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Modified Buyer Seller Watermarking Protocol based on Discrete Wavelet Transform and Principal Component Analysis

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Abstract

This digital watermarking protocol is basically applied to preserve the rights for both parties involving in E-commerce i.e. buyer and seller. Principal component analysis is used to reduce the correlation coefficient. This protocol uses wavelet transform with principal component analysis and integrates digital watermarking techniques and public key cryptosystem for proving the ownership of digital content. In this paper a watermark image that i.e. baby image is inserted into selected high frequency sub-bands of discrete wavelet transformed. Then we have applied the principal component analysis transformation for selecting the blocks. The process for selecting the blocks are depends by calculating the energy of every block and then the maximum energy blocks were selected. We have calculated parameters such as PSNR and NCC for checking the imperceptibility and robustness of the proposed approach.

Keywords: Copyright Protection, Cryptography, Multimedia, Principal Component Analysis

1. Introduction

The speedy development of internet and e-commerce needs a copyright protection mechanism for multimedia data. Straight off a day's digital watermarking becomes an important technique for protecting the digital rights[1]. This hidden data can later be extracted to prove the ownership of the digital content[2,3]. With the increasing role of the internet, there is always a need to protect the multimedia data over the web. Information hiding in still images has two main applications such as fingerprinting and copyright protection. But important aspects of digital watermarking systems include imperceptibility, robustness, capacity and security of the embedding and extracting process. Digital watermarking[4–8] techniques uses encrypted domain for embedding and extracting the watermarks. The rapidly growing of the internet encourages some bad usage too, like operations such as transformation, duplication and redistribution of digital content. With the avail of some software tools, we can easily identify these bad users and redistribution of digital content can also be placed. In history several buyer seller watermarking protocol[9–14] have been introduced.

In our protocol seller is responsible to embed a watermark[15,16] that identifies the buyer into a digital content.

The first PCA domain was introduced to gray-scale image watermarking[17]. Lai et al.[34] suggested a hybrid DWT-SVD watermarking procedure in which two halves of the watermark image is embedded into the two singular value matrices of intermediate frequency sub-bands obtained while taking one level DWT of host image. After embedding the watermark, the two halves are combined to get the watermarked image. Principal Component Analysis (PCA)[18–20] is often applied to subdue a large number of variables to a smaller set of their linear combinations that adequately identify the arrangement. The primary advantage of using PCA transform is to choose

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the suitable significant components into which we can embed the watermark.

In this paper we present a modified buyer seller watermarking protocol which uses DWT and PCA. Our protocol is focused on managing the watermark. We do not design new method, but simply use wavelets and principal components, PCs for embedding and extracting the watermarks.

The rest of this paper is structured as follows. In the section II we have discussed about the DWT and PCA transform. Section 3 presented our work that is modified buyer seller watermarking protocol based on DWT and PCA. Section 4 discussed the result and analysis. Finally, Section 5 provides the conclusion of this research paper.

2. DWT and PCA Transform

Wavelet transforms[15] is a theory that can localize the signal in various frequencies. Discrete wavelet transform divides an image into high frequency sub-bands and low frequency sub-bands. High frequency sub–bands contains more information about the image and very sensitive to human eyes so if we choose these bands then the quality of our original image will degraded and low frequency sub-bands does not contains more information and neither these bands are very sensitive to human eyes. So if we apply watermarking to low frequency sub-bands then the watermarking embedding algorithm will become more efficient. Wavelet based techniques[27–29] are gaining more attention because wavelets have advantages over other transform such as it contain low progressive rate transmission and scalability characteristics.

The wavelet transforms[31] have a very good compatibility with a human vision system model as compared to the Fourier transform or discrete cosine transform. Equation 1 shows the general form of a discrete wavelet transform.

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi(\frac{t-b}{a}) \quad (1)$$

Where *a and b* is the scaling and shifting parameter.

