# Non Correlation DWT Based Watermarking Behavior in Different Color Spaces

Mehdi Khalili
Dept. of Computer and Informatics Engineering
Payame Noor University
Tehran, Iran

Mahsa Nazari
Dept. of Computer and Informatics Engineering
Payame Noor University
Tehran, Iran

***Abstract*—There are two digital watermarking techniques. Digital watermarking techniques based on correlation and digital watermarking techniques that are not based on correlation. In previous work, we proposed a DWT2 based CDMA image watermarking scheme to study the effects of using eight color spaces RGB, YCbCr, JPEG-YCbCr, YIQ, YUV, HSI, HSV and CIELab, on watermarking algorithms based on correlation techniques. This paper proposes a non correlation based image watermarking scheme in wavelet transform domain and tests it in the same color spaces, to develop studying, reach a comprehensive analysis and focus on satisfying the requirements of based non coloration watermarking algorithms. To achieve more security, imperceptibility and robustness of the proposed scheme, first, the binary watermark image encodes by applying ATM, CCM and exclusive OR. Then, the scrambled watermark embeds into intended quantized approximation coefficients of wavelet transform by LSB insertion technique.**

***Keywords*—*ATM; CCM; DWT2; color spaces; non correlation watermarking technique***

## I. Introduction

In this modern era, computers and the internet are major communication media that bring the different parts of the world into one global virtual world. As a result, people can easily exchange information and distance is no longer a barrier to communication. However, the safety and security of long-distance communication remain an issue. This is particularly important in the case of confidential data. The need to solve this problem has led to the development of watermarking schemes [1, 2]. A digital watermark is an identification code that carries information about the copyright owner, the creator of the work, the authorized consumer, etc. It is embedded in the multimedia data, digital, serial number, text, image, logo and other types of information, and plays a role of copyright protection, signs product, secret communications, confirming data belonging, identifying data authenticity and so on [3].

Typical watermarking schemes embed the watermark by altering coefficients related to the original source in some specific domain, including the spatial domain methods, transform domain techniques using discrete cosine transform (DCT), discrete wavelet transform (DWT) and discrete Fourier transform (DFT), or singular value decomposition (SVD) and vector quantization (VQ) domain schemes [4, 5].

Among frequency domains, the discrete wavelet transform can strengthen the resistance under attacks [6, 7]. Although there are no universal requirements to be satisfied by all watermarking applications, some main directions are generally considered by the research studies. In order to be effective, the watermark should be perceptually invisible for a human observer (i.e. the imperceptibility property) and its detection should be successful even when the watermarked content is attacked (i.e. the security and robustness property) [8]. There are two digital image watermarking techniques. Digital watermarking techniques based on correlation and digital watermarking techniques that are not based on correlation [9]. In watermarking techniques based on correlation, to extract the watermark, the correlation coefficients between the watermarked content will calculate with a definite threshold and if the correlation is more than the defined threshold, it means that the watermark detector determines watermark image from the content of the image [10, 11]. The simplest example of a watermarking technique that is based on non correlation is the method of least significant bits insertion (LSB). In this method, the least significant bits of many components are watermarked by information [12]. Because the least significant bits do not include visual important information, therefore we can easily replace many of watermarked bits with this level [9, 13].

On the other hand, color spaces abound, but not all of them are appropriate for the entire spectrum of image processing tasks. A color space is a mean of specifying colors, and they can be classified into three basic parts: HVS (human visual system) based color spaces (e.g. RGB, HVS, HSI and etc.), application specific (e.g. YCbCr, YUV, YIQ and etc.) and CIE color spaces (e.g. CIELab and etc.) [14].

The motivation for this study is that there is not a common criterion about which color space is the best one to satisfy image watermarking requirements. There are a lot of studies which describe and use a lot of color spaces to improve each watermarking property, but each study usually focuses on a specific color space, showing the results obtained with that color format. Although, In [14], a DWT2 based CDMA image watermarking scheme proposed and tested in eight color spaces RGB, YCbCr, JPEG-YCbCr, YIQ, YUV, HSI, HSV and CIELab, to explore how the choice of color space, influences the results of correlation based image watermarking algorithms with respect to changes in watermarking anticipating properties such as imperceptibility and robustness against different attacks, but a similar study on based non correlation image watermarking has not done yet. Therefore, in this paper, using wavelet transform, a non correlation based image watermarking scheme proposes and testes in the same color spaces, to develop the results of previous work in [14] and achieve a comprehensive investigation on the effects of aforementioned color spaces on both based correlation and non correlation watermarking techniques. In the proposed approach, to achieve more security, imperceptibility and robustness of binary watermark image, first, it encodes by applying Arnold's transform map, cross chaos sequence and exclusive OR. Then, the scrambled watermark embeds into intended quantized approximation coefficients of wavelet transform by LSB insertion technique.

## II. BASIC THEORIES

### A. Two Dimensional Discrete Wavelet Transform

Single level 2D-DWT decomposes an image into 4 different frequency sub-bands LL, LH, HL and HH which are named according to the filter (high-pass or low-pass) applied to the original image in horizontal and vertical directions. For example, HL sub-band is obtained by applying a high pass filter in horizontal direction and low pass filter in vertical direction. The size of new sub-bands is reduced to 1/4 of original size. DWT has many advantages over other transforms due to its ability to represent an image in both spatial and frequency domain simultaneously and to separate the different frequency components of an image. Frequency separation property of DWT is utilized in digital image watermarking to insert watermarks in different frequency sub-bands [15, 16].

