A New DCT Based Watermarking Method Using Luminance Component

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***Abstract*—The main purpose of the digital watermarking is to provide information security and copyright protection. From this point of view, a robust blind watermarking method based on Discrete Cosine Transform for colour images is proposed in this paper. The proposed method provides hiding a binary watermark in a compressed Digital Colour Image. First, the Digital Color Image is transformed into YCbCr from RGB color space and then the Discrete Cosine Transform middle band of the luminance (Y) component is used for watermarking processes. Each bit of the binary watermark is embedded in a different Discrete Cosine Transform block. Thus, deterioration on the image is minimized achieving high invisibility. The situation is checked whether the watermark is lost after the image saved. If the watermark is lost in any block, the average of some neighbouring Discrete Cosine Transform coefficients is used for embedding the watermark bit. The experimental results show that the proposed method can be safely used when point of interest is binary watermarks. Moreover, extraction processes do not need the cover image and the watermark is recovered completely. Statistical and perceptual quality evaluations show that the proposed method is better than its counterparts.**

***Index Terms*—Invisible watermarking, discrete cosine transform, YCbCr transform, digital image.**

I. INTRODUCTION

Nowadays, the internet is growing rapidly and this situation has led to the emergence of various problems such as copyright protection and security. Therefore many internet users need to use data hiding methods such as Cryptology, Steganography and Watermarking [1]. The most widely used data hiding method for copyright protection and security is watermarking in the literature [2]. Watermarking schemes use digital images as cover media are performed into two domains, namely spatial domain and transform (frequency) domain [3]. In spatial domain methods, the watermark bits are directly embedded into the pixels of cover image [4]. In transform domain, first a transformation such as Discrete Cosine Transform (DCT) or Discrete Wavelet Transform (DWT) is performed on a cover media (e.g. an image) to obtain frequency coefficients. And then, the secret message bits are embedded into significant coefficients (i.e. coefficients with large absolute values) to achieve the robustness (i.e. secure against common attacks) [5].

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Many watermarking techniques use the DCT which has three regions, Low Frequency (DC), Mid-Band Frequency and High Frequency (AC). These regions have been used for hiding processes, for example DC [6], [7] and mid-band [8], [9].

Many data hiding algorithm use least significant bit (LSB) embedding method in standard color domain that is RGB color domain [10]. On the other hand, in compressing domains such as JPEG or MPEG, the color domain is converted to YUV and YCbCr [11]. Some researchers select to embed the watermark in each of the three components (Y, U, V) individually. Then they compare the results for each component and finally concluded that the most suitable primary for YUV-based embedding is primary Y [12]. Similarly, a DCT block based-approach has been applied to the Y channel of the YCbCr model in [13].

The main purpose of the digital watermarking is to provide information security and copyright protection. From this point of view, a robust blind watermarking method based on DCT for color images is proposed in this paper. The proposed method provides hiding a binary watermark in a compressed DCI (Digital Color Image). The developed method has been detailed below.

II. PROPOSED METHOD'S WATERMARK EMBEDDING PROCESSES

Let's assume that the image size is M×N, luminance component (Y) is divided 8×8 blocks for watermark embedding processes and the number of blocks is nb as seen in (1) [14]. Then, each block of Y component is separately transformed 2D-DCT after color transformation

$$I(M, N)_{nb}=(M\times N)/64. \tag{1}$$

It is important to note that the watermark is embedded several steps in the cover image. The steps are depending on the size of the cover image and the watermark. In the embedding process, each binary watermark bit has been embedded using DCT (5, 2) and DCT (4, 3) coefficients of the mid-band frequency fields of luminance (Y) component (Fig. 1).

The watermarking processes can be easily applied not only on two coefficients mentioned above but also on more than two coefficients. If the main goal is robustness to the attacks, more than two coefficients can be used but it is going to be more fragile in terms of robustness [15]–[18].

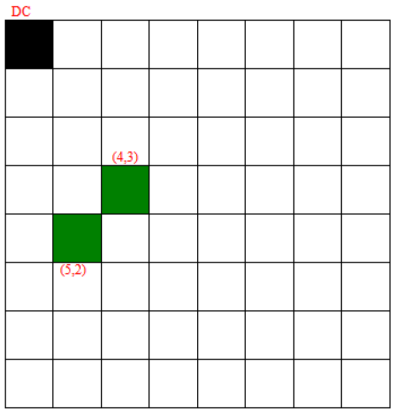

Fig. 1. DCT coefficients which are used for watermark bits.

