The comparison between SVD-DCT and SVD-DWT digital image watermarking

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Abstract. With internet, anyone can publish their creation into digital data simply, inexpensively, and absolutely easy to be accessed by everyone. However, the problem appears when anyone else claims that the creation is their property or modifies some part of that creation. It causes necessary protection of copyrights; one of the examples is with watermarking method in digital image. The application of watermarking technique on digital data, especially on image, enables total invisibility if inserted in carrier image. Carrier image will not undergo any decrease of quality and also the inserted image will not be affected by attack. In this paper, watermarking will be implemented on digital image using Singular Value Decomposition based on Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) by expectation in good performance of watermarking result. In this case, trade-off happen between invisibility and robustness of image watermarking. In embedding process, image watermarking has a good quality for scaling factor < 0.1. The quality of image watermarking in decomposition level 3 is better than level 2 and level 1. Embedding watermark in low-frequency is robust to Gaussian blur attack, rescale, and JPEG compression, but in high-frequency is robust to Gaussian noise.

1. Introduction
Development of computer technology will always be followed by the development of internet. Because of this, the long distance would not be a big problem since information in form of digital data can easily be accessed even though they are originally from far places. This ease of data exchange makes the content of data cannot be completely monitored. Therefore, various ideas are made to create an owner mark of the digital data possessed. It can be implemented by using Steganography technique called watermarking.

Watermarking is one of method to hide or give certain information into a digital data [5]. One application of watermarking is copyright-labelling [2,6]. There are various types of watermarking methods which each of them has its points of strength and weakness [2,6]. The watermarking technique that is used must be robust to the manipulation means, and this technique is called Robust Watermarking [15]. Based on the concept of insertion, watermarking is divided into two, which are spatial domain and transform domain. On this research [16], it is mentioned that for watermarking with the objective of data concealing (including copyright-labelling) will be more suited using transform domain.

There are many methods that can be applied on transform domain, such as Singular Value Decomposition (SVD), Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), Discrete
Wavelet Transform (DWT), Contourlet Transform (CT). There have been many research using transform domain method for watermarking either by one method or combining more than one methods. Singular Value Decomposition is a technique to decompose a matrix which is often used in various application like image compression[1], watermarking[2,4,6], and other applications. In this paper, watermarking performance using SVD-DCT and SVD-DWT will be compared. The watermarking term here is reconciled with the non-blind watermarking.

2. Related Works
As mentioned earlier, the development in computer technology makes it easier to retrieve data from any places, without exception, the digital medical images and medical records of patients. But confidentiality is the most important thing for medical record, since only the patient and authorized person is allowed to see it, and with this rapid technology development, it is kind of hard to find a secure network. Therefore, Widi Astuti’s research[7], implemented steganography to solve this problem. The technique itself embed secret data into the image to conceal the secret data. The research itself provide an implementation of data hiding scheme using Vector Quantization and graph coloring based on evolutionary algorithms which are Genetic Algorithm (GA) and Particle Swarm Optimization (PSO). The result of this research showed that GA provide better performance than PSO in terms of computational time, but both of this algorithm approximately gave the same performance in the hiding capacity.

Prathiwi et al.[8] proposed a watermark scheme where signature watermark is embedded into frequency domain (Integer Wavelet Transform). To improve robustness, Reed-Muller Codes is applied to detect and fix if there is a manipulation attack on the digital medical images. Authenticity Control in this system is sing Hash Block Chaining from hash MD5. This proposed scheme has a good performance for authenticity and integrity of digital medical images, where based on testing results, use of Reed-Muller on embedding process can improve the robustness of signature watermark from attack like Gaussian noise, sharpening, blurring and JPEG Compression.

Adiwijaya et al.[9] proposed a scheme of reversible watermarking using a modified LSB and Huffman compression to detect and recover the manipulated medical image. This Watermarking scheme shows a good detection performance, with the testing results as follows. The watermark scheme is able to detect attacks with up to 100% accuracy and can perform recovery with up to 98% accuracy for some attacks.

