

An Adaptive Gray-Scale image Watermarking Scheme using Smooth and Edge areas of an image

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Abstract—In this paper, we propose an adaptive watermarking scheme for gray-scale images. The proposed scheme use the difference between the consecutive and non-overlapping pair of pixels to embed the watermark bits. The watermark is embedded into the pair of pixels using least-significant bit(LSB) substitution method. The difference between pair of pixels is used to determine the smooth and edge regions of the image. In smooth region less number of watermark bits are embedded and in edge region more number of watermark bits are embedded. The pixels of the cover image are categorized into different types using the embedding capacity which is determined by the difference between the pair of pixels. For any pair of consecutive pixels, both pixels are embedded with variable bits of watermark using LSB substitution method. Here, the number of bits to be embedded is decided based on the category to which the difference value belongs. After embedding, the difference value between embedded pair of pixels is retained by readjustment so that the quality of the image is maintained and embedding capacity is improved. The experimental results show that the proposed scheme has high embedding capacity and less distortion in embedded images.

Index Terms—Adaptive; Edge region; Smooth region; Pixel Difference; Watermark

I. INTRODUCTION

In recent days, the Internet is becoming as the life channel for the transmission of text, audio, video etc. The new encoding and decoding methods together with the development of the Internet technology have made electronic distribution of data easy and convenient. The transmission of digital images has become very easy and convenient due to the drastic growth of Internet [11]. This advancement has enabled the extensive use of images in various applications. The Internet is an open source, anyone can easily access, modify or copy digital the images transmitted over the channel. Thus, it is difficult to verify the authenticity or integrity of the images being transmitted [1]. This difficulty can be resolved using Digital Rights Management standards. The Digital Right Management (DRM) is the technical measures that can be used to ensure that rights of digital image [1]. Two techniques can be used to ensure the rights of an image. One of them is Cryptography and the other is Watermarking. In cryptographic method, an image is distorted and the same is transmitted over the Internet. Public key or Private key cryptography system can be used

to distort the image. In watermarking technique, the owner of an image embeds a logo or information into an image [2], [4]. For authentication of an image the author extracts the information from the embedded image and justifies the rights. The information which is embedded into an image is perceptually undetectable and generated randomly such that the attackers are unable to obtain it. Thus, the watermarking method modifies the original image to embed watermark information.

Many watermarking schemes have been developed. However, these schemes can be grouped into two classes: spatial domain and frequency domain. The spatial domain methods are to embed the watermark by directly modifying the pixel values of the original image. LSB embedding is one of algorithm that uses spatial domain. When LSB is applied in the spatial or temporal domains, these approaches modify the least significant bits (LSB) of the host data. The invisibility of the watermark is achieved on the assumption that the LSB data are visually insignificant [13]. The watermark is generally recovered using knowledge of the PN sequence (and perhaps other secret keys, like watermark location) and the statistical properties of the embedding process. Most of these watermarking schemes distort the content of the original image. Generally, the performance of the watermarking schemes can be evaluated by payload capacity, image quality and complexity of embedding. But, high payload capacity and low distortion are conflicting requirements; the larger the capacity created by an embedding technique, the higher the distortion introduced by embedding [3].

In order to achieve high embedding capacity with controlled distortion, we propose a novel image watermarking scheme. The proposed scheme use the image adaptive based watermarking approach. The image adaptive based watermarking schemes are of great interest [5], [8]. These schemes have the impressive performance in transparency, sensitivity, and blind detection [6], [7], [12], [9]. The proposed scheme adaptively uses the difference value between the pair of consecutive pixels to embed the watermark bits. The number of bits to be embedded into the pixels are decided by computing the difference value between the pair of pixels. The large difference value indicates edge region and small difference

indicates smooth region. The more number of watermark bits are embedded into edge region and less number of watermark bits are embedded into smooth region.

The rest of the paper is organized as follows. The proposed watermarking scheme is explained in Section II. Section III gives details of the experimental results. Section IV concludes the paper.