The watermarking processes can be easily applied not only on two coefficients mentioned above but also on more than two coefficients. If the main goal is more watermark bit capacity, more than two coefficients can be used but it is going to be more fragile in terms of robustness [15]–[18].

Fig. 2 presents the proposed method's block diagram, where CT, WBE, DCT, IDCT and ICT denote that color transformation which is RGB to YCbCr, watermark bit embedding which is the most important step and the proposed method's base process, discrete cosine transform, inverse DCT and inverse color transform, respectively. The proposed method can be applied without the process of adding or subtracting to the coefficients of each DCT located in the blocks (8×8) unlike many others. WBE (Fig. 3), for the binary image used as a watermark, if the watermark bit equals to 1 then the DCT coefficient location for (5,2) is expected larger than the DCT coefficient for (4,3). If the data equals to $(0)_2$ then the DCT coefficient for (4,3) is expected larger than the DCT coefficient for (5, 2) as seen in (2)

$$w(i,j)=\begin{cases}1, & DCT(5,2)>DCT(4,3),\\ 0, & DCT(4,3)>DCT(5,2).\end{cases} \tag{2}$$

The DCT coefficients may become very close to each other depending on the cover image pixel values. That is why a constant ‘C’ (Fig. 3) is defined to prevent possible losses when the watermark is extracted by using (3) [2], [19]

$$w'(i,j)=\begin{cases}1, & DCT(5,2)>DCT(4,3),\\ 0, & DCT(4,3)>DCT(5,2).\end{cases} \tag{3}$$

By this way, watermarked coefficients are managed to get less affected from the distortions and the attacks by the DCT and IDCT processes. That embedding step is done one time each block and then new DCT coefficients $(Y_{DCT})'$ are implemented IDCT as follows

$$Y'=IDCT(Y_{DCT})'. \tag{4}$$

III. THE USE OF NEIGHBOUR DCT COEFFICIENTS FOR ROBUSTNESS

Some blocks are changed unexpectedly and some watermark bits have been deceived when a covered/ watermarked image is saved after IDCT process is done and the extraction process for watermarking is completed. In the proposed method, the main goal is that blocks are going to be clarified and reused after the settings are modified as mentioned below.

Table I shows that an example block including binary watermark bit $(0)_2$, namely DCT (5,2) < DCT (4,3). Table II shows the same block's DCT coefficients which obtained while extraction processes has been realized. It can be clearly seen that the watermark bit has been lost because DCT (5,2)>DCT (4,3) thus the block contains $(1)_2$, anymore.

In the proposed method, the use of some neighbour DCT coefficients has been offered to overcome the problem mentioned above. It has been realized by using the some neighbour DCT coefficients to the DCT (5,2) and DCT (4,3) while continuing to use the watermarking processes. The used neighbour DCT coefficients can be seen in Fig. 4.

It is important that demanding conditions are satisfied in terms of robustness of the proposed watermarking method while the watermark is extracted. Watermarking can be applied to the coefficients in mid-band which improves the applicability of this method. If the watermark bit (w) equals to $(1)_2$, average (AVG) of DCT (5,1), DCT (4,1) and DCT (4,2) coefficients is calculated and then it is performed that DCT (5,2)=AVG. Conversely, if the watermark bit (W) equals to $(0)_2$, AVG of DCT (4,2), DCT (3,3), DCT (3,2) coefficients are calculated and then it is calculated that DCT(5,2)=AVG.

