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Effect of Block Sizes on the Attributes of Watermarking Digital Images

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Abstract: This work examines the effect of block sizes on attributes (robustness, capacity, time of watermarking, visibility and distortion) of watermarked digital images using Discrete Cosine Transform (DCT) function. The DCT function breaks up the image into various frequency bands and allows watermark data to be easily embedded. The advantage of this transformation is the ability to pack input image data into a few coefficients. The block size 8 x 8 is commonly used in watermarking. The work investigates the effect of using block sizes below and above 8 x 8 on the attributes of watermark. The attributes of robustness and capacity increase as the block size increases (62-70db, 31.5-35.9 bit /pixel). The time for watermarking reduces as the block size increases. The watermark is still visible for block sizes below 8 x 8 but invisible for those above it. Distortion decreases sharply from a high value at 2 x 2 block size to minimum at 8 x 8 and gradually increases with block size. The overall observation indicates that watermarked image gradually reduces in quality due to fading above 8 x 8 block size. For easy detection of image against piracy the block size 16 x 16 gives the best output result because it closely resembles the original image in terms of visual quality displayed despite the fact that it contains a hidden watermark.

Keywords: discrete cosine transform; watermark attributes; multimedia; block sizes

1 Introduction

Watermarking is one of the multimedia (multiple form of media- text, graphics, images, animation, audio, video that are used together in the same application) security techniques[1-11]. It provides the state- of- arts technologies in the multimedia security areas. Digital watermarking is based on the science of steganography or data hiding [12,13]. Steganography comes from Greek meaning 'covered writing'. It is an area of research for communicating in a hidden manner. The technique of chaos is also applicable in watermarking [14-16].

Koch et al [17] introduced the first efficient watermarking. In their method, the image is first divided into square blocks of size 8 x 8 for DCT computation. A pair of mid-Frequency coefficients is chosen for modification from 12 pre-determined pairs.

Bors and Pitas [18] developed a mode that modifies the DCT coefficients satisfying a block site selection constraint. After dividing the image into blocks of size 8x8, certain blocks are selected based on a Gaussian network classifier decision. The middle range frequency DCT coefficients are then modified using either a linear DCT constraint or a circular DCT detection region. Cox, et al [19] developed the first frequency domain-watermarking scheme. Other works on watermarking via DCT are found by Suhail et al [20] and Nick Kingbury [21] used the two-dimensional DCT defined by the expression

$$g(x,y,0,0) = {}^{1}\!/_{N}$$

$$g(x,y,u,v)=\frac{1}{2}N^3\left[\cos(2x+1)u\pi\right]\left[\cos(2y+1)v\pi\right]$$

$$for x,y = 0,1,\ldots,N-1$$

$$u,v = 1,2,\ldots,N-1$$

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The DCT scheme relies on some ideas proposed by Cox et al [19] where they proposed a watermark that consists of a sequence of randomly generated real numbers. These numbers have a normal distribution with zero mean and unity variance. Watermarking is carried out by modifying the DCT coefficient (C_i, i = 1...N) of the image using the DCT coefficients (W_i, i = 1...N) of the watermarking to obtain the DCT coefficients (C'_i, i = 1...N) of the watermarked image according to the equation

$$C_i\prime = C_i + \alpha C_i W_i$$

$$i = 1, 2, \ldots, N, \alpha = 0.1$$

If the original image can be defined by Io and the watermarked image possibly distorted image I*w, then a possible corrupted watermark w* can be extracted. Reversing the embedding procedure can do this extracting. This is done using inverse DCT. Suhail et al, [20] did not watermark the whole image. They embedded the watermark in sub-images of the image. So the N x M image is subdivided into pixels of size 16 x 16 (256 pixels). The DCT of the block is then computed. After that the DCT coefficients are reordered into zig-zag scan.

Juan R et al [22] analyzed the DCT and applied to a block of 8 x 8 pixels as in the JPEG algorithms. The main goal was to present a novel analyzed framework that allow for the assessment of the performance of a given watermarking method in the DCT domain. They were able to discover new detector/decoder structure that outperforms the existing ones, usually based on calculating the correlation coefficient between the image and the watermark. Chaw-Sang et al [23] performed factor analysis of wavelet based on watermarked methods.

The aim of this paper is to determine the effect of block sizes (i.e. 2 x 2, 4 x 4, 8 x 8, 16 x 16, 32 x 32 and 64 x 64) used in watermarking of digital images, on various attributes (robustness, capacity, time of watermarking, visibility and distortion) of the watermarked image. The step size or quantization step is a parameter that can be changed to set the final quality of the image. The greater the step size the greater the compression. A block is an N x N matrix that can represent either luminance or the corresponding DCT coefficients.

