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Improvement of the Performance of DCT Based Digital Image Watermarking Technique

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Abstract

In this paper we propose an image watermarking technique based on DCT (Discrete Cosine Transform). The DCT is considered as containing low and high frequency band. The watermark signal is a binary sequence which is embedded to the selected DCT coefficients from high frequency band to the low frequency band of the host image. For watermark detection, the correlation between the selected DCT coefficients of the watermarked image and the watermark signal is compared with the predefined threshold which is used to determine whether the watermark is present or not. The experimental results show that the embedded watermark can resist to attack such as rotation, scaling, JPEG compression, cropping, and multiple watermarking.

Keywords: Blue Channel, Correlation, Decent watermarking, Discrete Cosine Transform, Threshold.

1. INTRODUCTION

The copyright of digital images i.e., the ownership and the rights of the author of those images, in the Internet, CD, DVD etc, can be easily violated by cropping and graphical modification. Some parts of an image such as the human face image can be cropped and applied to other images without permission which violates the copyright. To protect the copyright, the digital image watermarking technique is applied. In watermarking the secret information called as watermark, is invisibly embedded into the host media, while it should resist to malicious attacks. It is embedded permanently in an image and introduces invisible changes for the human vision that can be detected only by a computer program. To protect the cropping attack, the watermark should be embedded and distributed over the image. The watermarks must be robust to distortions such as those caused by image processing algorithms. Image processing does not modify only the image but may also modify the watermark as well. Thus, the watermark may become undetectable after intentional or unintentional image processing attacks. The watermark alterations should not decrease the image quality. A general watermarking framework for copyright protection has been presented in [1] and describes all these issues in detail. Watermarking techniques can be categorized into two types according to embedding and extraction processes. In the first type, the watermark is embedded in the time or spatial domain. The second type is the watermarking in the frequency domain. The advantages of embedding watermarks in the frequency domain over time domain is that the position of the watermark in time domain is sparsely spread, so that the intentional attempts to remove or destroy the watermark in time domain cannot be easily done. The disadvantage of embedding watermarks in the frequency domain is that, it does not yield better resistance in the cropping attack. Due to some techniques in the frequency domain [2], [3] they required the knowledge of an original image. Among the methods which do not use the original image for watermark detection, Piva *et al.* [5] suggested adding the watermark to a larger number of DCT coefficients which need not be significant. They order the DCT coefficients in a zigzag scan and the first 16000 coefficients are left out. The watermark is added to the next 25000 coefficients. Watermark detection is performed by correlating these 25000 coefficients in the test image with the original copy of the watermark. A larger number of coefficients are for a significant detector response as compared with the method in [2], since correlation is performed without subtracting out the original image. Since the watermark is added to such a large number of coefficients, visual masking is done in the spatial domain to prevent degradation in the perceptual quality of the image. But this masking cannot be taken into account in the process of watermark detection.

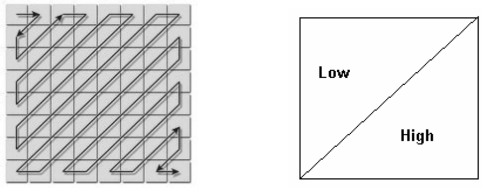
In this paper, we consider the watermarking in frequency domain and propose an image watermarking technique based on the discrete cosine transform (DCT). The DCT is a Fourier-related transform similar to the discrete Fourier transform (DFT), but uses only real numbers. DCT converts spatial information to "frequency" or spectral information, with the X and Y axes representing frequencies of the signal in different dimensions. The pixels when transformed are arranged from the most significant pixel to the least significant pixel i.e. DCT helps separate the image into parts of differing importance (with respect to the image's visual quality). The features of our proposed technique are: (i) Add watermark to significant coefficients. (ii) Does not use the *original* image for watermark detection. (iii) Amount of watermark added is *adapted* to the image. (iv) Image sized watermark is not required (v) No explicit *visual masking* is required (This highly improves the detector response and becomes computationally *fast*).

We experiment on our proposed technique and see that it is robust to JPEG compression when the compression ratio is up to 70%. Again it is accurate when the scale change(s) is greater than or equal to 0.5. It is also robust to cropping attack 80 x 80 or greater for a 128 x 128 image and also robust to rotation less than or equal to 10^0. Our proposed technique shows better performance from the existing method [11] on the basis of JPEG compression, cropping and scaling.

