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Image watermarking using discrete wavelet-tchebichef transform

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ABSTRACT

Image watermarking is one of the most popular techniques for authenticating copyright on the digital image. Many research on image watermarking has proved that the joint of Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) combinations can improve both imperceptibility and robustness when compared to DCT or DWT only. Discrete Tchebichef Transform (DTT) denotes an alternative transformation that has a similarity property with DCT. DTT has an advantage in reducing memory requirements during computing, so the calculation speed is much faster than DCT. This study tested the performance of DTT and DCT on non-blind image watermarking method, where DTT and DCT are performed after DWT. Based on the experimental results, this research proved that the DTT was combined successfully with DWT and very potential for further investigation because it has a computing performance much better than DCT. While the image watermarking quality, both the imperceptibility and robustness aspects were completely identical with the combination of DCT and DWT transformation.

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1. INTRODUCTION

Internet technology allows the spread of data becomes faster and easier. This is certainly very useful for human life. The growing number of internet users, increasing the risk of digital crime. Rules that ensure data security of internet users cannot be guaranteed by current law. This is due to the laws applicable in each different country, while the internet is used by all people in the world [1-3]. Then, it will be needed a method to improve security in transaction data on the internet, especially about copyright protection. Image watermarking is a popular method for authenticating copyright on digital image [4-6]. There are two important aspects of the image watermarking, i.e., imperceptibility and robustness. Imperceptibility is the quality of copyright insertion in the digital images, the better imperceptibility of the human vision cannot perceive changes in the digital images. While robustness is the aspect of copyright endurance against attacks. If the robustness aspect works well, copyright can survive when a digital image is manipulated [7-10].

Implementation of the frequency domain in image watermarking method has proved that more resistant to various attacks compared to spatial domains. The most commonly used frequency domain in image watermarking research is DCT and DWT [11-14]. In the image watermarking method, the combination of DCT and DWT have proved that the method can generate better results than the use of one transformation only [15-18]. This is caused by each transformation has its own advantages. Both of the transformations have also been widely used in various studies on image processing, such as image watermarking, image compression, image restoration, etc. Even has also been embedded in various hardware because both transformations are used as JPEG and JPEG 2000 compression standards [16, 19, 20]. DTT is a transformation that can be used as an alternative to DCT. DTT has an advantage in reducing code complexity and memory requirements for computation, thus speeding up the transformation calculation process [21-23], besides many similarities property with the DCT [9, 24]. DTT can also be implemented in image watermarking [25]. DTT is not a new algorithm as well as DCT, it is just that the use of DTT in watermarking on images is not as popular as DCT. The literature on DTT for image watermarking is also quite limited since DTT is mostly applied to image compression and digital video [21-23, 26, 27]. In Setiadi et al's study [9] there have also been comparisons between DCT and DTT. Aspects of imperceptibility and robustness are also very similar. Surely this research needs to be continued and piloted by combining with other transformations such as Wavelet.

2. RESEARCH METHOD

2.1. Discrete Tchebichef Transform (DTT)

DTT is one of the derivatives of the orthonormal Tchebichef polynomial [9, 28, 29]. DTT transforms the image with a polynomial recursive technique $r_q(d)$. To perform the transformation on image matrix with size $M * M$ where $M = 8$ can be seen in (1).

$$T_{qw} = \sum_{d=0}^{M-1} \sum_{e=0}^{M-1} r_q(d) r_w(e) f(d,e) \quad (1)$$

where,
T : is the result of the transformation
f : is the image pixel designated coordinates d and e
q, w : recursive order
while the recursive value of the polynomial $r_q(d)$ is defined in (2), (3), and (4).

$$r_0(d) = \frac{1}{\sqrt{M}} \quad (2)$$

$$r_1(d) = (2d + 1 - M)\sqrt{\frac{3}{M(M^2-1)}} \quad (3)$$

$$r_q(d) = (A_1 d + A_2) r_{q-1}(d) + A_3 r_{q-2}(d), \quad (4)$$

where: $q = 2, \dots M - 1$

To calculate the coefficientsA_1, A_2, A_3, use (5), (6), and (7).

