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A Comparative Study For Color Systems Used In The DCT-DWT Watermarking Algorithm

Khalid A. Al-Afandy*, El-Sayed M. EL-Rabaie[1], Fathi E. Abd El-Samie[1], Osama S. Faragallah[2], Ahmed ELmhalaway[2], A. M. Shehata[2]

[1] *Faculty of Electronic Engineering, Electronic and Communication Department, Menoufia University, Egypt*

[2] *Faculty of Electronic Engineering, Computer Engineering and Science Department, Menoufia University, Egypt*

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A B S T R A C T

This paper presents a comparative study of using different color systems on watermarking algorithms. This comparison aim is to determining the robustness and the stability of the color systems used in the watermarking scheme. The watermarking algorithm that is used in this paper is a hybrid scheme using the Discrete Wavelet Transform (DWT) in the Discrete Cosine Transform (DCT) domain. The DCT-DWT watermarking algorithm is applied using three color systems, the RGB (Red, Green and Blue) color system, the HSV (Hue, Saturation and Value) color system and the YIQ color system. The comparison is based on visualization to detect any degradation in the watermarked image, the Peak Signal-to-Noise Ratio (PSNR) of the watermarked image, the Normalized Correlation (NC) of the extracted watermark after extraction, the embedding algorithm CPU time, and applying different types of attacks and then calculating the PSNR and the NC.

1. Introduction

Information technology such as digital data and multimedia can be easily duplicated, manipulated, and distributed in this time, so it's very important to have a copyright protection to save owners copyrights. There are many protection techniques, one of them is watermarking. Watermarking technology is the process of hiding an image called watermark or label into original digital data (image, video or audio) [1,2]. Watermarking schemes can be classified into two categories; spatial domain and transform domain [3]. There are several schemes of transform domain watermarking technology. One of these schemes is the Discrete Wavelet Transform (DWT) [1,3]. It is based on dividing an image into four non-overlapping bands. These bands are calculated in different frequencies; approximation sub-band (low frequency LL), horizontal sub-band (high frequency LH), vertical sub-band (high frequency HL), and diagonal sub-band (high frequency HH) [1,3]. Other used scheme of transform domain is the Discrete Cosine Transform (DCT) [5]. This transform is used to convert spatial domain image into discrete transform domain [6]. The watermarking scheme based on transform the color image to 2D DCT for each color channel, embedding watermark into the DCT frequency, then the inverse DCT given watermarked image [5,6]. Hybrid schemes are used in watermarking schemes. One of them is DCT-DWT [7]. It is based on dividing the color image into 2D matrices. The DCT domain is extracted by applying the DCT for each 2-D matrix. Embedding watermark is done on the sub-band LL by utilize the DWT to divide the DCT domain into four sub-bands for each 2-D matrix [7-9].

Colors are an important communication tool for human; it is used for communication with outside environments [10]. Using colors in image processing improve the image data for better human understanding [10]. So it's important to represent colors as mathematical formulas. There are different color formats that can represent the image color information; they are called the color systems. One of these color systems is the RGB color system. It is an additive color system based on tri-chromatic theory, easy to implement and very common but non-linear with visual perception [11]. Other color system is the HSV (Hue, Saturation and Value) color system. It is a linear transform from the RGB color system. It is very easy to select a desire hue and modifying it by adjusting its saturation and value [11]. Another color system is the YIQ color system. It is an analogue space of NTSC (National Television Standard Committee) system and used for color TV [10]. It is

*Corresponding Author: Khalid Al-Afandy, Heliopolis, Cairo, Egypt, Khalid_yuosif@yahoo.com

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separate the RGB color system into a Luminance Y, and two chrominance information I,Q, it is useful in compression application [11].

The main aim of this paper is to apply the DCT-DWT watermarking algorithm using the RGB, the HSV and the YIQ color systems. A comparative study is done to determine the stability and the robustness of these three color systems after applying the watermarking algorithm.

The rest of this paper is organized as follows. Section 2 gives a description of the watermarking schemes. The color systems are shown in section 3. Section 4 shows the comparative topics. The simulation results are illustrated in section 5. Section 6 presents the conclusion followed by the most relevant references.

2. Watermarking Schemes

2.1. Discrete Wavelet Transform (DWT)

Wavelet transform is an information processing method; it has been widely used in many fields including image processing. The DWT divide an image into four non-overlapping bands. These bands are calculated in different frequencies [1]. Figure 1 shows the four sub-bands; approximation sub-band c_i (low frequency LL), horizontal sub-band (high frequency LH) ch_i, vertical sub-band (high frequency HL) cv_i, and diagonal sub-band (high frequency HH) cd_i. Figure 2 show the low pass and high pass analysis filter h[-m], g[-m] while the corresponding low pass and high pass synthesis filter are h[m] and g[m]; c_i and d_i are the low and high band output coefficient at level i [1,3].

The DWT analysis is given by:

$$ci+1[m,n] = (ci(m,n)*h[-m])\downarrow 2 \qquad (1)$$

$$di+1[m,n] = (ci(m,n)*g[-m])\downarrow 2 \qquad (2)$$

So the DWT synthesis is given by

$$Ci+1[m,n] = [(ci(m,n)\uparrow 2)*h[m]) + [(di(m,n)\uparrow 2)*g[m])] \qquad (3)$$

Where * denotes convolution and ↑↓ denotes down sampling and up sampling by factor of 2.

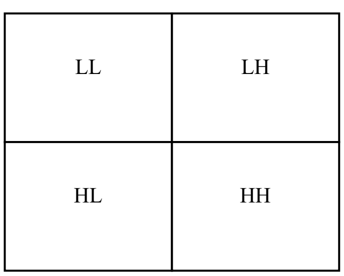


Figure 1. The DWT sub-bands [3].