In Section 2, the proposed DCT based technique is described. In section 2.1 the formula for DCT and Inverse DCT are described, in section 2.2 the proposed watermark embedding process is described in details in which the watermark signal is embedded from the high frequency band to the low frequency band of the blue channel of the host image and in section 2.3 the proposed detection process is described in details in which the watermark signal is detected without the original image. The experimental results are presented and described in section 3 and eventually, the conclusions are drawn in section 4.

2. THE PROPOSED DCT BASED TECHNIQUE

We consider the watermark as the binary watermark i.e. the watermark is represented in binary form as $w' = w'_{11}, w'_{12}, ...w'_{M_1 N_1}$, where $w'_{ij} \in \{0, 1\}$, of $M_1 \times N_1$ watermark signal. Here the value 0 represents black and 1 represents white color. The binary form of the message w' is then transformed to obtain $w = w_{11}, w_{12}, ...w_{M_1 N_1}$, with $w_{ij} \in \{1, -1\}$. The proposed scheme is an image-quality guaranteed watermarking scheme as well as the conventional schemes. In our proposed technique, any extra processing such as visual masking for watermark casting and the original image or image size watermark for watermark detection is not required whereas the existing methods require any or more of these. The amount of watermark added is adapted to the image so that less amount of watermark is added to a smooth image (e.g., *Lena*) and more to a non-smooth image (e.g., *baboon*). In the proposed technique DCT is considered as two frequency band (low and high as Figure 1). Generally, the human visual system is least sensitive to the range of high frequency [4]. In case of RGB color image, the blue channel has characteristic of the highest frequency range. In the proposed technique for high performance the blue channel is transformed into DCT domain and watermark is embedded only from the high frequency band to the low frequency band of the blue channel of the host image. So the greater invisibility of the watermark in the watermarked image is achieved.



(a) **(b)**

Figure 1: After taking DCT (a) Reordering of coefficients (b) frequency distribution

2.1 Formula for DCT and Inverse DCT

Formulas for DCT and corresponding Inverse DCT are as follows:

$$F(u,v) = \frac{2}{N} C(u) C(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) \cos\left[\frac{(2x+1)u\pi}{2N}\right] \cos\left[\frac{(2y+1)v\pi}{2N}\right] \quad (1)$$

$$f(i,j) = \frac{2}{N} \sum_{u=0}^{N-1} \sum_{v=0}^{N-1} C(u) C(v) F(u,v) \cos\left[\frac{(2x+1)u\pi}{2N}\right] \cos\left[\frac{(2y+1)v\pi}{2N}\right] \quad (2)$$

In the above formulas, $F(u,v)$ is the two-dimensional $N \times N$ DCT; $u, v, x, y = 0, 1, 2 \ldots N-1$; x, y are spatial coordinates in the sample domain; u, v are frequency coordinates in the transform domain and

$$C(u), C(v) = \frac{1}{\sqrt{2}} \text{ for } u, v = 0;$$
$$= 1 \text{ otherwise.}$$

f(x, y) is a two dimensional function defining an image, where x and y are spatial (plane) coordinates and *f* is the amplitude of that image at any pair of coordinates *(x, y)* which is called the intensity or gray level of the image at that point. After DCT encoding of the image *f(x, y)* we get a two dimensional DCT matrix *F (u, v)* which is used in the process of DCT decoding to get the image *f(x, y)* again. A general discussion base on DCT has been presented in [9], [10].

2.2 Watermark embedding process

Before embedding, the watermark signal is first encoded as described before. The proposed embedding method is shown in figure.2.

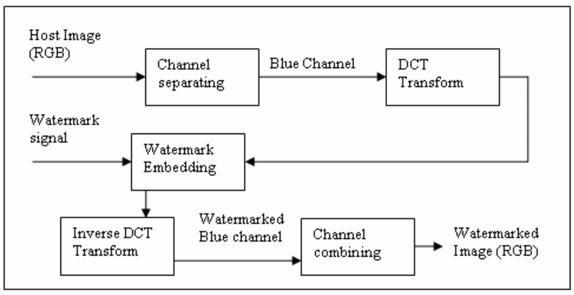


Figure 2: Block diagram of watermark embedding process

From the block diagram we see that, the three channels of RGB image are separated in channel separating stage and then only the blue channel is chosen to transform into DCT domain. However in case of grayscale image, it is transformed directly into DCT domain. Then the watermark is embedded from high frequency band to the low frequency band of that DCT domain and then it is transformed into inverse DCT domain. At this stage, for grayscale image we get the watermarked image but for RGB image we get the watermarked blue channel which is then combined to other two channels in channel combining stage to obtain the watermarked image. The equation used for the embedding process is as follows [3] [5]:

$$F'_{i,j} = F_{i,j} + K\left|F_{i,j}\right| w_{i,j} \tag{3}$$

Where i and j runs over all selected coefficients in the DCT domain and $F'_{i,j}$ and $F_{i,j}$ denote the DCT coefficient of the blue channel of the watermarked image and the original image respectively, $w_{i,j}$ is the watermark signal in encoded form and K is the scaling parameter whose value is determined in section 3.1. In the case of multiple watermarking, the equation (3) can be repeated as

$$F''_{i,j} = F'_{i,j} + K\left|F'_{i,j}\right| w'_{i,j} \qquad 3(a_1)$$

$$F'''_{i,j} = F''_{i,j} + K\left|F''_{i,j}\right| w''_{i,j} \qquad 3(a_2)$$

.

.

$$F^{n}_{i,j} = F^{n-1}_{i,j} + K\left|F^{n-1}_{i,j}\right| w^{n-1}_{i,j} \qquad 3(a_n)$$

Where the equations $3(a_1)$, $3(a_2)$ and $3(a_n)$ denote the watermarking in two times, three times and n times respectively. Exhaustive experiment is required to know the value of n of multiple watermarking. In the section 3.7 we have shown the result of watermarking in two times.

2.3 Watermark detecting process

In the detection process, we require a watermarked image $(N \times N)$ and watermark signal $(M_1 \times N_1, N_1 <= N, M_1 <= N)$ and the detector detect whether the watermark signal is present or not in the watermarked image. At first apply DCT transform on the blue channel of the given watermarked image and determine the coefficients $F'_{i,j}$ $(i, j = 1, 2 \ldots N)$. Now select $M_1 \times N_1$ coefficients from the high frequency part and compute the average T as shown in (4), which we consider as a threshold.

$$T = \frac{1}{M_1 N_1} \sum_{i=N-M1}^{N} \sum_{j=N-N1}^{N} \left|F'_{i,j}\right| \tag{4}$$

Now determine the correlation C_0 (as shown in (5)) between the selected DCT coefficients $F'_{i,j}$ and the provided watermark $w_{i,j}$ and compare C_0 with T.

$$C_0 = \frac{1}{M_1 N_1} \sum_{i=N-M1}^{N} \sum_{j=N-N1}^{N} F'_{i,j} w_{i,j} \tag{5}$$

If the provided watermark signal and the embedded watermark signal are similar then the value of the correlation is larger than the threshold value otherwise not, i.e. if $C_0 > T$ then we can say that the provided watermark is detected. As $F'_{i,j}$ may be negative and $w_{i,j}$ has values -1 or 1, so *T always greater than* C_0. As a result a scaling parameter α is required, where $\alpha \cong \frac{K}{2}$. The detail about K is described in section 3.1. So the adjusted threshold is as (6)

$$T = \frac{\alpha}{M_1 N_1} \sum_{i=N-M1}^{N} \sum_{j=N-N1}^{N} F'_{i,j} \tag{6}$$

The proposed detection process is shown in figure 3.

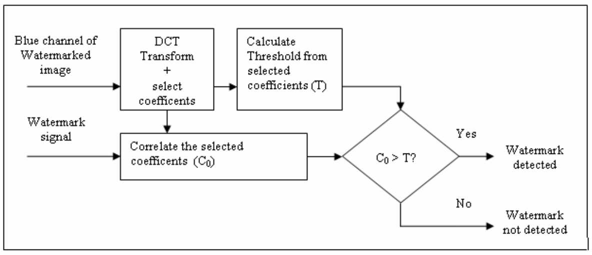


Figure 3: Block diagram of watermark detecting process

From the block diagram we see that the watermarked image (For RGB image, the blue channel of watermarked image) is first transformed into DCT domain. Then from the selected coefficients, the threshold is calculated. In the mean time, from the selected coefficients and the provided watermark signal the correlation is calculated. The value of threshold and correlation is used to make the decision whether the watermark is detected or not.

3. EXPERIMENTAL RESULTS

In this section, we illustrate and evaluate the performance of the proposed technique against rotation, scaling, cropping, JPEG compression and other attacks. Our proposed technique can be applied to both RGB and grayscale image. Here we present the experimental results using the standard image *"Lena"* (128×128 pixels, RGB) shown in Figure 4(b). Figure 4(a) shows a sample watermark signal (128×128 pixels, Black & White) and Figure 4(c) shows the corresponding watermarked image after embedding.

