Robust and Imperceptible Image Watermarking by DC Coefficients Using Singular Value Decomposition

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***Abstract*—Main problem frequently encountered in all schemes transform domain watermarking technique is the robustness and imperceptibility. Due to achieved optimal result most algorithms of image watermarking using combination two or more transformation domain. This paper proposed Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD) to embed binary watermark to color Image. Before the message embedded in the color images, we converting RGB to YCbCr color space. Luminance component will be split into sub-block and it has been transformed by DCT to produce DC and AC coefficients. DC coefficients selected as embedding place because it is perceptually usefulness and robust against various attacks. DC coefficients will be collected from every sub-block to create a reference image. Then apply SVD on reference image and embed message in singular values. Various attacks have been implemented and tested due to achieve robustness using Normalized Cross Correlation (NCC) and imperceptibility tested using Peak Signal to Noise Ratio (PSNR). High values of the measurement results show the feasibility of the proposed method. A highest PSNR value resulted 42.3009 dB, whereas a highest NCC values 0.9993 after JPEG Compression.**

Keywords—Discrete Cosine Transform, Singular Value Decomposition, DC Coefficient, Color Image, Watermarking

I. INTRODUCTION

Today development of internet technology has changed the way to work, learn, play, and get information, but resulted in increasingly widespread copyright violations. Digital image that accessed by mobile devices mostly through the compression process allows quickly accessed. This process enables the pixel values in the image changed. The existence of the software increases the chances of theft and misuse of copyright in the digital image. Therefore the development of technology for copyright protection urgently needed. With the aim to secure the image, a popular technique that can be applied that is watermarking. In watermarking, image security can be classified as copyright protection, tracking data ownership and prevent illegal copying.

In order to get effective process, an image watermarking should be fulfilled an imperceptible and robust towards image processing attacks like noise, filtering, JPEG compression, bluring and cropping. Usually the image watermarking scheme can be operated either by the spatial or frequency domain [1]. Spatial domain for image watermarking is done by directly manipulating the pixels in the digital images. This scheme is easy and simple to implement, but also vulnerable to various kinds of digital image manipulation. On the other hand, image watermarking scheme with frequency domain [2] is more resistant to various digital image manipulation.

Transformation domain is a mathematical transformation approach applied to the image that aims to transform the images from spatial domain into the frequency domain. Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DTT) are common algorithms used in the image watermarking [3][4][5]. In recent years, the transformation of is namely Singular Value Decomposition (SVD) has been investigated for the purpose of watermarking. The main idea of the use of this transformation is to eliminate redundant information, which is very useful for image compression. So we take advantage of this characteristic [6] where the message will be inserted on the cover image is the most important part of the message.

In this paper, we has been investigated a digital images watermarking using combining transform domain algorithm are DCT and SVD for color images. RGB to YCbCr color conversion are also applied in this study. This conversion is useful to improve the invisibility of the message will be inserted in the cover image. It is based on the characteristics of human vision system (HVS) for color images in multimedia content on devices with various features [7]. Luminance is a part that has most of image information, if the information embedded in this section, then it can improve invisibility and robustness messages from various attacks.

II. Research Methodology

A. Transformation Domain

Domain transformation is a step that uses to transform the spatial domain into the frequency domain. Frequency domain where needed while inserting copyright to the images. This is done so that copyrights are inserted into the images more robust and able to survive from manipulation of images [8]. This section will be presented briefly about the transformation of DCT and SVD, and the result experiment against some attacks.