2.2. Discrete Cosine Transform (DCT)

Discrete Cosine Transform (DCT) is a standout amongst the most well-known orthogonal change strategies utilized as a part of picture preparing. High vitality compaction property of the DCT is the reason. In watermarking, this property helps in choosing the area in image to insert the watermark with the most robustness [4]. The DCT divides aircraft carrier signal into three frequencies bands namely low, middle, and heights frequency bands. It is a frequency orbit watermarking scheme as the watermark is embedded into one of these three bands, carrier signal pixel are not modified directly [5].

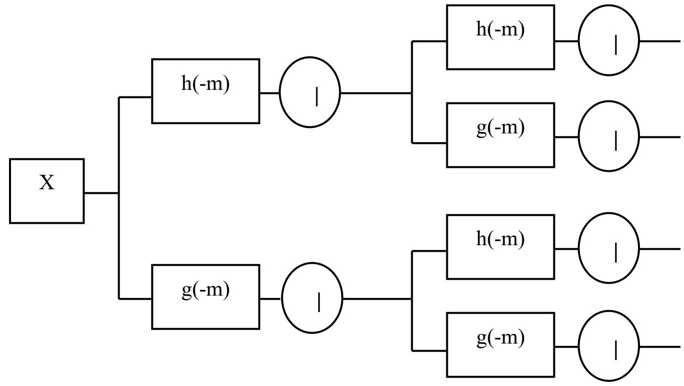


Figure 2. The two dimensional decomposition using DWT [3].

Two dimension discrete cosine transform 2D-DCT is defined as [6]

$$F(jk) = a(j)a(k)\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n)\cos\left[\frac{(2m+1)j\pi}{2M}\right]\cos\left[\frac{(2n+1)k\pi}{2N}\right] \qquad (4)$$

Inverse transform 2D-IDCT is defined as [6]

$$f(mn) = \sum_{j=0}^{M-1}\sum_{k=0}^{N-1} a(j)a(k)F(jk)\cos\left[\frac{(2m+1)j\pi}{2M}\right]\cos\left[\frac{(2n+1)k\pi}{2N}\right] \qquad (5)$$

Where M,N are image dimension,

$0 \le j \le M-1,\ 0 \le k \le N-1,$

$$a(j) = \begin{cases} \frac{1}{\sqrt{M}}, & j = 0 \\ \sqrt{\frac{2}{M}}, & 1 \le j \le M-1 \end{cases},$$

and

$$a(k) = \begin{cases} \frac{1}{\sqrt{N}}, & k = 0 \\ \sqrt{\frac{2}{N}}, & 1 \le k \le N-1 \end{cases}$$

2.3. The Hybrid Scheme DCT-DWT

The hybrid scheme DCT-DWT is based on utilized the DWT to divide the DCT domain into four sub-bands [7]. The color image is divided into three 2D matrices (depending on used color system). The DCT domain is extracted by applying the DCT for each 2D matrix. Embedding watermark is done on the sub-band LL by utilize the DWT to divide the DCT domain into four sub-bands for each 2D matrix [7-9].

3. Color System

3.1. The RGB (Red, Green and Blue) Color System

The RGB color system is an additive color system based on tri-chromatic theory, easy to implement, and very common, but non-linear with visual perception. It may be visualized as a cube with the three axis's corresponding to red, green and blue, this cube bottom corner when Red=Green=Blue=0 and opposite top corner when Red=Green=Blue=255. The RGB color system is frequently used in most computer applications [11]. In computer applications the RGB color image represented as a three dimensional array with dimension M×N×3, where M×N is image axis X,Y and 3 is the three color channel Red, Green and Blue respectively [10]. Figure 3 show the RGB color model [10].

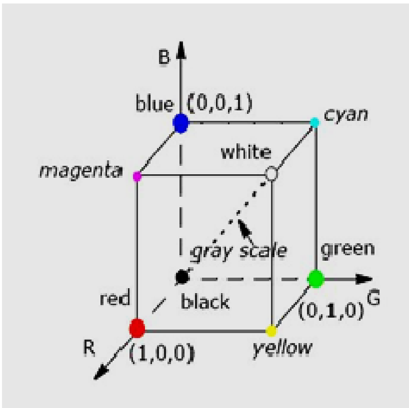


Figure 3. The RGB color model [10].

3.2. The HSV Color System

The HSV color system is a linear transform from the RGB color system. It is very easy to select a desire hue and modifying it by adjusting its saturation and value. It is defined as a position on a circular plane around the value axis. Hue is the angle from a nominal point around the circle to the color. Saturation is the radius from the central value axis to the color. Figure 4 show the HSV color model [10]. Conversion from the RGB color system to HSV color system as [11]:

Find the maximum and minimum values from the RGB triplet

$$\max = \max\,(R, G, B) \tag{6}$$

$$\min = \min\,(R, G, B) \tag{7}$$

If max=min then the image is monochrome (not color) because it is no Hue

The Saturation (S) is
$$S = \frac{\max - \min}{\max} \tag{8}$$

The Value (V) is
$$V = \max \tag{9}$$

$$R' = \frac{\max - R}{\max - \min} \tag{10}$$

$$G' = \frac{\max - G}{\max - \min} \tag{11}$$

$$B' = \frac{\max - B}{\max - \min} \tag{12}$$

If R=max $\quad H = 60\times(B' - G') \quad (13)$

If G=max $\quad H = 60\times(2 + R' - B') \quad (14)$

If B=max $\quad H = 60\times(4 + G' - R') \quad (15)$

If H>=360 $\quad H = H - 360 \quad (16)$

If H<0 $\quad H = H + 360 \quad (17)$

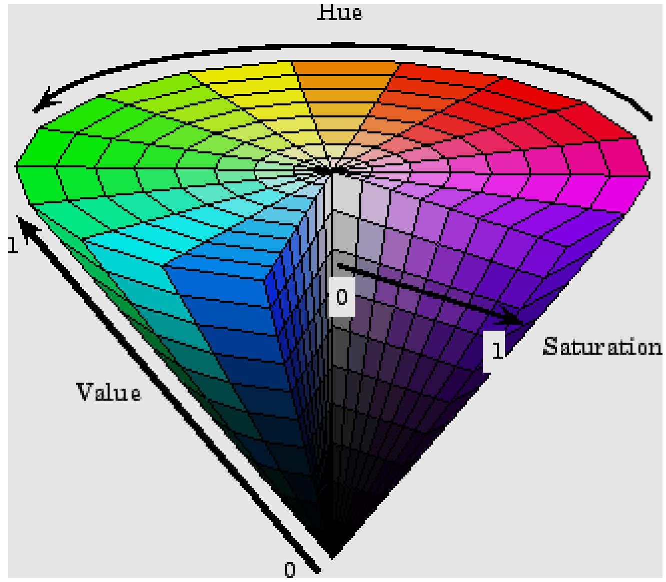


Figure 4. The HSV color model [10].

3.3. The YIQ Color System

The YIQ color system is an analogue space of the NTSC system that used for the American color TV. It separates the RGB color system into a Luminance Y, and two chrominance information I, Q. It is useful in compression application [11]. The YIQ system was designed to utilize sensitivity in luminance changes than hue or saturation changes. Figure 5 show the YIQ color system model [10]. The relation between the YIQ color system and the RGB color system as [11]:

From RGB to YIQ

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.586 & -0.275 & -0.321 \\ 0.212 & -0.528 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{18}$$

From YIQ to RGB

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 0.30 & 0.60 & 0.21 \\ 0.59 & -0.28 & -0.52 \\ 0.11 & -0.32 & 0.31 \end{bmatrix} \begin{bmatrix} Y \\ I \\ Q \end{bmatrix} \tag{19}$$

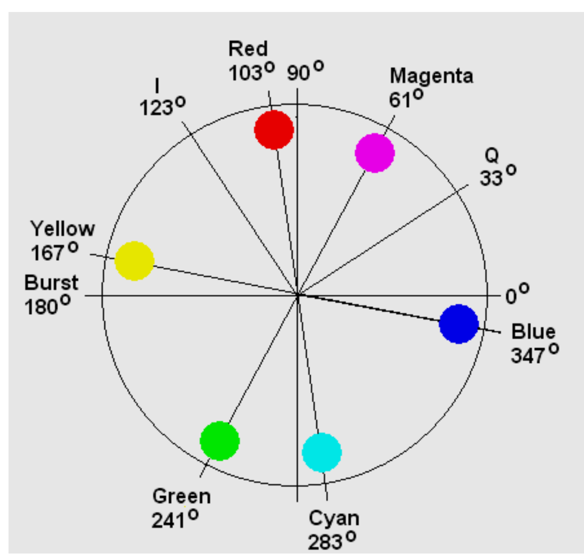


Figure 5. The YIQ color model [10].

4. The Comparative Topics

The aim of this paper is to present a comparative study of three different color systems used in watermarking scheme algorithms. The comparison is based on applying the DWT-DCT watermarking scheme algorithm for color images (host and watermark) using the RGB color system, the HSV color system and the YIQ color system. The DCT-DWT watermarking scheme is based on separation for each of the host and watermark color image into three 2-D matrices according to the used color system. The DCT domain is extracted by applying the DCT on each 2-D matrix extracted from color image. The DWT is utilized to divide the DCT domain for each 2-D matrix into four non-overlapping bands. The watermark is embedded into the LL sub-band [7-9]. A comparison is done between the three color systems RGB, HSV and YIQ. The comparison is based on visual detection, the PSNR, the NC, the embedding algorithm CPU time, and applying attacks to determine the robustness of color systems.

5. Simulation Results

All tests were performed using an Intel® core™i5 CPU M450 @2.4GHz with 6GB Memory and running Windows 7 64-bit operating system and using MATLAB 8. The images used are RGB colored JPEG images with size 512×512, and bit depth 24 host image Rokayya with resolution 72×72 dpi and watermark cats with resolution 180×180 dpi as shown in Figure 6. There are five main tests to determine the performance of a color system used in watermarking scheme algorithm. Visually test to determine the invisibility of watermark in the watermarked image and any degradation in colors compared to original image, the embedding algorithm CPU time, the Peak Signal-to-Noise Ratio (PSNR) of the watermarked image, the Normalized Correlation (NC) for the extracted watermark are calculated, and applying attacks on the watermarked image then extracting the watermark and calculating the PSNR and the NC again after attacks. PSNR can be calculated by [5]

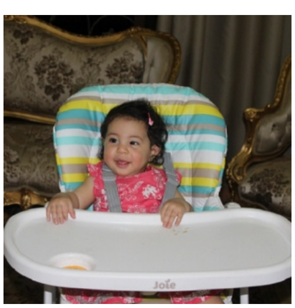
$$MSE = \frac{1}{\mathrm{M}\times\mathrm{N}} \sum_{\mathrm{x}=0,\mathrm{y}=0}^{\mathrm{M}-1,\mathrm{N}-1} (\mathrm{A_w}(\mathrm{x},\mathrm{y}) - \mathrm{A}(\mathrm{x},\mathrm{y}))^2 \tag{20}$$

$$PSNR\ (DB) = 10 \log_{10} \frac{255^2}{MSE} \tag{21}$$

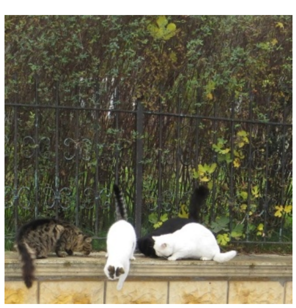
where A is original image, $\mathrm{A_w}$ is watermarked image and M, N size of original and watermarked image. NC calculate given by [5]

$$NC = \frac{W^{*}.\mathrm{W}}{\|W^{*}\|.\|W\|} \tag{22}$$

Where W is original watermark and W* is extract watermark



(a)



(b)

Figure 6. (a) The host Image Rokayya, (b) The watermark image cats.