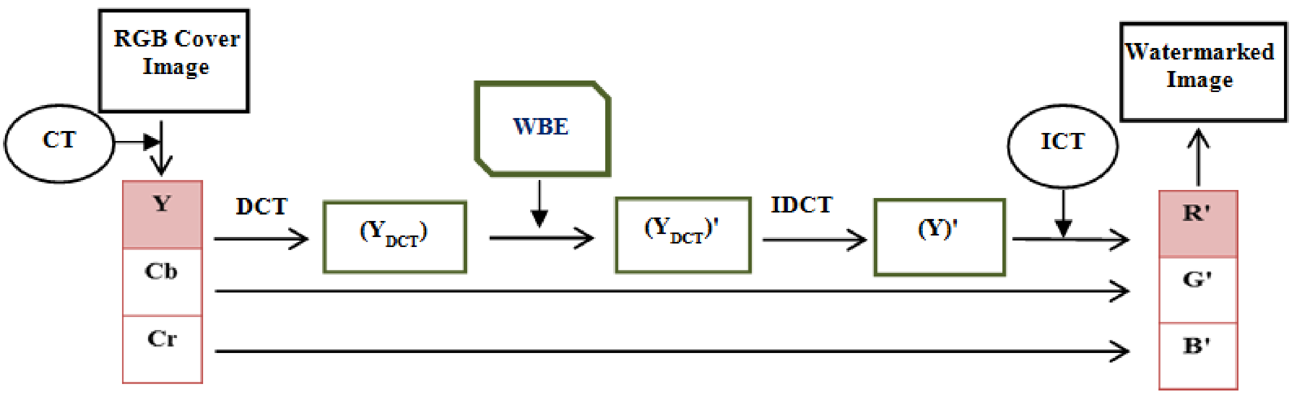

Fig. 2. Block diagram of the proposed watermarking method.

DCT (5,2) + C	if	w=1 and DCT (5,2) > DCT (4,3)
Temp= DCT (5,2) DCT (5,2)= DCT (4,3) DCT (4,3)= Temp **DCT (5,2) + C**		w=1 and DCT (5,2) < DCT (4,3)
DCT (4,3) + C	if	w=0 and DCT (4,3) > DCT (5,2)
Temp= DCT (4,3) DCT (4,3)= DCT (5,2) DCT (5,2)=Temp **DCT (4,3) + C**		w=0 and DCT (4,3) < DCT (5,2)

Fig. 3. Illustration of the watermark bit embedding.

TABLE I. THE IMAGE BLOCK'S DCT COEFFICIENTS WHICH CONTAIN A WATERMARK BIT $(0)_2$.

834.4787	10.5189	6.1709	-3.7910	-0.0235	-0.3971	0.3004	0.2140
-30.7783	18.8582	-3.1927	15.752	-2.6813	-0.2939	-0.2727	-0.1923
8.6051	-5.2111	0.3034	0.4988	-4.9210	0.2837	-0.0261	0.0854
-8.9292	4.6760	**11.9763**	-0.3073	0.3635	0.2688	0.0919	0.4053
0.5885	**-2.7654**	0.2768	0.1075	0.0693	0.0127	0.1405	-0.0516
2.8608	-0.4088	-5.6937	0.0946	-0.6742	0.6934	0.2164	-0.1194
4.6437	-0.0485	0.6299	0.1107	0.1761	-0.6316	-0.1259	-0.0661
-0.1298	0.2760	-0.2698	0.1569	-0.1782	0.3902	-0.2559	-0.2208

TABLE II. THE IMAGE BLOCK'S DCT COEFFICIENTS WHICH CONTAIN A WRONG WATERMARK BIT $(1)_2$ WHILE THE WATERMARK BIT EXTRACTION PROCESSES IS REALIZED.

878.7862	-78.2639	-53.9056	-26.0628	-10.2315	4.5424	9.8731	0.4126
-11.6278	3.9310	12.0756	-0.0841	8.0631	0.0709	0.6728	5.8198
-1.8054	1.6394	21560	3.1786	0.4190	-5.8556	0.5055	-0.0566
8.9278	-0.0471	**-2.3244**	2.0385	-5.3858	0.0204	-0.5292	-0.2759
-7.0593	**2.8026**	-0.0524	0.2448	6.7330	-0.0145	-0.3108	-0.2539
0.0748	-3.3527	0.5254	-0.2134	-0.0773	-0.1516	0.2706	-0.1085
-0.1195	-0.0364	-0.3602	0.0064	0.0603	0.2953	0.1648	-0.5713
-0.4457	0.3525	0.2181	-0.0330	-0.0167	-10.1895	-10.3368	-0.4280

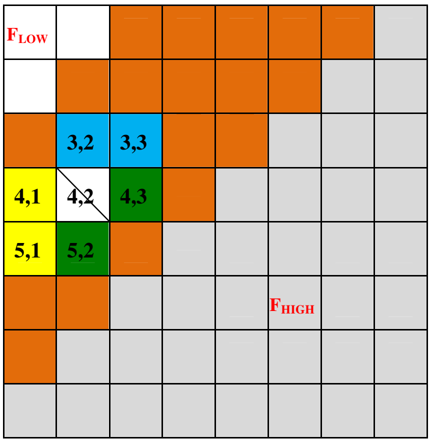

Fig. 4. Neighbour coefficients used for robustness of the proposed watermarking method.

