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A Novel Digital Image Watermarking Technique Based on Modified Periodic Plus Smooth Decomposition for Robustness and Security

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Abstract : Now a days billion of digital files are transferred via the internet per day so security problem, copyright of data, data transformation and some other issues has become a big question with multimedia source and content. This paper introduces a Robust and Secure Digital Image Watermarking Technique which is centered on Periodic Plus Smooth Decomposition (PPSD), Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD). In the first step the host and watermark image is decomposed into a smooth and periodic component. The smooth component decomposed into four frequency sub-bands through 2 nd level DWT. We apply SVD to one of frequency sub-band, the watermark singular matrix is combined with the singular matrix of host image. At last, the watermarked image is obtained by using the inverse of DWT. Through the proposed technique we improved the different parameters like PSNR, SSIM index, NCC. Thus, the experimental result displays that the proposed technique is imperceptible and robust to different attacks. This technique combines the advantages like a false positive problem that is solved by the digital signature. Ownership is authenticated before extracting watermarked image.

***IndexTerms*- Discrete wavelet transform (DWT); Periodic Plus Smooth Decomposition (PPSD); Singular Value Decomposition (SVD); Peak Signal to Noise Ratio (PSNR); Structural Similarity Index Measurement (SSIM); Normalized Correlation Coefficient (NCC); Region Of Curvature (ROC).**

I. INTRODUCTION

The communication and Internet technologies rapidly develop, which makes the multimedia data can simply be copied, distributed, accessed and used illegally. Thus, the security of the multimedia data is truly important. All watermarking technique has an embedding and extraction process. Watermarking is used in various fields like protect copyright, fingerprinting, broadcast monitoring and authentication applications. Copyright protection is the most important application. In this paper we proposed an algorithm which is based on PPSD, DWT, and SVD to obtain good quality, robustness and security. Robustness resists the resistance and withstands with several attacks, including image processing attacks and geometrical attacks. Robust Method adds Watermarks to Bitmap images by fading technique. Raise the text effect via adaptive multi-scale texture synthesis. Imperceptibility is the similarity between the original and the watermarked version. An imperceptible image is a clearly visible image. Partial Pivoting Lower and Upper triangular gives a good imperceptible value. Security is for authentication purpose. When authentication is needed, the digital signature is compared with signature saved before (Piper et al,2012). Digital signature confirmation appliance helps to resolve the false positive problem which was an important problem. For image authentication used the error correction coding. The peak signal-to-noise ratio (PSNR) is a metric that is cast-off to evaluate imperceptibility performance. If the PSNR is high then it indicates a higher imperceptibility. Watermarking is used in various fields like copyright protection, broadcast monitoring, and authentication purpose (Liu et al, 2017). Therefore it converts the research topic to search the new technique. Nowadays, digital watermarking is developing quickly due to the increased courtesy of copyright issues. With the development of web-communication and multimedia technology, more and more digital multimedia signal can be transmitted. So the study of digital watermarking is unfinished without secure data transfer, copyright protection, and image authentication to make an efficient algorithm to improve the PSNR, SSIM, and NCC.

II. PROPOSED APPROACH

This paper will propose a new approach which is based on PPSD-DWT-SVD to improve the imperceptibility, robustness, and security.

2.1 Periodic Plus Smooth Decomposition (PPSD)

PPSD is a well-organized way to a treaty with periodization artifacts. The discrete host, watermark and watermarked image are divided into two images: an image ‘p’ that is well surveyed by the DFT and for most images visually very comparable to u; and an image ‘s’ that has very smooth deviations except at the borders of the image. Therefore the images (p, s) ∈ $(R^{\Omega})^2$ mnimizes under the limits (Aherrahrou et al, 2017)

$$E(p,s) = \sum_{\substack{\mathbf{x}\in\Omega,\mathbf{y}\in\mathbb{Z}^2\setminus\Omega,\\ |\mathbf{x}-\mathbf{y}|=1}} \left(p(\mathbf{x}) - p(\dot{\mathbf{y}})\right)^2 + \sum_{\substack{\mathbf{x}\in\Omega,\mathbf{y}\in\Omega,\\ |\mathbf{x}-\mathbf{y}|=1}} \left(s(\mathbf{x}) - s(\mathbf{y})\right)^2 \qquad (2.1)$$

$$u = p + s, \quad \text{and} \quad \text{mean}(s) = 0,$$

Where $\dot{y}$ is the unique element of Ω equal to y modulo Ω, and

$$\text{mean}(s) = \frac{1}{|\Omega|}\sum_{\mathbf{x}\in\Omega} s(\mathbf{x}). \qquad (2.2)$$