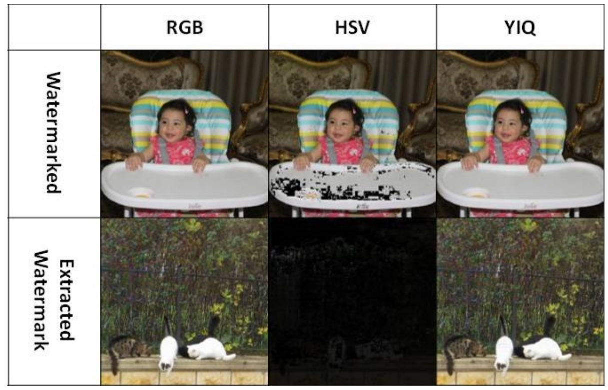


Figure 7 Visualization tests without any attacks.

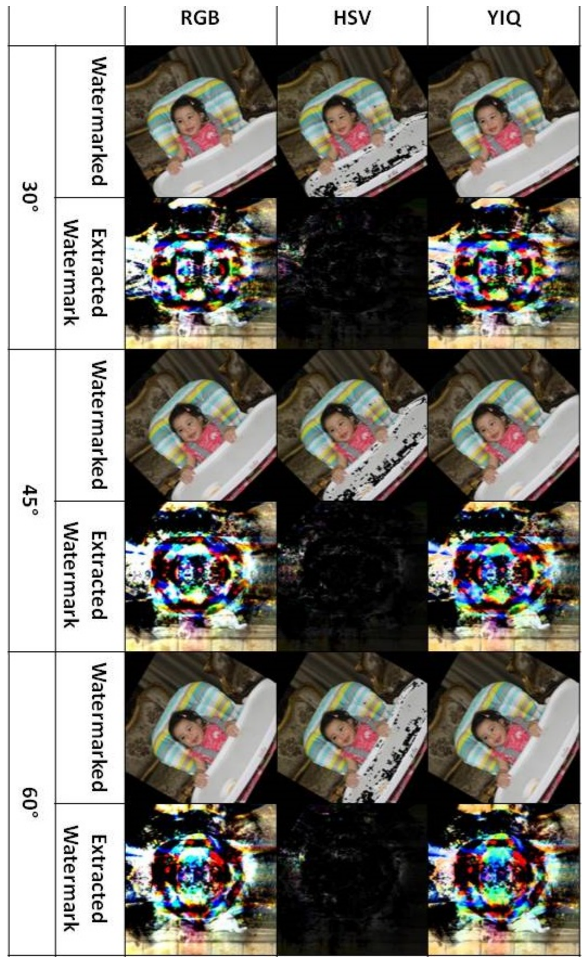


Figure 8 Visualization tests after rotation attacks 30°, 45°, and 60°.

Visualization comparison results without attacks are shown in figure 7. Figure 8 shows the rotate attacks (30°, 45° and 60°). Gaussian noise attacks are shown in figure 9 with variance parameters (0.01, 0.05 and 0.1). Figure 10 shows the blur attacks (motion, disk and average). The JPEG compression attacks are shown in figure 11 (20%, 40% and 60%). Figure 12 shows the resize to 256×256 attacks then resize to 512×512. The crop attacks are shown in figure 13. The evaluation matrices results (PSNR and NC) without attacks and embedding algorithm CPU time for the comparison are shown in table1 and figure 14. Table 2 and figure 15 show the evaluation matrices results (PSNR and NC) after attacks.

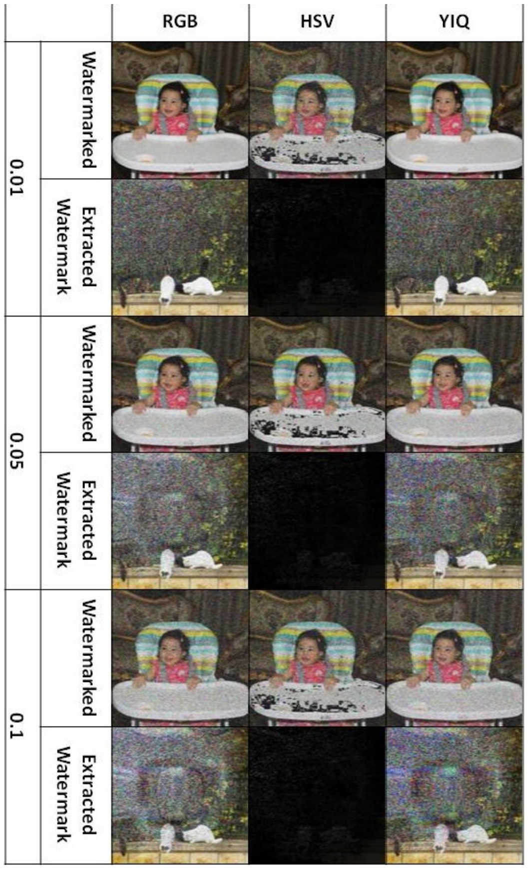


Figure 9 Visualization tests after Gaussian noise attacks with variance parameters 0.01, 0.05, 0.1.

