Performance Analysis of DCT Based Digital Image Watermarking Using Color Spaces Effects

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Abstract: Digital watermarking is the field of digital image processing which deals with hiding information in a digital content. In this paper, performance analysis of DCT (Discrete Cosine Transform) based digital image watermarking using color spaces is done. Mostly, images that are taken for digital watermarking experiments are in RGB (Red, Green and Blue) color space. Eight different color spaces are considered for evaluation viz. RGB, YCbCr, JPEG-YCbCr, YIQ, YUV, HIS, HSV, CIELab and the performance of proposed algorithm is tested to check for which color space the algorithm works well.

Keywords- Digital Watermarking; Discrete Cosine Transform; Color Spaces; Peak Signal to Noise Ratio; Mean Square Error

I. INTRODUCTION

Digital Watermarking is a process of adding or concealing some important data into a digital data i.e. image, audio, video etc. This area is gaining a lot of research interest now a days due to the rise of internet usage which is threatening the copyright of digital content.

Digital Watermark: It refers to a process of inserting, a pattern of bits into a digital data file. These bits are responsible to identify the file's copyright information (author, rights, etc.).

Digital Watermarking Process: The whole process of digital watermarking is divided into two stages:

I. Watermark Embedding
II. Watermark Extraction

- **Watermark Embedding:** It is a process of adding digital watermark into a digital image. The image that acts as a base image into which the embedding is done is known as Cover Image (CI) and the image that is embedded into the Cover Image is known as Watermark Image (WI). The resultant image is a combination of CI and WI known as Watermarked Image (WDI). The watermark embedding process is shown in Figure 1.
- **Watermark Extraction:** It is a reverse process of watermark embedding in which the embedded watermark is extracted from the WDI. The resultant image is known as Extracted Image (EI).

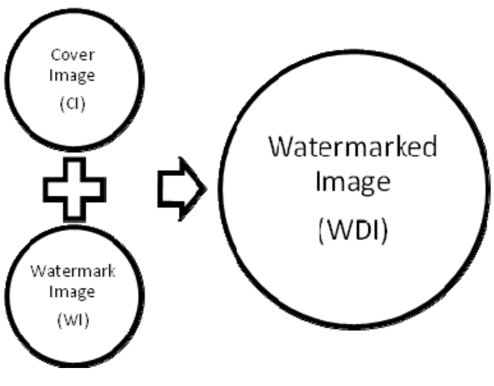

Figure 1: Watermark Embedding Process

Digital Watermarking Techniques: Digital Watermarking techniques are broadly divided into two categories. The former include Watermarking in Spatial Domain and the latter does watermarking in Frequency Domain.

Both these categories can further be classified into some other techniques as illustrated in the Figure 2. In Frequency domain, signal can be transformed using discrete cosine transform (DCT), discrete fourier transform (DFT), discrete wavelet transform (DWT), etc. [1].