Rosiyadi et al.[10] proposed copyright protection scheme using watermarking for e-government document which combine Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD) using a control parameter to avoid the false-positive problem. From the experimental result, this proposed scheme can improve the image quality GA-based evolution and that this approach is robust under several types of attacks.

Horng et al.[11] proposed a blind watermarking scheme using DCT-SVD and GA, it is found that this scheme has robustness and offers a high imperceptibility to various attacks. While Kurniawan et al.[12] proposed a watermarking technique which applied Reed-Solomon code for robust watermark in wavelet domain and SHA-256 for fragile watermark in Hash Block Chaining. The proposed technique can be implemented simultaneously on an image so that the integrity control and authenticity of the image detection can be applied at once.

Adiwijaya et al.[13] stated that the primary applications of watermarking are to protect copyright and integrity verification (authentication). The principle watermarking of this research is inserting digital data (text or image) into host medical image to maintain authority of ownership and to detect authenticity of medical image. Adiwijaya divide medical image into two parts, namely Region of Interest (ROI) and Region of Non-Interest (RONI). The reference watermark which is used to detect the authenticity of medical images (integrity control) that is embedded in the ROI image. Meanwhile, the signature watermark which is used for authority of ownership (proprietary rights) is embedded in the RONI image on the wavelet domain. This research used Reed-Muller Code method for signature watermark embedding using error correcting code, while Hash Block Chaining for reference watermark
embedding. With a host of type JPEG image, the quality of watermarked images was generated on each color component that has the same PSNR values. It is showed that PSNR values for each color component of this value is not much different from the value of PSNR as bitmap image of the host type.

Adiwijaya et al.\textsuperscript{14} proposed a graph coloring technique in the quantization process on image compression scheme based on Wavelet-SVD. The system shows a good performance based on PSNR and compression ratio, with the testing results as follows. The average compression ratio generated by the system stands between 50-60%, while the average PSNR stands between 40-80dB.

This research proposed the use of Singular Value Decomposition (SVD) algorithm, because it has proven to give good performance on processing image. SVD gave good performance on image compression compared to JPEG2000\textsuperscript{14}. Therefore, that Singular Value Decomposition will be suitable to be used on watermarking process.

3. Watermarking Using SVD Based on DCT and DWT

This research provided a scheme that will embed watermark image into host image that produce watermarked image. In addition, this scheme also extracts the embedded image from the watermarked image, so the image can be recovered. The scheme receives input consisting of host image (.bmp format), watermark image (.bmp format), input parameters decomposition level, embedding subband, scale factor and block for DCT. The output consisting of watermarked image, image disturbance result (.bmp format) and extraction image (.bmp format), along with value of PSNR and correlation coefficient for each image.

In a watermarking scheme using SVD based on DCT/DWT, there are two big actions; embedding process and extraction process. The figure below is the flow of SVD-DCT Insertion scheme in watermarking process to an image.

![Figure 1. The Flow of SVD-DCT Insertion](image)

Steps of watermark insertion process above are:

1. Applying DCT upon host image (A).
2. Zig-zag reading is aimed to make a vector asserting series of DCT coefficients from the low to the high frequency. Then, they are divided into 4 subbands of B1, B2, B3, and B4.
3. Determining the value of SVD subband chose for insertion location.
   
   \[ A^k = U_A^k S_A^k V_A^{kT} \]  \hspace{1cm} (1)

   where
   \[ k : \text{chosen subband} \]
   \[ A : \text{host image} \]
4. Applying DCT upon watermark image (W) which will be inserted.
5. Determining SVD value of watermark image (W).
   
   \[ W = U_w^w S_w^w V_w^T \]  \hspace{1cm} (2)

6. Singular value manipulation process is:
   
   \[ \lambda_i^{*k} = \lambda_i^k + \alpha_i \lambda_w \]  \hspace{1cm} (3)

   where
   \[ \lambda_i^{*k} : \text{element of the diagonal of manipulated subband singular matrix (} S_A^{*k} \text{).} \]
\[ \lambda_k : \text{element of the diagonal of host image singular matrix on subband where watermark is inserted (} S_k^h \text{).} \]
\[ \lambda_w : \text{element of the diagonal of watermark image singular matrix (} S_w \text{).} \]
\[ \alpha_k : \text{scale factor of watermark insertion on a subband } k. \]

Scale factor determines how big the singular value used in insertion.