Principal Component Analysis (PCA) is basically used to reduce the dimension of a dataset and it forms a new feature vector. It is used in various applications such as pattern recognition, compression, face detection etc. Principal component analysis gives good results when applied to linear algebra. It provides a way to explain how to bring down complex data sets to a lower data set. It is also used for removing the correlation coefficients amongst the dataset. In Yavuz[32,33] a reference image is generated from the cover image using PCA and the watermark is embedded according to the difference between the image and its reference image. PCA projects the data in the least square sense, it captures big variability in the data and ignores small variability. In data of high dimensions, where graphical representation is not possible, PCA[35] is a powerful tool for analyzing data and finding patterns in it.

3. Modified Buyer-Seller Watermarking Protocol (MBSWP) based on DWT and PCA

Our proposed protocol uses wavelets and PCs for embedding and extracting watermark from the original digital content. We have used the same trust model as it is used by[9,13]. Our approach inserted watermark information into the maximum coefficient of the PCA block this leads in great robustness. In our algorithm a watermark image i.e. a baby image is inserted into selected high frequency bands of discrete wavelet transform. After that, we have applied Principal Component Analysis (PCA)[36] on these high frequency wavelet coefficients and stored the mean (Ai) and covariance (Ci) of the data onto the first principal component called PCs. After applying Principal Component Analysis (PCA) transformation we have chosen blocks for embedding the watermark. Now we select only those blocks which contain maximum energy. Then the watermark bits is inserting only into the maximum coefficient of the PCA block. The extraction procedure of the watermark is same as we embed the watermark.

Algorithm 1: Watermark embedding scheme

Input : The original color image *I* of size 512×512 and the watermark image *W* of 128×128.

Output: Watermarked color image *I′ of size* 128×128.

Step 1: Apply DWT to the original color image. This results in four multi-resolution sub-bands: HH_1, $H(L_1)$, LH_1, LL_1. For every sub-band apply DWT again to get 16 sub-bands.

Step 2: Select $H(L_3)$, LH_3 high frequency sub-bands of the original color image *I*.

Step 3: Compute the energy of each sub-band using the following Equation no. 2.

$$E_r = \frac{1}{n \times n}\sum_{i=1}^{n}\sum_{j=1}^{n} C^2(i,j) \quad (2)$$

Where E_r denotes the energy, n × n is the size of sub-band, and C is the wavelet coefficient.

Step 4: Select only maximum energy blocks which are the edges and texture blocks of the image. Then we apply PCA to each selected block as described.

1. We get the block zero mean Z_i as below:

$$Z_i = E(B_{si} - M_i) \tag{3}$$

2. We calculate the covariance matrix C_i by Equation no. 4 of the zero mean blocks Z_i as:

$$C_i = Z_i \times Z_i^T \tag{4}$$

Where T denotes the transpose matrix

3. Then we have calculated the PCA transformation of every block by using Equation no. 5:

$$X_i = \phi^T Z_i \tag{5}$$

Where X_i is the principal component PCs of the blocks and ϕ is the matrix of eigenvectors.

Step 5: The watermark bits are embedded with strength α into maximum coefficient M_i of each principal component PCs block X_i. For embedding the watermark we use Equation no. 6:

$$M_i = M_i' \pm \alpha W \tag{6}$$

Where α is the watermark strength factor.

Step 6: We apply inverse PCA on the modified PCs blocks for obtaining the modified wavelet block by using Equation no. 7:

$$Z_i = \phi X_i \tag{7}$$

Step 7: Apply the *IDWT* to get the new watermarked coefficient. Finally reconstruct the watermarked color image from these new coefficients.

Algorithm 2: Watermark extracting scheme

Input: The watermark color image I' of size *512 × 512* and watermark W of *128 × 128.*

Output: The extracted watermarked color image W' of size *128 × 128.*

Step 1: Apply DWT on the watermarked image I' to decompose it into four non-overlapping multi-resolution coefficient sets: LL_3, HL_3, LH_3 and HH_3.