$$A_1 = \frac{2}{q}\sqrt{\frac{4q^2-1}{M^2-q^2}} \quad (5)$$

$$A_2 = \frac{1-M}{q}\sqrt{\frac{4q-1}{M^2-q^2}} \quad (6)$$

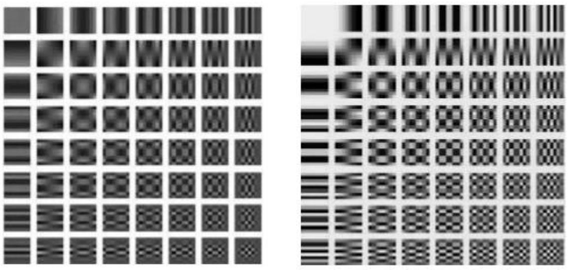
$$A_3 = \frac{q-1}{q}\sqrt{\frac{2q-1}{2q-3}}\sqrt{\frac{M^2-(q-1)^2}{M^2-q^2}} \quad (7)$$

while to perform inverse transformation DTT use (8).

$$f_{(d,e)} = \sum_{q=0}^{M-1} \sum_{w=0}^{M-1} T_{qw} r_q(d)\, r_w(e) \quad (8)$$

2.2. Similarities of DTT and DCT Proposed Method

Calculations of DTT and DCT have similarities, the first is a separable calculation. DTT and DCT can be written separately to calculate one-dimensional data, by applying the same way applicable to two-dimensional data. Second is the calculation of DTT and DCT can be symmetrically done. The third is DTT and DCT using orthogonal basis. Where in the lowest frequency base image there will be a top left corner or coordinates (0,0) and the highest frequency is in the lower left corner or coordinates (7,7) [21, 26, 27, 29]. Figure 1 shows the DCT and DTT two-dimensional image base. Another DTT and DCT similarities are having the same energy compaction way, that is, the core energy of the packed and compressed image to the low-frequency region. The compaction properties of the energy are very good for the highly correlated image so that the distortion that occurs during the reconstruction process is relatively small.



(a) (b)

Figure 1. 2-D image base of (a) DTT, (b) DCT

2.3. Discrete Wavelet Transform (DWT)

DWT is used as a transformation of the JPEG 2000 compression standard. Unlike DCT and DTT which transform images in high, medium and low frequencies. DWT divides the image into four subbands, ie LL, HL, LH, HH [12, 30, 31]. Where each subband contains a collection of frequencies. This subband division uses two kinds of filters that are low pass filter and high pass filter that is imposed on a row and column image. Subband LL contains low-frequency imagery, where image energy is centered here. The HL and LH subband contains the frequency of horizontal and vertical image approximation results. Whereas HH subband contains a high-frequency image or diagonal image. Figure 2 describes the result of image transformation with DWT.

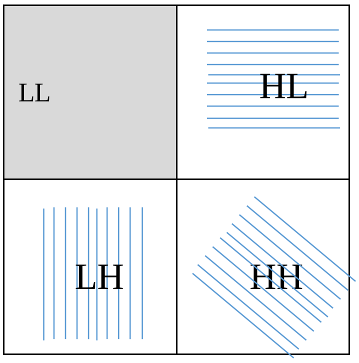


Figure 2. 2-D discrete wavelet transform

2.4. Proposed Watermark Insertion Scheme

The watermark insertion scheme used in this study is to combine DWT and DTT. Because in this research DTT is compared with DCT then the watermark insertion process is done by the same step between DTT and DCT, along with the alpha value used. Figure 3 shows a clear description of the steps of inserting a watermarking process. The steps below are the details of the process of insertion watermark proposed.