### B. Cross Chaotic Sequence (CCM)

Chaos is a kind of random-like process which occurred in nonlinear dynamic systems. It is neither periodic nor convergent, but significantly sensitive to its initial conditions. Cross chaotic map is defined as follows [17]:

$$\begin{cases} x_{i+1} = 1 - \mu * y_i^{\,2} \;; \quad x, y \in [-1,\ 1] \\ y_{i+1} = Cos(k\ Cos^{-1}\ x_i); \end{cases} \tag{1}$$

where μ and k are control parameters of the system. The system will show better chaotic behavior when μ=2 and k=6. Two chaotic sequences X= x0, x1...xm and Y= y0, y1…yn, using initial values x0, y0 and control parameters, are generated. X and Y are reconstructed as row and column matrix respectively. Then, they are multiplied with each other, to get a new matrix k′. Finally, this matrix is converted to a binary matrix by using the equation (2).

$$f(x) = \begin{cases} 0 \;; \quad 0 < \ k'(i,j) \ \leq 0.5 \\ 1 \;; \quad 0.5 < \ k'(i,j) \ \leq 1 \end{cases} \tag{2}$$

The advantage of cross chaotic map is that, it has larger key space than 1D logistic chaos sequence, which is used in previous discussed papers. This is due to the six unknown parameters. Because of its larger key space, it gives higher security to image. Also, cross chaotic map resist most of the known attacks such as statistical attack, differential attack and exhaustive attack [17].

### C. Arnold's Transform Map (ATM)

The Arnold transform map can shift the positions of pixels instead of changing their values. Recently, it is often used for image encryption and watermarking. It is expressed as [18]:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} \ \text{mod} \ \ N \tag{3}$$

where $\begin{pmatrix} x \\ y \end{pmatrix}$ and $\begin{pmatrix} x' \\ y' \end{pmatrix}$ represent the position vector of image pixel shifted before and after, respectively, and mod denotes the modulus after division. The parameter N is the size of the target image, which is used to determine the period of Arnold transform. The number of times Arnold transform is performed is fixed at different values along with different N for enhancing the security of image encryption. The period rules can recover the information of the original image. But we can also find that, when N becomes larger, the period is also larger. That is to say, we should use more transform times to recover the original information. So an inverse Arnold transform is demanded. The inverse Arnold transform can be written as:

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{pmatrix} 2 & -1 \\ -1 & 1 \end{pmatrix} \begin{pmatrix} x' \\ y' \end{pmatrix} \ \text{mod} \ \ N \tag{4}$$

where $A^{-1} = \begin{pmatrix} 2 & -1 \\ -1 & 1 \end{pmatrix}$ is used instead of $A = \begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix}$.

### D. Color Spaces

As it was mentioned above, a color space is a mathematical representation of a set of colors. Three fundamental color models are: color spaces based on HVS human visual system (e.g. RGB, HVS, HSI and etc.); application specific (e.g. YCbCr, JPEG-YCbCr, YUV, YIQ and etc.) and CIE color spaces (e.g. CIELab and etc.) [14]. In RGB model, colors are specified in terms of the three primary colors red (R), green (G) and blue (B). It is an additive model because all colors are created from these primary colors combining them in various ways. The amount of each primary color gives its intensity. If all components are of highest intensity, then the color white results. This is the most extended and used color format because it is the one used in displays technology [19]. In YCbCr model, colors are specified in terms of luminance (Y channel) and chrominance (Cb and Cr channels). Cb represents the value for the blue component (B − Y) and Cr saves the information for the red color component (R − Y). YCbCr is widely used for digital video encoding [19]. In [20], we presented a rescaling formula for YCbCr called JPEG-YCbCr which used in the JPEG image format, with Y, Cb and Cr in [0,1]. UUV model defines a color space in terms of one luminance (Y channel) and two chrominance components (UV channels). U represents the color difference between blue signal and luminance (B − Y) and V represents the difference between red and luminance (R − Y). YUV is used for analog television such as PAL or NTSC. Human vision is much more sensitive to luminance variations than chrominance variations. YUV codification takes advantages of this fact, giving more bandwidth to luminance so that the color space goes closer to the human perception (although YUV is not as close as HSV color space). YUV signals are created from an original RGB (red, green and blue) source. The weighted values of R, G and B are added together to produce a single Y signal, representing the overall brightness, or luminance, of that point. The U signal is then created by subtracting the Y from the blue signal of the original RGB, and then scaling; and V by subtracting the Y from the red, and then scaling by a different factor. Therefore, conversions between RGB and YUV formats can be done through linear transformations [19]. YIQ color space is similar to YUV model. The Y component represents the luminance information, while I (in-phase) and Q (quadrature) represent the chrominance information. In YUV, the U and V components can be thought as X and Y coordinates within the color space. I and Q can be thought as a second pair of axes on the same graph, rotated 33o, therefore IQ and UV represent different coordinate systems on the same plane. 'I' is in the range orange–blue, and 'Q' in the range purple–green. Therefore, transformations between RGB and YIQ color spaces are linear too [19]. HSI is the most frequently used applications oriented color space. HSI color space is based on the human visual perception theory and is suitable for describing, and interpreting color. H, S and I represent hue, saturation, and intensity respectively. The supposed separation of the luminance component from chrominance information is stated to have advantages in applications such as image processing. Embedding the watermark in the intensity component of HSI color space can resist the filtering, sharpening etc. attacks effectively [21]. HSV color space represents colors in terms of Hue (or color-depth), Saturation (or color-purity) and intensity of the Value (or color-brightness). Hue refers to color type, such as red, blue, or yellow. It takes values from 0 to 360 (but it is normalized to 0–100% in some applications). Saturation refers to the vibrancy or the purity of the color. It takes values from 0 to 100%. The lower the saturation of a color, the more "greyness" the color is represented and the more faded the color will appear. Finally, Value component refers to the brightness of the color. It takes the same range as the saturation (0–100%) [19]. In 1976, the International Commission on Illumination (CIE) recommended the CIE L*a*b*, or CIELab color space for color quality estimation. The color space CIELab is a perceptually uniform color space created by nonlinear transformations of tristimulus XYZ values to overcome the non-uniformity of color spaces which had been discussed by Macadam. The main intention was to provide a standard and approximate uniform color space which can be used to compare the color values easily. In this color space the differences between points plotted in the color space correspond to visual differences between the colors plotted. The CIE recommended to use XYZ coordinate system to transform RGB to L*a*b* [14].