Step 2: Select $H(L_3)$, LH_3 high frequency sub-bands of the watermarked image I'.

Step 3: For each block compute the energy E_r then select only the maximum energy blocks.

Step 4: Then we extract the watermark W' by applying the Equation no. 8:

$$W' = \frac{M_i' - M_i}{\alpha} \tag{8}$$

Step 5: Then the detected watermark is compared with the original watermark by calculating the similarity measure between them by Equation no. 9:

$$NC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n} W(i,j).W'(i,j)}{\sum_{i=1}^{m}\sum_{j=1}^{n} W(i,j)^2} \tag{9}$$

Where NC is the Normalized Correlation coefficient.

4. Results and Analysis

In this first section we have given the various parameters through which we can analyze the performance of the protocol. These parameters are PSNR, MSE and NC measurements.

4.1 Peak Signal-to-Noise Ratio (PSNR)

PSNR is used to calculate the distortion between the watermarked image and original image. For that we have used Equations no. 10 and 11.

$$PSNR = 10 * \log \frac{255^2}{MSE} \tag{10}$$

4.2 Mean Square Error (MSE)

The MSE represents the cumulative squared error between the compressed image and the original image. To calculate the PSNR, first calculates the Mean-Squared Error (MSE) using the next Equation:

$$\mathrm{MSE} = \sum_{i=1}^{x}\sum_{j=1}^{y} \frac{\left(\left|A_{i,j} - B_{i,j}\right|\right)^2}{x^* y} \tag{11}$$

Where is the width, height of the image and is the no. of pixels.

4.3 Normalized Correlation Coefficient (NCC)

NCC is used to calculating the robustness of the embedding scheme. NCC is defined by Equation no. 9:

4.4 Result Analysis

In this section we have demonstrated the results of our proposed protocol based on DWT and PCA. We know most of the details of the image[37] such as edges and textures are found into the high frequency bands of the DWT of the image. First, we decomposed the image up to 3 levels, select only HL_3 and LH_3 sub-bands of the DWT image, then watermark is embedded in the principal components of the high frequency wavelet coefficients. We have calculated PSNR and NCC values for that. We have used standard test images database of Lena, Peppers, Baboon and Fruits of size 512 × 512 each is shown in Figure 1 (a-d) and corresponding watermark image are shown in Figure 1 (e-h). The color watermark was a baby image of different sizes.

We have taken the gray-scale watermark of size 256 × 256. This watermark is embedded into Lena, Peppers, Baboon and Fruits images respectively. The presented method is implemented using MATLAB. Form 1 (e-h) shows the resultant watermarked images and corresponding PSNR values are presented in Table 1. We have compared our results with Run et al.[30], Lai et al.[34], Bhatnagar et al.[38] and Ahahmad et al.[25].

In Figure 1 we can see no perceptual degradation is observed between the original and watermarked images according to HVS[1]. Figure 2 shows the original watermark, extracted watermark and binary watermark. We know for every quaternion PCA coefficient there is real and imaginary components[1] so the color watermark image can also be embedded into the original images.

But In this, we have only use the gray-scale watermarks image to present the validity of our watermark embedding and extracting scheme. Figure 3 shows the extracted watermark from all images, i.e., (Figure 1 (a-d)) when no attacks were applied.

To assess the validity of embedding algorithm watermarked image was affected by different type of attacks such as Salt and Pepper Noise, Compression, Median Filter, Rotation and Gaussian Noise. Figures 4 and 5 represent the attacked image by JPEG compression at different values. We have taken Lena test images for compression and we select the compression ratio 50% and 30% for extracting the watermark. It is shown that in our approach, the watermarks can be easily extracted.

