A SEMI-BLIND WATERMARKING SCHEME FOR RGB IMAGE USING CURVELET TRANSFORM

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ABSTRACT

In this paper, a semi-blind watermarking technique of embedding the color watermark using curvelet coefficient in RGB cover image has been proposed. The technique used the concept of HVS that the human eyes are not much sensitive to blue color. So the blue color plane of the cover image is used as embedding domain. A bit planes method is also used, the most significant bit (MSB) plane of watermark image is used as embedding information. Selected scale and orientation of the curvelet coefficients of the blue channel in the cover image has been used for embedding the watermark information. All other 0-7 bit planes are used as a key at the time of extraction. The results of the watermarking scheme have been analyzed by different quality assessment metric such as PSNR, Correlation Coefficient (CC) and Mean Structure Similarity Index Measure (MSSIM). The experimental results show that the proposed technique gives the good invisibility of watermark, quality of extracted watermark and robustness against different attacks.

KEYWORDS

Digital Watermarking, Curvelet Transform, Bit Plane, MSSIM

1. INTRODUCTION

The internet is being used by numbers of user and this number increasing day by day. Due to the internet and the advantage of digital, Information material (multimedia data) is being distributed without loss of quality. So it's very difficult to protect the interest of an author or to preserve the copyright. The most effective solution to the unauthorized distribution problem is watermarking. Watermarking is a technique of embedding author information into the original work. Watermarking has following requirements.

1. Watermark should not be perceptual visible
2. Watermark should be difficult to remove or impossible for modify.
3. Watermark should be robust against the image distortions caused by attackers

There are two domains for embedding the watermark one is spatial domain and other is transform domain. In the first method of embedding, the watermark is by directly changing the original

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pixel intensity of the cover image. The disadvantage of spatial techniques is that it does not give the good robustness against the image processing attacks [1-2]. The second one is transformed domain, in which watermark is embedded by changing the frequencies of the cover image. The later one gives the good robustness. Embedding in transformations domain are common, some famous transform of watermarking are Fourier transform [3], Discrete Cosine Transform (DCT) [4-8]; Digital Wavelet Transform (DCT) [9-13], Ridgelet Transform (RT) [14] and much more. Cox et al. [2] renowned that watermark to be robust against the image processing operations, it must be located in perceptually important regions of the image. Watermarking is based on samples and embedded into largest DCT coefficients. R. Dugad [10] &Peining Tao [11] proposed watermarking using wavelet transformation which provides the multi-resolution representation of the image. J.-J. Lee [12] proposed a dual-tree implementation for complex wavelet transform (DT-CWT), which attains good directional selectivity and approximate shift invariance.

2. LITERATURE REVIEW

In literature, many authors embedded the watermark in the wavelet domain. Though wavelet transform has been explored broadly in image processing, due to the problem of representing line singularity, it fails to represent edges and curves [16-18]. The wavelet transform is not suitable for describing anisotropic elements. It includes only two directional elements it means transform is independent of scale. The disadvantage is overcome by the ridgelet transform. The basic idea of the ridgelet transform [14] is to plot a line singularity in the 2-D domain into a point by means of a radon transform. There is also some watermarking based on the ridgelet transform. But ridgelet transform cannot well represent curve edges. So Curvelet transform is developed, it is a multiscale pyramid with many directions and positions at each fine scale and has needle-shaped elements at the fine scales [15-16].