“Eq.1” represents the PPSD mathematical function and “Eq.2” represents the mean. The image ‘p’ is the periodic component of u (also written as per (u)) and‘s’ the smooth component of u. Now, the diagrammatical view is shown in Fig. 1. Where a) Host Image b) Periodic component c) Smooth component.

a) Host Image

b) Periodic component c) Smooth component

Figure 1 a) host image b) periodic component c) smooth component

2.2 Discrete Wavelet Transform (DWT)

Wavelet transforms [15] are special functions which, representing a signal in the form of sine and cosine. The filter divides the input image into four frequency sub-bands LL, LH, HL and HH [11,1]. The sub-bands LL represents the high magnitude coefficient but for further bands (HH, HL, and LH) magnitude is less. Embedding in the LL (low level) sub-bands robustness increase significantly. DWT level decomposition single level decomposition, 2nd level decomposition, 3rdlevel decomposition. We use 2nd level decomposition in our technique so the diagram is shown in Fig. 2.

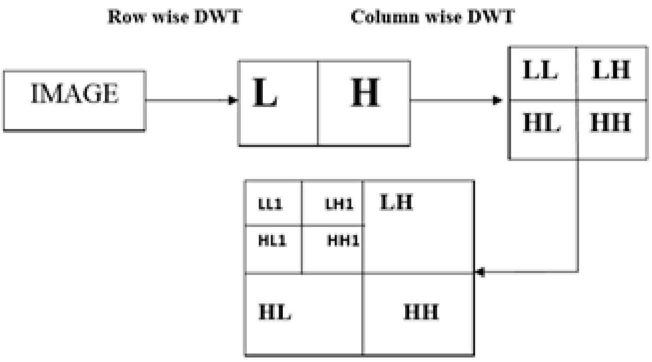


Figure 2 2^{nd} level decomposition [13]

2.3 Singular value decomposition (SVD)

This scheme was first introduced by Beltrami and Jordan in 1870. The SVD is a numerical exploration technique. It makes calculations easy by the singular matrix. Currently, the SVD is generally cast-off in applications for example image hiding, image watermarking, noise reduction and image compression. [13, 1]. Consider an image as matrix A of real/complex N×N with rank r, $A(r<N)$. Using SVD, a matrix A can be represented as follows: [15, 3]

$$A = U_A\, S_A\, V_A^T = \sum_{i=1}^{r} u_i * s_i * v_i^{\,T}$$
$$U_A = [u_1, u_2 \ldots, u_N]$$
$$V_A = [v_1, v_2 \ldots, v_N]$$

$$S_A = \begin{pmatrix} S_1 & & & & \\ & S_2 & & & \\ & & \cdot & & \\ & & & \cdot & \\ & & & & S_N \end{pmatrix} \quad (2.3)$$

Orthogonal matrices, UA and VA are N×N in which ui and vi, (1 ≤ i ≤N), respectively, represent their column vectors, whereas the SA is N×N diagonal matrix Eq. (3) including the singular values Si in a decreasing order. The widespread use of SVD in image processing applications is due to its important features and characteristics, which are the following:

1. Singular values SA of any image has Good stability.
2. The singular values (S) of an image specify its algebraic properties, representing an image's luminance, whereas the singular vectors (U and V) represent the geometry properties of an image.
3. Singular values are in descending order.
4. SVD can be applied on square or rectangle matrices.

Diagrammatical view of SVD show in Fig. 3:

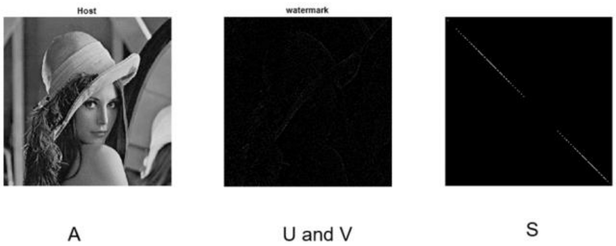


Figure 3 SVD Basic work

III. Embedding and Extraction process of our proposed approach

3.1 The embedding procedure

The Embedding process is shown in block diagram form Fig. 4

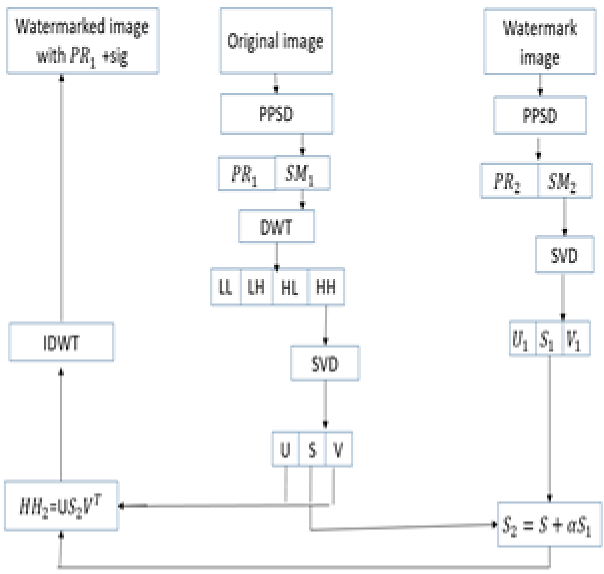


Figure 4 The Proposed Embedding Procedure

Embedding Steps:

•	Apply PPSD to Host and Watermark image.
•	Apply DWT to smooth component of the host image.
•	DWT decompose the host image into four frequency sub-bands.
•	Apply SVD to smooth component of watermark image and HH frequency sub-band.
•	Combine the singular matrix of host and watermark image and make the new singular matrix.
•	Now new singular matrix makes new frequency sub-bandHH_2.
•	Apply IDWT in which we give LL, LH, HL, HH_2 bands and at last get watermarked image with periodic component of the host image.
•	Apply a digital signature to the watermarked image.

3.2. The extracting procedure:

The Extraction process is shown in block diagram form Fig.5

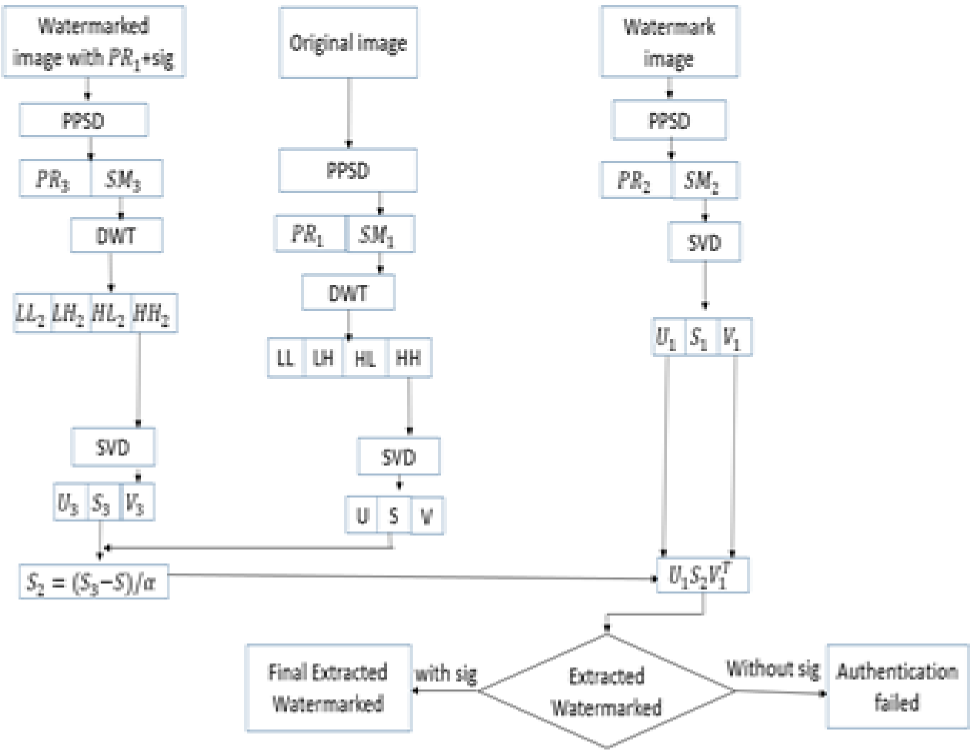


Figure 5 The proposed extracting procedure

Extraction Steps:

•	Apply PPSD to watermarked, host and watermark image.
•	Apply DWT to smooth component of watermarked and host image
•	Apply SVD to high frequency sub-band of watermarked and host image.
•	Apply SVD to smooth component of watermark image.
•	Subtract the host singular matrix through the watermarked singular matrix and get the new singular matrix of watermark image.
•	At last, we extract the watermarked image.
•	If we give digital signature final extracted watermark image extracted.
•	If digital signature not given or without digital signature, authentication failed.

