DFT-SVD and DCT-SVD Domain Digital Image Watermarking: Implementation and Performance Analysis

Dodi Sudiana[1] and Darmawan Apriyadi[2]
[1]Optics and Remote Sensing (OPRES) Research Group,
Department of Electrical Engineering, Faculty of Engineering
University of Indonesia
E-mail: dodi@ee.ui.ac.id
[2]Department of Electrical Engineering, Faculty of Engineering
University of Indonesia

Abstract

Transparent, robust watermarking schemes tend to insert invisible watermarks with the highest possible energy. Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD) have been used as mathematical tools for embedding data into an image. In this paper, we present three watermarking schemes based on SVD, combined DFT-SVD, and DCT-SVD. In the first scheme, both of insertion and extraction process is directly computed using SVD. In the combined schemes, after applying the DFT and DCT to the cover image, we map the DCT and DFT coefficients into four quadrants. A zig-zag and unzig-zag algorithm are applied in DCT-SVD. We try the size of the visual watermark of 1/4, 1/16 and 1/64 of the size of the cover image.

The performance of each method is evaluated by comparing the Peak Signal to Noise Ratio (PSNR) and correlation coeficients of each watermarking result. We ask 30 respondents to give their opinion and using Mean Opinion Score (MOS) method to evaluate the result subjectively. We test the robustness of watermarking results using Gaussian blur, Gaussian noise, JPEG compression, and rescaling.

In embedding process, image watermarking has a good quality (PSNR watermarked image > 30 dB) for: scaling factor < 0.1 (SVD and DCT-SVD), scaling factor < 0.05 (DFT-SVD). The quality of image watermarking in decomposition level 3 is better than level 2 and level 1. Embedding watermarked image based on DFT-SVD scheme is the most robust to attack, such as of Gaussian noise and rescaling attack (for level 2 dan 3) and Gaussian blur attack (all of level). As for JPEG compression attack, SVD and DCT-SVD schemes have a good quality of robustness compare to DFT-SVD scheme.

Keyword: image watermarking, Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT), Singular Value Decomposition (SVD)

1. Introduction

The idea to mark a copyright on a digital data could be implemented using watermarking, which is invisible to human eyes. Watermarking (data hiding) is the process of embedding data into a multimedia element such as an image, audio or video file. This embedded data can be later extracted from, or detected in, the multimedia for security purposes. The watermarking algorithm consists of the watermark structure, an embedding algorithm, and an extraction algorithm. Watermarks can be embedded in the pixel domain or a transform domain. There are several transformation domain which could be used, such as: DFT (*Discrete Fourier Transform*), DCT (*Discrete Cousine Transform*), DWT (*Discrete Wavelet Transform*), etc. In the application, embedded watermarks should be invisible, robust, and have a high capacity. In frequency domain watermarking schemes, there is a conflict between robustness and transparency. If the watermark is embedded in perceptually most significant components, the scheme would be robust to attacks but the watermark may be difficult to hide. On the other hand, if the watermark is embedded in perceptually insignificant components, it would be easier to hide the watermark but the scheme may be less resilient to attacks.

In image watermarking, two distinct approaches have been used to represent the watermark. In the first approach, the watermark is generally represented as a sequence of randomly generated real numbers having a normal distribution with zero mean and unity variance. This type of watermark allows the detector to statistically check the presence or absence of the embedded watermark. In the second approach, a picture representing a company logo or other copyright information is embedded in the cover image. The detector actually reconstructs the watermark, and computes its visual quality using an appropriate measure.

A few years ago, a transform called the Singular Value Decomposition (SVD) was explored for watermarking [2]. The SVD for square matrices was discovered independently by Beltrami in 1873 and Jordan in 1874, and extended to rectangular matrices by Eckart and Young in the 1930s. It was not used as a computational tool until the 1960s because of the need for sophisticated numerical techniques. Now, SVD is one of the most useful tools of linear algebra with several applications in image compression, and other signal processing fields.