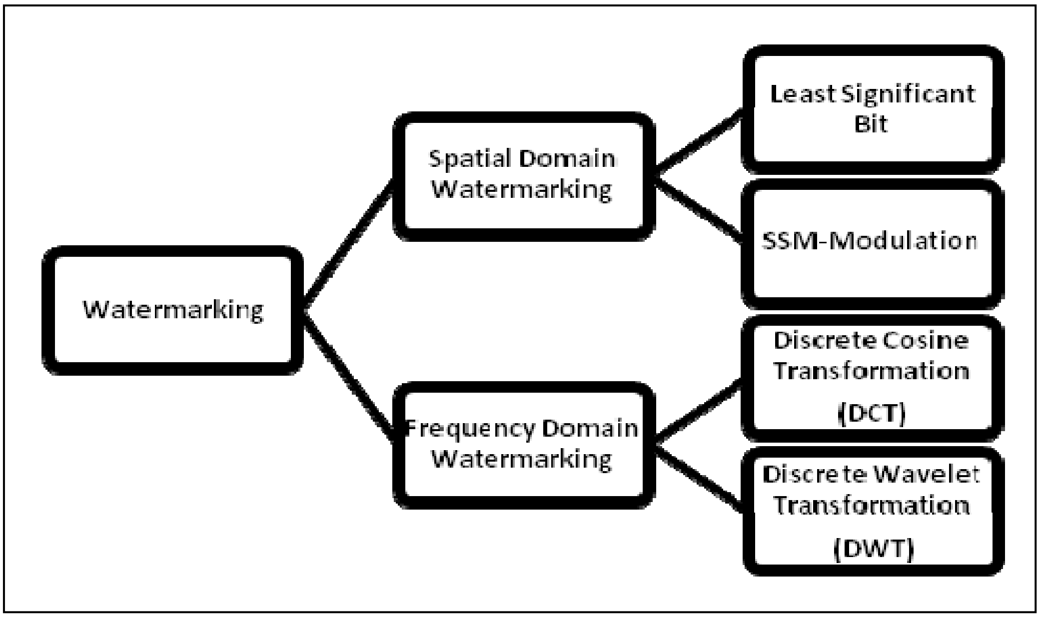

Figure 2: Digital Watermarking Techniques

Out of these techniques, this paper focuses on watermarking in frequency domain using DCT.

This paper is structured as follows: Section- II details out watermarking using DCT. Section-III represents various properties of different color spaces. Section-IV highlights the recent related work & Section-V provides the implementation details of our work. Section-VI holds all the experimental results. At last, conclusion and future scope of this work are discussed.

II. DISCRETE COSINE TRANSFORM

Discrete Cosine Transform (DCT) based watermarking works in frequency domain. DCT is most popular domain for embedding and extraction of watermarks in digital images. Like a Fourier Transform, DCT represents data in terms of frequency space rather than in amplitude space. The advantage lies in the fact that this domain corresponds more to the way humans perceive light, so that the parts that are not perceived can be identified and thrown away. The DCT allows an image to be broken up into different frequency bands, making it much easier to embed watermarking information into the middle frequency bands of an image. DCT based watermarking techniques are robust as compared to spatial domain techniques in operations like low pass filtering, brightness and contrast adjustment, blurring etc.

Basically, in DCT a signal is transformed from a spatial representation into frequency representation. Lower frequencies are more obvious in an image than higher frequency so when an image is transformed into its frequency components and a lot of higher frequency coefficients are thrown away, the amount of data needed to describe the image is reduced without sacrificing too much image quality. DCT is closely related to the Discrete Fourier Transform. It is known as separable linear transformation because its two-dimensional transform is equivalent to a one-dimensional DCT performed along a single dimension followed by a one-dimensional DCT in the other dimension [2].

III. COLOR SPACES

A color model is defined as an abstract mathematical model that describes a way to represent various colors using tuples of numbers. In other words, a color model along with a specific mapping of that model onto an absolute color space is called as Color Space. Three fundamental color models are color spaces based on human visual system (HVS), application specific color spaces and CIE color spaces. RGB, HVS and HSI are the color spaces that belong to first category while the application specific color spaces include YCbCr, JPEG-YCbCr, YUV, YIQ and a CIE color space is CIELab. All these eight color spaces will be considered for the experimental work. The RGB color space is the most widely used and the most popular color space in imaging. In RGB color space, three primary additive colors are red, green, and blue and these individual components are added together to form a desired color and are represented by a 3D, Cartesian coordinate system [10]. Unfortunately, RGB is not very efficient when dealing with the real world images [3]. In HVS color space, the color is decomposed into hue, saturation and luminance [4]. Out of these three components of HSV color space; hue is the attribute of a color, that decides about the actual color. Although, the control over the hue component of color is quite easier but it should not be changed for any pixel in order to enhance a color image because if hue gets changed then the color will get changed. In HSI, the three components H, S and I represent hue, saturation and intensity, respectively. HSI color space is based on the human visual perception theory and is suitable for describing and interpreting colors. Watermark Embedding in the intensity component of HSI color space can resist effects of various attacks [5]. YCbCr is a component color space that breaks the visual information into black and white signal and two color components. It separates luminance from chrominance i.e. lightness from color is separated in this color space. It is mostly used in digital videos. As the human eye is more attuned to brightness and less to color differences, therefore the YCbCr color system focuses more on Y, and less on Cb and Cr [6,10]. JPEG-YCbCr is a rescaling of YCbCr which is used in the JPEG image format, with Y, Cb and Cr in the range [0,1]. The YIQ system is the primary color system adopted by NTSC for color television broadcasting. YIQ is similar to RGB color space in the sense that both are device dependent which means that the actual color that is seen on the monitor depends on what kind of monitor is it and what its settings are. In this color space, Y-component stands for luminance or brightness, the I-component seems to mimic mostly shifts from blue, through purple, to red colors with increasing I, and the Q-component seems to mimic mostly the value of green; the I and Q components jointly represent the chromatic attributes [7]. The decorrelation of R, G and B component images makes the Y, I and Q component images complementary to each other [7]. The YUV color space is widely used in video and broadcasting today. It is very different from RGB color space; in YUV instead of three large color channels, it deals with one brightness or luminance channel i.e. Y and two color or chrominance channels i.e. U-blue and V-red. CIELab color space was recommended for color quality estimation [8]. 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 [8]. The main intention was to provide a standard and an approximate uniform color space which can easily be used to compare the color values.