## III. The Proposed Watermarking Algorithm

As it was mentioned before, the most watermarking algorithms which are based on non correlation techniques use LSB insertion method. In [22], the author has proposed a LSB-based method, called the inverted pattern (IP) LSB substitution in which each section of secret images is determined to be inverted or not inverted before it is embedded. Also, in embedding process, the calculation of mean square error between cover image and message image is used to embed the secret message bits or the inverted message bits. In [23], a watermarking algorithm has proposed in which the neighboring symbol's mean value of selected pixels is calculated to embed the watermark bits into LH2 coefficients of wavelet decomposition. In [24], the original watermark is generated by a halftoned version of the host image and inserted into least significant bits of host image.

In this paper, the properties of DWT2, ATM, CCM and also applying exclusive OR are combined in order to embed a highly imperceptible and robust watermark image for secured transmission of data. This scheme is blind and so there is no need to original watermark in the extraction process. The Figs.1 and 2 show the block diagrams of Watermark Embedding and Watermark Extraction, respectively.

### A. Watermark Embedding

Watermark embedding is used to insert the watermark into the host image to obtain the watermarked image.

Steps:

*1) Scramble original and watermark images by applying Arnold transform map, respectively, for N and M times.*

*2) Use Cross Chaos equation on scrambled watermark image.*

*3) Encrypt the watermark sequence by applying the exclusive OR.*

*4) Convert RGB channels of scrambled original image into the intended channels.*

*5) Make three-level wavelet decomposition to the first channel of converted image and use the coarsest subband LL3 is taken as the target subband for embedding watermarks.*

*6) Save the signs of selection coefficients in a sign matrix.*

*7) Quantize the absolute values of selection coefficients.*

*8) Embed encrypted watermark instead of the second least significant bits of target coefficients that have smallest quantization errors.*

*9) Effect the sign matrix to the embedded coefficients.*

*10) Make a wavelet reconstruction of all changed and unchanged DWT coefficients of the first channel.*

*11) Combine the watermarked channel with the other two channels.*

*12) Reconvert the image form intended color space to RGB color space.*

*13) Re-scramble the reconverted image by applying ATM for N times to generate the watermarked image.*

*14) Save the iterative numbers of Arnold transforms on the original and watermark images (N and M), the initial value of* *cross chaotic map, indexes of changed selection coefficients and index of the embedded subband as the authenticated keys.*

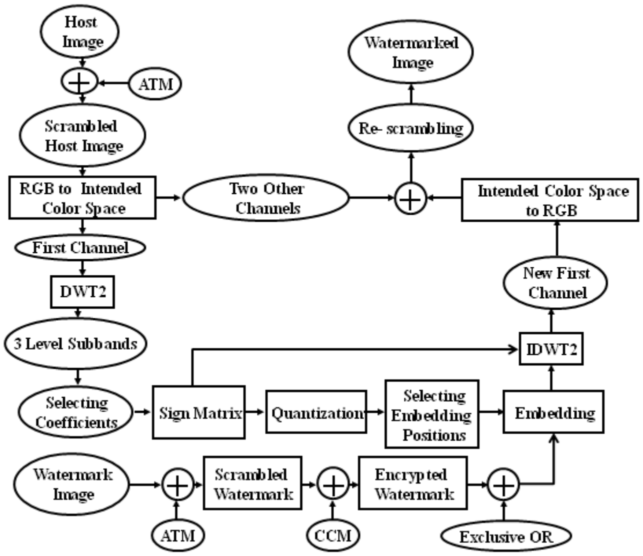



Fig. 1. The watermark embedding block diagram of the proposed approach

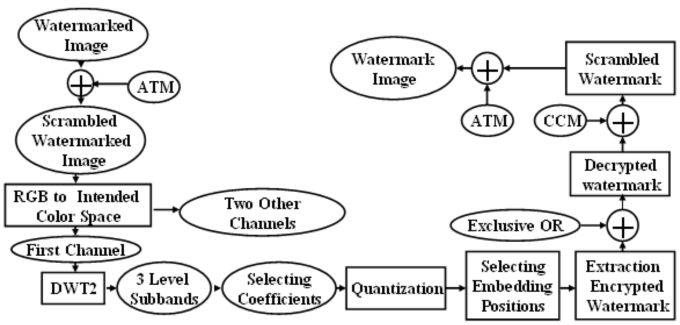



Fig. 2. The watermark extraction block diagram of proposed approach

## *B. Watermark Extraction*

The extracting algorithm of watermarking is the converse process of embedding. As it is a blind scheme, there is no need to the original image for extracting the watermarks. The detailed steps are described in details in the following steps:

*1) Re-fetch the stored authenticated keys.*

*2) Scramble the watermarked imaged by applying the Arnold's transformation for N times.*

*3) Convert RGB channels of a scrambled watermarked image into the intended color space.*

*4) Decompose the first channel into three levels with ten DWT subbands. The subband LL3 is taken as the target subband for extraction watermarks.*

*5) Quantize the absolute values of LL3 subband.*

*6) Extract the encrypted watermark from the second least significant bits of changed coefficients.*

*7) Decrypt the extracted watermark image by applying exclusive OR.*

*8) Take the initial value of cross chaotic map to make the extracted watermark image.*

*9) Re-generate the watermark image by applying Arnold's transform for M times.*

## IV. ANALYSIS OF PROPOSED ALGORITHM AND EXPERIMENTAL RESULTS

In order to evaluate the algorithm MATLAB R2007a software was used as a platform and the proposed algorithm is applied to three 256×256 famous images: Lena, Peppers and Baboon shown in Fig. 3(a-c) and a 27×27 binary watermark image shown in Fig. 3(d). Fig. 4 shows the scrambling process of watermark image by ATM method, too. Also, for computation of the wavelet transforms, 7-9 biorthogonal spline (B-spline) wavelet filters were used. Cause of using B-spline function wavelet is that, B-spline functions, do not have compact support, but are orthogonal and have better smoothness properties than other wavelet functions [25].

As we know, there is a direct relationship between processing time and computational complexity. So the processing times (in seconds) of the proposed scheme in all color spaces are calculated to consider the computational complexities of each one of them. The obtained results are shown in Table 1.

