# Color Image Watermarking using Cycle Spinning based Sharp Frequency Localized Contourlet Transform and Principal Component Analysis

**K.Kishore Kumar** *kishorekamarajugadda@gmail.com*
*Assistant Professor & HOD, ECE*
*Faculty of Science & Technology,*
*Icfai Foundation of Higher Education University,*
*Hyderabad, 501203, India*

**Movva Pavani** *pavanimovvap@gmail.com*
*Associate Professor, ECE*
*Aurora's Technological & Research Institute*
*Hyderabad, 500039, India*

**V.Seshu Babu** *seshubabuv@uurmi.com*
*Research Engineer,*
*UURMI Systems, Hyderabad. India*

**Abstract**

This paper describes a new approach for color image watermarking using **Cycle Spinning based Sharp Frequency Localized Contourlet Transform and Principal Component Analysis**. The approach starts with decomposition of images into various subbands using Contourlet Transform(CT) successively for all the color spaces of both host and watermark images. Then principal components of middle band(x bands) are considered for inserting operation. The ordinary contourlet transform suffers from lack of frequency localization. The localization being the most important criterion for watermarking, the conventional CT is not very suitable for watermarking. This problem of CT is over come by Sharp Frequency Localized Contourlet, but this lacks of translation invariance. Hence the cycle spinning based sharp frequency localized contourlet chosen for watermarking. Embedding at middle level sub bands(x band) preserves the curve nature of edges in the host image hence less disturbance is observed when host and watermark images are compared. This result in very good Peak Signal to Noise Ratio (PSNR) instead of directly adding of mid frequency components of watermark and host images the principal components are only added. Likewise the amount of payload to be added is reduced hence host images get very less distortion. Usage of principal components also helps in fruitful extraction of watermark information from host image hence gives good correlation between input watermark and extracted one. This technique has shown a very high robustness under various intentional and non intentional attacks.

**Keywords:** Color Image Watermarking, Contourlet Transform (CT), Principal Component Analysis(PCA), Cycle Spinning, Frequency Localization.

## 1. INTRODUCTION

Currently, all multimedia production and distribution is digital. The advantages of digital media for creation, processing and distribution of productions are well known: easy modification and possibility of software processing rather than the more expensive hardware alternative. Maybe the most important advantage is the possibility of unlimited copying of digital data without any loss of quality. This latter advantage is not desirable at all to the media producers and content providers. In fact, it is perceived as a major threat, because it may cause them considerable financial loss. Digital watermarks have been proposed as a way to tackle this problem. This digital signature could discourage copyright violation, and may help determine the authenticity and ownership of an image. Digital watermarking [1] emerged as a solution for protecting the multimedia data. Digital watermarking is the process of hiding or embedding an imperceptible signal (data) into the given signal (data). This imperceptible signal (data) is called watermark or metadata and the given signal (data) is called cover work.