The rest of the work is as follows: section 2 deals with the theory of DCT. Section 3 deals with effects of block sizes on the attributes of watermarked image. Section 4 states the experimental results and section 5 concludes the paper.

2 Theory of Discrete Cosine Transform (DCT)

Ahmed, Natarajan, and Rao developed discrete cosine transform in 1974 [25]. It is a close relative of discrete fourier transform (DFT). DCT is a technique for converting a signal into elementary frequency components [26, 27]. Figure 1 shows the DCT transformation function from spatial to frequency domain.

Among the three types of transform domain, the classic and still most popular domain for image processing is that of the Discrete-Cosine-Transform or DCT. The image is split into 8 x 8 (pixels) block. Each block is used to encode one signature bit in a pseudorandom manner. Image is thus broken up into various different frequency bands in DCT method, allowing watermarking data to be embedded easily into the middle frequency bands of the image. The reason why the middle bands are carefully selected is to avoid the exposure of the important parts of the images to removal through compression and noise attacks.

The DCT transformation function from Spatial to frequency domain is given by

$$F(u,v) = \frac{\Lambda(u)\Lambda(v)}{4} \sum_{i=0}^{7} \sum_{j=0}^{7} \cos\frac{(2i+1)\cdot u\pi}{16} \cos\frac{(2j+1)\cdot v\pi}{16} \cdot f(i,j)$$

$$\Lambda(\xi) = \begin{cases} 1/\sqrt{2}, & for\ \xi = 0 \\ 1, & otherwise \end{cases}$$

where ξ = u and v. f(i,j) (intensity of pixels in row i and column j) and F(u,v) are the transform coefficients.

2.1 Types of discrete cosine transform (DCT)

2.1.1 The one-dimensional DCT

The most common DCT definition of a 1-Dimensional sequence of length N is the forward transform as:

$$y(k) = \sum_{i=1}^{N} w(i)x(i) \cos\frac{\pi(2i-1)(k-1)}{2N}, k = 1, \cdots, N$$

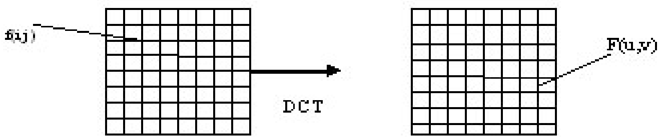

Figure 1: DCT transformation functions from Spatial to Frequency Domain

where as is shown in figure 1 above is given by

$$w(i) = \begin{cases} \frac{1}{\sqrt{N}}, i = 1 \\ \sqrt{\frac{2}{N}}, 2 \le i \le N \end{cases}$$

The inverse discrete cosine transform reconstructs a sequence from its discrete cosine transform (DCT) coefficients. $x(i) = \sum_{k=1}^{N} w(k)y(k)\cos\frac{\pi}{}\frac{(2i-1)(k-1)}{2N}, i = 1, \cdots, N$ where

$$w(k) = \begin{cases} \frac{1}{\sqrt{N}}, k = 1 \\ \sqrt{\frac{2}{N}}, 2 \le k \le N \end{cases}$$

Thus, the first transform coefficient is the average value of the sample sequence. In literature, this value is referred to as the DC Coefficient. All other transform coefficients are called the *AC* Coefficient$s$.DC and AC are borrowed from Direct Current and Alternating Current in electricity.

2.1.2 The two-dimensional DCT

The 2-Dimensional DCT is a direct extension of the 1-Dimensional case .It is a separable, linear transformation; that is, the 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. The definition of the two-dimensional DCT for an input image A and output image B is [20, 21].

$$B_{pq} = \alpha_p \alpha_q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} A_{mn} \cos\frac{\pi(2m+1)p}{2M} \cos\frac{\pi(2n+1)q}{2N}$$

$$0 \le p \le M-1$$

$$0 \le q \le N-1$$

$$\alpha_p = \begin{cases} \frac{1}{\sqrt{M}}, p = 0 \\ \sqrt{\frac{2}{M}}, 1 \le p \le M-1 \end{cases} \quad \alpha_q = \begin{cases} \frac{1}{\sqrt{N}}, q = 0 \\ \sqrt{\frac{2}{N}}, 1 \le q \le N-1 \end{cases}$$

where M and N are the row and column size of A, respectively. If you apply the DCT to real data, the result is also real. The DCT tends to concentrate information, making it useful for image compression applications.