II. PROPOSED SCHEME

The gray-scale image is represented by the standard 8 bits/pixel or 1 Bytes/pixel. Thus, each pixel is represented by 8 bits of gray-scale intensity values. The Least Significant Bit (LSB) substitution based watermarking scheme is an efficient scheme. Using LSB substitution scheme, more number of watermark bits can be embedded into cover image with less computational complexity [10]. If we use n bit LSBs substitution for each pixel we can able to embed the watermark at the most 8 bits/pixel. Generally, for all pixels the number of bits n may not be the same in entire image. The value of n is purely depend on the intensity of the pixel. But, the one of the conflicting requirement of the watermarking scheme is high embedding capacity with preserving perceptual quality of the watermarked image [4], [2].

In order to preserve the perceptual quality of image with large embedding capacity we proposed scheme, that embeds k bits of watermark into the pixels based on the difference between the consecutive non-overlapped pair of pixels. The difference between the consecutive pair of pixels will helps to determine the smooth and edge regions of the image. The proposed scheme reads the consecutive pair of pixels and determines the difference d between the pair of pixels. Then, these pixels are categorized into $\{s_1, s_2, s_3, s_4\}$ based on the d value. Table I show the grouping and determining the embedding capacity of pixels based on the value of d which is used in the proposed scheme. As shown in Table I the embedding capacity of each pixel is calculated and k bits of watermark is LSB substituted into pixels.

During embedding phase the proposed scheme use the variable number of watermark bits for LSB substitution. Hence, the embedding algorithm may alter the pixels by large value which led to change in d value. Which may shift the pairs of pixels from their initial category to other category. To address this problem we defined re-adjustment phase which adjusts the modified pixels to bring modified pixels into initial category. Fig. 1 show the flow diagram of embedding algorithm. The embedding and extraction algorithms are described in the following section

A. Embedding Algorithm

The embedding algorithm uses the gray-scale cover image I of size $m \times n$. The consecutive pairs of pixels p_i and p_{i+1} are retrieved from the image I and the difference $d_i = |p_i - p_{i+1}|$ is calculated. Based on the value of d_i the k bits of watermark is embedded into cover image. The embedding algorithm steps are given below:

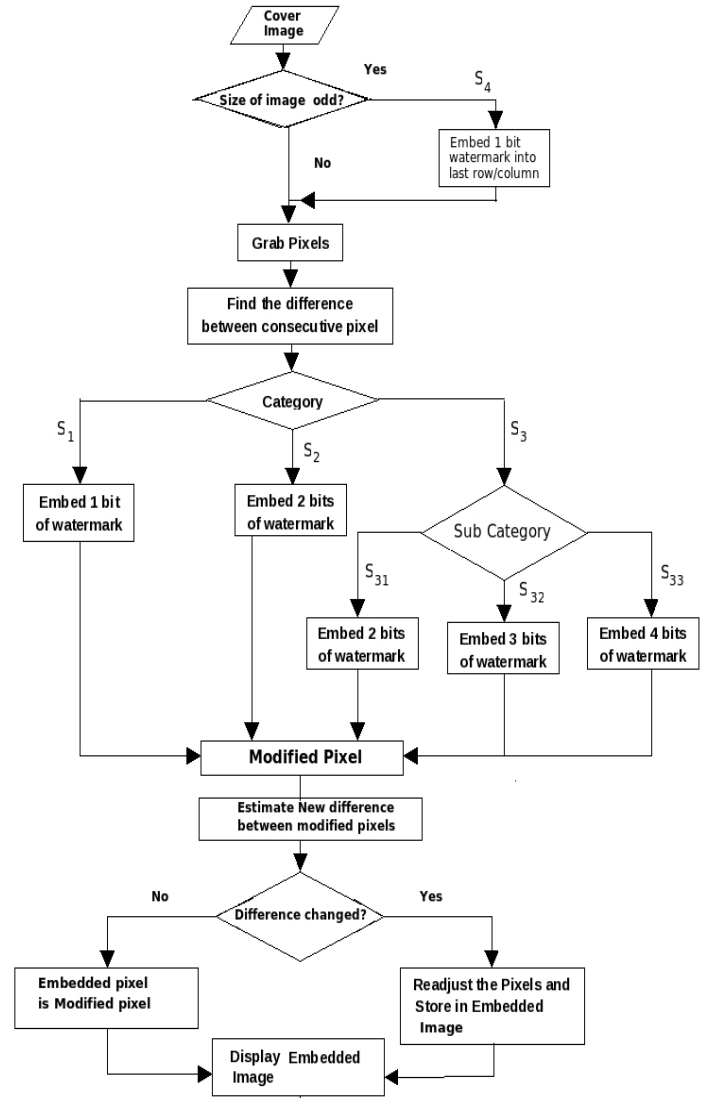


Fig. 1: Embedding algorithm

Embedding Algorithm:

- 1) Read cover image I of size $m \times n$
- 2) If $\{m, n\} \in$ even number
 - a) Find the difference value d_i between the pair of consecutive pixels say p_i and p_{i+1} i.e. $d_i = |p_i - p_{i+1}|$.
 - b) Find the number of bits k to be embedded into p_i and p_{i+1} based on the category to which the d_i belongs using Table I.
 - c) Apply k watermark bits LSB substitution on the corresponding pixel pairs. Assume the pixel pairs obtained after embedding are p'_i and p'_{i+1} .
 - d) After embedding, it may be possible that the difference d'_i between the pixel pairs p'_i and p'_{i+1} changes or shifts from its initial category to other

TABLE I: Categorizing and determining embedding capacity of the pixels based on d

Difference d	Category Based On d	Number Of Bits To Be Embedded
0 – 1	s_1	1 bit
2 – 8	s_2	2 bits
9 – 15	s_{31}	2 bits
16 – 32	s_{32}	3 bits
33 – 255	s_{33}	4 bits
If image contains odd number of columns/rows Last row/column is embedded	s_4	1 bit

 TABLE II: The $PSNR$ and MSE between the cover image and watermarked images

Properties	Lena	Flower	Elephant	Chessboard
Size	300 × 420	400 × 300	202 × 246	256 × 256
MSE	14	2	8	2
PSNR (dB)	36.66	45.12	39.10	38.88
Embedding Capacity (bits)	327174	187900	92358	65536
Embedding rate (bpp)	2.60	1.56	1.85	1

category. Hence, it is necessary to readjust the pixel pairs, such that their difference values shift back to its original category. Assume the pixel pairs obtained after the readjustment are x_i and x_{i+1} respectively. The readjustment should be done in such a way that x_i and x_{i+1} are within the range $[0, 255]$ and $(x_i - p_i)^2 + (x_{i+1} - p_{i+1})^2$ should be minimum to reduce the mean square error between the pixels.

e) Readjustment phase: If the difference $d'_i = |p'_i - p'_{i+1}|$ falls below the lower bound of d_i , then it is called lower level and if it exceeds the upper bound of d_i , then it is called upper level. Using following operations the readjustment of the pixels will be done:

- 1) $d_i \in s_1$ and $d'_i \in$ higher level then using the steps as given Fig 2 readjustment of the pixel is done:
- 2) $d_i \in s_{33}$ and $d'_i \in$ lower level then using the steps as given Fig 3 readjustment of the pixel is done:
- 3) $d_i \in s_2$ and $d'_i \in$ lower level, then use step 2 to readjust the pixels.
- 4) $d_i \in s_{31}$ and $d'_i \in$ lower level, then use step 2 to readjust the pixels.
- 5) $d_i \in s_{32}$ and $d'_i \in$ lower level, then use step 2 to readjust the pixels.
- 6) $d_i \in s_2$ and $d'_i \in$ higher level, then use step 1 to readjust the pixels.
- 7) $d_i \in s_{31}$ and $d'_i \in$ higher level, then use step 1 to readjust the pixels.
- 8) $d_i \in s_{32}$ and $d'_i \in$ higher level, then use