In this research, we proposed a watermarking method using the SVD itself, combination SVD with DFT and DCT to embed an image to media image using blocking division technique. The following figures (Figs. 1-3) show the illustration of the schemes implemented in the program.

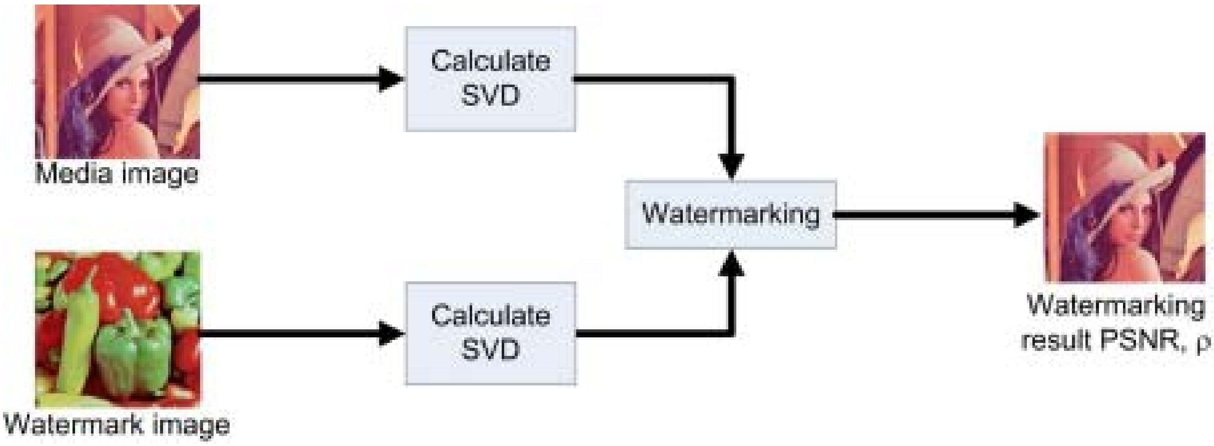

Figure 1. Block diagram of image watermarking using SVD method