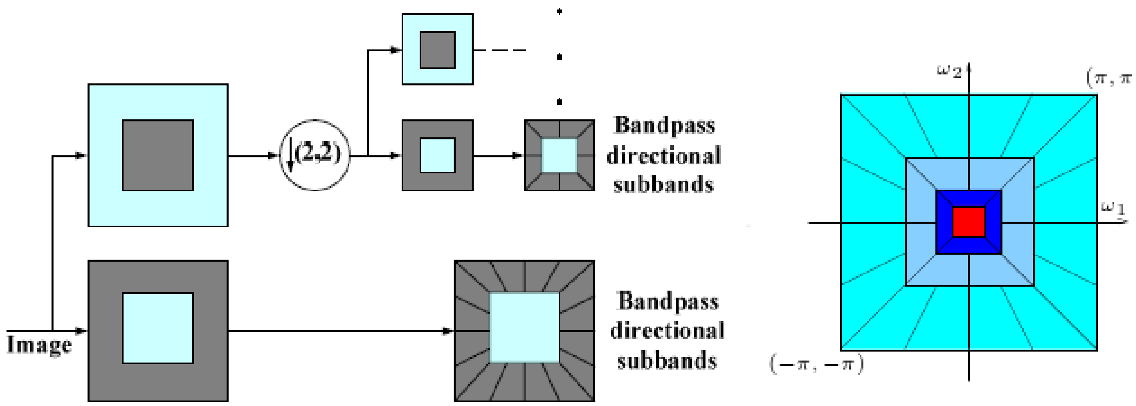
Watermarking techniques can be broadly classified into two categories: Spatial and Transform domain methods. Spatial domain methods [2,3] are less complex and not robust against various attacks. Transform domain methods [4-6] are robust compared to spatial domain methods. In transform domain methods when image is inverse transformed, watermark is distributed irregularly over the image, making the attacker difficult to get the knowledge of presence of watermark. The localization is the most essential criterion to adapt a technique in watermarking. Wavelet is one of the transform domain technique that features localization. Barni et al. [7] proposed a wavelet domain based method which gives better invisibility with respect to (HVS). Based on the texture and the luminance content of all image sub bands, a mask is accomplished pixel by pixel. Dawei et al. [8] proposed a new type of technique in which the authors used the wavelet transform applied locally, based on the chaotic logistic map. This technique shows very good robustness to geometric attacks but it is sensitive to common attacks like filtering and sharpening.

Kundur et al. [4] proposed the use of gray scale logos as watermark. They addressed a multi-resolution fusion based watermarking method for embedding gray scale logos into wavelet transformed images. The logo undergoes 1-level decomposition for watermarking. Each sub band of the host image is divided into block of size equal to the size of sub band of the logo. Four sub bands of the logo corresponding to different orientations are added to the blocks of the same orientation. For fusion, the watermark is scaled by salience factor computed on a block by block basis. Reddy et al. [9] proposed a method in which the authors used a gray scale logo as watermark. To embed watermark, HVS characteristics were used to select the significant coefficients and watermark is added to these selected coefficients. Further, they used the model of Barni et al. [7] to calculate the weight factors for wavelet coefficients of the host image. They extracted watermark from the distorted image by taking into consideration the distortion caused by the attacks.

However, by traditional two dimensional wavelet it is hard to represent sharp image transitions [10] and smoothness along the contours [12]. Hence, bandelet [11] with adaptation to the geometric structure and contourlet [12] with anisotropy scaling law and directionality are presented to sparsely represent natural images. However, the computation of geometry in bandelet is in high complexity thus it is not possible to use in watermarking. Contourlet [12] proposed by Minh N. Do and Martin Vetterli is utilized to capture intrinsic geometrical structure and offer flexible multi scale and directional expansion form images. Because of the nearly critical sampling and fast iterated filter bank algorithm, contourlet is in lower complexity than bandelet. However, non-ideal filter are used in the original contourlet result in significant amount of aliasing components showing up at location far away from the desired support [13] and exhibit some fuzzy artifacts along the main image ridges. Yue Lu [13] proposes a new construction of the contourlet, called sharp frequency localization contourlet transform (SFLCT) and alleviates the non-localization problem even with the same redundancy of the original contourlet. Unfortunately, due to the down samplers and up samplers presented in the directional filter banks of SFLCT, SFLCT is not shift invariant, which is important in image watermarking and easily causes pseudo-Gibbs phenomena around singularities [14].In this paper, we apply cycle spinning [14] to compensate for the lack of translation invariance property of SFLCT and successfully employed in image watermarking. Experimental results demonstrate that our proposed method outperforms the original contourlet (CT), SFLCT and cycle spinning-based contourlet (CS-CT) in terms of PSNR and visual effect.

## 2. SHARP FREQUENCY LOCALIZED CONTOURLET TRANSFORM

The original contourlet [12] is constructed by the combination of laplacian pyramid, which is first used to capture the point discontinuities and the directional filter banks (DFB), which is used to link point discontinuities into linear structure. In the frequency domain, the laplacian pyramid iteratively decompose a two dimensional image into low pass and high pass sub bands and the DFB divide the high pass subbands into directional sub bands as shown in Fig.1.