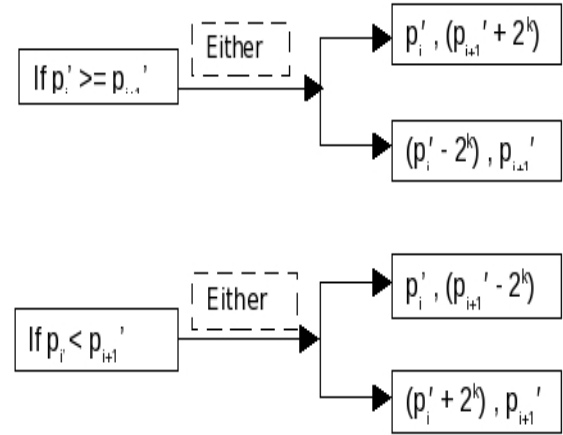


Fig. 2: Readjustment of pixel

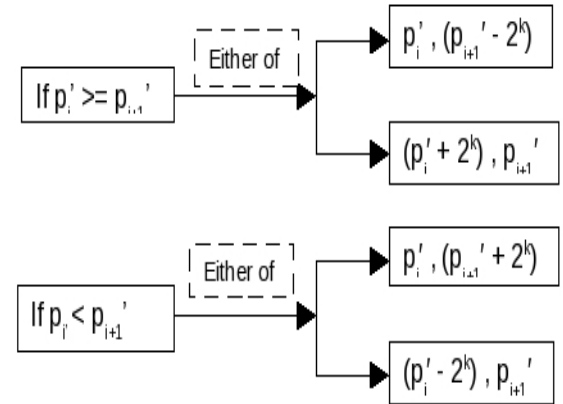


Fig. 3: Readjustment of pixel

step 1 to readjust the pixels.

- f) If $\{m, n\} \in$ odd number: Read the pixels from the last column/row pixels of an image and embed one bit of watermark to create category s_4 and use step (2) for an image with even size for rest of the pixels.

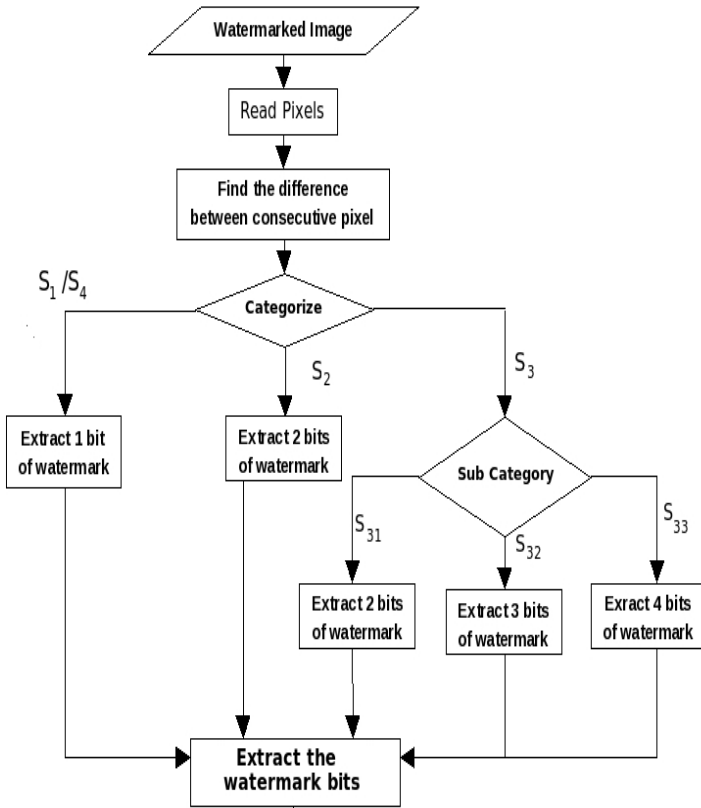


Fig. 4: Extraction algorithm

B. Extraction Algorithm

The extraction algorithm use the gray-scale watermarked cover image I' of size $m \times n$. The consecutive pairs of pixels p'_i and p'_{i+1} are retrieved from the image I' and the difference $d'_i = |p'_i - p'_{i+1}|$ is calculated. Based on the value of d'_i the k bits of watermarks are extracted from the watermarked cover image. Fig. 4 show the flow diagram of extraction algorithm. The extraction algorithm steps are given below:

Extraction Algorithm:

- a) Read watermarked cover image I' of size $m \times n$
- b) If $\{m, n\} \in$ even number
 - i) Find the difference d'_i between p'_i and p'_{i+1} i.e. $d'_i = |p'_i - p'_{i+1}|$.
 - ii) Determine the category to which d'_i belongs.
 - iii) Extract the watermark from the LSB's of all the pixel pairs based on the category to which it belongs.
- c) If $\{m, n\} \in$ odd number, then extract one bit of watermark from the last column/row pixels.

C. Illustration with example

In this section, we describe few examples of pixel pairs with the embedding of the watermark and readjusting of the pixel pairs.

Example 1:

- a) Assume the pixel pairs $p_1 = 255$ and $p_2 = 254$.
- b) The difference d between p_1 and p_2 is calculated as $d = |p_1 - p_2| = |255 - 254| = 1$.
- c) Since $d = 1$ and it falls into s_1 category, one bit of watermark is to be embedded into pixels.
- d) Select randomly generated watermark bit $k_1 = 0$ and $k_2 = 1$.
- e) After performing the LSB substitution of k_1 and k_2 into the pixels p_1 and p_2 respectively, p_1 changes to $p'_1 = 254$ and p_2 changes to $p'_2 = 255$.
- f) The new difference d' between p'_1 and p'_2 is calculated as $d' = |p'_1 - p'_2| = |254 - 255| = 1$.
- g) Since d falls into the same category i.e., s_1 no readjustment is required.

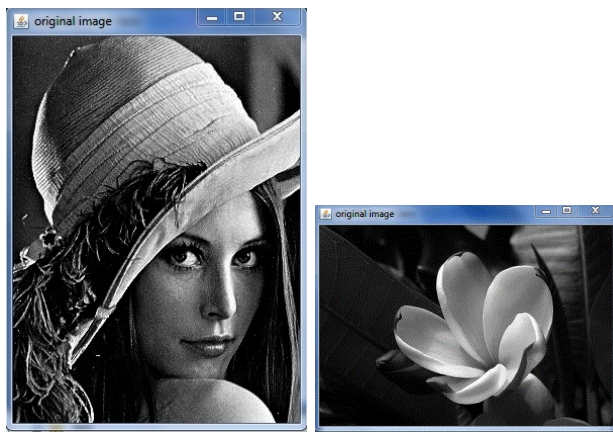
Example 2:

- a) Assume the pixel pairs $p_1 = 255$ and $p_2 = 253$.
- b) The difference d between p_1 and p_2 is calculated as $d = |p_1 - p_2| = |255 - 254| = 1$.
- c) Since $d = 1$ falls into s_2 category hence two bits of watermark is to be embedded into pixels.
- d) Select randomly generated watermark bits $k_1 = 11$ and $k_2 = 11$.
- e) After the LSB substitution of k_1 and k_2 into the pixels p_1 and p_2 respectively, then p_1 changes to $p'_1 = 255$ and p_2 changes to $p'_2 = 255$.
- f) The new difference d' between p'_1 and p'_2 , is calculated as $d' = |p'_1 - p'_2| = |255 - 255| = 0$.
- g) Since d' shifts its category from s_2 to s_1 , there is a need to readjust the pixels as $p_1=255$ and $p'_2 = 255 - 2^2 = 255 - 4 = 251$.
- h) Now, the difference $d' = 4$ which shifts pair of pixels back to s_2 category.