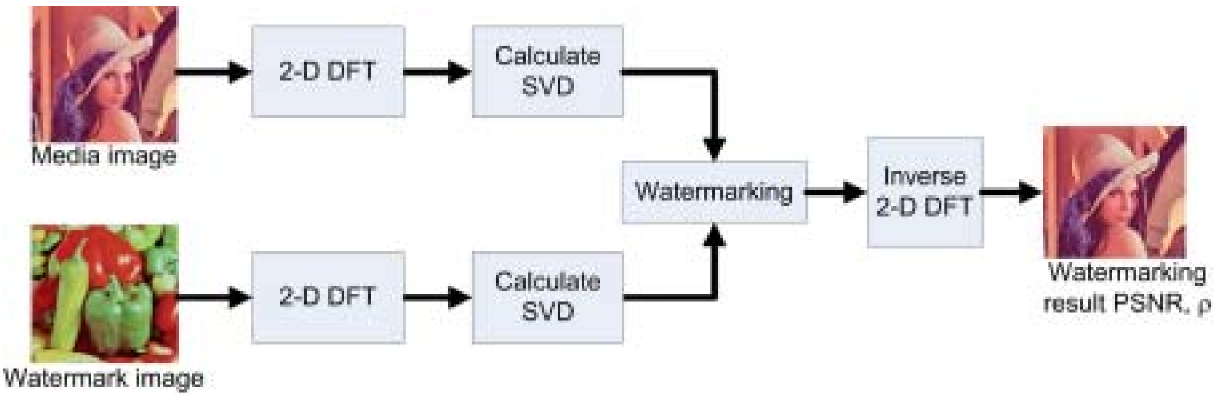

Figure 2. Block diagram of image watermarking using combined SVD-DFT method

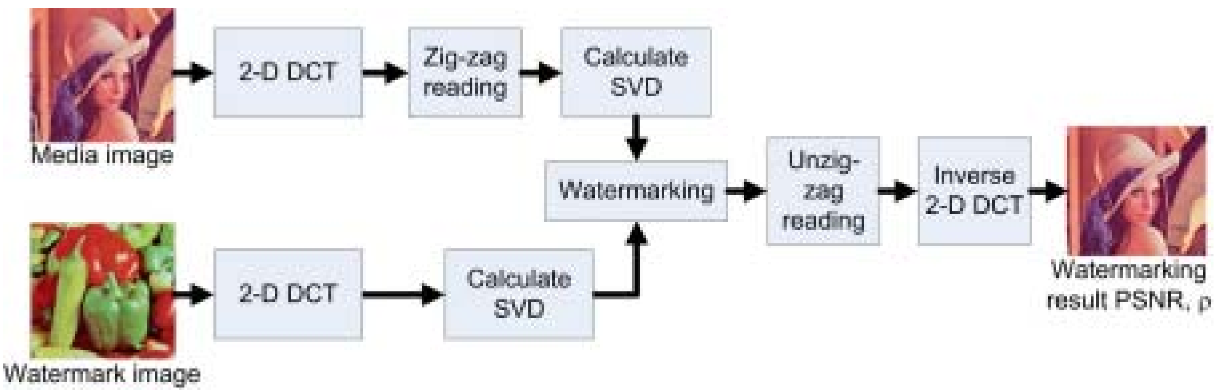

Figure 3. Block diagram of image watermarking using combined SVD-DCT method

To extract the original image, Figure 4-6 show the block diagram of each method.

