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Genetics algorithm optimization of DWT-DCT based image Watermarking

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Abstract. Data hiding in an image content is mandatory for setting the ownership of the image. Two dimensions discrete wavelet transform (DWT) and discrete cosine transform (DCT) are proposed as transform method in this paper. First, the host image in RGB color space is converted to selected color space. We also can select the layer where the watermark is embedded. Next, 2D-DWT transforms the selected layer obtaining 4 subband. We select only one subband. And then block-based 2D-DCT transforms the selected subband. Binary-based watermark is embedded on the AC coefficients of each block after zigzag movement and range based pixel selection. Delta parameter replacing pixels in each range represents embedded bit. +Delta represents bit “1” and -delta represents bit “0”. Several parameters to be optimized by Genetics Algorithm (GA) are selected color space, layer, selected subband of DWT decomposition, block size, embedding range, and delta. The result of simulation performs that GA is able to determine the exact parameters obtaining optimum imperceptibility and robustness, in any watermarked image condition, either it is not attacked or attacked. DWT process in DCT based image watermarking optimized by GA has improved the performance of image watermarking. By five attacks: JPEG 50%, resize 50%, histogram equalization, salt-pepper and additive noise with variance 0.01, robustness in the proposed method has reached perfect watermark quality with BER=0. And the watermarked image quality by PSNR parameter is also increased about 5 dB than the watermarked image quality from previous method.

1. Introduction

Digital watermarking is a method to embed any specific information into a content either sound, image, or video [1]. Any specific information embedded into the content is called watermark. And the content as a place for embedding the data is known as host. The transparency of watermark depends on the watermarking application needs. It consists of 2 kind of transparency, such as : perceptible and imperceptible. Generally, watermark is embedded in the way that the human can not sense or the watermark is imperceptible. The imperceptibility of watermark in the content is important for keeping the content quality into human perception. Human still assume that the content is original and they enjoy the content without unsatisfaction because of the lack of content quality due to watermark existing.

Image watermarking is defined as a watermarking in which the host is a digital image. The watermark could be any digital information, as example text, audio or image having ownership information of the content. There are several parameter that controls the image watermarking performance, such as [2]:



- a. Imperceptibility – In this paper we design the image watermarking in which the perceptibility of the watermarks is imperceptible. It means that the watermarks embedded into host image have to be invisible. The invisibility parameter is represented by Peak Signal To Noise Ratio (PSNR).
- b. Robustness – The watermarks must have good robustness to face the watermarked image attack. Stirmark benchmark is a tool representing image or audio attack. It is useful to examine the robustness of embedded watermarks. Stirmark benchmark described all image watermarking attacks types which consists of compression, geometric transformation, and enhancement techniques. The performance parameter used for robustness is Bit Error Rate (BER). If the watermark is an image, the performance parameter could be (Structural Similarity) SSIM or PSNR.
- c. Capacity – The number of bits which is embedded into the image is also a parameter for watermarking performance. Although the capacity of watermark is not as well as robustness but it is needed for controlling the trade-off between robustness and imperceptibility.

DCT-based image watermarking were already published in several papers. J.R. Hernandez et al [3] Yoonki et al [4] proposed image watermarking utilizing inter-block correlation of DCT coefficients. DCT-based image watermarking method and mixed with time-domain was proposed by Dongyang et al [5]. Dongyang generated watermarked image by using both domain, time domain and frequency domain. Qiusheng Wang et al [6] proposed DCT-based image independent image watermarking. He generated the watermarks from original host image characteristic first, and then embedded it into the host image in frequency domain similar as JPEG compression. Juan et al [3] proposed a spread-spectrum-like DCT watermarking technique for copyright protection of still digital images. He made the watermark in such a way that the watermark can have information to track illegal misuses.

There are several authors who proposed DWT-based image watermarking. Qiudong Sun et al [7] used HVS as selected color scale for hiding the watermark after selecting subband from DWT decomposition. The embedding method in his published paper is just noticeable difference (JND) in detail subband feature adjustment. Chi Ma et al [8] proposed a self-adaptive DWT digital watermarking algorithm. She decomposed three-level wavelet of image before embedding the watermark by adaptive selected coefficients of detail subband. Shih-Hsuan Yang [9] proposed DWT-domain image watermarking by multiresolution analysis. She used seven biorthogonal DWT kernels for embedding the watermark. In another case, Alessandro Piva et al [10] used DWT as transform method before embedding watermark in frame-basis at video watermarking in MPEG-4 standard. Khrisna et al [11] proposed block based robust blind image watermarking using DWT. He used DWT decomposition and SVD before embedding is applied. Yuan Xu et al [12] proposed scale invariant feature transformation (SIFT) after DWT decomposition for embedding watermark. Optimized DWT-based image watermarking in Genetics Algorithm was proposed by Ali Al Haj et al [13]. He used selected subband and specific watermark-amplification parameter value for embedding watermark, and optimized both parameters by GA.