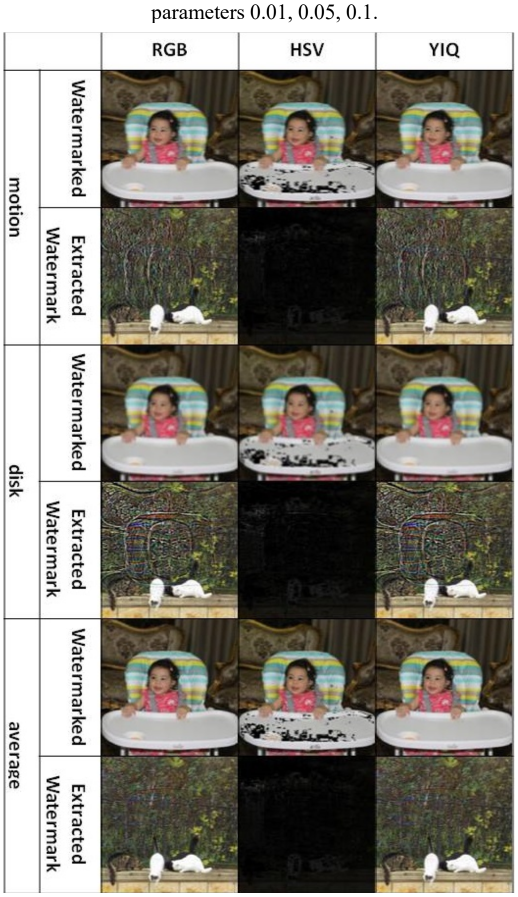


Figure 10 Visualization tests after blur attacks (motion, disk, and average).

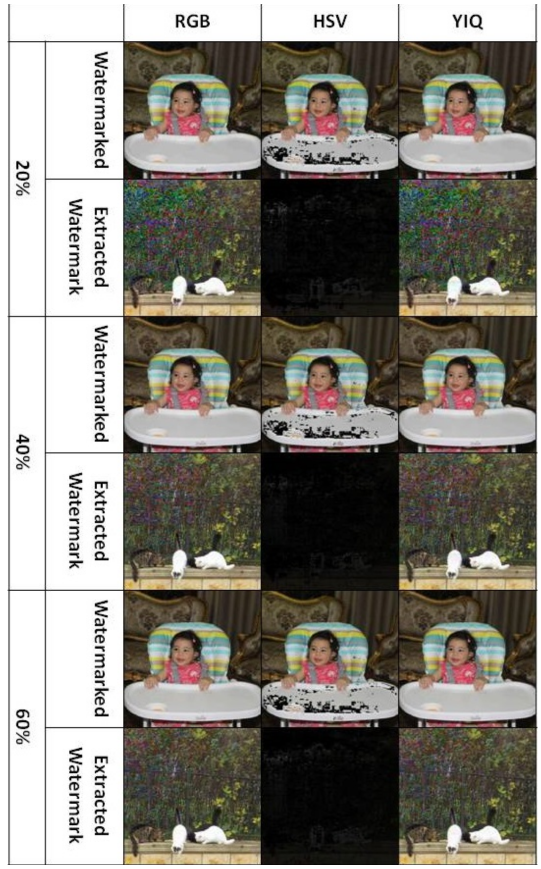


Figure 11 Visualization tests after JPEG compression attacks 20%, 40%, and 60%.

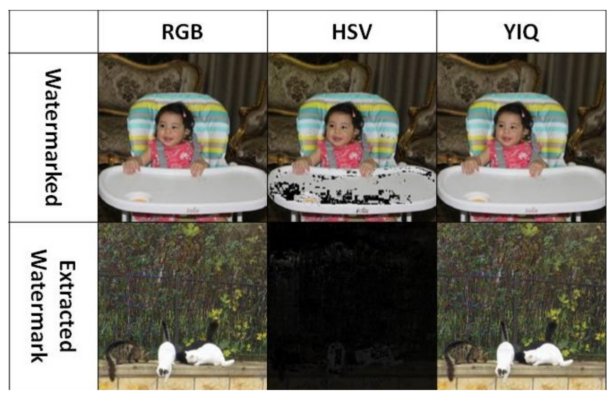


Figure 12 Visualization tests after resize to 256×256 then resize to 512×512 attacks.

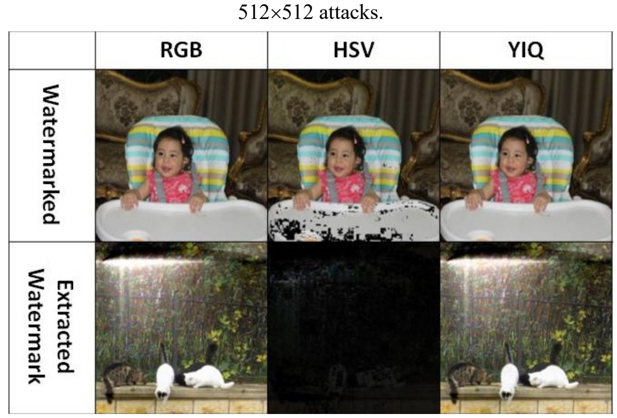
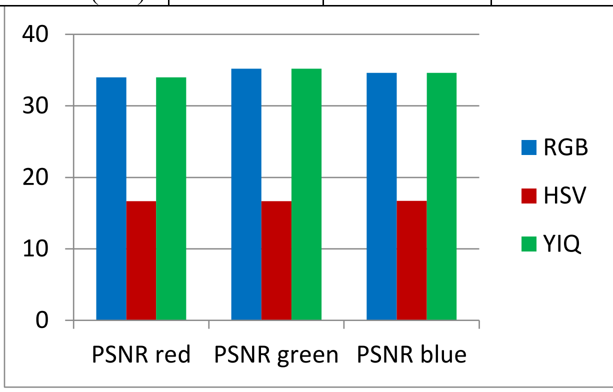


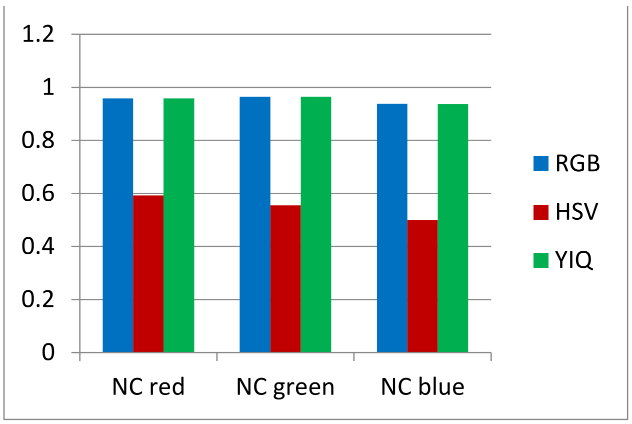
Figure 13 Visualization tests after crop attacks.