IV. RECENT RELATED WORK

In year 2011, Baisa Gunjal and Suresh Mali proposed a strongly robust and multilayer security based color image watermarking algorithm in DWT-DCT domain. They worked on RGB color spaces [11].

Later in the same year, they presented another color image watermarking technique based on discrete wavelet transform-singular value decomposition (DWT-SVD) with Arnold scrambling and tested the proposed technique in YUV, RGB and YIQ color spaces [12].

El-Fegh and Mustafa[13] along with their companions proposed block DCT-based digital watermarking scheme based on embedding an adapted watermark original colour image. They considered only RGB color space.

In 2013, Yesilyurt,Yalman and Ozcerit[14] presented a New DCT Based Watermarking Method Using Luminance Component. They considered the YCbCr color space to aquire the Y component of the image and used this component to embed watermark.

Lastly, Mehdi Khalili and David Asatryan[10] analyzed the effects of color spaces on digital watermarking using DWT.

The effects of color spaces on watermark embedding using the technique of DCT are not yet analyzed. This paper focuses on the performance of DCT based watermarking in eight different color spaces.

V. IMPLEMENTATION

All the implementations of this research work have been done on MATLAB 2012b. Six different images have been taken as cover images for the purpose of analyzing the performance of DCT based watermarking. A binary image is taken as watermark image which is embedded in all the above mentioned cover images. Then a comparative study of the proposed work in eight different color spaces viz. RGB, YCbCr, JPEG-YCbCr, YIQ, YUV, HIS, HSV, CIELab is performed.

Implementation Specifications: All the six cover images are of *.jpg* format and the watermark image is a binary image representing name of the institute. Binary image is basically an image in which each pixel can either have a value of 0 or 1. Figure 3 shows the six cover images as well as the binary watermark image.

DCT based Watermark Embedding: As already discussed in Section-I, the process of watermarking is divided into two parts embedding and extraction. Now, in this section both these parts are explored on the basis of DCT. The following algorithm explains the steps involved in embedding of the watermark image into cover image.

Algorithm:

Step 1. Initialize the value of strength factor alpha.

Step 2. Read a cover image say CI using imread() function of MATLAB.

Step 3. Resize CI into a 512x512 matrix using imresize() function of MATLAB.

Step 4. Read the binary watermark image say WI using the same imread() function.

Step 5. Resize WI into a 64x64 matrix using imresize().

Step 6. Initialize the WI Sub-Block row values and Sub-Block column values.

Step 7. Retrieve 8X8 sub-block from CI.

Step 8. Apply DCT to each Sub-block say d.

Step 9. Apply the Watermark embedding formula i.e.

$$CI(x,y) * WI(x,y) * alpha$$

Step 10. Apply Inverse DCT to d.

Step 11. As a result, a watermarked image says WDI is obtained.

Step 12. Display WDI using imshow() function of MATLAB.

DCT based Watermark Extraction: After the Watermark embedding and analyzing the effects of color spaces, extraction of the watermark image is required. For this purpose following extraction algorithm is followed.

Algorithm:

Step 1. Initialize the value of strength factor alpha.

Step 2. Initialize the watermark Image Sub-Block row values and Sub-Block column values.

Step 3. Retrieve 8X8 sub-block from original Image.

Step 4. Apply DCT to each Sub-block say d'

Step 5. Apply the Watermark extraction formula i.e.

$$EI = \frac{WDI(x,y)}{alpha}$$

Step 6. As a result, an extracted image is obtained say EI.

Step 7. Display the EI using imshow() function of MATLAB.

Performance Evaluation: For computing and analyzing the performance of various color space effects on DCT based watermarking two performance parameters are used viz. Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR).

MSE (Mean Square Error): The mean square error measures the average of the squares of the "errors" i.e. the difference between the actual and the estimated signals. MSE corresponds to the expected value of the squared error loss or quadratic loss and is considered as a risk function. The difference occurs because of randomness or because the estimator doesn't account for information that could produce a more accurate estimate. It is expressed as follows [9]:

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i-j) - K(i,j)]^2 \qquad (1)$$

where I, K represent the input cover image and watermarked image respectively of size m x n, and i, j represent the pixels of images.