(a) (b)

**FIGURE 1:** The original contourlet transform (a) Block diagram (b) Resulting frequency division

However, the frequency division in Fig.1 (b) is obtained by ideal filters. When non ideal filters are combined with laplacian pyramid, and suppose only one direction is extracted, the aliasing frequency spectrum will concentrate along two parallel lines 2ω= ±π as shown in Fig.2 (a). Furthermore, if the directional filters are up sampled by 2 along each dimension, the aliasing components will be folded towards the low pass regions, as patterned in Fig.2 (b), and concentrated mostly along two lines 2 2 πω = ± .When the directional filters are combined with bandpass filter in laplacian pyramid, the contourlets are not localized in frequency, with substantial amount of aliasing components outside of the desired trapezoid shaped support [13] as the gray region shown in Fig.2 (d).

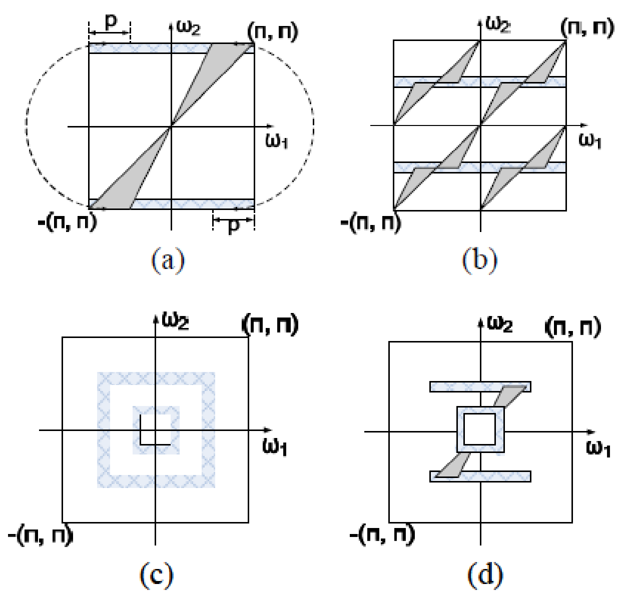
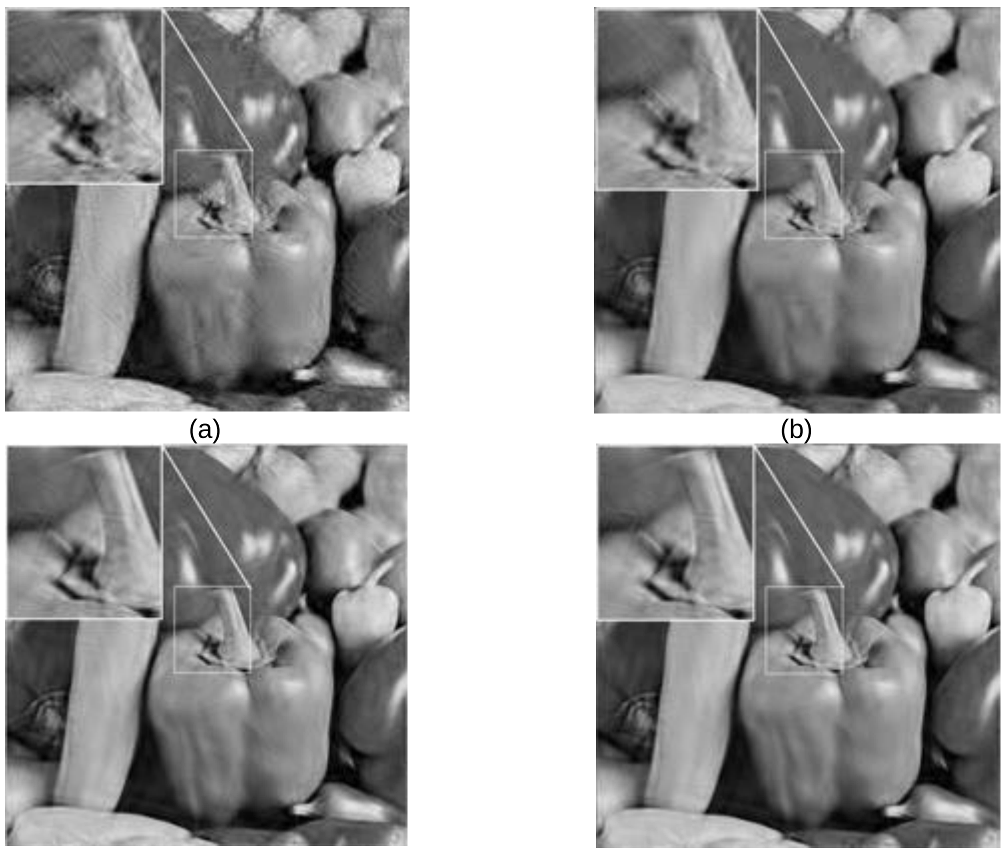



