Digital Image-in-Image Watermarking For Copyright Protection of Images Using the Slant Transform

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Abstract- In this paper, a robust and efficient digital image watermarking algorithm using the Slant transform is proposed for the copyright protection of images. This algorithm can embed or hide an entire image or pattern as a watermark such as an Institution's logo or trademark directly into the original image. In the existing method a visible/invisible watermarking process for embedding and extraction a digital watermark into/form an image is carried out in hadamard transform domain using scaling factor. It is calculated with the help of the underlying cover image. This method facilitates in preserving ownership rights of the owner. In the proposed system, an adaptive visible/invisible watermarking scheme is done to prevent the privacy and preserving copyright protection of digital data with good energy compaction using Slant transform based on the scaling factor of the image. The value of scaling factor depends on the control parameter. The control parameter can be adjusted to make the watermarking scheme as either visible or invisible. The performance of the proposed algorithm is evaluated using various attacks. Results show that this algorithm is very robust and can survive up to 60% of all attacks. These attacks were tested on a number of test images of size 512×512×8bit, embedded with a watermark image of size 256×256×8 bits. The simplicity of the slant transform also offers a significant advantage in shorter processing time and ease of implementation.

Keywords:- Copyright Protection, Digital Watermarking, Images, Slant Transform

1 Introduction

With the advent of the Internet, the online purchasing and distribution of satellite or medical images can now be performed relatively easily. Over the past few years, the technology of digital watermarking has emerged as a leading candidate that could solve the problems of legal ownership and content authentications for digital multimedia data. A great deal of research efforts has been focused on digital image watermarking in recent years. The techniques proposed so far can be divided into two main groups. One is the spatial domain approach. The earliest watermarking techniques are mainly focused in the spatial domain and the simplest example is to embed the watermark into Least Significant Bits (LSBs) of the image pixels [1].However, this technique has relatively low information hiding capacity. The other is the frequency domain approach, this approach can embed more information bits and is relatively robust to attacks. Cox et al.'s . used the spread spectrum communication for digital multimedia watermarking. They embedded a Gaussian distributed sequence into the perceptually most significant frequency components of container image[2] . Hsu and Wu, embedded an image watermark into the selectively modified middle frequency of Discrete Cosine Transform (DCT) coefficients of the container image [3]. In Mohanty et al., proposed the scheme, the scaling factors are determined adaptively in DCT domain using the effect of luminance.[6]. Image fusion-based visible watermarking algorithm is presented in Hu and Kwong., which uses DWT domain and it classifies blocks into different perceptual classes based on features. It uses truncated Gaussian function to approximate the effect of luminance masking in the embedding rule and insertion of watermark takes place pixel-wise[7]. Luo et al., have proposed translucent digital watermark based on wavelets and error correction code using few embedding weights [8] . A lossless visible watermarking scheme that adaptively varies the watermark strength to be embedded in different areas of the cover image, depending on the underlying image content and Human Visual System (HVS) is proposed in Yang et al., based on the underlying content, either DC coefficients alone or both DC and AC coefficients are used for calculating the scaling and embedding factors in block transform domain[9]. Tsai et al., have proposed a v isible watermarking system based on the game theoretic architecture that provides an optimum solution for the decision maker by studying the intensity and perceptual efficiency. The robustness of proposed scheme is tested against JPEG compression attack with various quality factors [10]. Adaptive invisible watermarking procedure is presented in Mohanty and Bhargava, in which cover data is segmented to identify sensitive and perceptually important regions. A compound watermark is created by fusing the watermark image with the sub-image identified in DCT domain and the scaling and embedding factors are empirically chosen. Finally, the compound watermark is invisibly embedded into the important block of the cover image. Selection of sensitive and perceptually important regions is carried out adaptively but not in calculation of scaling factor [11]. In Tian et al., in which watermarking is carried out in three stages. Region of interest (ROI) is captured from each image automatically. The number of salient regions to be captured and the size of each ROI are adaptive to each image. This is carried out based on P roto-Object recognition. The watermark is embedded into each adaptively chosen ROI and the watermarked image is formed. In the LL band of K-level wavelet decomposition of the watermarked image, the edge map of one of the ROI is inserted adaptively using quantization step[12]. Wang et al., have proposed informed watermarking algorithm using Hidden Markov Model (HMM) and genetic algorithm [13]. The process of inserting a d igital watermark can be carried out either in frequency domain or in spatial domain. Digital watermarking in frequency domain is more robust than in spatial domain. Different transformation techniques are available to transform an image from spatial domain to frequency domain. The most frequently used transformations include Discrete Cosine Transformation (DCT) , Discrete Wavelet Transform (DWT), Discrete/Fast Fourier Transform (DFT/FFT), Hadamard Transform etc., Though many transformation techniques have been used extensively in digital watermarking field, the Hadamard transformation has good energy compaction property and its transformation matrix could be generated using fast algorithms and hence it is called Fast Hadamard Transform (FHT) the elements of its transformation matrix are +1 and -1[14]. Slant transformation technique is the best choice, it requires only addition, subtraction and multiplication operations which slightly increases processing time. Slant transform has good energy compaction property. Moreover, some of these techniques are quite complicated to implement in real-time. In this paper, we propose a slant transform based watermarking approach. Gray scale image can be used as watermark, which is inserted into slant coefficients of sub-blocks of the original container image. This paper is organized as follows: the forward and reverse transformation of Slant transform is described in Section 2. In Section 3, image embedded watermarking algorithms are discussed. Experimental results under various attacks on a image and the relevant discussions are presented in Section 4. Finally, the Conclusion is given in Section 5.

