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Advanced Multiple Watermarking Scheme for Copyright Protection and Image Authentication

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Abstract— **The advancement in communication medium is producing large volume of digital information which needs to be protected. Watermarking is a technique that is used to hide secret information into original signal in a manner that improves overall quality of the original signal. In case of digital image watermarking, another area that is drawing attention is the multiple watermarking, where more than one watermark is embedded into single multimedia object. Multiple watermarks are normally proposed as a method to provide extra security to an image by embedding two or more secret messages into the cover image. In the present research work, the concept of multiple watermarking is used to hide both copyright and authentication information into a color image. For this purpose a wavelet transformation based on texture properties and secret sharing using visual cryptography is used. The various benchmarks and attacks are applied on the watermarked images to evaluate the performance of the proposed scheme. Experimental results indicate that the proposed watermarking scheme is highly robust and does not degrade the original signal. To minimize the difference between original and watermarked singular values, an optimized-quality formula is proposed. First, the peak signal-to-noise ratio (PSNR) is defined as a performance index in a matrix form. Then, an optimized-quality functional that relates the performance index to the quantization technique is obtained. Experimental results show that the watermarked image can keep a high PSNR and achieve less mean square error (MSE) even when the number of coefficients for embedding a watermark bit increases.**

Index Terms—**Watermarking, PSNR, MSE, DWT.**

I. INTRODUCTION

With the rapid development of activity on the internet, much digital information is widely spread. Digital watermarking was developed to hide digital information and protect the copyright of multimedia signals, like audio, images, etc. Due to the fact that discrete-time wavelet transform (DWT) provides a useful platform, numerous DWT-based algorithms for digital watermarking have been proposed in recent years.
Watermarking in the spatial domain [1–11] is usually more vulnerable than watermarking in the frequency domain [12–29] with the same embedding capacity due to the fact that spatial-domain methods are generally fragile to image-processing operations and other attacks [23–25]. The spatial-domain singular value decomposition (SVD) for image watermarking was first introduced by Liu et al. [8]. In this paper, the authors used a spread-spectrum technique to embed a watermark by modifying the singular values of the host image in the spatial domain. Some authors embedded watermark to U and V components to increase embedding capacity [9, 10] while Ghazy et al. [11] presented a blockby-block SVD-based image-watermarking scheme to increase embedding capacity. However, the robustness of SVD-based image watermarking in the spatial domain is low. In recent years, many image-watermarking techniques combine DWT and SVD to achieve better transparency and robustness [17, 18, 24, 25]. Bao et al. [17] proposed a novel, yet simple, image-adaptive watermarking scheme for image authentication by applying a simple quantization index-modulation process on each single singular value of the blocks in the wavelet domain. Their watermarking scheme is blind and is robust against JPEG compression but extremely sensitive to malicious manipulation such as filtering and random noising. Ganic et al. [18] applied SVD to all details, approximating part of the DWT and watermark image to increase embedding capacity. Gaurav and Balasubramanian [24] embedded a watermark into the reference image by modifying the singular value of the reference image using the singular values of the watermark. The robustness is slightly enhanced. However, the computation is significantly increased. Lai and Tsai [25] reduced the computation in [24] by directly embedding the watermark into the singular values in the wavelet domain. In this work, we first divide the DWT middle frequency parts LH3 and HL3 into several square blocks to have high embedding capacity. Unlike the traditional spread-spectrum technique on single singular values [24, 25], we use multiple singular value quantizations to embed a watermark bit. It does not only keep a high embedding capacity but also achieves strong robustness against median filtering. On the other hand, an optimized quality formula is proposed by minimizing the difference between original and watermarked singular values. First, the peak signal-to-noise ratio (PSNR) is defined as a performance index in matrix form. Then, an optimized quality functional that relates the performance index to the quantization technique is obtained. Finally, the Lagrange Principle is utilized to obtain the optimized quality formula; then, the formula is applied to watermarking. Experimental results show that the watermarked image can keep a high PSNR and achieve a better bit error rate (BER) even when the number of coefficients for embedding a watermark bit increases. In particular, the robustness against median filtering is significantly improved.
This paper is organized as follows. In Section II, we review some mathematical preliminaries. Section III introduces the proposed watermark embedding and extraction. In Section IV, we rewrite PSNR as a performance index. An optimized-quality equation that relates the performance index to the quantization constraint is proposed, and the Lagrange Principle is used to solve the optimized-quality problem. The solution is utilized to embed the watermark, and we discover a very good result; the watermark is extracted without the

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original image. In Section V, we present some experiments to test the performance of the proposed scheme and also appear some performance table. Finally, conclusions are drawn in Section VI. Assistant

II. PRELIMINARIES

In this section, some related steps for the proposed image watermarking scheme are reviewed.

