < (2k+1)Q_s \\ (2k+1)Q_s & \text{if } w_1(i) = 1 \ \& \ 2kQ_s < LL(i) < 2(k+1)Q_s \end{cases} , \quad (5)$$

where $LL(i)$ and $LL(i)_w$ are i-th coefficient of LL sub-band in IWT domain and $w_1(i)$ is i-th semi-fragile watermark bit. After all watermark bits are embedded, the inverse IWT is applied to $LL(i)_w$ and others three sub-bands to obtain the watermarked image. In the case of color image, using watermarked luminance channel and others two chrome channels, watermarked color image is obtained.

Figs. 12 and 13 show the original grayscale and color images and its respective watermarked versions. Image quality of the watermarked grayscale image (Fig. 12 (b)) respect to the original one is 36.2 dB, and the quality of watermarked color image (Fig. 13 (b)) is aprox. 34.7 dB.

Fig. 12 (a) Original grayscale image (b) watermarked grayscale image.

Fig. 13 (a) Original color image (b) watermarked color image.

C. Semi-Fragile and Robust Watermark Extraction

If the watermarked image is a color, firstly RGB color space is converted in YCbCr color space. The luminance channel Y of the watermarked color image is used to extract the semi-fragile watermark sequence. In the grayscale watermarked image, this process is omitted. Firstly the semi-fragile watermark sequence is extracted, decomposing the watermarked and possibly altered image into sub-bands LL_a by IWT.

$$\hat{w}_1(i) = \begin{cases} 0 & \text{if } round\left(\frac{LL_a(i)}{Q_s}\right) \text{ is even} \\ 1 & \text{if } round\left(\frac{LL_a(i)}{Q_s}\right) \text{ is odd} \end{cases} , \qquad (6)$$

where $LL_a(i)$ is i-th IWT LL-coefficient of the watermarked and possibly altered grayscale image, Qs is the quantization step used in the embedding stage, and $\hat{w}_1(i)$ is i-th extracted watermark bit. The extracted sequence is permuted inversely using the secret key2 to obtain the semi-fragile watermark sequence.

Once the semi-fragile watermark sequence is extracted, consecutively the robust watermark sequence is extracted from the extracted semi-fragile watermark sequence. Using the same method used in the embedding stage, the "flippable" pixels are detected and permuted using key1. The permuted "flippable" pixels are segmented into LxL blocks and applying the extraction method given by (7), the robust watermark sequence is extracted.

$$\hat{w}_2(i) = \begin{cases} 0 & \text{if } round\left(\dfrac{NB_a(i)}{Q_r}\right) \text{ is even} \\ 1 & \text{if } round\left(\dfrac{NB_a(i)}{Q_r}\right) \text{ is odd} \end{cases}, \quad (7)$$

where $NB_a(i)$ is number of black pixels in i-th block of the permuted "flippable" pixels map of the watermarked and possibly altered image, and $\hat{w}_2(i)$ is the extracted i-th bit of the robust watermark sequence.

D. Authentication and Recovery Process

The extracted semi-fragile watermark sequence W_1 must be very similar to the watermarked grayscale image, if it is not tampered intentionally. Therefore to compare the extracted watermark and the watermarked image, the halftone image must be converted into a grayscale image using inverse halftoning. Here a low-pass filter-based inverse halftone method is applied.

The authentication process is carried out in block-wise. The grayscale image GW_1 generated from the extracted semi-fragile watermark sequence and the watermarked and possibly altered one $\hat{I}_w$ or $\hat{Y}_w$ are segmented into blocks of size MxM. The difference between values of the corresponded blocks is calculated by

$$D_k = \frac{1}{M^2} \sum_{(i,j)\in B_k} \left| B_{GW1}(i,j) - B_{IW}(i,j) \right| \quad (8)$$

where B_{GW1} and B_{IW} are blocks of grayscale image GW_1 and the watermarked image $\hat{I}_w$ or $\hat{Y}_w$, respectively. The difference of k-th block D_k is compared with a predetermined threshold value Th_d, if the difference is larger than Th_d, this block is considered as tampered. The block size employed is 16x16 (M=16).