DWT-DCT based image watermarking were also already published by several authors. Afroja Akter et al [14] proposed DWT-DCT based image watermarking by two until four level DWT decomposition. He decomposed host image into 2 until 4 level DWT decomposition, then transformed by DCT before embedding. The watermark first is transformed to frequency domain by DCT before embedded into host audio. Baisa et al [15] proposed multilayer secured DWT-DCT and YIQ color space based image watermarking technique. He embedded watermark at HL region of DWT and used 4x4 DCT.

Image watermarking optimization by GA on DWT-DCT method has been proposed by Abduljabbar et al [16]. But in his paper, the method was not clear described. He only described that the watermark is embedded at DC coefficient after DCT.

In this paper we propose image watermarking by DWT and DCT transform method in certain color space and layer, and optimized by Genetics Algorithm. First, the host RGB image is converted to certain color space. The available and chosen color spaces are RGB, YCbCr or NTSC. The layer in

which the watermark is embedded also can be selected. The available choices are 1st layer, 2nd layer, 3rd layer, 1st & 2nd layer, 2nd & 3rd layer, 1st & 3rd layer and all layers. After the selected layer of image in certain color space is transformed by DWT, one subband from subband LL, LH, HL, and HH is selected and then transformed again in block based to frequency domain by DCT. Then one bit watermark is embedded on the AC component of each block such a way that the bit is represented by specific value called delta in a zigzag and vary length of pixel. The vary parameters optimized by Genetics Algorithm are selected color space, selected layer, selected subband, block size, length of pixel to be embedded by one bit watermark, and delta. Bit “1” is represented by +delta, and bit “0” is represented by -delta in vary length of pixel after zigzag.

This paper is one of series paper as the research result funded by high education ministry of Indonesia at 2016. The previous published paper by Iwan Iwut [17] described DCT-based image watermarking designed is optimized by GA without DWT decomposition. In this paper we propose DWT decomposition added in the embedding and extraction before DCT conversion to improve the performance of image watermarking.

This paper is organized as follow : section 1 describes image watermarking introduction, section 2 describes the image watermarking model containing DWT, DCT, and embedding-extraction algorithm, section 3 presents GA optimization model, and section 4 describes evaluation of performance and discussion and the conclusion is presented in section 5.

2. Image Watermarking Model

In this section, image watermarking at embedding and extraction stage with the preprocessing of the image is described. Preprocessing before embedding stage consists of color space and layer choice for embedding watermark, DWT decomposition, DCT transformation and AC coefficient selection. The rest of this section describes embedding and extraction algorithm.

2.1. Color Space, Layer, DWT Subband and DCT

In this proposed method there are 3 color spaces used and selected only one of them. And there are also 7 layers used and selected only one of them. Three color spaces used are RGB, YCbCr, and NTSC color space. The conversion from RGB into YcbCr, NTSC and vice versa are as follow [15] [18] [17]:

$$Y=0.299*R + 0.587*G + 0.114*B \quad (1)$$

$$I=0.596*R - 0.274*G - 0.322*B \quad (2)$$

$$Q=0.211*R - 0.522*G + 0.311*B \quad (3)$$

$$R=Y + 0.956*I + 0.621*Q \quad (4)$$

$$G=Y - 0.272*I - 0.647*Q \quad (5)$$

$$B=Y - 1.106*I + 1.702*Q \quad (6)$$

$$Y=16 + 65.481*R + 128.553*G + 24.966*B \quad (7)$$

$$Cb=128 - 37.797*R - 74.203*G + 112*B \quad (8)$$

$$Cr=128 + 112*R - 93.786*G - 18.214 *B \quad (9)$$

$$R=1.1644*Y + 0*Cb + 1.596*Cr - 222.921 \quad (10)$$

$$G=1.1644*Y - 0.3918*Cb - 0.7856*Cr + 135.576 \quad (11)$$

$$B=1.1644*Y + 2.0172*Cb + 0*Cr - 276.836 \quad (12)$$

The choice layer used from 3 layer image are : layer 1, layer 2, layer 3, layer 1-2, layer 1-3, layer 2-3, and layer 1-2-3. Layer 1, 2 and 3 for RGB is R, G, and B. Layer 1, 2 and 3 for NTSC is Y, I, and Q. And layer 1, 2 and 3 for YCbCr is Y, Cb, and Cr. Selected color space and selected layer used are two parameters optimized by GA. Thus, color space parameter value is limited on range 1-3, and layer parameter value is limited on range 1-7.