2 Slant Transform of an Image

The Slant transform has been used extensively in image compression applications and energy compaction.

Let I represents the original image and $\boldsymbol{I'}$ is the transformed image, the Slant transform is given by $[\boldsymbol{I'}] = \mathbf{S_N}[\mathbf{I}]\mathbf{S_N}$ where, $\mathbf{S_N}$ - Represent N X N Slant matrix with N=2^n n=1,2,3…, with element values either +1 or –1. S = $\boldsymbol{S}^*$ & $\boldsymbol{S^T} = \boldsymbol{S^{-1}}$. When the Slant matrix S is the product with Slant transpose matrix $\boldsymbol{S^T}$ it gives an identity matrix. S $\boldsymbol{S^T}$ = $\boldsymbol{S^T}$ S = I. The advantages of Slant transform are (i) Its elements are real. (ii) The slant transform is a fast transform (iii) Its rows and columns are orthogonal to each other. (iv) It has very good energy compaction for images.

The inverse Slant transform is given as [I] = $\mathbf{S_N}[\mathbf{I}]\,\mathbf{S_N} = \boldsymbol{S_N}[\boldsymbol{I'}]\,\boldsymbol{S_N}$

In our algorithm, the transform process is carried out based on the 8×8 sub-blocks of the whole image, the lowest order Slant matrix $\boldsymbol{S_2}$ is constructed as given in equation (1)

$$\boldsymbol{S_2} = \frac{1}{\sqrt{2}}\begin{bmatrix} \mathbf{1} & \mathbf{1} \\ \mathbf{1} & \mathbf{-1} \end{bmatrix} \quad \text{--- (1)}$$

Slant matrices of any order N whose dimensions are power of two can be constructed using the equation (2)

$$S_N = \frac{1}{\sqrt{2}} \left[\begin{array}{cc|c|cc|c} 1 & 0 & 0 & 1 & 0 & 0 \\ a_N & b_N & & -a_N & b_N & \\ \hline \multicolumn{2}{c|}{0} & I_{\left(\frac{N}{2}\right)-2} & \multicolumn{2}{c|}{0} & I_{\left(\frac{N}{2}\right)-2} \\ \hline 0 & 1 & 0 & 0 & -1 & 0 \\ -b_N & a_N & & b_N & a_N & \\ \hline \multicolumn{2}{c|}{0} & I_{\left(\frac{N}{2}\right)-2} & \multicolumn{2}{c|}{0} & I_{\left(\frac{N}{2}\right)-2} \end{array}\right] \left[\begin{array}{c|c} S_{\frac{N}{2}} & 0 \\ \hline 0 & S_{\frac{N}{2}} \end{array}\right]$$

---- (2)

Where, I_N is the identity matrix of order N×N.
The coefficient are defined in equations 3 and 4 as

$$a_N = \left[\frac{3N^2}{4(N^2-1)}\right]^{\frac{1}{2}} \quad \text{---- (3)}$$

$$b_N = \left[\frac{N^2-4}{4(N^2-1)}\right]^{\frac{1}{2}} \quad \text{---- (4)}$$

The number of sign changes is referred to as sequency [4]. Zero sign transitions correspond to DC and a large number of sign transitions correspond to high frequency. In Slant matrix, the rows are arranged by the number of sign changes. The slant transform reproduce linear variations of brightness very well. It is possible that in the watermarking process, some of the watermark information can be embedded into the low frequency AC components. This increases the mark reliability and makes it more difficult to attack and remove. Moreover, slant transform has more useful middle and high frequency bands available, for hiding the watermark, as compared to other high coding gain transforms like DCT, at high noise environment. It has been shown that transforms including DCT are suitable for watermarking when the channel noise is low [5]. But low channel noise is not always the case. For low quality JPEG as well as some linear or nonlinear filtering, the processing noise is high. In these cases, the high gain transform watermarking methods are not very robust. But middle and high frequency slant transform coefficients have components equivalent to where many DCT low-frequency AC coefficients are located. So it is more likely that in high noise environment the slant transform bands would remain and unscathed. Another advantage of using the slant is that it has a shorter processing time and its ease of implementation.