Once the tampered blocks are detected, the recovery process is triggered, in which the tampered blocks are replaced by the corresponded blocks of GW_1.

IV. Experimental Results

The watermark robustness, tampered region detection and recovery capability of the proposed algorithm, when the original image is grayscale version and color version, are evaluated. Firstly the most adequate values for some parameters used in the proposed algorithm, such as quantization step size Q_r for the robust watermark embedding and threshold value Th_d is analyzed.

A. Analysis of Parameters

The quantization step size Q_r for the robust watermark embedding, controls watermark robustness against several attacks, such as JPEG compression and noise contamination, and also this value limits the robust watermark length. In table I, the upper limit value of Q_r for several watermark lengths and Bit Error Rate (BER) of the extracted watermark when the watermarked image suffered several attacks. From the table and the watermark imperceptibility points of view, the Q_r=19 and the watermark length LxL=64 bits are used.

Table I. Bit Error Rate of the extracted robust watermark with several watermark length with its upper limit of Q_r

Bit Error Rate										
L	Q_r	JPEG Quality Factor						Noise		
								Impulsive		Gauss
		100	90	80	70	60	50	1%	5%	
4	300	0	0	0	0	0	0.13	0	0.38	0.38
8	50	0	0	0	0.18	0.41	0.53	0.16	0.64	0.64
16	11	0	0	0.16	0.41	0.48	0.5	0.32	0.51	0.52

To determine if the block is tampered or not the threshold value Th_d is very important. This value must be selected considering that both false alarm probability and false negative probability will be smallest. Here $Th_d = 19.5$ is empirically selected using several tampered and un-tampered watermarked images

B. Tampered Region Detection and Recovery Capability

To evaluate tampered region detection capability, several watermarked images are altered intentionally, superimposing some objects into images. Fig. 14 shows the watermarked image, tampered image, result of tampered region detection and the image with the tampered region recovered.

Fig. 14 (a) Watermarked image (b) watermarked and tampered image (c) Tampered region detection results (d) Image with tampered region is recovered.

In this figure, the tampered regions are indicated by black blocks and these tapered regions are replaced with grayscale region generated from the extracted semi-fragile watermark sequence. As we can observe from the figure, the proposed algorithm detects correctly the tampered regions and recovered. Another evaluation results for color image is shown by Fig. 15, in this figure, the original image (a), watermarked image (b), watermarked and tampered image (c) are shown in the upper row, and in the lower row difference image (d), the tampered region detection results (e) and recovered image (f) are shown, respectively.

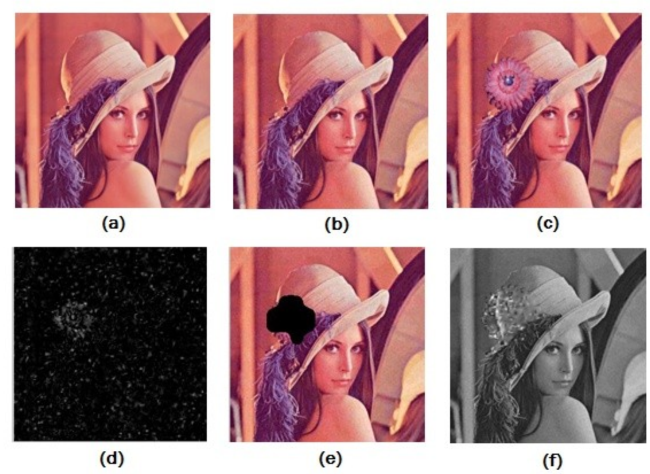


Fig. 15 (a) Original image, (b) Watermarked image (c) watermarked and tampered image (d) Difference image D_k , (e) Tampered region detection (f) Grayscale image with tampered region is recovered.

The image with recovered region (Fig. 15 (f)) is a grayscale image, since the original versions of chrome channels Cb and Cr are not available in the authentication and recovery stage. However from the grayscale recovered image, original contents of the tampered region can be estimated.

The extracted robust watermark sequences from Fig. 14 (b) and Fig. 15 (c) are shown in Figs. 16 and 17, respectively. In both figures, the extracted robust watermark sequence (b), together with its original version (a) are shown. The BER of the extracted watermark in both figures are aprox. 0.03 and 0.06, which means the robust watermark sequence can be extracted with low BER from the tampered images and owner's copyright can be protected.