Researchers have changed their focus to the curvelet transform [18] for its properties such as it provide sparse representations of objects along a curve and it is anisotropic with strong direction. Thai Hien et al. [19] embedded the watermark in the curvelet transform which contains as much edge information as possible. It has good invisibility but poor robustness. The method of Thai Hien et al. [20] embedded a watermark in curvelet coefficients which are selected by a threshold. This method has good invisibility and robustness. Shi et al. [21] proposed a semi-fragile watermarking algorithm by embedding the watermark in the supreme module of curvelet coefficient. This technique gives good robustness against compression operation.Among these techniques, those require the original cover image, key and bits of watermark for watermark extraction are called non-blind watermarking techniques [4]. Robustness of non-blind technique is good under image processing attacks. But it is not appropriate for watermark detection in DVD player because the original data is not accessible. Those need the secret key but not require original cover image at the time of extraction is called a blind watermarking technique. This technique is suitable for all types of application, but the blind watermarking is usually less robust compared with the non-blind watermarking scheme. Those require the key and the watermark bit sequence is called semi-blind watermarking technique. Semi-blind watermarking techniques give the yield good robust against attacks and suitable for most of the application. In this paper, we discuss the semi-blind technique of watermarking.Literature also gives some semi-blind technique Lin et al. [22] proposed a semi-blind watermarking scheme using the Discrete Fourier Transform (DFT). Solachidis et al [23] use circular symmetric in DFT domain. Licks et al. [24] proposed a circular symmetric watermarking in which watermark is extracted by an exhaustive search. Stankovic et al. [25] embed the watermark by mean of a 2D radon –Wigner distribution.

There is not so much literature found on color watermarking in curvelet domain. Some of the author takes the colored image as the cover image in best of author knowledge no one tried to embed the color watermark in the color cover image using curvelet transform. In this paper, we tried to embed an RGB watermark image into curvelet coefficients of RGB cover image. Here author used a bit plane method to split watermark image. The Most significant bit is used an embedding information and other lower bit planes used as the key. To evaluate the invisibility and the robustness of proposed method PSNR, Normalized Correlation (NC) and MSSIM metrics are used.

3. CURVELET TRANSFORM

This block ridgelet-based transform is called as curvelet transform. It was first proposed by Candes and Donoho [15]. Actually the ridgelet transform is the fundamental for the curvelet transform. The ridgelet transform is optimal at representing straight-line singularities. Unfortunately, worldwide straight-line singularities are rarely used in many applications [31]. To analyze local line or curve singularities, the natural idea is to consider a partition of the image, and then to apply the ridgelet transform to the obtained sub-images. So the block based ridgelet transform is named as curvelet transform[31-32].

Let μ be the triple (j, l, k) in the function plane. Where *j=0,1….* is a scale parameter, *l= 0,1,2…..* an orientation parameter and $k = (k_1, k_2); k_1, k_2 \in Z$ is the translation parameter pairs. A curvelet coefficient is simply the inner product between an element $f \in L^2(R^2)$ and curvelet ϕ_m given by

$$C_\mu = \langle f, \phi_\mu \rangle = \int_{R^2} f(x)\overline{\phi_\mu(x)}\,dx = \frac{1}{(2\pi)^2}\int \hat{f}(w) U_j(R_{\theta_l} w) e^{i\langle x_k^J, w\rangle} \ldots\ldots\ldots\ldots (i)$$

Where $R_\theta$is the rotation by θ radian*, J= (j,l)* is the index of wedge for all *k* with it and U_j is a polar wedge window of radial dilation and angular transformation[17]. Define coarse scale curvelet as

$$\phi_{j,0,k} = \phi_{j,0}(x - 2^{-j,0,k}) \ldots\ldots\ldots\ldots (ii)$$

$$\bar{\phi}_{j,0}(w) = 2^{-j0} A_0(2^{-j,0}|w|) \ldots\ldots\ldots\ldots\ldots\ldots (iii)$$

Similar to other multi-scale pyramids, curvelet transform images into several frequency scales. An important factor in curvelet domain is not the “Approximation Rate”. If having an object in the domain $[0,1] \times [0,1]$, how fast can approximate it using the certain system of function?

$$\|f - \widetilde{f_m}\|_2^2 = O\left(m^{-\frac{1}{2}}\right) \ldots\ldots\ldots\ldots\ldots (iv)$$

$$\|f - \widetilde{f_m}\|_2^2 = O(m^{-1}) \ldots\ldots\ldots\ldots\ldots (v)$$

$$\|f - \widetilde{f_m}\|_2^2 = O(m^{-2} log^3 m) = O(m^{-2}) \ldots\ldots\ldots\ldots\ldots (vi)$$