That is very important to lower the damage to a minimum by getting the average of the values DCT (5,2) and DCT (4,3) as seen in (5). The main advantage of using the neighbour DCT coefficient is that the changing in the DCT coefficients (especially DCT (5,2) and DCT (4,3)) after ".jpeg" file saving is kept at minimum levels. Thanks to the use of the neighbour coefficients, blocks in the process of correction, to increase the number of corrected blocks desired, watermark constant 'C' can be used in specific proportions (6). Constant values (C, C/2, C/3, C/4, C/6) are added to DCT (5,2) and DCT (4,3) coefficients thus reorganized the block numbers to increase. This adding process causes the decrease of the PSNR values (from 0.10 dB to 0.20 dB). However, this situation has not been noticed by the Human Visual System (HVS) and the watermark can be completely recovered. Table III shows that the re-organization results of the block shown in Table II using watermark constants (C/6):

$$DCT(5,2), DCT(4,3) = \begin{cases} DCT(5,2) = (DCT(5,1) + DCT(4,1) + DCT(4,2))\, {}^{1}\!/_{3}, & w = 1, \\ DCT(4,3) = (DCT(4,2) + DCT(3,3) + DCT(3,2))\, {}^{1}\!/_{3}, & w = 0, \end{cases} \tag{5}$$

$$DCT(5,2), DCT(4,3) = \begin{cases} DCT(5,2) = (DCT(5,1) + DCT(4,1) + DCT(4,2))\, {}^{1}\!/_{3}) + C, & w = 1, \\ DCT(4,3) = (DCT(4,2) + DCT(3,3) + DCT(3,2))\, {}^{1}\!/_{3}) + C, & w = 0. \end{cases} \tag{6}$$

TABLE III. THE NEW DCT COEFFICIENTS AFTER RE-ORGANIZATION PROCESS OF THE BLOCK SHOWN IN THE TABLE II (WATERMARK BIT IS $(0)_2$ ANYMORE).

878.7862	-78.2639	-53.9056	-26.0628	-10.2315	4.5424	9.8731	0.4126
-11.6278	3.9310	12.0756	-0.0841	8.0631	0.0709	0.6728	5.8198
-1.8054	1.6394	2.1560	3.1786	0.4190	-5.8556	0.5055	-0.0566
8.9278	-0.0471	5.2494	2.0385	-5.3858	0.0204	-0.5292	-0.2759
-7.0593	2.8026	-0.0524	0.2448	6.7330	-0.0145	-0.3108	-0.2539
0.0748	-3.3527	0.5254	-0.2134	-0.0773	-0.1516	0.2706	-0.1085
-0.1195	-0.0364	-0.3602	0.0064	0.0603	0.2953	0.1648	-0.5713
-0.4457	0.3525	0.2181	-0.0330	-0.0167	-10.1895	-10.3368	-0.4280

IV. PROPOSED METHOD'S WATERMARK EXTRACTION PROCESSES

At the first step of extraction processes, the watermarked image is converted from RGB to YCbCr color space. Then, luminance (Y) component's DCT coefficients are calculated for each 8×8 block. DCT (5,2) and DCT (4,3) coefficients are used for obtaining the watermark bit. According to the relationship between these coefficients, one bit from each block is obtained. The binary watermark extraction step can be seen in (7) and Fig. 5

$$w' = \begin{cases} 1, & DCT(5,2) > DCT(4,3), \\ 0, & DCT(5,2) < DCT(4,3). \end{cases} \quad (7)$$