IV. RESULTS

Watermarking algorithms are usually evaluated with respect to robustness and imperceptibility. Imperceptibility is the measure of the quality of the watermark image. The original image should not be distorted by the presence of the watermark or any kinds of attack. Robustness is the measure of the resistance of a watermark against attacks. These attacks may add some signal processing operation such as blurring, contrast enhancement, gamma correction, histogram equalization, sharpening, flipping, and adaptive white Gaussian noise. The proposed technique work for all grey images. The computational time of our process is 1.467848 second.

4.1 Imperceptibility:

Imperceptibly can measure capability by measuring the peak signal to noise ratio (PSNR) which shown in "Eq.4.1". The PSNR unit is decibel (dB) (Agoyi et al,2014)

$$PSNR_{dB} = 10\log(\frac{MAX^2}{MSE}) \qquad (4.1)$$

Logarithm base =10; MAX = 255 (maximum possible pixel value of the image);

MSE (mean square error) = It is an average of the pixel difference between the two images which shown in "Eq. 4.2" (Agoyi et al., 2014)

$$MSE = \frac{1}{S}\sum_{1}^{S}(I(S) - W(S))^2 \qquad (4.2)$$

Where I(S) = original image before watermarking; W(S) = watermarked image.

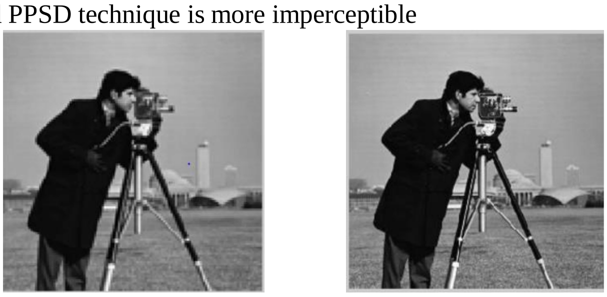
4.1.1 The imperceptibility test of the modified PPSD technique:

The imperceptibility test image value of the proposed modified PPSD technique is compared to CZT-DWT-SVD (Agoyi et al,2014), IWT-SVD (Makbol,2014), DWT-DCT-SVD (Islam et al,2014), Adaptive Logo (Andalibi et al,2015), PPSD (Aherrahrou et al,2017) which shown in Table 1.

Table 1 Imperceptibility comparison values using PSNR (dB) for 'Lena' and 'baboon' image

Techniques	**Lena Image**	**Baboon Image**
CZT +DWT+ SVD	29.41	21.44
IWT + SVD + Digital Signature	43.6769	N.A
DWT + DCT + SVD	51.318	51.209
Adaptive logo texturing	39.48	N.A
PPSD	74.1504 (avg. of 100 images) (max=87.9687 min= 60.3316)	
Proposed Modified PPSD	92.9075	92.9076

For more clearance see Fig. 6 which display the image under zero attack. The figure displays the performance of the proposed modified PPSD technique in term of imperceptibility. The Extracted watermark image of b) proposed Modified PPSD is clearer than a) PPSD . So we say that our Modified PPSD technique is more imperceptible



a) b)

Figure 6 Extracted watermark image of a) PPSD ((Aherrahrou et al, 2017) and b) proposed Modified PPSD

4.2. Robustness:

To measure the robustness capability, SSIM watermarked, SSIM extracted watermark and NCC can be castoff to measure the degree to which the used algorithm which can withstand to attack. A robust watermark should be able to resist contrast enhancement, flipping, additive histogram equalization, blurring, sharpening, AWGN and gamma correction. The SSIM measure by "Eq.4.3"

$$\mathbf{SSIM(x,y)}= \frac{(2\mu_x\mu_y+C_1)(2\sigma_{xy}+C_2)}{(\mu_x^2+\mu_y^2+C_1)(\sigma_x^2+\sigma_y^2+C_2)} \qquad (4.3)$$