3. Watermarking in Slant Transform

The block diagram of the proposed watermarking system is shown in Fig. 1 and Fig. 2. In proposed work, an adaptive visible/invisible watermarking scheme for digital images is done through Slant transform by calculating scaling factor. The value of the scaling factor is based on control parameter. It can be adjusted to make the watermark scheme as either visible or invisible.

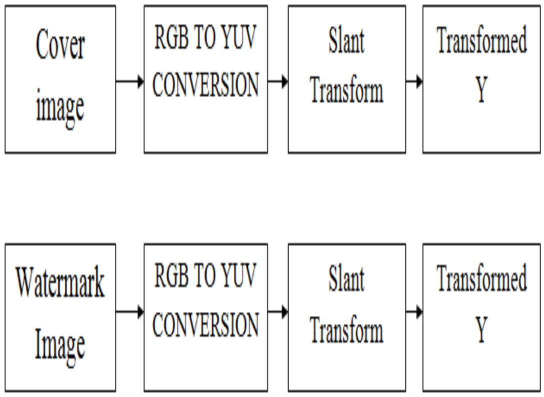

Figure 1. Block diagram of the Proposed Watermarking system.

After the Slant transform, watermark is embedded based on the scaling factor of the cover image. The cover image to be protected or to be watermarked is transformed into frequency components using Slant transform technique. I is the original cover image and $\mathbf{I}'$ is the transform coefficients or frequency components of cover image and $\mathbf{S_N}$ is the Slant matrix. Using Equation (5) and (6) the mean value of $\mathbf{I}'$ is calculated for each input image using $\mu(\mathbf{I}')$ and passed as an input to function in $\boldsymbol{\alpha_1}$.

$$\mu(\boldsymbol{I}') = \frac{1}{P \times Q}\sum_{a=1}^{P}\sum_{b=1}^{Q}\boldsymbol{I}'(a,b) \quad \text{-- (5)}$$

$$\boldsymbol{\alpha_1} = \frac{1}{(1+e^{-\mu(I')})} \quad \text{---- (6)}$$

The scaling factor obtained from $\boldsymbol{\alpha_1}$ is adjusted by multiplying it with inverse multiples of 10 as given in Equation (7). Here m represents the controlling parameter which takes integer value 0 onwards that controls the strength of scaling factor α to get the desired watermarking scheme.

$$\alpha = \boldsymbol{\alpha_1} \times \frac{1}{10^m} \quad \text{---- (7)}$$

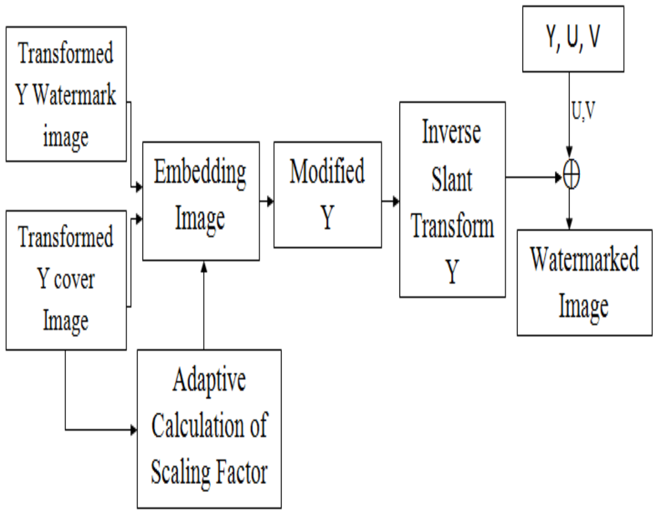

Figure 2. Watermark Embedding Process

Based on the value of m, the watermarking scheme is classified as either visible or invisible. For m = 0 the watermark dominates the cover image and destroy the underlying image quality greatly. For m = 1 t he visibility of the watermark is good without destroying the underlying content. For m = 2 the watermark become invisible without degrading the quality of underlying digital image. Thus the value of controlling parameter m = 1 pr ovides visible watermarking scheme and m = 2 provides invisible watermarking scheme.