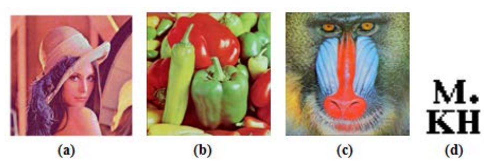



Fig. 3. (a-c) The host Lena, Peppers, and Baboon images and (d) The watermark image

As it is seen, RGB need the minimum times for embedding and extraction processes of an image. Afterwards, respectively YCbCr, YUV, YIQ, JPEG-YCbCr, HSI, HSV and finally CIELab need the minimum processing times. It was expectable. Because, in RGB, there is no need to color space conversion; in opposite, CIELab has the most complicated formulas to color space conversion. Therefore, we can conclude that in non correlation based watermarking techniques, the maximum computational complexities respectively belong to CIELab, HSV, HSI, JPEG-YCbCr, YIQ, YUV, YCbCr and RGB.

After a brief discussion on computational complexities, the similarity of original host images and watermarked images is measured by the standard correlation coefficient (Corr) as [26]:

$$Correlatio = \frac{\sum (x - x')(y - y')}{\sqrt{(x - x')^2}\sqrt{(y - y')^2}} \tag{5}$$

TABLE I. PROCESSING TIMES THE PROPOSED SCHEME IN DIFFERENT COLOR SPACES

| Color Space | *Lena* | | *Peppers* | | *Baboon* | |
|---|---|---|---|---|---|---|
| | ***Embedding Time (S)*** | ***Extracting Time (S)*** | ***Embedding Time (S)*** | ***Extracting Time (S)*** | ***Embedding Time (S)*** | ***Extracting Time (S)*** |
| **RGB** | 1.1948 | 0.3432 | 1.2216 | 0.3588 | 1.3444 | 0.3604 |
| **YCbCr** | 1.4976 | 0.6690 | 1.5012 | 0.5701 | 1.5468 | 0.6083 |
| **JPEG-YCbCr** | 1.6224 | 0.7188 | 1.6681 | 0.7276 | 1.6925 | 0.7744 |
| **YIQ** | 1.5288 | 0.5890 | 1.5444 | 0.6011 | 1.5600 | 0.6185 |
| **YUV** | 1.5176 | 0.5741 | 1.5262 | 0.5844 | 1.5590 | 0.6119 |
| **HSV** | 1.7316 | 0.7976 | 1.7559 | 0.8163 | 1.8222 | 0.8295 |
| **HSI** | 1.7160 | 0.7900 | 1.7401 | 0.8077 | 1.8006 | 0.8238 |
| **CIELab** | 2.1620 | 1.0900 | 2.3664 | 1.5133 | 2.6088 | 1.8777 |

Moreover, the peak signal-to-noise ratio (PSNR) is used to evaluate the quality of the watermarked images as [27]:

$$PSNR = 10 \log_{10} \frac{255^2}{MSE} \ (dB) \tag{6}$$

where mean-square error (MSE) is defined as [27]:

$$MSE = \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} \left( h_{i,j} - h'_{i,j} \right)^2 \tag{7}$$

where $\{h_{i,j}\}$ and $\{h'_{i,j}\}$ are the gray levels of pixels in the host and watermarked images, respectively.

Also the normalized correlation (NC) coefficient is used to measure the similarity between original watermarks W and the extracted watermark W'. It was defined as [27, 28]:

$$NC = \frac{\sum_i \sum_j w_{i,j} * w'_{i,j}}{\sum_i \sum_j w_{i,j}^{\ 2}} \tag{8}$$

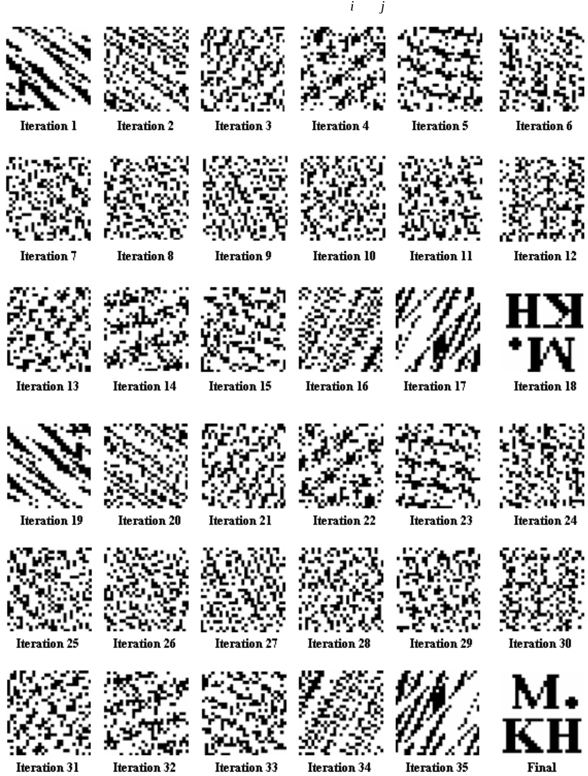



Fig. 4. The scrambling process of watermark image by ATM method

## A. *Imperceptibility and Transparency Experiments*

According to literature, if the PSNR be greater, the image quality is better. In general, a watermarked image is acceptable by human perception if its PSNR is greater than 30 dBs. In other words, the correlation is used for evaluating the robustness of watermarking technique and the PSNR is used for evaluating the transparency of watermarking technique [26, 28]. Fig. 5 shows the watermarked images in all color spaces and table 2, shows the obtained results of PSNR, correlation and normalized correlation values.