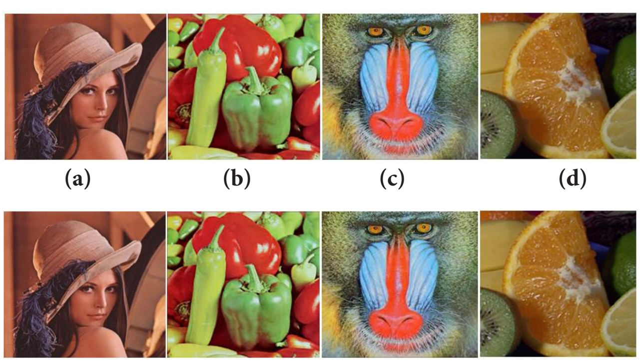


Figure 1. **(a)** Lena **(b)** Peppers (c) Baboon **(d)** Fruits **(e)** Watermarked Lena **(f)** Watermarked Peppers **(g)** Watermarked Baboon **(h)** Watermarked Fruits.

Table 1. Peak Signal to Noise Ratio (PSNR) dB for each original color image

Test color images	Lena	Peppers	Baboon	Fruits
PSNR	43.59	41.68	39.25	38.57

Figure 2. **(a)** Original watermark **(b)** Extracted watermark **(c)** Binary watermark.

Figure 3. **(a-d)** Extracted watermark when no attacks were applied.

Figure 4. JPEG compression attacks at quality factor 50, 40, and 30.

Figure 6 shows the test images of Lena and fruits for rotation attacks. For rotation three different angles are used, i.e., 50º, 65º and 75º, then we have extracted the watermark from the watermarked images. These watermarks are shown in Figures 6 and 7 and can be easily recognized by human eyes or by Human Vision System (HVS).

Our watermarking embedding algorithm gives very good result against attacks such as in the case of salt and pepper noise the algorithm has better watermark extraction effect, then another image processing effect because the scheme uses real and imaginary PCA components.

In case of Gaussian noise we select Lena image for generating the results. For that we set mean to zero and covariance to 0.002 to the watermarked image, extracted watermark are shown in Figure 8. The figure shows that the watermark is still recovering after high density of Gaussian noise.

Here we have indicated the effect of our watermark embedding algorithm with the salt and pepper noise

(c)

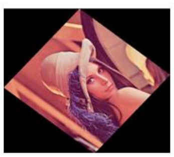
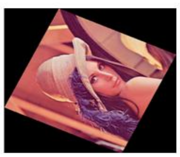
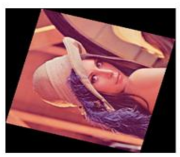
Attack	Rotation Transform with Rotation Angel 50°	Rotation Transform with Rotation Angel 65°	Rotation Transform with Rotation Angel 75°
Attacked Image	 PSNR = 35.11dB	 PSNR = 33.71dB	 PSNR = 31.34dB
Extracted Watermark	 NC= 0.8325	 NC=0.6129	 NC= 0.4876

Figure 5. Rotation transform attack with rotation angle 50º, 65º, and 75º for Lena.

Attack	Rotation Transform with Rotation Angel 50°	Rotation Transform with Rotation Angel 65°	Rotation Transform with Rotation Angel 75°
Attacked Image	 PSNR = 33.57dB	 PSNR = 31.12dB	 PSNR = 29.32dB
Extracted Watermark	 NC= 0.7334	 NC=0.5129	 NC= 0.3876

Figure 6. Rotation transform attack with rotation angle 50º, 65º, and 75º for fruits.

Attack	Gaussian Noise at 0.02	Gaussian Noise at 0.08
Attacked Image	 PSNR = 40.63dB	 PSNR = 38.48dB
Extracted Watermark	 NC= 0.8172	 NC= 0.6338

Figure 7. Gaussian noise of density 0.02 and 0.08.