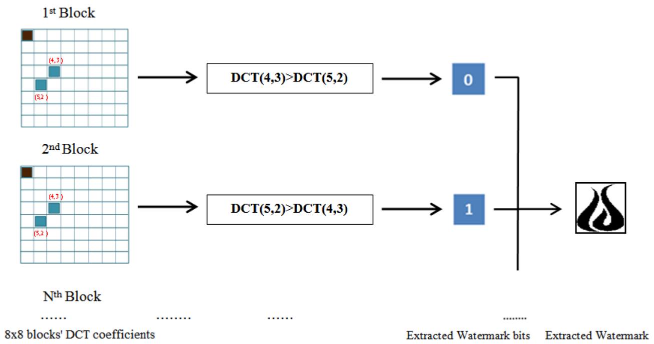

Fig. 5. Watermark extraction process.

V. EXPERIMENTAL RESULTS

In this section, experimental results of the proposed method are presented. The performance results are analyzed based on Peak Signal to Noise Ratio (PSNR) and Normalized Cross-Correlation (NC). RGB color images (i.e., Lena, Airplane, Baboon, Peppers and Tiffany (512×512×3)) have been used as cover/carrier images and a 64×64 binary image has been used a watermark for experimental applications. Perceptual results of watermarked images are pretty good as seen in Fig. 6.

In the proposed method, the luminance (Y) component of the original cover image has been used for watermark embedding as described above. A bit is embedded to each Y block (8×8), thus the watermark bit capacity is linearly proportional to the cover image size. The test images using Lena, the airplane, the baboon, the peppers and Tiffany, which are usually used in the literature, have been determined for the experimental applications. Table IV shows that average PSNR values are about 39 dB.

Table V shows that the proposed method has improved the PSNR for the well-known Lena image compared to its important counterparts. It can be easily said that the proposed method's performance is much better PSNR values compared to the other watermarking methods presented in the literature. Using neighbour DCT coefficients for robustness provides that number of reorganized blocks increases at the same rate watermark constant.

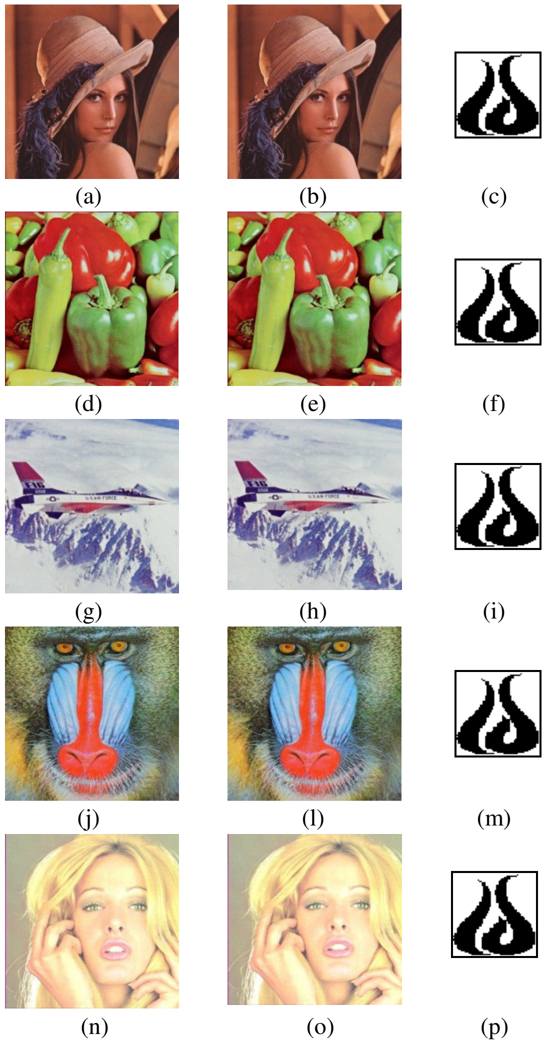

Fig. 6. Original images (a, d, g, j, n), watermarked images (b, e, h, l, o) and embedded watermarks (c, f, I, m, p).

TABLE IV. PSNR RESULTS FOR THE PROPOSED METHOD.

Cover Image	**PSNR Results (dB)**
Lena	40.14
Airplane	39.29
Baboon	32.63
Peppers	40.18
Tiffany	41.44

TABLE V. PSNR RESULTS COMPARISONS BETWEEN PROPOSED METHOD AND ITS COUNTERPARTS.