DISCRETE-TIME WAVELET TRANSFORM (DWT)

The wavelet transform is obtained by a single prototype function which is regulated with a scaling parameter and shift parameter [28–31]. The discrete normalized scaling and wavelet basis function are defined as follows:

$$\varphi_{j,l}(t) = 2^{j/2}\varphi\left(2^{j}t-\tau\right) \tag{1}$$

$$\psi_{j,l}(t) = 2^{j/2}\psi\left(2^{j}t-\tau\right) \tag{2}$$

where j and τ are the dilation and translation parameters; from this, one can require that the sequence

$$\{0\}\subset\cdots\subset V_1\subset V_0\subset V_{-1}\subset\cdots\subset L^2(\mathbb{R}) \tag{3}$$

Forms a mutiresolution analysis of L2(ℝ) and that the subspaces · ··, W1, W0, W_{-1}, · · · are the orthogonal differences of the above sequence; that is, Wj is the orthogonal complement of Vj inside the subspace Vj − 1. Then, the orthogonality relations follow from the existence of sequences h = {hτ}τ ∈ ℤ and g = {gτ}τ ∈ ℤ that satisfy the following identities:

$$h_\tau = \varphi_{0,0}, \varphi_{-1,\tau} \text{ and } \varphi(t) = \sqrt{2}\sum_{\tau\in\mathbb{Z}} h_\tau \varphi(2t-\tau) \tag{4}$$

$$g_\tau = \psi_{0,0}, \phi_{-1,\tau} \text{ and } \psi(t) = \sqrt{2}\sum_{\tau\in\mathbb{Z}} g_\tau \varphi(2t-\tau) \tag{5}$$

where h = {hτ}τ ∈ ℤ and g = {gτ}τ ∈ ℤ are, respectively, the sequence of low-pass and high-pass filters. In this paper, we use a Haar scaling function and wavelet to transform the host image into the orthogonal DWT domain by three-level decomposition. A method to implement DWT is a filter bank that provides perfect reconstruction. DWT has local analysis of frequency in the space and time domains, and it obtains image multi-scale details step by step. If the scale becomes smaller, every part gets more accurate and ultimately all image details can be focalized accurately. If DWT is applied to an image, it will produce high-frequency parts, middle-frequency parts, and a lowest-frequency part. Figure 1 shows the procedure of applying one-level DWT to an image. In order to guarantee both image quality and robustness, this study embeds the watermark into the middle frequency parts LH3 and HL3 in DWT level-three.

SINGULAR VALUE DECOMPOSITION (SVD)

The singular value decomposition of a matrix A with size m × n is given by

$$A = UDV^T \tag{6}$$

Where, U and V are orthogonal matrices, and D = diag(λi) is a diagonal matrix of singular values λi, i = 1, 2, ···, which are arranged in decreasing order. The columns of U are the left singular vectors, and the columns of V are the right singular vectors of image A.

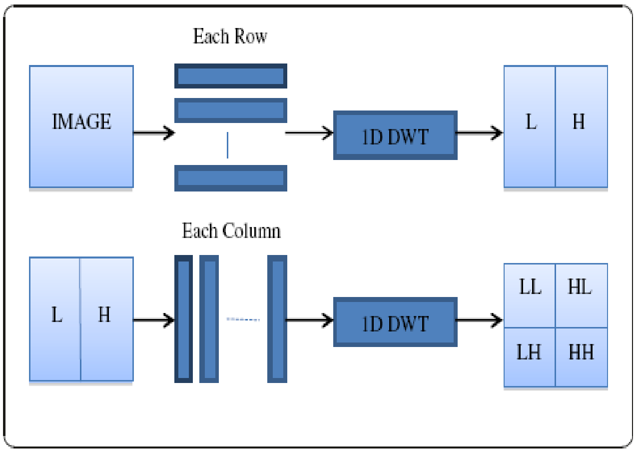


Figure 1: 2D DWT

III. OPTIMIZATION SOLVER

To find the extreme of the matrix function, some optimization methods are summarized in [29–31]. The operations of the matrix function are first shown as follows:

Theorem 1: If W is a k × k constant matrix, and X^ is a k × 1 column vector with k unknown variables, then

$$\frac{\partial \mathbf{W}\hat{X}}{\partial \hat{X}} = \mathbf{W} \tag{7}$$

Theorem 2: If X is a k × 1 constant vector and ^X is a k × 1 column vector with k unknown variables, then

$$\frac{\partial\left(\hat{X}-X\right)^T\left(\hat{X}-X\right)}{\partial\left(\hat{X}-X\right)} = 2\left(\hat{X}-X\right) \tag{8}$$

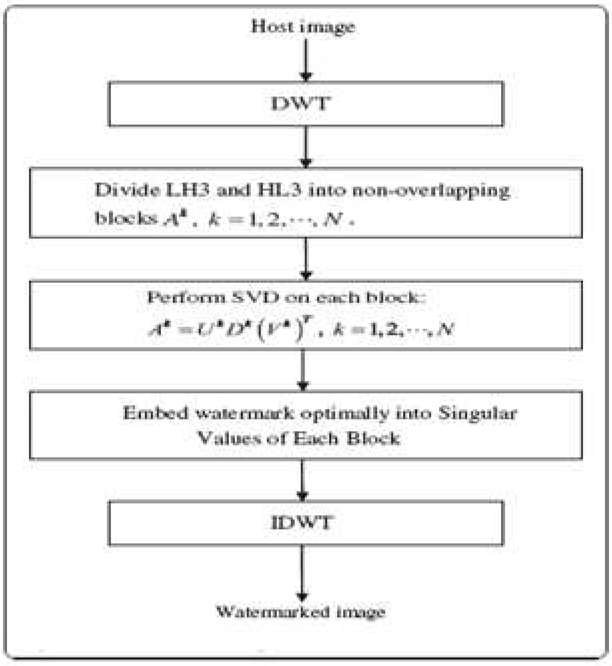


Figure 2: Watermark Embedded Process

$$\nabla f(\hat{X}) = \frac{\partial f}{\partial \hat{X}} = \left[\frac{\partial f}{\partial \hat{X}_1}\ \frac{\partial f}{\partial \hat{X}_2} \cdots \frac{\partial f}{\partial \hat{X}_k}\right]^T$$

Now we consider the problem of minimizing (or maximizing) the matrix function f (X^) subject to a constraint
bX¼ 0. This problem can be described as follows:

$$\text{minimize } f(\hat{X}) \tag{9(a)}$$

$$\text{subject to } g(\hat{X}) = 0 \tag{9(b)}$$

Theorem 3: Suppose that g is a continuously differentiable function of $\hat{X}$ on a subset of the domain of a function f. Then if $\hat{X}_o$ minimizes (or maximizes) f ($\hat{X}$) subject to the Constraint ($\hat{X}$) ; ∇f ($\hat{X}_o$) and ; ∇g ($\hat{X}_o$) are parallel.

That is, if b_X0_≠0, then there exists a scalar ξ such that

$$\nabla f(\hat{X}_0) = \xi \nabla g(\hat{X}_0). \tag{10}$$

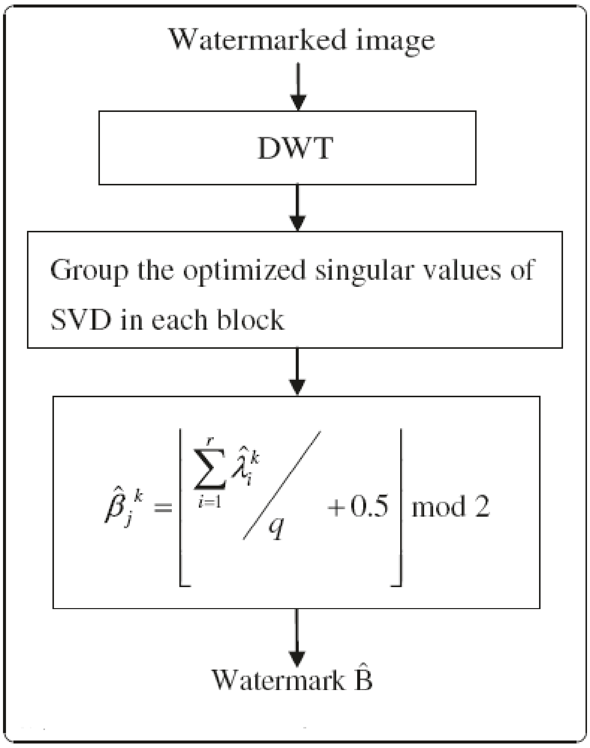


Figure 3: Watermark extraction process

$$H(\hat{X}, \xi) = f(\hat{X}) + \xi g(\hat{X}) \tag{11}$$

Then the original problem (9) becomes a function H ($\hat{X}$ξ) which has no constraint. The necessary conditions for existence of the extreme of function H ($\hat{X}$ξ) are:

$$\frac{\partial H}{\partial \xi} = 0, \tag{12}$$

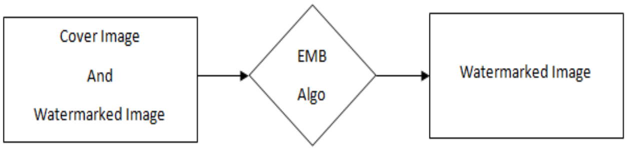
$$\frac{\partial H}{\partial \hat{X}} = 0. \tag{13}$$

IV. PROPOSED WATERMARKING SCHEMES

The proposed watermarking scheme is introduced in this section. The watermark is extracted without the original image.

A. *Embedding Algorithm*

Input: Cover Image and Watermark Image
Output: Watermarked Image



Step 1: Read cover image 'P' and watermark image 'WI' with NXN size.

Step 2: The cover image and watermark image is converted into YCbCr colour space from RGB colour space and one of the channel is chosen for embedding.

Step 3: Perform 1-LWT on the Y channel of P and WI to split into four groups.

Step 4: Perform 2-LWT on the HL band of P and WI to split into four groups.

Step 5: Apply WHT on HL band of cover and watermark image.
for x,m = 0,1,2,........,M-1, and y,n = 0,1,2,... ...... N-1.For MxM square images the above transform pair is reduced to

$$H(m,n) = \frac{1}{M}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} HL(x,y)\,(-1)^{\sum_{i=0}^{n-1}[b_i(x)b_i(m)+b_i(y)b_i(n)]}$$

$b_z(k)$ is the k^th bit in the binary representation of z, $HL(x,y)$ is the HL band of cover and watermark image in rows and columns.For (m,n) = 0,1,2,. . . . . . .N-1, n = is order of sequence

Step 6: Perform SVD on the WHT coefficient of the P and WI image.

$$[U_j, S_j, V_j] = svd(X(k))$$

Step 7: Modify the singular value of S_i by embedding the singular value of watermark image such that

$$S_e = S_i + alpha * S_j$$

Where WI is modified matrix of S_j and alpha denotes the scaling factor, is used to have power over the signal S_j power of watermark.

Step 8: Embed singular matrices with orthogonal matrices for final watermark image as W with below formula:

$$W = U_i * S_e * V_i'$$

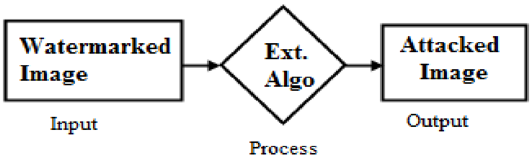
Step 9: Apply 2D-IWHT to reconstruct the matrix.

$$HL(x,y)=\frac{1}{M}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}H(m,n)\,(-1)^{\sum_{i=0}^{u-1}[b_i(x)b_i(m)+b_i(y)b_i(n)]}$$

Step 10: Perform the two level inverse LWT (ILWT) on the LWT transformed image, to obtain the watermarked image on four coefficients.

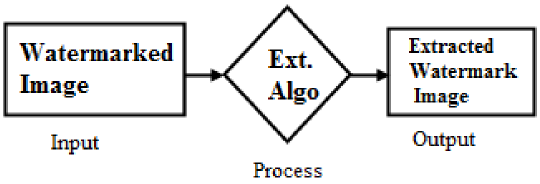
B. Extraction Algorithm

Input: Watermarked Image
Output: Attacked Image



Step 1: Apply Gaussian Attack and Crop Attack on watermarked image for security and robustness.

Input: Watermarked Image
Output: Extracted Watermark Image



Step 1: Apply two levels LWT transform to decompose the watermarked image W into four overlapping sub-bands.

Step 2: Apply WHT to HL sub band using equation (4.1).