Attack	Salt and Pepper Noise at 0.02	Salt and Pepper Noise at 0.08
Attached Image	 PSNR= 43.59dB	 PSNR= 40.12dB
Extracted Watermark	 NC=0.9741	 NC=0.7137

Figure 8. Salt and pepper noise of density 00.2 and 0.08.

attack. For that Lena image is taken and zero mean and the value of covariance 0.002 is used.

Figure 9 shows the result of our scheme against salt and pepper noise. The scheme shows very good performance against salt and pepper noise attack. The results show that watermarks are easily recognized.

Figure 10 shows the extracted watermark against median filter attack. For that we take a Lena image, the value of mean and covariance is same as in the case of saltand pepper noise. We have tested the image for the filter size M = 3 and M = 8 if we are increasing the filter size normalized correlation decrease. The result against this attack shows those watermarks are still extracted when we increase the filter size.

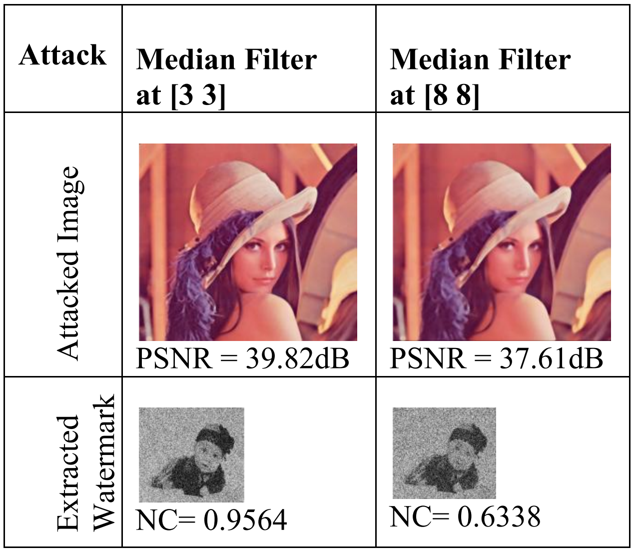


Figure 9. Median filter attack at [3 3] and [8 8].

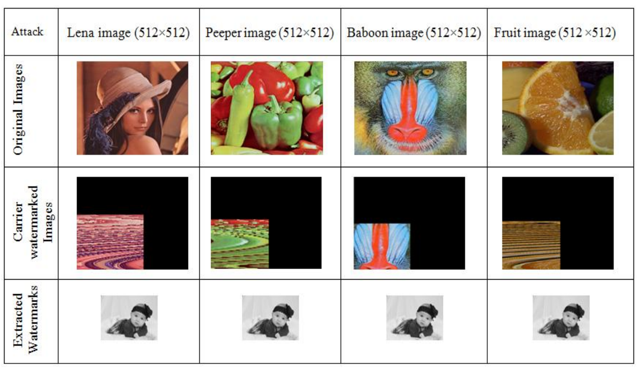


Figure 10. Watermark extraction result against Geometric distortion on test images.

Here we have shown some more result of our scheme against geometric distortion. In this the correctness of the watermark extraction depends on the feature points of the image[1]. If we talk about salt and pepper noise the scheme has effective extraction of watermark when compare to other image processing attacks. We have successfully extracted the watermark from JEPG compression, Median filter, Gaussian noise, salt and pepper noise and rotation attacks. Table 2 demonstrated coefficients for all extracted watermarks after attacks.

4.5 Comparative Analysis

In this section we have compared our watermarking embedding method with the existing methods (Run et al. 2012[30]) (Lai et al. 2010[34]) (Bhatnagar et al. 2012[38]). The comparative analysis is provided through the Table 3. By adding a noise into the host image[26] is responsible for the degradation and distortion of the image. The watermark data are also affected by adding the noise that makes difficult for watermark extraction. It is well-defined from the Table 3 the performance of our scheme shows better resolution than existing methods. Table 3 shows very good performance against JPEG compression and salt and pepper noise attack. For Median filtering, our scheme extracts the watermark upto 8 × 8 and in case of Rotation and Median filter, our method shows excellent results. The performance of our scheme against the JPEG compression attack is very close to Run et al.[30] Bhatnagar et al.[38] and better than the watermarking algorithm reported by Lai et al.[34] and Ahahmad et al.[25].