**FIGURE 2:** Spectrum aliasing of the original contourlet. Gray regions represent the ideal pass band support. Patterned regions represent the aliasing components or transition bands.
(a) One directional filter, (b) The directional filter up sampled by 2, (c) A band pass filter from the laplacian pyramid, (d) The resulting contourlet subband.

To solve this problem, Yue Lu [13] proposes a new construction of sharp frequency localization contourlet (SFLCT). Since the combination of laplacian pyramid and directional filters banks make the aliasing problem serious, new multi scale pyramid with different set of low pass and high pass filters for the first level and all other levels are employed. Though SFLCT is sharply localized in the frequency domain and improves the watermarking performance [13], down samplers and up samplers presented in the directional filter banks of SFLCT make it lack shift invariance, which could easily produce artifacts around the singularities, e.g. Edges. Thus, cycle spinning is employed here to compensate for the lack of translation invariance. It is a simple yet efficient method to improve the quality of watermarking for a shift variant transform. In order to show the way of effective representation of input image textures in output watermarked and extracted images, the proposed Cycle Spinning based SFLCT (CS-SFLCT),it is compared with the original SFLCT [13] and Contourlet (CT) [12] as well as the Cycle Spinning based Contourlet (CS-CT) [15], by using '9-7' and 'pkva' filters are used in pyramidal and directional decomposition and inverse of the transform is applied on them and the figure below shows the presence of artifacts in the processed peppers image.




(c) (d)

**FIGURE 3:** (a)-(d) are the processed images using CT, CS-CT, SFLCT, CS-SFLCT and their inverses respectively

## 3. PRINCIPAL COMPONENT ANALYSIS

An effective way to suppress redundant information and provide only one or two composite data most of the information from the initial data is also called principal component analysis. This plays vital role in our proposed approach by reducing redundant information, which acts as additional payload in the Meta data (the information to be embedded)

**EXISTING SYSTEM**

The existing non blind watermarking algorithms include wavelet transforms that are failing to preserve the edge with curvy structure. This makes lot of degradation in the quality difference of host and watermarked Images. This is becoming a serious issue. Adding watermark directly to wavelet coefficients is also not a good practice. The Peak Signal to Noise Ratio is less for the above reasons. Some people have used contourlet transform instead of wavelet. This has improved the performance in better representing curves than wavelets. But non ideal filters are used in the original contourlet transform, especially when combined with laplacian pyramid, which results in pseudo-Gibbs phenomena. This causes aliasing of frequency components introducing some unwanted artifacts and results distortions in watermarked image

**PROPOSED ALGORITHM**

We are using Cycle Spinning-based Sharp Frequency Localized Contourlet Transform in place of wavelets or contourlets which gives better representation of curves without introducing unnecessary artifacts as mentioned above. Instead of adding watermark information to *CS-SFLCT* coefficients we are applying *CS-SFLCT* to watermark and embedding action is taking place at principal components instead at contourlet coefficients. The additive technique is also varied in accordance with the amplitudes of principal components of host images, This increases still more distortions and resulting watermarked image will perfectly resembles with host images according to Human Visual System.