DWT is time to time-based transformation. For image, DWT is calculated in 2 dimensions and convert the spatial image to spatial image with separated frequency. A digital image converted by DWT will obtain 4 subbands with different frequency, such as : LL, LH, HL, and HH subband. Only

one subband will be selected for embedding process. Thus, the parameter value for subband parameter is limited on range 0-3.

DCT is time to frequency-based transformation at real number. Due to the host is a digital image, DCT used is 2 dimension. DCT will be executed after selecting one subband of DWT decomposition result. DCT calculation is block-based processing with size $M \times M$. The DCT formula is as follow [19] [17]:

$$C(u, v) = \alpha(u)\alpha(v) \sum_{x=0}^{M-1} \sum_{y=0}^{M-1} f(x, y) \cos \left[\frac{\pi(2x+1)u}{2M} \right] \cos \left[\frac{\pi(2y+1)v}{2M} \right] \quad (13)$$

$$f(x, y) = \sum_{x=0}^{M-1} \sum_{y=0}^{M-1} \alpha(u)\alpha(v) C(u, v) \cos \left[\frac{\pi(2x+1)u}{2M} \right] \cos \left[\frac{\pi(2y+1)v}{2M} \right] \quad (14)$$

Where :

u & $v = 0, 1, \dots, M-1$

x and y is respectively vertical and horizontal pixel position of the image.

$$\alpha(u) = \begin{cases} \sqrt{\frac{1}{M}}, & \text{for } u = 0 \\ \sqrt{\frac{2}{M}}, & \text{for } u \neq 0 \end{cases} \quad (15)$$

2.2. Embedding process

Embedding process of image watermarking contains several steps as follow :

- The host image is read and converted to selected color space from RGB to selected color space.
- Select only one layer from 7 layer used as described in section 2.1.
- The selected layer is decomposed into 4 subband by DWT.
- Select only one subband from subband LL, LH, HL and HH.
- The selected subband is block based segmented into $M \times M$.
- Each segment from step 5 is transformed by DCT to frequency domain.
- Each segment in frequency domain is zigzag processed excluding DC component produces the vector which its size is $(1 \times (M^2-1))$.
- The selected vector from zigzag vector scheme is assumed as $s(n)$ and the watermark bit is $w(n)$. $s(n)$ length for embedded is POS2-POS1+1. Where, POS1 is initial range position and POS2 is last range position of $s(n)$. In embedding stage, the selected vector of zigzag vector scheme or $s(n)$ is replaced by one bit watermarks or $w(n)$ in such way as follow:

If $w(n)$ is "0" then

$s(n) = -\delta$

if $w(n)$ is "1" then

$s(n) = +\delta$

(16)

δ is a rational number parameter which can be changed, and it is also optimized by Genetics Algorithm to find the optimal trade off performance between robustness and imperceptibility.

The range of δ is from 0.1 to 127. Different bit will be embedded in different block.

- After all bits are embedded and modify $s(n)$, inverse DCT is applied to each block.
- Combine all block from IDCT result, and IDWT is applied by combining modified subband and unmodified subband.
- Combine the embedded layer with unused layer and convert back to the RGB color space from selected color space.

2.3. Extraction process

Extraction process of image watermarking consists of several steps. The detailed steps of extraction stage is as follow :

- The watermarked image is read and converted to color space same as the color space used in embedding process.
- Select the layer used for extraction same as the layer used in embedding process.

3. The selected layer is decomposed into 4 subband by DWT.
4. Select only one subband from subband LL, LH, HL and HH.
5. The selected subband is block based segmented into $M \times M$.
6. Each segment from 5 is transformed by DCT to frequency domain.
7. Each segment in frequency domain is zigzag processed excluding DC component produces the vector $s(n)$ which its size is $(1 \times (M^2-1))$.
8. Select the $s(n)$ in the range from POS1 until POS2 and do the extraction stage below:

$$\begin{aligned} &\text{If } \sum_{n=POS1}^{POS2} s(n) < 0 \text{ then} \\ &\quad \hat{w}(n) = 0 \\ &\text{if } \sum_{n=POS1}^{POS2} s(n) \geq 0 \text{ then} \\ &\quad \hat{w}(n) = 1 \end{aligned} \tag{17}$$
9. After all segments or blocks are extracted as point 8, recover the bits into a vector of bit, then we get the watermarks back.