(a) **(b)** **(c)**

Figure 4: (a) Sample watermark signal (b) Host image (c) watermarked image

3.1 Determining the scaling parameter K

In the proposed method the scaling parameter (*K*) is an important factor. The larger the value of *K* the more the image quality is degraded. But small value of *K* degrades the detector response. So the value of *K* must be in a reasonable range for successful watermark detection. Table 1 shows the *Mean of luminance*, *Std. Deviation of luminance*, *Median of luminance* of original *Lena* image and the watermarked image for different values of *K*. Luminance is a measure of the amount of energy an observer perceives from a light source. High luminance can be detected to alteration by the human eyes less than at the lower luminance pixel. From the Table 1 we see that, the value for *K* = 0.2, the image quality remains in the acceptable range. For this reason for various experiments we use this value of *K*.

Table 1: Characteristics of original *Lena* and the watermarked image for different values of *K*

	Original *Lena*	**K = 0.2**	K = 0.4	K = 0.8
Mean of luminance	133.61	**133.39**	133.81	143.95
Std. Deviation of luminance	43.04	**43.02**	42.47	41.89
Median of luminance	137	**140**	136	147

3.2 Scaling

We scaled the watermarked image (Figure 4(c)) by using the scales listed in the column *Scale* of Table 2. From the table we see that the method performs well under scaling. When the scaling is greater than 1, the correlation is always greater than the threshold. However we note that the detection becomes inaccurate when the scale change(s) is less than 0.5, whereas in [11] becomes inaccurate when the scale change(s) is 0.5 or less. So our proposed method shows a better performance in the case of scaling.

Table 2: Scaling

Scale	Threshold	Correlation
0.5	0.4688	0.5812
0.6	0.4697	0.6910
0.7	0.4700	0.8312
0.8	0.4709	0.9065
1	0.4713	0.9494
1.2	0.5132	0.9761
1.3	0.5610	0.9912

3.3 JPEG Compression

We compressed the watermarked image (Figure 4(c)) by different compression ratio, the test results are shown in Table 3.

Table 3: JPEG Compression

Compression ratio	Threshold	Correlation
No Compression	0.4713	0.9494
10%	0.4915	0.9242
20%	0.5110	0.9307
30%	0.5321	0.9599
40%	0.5731	0.9310
50%	0.6120	0.9488
60%	0.6215	0.9764
70%	0.7214	0.9381
80%	0.8657	0.8121

From the table we see that the method performs well against JPEG up to compression ratio 70% (this performance is similar to the method in [11]), i.e. in these cases, the correlation is always greater than threshold value**.** After this level of compression most of the high frequency band is ignored, since the watermark is embedded from high frequency band to low frequency band of the DCT domain, so the watermark is more difficult to detect.

3.4 Cropping

We cropped the watermarked image (Figure 4(c)) by different range listed in the column *Crop* of Table 4. When the image is cropped by *64 × 64* the correlation value is less than threshold value, so the watermark cannot be detected because in this case most of the image part are lost. But if the cropping is in a reasonable range like *80 × 80 or more* for *128 × 128* watermarked image, few of the image part is lost, so it can be detected by our proposed method, this cropping ratio is larger than in (Table 2, [11]).

Table 4: Cropping

Crop	Threshold	Correlation
128 × 128	0.4713	0.9494
120 × 120	0.4821	0.9043
100 × 100	0.4910	0.8627
80 × 80	0.5125	0.8390
64 × 64	0.9150	0.8121

3.5 Rotation

Rotation invariance is very useful because the digital copies coming from printing and rescanning may be rotated in comparison to the initial image. We rotated the watermarked image (Figure 4(c)) counter-clock wise by different angles listed in the column *Angle* of Table 6. The four corners of the watermarked image have been cropped, due to the rotation. From the table we see that the method performs well when the rotated angle is less than 10^0, in these cases the correlation is always greater than the threshold value**.** However, it becomes inaccurate when the rotated angle is greater than or equal to 10^0. This is due to the fact that when rotational degree becomes bigger, larger areas are cropped and more information is lost.

Table 6: Rotation

Angle	Threshold	Correlation
0^0	0.4713	0.9494
0.5^0	0.4794	0.9121
1^0	0.4790	0.8819
1.5^0	0.4810	0.8714
2^0	0.4770	0.8415
3^0	0.4710	0.8510
3.5^0	0.4890	0.8140
4^0	0.4880	0.8141
5^0	0.4780	0.8910
10^0	0.4940	0.4741
20^0	0.4980	0.3910

3.6 Performance on random watermark test

We have performed our proposed watermarking system on different watermarks (shown in Figure 5), here a watermarked image and 1000 watermark signal are used for watermark detection. Here one watermark signal is the same as the embedded watermark signal among the 1000 signals. In the figure 5, the X-axis represents 1000 randomly generated watermark signal with the embedded signal and the Y-axis shows the corresponding detector results. From Figure 5 we see that only watermark number 400 crosses the predetermine threshold value, which was the actual watermark that was embedded.