This transform can be inverted using the two-dimensional inverse DCT transform:

$$A_{mn} = \alpha_p \alpha_q \sum_{p=0}^{M-1} \sum_{q=0}^{N-1} \alpha_p \alpha_q B_{pq} \cos \frac{\pi(2m+1)p}{2M} \cos \frac{\pi(2n+1)q}{2N}$$

$$0 \le m \le M-1$$

$$0 \le n \le N-1$$

$$\alpha_p = \begin{cases} \frac{1}{\sqrt{M}}, p = 0 \\ \sqrt{\frac{2}{M}}, 1 \le p \le M-1 \end{cases} \quad \alpha_q = \begin{cases} \frac{1}{\sqrt{N}}, q = 0 \\ \sqrt{\frac{2}{N}}, 1 \le q \le N-1 \end{cases}$$

3 Effect of block sizes on attributes of watermarked image

3.1 Watermark attributes

The technique used for watermarking in this paper is Discrete Cosine Transform (DCT). The DCT function transforms spatial domain data to frequency domain. The image is split into various blocks and the attributes of watermarked image is compared based on the block sizes used.

The host image and the watermark are combined by the equation.

$$C'_{ij}(n) = \alpha_n C_{ij}(n) + \beta_n W_{ij}(n)$$

$$n = 1, 2 \ldots.$$

α_n and β_n coefficients are for block n. C_{ij} (n) are the DCT coefficient of the host image block and W_{ij}(n) the DCT coefficient of the watermarked image block. α_n is the scaling factor and β_n is the embedding factor. α_n=1 and $\beta_n = \frac{1}{2^n}$ where n represents the value of block size and ranges from 1 to 6. The effect of block sizes is investigated from the various attributes of watermarked image.

3.1.1 Channel capacity.

The channel capacity, which is an upper bound on the rate at which communication reliably occurs, is given by

$$C = W \log_2 (1 + S/N)$$

or

$$C = \frac{1}{2} \log_2 (1 + S/N)\,.$$

Jim Chou et al (2001). W= bandwidth given in units of pixel $^{-1}$. Channel capacity has unit of bits per pixel.

3.1.2 Imperceptibility

The signal to noise ratio (SNR) is a rough estimate of perceptibility. The higher is the SNR the more visible the modulated carriers. Mathematical matrix such as (Mean Square Error (MSE) and visual analysis of watermarked image can also be used.

3.1.3 Robustness

Peak signal-to -noise ratio (PSNR) is to quantify distortion due to watermarking.

$$PSNR = 10\log_{10}\left(\frac{256^2}{MSE}\right)$$

3.1.4 Distortion

The method used for measuring distortion caused in the watermarked image is the mean square error (MSE). The signal to noise ratio can also be used for measuring distortion in digital images. The MSE is given by the equation below:

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{i=1}^{N}\left((P_{ij} - P'_{ij})\right)^2$$

M= number of component colours, N= number of pixels, P_{ij} = original image , P'_{ij} = watermarked image. The SNR can be used as a measure for distortion of images. The larger is the SNR the better the quality of the image.

The SNR is related to MSE by the equation:

$$SNR = \frac{10\log\sum_{i=1}^{M}\sum_{j=1}^{N}\left(\left(I'_{ij}\right)\right)^2}{MN \cdot E_{ms}}$$

$$e_{ij} = I_{ij} - I'_{ij}$$

$$MSE = Ems = \frac{1}{MN}\sum_{i=1}^{M}\sum_{i=1}^{N} e_{xy}{}^2$$

3.2 Implementation

To achieve the objectives of this work the following will be carried out:

- Transform the original image and watermark image into blocks
- DCT coefficients for each block of original image are found out.
- Insert α_n and β_n for combining the images
- DCT for the watermark image blocks are found out.
- The final watermarked image is modified according the result above by adding the original image to the watermark image.
- Perform distortion test on watermarked image.
- Perform robustness test on watermarked image.
- Perform capacity test on watermarked image.
- Compare the results obtained.

4 Experimental results

4.1 Images used

The images used for the watermarking is the logo of Federal University of Agriculture, Abeokuta, Nigeria, as shown in Figure 2 and the image "LENA" popularly used for image processing, downloaded from the Internet as shown in Figure 3.

Figure 2: UNAAB logo.

Figure 3: Lena Image.

A visible watermarked image is shown in Figure 4 for key = 2 while Figure 5 shows an invisible watermarking at key =16.

Figure 4: Visible watermarking.

Figure 5: Invisible watermarking.

4.2 Results and Discussion

The functions of robustness, channel capacity and distortion were coded in MATLAB 7.1. The results from the program were based on various effects of block sizes on time, capacity, robustness, distortion and imperceptibility of the watermarked image after subjecting the watermarked image to various tests according to their block sizes. Table 1 summarizes the results of the above attributes. Looking at Table 1, the DCT time is very high at block size 2 x 2 with 7.31s and gradually reduces to 5.160 at block size 4 x 4 and 0.616s at block size 64 x 64.