3. GA optimization model

The GA model refers to our previous paper in [17]. The parameters to be optimized by Genetics Algorithm such as: color index (CI), layer index (L), $M \times M$ block segment (M), beginning of selected zigzag vector (POS1), end of selected zigzag vector (POS2), and δ . The additional parameter for this proposed method is selected subband (SS). The output parameters will be BER and PSNR that is combined to one output parameter called Fitness Function (FF). In this paper we ignore capacity due to the previous research result in [17] showed that capacity parameter decreased the impact of robustness and imperceptibility. In fact, robustness and imperceptibility are two more important parameter than capacity. We propose new FF which will focus to robustness and imperceptibility only. Thus, the FF formula will be as follow :

$$FF = 1 - BER + PSNR/60 \tag{18}$$

Formulation of BER and $PSNR$ is as follow :

$$BER = \frac{\text{Number of Bit Error from extraction}}{\text{Watermark Bit Number}} \tag{19}$$

$$PSNR = 10 * \log \left(\frac{255^2}{MSE} \right) \tag{20}$$

$$MSE = \frac{1}{PQ} \sum_{x=0}^{P-1} \sum_{y=0}^{Q-1} (f(x,y) - \hat{f}(x,y))^2 \tag{21}$$

The GA procedure for finding the optimum performance refers to our previous paper [17] displayed in figure 1 is described as follow :

- a. Initialization of all parameter inputs and then execute embedding and extraction process to get FF
- b. Sort the outset population matrix in descending order at FF .
- c. Execute the tasks below until FF is stable for hundred generations :
 - 1) Select the top ten rows of updated FF . This matrix is also called as elite matrix.
 - 2) Do crossover 3 times producing 2 children from 2 parents in each iteration. And do mutation with specific mutation probability. Crossover and mutation result combines with elite matrix and obtain updated FF .
 - 3) If there is no change of highest value of updated FF for more than 100 generations, the parameters are already optimum. Thus we get the optimum parameters at top of last updated FF matrix.

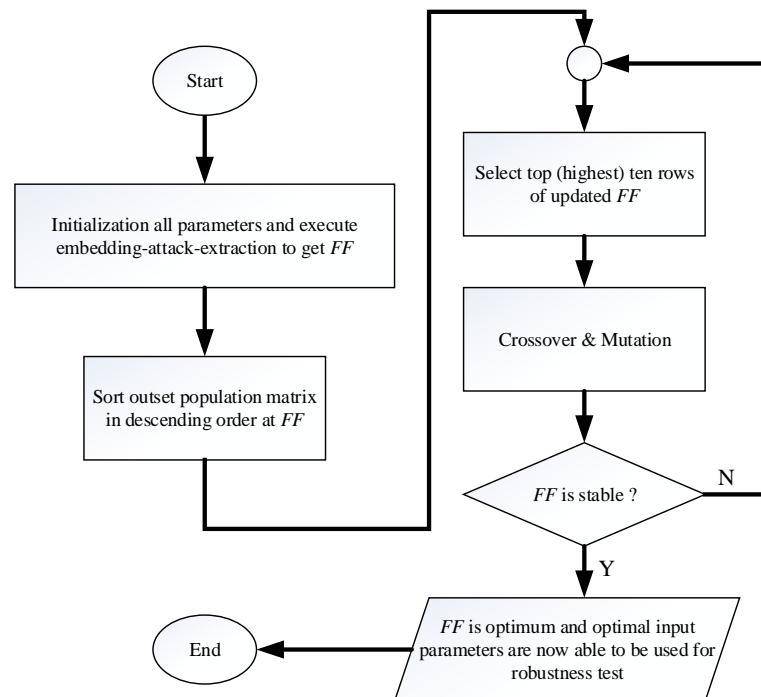


Figure 7. Genetics Algorithm Procedure [17]

4. Performance Evaluation

The host and watermark image to be tested and GA parameters refers to our previous research [17]. There are 5 host images with free copyright and binary watermarks to be tested. “Fruits.png” image will be tested image for optimizing the watermarking parameter at no attack and JPG-rescale attack condition.

Table 1. Parameter Optimization Result for “Fruits.png” from No attack and JPG/Rescale attack

FF	Delta	Blok	Warna	Layer	Pos1	Pos2	Subband	BER	C	PSNR	Attack	Method
1.53	28	5	3	2	11	16	-	0	113	31.54	JPEG 75%	[17]
1.81	2	7	2	3	23	26	-	0	196	48.46	No Attack	[17]
1.60	41	10	3	0	42	53	LL	0	112	36.03	JPEG 50% + Rescale 50%	Proposed
1.90	3	6	3	1	14	18	HH	0	185	53.91	No Attack	Proposed

The simulation result of finding optimum parameter by GA with proposed method comparing with previous method [17] is displayed in table 1. In previous method, GA was applied to no attack and JPEG 75% attack obtaining PSNR 48.46 dB and 31.54 dB with perfect robustness (BER=0). With additional DWT in the embedding-extraction process, proposed method improves the performance. By no attack and stronger double attack (JPEG 50%+Rescale 50%), GA by proposed method obtains PSNR 53.91 dB and 36.03 dB with perfect robustness. The robust subband used for stronger and double attack is LL.