TABLE II. THE PSNRS, CORRELATION (CORR) AND NORMALIZED CORRELATION (NC) VALUES OF WATERMARKED IMAGES IN DIFFERENT COLOR SPACES

| | **PSNR (dB)** | | |
|---|---|---|---|
| **Color Space** | ***Watermarked Images*** | | |
| | ***Lena*** | ***Peppers*** | ***Baboon*** |
| **RGB** | 54.95 | 54.73 | 54.43 |
| **YCbCr** | 54.65 | 54.02 | 54.05 |
| **JPEG-YCbCr** | 55.68 | 55.94 | 55.47 |
| **YIQ** | 55.36 | 55.80 | 54.71 |
| **YUV** | 55.36 | 55.80 | 54.71 |
| **HSV** | 55.44 | 54.99 | 55.36 |
| **HSI** | 55.43 | 54.98 | 55.35 |
| **CIELab** | 54.74 | 54.67 | 54.31 |
| | **Corr** | | |
| **Color Space** | ***Watermarked Images*** | | |
| | ***Lena*** | ***Peppers*** | ***Baboon*** |
| **RGB** | 0.9999 | 0.9999 | 0.9999 |
| **YCbCr** | 0.9997 | 0.9998 | 0.9996 |
| **JPEG-YCbCr** | 0.9998 | 0.9999 | 0.9997 |
| **YIQ** | 0.9998 | 0.9999 | 0.9997 |
| **YUV** | 0.9998 | 0.9999 | 0.9997 |
| **HSV** | 1.0000 | 1.0000 | 1.0000 |
| **HSI** | 1.0000 | 1.0000 | 1.0000 |
| **CIELab** | 0.9996 | 0.9992 | 0.9990 |
| | **NC** | | |
| **Color Space** | ***Watermarked Images*** | | |
| | ***Lena*** | ***Peppers*** | ***Baboon*** |
| **RGB** | 1.0000 | 1.0000 | 1.0000 |
| **YCbCr** | 1.0000 | 1.0000 | 1.0000 |
| **JPEG-YCbCr** | 1.0000 | 1.0000 | 1.0000 |
| **YIQ** | 1.0000 | 1.0000 | 1.0000 |
| **YUV** | 1.0000 | 1.0000 | 1.0000 |
| **HSV** | 1.0000 | 1.0000 | 1.0000 |
| **HSI** | 1.0000 | 1.0000 | 1.0000 |
| **CIELab** | 1.0000 | 1.0000 | 1.0000 |

The table results show, in all color spaces, the proposed scheme yields satisfactory watermark imperceptibility and transparency. All of the PSNRs are greater than 54 dB and correlation values are all greater than 0.999. In addition, normalized correlations are all equal to 1. It means the embedded watermark images are extracted completely, without any error. It should be mentioned that the proposed scheme increases security in comparing with the similar algorithms because of three times encoding (i.e. using ATM, CCM and exclusive OR) on watermark image. In addition, encoding host images by ATM method and embedding watermarks in the first channel of each color space are the other criteria for increasing security.

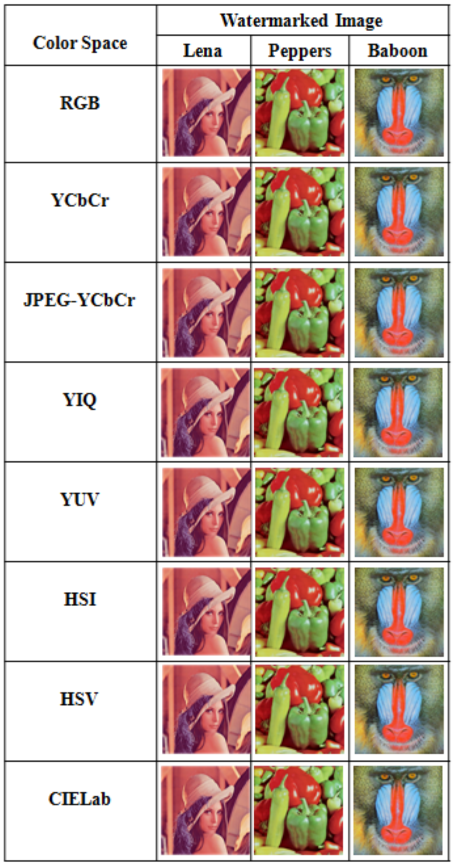



Fig. 5. The watermarked images in different color spaces

By comparing different color spaces, it could be found that in based non correlation watermarking algorithms not only our proposed formula called JPEG-YCbCr color space in [20] improves correlation and PSNR values of YCbCr color space, rather like previous work for based correlation watermarking algorithms in [14], it satisfies imperceptibility more than the other color spaces. After that, respectively, HSV, HSI, YUV & YIQ, RGB, CIELab and YCbCr color spaces have the most ability to satisfy imperceptibility requirement. Also, PSNR and correlation values in HSI and HSV color spaces are so near together, while in YIQ and YUV they are exactly the same and can satisfy imperceptibility and transparency properties like each other.

## B. Robustness Experiments

Most standard watermarking techniques do not survive wavelet based compression and may also not be compatible with the scalability feature of wavelet based compression. Therefore, to assess the robustness of the proposed algorithm to compression attack, wavelet based compression was chosen. So that, watermarked images were compressed by wavelet compression method in different thresholds (Thr): 1, 3, 6, 9, 12 and 15, and then the watermark image was extracted from the compressed watermarked images. The extracted watermarks and their percentage of error bit rates (EBR %) of all color spaces are shown in Figs. 6 and 7, respectively. They indicate the proposed scheme can successfully withstand wavelet based compression, as well as standard watermark attacks. The maximum percentage of error bit rate for extracted watermarks in all color spaces under high compression thresholds 12 is lower than 25.86% in baboon (for YCbCr), which demonstrates the appropriate quality of the images under wavelet compression attacks.