PSNR (Peak Signal to Noise Ratio): It is defined as the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. PSNR is usually expressed in terms of the logarithmic decibel scale. Mathematically, it is expressed as follows [9]:

$$PSNR = 10.\log_{10}\left(\frac{MAX_I^2}{MSE}\right) \qquad (2)$$

where MAX =255, and MSE is calculated using equation (1) mentioned above. In general, a higher PSNR value should correlate to a higher quality image.

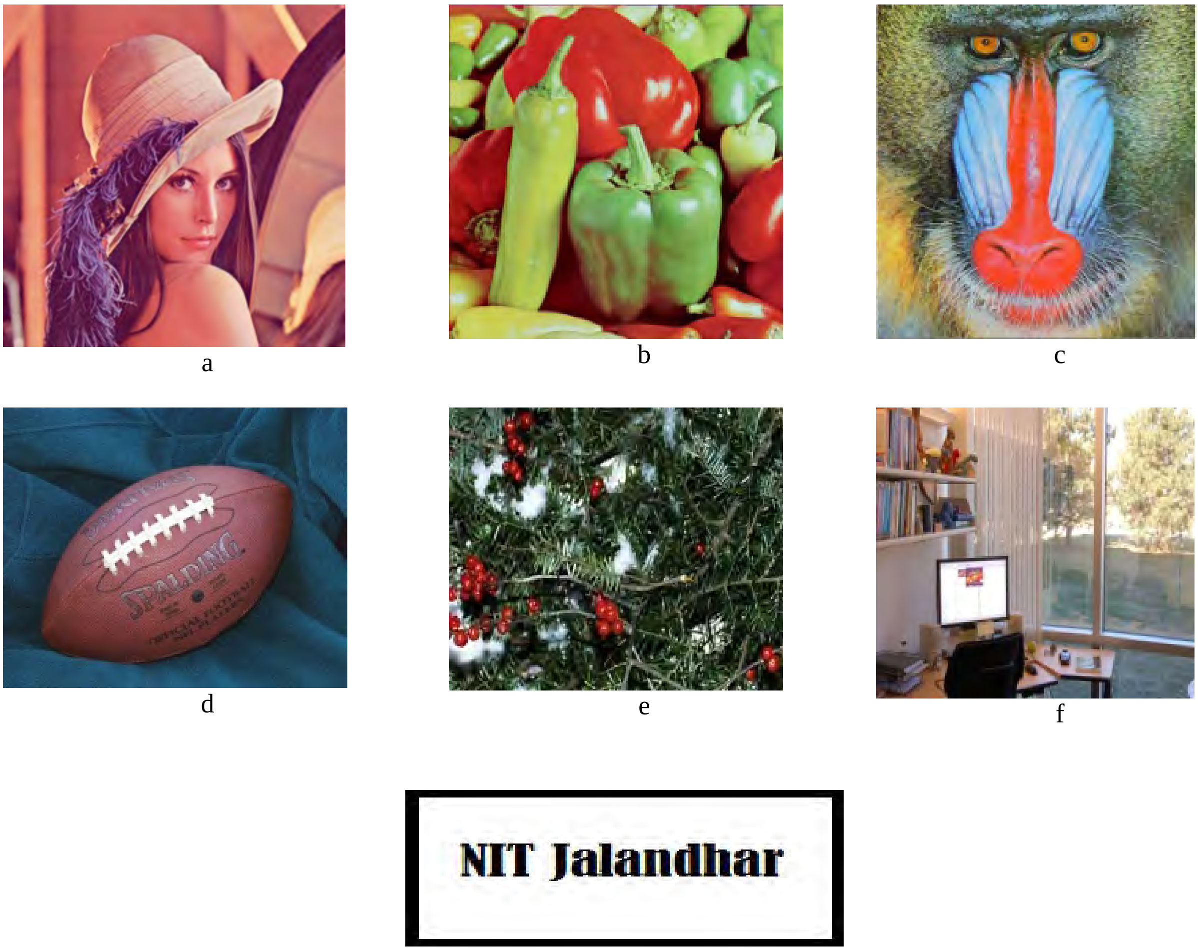

Figure 3: Input Images

a-f: Six cover Images leena, pepper, baboon, football, green, office
g: Binary Watermark Image

VI. EXPERIMENTAL RESULTS

Different color spaces are tested using DCT technique of watermarking on the ground of six cover images and the binary watermark image. All the discussions and results obtained are as follow.