Step 1: Read the host image, then do DWT on the host image
Step 2: Select the LL subband, then divide the subband into a small sub-blocks of size 4 * 4
Step 3: Transform each sub-blocks using DTT.
Step 4: Collect coefficient (1,1).
Step 5: Read the watermark image
Step 6: Insert watermark image into collected coefficient (1,1) using the alpha value
Step 7: Do inverse DTT, then inverse DWT, and get the watermarked image.

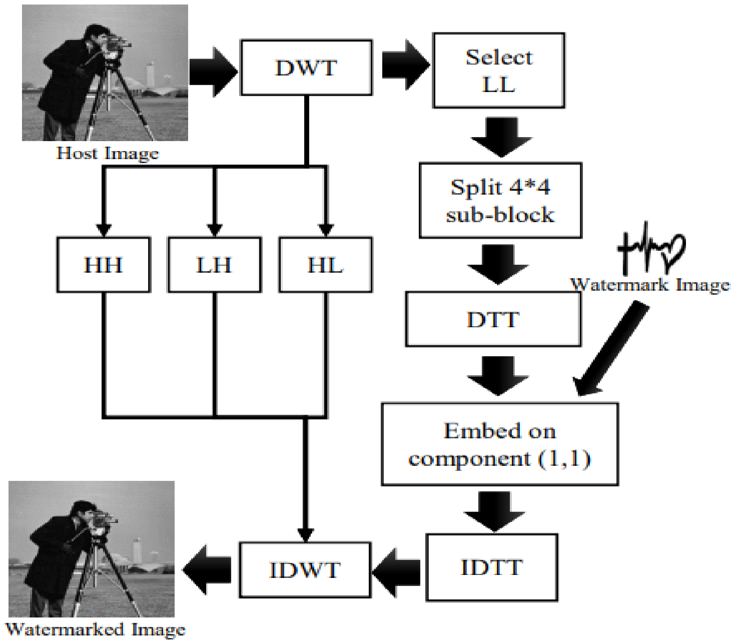


Figure 3. Watermark insertion scheme

2.5. Watermark Extraction Scheme

As the insertion process, the extraction process is also carried out with the same steps for DTT and DCT. Both transformations are done after DWT. Figure 4 shows a description of the steps of the watermark extraction process. The steps below are the details of the process of extraction watermark proposed.

Step 1 : Read the host image also watermarked image, then do DWT on both images.
Step 2 : Select the LL subbands on each image.
Step 3 : Divide the LL subband into a small sub-blocks with size 4*4.
Step 4 : Transform each sub-blocks using DTT.
Step 5 : Collect the coefficient (1,1) and save it on a different matrix.
Step 6 : Perform the extraction process by comparing the coefficient matrix (1,1) in the host image and the watermarked image using the alpha value.
Step 7 : Get the watermark image.