Step 3: Apply SVD to X_m sub band i.e. $[U_m, S_m, V_m] = svd(X_m)$
Step 4: Modify the singular value of S_i by extracting the singular value of watermarked image such that

$$S_j = (S_m - S_i)/alpha$$

Step 5: Extract singular matrices with orthogonal matrices for final extracted watermark image and cover image as W with below formula:

$$W = U_m * S_j * V_m'$$

Step 6: Apply 2D-IWHT to reconstruct the matrix in equation (4.5).

Step 7: Perform the two level inverse LWT (ILWT) on the LWT transformed image, to obtain the extracted watermark and cover image on four coefficients.

Step 8: Calculate PSNR and RMSE value of watermarked and cover image.

$$RMSE(x) = \sqrt{\frac{1}{N}\|x - x^\wedge\|^2 = \frac{1}{N}\sum_{i=1}^{N}(x - x^\wedge)^2}$$

Where x is cover image, x^ is watermarked image, N is the size of the cover image

$$PSNR(x) = \frac{10\ X\log((255))}{RMSE(x)}$$

Where m is the maximum value of the cover image

V. RESULTS

Original image or input images have a RGB combination. Image processing begins with an image acquisition process. The two elements are required to acquire digital images.

The following figure 4 has been taken to test the system.

Figure 4 Experimental Dataset

Now here, we have use Gaussian Attack and Crop Attack, while watermarking the images.

we have taken cover image as body parts image and watermark image as Rose image with Gaussian attack using ref techniques shown in figure 5.

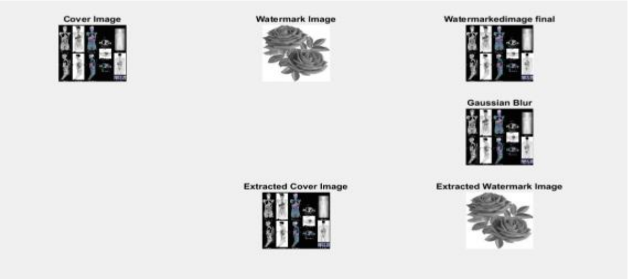


Figure 5 Watermarking Procedure with Gaussian attack

We have taken cover image as Body parts image and watermark image as Rose image with Crop attack using ref techniques shown in figure 6.

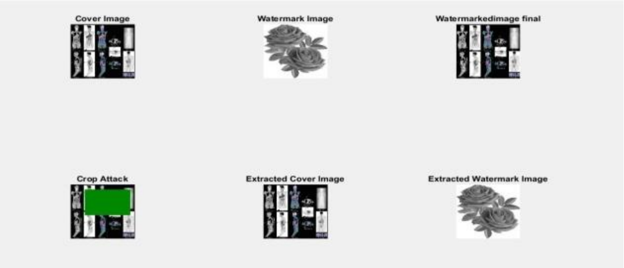


Figure 6 Watermarking Procedure with Crop attack

We have taken cover image as Body parts image and watermark image as Rose image with Gaussian attack with proposed techniques shown in figure 7.

Figure 7 Watermarking Procedure with Gaussian attack

We have taken cover image as Body Parts image and watermark image as Rose image with average attack using proposed techniques shown in figure 8.

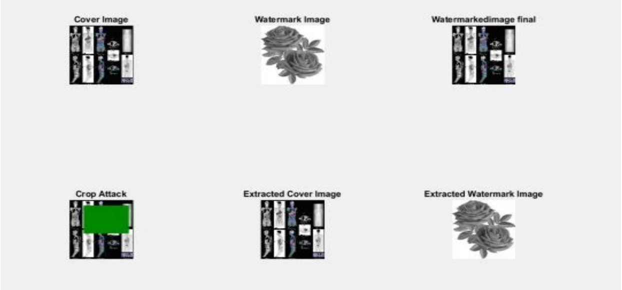


Figure 8 Watermarking Procedure with Crop attack

Similarly, we can test with different images; the following table illustrates the performance.

Table 1: PSNR comparison between ref and proposed for watermarking

Tick Label	Cover Image	Watermark Image	Ref PSNR	Proposed PSNR
A	Bodyparts	Rose	53.2186	58.80
B	Baboon	Pepper	53.1970	53.91
C	Sonogram	Ship	53.1722	65.44
D	Lena	Pepper	53.1418	57.24
E	Head	Rose	53.1282	56.24
F	Modi ji	Ship	53.1080	52.56

Table 2: Time comparison between ref and proposed for embedding

Tick Label	Watermarked Image	Ref Embedding Time	Proposed Embedding Time
A	Rose	0.5413	0.8413
B	Pepper	0.5734	0.7334
C	Ship	0.5298	0.6598
D	Pepper	0.5487	0.5987
E	Rose	0.5206	0.6806
F	Ship	0.5350	0.6450

Table 2 shows the comparison between Ref and proposed scheme using Embedding Time. It describes the time of adding two images using proposed algorithm.