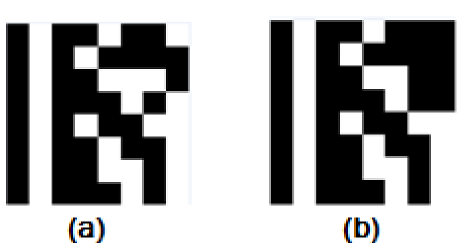


Fig. 16 (a) Original robust watermark (b) extracted robust watermark from the tampered image Fig. 14(b).

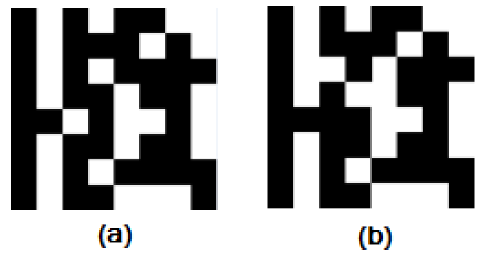


Fig. 17 (a) Original robust watermark (b) extracted robust watermark from the tampered image Fig. 15(c).

Obviously increasing the tampered region, BER is also increased and the reliable copyright protection becomes difficult. Fig. 18 shows the relationship between tampered region percentage and average BER when an object with different size is superimposed in several watermarked images.

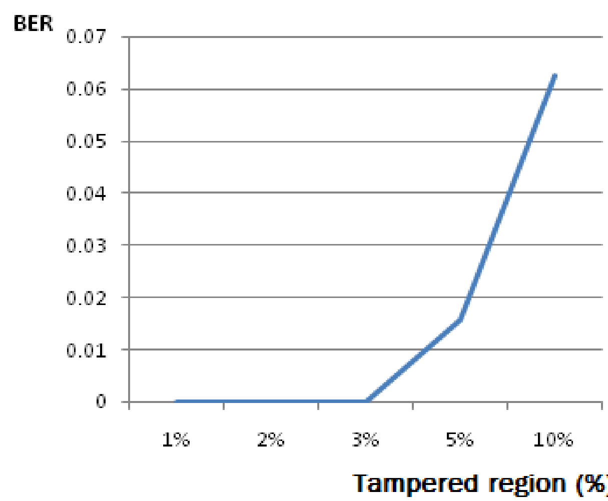


Fig. 18 Relationship between percentage of tampered region and BER of the extract robust watermark.

The tampered region (%) is calculated by

$$\text{Tampered region\%} = \frac{\text{number of altered pixels}}{N^2} \times 100 \qquad (9)$$

where N^2 is number of total pixels of the original image.

The Fig. 18 shows that even if the watermarked image tampered more than 10% of pixels, using the robust watermark, copyright protection can be claimed reliably.

V. Conclusions

In this paper, a novel multipurpose watermarking algorithm is proposed, in which firstly halftone image is generated using error diffusion halftoning method from the original image. Next the robust watermark sequence is embedded into the halftone image for copyright protection purpose. The watermarked halftone image becomes the semi-fragile watermark to be used for authentication purpose, which is embedded into the lowest sub-band of Integer Wavelet Transform (IWT). In the authentication stage, the extracted semi-fragile watermark sequence is converted in continuous tone image using inverse halftoning method, and then it is compared with the grayscale watermarked image to detect tampered region. Once the tampered region is detected, it can be replaced with continuous tone region generated from the extracted semi-fragile watermark sequence. The simulation results show desirable tamper detection and recovery capabilities. The robust watermark can be extracted with low BER even if the watermarked image suffered some content alterations, and this means that the proposed algorithm offers a reliable copyright protection.

ACKNOWLEDGMENT

The authors would like to thank the National Council of Science and Technology (CONACyT) of Mexico, ICyTDF of Mexico City and IPN for financial support.