3.1 Embedding Algorithm

The Algorithm for inserting a visible/invisible watermark is given below:-

$\mathbf{I}'$ = watermark_ Insertion (I, W)
Input : Cover image (I), Watermark image (W)
Output : Watermarked image ($\mathbf{I}'$)

Step1: Read cover image and watermark image
Step2: The given cover image I is converted from RGB to YUV color space
$[YUV] \leftarrow RGB2YUV\ (I)$
Step3:The luminance channel Y is transformed into frequency components using Slant transform.
$\mathbf{Y}' = [H\ Y\ H]$
Step4: The Watermark image is also converted into frequency components using Slant transformation technique.
$\mathbf{W}' = [S\ W\ S]$
Step 5: Calculation of scaling factor (α) using $\mu(\mathbf{I}')$ and $\boldsymbol{\alpha_1}$
$\alpha = \boldsymbol{\alpha_1} \times \frac{1}{10^m}$
Step 6: The watermark is inserted by modulating the frequency components of cover image with watermark image.
$\mathbf{Y}'' = \mathbf{Y}' + \alpha W$
Step 7:Inverse Slant transform on $\mathbf{Y}''$
$\mathbf{Y}''' = [S\ \mathbf{Y}'' S]$
Step 8: Conversion of YUV components into RGB components
$[\mathbf{R}'\mathbf{G}'\mathbf{B}'] \leftarrow YUV2RGB\ (\mathbf{Y}'''UV)$
Step 9: Reconstruction of watermarked image in RGB component
$\mathbf{I}' = RECONT\ (\mathbf{R}'\mathbf{G}'\mathbf{B}')$

3.2 Watermark Extraction

The proposed watermark extraction process is shown in Fig. 3.

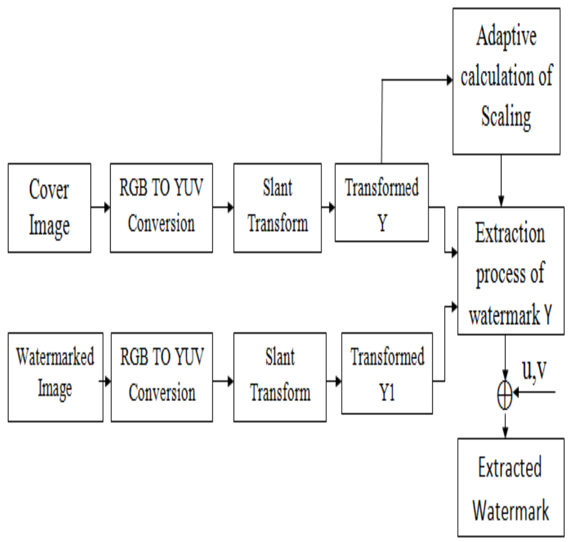

Figure 3. Watermark Extraction Process

The given original cover image and watermarked image are taken as input and converted into YUV color space. Slant transformation technique is applied on the luminance channel of cover image and watermarked image. Slant transformed cover image is used to calculate the scaling factor and watermark is extracted.

3.2.1 Extraction Algorithm

The pseudo code for extracting watermark from the watermarked image is given below:

$\mathbf{W}'$ = Watermark_ Extraction (I, $\mathbf{I}'$)
Input : Cover image (I), Watermarked image ($\mathbf{I}'$)
Output : Watermark image ($\mathbf{W}_1'$)

Step 1: Read Original image and watermarked image
Read (I, $\mathbf{I}'$)
Step 2: The given cover image I is converted from RGB to YUV color space
$[YUV] \leftarrow$ RGB2YUV (I)
Step 3: The Watermarked image $\mathbf{I}'$ is converted from RGB toYUV color space
$[\mathbf{Y_1}\,\mathbf{U_1}\,\mathbf{V_1}] \leftarrow$ RGB2YUV ($\mathbf{I}'$)
Step 4: The luminance channel Y of cover image (I) is transformed into frequency components using Slant transform.
$\mathbf{Y}' = [S\ Y\ S]$
Step 5: The luminance channel Y of watermarked Image ($\mathbf{I}'$) is transformed into frequency components using Slant transform.
$\mathbf{Y}_1' = [S\ \mathbf{Y_1}\ S]$
Step 6: Calculation of scaling factor(α) using $\mu(\mathbf{I}')$ and $\boldsymbol{\alpha_1}$
$\alpha = \boldsymbol{\alpha_1} \times \frac{1}{10^m}$
Step 7: By applying a transform on $\mathbf{W_1}$
$\mathbf{W}_1' = [S\ \mathbf{W_1} S]$

4 Experimental Results and Discussion

In this section, the experimental results obtained are presented with detailed analysis. The proposed work is implemented on Intel dual core CPU with 1 GB RAM configured system using MATLAB version R2009b. The most commonly used test images are taken for experimentation. The watermark used to test the performance of proposed work is shown in Fig .4. Similarly sample test cover images used for experimentation are shown in Fig. 5.Calculated scaling factor for sample cover images and corresponding images are given in Table 1 and Fig. 6(a) – 6(c) respectively.