Where the universal image quality index corresponds to the case of $C_1 = C_2 = 0. \mu_X = mean\ of\ x,\ \mu_y = mean\ of\ y, \sigma_x = standard\ deviation\ of\ x,\ \sigma_y = standard\ deviation\ of y,\ and\ \sigma_{xy} = cross\ correlation.$

Normalised correlation coefficient: NCC measure by "Eq. 4.4"

$$\rho(W, K) = \frac{\sum_{i-1}^{n} W_i K_i}{\sqrt{\sum_{i-1}^{n} W_{i^2}}\sqrt{\sum_{i-1}^{n} K_{i^2}}} \qquad (4.4)$$

W=correlation factor of watermark image;
K=correlation factor of an extracted image

4.2.1 The robustness test of the modified PPSD technique:

The Robustness test in developing digital watermarking technique is done by calculating different parameters: SSIM values of watermarked, extracted and NCC. We can describe the different parameters in Table 2, Table 3 and Table 4. The test is done by giving different attacks at different images such as contrast enhancement, gamma correction, histogram equalization, blurring, sharpening, AWGN, and flipping. The SSIM index and NCC of the extracted watermarked image after various attacks were measured for our modified PPSD technique and were compared it with the CZT-DWT-SVD (Agoyi et al,2014) technique.

Table 2 The robustness test w.r.t SSIM value for attacked watermarked image

	CZT-DWT-SVD (Agoyi et al, 2014)	**Proposed modified PPSD technique**
Lena		
Hist. equalization	0.7255	0.7750
sharpening	0.4561	0.8569
flipping	0.2258	0.8572
blurring	0.6373	0.8603
Contrast adjustment	0.8195	0.7915
Gamma correction	0.6061	0.8176
AWGN	0.1960	0.8421
Baboon		
Hist. equalization	0.2212	0.7817
sharpening	0.0352	0.7956
flipping	0.0179	0.7960
blurring	0.2959	0.7970
Contrast adjustment	0.2085	0.7771
Gamma correction	0.1295	0.7430
AWGN	0.988	0.7898

Table 3 The robustness test w.r.t SSIM value for attacked extracted image

	CZT-DWT-SVD (Agoyi et al, 2014)	**Proposed modified PPSD technique**
Lena		
Hist. equalization	0.4823	0.9924
sharpening	0.1136	0.9924
flipping	1.0000	0.9924
blurring	-0.0896	0.9924
Contrast adjustment	0.6439	0.9924
Gamma correction	0.6881	0.9924
AWGN	0.1725	0.9924
Baboon		
Hist. equalization	0.8968	0.9929
sharpening	0.9926	0.9930
flipping	1.000	0.9929
blurring	-0.6445	0.9925
Contrast adjustment	0.9768	0.9930
Gamma correction	0.9921	0.9929
AWGN	0.6684	0.9929

Table 4 The robustness test w.r.t NCC value for extracted watermarked image

	CZT-DWT-SVD (Agoyi et al, 2014)	**Proposed modified PPSD technique**
Lena		
Hist. equalization	0.9776	0.9924
sharpening	0.9791	0.9924
flipping	1.000	0.9924
blurring	-0.6533	0.9922
Contrast adjustment	0.9916	0.9924
Gamma correction	0.9810	0.9924
AWGN	0.6362	0.9928
Baboon		
Hist. equalization	0.9373	0.9928
sharpening	0.9547	0.9928
flipping	1.000	0.9927
blurring	-0.6246	0.9924
Contrast adjustment	0.9782	0.9928
Gamma correction	0.9967	0.9928
AWGN	0.6117	0.9929

To check the robustness of our method, we applied attacks and measure the SSIM watermarked, SSIM extracted and NCC parameters. Table 2, Table 3 and Table 4 show that our proposed Modified PPSD technique show the higher robustness and Fig. 7, Fig. 8 shows that the extracted watermark image visibility is more clear than PPSD [2] technique when AWGN attack is applied.