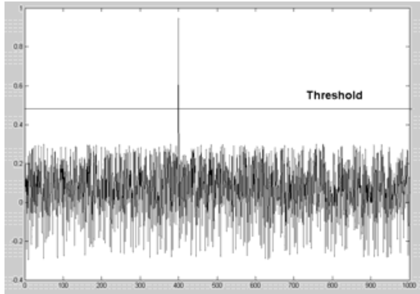


Figure 5: Detector response to 1000 randomly generated watermarks. Only watermark number 400 matches that embedding

3.7 Performance on Multiple watermarks

Some applications require that more than one watermark is inserted in the image. To test the performance of our proposed technique, the original image was watermarked with two different watermarks. Figure 6 shows the detector response, which indicates the presence of all the two watermarks embedded in the image.

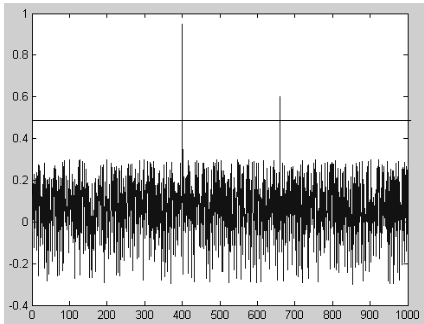


Figure 6: Detector response on two different watermarks

The proposed method was also tested against printing and rescanning. We have performed the similar experiments discussed above to other test images and we obtained the similar results. From the experimental results, we can conclude that our method is robust to some attacks such as JPEG compression, Scaling and cropping compare to existing method [11].

4. CONCLUSIONS

This paper presents a digital image watermarking method based on DCT applied to the blue channel of the *RGB* image. The main goal of the proposed method is to improve the performance of the digital image watermarking process. To improve the performance of our watermarking technique based on DCT, a scaling parameter is used which is very important for invisibility and detection of the watermark signal. From the experimental results we find that the proposed approach can outperform some existing methods in scaling, cropping and competitive in JPEG compression.

REFERENCES

[1] G. Voyatzis and I. Pitas, "Protecting digital-image copyrights: a framework," *IEEE Comput. Graph. Applicat.*, vol. 19, pp. 18–24, January/February 1999.

[2] I. J. Cox, J. Kilian, F.T. Leighton and T. Shamoon, "Secure spread spectrum watermarking for multimedia," *IEEE Trans. on Image Processing*, Vol. 6, pp. 1673-1687, December 1997.

[3] H. Inoue, A. Miyazaki, A. Yamamoto and T. Katsura, "A digital watermarking based on the wavelet transform and its robustness on image compression and transformation," *IEICE Trans. Fundamentals,* Vol. E82-A, No.1. pp. 1-9, January 1999.

[4] R.C. Gonzalez and R.E. Woods, "Digital image processing," *Wesley*, pp. 21-25, 191-195, 1993.

[5] A. Piva, M.Barni, F. Bartolini and V. Cappellini, "DCT-based watermark recovering without restoring to the uncorrupted original image," *International Conference on Image Processing,* vol. III, pp. 520-523, 1997.

[6] S. Ratanasanya and T. Amornraksa, "Digital watermarking using cascading transform," *ISCIT, On Acoustics, Speech and Signal Processing*, Munich, Germany, April 21-24, 1997. Sapporo, Japan, October, 2004

[7] T. Tachibana, M. Fujiyoshi and H. Kiya, "An image-quality guaranteed watermarking scheme with spreading spectrum of watermark," *ISCIT*, Sapporo, Japan, October, 2004.

[8] D. Zheng and J. Zhao, "RST invariant digital image watermarking: importance of phase information," *IEEE canadian Conference on Electrical and Computer Enginnering (CCECE)*, 2003

[9] N. Ahmed, T. Natarajan and K. R. Rao, "Discrete cosine transform," *IEEE Transactions on Computers*, vol. C-32, pp. 90-93, Jan. 1974.

[10] G. Strang, "The Discrete Cosine Transform," *SIAM Review*, Volume 41, Number 1, pp. 135-147, 1999.

[11] S. Pereira, J.K. Ruanaidh and F. Deguillaume, "Template based recovery of Fourier-based watermarks using log-polar and log-log maps", *IEEE Int. Conf. on Multimedia computing an Systems*, Florence, Italy, June, 1999.