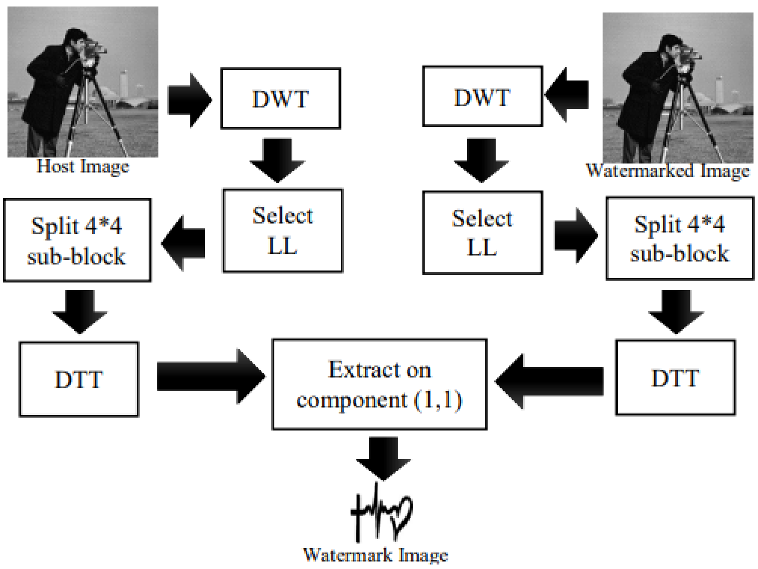


Figure 4. Watermark extraction scheme

3. RESULTS AND ANALYSIS

This section begins with collecting image data used in the test. The image used as the host image is the grayscale image and the binary image for the watermark. There are seven cover images used with 512 * 512. While the watermark image size is 64 * 64. The image used is a standard image that is widely used in various studies of image processing, this is to facilitate comparison for subsequent research. Furthermore, the watermark image is inserted with the proposed method for a comparative test. Figure 5 displays the image used in this study.

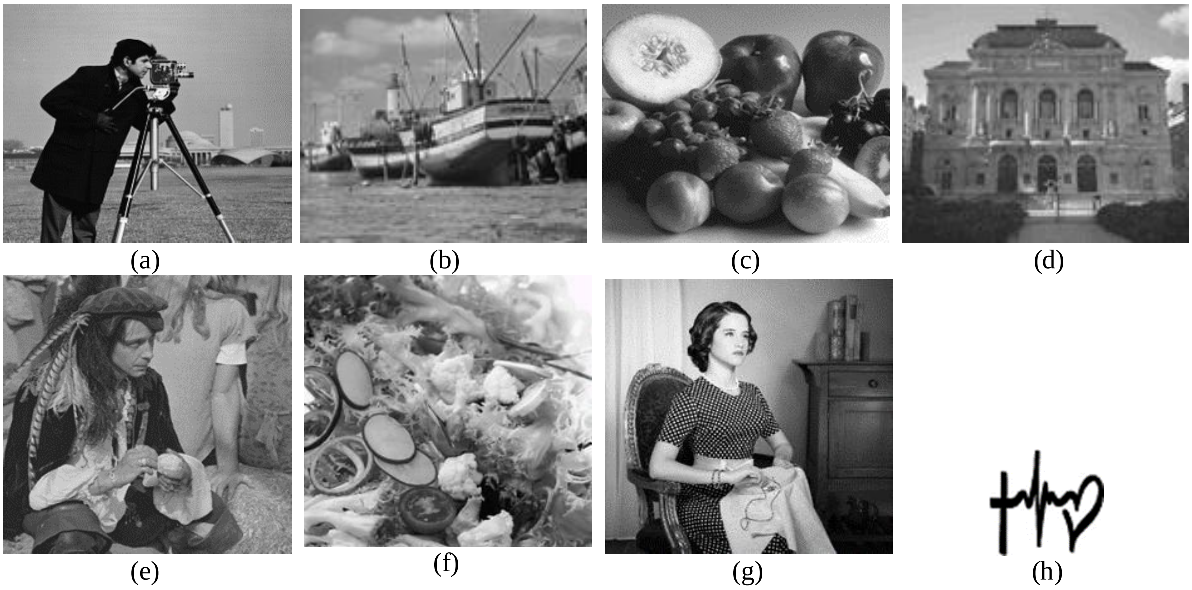


Figure 5. (a-g) Cover image used{(a) cameraman; (b) fishing boat; (c) fruit; (d) opera; (e) pirate; (f) vegetable; (g) women}; (h) watermark image

This study evaluated DTT-DWT combination performance when applied to non-blind watermarking techniques. The DTT-DWT combination is also comparable to the DCT-DWT combination. Both combinations of these methods will be similarly measured for performance in the watermark insertion and extraction scheme. Figure 6 shows the sample image of the watermarked insertion with the proposed method. It can be seen in Figure 6 by plain view no difference at all between the watermark image with the DWT-DTT method, DWT-DCT method, and with the original image. So this study uses MSE and PSNR to measure the imperceptibility quality of the watermarked image. Where the measurement of MSE value using (9) while the PSNR value using (10) [32, 33]. Table 1 shows the measurements of MSE and PSNR values.

$$MSE = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} \| W(m,n) - H(m,n) \|^2 \tag{9}$$

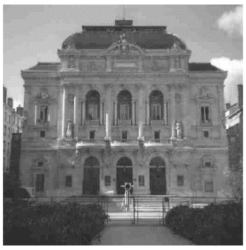
$$PSNR_{dB} = 10 \log 10 \left(\frac{255^2}{\sqrt{MSE}} \right) \tag{10}$$

where m and n is the size of row and column image, W is watermarked image and H is host image.