Eq. *(iv),* Eq. *(v)* and Eq. *(vi)* gives the approximate rate of Fourier Transform, wavelet transform and curvelet transform respectively. Conceptually the curvelet transform is a multiscalepyramid with many directions and positions at each fine scale and needle-shaped elements at fine scales [30]. Based on the curvelet transform, it is possible to embed watermarks onto more significant components and spread the amendments to more space locations.

4. PROPOSED WATERMARK EMBEDDING TECHNIQUE

Here we proposed a technique of embedding the color watermark in an RGB image. To embed the watermark, the original cover image is being divided into color planes. The cover image has three color planes red, green and blue. The embedding has following steps

4.1 Embedding algorithm

a) Watermark image is also colored so firstly separates there color planes B_r, B_g and B_b red plane, green plane and blue plane of the watermarked image respectively. Now obtain bit planes of each color plane. $\{B_{r1}, B_{r2}....B_{r8}\}$, $\{B_{g1}, B_{g2}...B_{g8}\}$ and $\{B_{b1}, B_{b2}...B_{b8}\}$ are the set of bit planes of red, green and blue color planes respectively. $B_{r1}.B_{g1}$ and B_{b1} is the least significant bit of red, green and blue color. B_{r8}, B_{g8} and B_{b8} are most significant bit plane of red, green and blue color used as the watermark (to be embedded) and remaining other $\{B_{r1}, B_{r2}....B_{r7}\}$, $\{B_{g1}, B_{g2}...B_{g7}\}$ and $\{B_{b1}, Bb2...B_{b7}\}$ are used as a key at the time of extraction.
b) The frequency spectrum is independent of transmission medium. Absorption spectrum gives the idea about the spectral sensitivity of 3 cones. This shows that the eyes are not much sensitive to blue color. The processed watermark has been embedded into the blue color plane of frequency domain of the cover image. The semi blind method of embedding watermark in curvelet domain is given below
c) Read the original cover image *C* and decomposed cover image *C* into RGB color planes. Let C_r, C_g and C_b represent the red, green and blue color plane of the original cover image respectively.
d) Perform a curvelet transform on the blue color plane (C_b) with a *j* number of decomposition level and *l* number of scales. In this paper *4* decomposition level and *3* scales are used. The resultant curvelet coefficients being stored in multidimensional array C_{let}
e) Select the orientation and scale for embedding the watermark. Let selected scale *j* and orientation k_1, k_2 and k_3 for embedding the bit planes B_{r8}, B_{g8} and B_{b8} respectively. Stored the selected oriented and scale coefficients
f) Set α i.e the key of embedding.

$$S_r = \left\lfloor \frac{C_{let}(j,k_1)}{\alpha} \right\rfloor,\ S_g = \left\lfloor \frac{C_{let}(j,k_2)}{\alpha} \right\rfloor \ and\ \ S_b = \left\lfloor \frac{C_{let}(j,k_3)}{\alpha} \right\rfloor$$

g) For each coefficients of selected orientation and scale modified by

- $If \left(\frac{S_r+B_{r8}}{2} == 1\right)\ than\ O_r = (S_r - 0.5) * \alpha$
  - $Else\ \ O_r = (S_r + 0.5) * \alpha$
- $if \left(\frac{S_g+B_{g8}}{2} == 1\right)\ than\ O_g = (S_g - 0.5) * \alpha$

- $Else\ \ O_g = (S_g + 0.5\ ) * \alpha$
- $if\ \left(\frac{S_g+B_{b8}}{2} == 1\right)\ than\ O_b = (S_g - 0.5\ ) * \alpha$
- $Else\ \ O_b = (S_b + 0.5\ ) * \alpha$

h) Apply inverse curvelet transform with the same scale on to the modified coefficients to change the resulted image from frequency domain to time domain. Add this modified blue color plane to red and green plane, means to convert resulting image into an RGB watermarked image