7. Determining the new matrix of modified image, by using:
\[ A^k = U^k_k S^k_k V^k_k \text{ (4)} \]
where
\[ A^k : \text{matrix of watermarking image in frequency domain} \]
\[ S^k_k : \text{matrix of modified singular subband} \]

8. Doing position replacement using un-zig-zag reading of the new modified image matrix.

9. Applying inverse DCT after doing replacement to the original position.

The steps of extraction process are provided in Figure 2.

![Figure 2. The Flow of Watermark SVD-DCT Extraction Process](image)

To show the comparison of watermarking process, the insertion and extraction scheme in watermarking process using SVD based on DWT is provided.

![Figure 3. Embedded Process of Image Watermarking](image)

The steps of watermark embedding process are:
1. Wavelet transform is charged on host image and produce a media image in frequency domain (there are 4 subband: LL, LH, HL, and HH)
2. One of the subband is selected as the embedding point, then determining the SVD value
\[ A^k = U^k_a S^k_a V^k_a \text{ (5)} \]
where, \( k = 1,2,3,4 \) which indicate LL, LH, HL, and HH
\[ A = \text{host image} \]
3. Calculate SVD value of watermark image
\[ W = U^w_w S^w_w V^w_w \text{ (6)} \]
where, \( W = \text{watermarked image} \]
4. In the embedding process, there is a manipulation process of the subband singular matrix from original image \( S^k_a \) with singular matrix from watermark image \( S^k_w \). The manipulation process is as follows:

\[
\lambda_i^{*k} = \lambda_i^k + \alpha \lambda_i^w
\]

where, \( \lambda_i^{*k} \) = diagonal entry singular matrix of the manipulated subband \( S^k_a \).
\( \lambda_i^k \) = diagonal entry singular matrix of original image subband \( S^k_a \).
\( \lambda_i^w \) = diagonal entry singular matrix of watermarked image subband \( S^k_w \).

5. Produce a modified image matrix

\[
A^{*k} = U^k_a S^k_a V^k_a^T
\]

where, \( A^{*k} \) = singular matrix of watermarked image in frequency domain.
\( S^k_a \) = Singular matrix of watermarked image

6. Inverse wavelet transform is charged on matrix \( A^{*k} \) and produce a watermarked image.

![Figure 4. Extraction Process of Watermarked Image](image)

The steps of watermark extraction process are:

1. Wavelet transform is charged on watermarked image \( A^* \), producing 4 subband : LL*, LH*, HL*, and HH*

2. Wavelet transform is charged on original image \( A \), producing 4 subband : LL, LH, HL, and HH

3. Compare the coefficient value of watermarked image subband with coefficient value of original image, so it detects in which subband watermark is embedded.

4. Calculate singular matrix of watermarked image subband \( S^k_a \)

\[
A^{*k} = U^k_a S^k_a V^k_a^T
\]

5. Calculate singular matrix of original image subband \( S^k_a \)

\[
A^k = U^k_a S^k_a V^k_a^T
\]

6. In the extraction process, singular matrix of watermarked image subband \( S^k_a^{*k} \) is reduced by singular matrix of original image \( S^k_a^k \), and producing a singular matrix of watermark image \( S^k_w \). The reduction operation is as follows:

\[
\lambda_i^w = \frac{(\lambda_i^{*k} - \lambda_i^k)}{\alpha}
\]

7. Producing a matrix watermark image by multiplying the singular matrix watermark with its 2 orthogonal matrices.

\[
W = U_w S^k_w V_w
\]
4. Outcome and Test Analysis

The test is done by using a host image that showed on figure 5(a), the size is 512x512 which in .bmp format and the watermark image is showed on figure 5(b), the size is 128x128 which in *.bmp format and doing insertion on low frequency. It is for insertion on low frequency resulting extracted image which will be more robust towards several noises. This research provides correlation coefficient graphs showing the influence of scala factor on invisibility and robustness value if the watermark image is inserted in different subband and difference decomposition level of DWT and also difference block of DCT.