The Host and Watermark images we are using of true color images and the watermarking coefficient is varying from 0.001 to 0.25 in steps of 0.005 (a total of 50 values are used).
Our watermarking system consists of three main parts namely
1.Embedding at Transmitter Part.
2.Channel effects and attacks
3. Extraction at Receiver Part.

**4.1 EMBEDDING AT TRANSMITTER PART**

The multimedia data to be sent/broadcast is processed to Embedding process. The embedding process typically involves the following procedure.

**Step1:** Apply *CS-SFLCT* to the R, G, B planes of true color host image and watermark image.
**Step2:** Consider the mid frequency subband of each color space and apply PCA to each of them.
**Step3:** As the watermark image is also a true color image apply the steps 1& 2 to watermark image.
**Step4:** Principal components obtained in steps 2 and 3 are processed by the following procedure

```
max=maximum(PCA_MSB_HI);
min=minimum(PCA_MSB_HI);
Range=(max-min)/Count;
temp=(PCA_MSB_HI[i,j]-min)/Range;
alp=0.001+(temp-1)*0.005;
PCA_MSB_Wmkd[i,j]=PCA_MSB_HI[i,j]+alp*PCA_MSB_WI[i,j];
```

Where PCA_MSB_HI: Principal components of Middle Sub band of Host Image at one of the three color Spaces
PCA_MSB_WI: Principal Components of Middle Sub band of Host Image at one of the three color spaces.
PCA_MSB_Wmkd: Resulting Principal Components of Watermarked image.
Alp is the watermarking Coefficient varies from 0.001 to 0.25 (takes a total of 50 values).
**Step 5:** The PCA_MSB_Wmkd and covariance matrix obtained in step 2(during the calculation of PC's of Host image sub band ) are multiplied and resulting will be the middle sub band coefficients of watermarked image. This is repeated for R,G,B color spaces.
**Step 6:** The coefficients obtained in step5 and coefficients of host images are fed to inverse *CS-SFLCT* to get the watermarked image. This is repeated for R,G,B color spaces.

**Step7**: The watermarked image obtained will converted to unsigned integer 8 representation from double to be checked for invisibility using PSNR.

### 4.2. CHANNEL EFFECTS AND ATTACKS:

When the watermarked images are broad casted or transmitted through various channels it will undergo with some properties of channel such as noise and filtering effects. Generally when a signal is traveling through a channel, the channel output will be the convolution of channel transfer function and input signal. The transfer function of channel is dependence on some of its physical features and mainly on its band width. So the final output from the channel is filtered.

At this stage one do not have the knowledge of channel that is going to be used,so our algorithm should be tested with respect to the channel affects. That is why, we have processed the watermarked image with low pass filtering, Median filtering, Gaussian noise and salt & pepper noise etc.

When a multimedia data is made to transfer over a public channel, always we have the threat of hackers and malware issues. Now a days there are marvelous number of software and malware over World Wide Web to introduce significant changes in Multimedia Data. That is why our algorithm is tested with respect to some more attacks like Histogram equalization, scaling,rotation,Gamma Correction, Cropping, row or column removal, Wiener filtering, Blurring, Dilation, Color Space Conversions, shearing etc.

### 4.3. EXTRACTION AT RECEIVER PART:

The direct watermarked image or channel processed and received image is checked for authentication. This is done at receiver side. Our watermarking system is non blind in which the host image is required for extraction of hidden watermark in the watermarked image.
The Procedure of Extraction as follows:

**Step1:** Apply *CS-SFLCT* to the R, G,B planes of true color host image and watermarked image.

**Step2:** Consider the mid frequency sub band of each color space and apply PCA to each of them.(both for host and watermarked images)
**Step3**: Principal components obtained in steps 2 are processed by the following procedure.

```
max=maximum(PCA_MSB_Wmkd);
min=minimum(PCA_MSB_Wmkd);
Range=(max-min)/Count;
temp=(PCA_MSB_Wmkd[i,j]-min)/Range;
alp=0.001+(temp-1)*0.005;
PCA_MSB_Extd[i,j]=(PCA_MSB_Wmkd[i,j]-PCA_MSB_HI[i,j])/alp;
```