4.2 Extraction Algorithm

Read watermarked image and obtains its color plane W_r, W_g and W_b are the color planes of red, green and blue color respectively. Apply selected scale and perform curvelet transform on blue color plane *(W_b)* of watermarked image. Stored the curvelet coefficient let E_x

a) Apply selected scale and orientation where watermark had been embedded. Let selected scale *j* and orientation k_1, k_2,k_3 for red, green and blue bit planes

b) $ES_r = \left\lfloor\frac{Ex(j,k_1)}{\alpha}\right\rfloor, ES_g = \left\lfloor\frac{Ex(j,k_2)}{\alpha}\right\rfloor andES_b = \left\lfloor\frac{Ex(j,k_3)}{\alpha}\right\rfloor$

c) For each coefficient of ES_r, ES_g, ES_b

d) Extract each bit planes of watermark
   - *a.* $if\ (ES_r\%\,2 -- 1\ )then\ \ EW_r - 1;\ \ else\ EW_r - 0;$
   - *b.* $if\ (ES_g\%\,2 == 1\ )then\ \ EW_g = 1;\ \ else\ EW_g = 0;$
   - *c.* $if\ (ES_b\%\,2 == 1\ )then\ \ EW_b = 1;\ \ else\ EW_b = 0;$

e) From the 6^{th} step we find the most significant bit planes now we used stored watermark bit plane to extract the color watermark. For each color plane and for each bit.
   $Ext_r=EW_r *2\text{^}7+ B_{r7}*2\text{^}6+ B_{r6}*2\text{^}5+ B_{r5}*2\text{^}4+B_{r4}*2\text{^}3+B_{r3}*2\text{^}2+B_{r2}*2\text{^}1+B_{r1}*2\text{^}0;$
   $Ext_g=EW_g*2\text{^}7+ B_{g7}*2\text{^}6+ B_{g6}*2\text{^}5+ B_{g5}*2\text{^}4+B_{g4}*2\text{^}3+B_{g3}*2\text{^}2+B_{g2}*2\text{^}1+B_{g1}*2\text{^}0;$
   $Ext_b=EW_b*2\text{^}7+ B_{b7}*2\text{^}6+ B_{b6}*2\text{^}5+ B_{b5}*2\text{^}4+B_{b4}*2\text{^}3+B_{b3}*2\text{^}2+B_{b2}*2\text{^}1+B_{b1}*2\text{^}0;$

f) Ext_r, Ext_g and Ext_b are the color planes of red, green and blue color plane of extracted watermark image. Combine these color planes and get the RGB extracted watermark.

5. QUALITY ASSESSMENT METRICS

Embedding the watermark in the cover image may degrade visual quality of the image. Quality assessment metrics are based on well mathematical models that can predict visual quality by comparing a watermarked image against a cover image. Following are the various metrics used for the measurement of visual quality comparison.

5.1 Peak Signal to Noise Ratio (PSNR)

The most common evaluation method is to compute the peak signal-to-noise ratio (PSNR) between the host and watermarked signals. PSNR is defined as follows:

$$PSNR = 10\log_{10}\frac{255^2}{MSE}$$

More PSNR means better image quality. Where MSE (Mean Square Error) is define as

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(Im(i) - Iw(i))^2$$

Where I_m = Original image, I_w= watermarked image

5.2 Correlation Coefficient (CC)

Correlation Coefficient is the well knows measure for comparing the visual quality of two images. The metric of CC defined as follows.

$$CC = \frac{\sum_m \sum_n (I_m - \overline{I_m})\,(I_w - \overline{I_w})}{\left[\sum_m \sum_n (I_m - \overline{I_m})^2 (I_w - \overline{I_w})^2\right]^{1/2}} \ldots \ldots .(vii),$$

where I_m , I_w are the pixel intensities of cover and watermarked image respectively with $m*n$ size.