Table 1: MSE Values corresponding to Watermarked Images in different color spaces

IMAGE / COLOR SPACE	Leena	Pepper	Baboon	Football	Green	Office
RGB	0.04	0.04	0.06	0.03	0.02	0.07
YCbCr	0.07	0.06	0.06	0.06	0.05	0.06
HIS	0.05	0.06	0.04	0.03	0.03	0.04
HSV	0.09	0.10	0.07	0.06	0.04	0.06
CIELAB	0.08	0.08	0.06	0.05	0.06	0.06
YIQ	0.00	0.01	0.00	0.00	0.00	0.00
YUV	0.04	0.04	0.06	0.03	0.02	0.07
JPEG-YCbCr	0.07	0.06	0.06	0.06	0.05	0.06

Table 2: PSNR Values corresponding to Watermarked Images in different color spaces

IMAGE / COLOR SPACE	Leena	Pepper	Baboon	Football	Green	Office
RGB	61.85	61.78	60.28	63.84	64.31	59.46
YCbCR	59.66	60.64	60.60	60.44	60.87	60.62
HIS	61.51	60.78	61.99	63.23	63.71	61.85
HSV	58.47	58.15	59.85	60.69	61.99	60.71
CIELAB	59.16	59.09	60.07	60.74	60.48	60.27
YIQ	71.20	70.58	73.38	76.44	80.50	80.23
YUV	61.85	61.78	60.28	63.85	64.31	59.46
JPEG-YCbCr	59.66	60.64	60.60	60.44	60.87	60.62

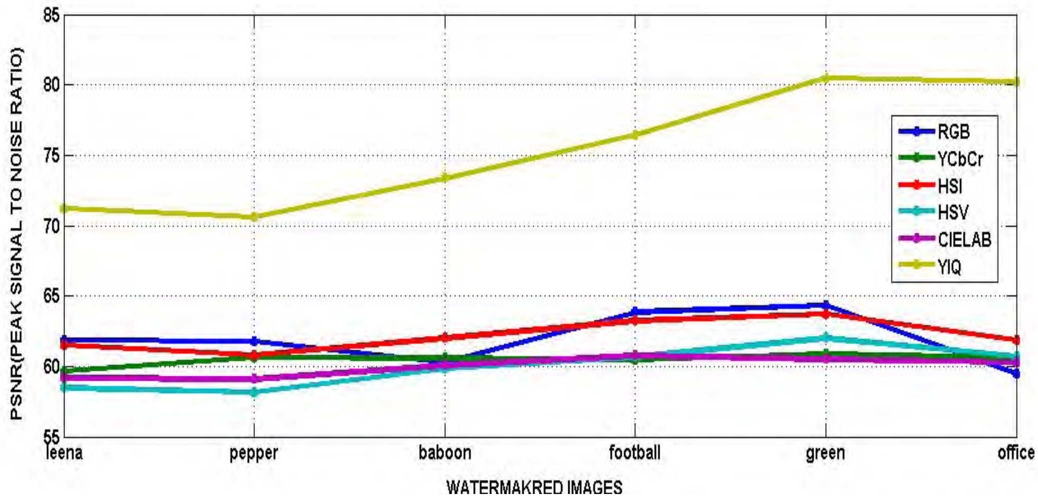

Figure 4: Plot for PSNR using Watermarked Images in different color spaces

Figure 4 represents the changes in the values of PSNR with respect to each image color space. Out of eight considered color spaces, RGB and YUV gave similar results. Also, YCbCr and JPEG-YCbCr produced the same result, hence YUV and JPEG-YCbCr are omitted from the graphical results but these omitted values are shown in tabular results i.e. in table 1.

Figure 5 shows the watermarked images corresponding to various cover images in different color spaces where C1 is RGB, C2 is YCbCR, C3 is HIS,C4 is HSV , C5 is CIELAB, C6 is YIQ, C7 is YUV and C8 is JPEG-YCbCr. After the whole process of Watermark embedding and extraction, performance analysis and evaluation is done.

As already discussed in previous section, MSE and PSNR are used for comparison purposes.

Table 1 and Table 2 illustrate the values of both parameters corresponding to each watermarked image and each color space.