Method	Domain	Color Model (used component)	PSNR (dB)	Cover Image Size	Watermark (bits)
Saxena and Gupta [23]	DCT	RGB (B)	39.40	512×512	80×40
Feng et al. [18]	DCT	YUV (Y)	33.90	512×512	32×32
Zhou and Liu [20]	DCT	YCbCr (Cb)	36.12	512×512	ASCII
Jadhav and Bhalchandra [21]	BSS	RGB (B)	29.33	512×512	64×64
Kaurand and Kaur [22]	DCT	YCbCr (Y)	39.00	512×512	64×64
Bei et al. [17]	DCT-DWT	YCbCr(Y)	Not mentioned	512×512	64×64
The proposed method	DCT	YCbCr(Y)	40.14	512×512	64×64

According to the WBE method, binary watermark does not add or extract in DCT coefficients. Thus, changes in the DCT coefficient values do not cause data loss on the watermark. In Fig. 7, the highest value of the watermark constant (C=24), C/6, C/4, C/3, C/2 rate is used, and the recovery rates are a varied number of reorganized blocks (RB) that are close to each other. Fig. 7 shows, their rates between C values and the number of RB, the (C/2) value, and the number of reorganized blocks have increased in 2.5 times.

Table VI shows that the proposed method's PSNR performance without using neighbour coefficients and with using neighbour coefficients. Level of decrease on the PSNR values has been realized between acceptable limits.

TABLE VI. THE PROPOSED METHOD'S PSNR PERFORMANCE WITHOUT USING NEIGHBOUR COEFFICIENTS (A) AND WITH USING NEIGHBOUR COEFFICIENTS (B).

Method	Lena	Airplane	Baboon	Peppers	Tiffany
(A)	40.14	39.29	32.63	40.18	41.09
(B)	40.05	39.13	32.53	39.89	41.02

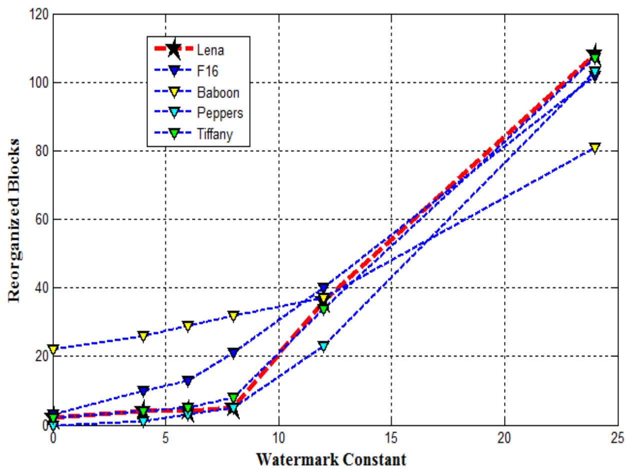

Fig. 7. Number of RB and PSNR values for watermark constant (C/6, C/4, C/3, C/2).

VI. ROBUSTNESS OF THE PROPOSED METHOD

To compare our method with two counterparts ([17] and [18]) to show robustness of the proposed method in terms of JPEG compression and some other attacks. The experimental results are given in Table VII.

Table VII shows NC and PSNR values of extracted watermarks after attacked by different attacks such as sharpen, gaussian blur, auto contrast and so on. Even so the attack on the watermark is recovered completely, from reorganized blocks with neighbour pixels method. NC values of extracted watermark are 1 against, Sharpen, Sharpen Edge, Unsharp Mask, Auto Contrast and Equalize attacks, as well as, NC values are 0.9861, 0.9653 respectively, after the despeckle, gaussian (3%) attacks. Experimental results show NC values has high performance over the counterparts ([17], [18]).

In addition, Table VII shows the NC and PSNR values of extracted watermarks after attacked by JPEG compression with different quality factors. Image quality is decreased when the Compression Ratio (CR) is increased. Thus, watermarked image are prompted to be resistant against JPEG compression attacks. Photoshop CS3® has been used for attacks. NC and PSNR values have been investigated by decreasing the quality value (Q) for the purposed method in Table VII. Considering the extracted binary images, NC values have been obtained 1 for Q=9, Q=8, Q=7, Q=6 and Q=5.