Although CC and PSNR is convenient to calculate and also has clear physical meaning but still it does not correlate strongly enough with the visual quality of the image for most applications [26].The scope of perceptual quality is widened in the Mean Structure Similarity Index Measure (MSSIM) [27-29].

5.3 Mean Structure Similarity Index Measure (MSSIM)

MSSIM is the combination of three perceptual properties namely Luminance, Contrast and structure at every point of the two images being compared. For the purpose of calculation of MSSIM the image to be compared are broken in to number of windows of $G*G$, further the two images must be of the same size [27]. If x and y are two images, M is the number of $G*G$ windows and N is the number of pixels in each window then MSSIM is define in the following steps.

$$\text{SSIM} = \frac{(2\mu_x\mu_y + c_1)\,(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \ldots \ldots \ldots \ldots .(viii),$$

where $\mu_x = \frac{1}{N}\sum_{i=1}^{N} x_i$, $\mu_y = \frac{1}{N}\sum_{i=1}^{N} y_i$

$$\sigma_x = \sqrt{\left(\frac{1}{N}\sum_i^N (x_i - \mu_x)^2\right)} \ , \ \sigma_y = \sqrt{\left(\frac{1}{N}\sum_i^N (y_i - \mu_x)^2\right)}$$

$c_1 = (k_1 L)^2, c_2 = (k_2 L)^2$. In paper [28] $k_1 = 0.01$, $k_2 = 0.03$ has been proposed
L= Dynamic range of the pixel values (255 for 8 bit gray scale image)
MSSIM (Mean SSIM) = $\frac{1}{M}\sum_{j=1}^{M} SSIM\ (x_j, y_j)$

6. EXPERIMENTAL RESULTS AND DISCUSSION

To test the algorithm colored "lana.jpg" image used a cover image and a colored "thaper.jpg" image used a watermark image. Fig. 1 and Fig.2 show the "lana.jpg" and "thaper.jpg" image respectively. Fig. 3 shows the resulting watermarked image. Algorithm has been tested against all the requirement parameter such as invisibility, effectiveness, and robustness. Here we compared the quality of watermarked image and extracted watermark by the above-defined quality assessment metrics such as PSNR, CC, and MSSIM. To show that the algorithm gives the good robustness, the different image processing operations are being applied to the watermarked image. The quality of extracted watermark from the distorted image have been analyzed by the quality assessment metrics.

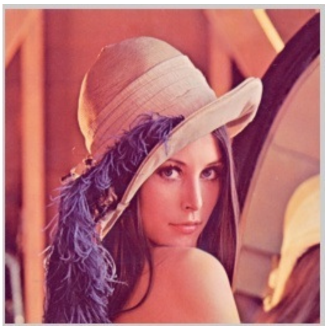

Fig. 1 lana.jpg

ig. 2 thapar.jpg

Fig. 3 Watermarked Image

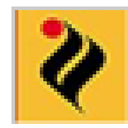

Fig. 4 Extracted watermark

6.1 Invisibility

Embedding extra information in the original signal will cause degradation and perceptual distortion. [4]. the most common evaluation method is to compute the peak signal-to-noise ratio (PSNR) between the cover image and watermarked image. In this paper to test the invisibility of the algorithm the quality of watermarked image and cover image are compared with the help of quality assessment metrics. Fig 1.3 shows the watermarked image.The quality of watermarked image has been analyzed by PSNR, CC and MSSIM metrics on each plane. Table 1.1 shows the values of quality assessment metrics. In Table 1.1 Red_CC, Gr_CC, Blue_CC, Red_MSSIM, Gr_MSSIM and Blue_MSSIM represent the correlation coefficients (CC) and MSSIM of the red, green and blue color respectively. It may be observed that the PSNR is 44.97 confirming a high invisibility of the watermark. Besides, the correlation coefficient, MSSIM is 0.99 for image confirming almost no difference between the cover and watermarked image. This clearly shows that the watermark is perfectly invisible.