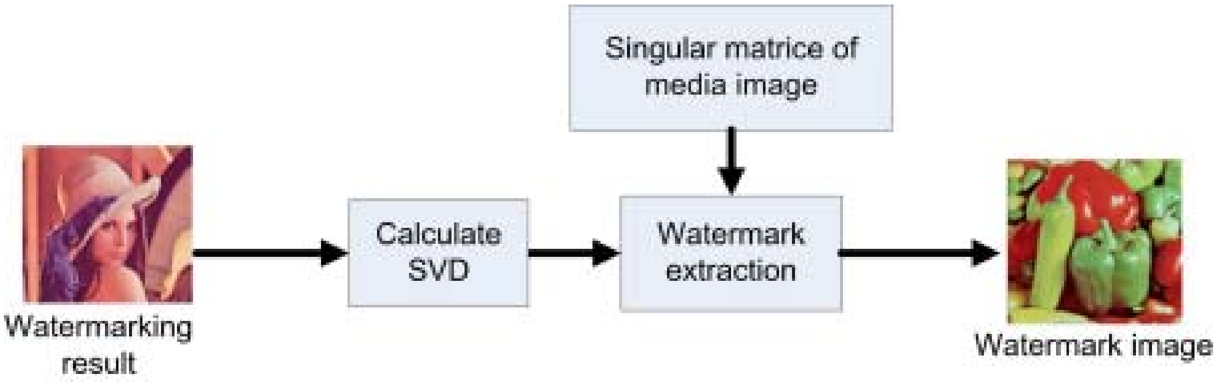

Figure 4. Block diagram of image extraction using from SVD watermarking method

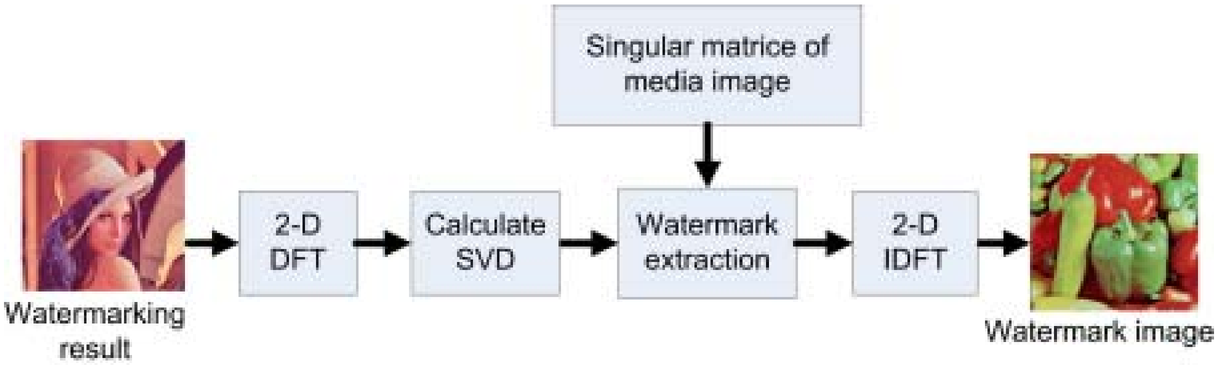

Figure 5. Block diagram of image extraction using from combined SVD-DFT watermarking method

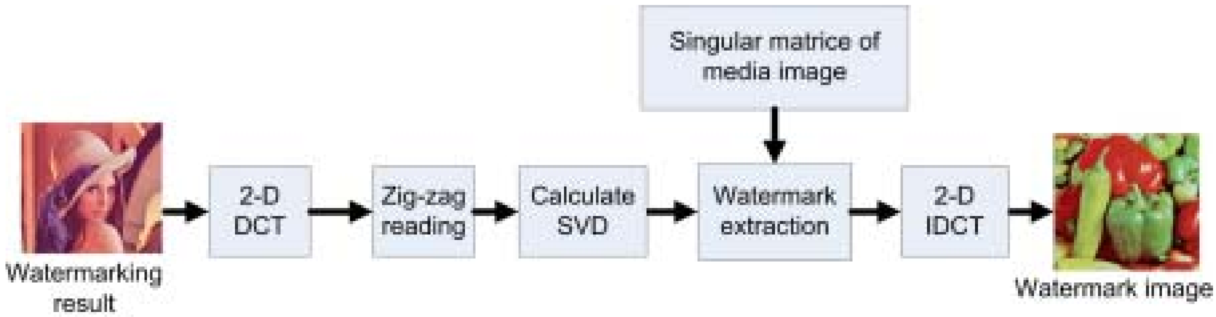

Figure 6. Block diagram of image extraction using from combined SVD-DCT watermarking method

2. Experiment

Three methods have been implemented to embed an 24-bit color image (in .BMP format) with 256×256 in size as sample data. The watermarking images are then distorted and processed using *gaussian noise*, *gaussian blur*, *rescale*, and JPEG compression. The watermarking image before and after distortion is then extracted and evaluated to check the performance of each method. Figure 7 shows the media and watermark images used in the experiment.