![Image A](image1.png) ![Image B](image2.png)

Figure 5. (a) Original host image, (b) watermark image

![Graph](graph.png)

Figure 6. Influence of Scala factor on Invisibility
Figure 7. PSNR Invisibility of Watermarked Image (a) DCT (b) DWT

Figure 6 and 7 show that the increasing of the scale factor will increase the robustness of watermark against attacks, but it will increase the distortion of the watermarked image. That is why the PSNR value is decreasing. The decreasing of the scale factor will decrease the robustness of watermark against attacks, but it will also decrease the distortion of the watermarked image. Therefore, the selection of the scale factor must preserve the balance between robustness and the perceptual invisibility (distortion of watermarked image). The bigger scale factor used, the bigger image singular value inserted; hence the alteration watermarking image is bigger. The bigger alteration between watermarking image and original image will increase the error rate. It is shows that in scaling factor up to 0.1, watermarked image still has a good PSNR value (>30db) for all subband and all decomposition levels and all blocks.

Figure 7 (a) and (b) shows comparison between watermarking using DCT-SVD and DWT-SVD where the quality of watermarking image using DCT-SVD is equal with using DWT-SVD.
Figure 8. Robustness of Watermarking

Figure 8 shows that the bigger scale factor used, the bigger robustness of inserted image to a noise. Meanwhile, Figure 6 and 7 show that PSNR invisibility value is decreasing along with increasing on scale factor; but this increasing causes better robustness on watermark image. Figure above also proves trade-off between invisibility and robustness.

Correlation coefficient is a value that indicates the degree of connectivity between two variables. In general, it can be said that if the value of correlation coefficient is huge, then it means that the connectivity of the variables is strong and vice versa. The formula of correlation coefficient represents data as 

\[ \rho(x, y) = \frac{\sum_{i=1}^{K} x_i y_i - (\sum_{i=1}^{K} x_i)(\sum_{i=1}^{K} y_i)}{\sqrt{\left(\sum_{i=1}^{K} x_i^2 - (\sum_{i=1}^{K} x_i)^2\right)\left(\sum_{i=1}^{K} y_i^2 - (\sum_{i=1}^{K} y_i)^2\right)}} \]

where \( X \) is host image and \( Y \) is watermarked image. Therefore, if the correlation coefficient is huge between those 2 variables, then there’s a strong connectivity between them. If there’s a strong connectivity between the host image and the watermarked image, then the less damage that will occur to the watermarked image (not many watermarked image information lost), therefore the more data contained within can be restored to its original form.

Scale factor is a measure of how many data that will be inserted into an image, in this case is a singular matrix of watermark image. For example, if the scale factor is 0.05 then the amount of data that is inserted into the image is 5%. Therefore, scale factor shows the capacity of the inserted data.

Noise in watermarked image will decrease the quality of that image and influenced the durability of the image. But this decrease is not only influenced by the selection of subband insertion place, it is also influenced by the intensity of the interference.

This research provides scale factor effect to inserted image robustness. Disturbances given are noise, rescale, and JPEG compression.
• **Gaussian Noise**

Below is a correlation coefficient of watermark image robustness on the host image against JPEG compression.