Table 1.1 Invisibility Test

Image Name	**PSNR**	**Red_CC**	**Gr_CC**	**Blue_CC**	**Red_MSSIM**	**Gr_MSSIM**	**Blue_MSSIM**
Watermarked	44.974	0.9996	0.9996	0.9991	0.9941	0.9950	0.9943

Table 1.2 Effectiveness Test

Extracted watermark Image	**PSNR**	**Red_CC**	**Gr_CC**	**Blue_CC**	**Red_MSSIM**	**Gr_MSSIM**	**Blue_MSSIM**
Fig. 4	38.5623	1	1	1	0.9761	0.9981	0.9953

6.2 Extraction

Effectiveness refers to whether it is possible to detect a watermark immediately following the embedding process. To test the effectiveness of the algorithm the same but in the reverse scheme is used to extract the watermark from the watermarked image. There is no need of cover image while extracting the watermark because the above discuss algorithm gives the semi-blind extraction. Fig. 4 shows the extracted watermark image. The extracted watermark is compared with the original watermark. Table 1.2 shows the extracted watermark and the quality of extracted watermark is being analyzed by quality assessment metrics. The PSNR of extracted watermark is 38.5623, CC is one in all planes and MSSIM is also quite good. Table 1.2 verifies that the visual quality of extracted watermark is very good and highly matched with original one.

6.3 Robustness Test

Robustness refers to the ability of the detector to detect the watermark after signal distortion, such as format conversion, the introduction of transmission channel noise and distortion due to channel gains. In order to test the robustness of the technique, one requires adding some sort of noise into the watermarked image and then extracting the watermark. Besides, robustness is also tested by applying various image processing operations such as filtering, rotation, cropping, adding sparsity and shearing on the watermarked image and then extracts the watermark. Thereafter, the extracted watermark is compared by original watermark image by applying the quality assessment metrics. Fig. 5 to Fig. 11 show the quality of extracted watermarks from the distorted watermarked images. Table 1.3 shows the results of extracted watermark under various attacks. Robustness has been testing under approximately all the image processing attacks.

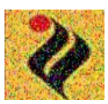

Fig. 5 Extracted watermark from Gaussian Noised watermarked image

Fig. 6 Extracted watermark from Pepper salt noised watermarked image

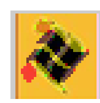

Fig. 7 Extracted watermark from 90^0rotated watermarked image

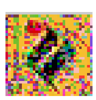

Fig.8 Extracted watermark from un-sharp filtered watermarked image

Fig. 9 Extracted watermark from 128*128 cropped watermarked image

Fig. 10 Extracted watermark after projective shearing operation on watermarked image

Fig. 11 Extracted watermark after sparsity (128*256) on watermarked image

6.3.1. Anti- Noise

Test the robustness against noise operation. Authors add two types of noise one is Gaussian noise with 0.1 variance and other is pepper salt noise with noise density 0.01 on watermarked image then tried to extract the watermark from noised watermarked image. Fig. 5 and Fig. 6 show the visual quality of Extracted watermark from Gaussian Noised watermarked image and pepper salt noised watermarked image respectively. The results are presented in Table 1.3 with two types of noise namely pepper salt and Gaussian. The similarity measure MSSIM and CC confirm the presence of watermark to the extent of more than 70 % similarity on red and green color planes. The red color planes are more sensitive to human eyes.The CC and MSSIM of red color planes of extracted watermark are 0.9. This shows that the technique is robust enough against noise addition.