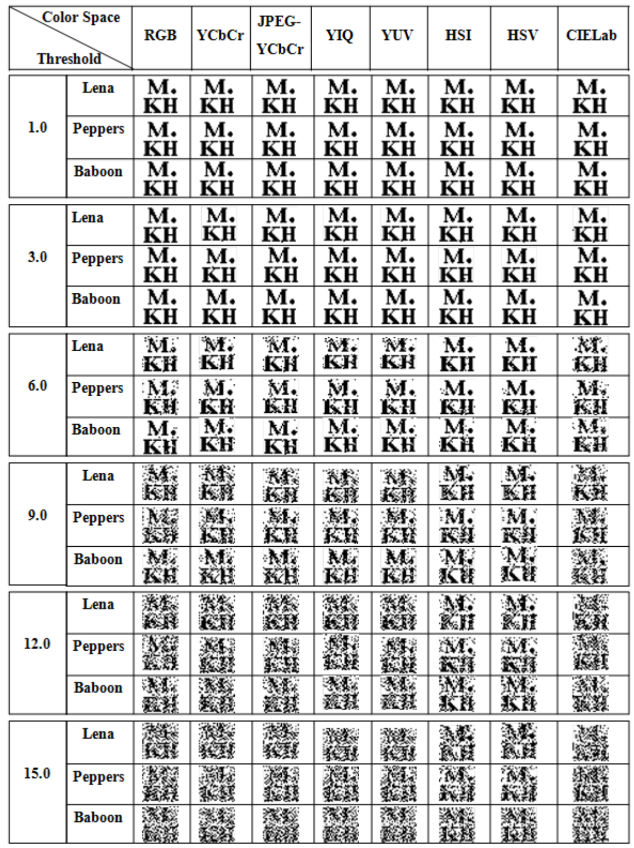


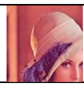
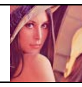
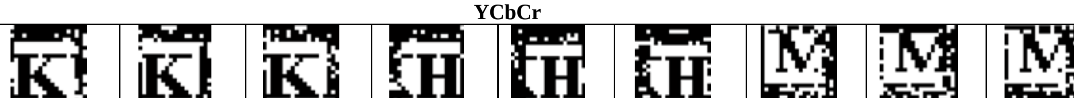
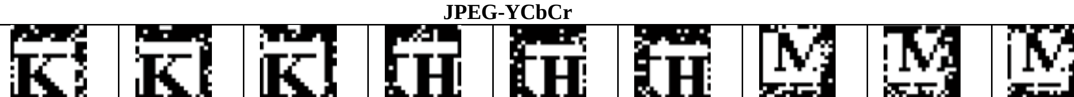
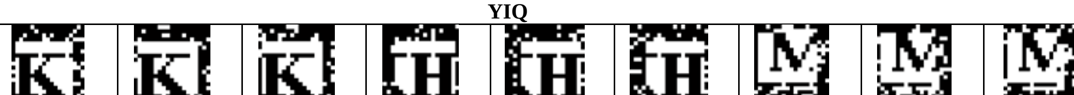

Fig. 6. The extracted watermarks from compression experiment in different color spaces

By comparing all color spaces, it can be found that YUV & YIQ and also HSI & HSV color spaces have the same robustness against wavelet compression. The lowest error bit rate belongs to HSI & HSV. So, these color spaces are more robust than the other color spaces against compression attacks. Then, respectively, our proposed formula in [20] called JPEG-YCbCr, RGB, YUV & YIQ, RGB, CIELab and finally YCbCr color spaces yield most robustness against wavelet compression. The interesting point is our proposed formula called JPEG-YCbCr in [20] not only increases YCbCr robustness, rather it yields better results in comparing RGB, YUV & YIQ, RGB and CIELab color spaces.

After achieving satisfactory results in compression experiment, the robustness of the proposed algorithm against cropping attacks was tested. So that, three different areas of watermarked images were being under cropping attacks and then the extraction process of watermark on the cropped areas was performed. Table 3 shows the extracted watermarks from cropped watermarked images and their percentage of error bit rates (EBR %). The table results show, the maximum percentage of error bit rate in all color spaces is lower than 47.32% (in YCbCr) and the watermarks are still recognizable after cropping attacks as well.

By comparing different color spaces, it can be found that YUV & YIQ and HSI & HSV color spaces have the same robustness against cropping attacks. The lowest percentage of error bit rate belongs to CIELab. So, this color space yields more robustness than the others. After that, JPEG-YCbCr, RGB, HSI & HSV, YIQ & YUV and finally YCbCr color spaces lead to most robustness against cropping attacks. It is necessary to note that, like compression experiment, our presented formula in [20] called JPEG-YCbCr not only enhances the YCbCr robustness, rather it leads to better results in comparing HSI & HSV, YIQ & YUV and RGB color spaces.

TABLE III. THE EXTRACTED WATERMARKS FROM CROPPED WATERMARKED IMAGES AND THEIR PERCENTAGE OF ERROR BIT RATES

| | Cropped Area 1 | | | Cropped Area 2 | | | Cropped Area 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| **Image** | ***Lena*** | ***Peppers*** | ***Baboon*** | ***Lena*** | ***Peppers*** | ***Baboon*** | ***Lena*** | ***Peppers*** | ***Baboon*** |
| **Cropped Image** |  |  |  |  |  |  |  |  |  |
| **RGB** | | | | | | | | | |
| **Extracted Watermark** |  | | | | | | | | |
| **EBR %** | 44.91 | 44.54 | 44.36 | 45.09 | 44.52 | 44.67 | 43.67 | 43.54 | 42.22 |
| **YCbCr** | | | | | | | | | |
| **Extracted Watermark** |  | | | | | | | | |
| **EBR %** | 47.32 | 45.54 | 45.96 | 46.73 | 45.74 | 45.74 | 44.85 | 45.54 | 46.39 |
| **JPEG-YCbCr** | | | | | | | | | |
| **Extracted Watermark** |  | | | | | | | | |
| **EBR %** | 44.80 | 43.27 | 43.71 | 44.39 | 43.71 | 43.18 | 42.62 | 42.44 | 41.07 |
| **YIQ** | | | | | | | | | |
| **Extracted Watermark** |  | | | | | | | | |
| **EBR %** | 47.18 | 45.13 | 45.81 | 46.63 | 45.54 | 45.67 | 44.71 | 45.13 | 45.26 |
| **YUV** | | | | | | | | | |
| **Extracted Watermark** |  | | | | | | | | |
| **EBR %** | 47.18 | 45.13 | 45.81 | 46.63 | 45.54 | 45.67 | 44.71 | 45.13 | 45.26 |
| **HSV** | | | | | | | | | |
| **Extracted Watermark** |  | | | | | | | | |
| **EBR %** | 45.67 | 45.09 | 45.09 | 45.95 | 44.81 | 45.26 | 44.12 | 43.89 | 43.07 |
| **HSI** | | | | | | | | | |
| **Extracted Watermark** |  | | | | | | | | |
| **EBR %** | 45.67 | 45.09 | 45.09 | 45.95 | 44.81 | 45.26 | 44.12 | 43.89 | 43.07 |
| **CIELab** | | | | | | | | | |
| **Extracted Watermark** |  | | | | | | | | |
| **EBR %** | 44.40 | 42.63 | 43.30 | 44.22 | 43.54 | 42.22 | 41.71 | 41.45 | 40.75 |