TABLE VII. EXPERIMENTAL RESULTS OF IMAGE PROCESSING ATTACKS.

Attacks	Proposed Method		Y. Bei [17]		S. Feng [18]	
	NC	PSNR	NC	PSNR	NC	PSNR
Sharpen	1	99	-	-	0.96	28.00
Sharpen Edge	1	99	-	-	1	30.32
Unsharpmask	1	99	0.96	38.95	0.98	29.72
Despeckle	0.98	20.21	-	-	0.79	30.51
Gaussian(%3)	0.96	15.44	0.93	26.37	-	-
Autocontrast	1	99	-	-	0.99	27.53
Equalize	1	99	-	-	0.85	22.59
JPEG Quality=90	1	99	-	-	0.97	33.50
JPEG Quality=80	1	99	0.98	40.37	0.97	33.00
JPEG Quality=70	1	99	-	-	0.97	31.40
JPEG Quality=60	1	99	0.92	36.85	0.93	30.50
JPEG Quality=50	1	99	0.89	32.85	0.96	29.00

The experimental results show that a noticeable improvement has been made, both on the robustness and on the imperceptibility, and this is achieved by the proposed method listed below.

Referring to the proposed method, it provides not only good visual quality for watermarked images but also the robustness for watermarking. Therefore, this method is robust against attacks. So it can be said that in the mid-band coefficients at positions DCT (5,2) and DCT (4,3) are very useful for watermarking applications.

VII. CONCLUSIONS

The main object of this study is to design and implement a robust watermarking method for 24 bits digital color images. At the first step, color images are transformed from RGB to YCbCr color space. Then, the luminance (Y) component of YCbCr color space is used for the embedding process. It is then applied on the middle band DCT coefficients. The Y component of the cover image is divided into 8×8 blocks and then a binary watermark bit is embedded to each block.

Experimental results of the proposed method show that developed algorithm provides robust watermarking results for digital color images. We have been determined that there is some deterioration in some of the blocks in watermarking and these blocks are aimed to be bought for watermarking. The average of neighbouring pixels has been used in the DCT coefficients.

The proposed idea to prevent the loss of the watermark bit in DCT block is to reorganize the block method, the average of the neighbouring pixels used, the changes made on the DCT coefficients, and the image deterioration to decrease to the minimum level. The number of corrected blocks are directly proportional to the magnitude of the watermark constant. During this process, the value of the PSNR is 38.5 dB levels fully recovered and the watermark can be obtained exactly as watermarking of the proposed method ensures them to be effective and powerful. This proposed method is not only in images compressed video (Mpeg) for media compatibility but also offers an application domain and the potential for widespread impact.

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REFERENCES

[1] O. Cetin, A. T. Ozcerit, “A new steganography algorithm based on color histograms for data embedding into raw video streams”, *Computers & Security*, vol. 28, pp. 670–682, 2009. [Online]. Available: http://dx.doi.org/10.1016/j.cose.2009.04.002

[2] M. Yesilyurt, Y. Yalman, I. Erturk, A. T. Ozcerit, “A DCT based invisible watermarking application for compressed images”, in *Proc. of the 8th International Conference on Electronics and Computer Technologies,* 2011, pp. 18–24.

[3] T. H. Lan, A. H. Tewfik, “A novel high-capacity data embedding system”, *IEEE Transactions on Image Processing*, vol. 15, no. 8, pp. 2431–2440, 2006. [Online]. Available: http://dx.doi.org/10.1109/TIP.2006.875238

[4] J. A. Hussein, “Spatial domain watermarking scheme for colored images based on log-average luminance”, *Journal of Computing*, vol. 2, no. 1, pp. 100–103, 2010.

[5] C. C. Chang, Y. C. Chou, “Reversible data hiding scheme using two steganographic images”, in *Proc. of the IEEE Tencon 2007*, Taiwan, 2007, pp. 1–4.

[6] M. I. Khan, V. A. Jeoti, “Blind watermarking scheme using bitplane of DC component for JPEG compressed images”, in *Proc. of the 6th International Conf. on Emerging Technologies*, 2010, pp. 150–154.