PPSD (Aherrahrou et al,2017)	Modified PPSD
 a)	 b)
 c)	 d)

Figure 7 a) Watermarked image after AWGN attack; b) Watermarked image AWGN attack; c) Extracted watermark from (a); d) Extracted watermark from (b)

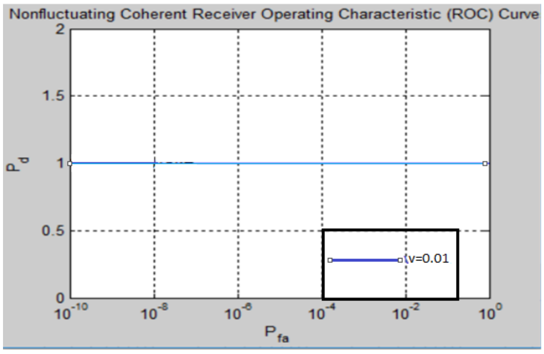
Here, we applied the same Adaptive White Gaussian Noise to 'Baboon' image and check the performance characteristic of both the techniques.

PPSD (Aherrahrou et al, 2017)	Modified PPSD
 a)	 b)
 c)	 d)

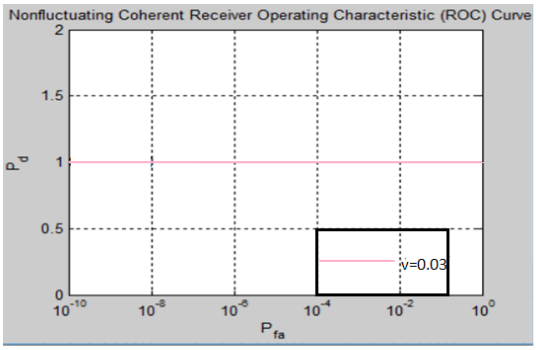
Figure 8 a) Watermarked image after AWGN attack; b) Watermarked image AWGN attack; c) Extracted watermark from (a); d) Extracted watermark from (b)

4.2.2 The robustness test w.r.t ROC curve:

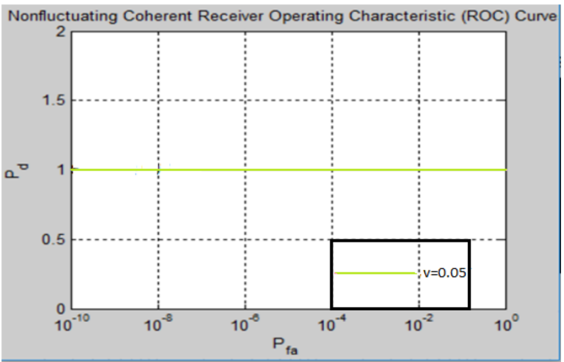
We also plot the ROC curve w.r.t true positive detection rate versus false positive detection rate shown in Fig. 10.



a)



b)



c)

Figure 9 ROC curve for adaptive white Gaussian noise of a) variance v=0.01, b) v=0.03, c) v=0.05 for Modified PPSD

The robustness of the proposed technique against adaptive white Gaussian noise is evaluated. The results obtained are reported in Fig. 10. In this figure we analysed the variation of the probability of false detection, we observe that the probability of detection of the watermark is still high and almost unchanged against in density of noise of variance v=0.05, v=0.03, v=0.01.

4.3 Security:

Digital data can be simply copied to another user without loss of data and quality of data. So the study of watermarking is incomplete without protected data transfer. The watermark can leave security on the image which is covered in the host image. It is objective like a 'digital key' which offers a sense of validity and safety to the image. The security test is shown in Fig. 10.

The security test of the proposed technique:

a) b)

Figure10 Extracted watermark image a) without key b) with key

V. CONCLUSIONS

In this paper, a robust and secure digital image watermarking technique based on Modified PPSD has been presented. The main features of the modified technique are

(i) The imperceptibility of the image is improved by high PSNR and the PSNR is 92.9075.

(ii) The image is robust with respect to different attacks like sharpening, blurring, gamma correction, flipping, contrast enhancement etc.

(iii) The proposed modified technique solve the false positive problem by the digital signature authentication mechanism.

Thus we increase imperceptibility, robustness, and security but the computational time is quite increased 0.2-0.3 second which we neglect because it's too small. To define the efficiency of our proposed modified technique we compared our experimental results with CZT-DWT-SVD (Agoyi et al,2014), IWT-SVD-Digital Signature (Makbol et al, 2014), DWT-DCT-SVD (Islam et al,2014), Adaptive logo texturing (Andalibi et al, 2015), PPSD (Aherrahrou et al, 2017) techniques. Our experimental results show that our proposed modified technique provides the best compromise between robustness, invisibility and security.

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