Table 1. The PSNR for watermarked image, the NC for extracted watermark without attacks and the CPU time for embedding algorithm.

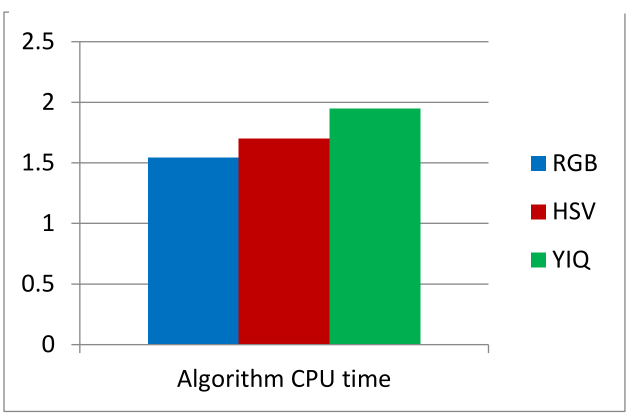
Without attack	RGB	HSV	YIQ
PSNR red	33.9764	16.6698	33.9764
PSNR green	35.2180	16.6828	35.2180
PSNR blue	34.6320	16.6906	34.6320
NC red	0.9587	0.5927	0.9585
NC green	0.9646	0.5554	0.9644
NC blue	0.9377	0.4997	0.9373
CPU time (Sec)	1.5444	1.7004	1.95



(a) The PSNR for watermarked images.



(b) The NC for extracted watermark.



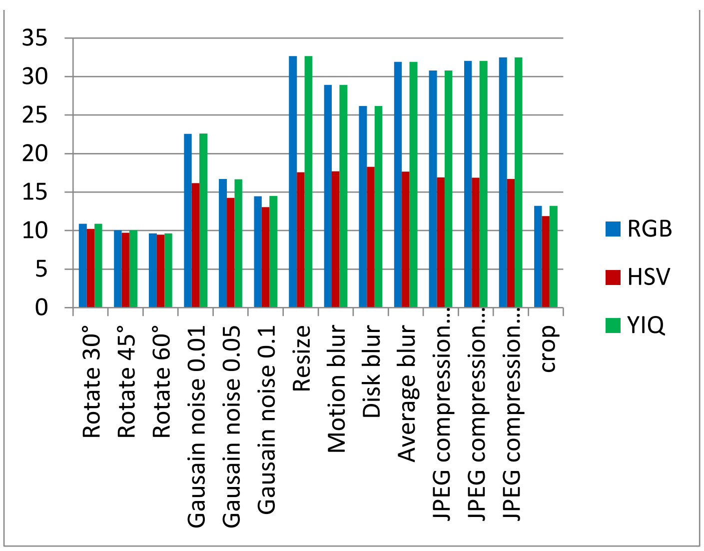
(c) Algorithm CPU time.

Figure 14. The evaluation matrices comparison based on the PSNR for watermarked image, the NC for extracted watermark without attacks and the CPU time for embedding algorithm.

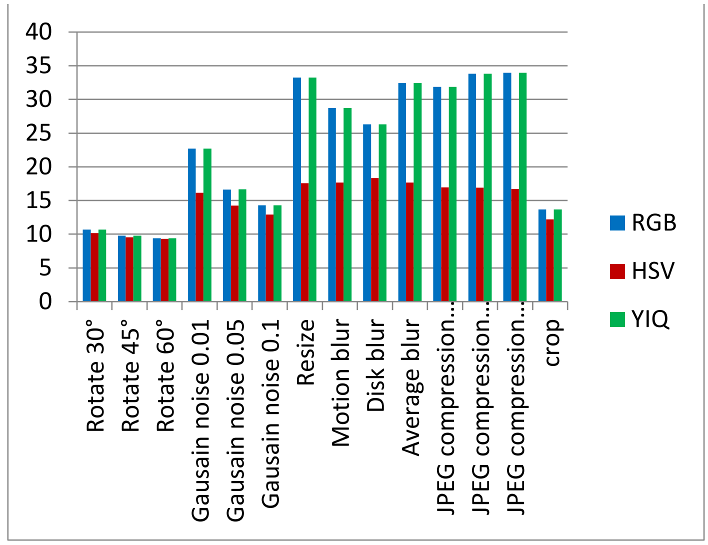
Table 2. The PSNR for watermarked image, and the NC for extracted watermark after attacks.