B. Discrete Cosine Transform

Standard use of DCT in digital image processing is operated by resolving the image on a sub-block of 8x8 pixels [8]. The result of the operation of the 8x8 sub-block will be transformed into a coefficient of 64 which is classified into AC and DC coefficients. The number of such coefficients is one and sixty three [9]. To find out more the coefficient calculations on DCT, can be seen in Eq. 1-3. In the equation below can be described that the input image is A while the image of the coefficient calculation is B. whereas the value of the input image with the pixel value I x J, C (i, j) is known as the intensity of the image pixel on row m and column n, and T (p, q) is known as the DCT matrix coefficient on row u and column v.

$$T_{pq} = \alpha_p \alpha_q \sum_{i=0}^{I-1} \sum_{j=0}^{J-1} C \cos\frac{\pi(2i+1)p}{2I} \cos\frac{\pi(2j+1)q}{2J}, \quad 0 \le p \le I-1, \quad 0 \le q \le J-1 \tag{1}$$

where

$$\alpha_p = \begin{cases} \frac{1}{\sqrt{I}}, p = 0 \\ \sqrt{\frac{2}{I}}, 1 \le p \le I-1 \end{cases} \tag{2}$$

and

$$\alpha_q = \begin{cases} \frac{1}{\sqrt{J}}, q = 0 \\ \sqrt{\frac{2}{J}}, 1 \le q \le J-1 \end{cases} \tag{3}$$

After DCT operation done, we have to restore it into its original image using Eq. 4-6.

$$C_{ij} = \sum_{i=0}^{I-1} \sum_{j=0}^{J-1} \alpha_p \alpha_q T_{pq} \cos\frac{\pi(2i+1)p}{2I} \cos\frac{\pi(2j+1)q}{2J}, \quad 0 \le p \le I-1, \quad 0 \le q \le J-1 \tag{4}$$

where

$$\alpha_p = \begin{cases} \frac{1}{\sqrt{I}}, p = 0 \\ \sqrt{\frac{2}{I}}, 1 \le p \le I-1 \end{cases} \tag{5}$$

and

$$\alpha_q = \begin{cases} \frac{1}{\sqrt{J}}, q = 0 \\ \sqrt{\frac{2}{J}}, 1 \le q \le J-1 \end{cases} \tag{6}$$

DCT has several reasons to be used in image watermarking according to [8][9][10], that is:

1. Embedding process using transformation domain is more effective by means of Human Visual System (HVS).
2. DCT has advantage in invisible aspect. It is come from the energy from copyright was embed using transformation domain will deploy over all pixels.
3. DCT can be implemented towards image or video compression like JPEG, MPEG, H. 261, and H.263 DCT-based.

C. Singular Value Decomposition

SVD namely a mathematical transformation tools used to analyze a matrix such as a digital image [11]. A matrix will be decomposed into three matrices, two matrices is orthogonal and one diagonal matrix also called singular matrix [12]. For example, there is matrix A, then A=USVT where U and V are orthogonal matrices and S is singular value, VTV=B, UTU=B, B is an identity matrix. The columns of U are called the left singular vectors of A, and the columns of V are called the right singular vectors of A. This decomposition is known as the Singular Value Decomposition (SVD) of matrix A. In SVD usually message is inserted in the singular matrix, and if the message is inserted in the orthogonal matrices [11], then the perceptibility of watermarked image will be increase but reduce robustness from some attacks. It caused the matrix elements from orthogonal matrix in a small form. Based on [5], SVD has characteristics such as: (1) When deviation occurs, the singular value not overly change; (2) The singular matrix value represents property of the image compilation; (3) The singular value determines the light intensity value for every image layer whereas the orthogonal value determines the geometry of the image.

III. Proposed Method

This section will be explained our proposed method especially in DC coefficient operation. This is done with the aim to obtain two main aspects of watermarking are robustness and imperceptible.

A. Embedding Algortihm

Embedding message using DCT-SVD will be illustrated as shown in Fig. 1. Here, first step has been done by DCT coefficient sub block and the next step will be computed the DC matrix toward embedding process.