Table 1.3 Robustness test against Noise

Attacks	PSNR	Red_CC	Gr_CC	Blue_CC	Red_MSSIM	Gr_MSSIM	Blue_MSSIM
Gaussian Noise	19.631	0.9596	0.8979	0.7136	0.8998	0.7916	0.6555
Pepper Salt Noise	18.953	0.9496	0.8579	0.7086	0.8783	0.7716	0.5955

6.3.2. Anti-Rotation

Rotation is very important to image processing operation, but most of the authors do not test the robustness of their techniques against the rotation. Here we test the robustness against rotation operation the watermarked image is rotated by 90 degrees and the watermark is extracted. Fig. 7 shows the visual quality of the Extracted watermark from 900 rotated watermarked image. The extracted watermark is being compared by original watermark image using different quality assessment metrics on each color planes. Table 1.4 shows the values of visual quality of extracted watermark with the original one. It may be observed that both similarities measure MSSIM and CC are reasonably good in each color planes that confirming the similarity of extracted watermark with an original one. Therefore, it may be concluded that the technique is robust against rotation operation.

6.3.3. Anti – Filtering

In order to check the robustness against filtering operation, the unsharp filter was applied on watermarked image and thereafter the watermark was extracted from the filtered watermarked image and compared with original watermark image. Fig.8 shows the visual quality of extracted watermark from un-sharp filtered watermarked image. Table 1.4 shows the values of quality assessment metric by comparing extracted watermark from the filtered watermark image and the original watermark. The CC and MSSIM are good in all the color planes that show the similarity of extracted watermark with the original one. Table 1.4 verifies that this watermarking technique is robust against the filtering operation of image processing.

6.3.4 Anti- cropping

Cropping of an image means to cut a part of the image. Accordingly, it is now required to check whether the watermark is present in the cropped part of the image. Here, cropped parts of size 128*128 of the watermarked image are taken and then the watermark is being extracted by the cropped part of watermarked image. Fig. 9 shows the visual quality of extracted watermark. The values of quality assessment metrics are shown in Table 1.4. It is observed that the values of similarity metrics MSSIM, CC are slightly lower than 0.6 in general. This is obviously due to the relatively smaller size of the cropped part. However, the values confirm the presence of the watermark in these cropped sizes

Table 1.4 Robustness test against image processing Operations

Attacks	PSNR	Red_CC	Gr_CC	Blue_CC	Red_MSSIM	Gr_MSSIM	Blue_MSSIM
90 Degree Rotation	14.649	0.9293	0.7614	0.6682	0.8629	0.7311	0.6216
Un-sharp Filtering	11.232	0.8787	0.7583	0.7025	0.8073	0.6889	0.6665
Cropping 128*128	13.089	0.7843	0.6339	0.5994	0.7723	0.6047	0.5418
Projective Shearing	8.5845	0.8555	0.7001	0.6879	0.7858	0.6530	0.6338
Sparsity (128*256)	11.649	0.8379	0.7487	0.8122	0.7912	0.6939	0.7979

6.3.5 Anti – with other attacks

To test the robustness of the technique two more attacks are performed on watermarked image one is projective shearing and other is adding some sparsity. Sparsity means adding a number of zeros in the image. Here a vertical 128*256 sparsity is added into watermarked image. Fig. 10 and Fig. 11 show the visual quality of extracted watermark after the projective shearing operation and after adding 128*256 sparsity on watermarked image respectively. Table 1.4 shows the quality of extracted watermark image from these operations. The values of CC and MSSIM in each color planes are nearly 0.7 in general that is reasonably good confirming the similarity of watermarks. Therefore, it may be concluded that the technique is robust against any image processing operations.

7. CONCLUSION

The semi-blind color watermarking technique of embedding the color watermark in RGB image has been presented. The extraction does not need the original cover image at the time of extraction. The bit plane and HVS concepts are used for embedding the watermark. The most significant bit planes of each color planes of watermark image are embedded into the curvelet coefficients of the blue color plane of the original cover image. To test the scheme, the algorithm has been tested against invisibility, effectiveness, and robustness. The quality of watermarked image and extracted watermark are being analyzed by the quality assessment metric such as PSNR, CC, and MSSIM. By the Experimental results show the above discussed watermarking technique fulfill all the requirements of watermarking and gives a robust color watermarking without the loss of quality of the original cover image.

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