Where PCA_MSB_Extd : Resulting principal components of Extracted image.
Alp is the watermarking Coefficient varies from 0.001 to 0.25 (takes a total of 50 values).and this i separated for R,G,B color spaces.
**Step 4:** As an authentication key, the extractor should carry the partial information of watermark image.That will be the Covariance matrix and other sub bands of Watermark image.They are used to apply inverse PCA and Inverse *CS-SFLCT* to get back the watermark image by doing same for R,G and B color spaces.
**Step5:** Extracted image obtained will converted to unsigned integer 8 representation from double to be check for Robustness by comparing with original watermark image using Normalized Correlation Coefficient.

## 5. INTERVISIBILITY AND ROBUSTNESS MEASURES

As our total concept wanders around Data Security issues, keeping the knowledge of watermarking makes an added advantage. Likewise the watermarked image and Host image should perfectly resemble each other with respect to HVS.The degree of disagreement can be measured in the MSE (Mean Square Error) or PSNR (Peak Signal to Noise Ratio).The more the PSNR, more the invisibility.

$$\mathrm{MSE} = \sum_{y=1}^{M}\sum_{x=1}^{N}[I(x,y) - I'(x,y)]^2$$

$$PSNR = 20 \times Log_{10}\left(\frac{255}{\sqrt{MSE}}\right)$$

Robustness is also one of the quality measure of watermarking system with respect to watermark image and extracted image. The robustness gives the quality measure of watermarking system with respect to intentional and intentional attacks and channel actions. After undergoing all these, if the watermarked image is driven to extraction process at receiver part, the extracted image should match with the original watermark image. Then only the system is said to have Robustness. The quality of match can be measured by Bit Error Rate and Normalized Correlation Coefficient.

$$NCC = \frac{\sum_{x=1}^{m}\sum_{y=1}^{n}\left(A_{mn} - \overline{A}\right)\left(B_{mn} - \overline{B}\right)}{\sqrt{\left[\sum_{x=1}^{m}\sum_{y=1}^{n}\left(A_{mn} - \overline{A}\right)^2\right]\left[\sum_{x=1}^{m}\sum_{y=1}^{n}\left(B_{mn} - \overline{B}\right)^2\right]}}$$

$$BER = {No.of.Error.Bits}\big/{Total.No.of.Bits}$$

## 6. EXPERIMENTAL RESULTS

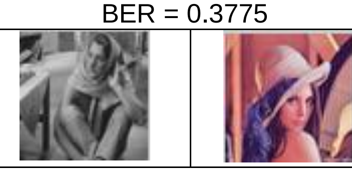
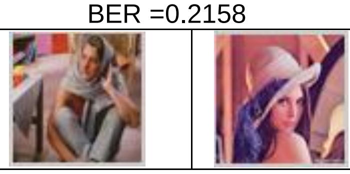
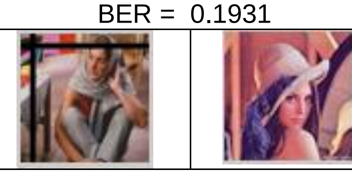
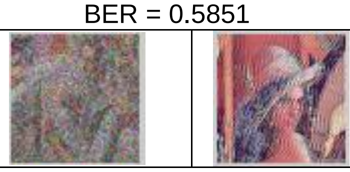
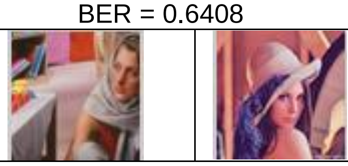
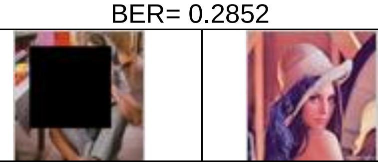
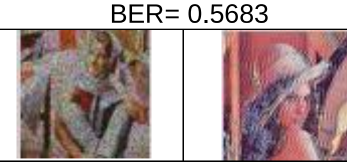
True color images barbara.pgm and lena.pgm of sizes 256X256 as host and watermarked images. The experiment is repeated for different ranges of alpha(the watermarking coefficient).The prominent value with good invisibility is observed at alpha 0.001 to 0.25.Under ideal channel without any attacks we have observed PSNR of 63.72dB and NCC of 0.9999, BER=0.0002.The NCC less than one is because the PCA is not completely reversible technique. Experiment is repeated for different intentional and unintentional malicious attacks and results are stated below.