Table 3: PSNR comparison between ref and proposed when different channels are chosen to embed

Tick Label	Ref PSNR (in dB)			Proposed PSNR		
	Y	Cb	Cr	Y	Cb	Cr
A	24.46	10.67	10.84	50.79	58.90	59.48
B	14.57	10.75	9.36	42.95	63.82	63.26
C	13.54	9.79	7.89	64.11	70.59	70.67
D	12.55	12.03	11.31	49.57	68.95	68.58
E	14.67	14.64	8.95	45.29	67.45	67.75
F	22.41	9.48	13.37	41.41	57.21	57.69

Table 4: RMSE after various attacks when Y-channel was used for watermarking

Tick Label	Cover Image	Watermark Image	Attacks	
			Gaussian	Crop
A	Bodyparts	Rose	23.98	97.49
B	Baboon	Pepper	34.59	93.54
C	Sonogram	Ship	7.41	87.33
D	Lena	Pepper	12.84	89.64
E	Head	Rose	10.49	89.95
F	Modi ji	Ship	4.10	87.75

Table 5: RMSE after various attacks when Cb-channel was used for watermarking

Tick Label	Cover Image	Watermark Image	Attacks	
			Gaussian	Crop
A	Bodyparts	Rose	1.49	87.69
B	Baboon	Pepper	1.72	87.67
C	Sonogram	Ship	0.99	87.67
D	Lena	Pepper	1.43	87.65
E	Head	Rose	1.16	87.67
F	Modi ji	Ship	1.08	89.95

Table 6: RMSE after various attacks when Cr-channel was used for watermarking

Tick Label	Cover Image	Watermark Image	Attacks	
			Gaussian	Crop
A	Bodyparts	Rose	1.79	87.74
B	Baboon	Pepper	2.23	87.69
C	Sonogram	Ship	0.99	87.67
D	Lena	Pepper	1.46	87.63
E	Head	Rose	1.15	85.45
F	Modi ji	Ship	1.08	86.98

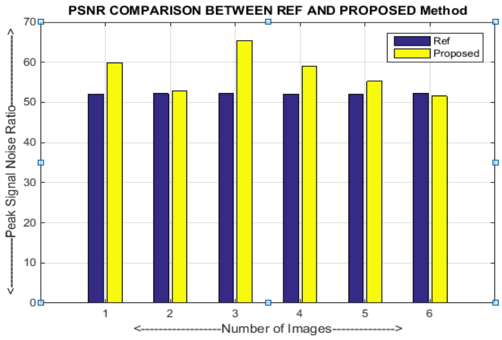


Figure 9 PSNR comparisons between Ref and Proposed method

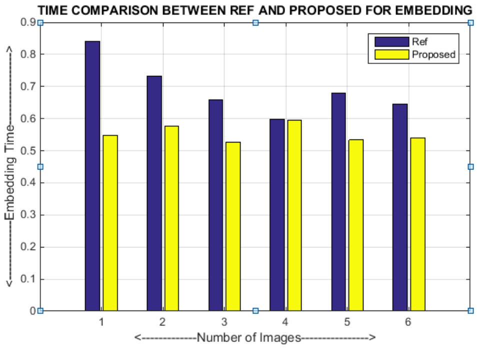


Figure 10 Time comparison between Ref and Proposed for embed

The purpose of calculating the performance of the image and after that comparison between ref and proposed methods will show which method is better for image watermarking. Such method is mainly due to highly accurate detection with various attacks. The (Peak signal to noise ratio) PSNR, (Signal to noise ratio) SNR is high; (mean squared error) MSE is low. This proposed method is a fast method for image watermarking.

VI. CONCLUSION

This study improved the robustness of traditional SVD based Digital image watermarking by using optimization-based quantization on multiple singular values in the wavelet domain. Experimental results show that the watermarked image can keep a high PSNR and achieve a lower MSE even when the number of coefficients for embedding a watermark bit increases. In particular, the robustness against JPEG compression, Gaussian noise, and median filtering is significantly improved. The future work is the consideration of improving robustness against rotation.

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