Table 2. Comparison of normalized correlation coefficient with existing methods

Attacks	Bhatnagar et al. [38]	Our method et al. [25]	Ahahmad	Run et al. [30]	Lai et al. [34]
JEPG compression	0.9645	0.5156	0.9512	0.5376	0.9637
Rotation	0.8324	0.4972	Not given	0.4972	0.9025
Gaussian Noise	0.8172	0.5376	0.7566	0.4279	0.3603
Salt and pepper Noise	0.9741	0.3537	Not given	0.4255	0.4635
Median filter	0.9564	Not given	0.9564	Not given	0.4624

Table 3. Comparison of our method with Run et al.[30], Lai et al.[34] and Bhatnagar et al.[38]

Attacks	Our method	Run et al. [30]	Lai et al. [34]	Bhatnagar et al. [38]
Extraction technique	Semi-blind	Non-blind	Semi-blind	Non-blind
Embedding domain	DWT+SVD	DWT+SVD	FRFT+SVD	DWT+SVD
Size of watermark	256×256	256×256	256×256	128×128
Size of original image	512×512	512×512	512×512	256×256
JEPG compression	QF=1 to 80	QF=1 to 75	QF=1 to 100	QF=1 to 100
Rotation	50°	Not tested	50°	50°
Gaussian Noise	Up to 50 %	Up to 10 %	Up to 100 %	Up to 10 %
Salt and pepper Noise	Up to 50 %	Not tested	Up to 100 %	Not tested
Median filter	3×3	Not tested	11×11	Not tested

From the comparative analysis table it may be figured out that our scheme is very robust against salt and pepper noise and Median filter attack and Table 4 shows that our watermarking embedding scheme gives good result in case of all attacks when compare to Run at al.[30], Lai et al.[34],

shows better performance over the methods proposed by Lai et al.[34] and Ahahmad et al,[25]. Tables 4 have been used for comparing the PSNR values of our watermarking embedding scheme and the other method reported by Run et al.[30] Lai et al.[34] Bhatnagar et al.[38]. It is very clear from table 4 that our watermarking embedding scheme gives better results compared to existing methods.

Table 4 shows that our watermarking embedding scheme gives good result in case of all attacks when compared to Run at al.[30], Lai et al.[34], Bhatnager et al.[38]. The performance of our watermarking scheme against the all attacks is very close Bhatnagar et al.[38] and the Lai et al.[34] and far better than the water marking algorithm reported by Run et al.[30]. The imperceptibility of our watermarking scheme has also been compared with the other existing algorithms (Run et al.[30], Lai et al.[34] and Bhatnagar et al.[43], shown in Table 4.

Figure 12 shows the comparison of our embedding scheme with other existing techniques (Run et al.[30], Lai et al.[34] and Bhatnager et al.[38]. In this figure we have compared imperceptibility and watermark payload for Lena image.

Table 4. Comparisons of peak signal to noise ratio (PSNR) dB with existing methods

Test color images	Our method	Run et al. [30]	Lai et al. [34]	Bhatnagar et al. [38]
Lena	43.59	32.54	36.11	39.25
Peppers	41.68	31.47	36.24	37.96
Baboon	39.25	33.93	32.18	37.57
Fruits	38.57	31.72	35.86	37.32

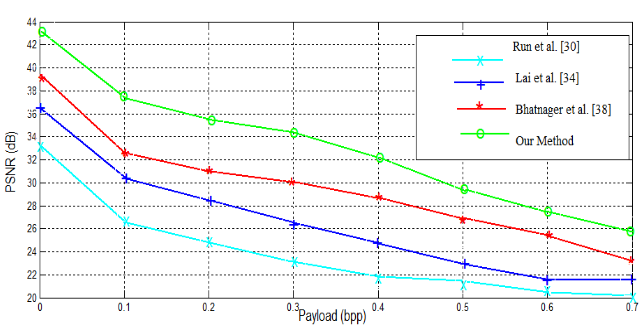


Figure 11. Performance comparison our watermarking scheme with existing approaches for Lena image .