For the attribute of robustness, the percentage signal-to-noise ratio is very low at block size 2 x 2 with 62.063 db and gradually increases to 65.490(block size 4 x 4), 68.731(block size 8 x 8), 69.996(block size 16 x 16),70.904(block size 32 x32) and 70.989 (block size 64 x 64). The attribute of capacity gradually increases as the block size increases as depicted in Table 1.

Every communication channel suffers from distortion. Therefore, hiding a watermark in an image will introduce some measures of distortion in the original image. Distortion in this study showed that the values vary significantly with block sizes together with the step size as illustrated in Table 2. For example, at block size 2 x 2 with steps 2, 4, 8, 16, 32 and 64, distortion values are 0.3629, 4.0646, 1.2178, 13.2961, 39.999, and 132.5639. Figure 6 shows the distortion values of block sizes (2 x 2, 4 x 4, 8 x 8, 16 x 16, 32 x 32 and 64 x 64) as against step 2. The same fluctuations are noticed for other distortion values of block sizes as against their step sizes. Moreso, values of distortion in various step sizes as against a particular block size are also noted as illustrated in table 2 with their fluctuation as shown in figure 6.

The block size used for watermarking is independent of the imperceptibility of the watermark. The embedded image introduced distortions into the original image and does not control the imperceptibility of the watermark. The imperceptibility depends on the embedding factor, β of the watermark. The perceptibility of watermark reduces as the key used (2, 4, 8, 16, 32, 64, etc) which corresponds to block sizes (2 x 2, 4 x 4, 8 x 8, 16 x 16, 32 x 32, 64 x 64, etc) increases. For example, the watermark is visible with keys 2, 4, and 8 but not visible with keys 16, 32, and 64 as shown in table 1. At key 16 which corresponds to block size 16 x 16, the watermarked image still looks like the original image despite the hidden watermark.

Table 1: The summary of the various attributes values.

Key	Block_Size	Robustness	Time	Visibility	Capacity
2	2x2	62.063	7.318	Visible	31.532
4	4x4	65.490	5.160	Visible	33.245
8	8x8	68.731	1.760	Visible	34.865
16	16x16	69.996	0.880	Not visible	35.455
32	32x32	70.904	0.716	Not visible	35.952
64	64 x 64	70.989	0.616	Not visible	35.966

Table 2: Summary of Block size with Distortion values in different step Sizes.

Block size	Distortion Step=2	Distortion Step=4	Distortion Step=8	Distortion Step=16	Distortion Step=32	Distortion Step=64
2 x 2	0.3629	4.0646	1.2178	13.2961	39.9999	132.5639
4 x 4	0.3051	3.3734	1.0026	10.5401	30.5552	79.7364
8 x 8	0.2721	2.1697	0.6867	7.4734	27.6999	72.1493
16 x 16	0.3007	3.1966	0.9945	10.4414	29.1143	72.9128
32 x32	0.3177	3.8375	1.1307	12.0094	33.2575	81.4464
64 x 64	0.3302	4.4939	1.2562	14.3236	39.4926	93.7040

Step=2

DT = 0.3629 0.3051 0.2721 0.3007 0.3177 0.3302
DT= distortion.

5 Conclusion

This work has applied discrete cosine transform (DCT) to achieve visible and invisible watermarking of a digital image against piracy. The work has also investigated the effect of block size and step size on the attributes of the watermarked image. It was found that the time for watermarking reduces as block size increases, capacity and robustness increase with block size. Distortion fluctuated below block size 8 x 8 but gradually increases above the block size. Above 8 x 8 the watermark is invisible and block size 16 x 16 can serve as a means of checking piracy of digital images because the watermarked image produced resembles the original image despite the fact that it contains a hidden watermark.

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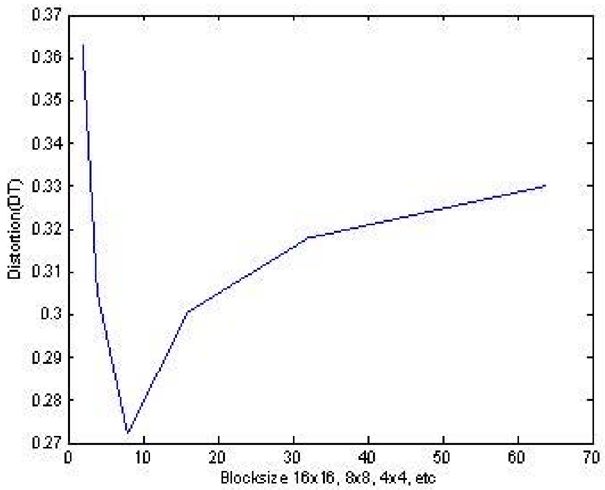

Figure 6: Distortion values of various block sizes with step size 2.

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