[7] S. D. Lin, S. C. Shie, J. Y. Guo, “Improving the robustness of DCT based image watermarking against JPEG compression”, *Computer Standards & Interfaces*, vol. 32, pp. 54–60, 2010. [Online]. Available: http://dx.doi.org/10.1016/j.csi.2009.06.004

[8] B. Kaur, A. Kaur, J. Singh, “Steganographic approach for hiding image in DCT domain”, *International Journal of Advances in Engineering & Technology*, vol. 1, no. 3, pp. 72–78, 2011.

[9] M. Wu, B. Liu, “Data hiding in binary image for authentication and annotation”, *IEEE Transactions on Multimedia*, vol. 6, no. 4, pp. 528–538, 2004. [Online]. Available: http://dx.doi.org/10.1109/TMM.2004.830814

[10] A. Benhocine, L. Laoumer, L. T. Nana, A. C. Pascu, “Improving extraction of watermarks in color attacked watermarked images”, *Journal of Communi. and Computer*, vol. 6, no. 5, pp. 36–45, 2009.

[11] S. K. Singh, S. K. D. Agarwal, A. Gambhir, S. Kumar, “Colour space entropy based lossy and lossless colour image compression system”, *Int. Journal of Computer Science and Network Security*, vol. 9, no. 3, pp. 327–337, 2009.

[12] R. Hovancak, D. Levicky, “Digital image watermarking in different color models”, in *2nd Slovakian-Hungarian Joint Symposium on Applied Machine Intelligence*, Slovakia, 2004.

[13] A. Al-Gindy, H. Al-Ahmad, R. Qahwaji, A. Tawfik, “Watermarking of colour images in the DCT domain using Y channel”, *IEEE/ACS International Conference on Computer Systems and Applications*, 2009, pp. 1025–1028. [Online]. Available: http://dx.doi.org/10.1109/AICCSA.2009.5069457

[14] I. Martisius, D. Birvinskas, V. Jusas, Z. Tamosevicius, “A 2-D DCT hardware codec based on loeffler algorithm”, *Elektronika ir Elektrotechnika (Electronics and Electrical Engineering), no.* 7, pp. 47–50, 2011.

[15] H. V. Singh, S. Rai, A. Mohan, S. P. Singh “Robust copyright marking using weibull distribution”, *Computer and Electrical Engineering*, vol. 37, no. 5, pp. 714–728, 2011. [Online]. Available: http://dx.doi.org/10.1016/j.compeleceng.2011.04.006

[16] P. K. Amin, N. Liu, K. P. Subbalakshmi, “Statistically secure digital image data hiding”, in *Proc. of the IEEE 7th Workshop on Multimedia Signal Processing*, China, 2005, pp. 1–4.

[17] Y. Bei, D. Yang, M. Liu, L. Zhu, “A multi-channel watermarking scheme based on HSV and DCT-DWT”, in *Proc. of the IEEE International Conference on Computer Science and Automation Engineering,* 2011, pp. 305–308.

[18] S. Feng, D. Lin, S. C. Shie, J. Y. Guo, “Improving the robustness of DCT based image watermarking against JPEG compression”, *Computer Standards & Interface*, vol. 32, pp. 54–60, 2010. [Online]. Available: http://dx.doi.org/10.1016/j.csi.2009.06.004

[19] F. A. P. Petitcolas, “Watermarking schemes evaluation”, *IEEE Signal Processing Magazine*, vol. 17, pp. 58–64, 2000. [Online]. Available: http://dx.doi.org/10.1109/79.879339

[20] Y. Zhou, J. Liu, “Blind watermarking algorithm based on DCT for color images”, in *Proc. of the 2nd Int. Congress on Image and Signal Processing*, 2009, pp. 1–3.

[21] S. D. Jadhav, A. S. Bhalchandra, “Blind source separation based color image-adaptive watermarking”, in *Proc. of the IEEE 5th International Conference on Image and Graphics*, 2009, pp. 13–17.

[22] M. Kaurand, P. Kaur,“Robust watermarking into the color models based on the synchronization template”, in *Proc. of the International Conference on Information and Multimedia Technology*, 2009, pp. 296–300.

[23] V. Saxena, J. P. Gupta, “A novel collusion attack resistant watermarking scheme for color images”, *IAENG International Journal of Computer Science*, vol. 34, no. 2, pp. 171–177, 2007.