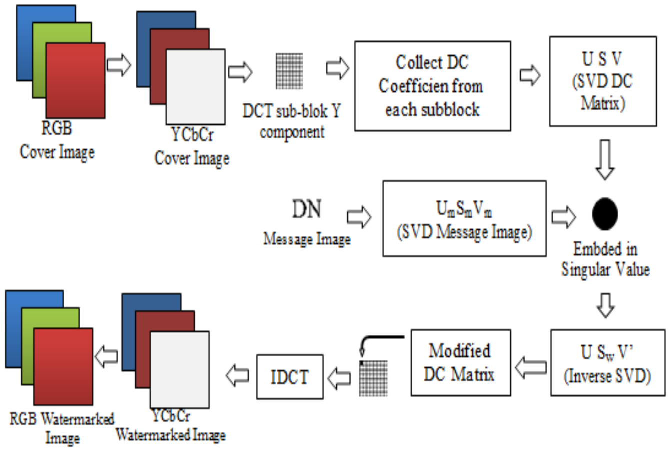

Fig. 1. Embedding Message using DCT-SVD

Based on Fig. 1, embedding process using DCT-SVD appears as follows:

1. Original image RGB changed to YCbCr model color space with Eq. 7.
2. Y component of YCbCr color space is selected and split it into sub block in 16 x16 blocks to implement DCT algorithm.
3. DC Coefficient will collect from every single sub block to compute the DC matrix.
4. SVD DC matrix is transformed again with SVD.
5. At the same time perform SVD in the message image.

Embed message in the singular value, then embedding is done as follows:

$$S_w=S+(\alpha*S_m) \quad (9)$$

Where is:

Sw = Singular value after embedding

S = Singular value of DC matrix

α = the intensity factor of embedded

Sm = Singular value of message

6. Perform inverse SVD then the produce modified DC matrix
7. To perform inverse of DCT and generate YCbCr image after change, replace the coefficient that has been changed.
8. Convert YCbCr color space into RGB color space with Eq. 8.

B. Extraction Algortihm

Extracting model will be given in Fig. 4 using inverse of DCT.

1. RGB watermarked Image converted to YCbCr color space, at the same time RGB cover image converted to YCbCr color space too.
2. Y component of YCbCr color space watermarked and cover image is selected and split it into sub block in 16 x16 blocks to implement DCT algorithm.
3. DC Coefficient will collect from every single sub block to compute the DC matrix.
4. At other times perform SVD in the message image

Extract message in the singular value, then extracting is done as follows:

$$Se=Sw-(\alpha*Sc) \quad (10)$$

Where is:

Se = Singular value of after extracting

Sw = Singular value of DC matrix watermarked image

α = the intensity factor of embedded

Sc = Singular value of DC matrix cover image

5. Calculate invers SVD then resulting recover message image.

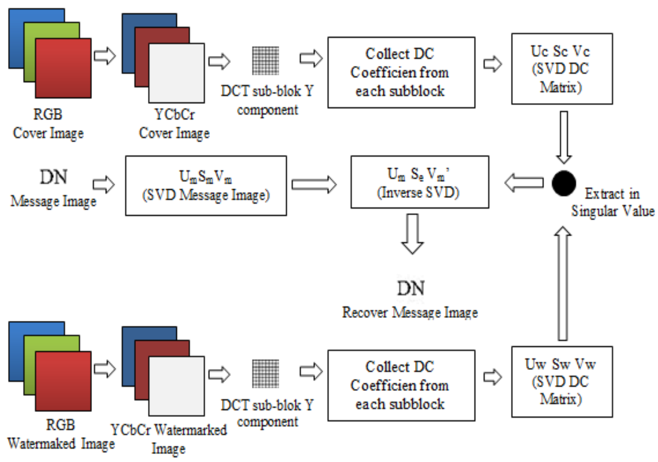

Fig. 2. Extracting Copyright Image using DCT-SVD

IV. EXPERIMENT RESULT

Our experiment uses 15 grayscale images taken from www.petitcolas.net. All of images are 512x512 pixels and in *.jpg. Images measurement will be conducted by Peak Signal to Noise Ratio (PSNR) and also Normalized Cross Correlation (NCC). PSNR used as measure the different between original image and the watermarked image. It will be produce some value in dB. This value reflected earning imperceptibility from our proposed method. The higher PSNR value indicated as a good process in image watermarking, while the standard in 40 dB. PSNR calculation has related part of MSE as describe in Eq. 15.