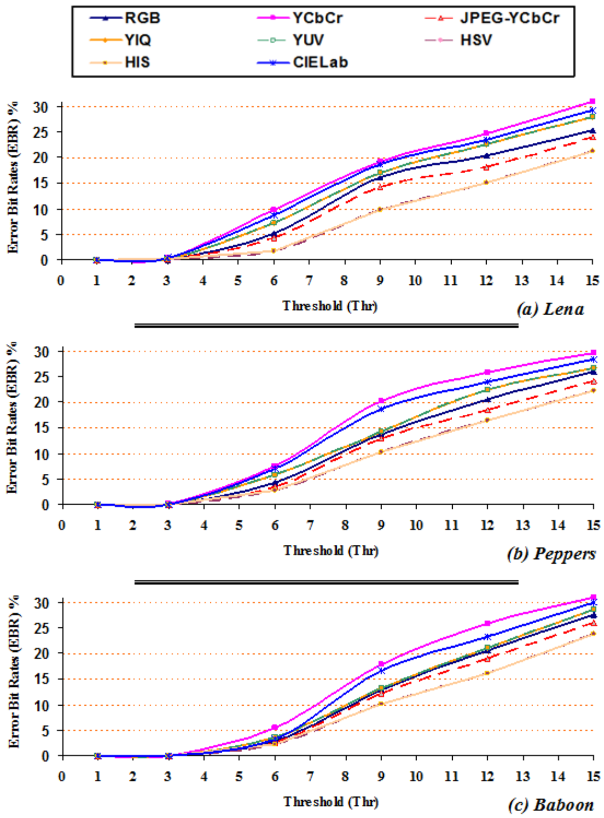



Fig. 7. The percentage of error bit rates (EBR %) of the extracted watermarks from compression experiment in different color spaces

## V. Conclusion

In this paper, a non correlation based image watermarking scheme using DWT2 proposed and tested in eight historical color spaces: RGB, YCbCr, YIQ, YUV, HSI, HSV, CIELab and improved YCbCr color space, called JPEG- YCbCr which is presented by our formula in [20], to develop the results of previous work in [14] and achieve a comprehensive investigation on the effects of different color spaces on both based correlation and non correlation watermarking techniques. The watermarking security is more satisfactory than the similar works. Because, the watermark W becomes encoded three times by ATM, CCM and exclusive OR and embedded into wavelet decomposition coefficients of a scrambled original image. By the way, scrambling the host image by ATM and embedding encoded watermarks in the first channel of intended color space increase security, more. The experimental results show that in all color spaces, the proposed approach has achieved satisfactory imperceptibility and excellent robustness from three tested benchmark images, simultaneously. In different color spaces, All of the correlation values are greater than 0.999, the lowest PSNR is greater than 54 dB (in YCbCr) and all of the normalized correlations are equal to 1. Also, the maximum percentage of error bit rates for extracted watermarks from huge cropped watermarked images and compressed watermarked images in compression threshold 12 are respectively equal to 47.32% and 25.86% (in YCbCr); which it means the extracted watermarks from cropping and compression experiments are recognizable as well, even if cropped area is big or compression threshold is high.

The proposed approach has the following results in non correlation based watermarking techniques:

*1) Our presented formula in [20] called JPEG-YCbCr color space, not only enhances YCbCr imperceptibility and robustness, rather it leads to most results in comparing the other color spaces. In addition, it yields more robustness against compression attacks in comparing RGB, YUV & YIQ, RGB, CIELab color spaces and cropping attacks in comparing RGB, HSI & HSV, YIQ & YUV color spaces.*

*2) YIQ & YUV color spaces exactly satisfy imperceptibility and robustness against compression and cropping attacks, equaly. Also, imperceptibility results in HSI & HSV color spaces are very near together; while they exactly lead to same robustness against wavelet compression and image cropping.*

*3) After JPEG-YCbCr, respectively, HSV, HSI, YUV & YIQ, RGB, CIELab and YCbCr color spaces yield most imperceptibility.*

*4) HSI & HSV satisfy robustness against compression more than the other color spaces. Then, respectively, JPEG-YCbCr, RGB, YUV & YIQ, RGB, CIELab and finally YCbCr lead to most robustness.*

*5) CIELab yields most robustness against cropping attacks in comparing the other color spaces. After that, respectively, JPEG-YCbCr, RGB, HSI & HSV, YIQ & YUV and YCbCr color spaces have the most robustness.*

*6) In non correlation based watermarking, the minimum computational complexities and processing time in embedding and extraction processes belong to RGB. Afterwards, respectively, they belong to YCbCr, YUV, YIQ, JPEG-YCbCr, HSI, HSV and CIELab spaces.*

## References

[1] X. Y. Wang, C. P. Wang, H. Y. Yang, P. P. Niu, "A Robust Blind Color Image Watermarking in Quaternion Fourier Transform Domain," The Journal of Systems and Software, vol. 86, 2013, pp. 255– 277.

[2] N. H. Abdul-mahdi, A. Yahya, R.B. Ahmad, O.M. Al-Qershi, "Secured and Robust Information Hiding Scheme," *Procedia Engineering*, vol. 53, 2013, pp. 463 – 471.