![Figure 9. Robustness of watermarked image from Noise](image1)

Showed on figure 9, the bigger scale factor used, inserted image will be more robust to the noise. Using DCT results better robustness on inserted image than using DWT. It is also known that the inserted watermark image on subband LL couldn’t withstand Gaussian noise for all scaling factor. This is due to the high coefficient that subband LL has compared to the others. The sum of noise matrix directly on subband LL coefficient will cause a huge change on subband coefficient, so at the time of extraction there are some components of the original low frequency image that get into high frequency range, so that only a little watermark image on the LL subband that can be extracted.

• **Rescale**

Below is a correlation coefficient of watermark image robustness on the host image against JPEG compression.

![Figure 10. Robustness of Watermarked Image from Rescale](image2)

Figure 10 shows that the bigger scale factor used, inserted image will be more robust to rescale. Using DCT relatively results better robustness on inserted image than using DWT. It is known that watermark image durability towards rescale disturbance is determined by decomposition level, subband insertion place and wavelet filter that is used and also the image characteristic. This happened because rescale is a type of disturbance on spatial domain, that is by changing the size of the image resulted from...
watermarking to be a smaller size and then the size of the image will be returned to normal, so that there would not be any duplicated image component. If the watermark image is inserted on frequency image, it will cause inconsistency on an image durability towards rescale disturbance on specific level and wavelet filters.

- **JPEG Compression**

Below is a correlation coefficient of watermark image robustness on the host image against JPEG compression.

![Figure 11. Robustness of Watermarked Image from JPEG Compression](image)

On figure 11, the bigger scale factor used, then the inserted image will be more robust to compression, the correlation between the watermark image from extraction process and original watermark image is better, this is because of the higher scaling factor of JPEG Compression then the less information of watermarked image lost and the data contained can be restored. Using DWT relatively results better robustness on inserted image than using DCT. Besides, insertion on low frequency is relatively more robust than insertion on high frequency subband. It is also known that watermark image has a good durability if it is inserted on LL subband for all scaling factor. This is because LL subband has subband approximation, therefore LL subband coefficient has an important meaning on representing an image. While JPEG compression using DCT transformation that transforms an image from spatial domain to frequency domain. In DCT, the coefficient is sorted from the most important to the least important, the most important value will be on the top-left, and getting to the bottom-right it is getting less important. It also causes durability to scaling factor for DCT lower than DWT.

Compression is done by quantizing and removing the value from the bottom-right to the top-left to the desired quality limit. If the data is inserted on LL subband, then the image component that keep that data would not be wasted too much, so there will be many data that can be restored. The greater the JPEG compression quality used, the better the watermark image on the LL subband.

From Figure 9, 10, 11 above, it can be concluded that watermark image durability towards certain types of disturbance are influenced by the magnitude of the scale factor used and the use of a combination of input parameters (subband, decomposition level on DWT and block on DCT).

5. **Conclusion**

The bigger scale factor used, the more visible of alteration on the image; but the watermark image inside is more robust to noise. Furthermore, scale factor selection should consider the subband of insertion. High frequency insertion is better using smaller scale factor than in low frequency insertion. Watermark image robustness to noise is influenced by the type and intensity of noise, and insertion location on subband. Insertion on low frequency subband will be robust to From the experiment results, combination
of SVD-DCT method result a better watermark robustness from combination of SVD-DWT method. The correlation coefficient is related with robustness of watermark method, from the robust watermarking method shows that if watermark image after extraction and attacking process is compared with original watermark image, it has a good similarity (correlation coefficient). The proposed future works can be listed as follows:

a. The proposed watermarking scheme can be implemented on other digital medias such as audio and video;
b. The watermarking technique can be used and implemented on different kind of fields such as fingerprint, tamper detection, owner identification, data authentication and etc. Therefore, the proposed watermarking scheme can be implemented on other fields beside copyright-labelling;
c. The proposed watermarking scheme is a non-blind watermarking, therefore in the near future, a research can be done for the blind watermarking scheme using the proposed method;
d. A combination of watermarking methods can also be explored more in the near future and some optimization algorithms can also be used to maximize the result of the research.
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