$$PSNR_{dB} = 10\log 10\left(\frac{255^2}{\sqrt{MSE}}\right) \qquad (11)$$

Due to achieve the robustness aspect, we used (NCC) metric values as follow:

$$NCC = \frac{M_{ij} \times R_{ij}}{M_{ij} \times M_{ij}} \qquad (12)$$

where:

M_{ij} = message image

R_{ij} = recover message image

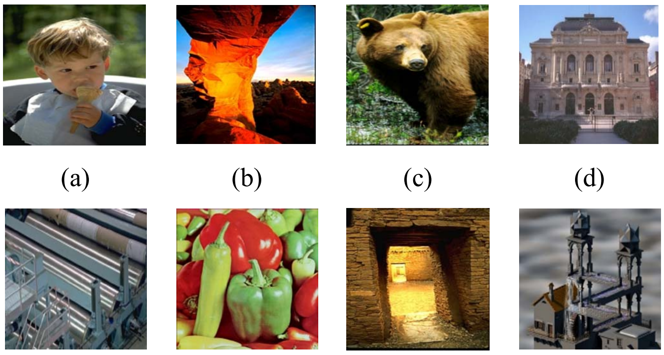

Fig. 3. Cover Image (512x512 pixels in .jpg): (a) kid, (b) skyline_arch, (c) bear, (d) opera, (e) papermachine, (f) peppers, (g) pueblo_bonito, (h) waterfall

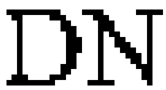

Fig. 4. Message Image (size 32x32 pixels in .bmp)

TABLE I. MSE AND PSNR VALUE FOR EMBEDDING USING DCT-SVD

Images	MSE	PSNR (dB)
Kid	3.9875	42.1238
Skyline_arch	3.8282	42.3009
Bear	4.4884	41.6099
Opera	4.3838	41.7123
papermachine	4.3475	41.7485
Peppers	4.6013	41.5020
Pueblo_bonito	4.1697	41.9297
Waterfall	4.4502	41.6470

This paper using several attacks such as salt and pepper with d=0.2, whereas the default of dimana default for d is 0.05. Another attack is gaussian filter with v=0.5, JPEG Compression with quality in Q=10 %, Median filter, Bluring with α=3 dan rotate in 90^0. All of images has been achieved NCC more than 0.5 and a higher PSNR in 42.3009 dB. It means our proposed method proved that impelemented SVD and DCT based on DC coefficient yielded PNSR as the evidential value of imperceptibility dan NCC as the evidential value of robustness. Whereas NCC closed to 1 is good and PSNR more than 40 dB [10] fulfills Human Visual System as shown in Fig. 5.

TABLE II. NCC VALUE AGAINST SEVERAL ATTACKS

Images	No attack	Attacks: JPEG Compression (Q=10%)	Salt & pepper (d=0.5)	Gaussian Filter (v = 0.05)	Median Filter	Bluring (α=3)	Rotate (90^0)
Kid	0.9056	0.8145	0.8374	0.8926	0.8990	0.8779	0.8998
Skyline_arch	0.9036	0.8970	0.6896	0.7710	0.8934	0.8797	0.9000
Bear	0.9934	0.9917	0.8874	0.8912	0.9950	0.9545	0.9937
opera	0.9951	0.9965	0.6521	0.6673	0.9886	0.9804	0.9946
papermachine	0.9837	0.9717	0.9555	0.9350	0.9384	0.9341	0.9839
peppers	0.9991	0,9993	0.6652	0.6555	0.9964	0.9790	0.9991
Pueblo_bonito	0.9099	0.8824	0.8117	0.9191	0.9122	0.8771	0.8993
Waterfall	0.9910	0.9810	0.9565	0.9512	0.9852	0,9639	0.9909

According to Fig. 5, our proposed method ahieved high NCC values. All of NCC before attacks are close to perfect. A highest NCC before attacked was obtained by peppers.jpg with 0.9993 using JPEG Compression. Whereas the lowest one was obtained by opera using salt and pepper in 0.6521. another low NCC also obtaiuned by peppers using gaussian filter in 0.6555. here is rarely a watermarking image that has value of NCC 1. On the other hand, papermachine.jpg achieved all of NCC values up to 0,93 and proved by Fig. 6.