After attack		RGB	HSV	YIQ
Rotate 30°	PSNR red	10.8712	10.2095	10.8712
	PSNR green	10.7056	10.1637	10.7056
	PSNR blue	10.2787	9.7696	10.2787
	NC red	0.4134	0.1261	0.4385
	NC green	0.3737	0.1128	0.4029
	NC blue	0.3110	0.0758	0.3429
Rotate 45°	PSNR red	10.0475	9.7151	10.0475
	PSNR green	9.7717	9.5316	9.7717
	PSNR blue	9.3565	9.1425	9.3565
	NC red	0.4349	0.1309	0.4709
	NC green	0.3691	0.1242	0.4000
	NC blue	0.2992	0.0773	0.3192
Rotate 60°	PSNR red	9.6386	9.4558	9.6386
	PSNR green	9.4120	9.3174	9.4120
	PSNR blue	8.9305	8.8420	8.9305
	NC red	0.4347	0.1782	0.4660
	NC green	0.3594	0.1484	0.3848
	NC blue	0.3049	0.1052	0.3219
Gaussian noise 0.01	PSNR red	22.5692	16.1464	22.5873
	PSNR green	22.6814	16.1505	22.6942
	PSNR blue	22.6411	16.1870	22.6542
	NC red	0.6281	0.3893	0.6381
	NC green	0.5946	0.3712	0.6014
	NC blue	0.5402	0.3044	0.5505
Gaussian noise 0.05	PSNR red	16.6907	15.2738	16.6774
	PSNR green	16.6384	14.2272	16.6643
	PSNR blue	16.7434	14.3356	16.7488
	NC red	0.4637	0.1376	0.5034
	NC green	0.4144	0.1350	0.4472
	NC blue	0.3507	0.1189	0.3807
Gaussian noise 0.1	PSNR red	14.4521	13.0484	16.4830
	PSNR green	14.3016	12.9226	14.3182
	PSNR blue	14.4515	13.0859	14.4692
	NC red	0.4015	0.1027	0.4555
	NC green	0.3481	0.1054	0.3887
	NC blue	0.2765	0.0936	0.3104
Resize	PSNR red	32.6509	17.5709	32.6509
	PSNR green	33.2573	17.5776	33.2573
	PSNR blue	32.9487	17.5823	32.9487
	NC red	0.9318	0.6209	0.9316
	NC green	0.9333	0.584	0.9329
	NC blue	0.9050	0.5326	0.9045
Motion blur	PSNR red	28.9065	17.6938	28.9065
	PSNR green	28.7466	17.6686	28.7466
	PSNR blue	28.8790	17.6937	28.879
	NC red	0.8434	0.5767	0.8438
	NC green	0.8284	0.5423	0.8291
	NC blue	0.8024	0.4743	0.8038
Disk blur	PSNR red	26.1620	18.2997	26.1620
	PSNR green	26.3194	18.3153	26.3194
	PSNR blue	26.3862	18.3299	26.3862
	NC red	0.7696	0.5386	0.7702
	NC green	0.7600	0.5101	0.7620
	NC blue	0.7346	0.4336	0.7374

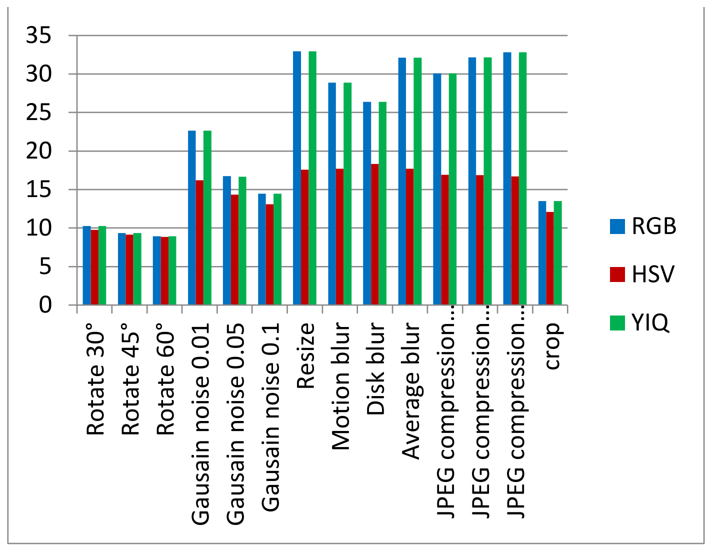
Average blur	PSNR red	31.9021	17.6811	31.9021
	PSNR green	32.4367	17.6901	32.4367
	PSNR blue	32.1206	17.6905	32.1206
	NC red	0.9250	0.6214	0.9247
	NC green	0.9269	0.5835	0.9265
	NC blue	0.8990	0.5307	0.8984
JPEG compression	PSNR red	30.8030	16.9024	30.8030
	PSNR green	31.8857	16.9348	31.8857
	PSNR blue	30.1031	16.8905	30.1031
	NC red	0.8804	0.5430	0.8792
	NC green	0.8892	0.5023	0.8883
	NC blue	0.8225	0.4338	0.8209
JPEG compression	PSNR red	32.0421	16.8709	32.0421
	PSNR green	33.8185	16.9056	33.8185
	PSNR blue	32.1418	16.8881	32.1418
	NC red	0.9186	0.6038	0.9181
	NC green	0.9319	0.5630	0.9311
	NC blue	0.8809	0.4939	0.8797
JPEG compression	PSNR red	32.5064	16.6962	32.5064
	PSNR green	33.9616	16.7221	33.9616
	PSNR blue	32.8417	16.7128	32.8417
	NC red	0.9345	0.5899	0.9341
	NC green	0.9423	0.5560	0.9417
	NC blue	0.9036	0.4939	0.9025
Crop	PSNR red	13.2283	11.8709	13.2283
	PSNR green	13.6797	12.1924	13.6797
	PSNR blue	13.5194	12.0834	13.5194
	NC red	0.6993	0.4286	0.6991
	NC green	0.7009	0.3664	0.7056
	NC blue	0.6567	0.3253	0.6645