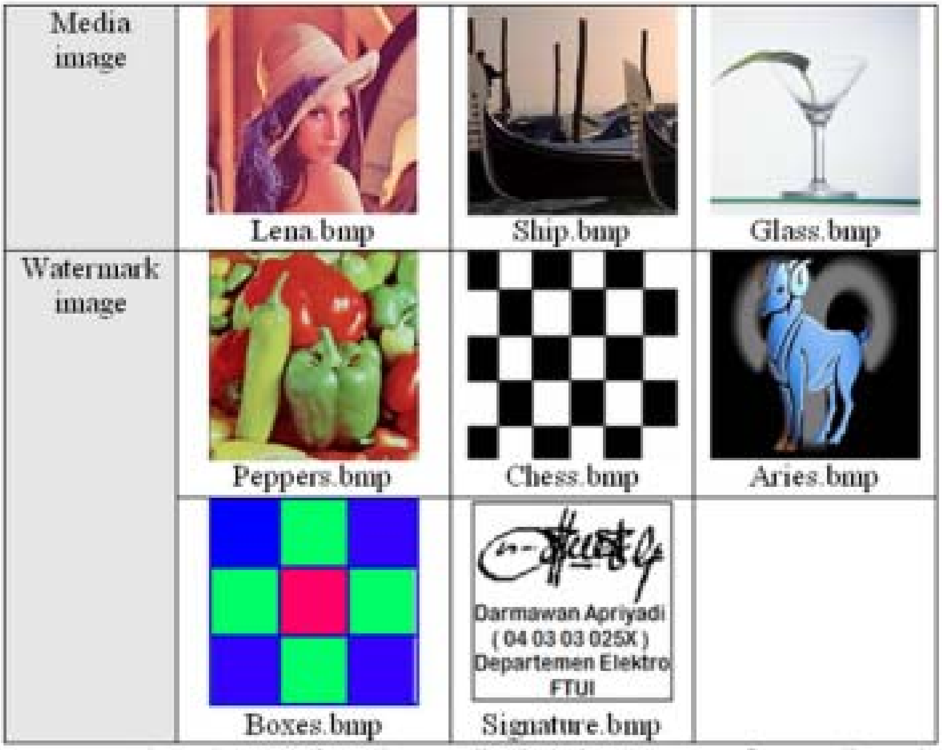

Figure 7. The media and watermark images used in the experiment

3. Performance of each method

To measure the performance indicator of each method, we used the PSNR (Power to Noise Signal Ratio) of the invisibility of watermarking method. The experiment included the robustness of the method to scaling factors, scaling factors evaluated using Mean Opinion Score MOS, Gaussian noise distortion, convolution matrice size, rescaling, and JPEG compression and showed in Figs. 8-13, respectively.

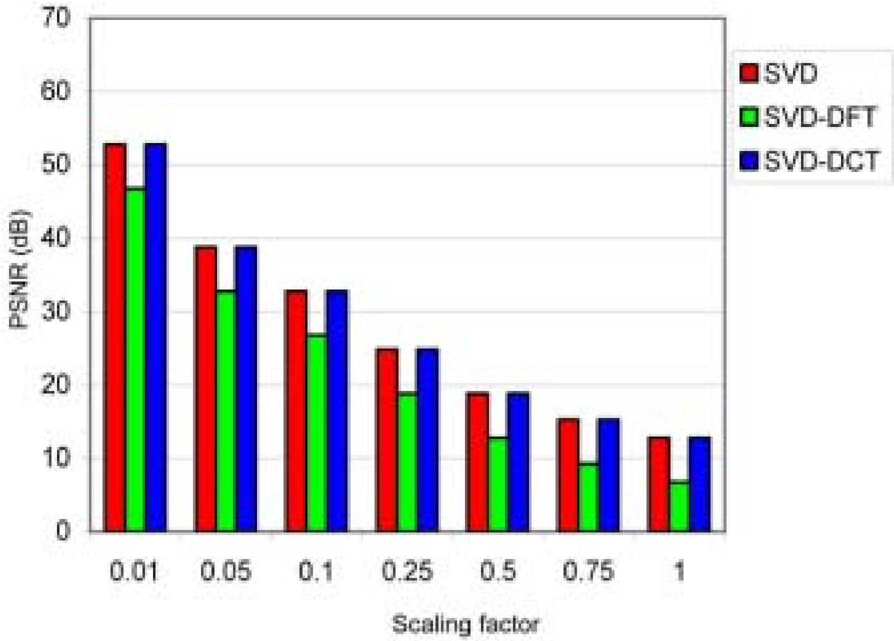

Figure 8. The robustness of each watermarking method to scaling factors.