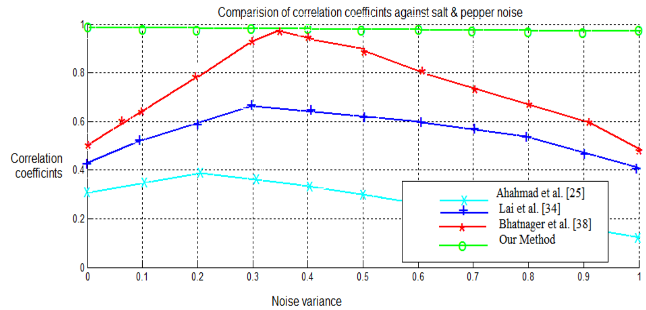


Figure 12. Performance of our watermarking scheme for different salt & pepper noise attack.

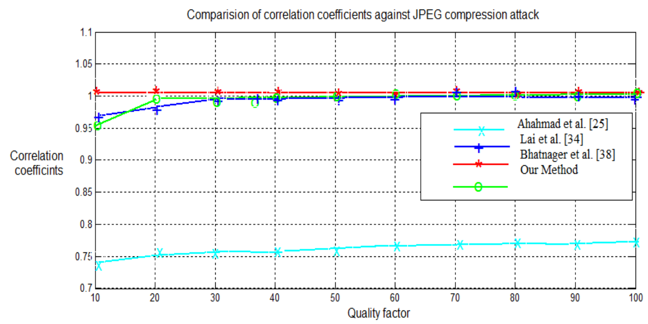


Figure 13. Performance of our watermarking scheme by varying the value of quality factor.

Our scheme produces very impressive results against salt and pepper noise and JPEG compression, hence we have graphically presented and compared our result with these two attacks in Figures 13 and 14. These two figures provide a performance comparison of our method for salt and pepper noise.

In Figure 13 we have compared our embedding algorithm with salt and pepper noise attack with existing method of Run et al.[30], Lai et al.[34] and Bhatnager et al.[38]. by adjusting the value of noise variance. The performance of our scheme against the salt and pepper noise attack is in close proximity of the Bhatnager et al.[38] and far better than the watermarking algorithm reported by Run et al.[30] and Lai et al.[34].

In Figure 14 we have provided a performance comparison of our method for JPEG compression attack by varying the quality factor. For assuring the robustness, of watermarked image the value of quality factor has been carried from 10 to 100. It has been concluded that the performance of our embedding scheme is very close to the algorithm proposed by Bhatnager et al.[38] and Lai et al.[34]. Our scheme is superior over the algorithm proposed by Ahahmad et al.[25].

5. Conclusion

In this paper, we have proposed a modified buyer seller watermarking protocol, which uses wavelets and PCA transform. The method is implemented using 3-level DWT with PCA transform. The method is also image dependant and able to survive under geometric distortion and image processing attacks. PCA transform help us for reducing correlation coefficient among the wavelet coefficients. We have decomposed the original image up to 3 levels, then we select only HL_3 and LH_3 bands of the DWT image, then watermark bits are inserted into the principal components PCs. A gray-scale watermark image has been embedded only the maximum energy blocks were chosen for the embedding procedure. Our scheme performs better when compared with existing reporting methods (Run et al.[30], Lai et al.[34], Ahahmad et al.[25] and Bhatnager et al.[38]). Our results proves that the scheme gives better result against Median Filter, Salt and Pepper Noise, JPEG Compression, Rotation and Gaussian Noise.

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