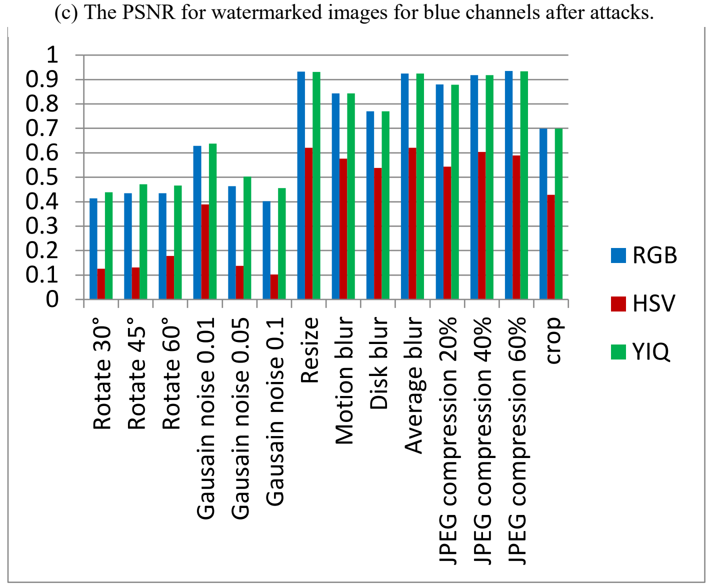
(a) The PSNR for watermarked images for red channels after attacks.



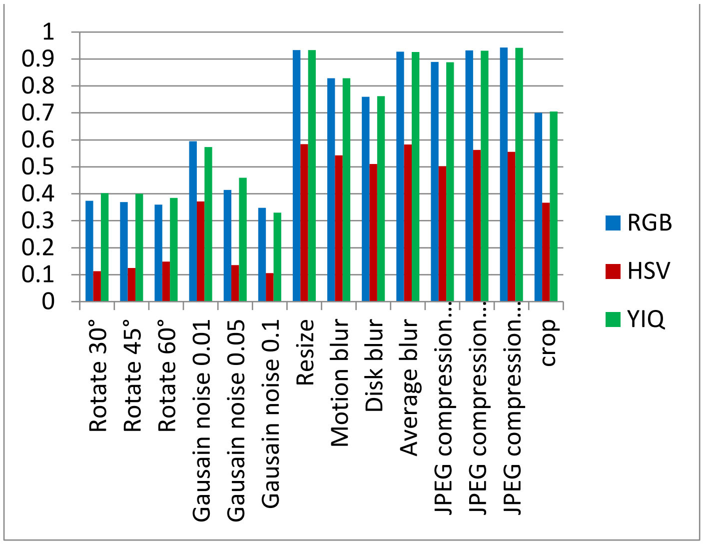
(b) The PSNR for watermarked images for green channels after attacks.



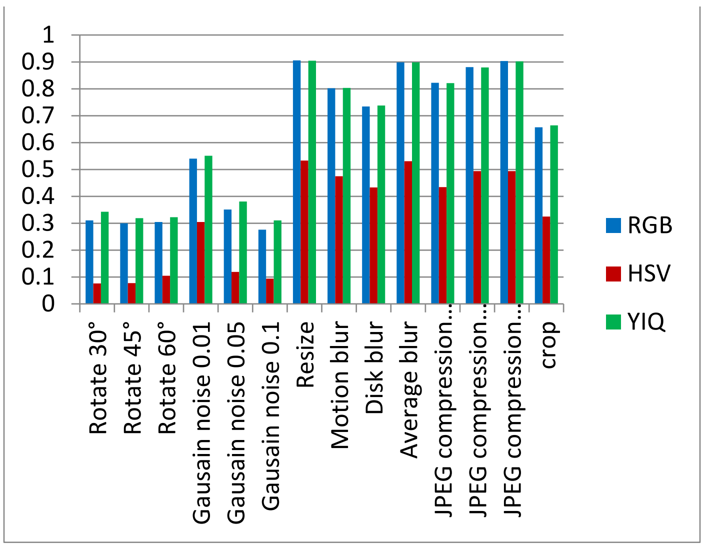
(c) The PSNR for watermarked images for blue channels after attacks.



(d) The NC for extracted watermark for red channel after attacks.



(e) The NC for extracted watermark for green channel after attacks.



(f) The NC for extracted watermark for blue channel after attacks.

Figure 15. The evaluation matrices comparison based on the PSNR for watermarked image, and the NC for extracted watermark after attacks.

As shown from visualization test, experimental results and evaluation figures with and without attacks, results illustrate that; there is a degradation in colors for the watermarked images and the extracted watermark is not good for using the HSV color system, where there are no degradation in colors for the watermarked images and the extracted watermarks are good for using the RGB and the YIQ color systems. The PSNR and the NC values without and after attacks for the HSV color system are less than the RGB and the YIQ color systems. The PSNR and the NC values without attacks for the RGB color system are little higher than the YIQ color system. The PSNR and the NC values after some attacks for the YIQ color system are little higher than the RGB color system and similar after other attacks. The Embedding algorithm CPU time show that the RGB color system is the faster and the slower is the YIQ color system but the difference is fractions of second so that the three color systems are approximately similar in embedding algorithm CPU time.

The HSV color system is worse than the RGB and the YIQ color systems and weak against attacks. The RGB color system and the YIQ color system are approximately similar and robust against attacks.

6. Conclusion

This paper presents a comparison between three different color systems; the RGB color system, the HSV color system, and the YIQ color system in watermarking algorithms. This comparison is to determine the stability and the robustness of color systems that used for applying the watermarking schemes. The watermarking algorithm that is used in this paper is the hybrid scheme DCT-DWT. This comparison illustrates that the HSV color system is the weakest when compared to the RGB and the YIQ color systems and is not robust against attacks. The RGB color system and YIQ color system are approximately similar and robust against attacks. The YIQ color system is a little robust against attacks when compared to the RGB color system. The embedding algorithm CPU time using the RGB color system is a little faster than the HSV and the YIQ color systems; the difference is a fraction of second. The results reveal the superiority of using the RGB and the YIQ color systems over the HSV color system.

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