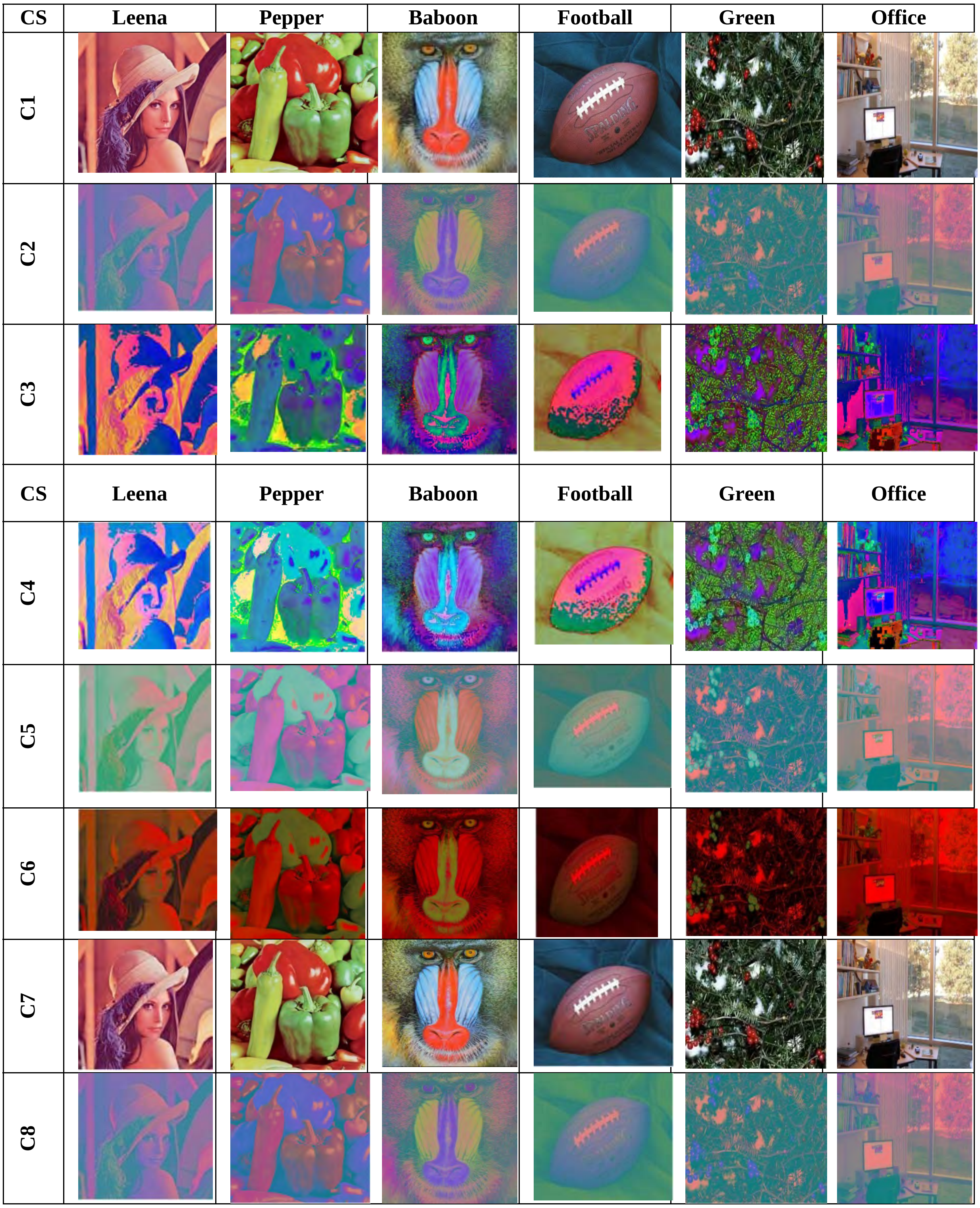

Figure 5: Watermarked Images in different color spaces

VII. CONCLUSION AND FUTURE SCOPE

In our complete research, it has been analyzed that DCT based watermarking technique gives better results in YIQ color space as compared to all other considered color spaces. It means, performing the proposed method in YIQ color space and then, respectively, RGB, HSI, YUV, JPEG-YCbCr, CIELab and HSV color spaces lead to the best watermark imperceptibility property.

In future, this work can be extended to improve the performance of DCT in the field of watermarking by combining it with other existing watermarking techniques. Further, various other color spaces can be used to analyze the performance of aforesaid techniques.

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