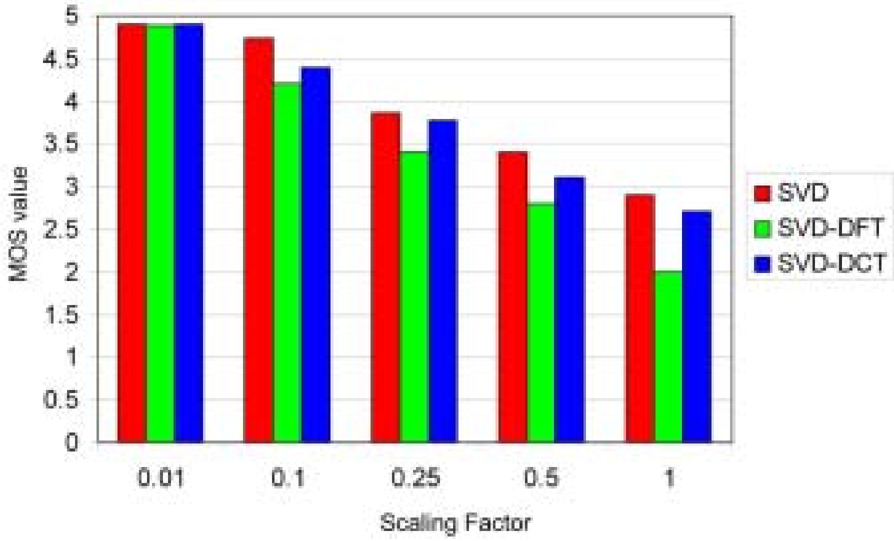

Figure 9. The robustness of each watermarking method to scaling factors evaluated using MOS

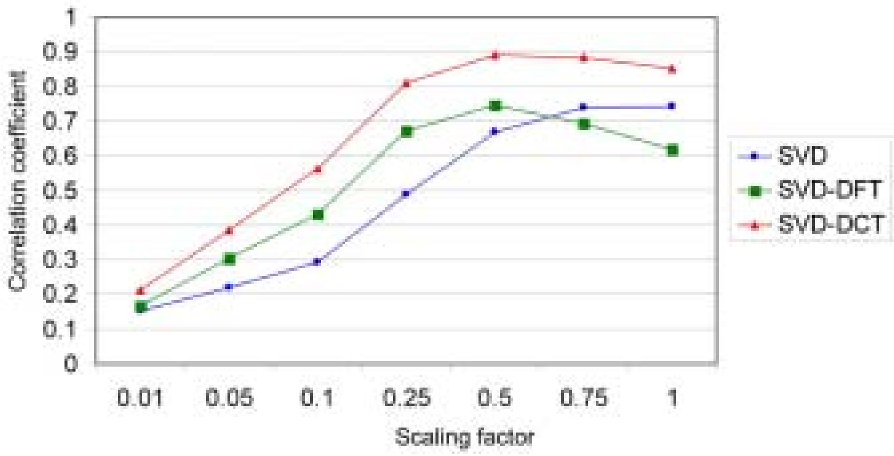

Figure 10. The robustness of each watermarking method to Gaussian noise shown by the correlation coefficient

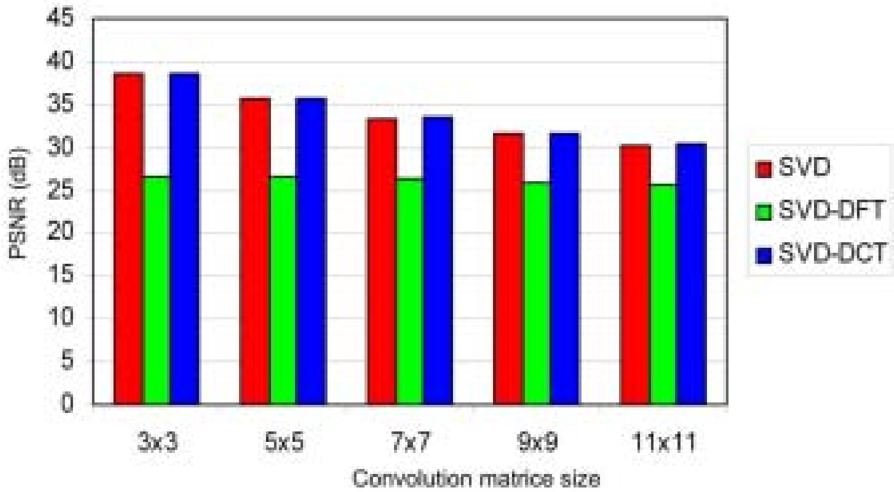

Figure 11. The robustness of each watermarking method to convolution matrice size