III. EXPERIMENTAL RESULTS

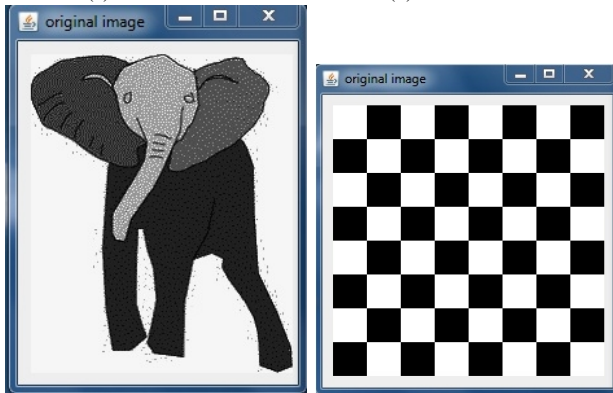
For the experimental analysis, we have implemented the proposed scheme using JAVA package. In the series of experiments, the perceptual quality of watermarked image is measured using Peak Signal to Noise ($PSNR$) and Mean Square Error (MSE) between the watermarked and cover image respectively. The experimental values of $PSNR$ and MSE between watermarked and cover image shows that both images are perceptually similar.

In order to analyze the embedding capacity of the proposed scheme, we considered different watermark bits for embedding on different cover images. For the experimental determination of the embedding capacity, we considered the Lena, Flower, Elephant and Chessboard images of each with different sizes as shown in Fig. 5. Four different watermarks of different sizes are



(a) Lena

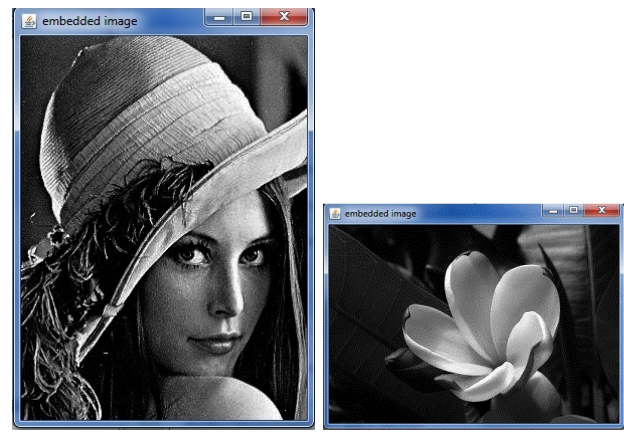
(b) Flower



(c) Elephant

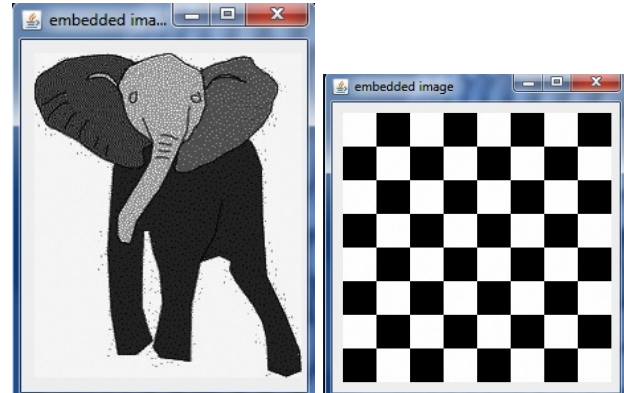
(d) Chessboard

Fig. 5: Cover images



(a) Lena

(b) Flower



(c) Elephant

(d) Chessboard

Fig. 6: Watermarked images

generated using pseudo random generator and used in the embedding algorithm. Fig. 6 shows the watermarked images generated by proposed scheme. Table II show the values MSE and $PSNR$ estimated between original cover image watermarked cover images.