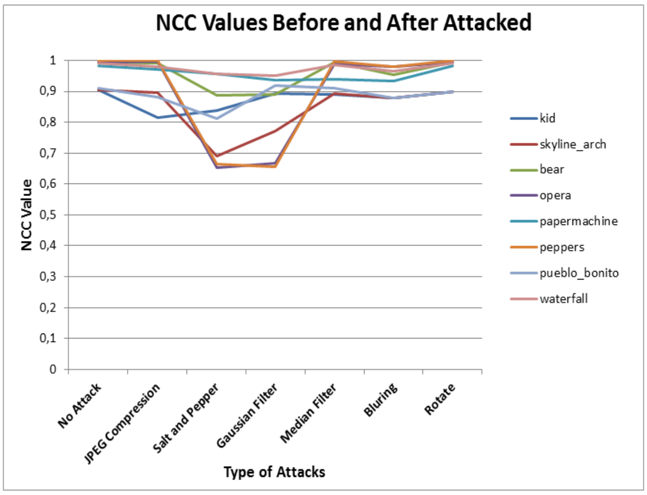

Fig. 5. NCC Values Before and After Attacked

The results of the implementation using some attacks, for example papermachine.jpg can be seen as shown below:

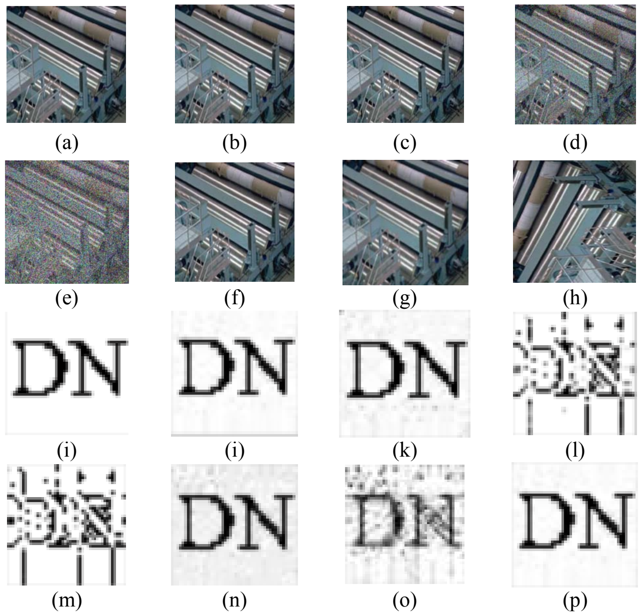

Fig. 6. Example Result Before and After being Attacked: (a) Cover Image, (b) Watermarked Image Non Attack, (c) After JPEG Compression with Q=10, (d) After Salt and Pepper with d=0.2, (e) After Gausian Filter with v=0.05, (f) After Median Filter, (g) After Bluring with α=3, (h) After rotate 90^0, (i) Message Image, (j) Recovered Image Non Attack, (k) Recovered Image Atfer JPEG Compression, (l) Recovered Image After Salt and Pepper, (m) Recovered Image After Gaussian Filter, (n) Recovered Image After Median Filter, (o) Recovered Image After Bluring, (p) Recovered Image After Rotate

V. CONCLUSION

There are two coefficients inside of DCT called AC and DC. In this paper, DC coefficient chosed as a place to insert a message image. DCT as know as a popoular transform domain has been impelented using SVD in color image watermarking, wherein image are uses in 512x512 pixels cover image and 32x32 message image. Our proposed algorithm are fulfills both of imperceptibility and robustness proved and could be seen in PSNR and NCC. The results achieved high PSNR more than 40 dB. It is mean our DCT-SVD based on DC coefficient has been succesfully to carry out the process of inserting message. The other one, NCC achieved almost perfect values in all images, although there are three images after being attaked with salt and pepper (d=0,2) yielded less than 0,7. On the other hand, papermachine yielded more than 0,9 in all of recovered image using six kinds of attacks.

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