Table 1. Comparative MSE and PSNR values

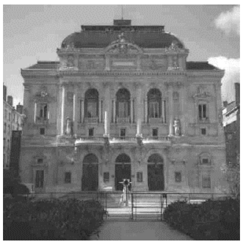
Image	DWT-DTT		DWT-DCT	
	MSE	PSNR	MSE	PSNR
cameraman	12.2867	37.2365	12.2867	37.2365
fishingboat	12.2888	37.2357	12.2888	37.2357
fruit	12.2305	37.2564	12.2305	37.2564
opera	12.2575	37.2468	12.2575	37.2468
pirate	12.2891	37.2356	12.2891	37.2356
vegetable	12.1300	37.2922	12.1300	37.2922
women	12.2846	37.2372	12.2846	37.2372
Average	12.2525	37.2486	12.2525	37.2486


Cameraman DWT-DTT


Opera DWT-DTT


Pirate DWT-DTT


Cameraman DWT-DCT


Opera DWT-DCT


Pirate DWT-DCT

Figure 6. Comparison of the watermarked image using DWT-DTT and DWT-DCT

The PSNR and MSE values are displayed in Table 1 are quite surprising because both values are very identic even exactly the same when rounded into four numbers behind the commas. Where the alpha value used in this study is 30. This result is real and not intentional, the test has also been done repeatedly and showed the same results. At the stage of extraction used normalize cross-correlation (NCC) [34]. Where the value of NCC can be calculated by (11). NCC serves to calculate the correlation of watermark image with extraction watermark image. Figure 7 shows the NCC values of watermark extraction on each method.

$$NCC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} w(i,j)\ x\ w\prime(i,j)}{\sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n} w(i,j)}\sqrt{\sum_{i=1}^{m}\sum_{j=1}^{n} w\prime(i,j)}} \tag{11}$$

where:
$w(i,j)$ = pixel value from original watermark image
$w'(i,j)$ = pixel value from extracted watermark image