IV. CONCLUSION

The proposed watermarking scheme is blind, invisible and spatial domain based scheme. The proposed scheme uses method of adaptive LSB substitution for embedding watermark bits. It uses the difference between the pair of pixels to determine the smooth and edge areas of the cover image. Adaptively in smooth area a small number of watermark bits are embedded where as in edge area large number of watermark bits are embedded. The readjusting phase is used to maintain the perceptual quality of watermarked image. Experimental results show that our approach obtains both larger capacity and higher perceptual quality of watermarked image.

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REFERENCES

- [1] W. Jonker, J.P. Linnartz, *Digital Rights Management in Consumer Electronics Products*, IEEE Signal Processing Magazine, Vol. 21, Issue 2, pp. 82-91, March 2004.
- [2] S. Katzenbesser and F.A.P Petitcolas, "Information Hiding Techniques for Steganography and Watermarking", Artech House, Inc. Norwood, MA, USA, (2000).
- [3] Cox, I. Robust watermarking, ENCRYPT Summer School on Multimedia Security, Salzburg, Austria, Sept. 22, 2005.
- [4] I.J. Cox, M.L. Miller and J. A. Bloom, J. Fridrich, T. Kalker, "Digital Watermarking and Steganography", Second edition, Morgan Kaufmann Publishers, 2008.
- [5] Podilchuk, C., Zeng, W., Image-Adaptive Watermarking Using Visual Models, IEEE Journal on Selected Areas in Communications, Issue 16, vol.4, 1998, pp. 525-539.
- [6] Al-Otum H, Samara N. "Adaptive blind wavelet-based watermarking technique using tree mutual differences". Journal of Electronic Image vol. 15, issue 4, pp. 043011.1- 043011.12, 2006.
- [7] Jianzhong Li, Xiangsu Zhang, Shou Liu, Xuechang Ren, "An Adaptive Secure Watermarking Scheme for Images in Spatial Domain Using Fresnel Transform", 1st International Conference on Information Science and Engineering (ICISE), pp.1630-1633, 26-28 Dec. 2009.
- [8] Qing Guoa, Jun Guob, Zhengjun Liuc, Shutian Liud, "An adaptive watermarking using fractal dimension based on random fractional Fourier transform", Journal of Optics & Laser Technology, vol. 44, Issue 1, pp. 124-129, February 2012.
- [9] Ming Tong, Jia Hu and Hongbing Ji, "An adaptive digital image watermark algorithm based on gray-scale morphology", Journal of Electronics (China), vol.26, No.3, pp.417-422, 2009.
- [10] Larjani, H.H, Rad, G.R., A new spatial domain algorithm for gray scale images watermarking, International Conference on

- Computer and Communication Engineering, ICCCE-2008, pp.157-161, 2008.
- [11] Ingemar, J. Cox and Matt. L. Miller, *The First 50 Years of Electronic Watermarking*, EURASIP Journal on Applied Signal Processing, Vol.2, pp.126-132,2002.
 - [12] Cheng-Hsing Yang, Chi-Yao Weng, Shih-Jeng Wang and Hung-Min Sun, "Adaptive Data Hiding in Edge Areas of Images With Spatial LSB Domain Systems", IEEE Transactions on Information Forensics and Security, vol. 3, no.3, pp. 488-497, 2008
 - [13] Ingemar, J. Cox, Matthew, L. M., Jeffrey, A. Bloom, Jassica Fridrich, Tan Kalker, *Digital Watermarking and Steganography*, Second edition, M.K. Publishers, 2008.
 - [14] B.M. Macq and J.J. Quisquater, *Cryptology for digital tv broadcasting*, Proceeding of the IEEE, vol. 83, pp. 944-957, June 1995.
 - [15] W. Bender, D. Gruhl, N. Marmorato, and A. Lu, *Techniques for data hiding*, IBM Systems Journal, vol. 35, no 3, pp 313-336, 1996.
 - [16] Nino, D. Abdallah, M. Harnam, B. *Dual Domain Watermarking in the Biological Color Model*, IEEE International Conference on Information and Automation (ICIA), pp. 407-411, 15-17 Dec 2006.