Host Image
Barbara.pgm


Watermark Image
Lena.pgm


Watermarked Image
PSNR=63.72dB


Extracted Image
NCC=0.9999,BER=0.1319

| | | |
|---|---|---|
| Salt & Pepper Noise<br>PSNR=53.6935,NCC= 0.9858<br>BER=0.3586 | JPEG Compression<br>PSNR=42.9998,NCC= 0.9861<br>BER= 0.3105 | Gaussian Blur<br>PSNR= 26.8958,NCC = 0.9899<br>BER = 0.2952 |
|  |  |  |
| JPEG2000 Compression<br>PSNR=53.5443,NCC=0.9995<br>BER=0.1658 | Low Pass Filtering<br>PSNR= 51.0915,NCC= 0.9893<br>BER=0.2966 | Dilation<br>PSNR=35.3595,NCC = 0.9851<br>BER= 0.6405 |
|  |  |  |
| Rotation<br>PSNR=40.2362, NCC=0.9868<br>BER= 0.3055 | Histogram Equalization<br>PSNR= 26.8958, NCC= 0.9807<br>BER= 0.3512 | Shearing Attack<br>PSNR=25.856, NCC = 0.9893<br>BER = 0.2969 |
|  |  |  |
| Median Filtering<br>PSNR= 36.9651, NCC= 0.9852<br>,BER= 0.3298 | Contrast Adjustment<br>PSNR= 38.8907, NCC= 0.9998 ,<br>BER= 0.1058 | Color to Gray scale conversion<br>PSNR= 25.0829, NCC = 0.9441<br>BER = 0.3775 |
|  |  |  |
| Wiener Filtering<br>PSNR=48.3950, NCC=0.9989<br>BER =0.2158 | Gamma Correction<br>PSNR=56.2008, NCC = 0.9996,<br>BER = 0.0728 | Row Column removal<br>PSNR= 35.5668, NCC = 0.9977<br>BER = 0.1931 |
|  |  |  |
| Gaussian Noise<br>PSNR=38.4451, NCC = 0.7266<br>BER = 0.5851 | Sharpening<br>PSNR=40.6818, NCC = 0.8448<br>BER = 0.5177 | Row column copying<br>PSNR=38.9696, NCC = 0.9895<br>BER= 0.3208 |
|  |  |  |
| Rescaling (150%)<br>PSNR=48.9696, NCC = 0.9861<br>BER = 0.6408 | Automatic cropping (85%)<br>PSNR= 28.9606, NCC= 0.9936<br>BER= 0.2852 | Speckle Noise<br>PSNR=38.5177, NCC= 0.7031<br>BER= 0.5683 |
|  |  |  |

## 7. CONCLUSION AND FUTURE SCOPE

Our hybrid approach “Image watermarking using *CS-SFLCT* and PCA" is showing good performance when compared with DWT and PCA, CT and SVD, CT and PCA in both invisibility and robustness. The usage of *CS-SFLCT* is reducing aliasing effects and by means of which reducing unexpected artifacts like in contourlet transform. Usage of PCA as hybrid improves still further improving the quality of watermarking system. But our approach being non blind requires host image and some partial information of watermark also at the receiving end. Usage of security key still further improves the authentication. This system is best suitable for medical images especially because the action of unexpected artifacts in CT will change the information it contains. This work can be extended to blind technique (at the extraction stage only watermarked image is sufficient) using regression techniques. It is also observed that usage of Cycle Spinning-based form of Sharp Frequency Localized Contourlet greatly reduces extra time taking of watermarking using non subsampled Contourlet Transform.

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