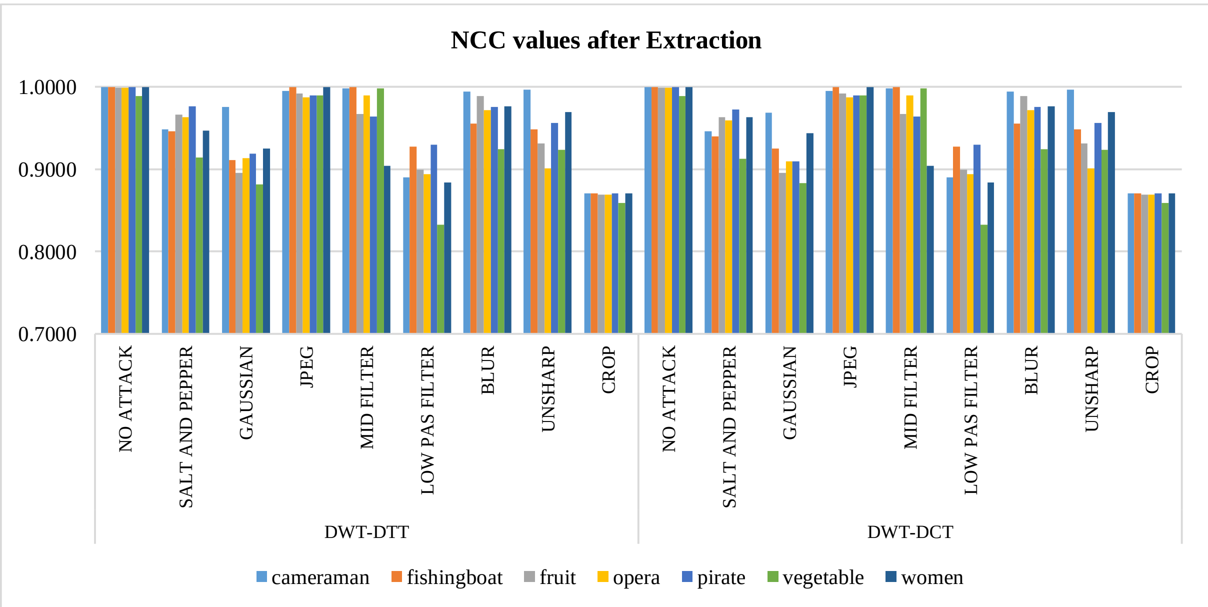


Figure 7. NCC values Chart

Based on the observations in Figure 7 and Figure 8 it appears that both methods are also equally strong in the robustness aspect. It is very differentiated only at the time needed for the calculation process both in the process of watermark insertion, as well as watermark extraction, where the results can be seen in Table 2. Measurement of time required using the tic toc function on MATLAB and with the same hardware.

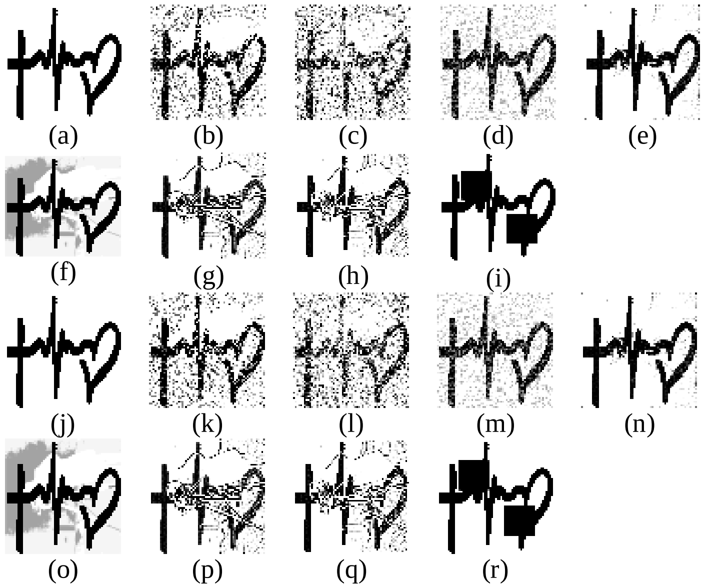


Figure 8. Sample Extracted Watermark from Cameraman Image (a-i) using DWT-DTT; (j-r) using DWT-DCT {(a,j) no attack; (b,k) salt and pepper; (c,l) Gaussian noise; (d,m) JPEG compression; (e,n) mid filter; (f,o) low pass filter; (g,p) blur; (k,q) sharpening; (i,r)cropping}

Table 2. Comparative time took

Image	DWT-DTT (in a second)		DWT-DCT (in a second)	
	Embed	Extract	Embed	Extract
cameraman	0.6454	0.4174	1.8706	1.1138
fishing boat	0.6456	0.4108	1.9918	1.1003
fruit	0.6497	0.4077	1.8460	1.2029
opera	0.6386	0.4134	1.8142	1.1403
pirate	0.6420	0.4180	1.8460	1.1225
vegetable	0.6889	0.4020	1.8280	1.1059
women	0.6519	0.4076	1.8262	1.1329
Average	0.6517	0.4110	1.8604	1.1312

4. CONCLUSION

Based on the previous studies and simulations results and also performance tests that have been tested in this study, it can be concluded that the performance of DTT and DCT from the aspect of imperceptibility and robustness is completely identical in the non-blind watermarking method when combined with wavelet transformation. But DTT has an advantage in calculation times that are much better bathed with DCT. Then DTT needs to be studied further and developed again because it is potentially as an alternative DCT in image watermarking method.

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