By optimized parameter from table 1, image watermarking with 5 host images and 5 attacks are applied. Five attacks include JPEG compression 75% quality, salt-pepper and additive noise with variance 0.01, resizing 50% and histogram equalization attack. And simulation result of proposed method comparing with the previous simulation research [17] is displayed in table 2. By same attacks as the previous research [17], the proposed method reach perfect result. The proposed method is robust

perfectly to all attacks with BER=0. Additional DWT in the embedding-extraction algorithm has significantly improved the robustness of the image watermarking. Table 2 also displays the imperceptibility/fidelity result of watermarked image by optimized parameter from table 1. Comparing with previous research, the imperceptibility or PSNR also has improved to more than 35 dB. In the previous research PSNR only reached in about 30-31 dB.

Table 2. Robustness and imperceptibility test result for “Fruits.png” compared to previous research

Image	PSNR		BER									
			JPEG Compression 75%		Salt & Pepper 0.01		Additive Noise 0.01		Resizing 50%		Histogram Equalization	
	[17]	prop.	[17]	prop.	[17]	prop.	[17]	prop.	[17]	prop.	[17]	prop.
Tulips	30.8934	35.0406	0	0	0.02	0	0.01	0	0.18	0	0	0
Airplane	30.9459	35.1692	0	0	0	0	0.02	0	0.02	0	0	0
Baboon	31.1132	35.3904	0	0	0	0	0.02	0	0.22	0	0	0
Peppers	31.0832	35.5149	0.01	0	0	0	0.01	0	0.22	0	0	0
Fruits	31.5359	36.0329	0	0	0	0	0.02	0	0.125	0	0	0

Table 3. Image watermarking robustness against attack with vary value parameters

Image	BER												
	JPEG Compression				Additive Noise			Salt & Pepper			Resizing		
	Quality Factor				Variance			Variance			Scaling Factor		
	50%	25%	10%	0%	0.01	0.05	0.1	0.01	0.1	0.5	40%	30%	25%
Tulips	0	0.0104	0.0313	0.3646	0	0.0104	0.0417	0	0.0208	0.2604	0	0.1146	0.3125
Airplane	0	0	0.0833	0.3021	0	0	0.0625	0	0.0208	0.2396	0	0.0417	0.1458
Baboon	0	0	0.0313	0.0963	0	0	0.0625	0	0.0208	0.2188	0	0.0521	0.3438
Peppers	0	0	0.0625	0.3542	0	0.0104	0.0625	0	0.0104	0.1875	0	0.0729	0.2292
Fruits	0	0	0.0729	0.3854	0	0.0208	0.0729	0	0.0104	0.2396	0	0.0313	0.1354

Table 3 displays image watermarking robustness against several attack with vary value of its parameter. Image watermarking applies the optimized parameter from table 1. JPEG attack has quality factor (QF) 50%, 25%, 10% and 0%. Additive noise attack has variance 0.01, 0.05, and 0.1. Salt & Pepper noise attack has variance 0.01, 0.1, and 0.5. And resizing attack has scaling factor 40%, 30%, and 25%. The robustness against attack result shows normal tendency. For JPEG compression attack, lower the quality factor will be much more of loss image information, and it causes the robustness will be worse. The quality factor of JPEG that can still be resisted by the image watermarking is 25%. Only one image, “tulips.png” has BER 0.0104 when it’s attacked by JPEG with QF 25%. Variance of noise, either salt-pepper and additive noise will have any effect to robustness. The higher of variance will be the lower of robustness. And for resizing attack, tolerable scaling factor for this optimized parameter is at 40% which still has perfect quality watermark, that is BER=0.

5. Conclusion

Additional DWT decomposition in DCT based image watermarking optimized by GA has improved the performance of image watermarking. Either imperceptibility or robustness has been improved to significant performance. By five attacks: JPEG 50%, resize 50%, histogram equalization, salt-pepper and additive noise with variance 0.01, robustness in the proposed method has reached perfect watermark quality with BER=0. And the watermarked image quality by PSNR parameter is also increased about 5 dB than the watermarked image quality from previous method.

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