REFERENCES

[1] The National Archives of United Kingdom, http://www.nationalarchives.gov.uk/news/stories/195.htm?homepage=newsS, 2008.
[2] I. J. Cox, J. Kilian, F. T. Leighton and T. Shamoon, "Secure spread spectrum watermarking for multimedia" *IEEE Trans. Image Processing*, vol. 6, no. 12, pp. 1673-1687,1997.
[3] M. Celik, G. Sharma, E. Saber and A. Tekalp, "Hierarchical watermarking for secure image authentication with localization", *IEEE Trans. Image Processing*, vol. 11, no. 6, pp. 585-595, 2002
[4] K. Maeno, Q. Sun, S. Chang and M. Suto, "New semi-fragile image authentication watermarking techniques using random bias and nonuniform quantization", *IEEE Trans. Multimedia*, vol. 8, no. 1, pp. 32-45, 2006.
[5] W.-T. Huang, S-Y. Tan, Y.-J Chang and C.-H. Chen, "A robust watermarking technique for copyright protection using discrete wavelet transform", *WSEAS Trans. Computers*, vol. 9, no. 5, pp. 485-495, 2010.
[6] V. Hernandez, M. Nakano-Miyatake and H. Perez-Meana, "A robust DWT-based image watermarking algorithm", *WSEAS Trans. Communications*, vol. 4, no. 10, pp. 1048-1057, 2005.
[7] C. Zhu and Y. Hu, "A multipurpose watermarking scheme for image authentication and copyright protection", in *Conf. Rec. 2008 IEEE Int. Symp. Electronic Commerce and Security*, pp. 930-933.
[8] F. Gu, Z-M. Lu and J-S. Pan, "Multipurpose image watermarking in DCT Domain using subsampling", in *Conf. Rec. 2005 IEEE Int. Symp. Circuit and Systems*, vol. 5, pp. 4417-4420.
[9] Y. Wei, Y. Hao and Y Li, "A multipurpose digital watermarking algorithm of color image", in *Conf. Rec. 2009 IEEE Int. Conf. Mechatronics and Automation*, pp. 112-117.
[10] C.-S. Lu and H-Y Liao, "Multipurpose watermarking for image authentication and protection", *IEEE Trans. Image Processing*, vol. 10, no. 10, pp. 1579-1592, 2001.
[11] C. Zhang, L- Cheng, Z. Qiu and L. Cheng, "Multipurpose watermarking based on multiscale curvelet transform", *IEEE Trans. Information Forensic and Security*, vol. 4, no. 4, pp. 611-619, 2008.
[12] W. C. Chu, "DCT-based image watermarking using subsampling", *IEEE Trans. Multimedia*, vol. 5, no. 4,pp. 34-38, 2001.
[13] C. S. Lui, S. K. Huang, C. J. Sze and H. Y. Liao, "Cocktail watermarking for digital image protection", *IEEE Trans. Multimedia*, vol. 2, pp. 209-224, 2000.
[14] K.-M. Hung, C.-T. Hsieh and K.-T. Yeh, "Multi-purpose watermarking schme for color halftone image", in *Conf. Rec. 2006 WSEAS Signal, Speech and Image Processing,* pp. 37-42.
[15] D. Demera-Venkata and B. Evans, "Adaptive threshold modulation for error diffusion halftoning", *IEEE Trans. Image Processing*, vol. 10, no. 1 pp. 104-116, 2001.
[16] D. Kacker and J. P. Allebach, "Joint halftoning and watermarking", *IEEE Trans. Signal Processing*, vol. 51, no. 4, pp. 1054-1068, 2003.
[17] Z. Guannan and W. Shuxun, "A private watermarking for halftone image by Stochastic error diffusion", in *Conf. Rec. 2004 IEEE Int. Conf. Signal Processing*, pp. 2362-2365.
[18] M. Wu and N. Liu, "Data hiding in binary images for authentication and annotation", *IEEE Trans. Multimedia*, vol. 6, no. 4, pp. 528-538, 2004.
[19] H. Yang and A. C. Kot, "Text document authentication by integrating inter character and word spaces watermarking", in *Conf. Rec. 2004 IEEE Int. Conf. Multimedia and Expo*, pp. 955-958.
[20] A.R. Calderbank, I. Daubechies, W. Sweldens and B-L, Yeo, "Lossless image compression using integer to integer wavelet transforms", in *Conf. Rec. 1997 IEEE Int. Conf. Image Processing*, vol. 1, pp. 596-599.