[3] X. Rui, C. X. Jun, S. Jinqiao, "A multiple Watermarking Algorithm for Texts Mixed Chinese and English," *Procedia Computer Science*, vol. 17, 2013, pp. 844 – 851.

[4] S. C. Chu, L. C. Jain, H. C. Huang, J. S. Pan, "Error-Resilient Triple-Watermarking with Multiple Description Coding," *Journal of Networks*, vol. 5, 2010, pp. 267-274.

[5] M. Khalili, " DCT-Arnold Chaotic Based Watermarking Using JPEG-YCbCr," *Optik*, Vol. 126, 2015, pp. 4367 - 4371.

[6] H. V. Dang, W. Kinsner, "An Intelligent Digital Colour Image Watermarking Approach Based on Wavelets and General Regression Neural Networks," *Proc. Int. Conf. Cognitive Informatics & Cognitive Computing*, Kyoto, Japan, August 2012, pp. 115-123.

[7] S. Singh, H. V. Singh, A. Mohan, "Secure and Robust Watermarking Using Wavelet Transform and Student t-distribution," *Procedia Computer Science*, Vol. 70, 2015, pp. 442-447.

[8] M. Hasnaoui, M. Mitrea, "Multi-symbol QIM Video Watermarking," *Signal Processing: Image Communication*, in press, 2013, pp. 1-21.

[9] G. C. Langelaar, I. Setyawan, R. L. Lagendijk, "Watermarking Digital Image and Video Data," *IEEE Signal Processing Magazine*, vol. 17, no. 5, 2000, pp. 20-46.

[10] F. Hartung, B. Girod, "Digital Watermarking of Raw and Compressed Video," *Proc. Conf. SPIE 2952, Digital Compression Technologies and*

*Systems for Video Communication*, Berlin, Germany, September, 1996, pp. 205-213.

[11] A. Hanjalic, G. C. Langelaar, J. Biemond, et al., *Image and Video Databases: Restoration, Watermarking and Retrieval*, S. (Ed.): Science, Advances in Image Communications, book 8, 1st edn, Elsevier Science, 2000.

[12] R. K. Singh, D. K. Shaw, M. J. Alam, "Experimental Studies of LSB Watermarking with Different Noise," *Procedia Computer Science*, Vol. 54, 2015, pp. 612-620.

[13] L. Laouamer, M. AlShaikhb, L. Nanab, e al., "Robust Watermarking Scheme and Tamper Detection Based on Threshold Versus Intensity," *Journal of Innovation in Digital Ecosystems*, In Press, doi:10.1016/j.jides.2015.10.001.

[14] M. Khalili, D. Asatryan, "Colour Spaces Effects on Improved Discrete Wavelet Transform-based Gigital Image Watermarking Using Arnold Transform Map," *IET signal Processing*, vol. 7, no. 3, 2013, pp. 177-187.

[15] F. Lusson, K. Bailey, M. Leeney, K. Curran, "A Novel Approach to Digital Watermarking, Exploiting Colour Spaces," *Signal Processing*, vol. 93, 2013, pp. 1268–1294.

[16] N. A. Abbas, "Image Watermark Detection Techniques Using Quadtrees," *Applied Computing and Informatics*, Vol. 11, 2015, pp. 102–115.

[17] C. Pradhan,S. Rath, A. K. Bisoi, "Non Blind Digital Watermarking Technique Using DWT and Cross Chaos," *Procedia Technology*, vol. 6, 2012, pp. 897 – 904.

[18] L. Chen, D. Zhao, F. Ge, "Image Encryption Based on Singular Value Decomposition and Arnold Transform in Fractional Domain," *Optics Communications*, 2013, vol. 291, pp. 98–103.

[19] J. M. Chaves-González, M. A. Vega-Rodríguez, J. A. Gómez-Pulido, et al., "Detecting Skin in Face Recognition Systems: A Colour Spaces Study," *Digital Signal Processing*, vol. 20, no. 3, 2010, pp. 806–823.

[20] M. Khalili, D. Asatryan, "An Improved DWT Based Watermarking Using JPEG-YCbCr," *Proc. Int. Conf. Computer Science and Information Technologies*, Yerevan, Armenia, August, 2011, pp. 213-216.

[21] F. Kong, Y. Peng, "Color Image Watermarking Algorithm Based on HSI Color Space," *Proc. Int. Conf. Industrial and Information Systems*, Tianjin, China, July, vol. 2, 2010, pp. 464-467.

[22] C. H. Yang, "Inverted Pattern Approach to Improve Image Quality of Information Hiding by LSB Substitution," *Pattern Recognition*, vol. 41, no. 8, 2008, pp. 2674 – 2683.

[23] I, Hong, I, Kim, S. S. Han, "A Blind Watermarking Technique Using Wavelet Transform," *Proc. IEEE Int. Symposium on Industrial Electronics, Pusan, Korea, Jun, vol.* 3, 2001, pp. 1946 – 1950.

[24] H. Lua, S. C. Chu, Z. M. Lu, "Self Embedding Watermarking Using Halftoning Technique," *Circuits, Systems Signal Processing*, vol. 27, no. 2, 2008, pp. 155-170.

[25] L. Fan, T. Gao, "A Novel Blind Robust Watermarking Scheme Based on Statistic Characteristic of Wavelet Domain Coefficients," *Proc. Int. Conf. Signal Processing Systems, Tianjin, China*, May 2009, pp. 121-125.

[26] F. Zhang, G. Yang, X. Liu, et al., "Image Watermarking Algorithm Based on the Code Division Multiple Access Technique," *Proc. Int. Conf. Knowledge-Based Intelligent Information and Engineering Systems*, Bournemouth, UK, October 2006, pp 204-211.

[27] S. A. H. Nair, P. Aruna, "Comparison of DCT, SVD and BFOA Based Multimodal Biometric Watermarking Systems," *Alexandria Engineering Journal*, Vol. 54, 2015, pp. 1161–1174.

[28] Aparna J R, S. Ayyappan, " Image Watermarking using Diffie Hellman Key Exchange Algorithm," *Procedia Computer Science*, Vol. 46, 2015, pp. 1684-1691.