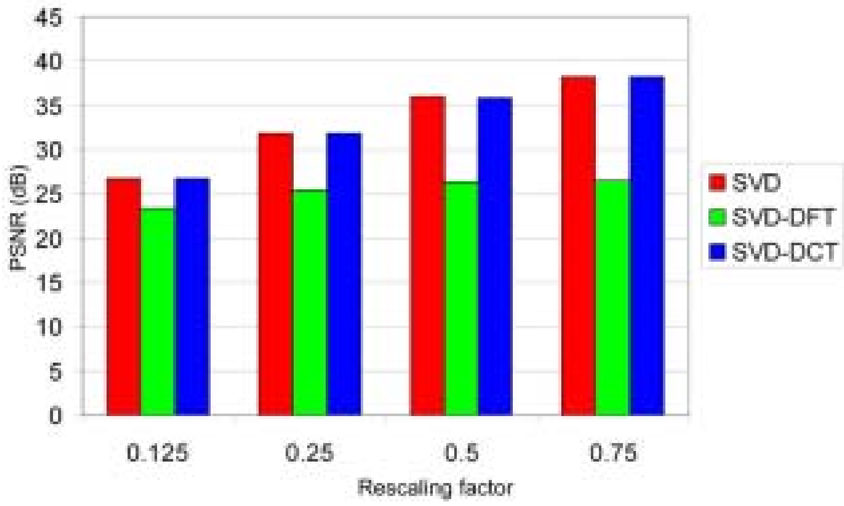

Figure 12. The robustness of each watermarking method to rescaling factors

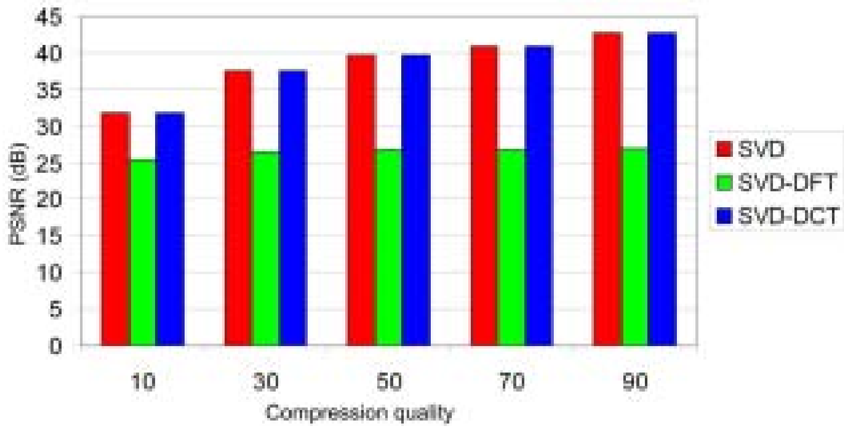

Figure 13. The robustness of each watermarking method to JPEG compression

5. Conclusion

1. In embedding process, image watermarking has a good quality (PSNR watermarked image > 30 dB) for scaling factor < 0.1 (SVD and DCT-SVD) and scaling factor < 0.05 (DFT-SVD).
2. The quality of image watermarking in decomposition level 3 is better than level 2 and level 1.
3. Embedding watermarked image based on DFT-SVD scheme is the most robust to attack, such as of Gaussian noise and rescaling attack (for level 2 dan 3) and Gaussian blur attack (all of level).
4. As for JPEG compression attack, SVD and DCT-SVD schemes have a good quality of robustness compare to DFT-SVD scheme.

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