Figure 4. Watermark Image

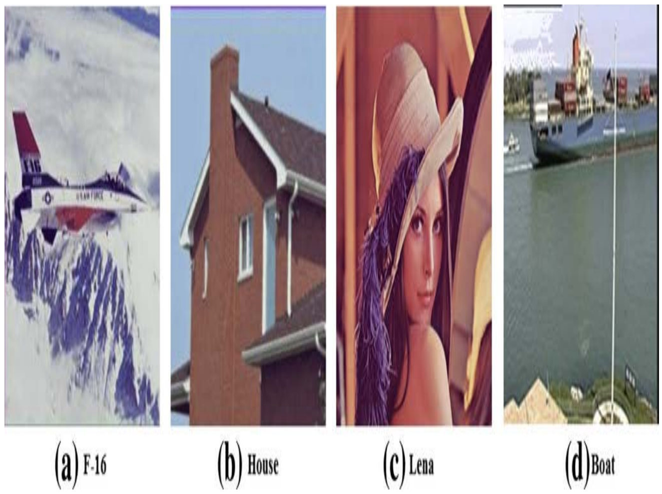

Figure 5.Sample cover images.

Table 1 Calculated scaling factor for sample cover images

Sample cover images	Mean value of cover images	Calculated scaling parameter		
		m=0	m=1	m=2
Lena	0.50287	0.5006	0.0500	0.0050
F-16	0.71341	0.5005	0.0500	0.0050

Table 1 gives the relationship between the mean value and the corresponding calculated scaling factor. It states that this function creates a linear relationship between these two factors.

Figure 6(a) Watermarked sample images for m=0

Figure 6(b) Watermarked sample images for m=1

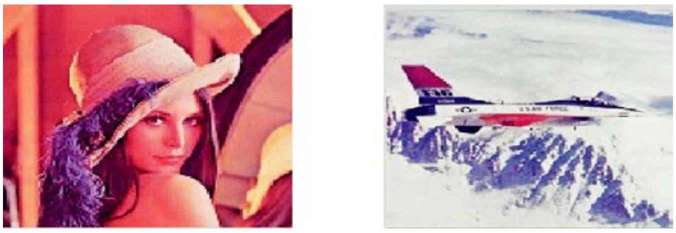

Figure 6(c) Watermarked sample images for m=2

The performance for an adaptive visible/invisible watermarking scheme have been evaluated and compared on the basis of three measures: Peak Signal to Noise Ratio (PSNR), Normalized Correlation Coefficient (NCC) and Universal Image Quality Index (UIQI), they are computed as follows

Peak Signal to Noise Ratio

The Peak Signal-to-Noise Ratio (PSNR) is a statistical measure of the ratio between the original image and the modified or distorted image in decibels. The Root Mean Square Error (RMSE) between original image I and watermarked images $\mathbf{I}'$ is calculated using equation (8) RMSE and substituted in equation (9) to calculate peak signal to noise ratio .

$$\mathbf{RMSE} = \sqrt{\frac{1}{(\mathbf{WD}\times\mathbf{HT})}\sum_{i=0}^{WD-1}\sum_{j=0}^{HT-1}[\mathbf{I}(i,j) - \mathbf{I}'(i,j)]^2} \quad \text{---- (8)}$$

Where,WD and HT are width and height of the cover image respectively.

PSNR = 10 * log 10 (MAX^2 / MSE) ----- (9)

Universal Image Quality Index

It is used for measuring the quality of watermarked image. It is designed to model image distortion using three factors namely loss of correlation, luminance distortion and contrast distortion. For any two images x and y, the UIQI is given in equation (10)

$$Q= \frac{\sigma_{xy}}{\sigma_x\sigma_y} \cdot \frac{2\bar{x}\bar{y}}{(\bar{x})^2+(\bar{y})^2} \cdot \frac{2\sigma_x\sigma_y}{\sigma_x^2+\sigma_y^2} \quad \text{----- (10)}$$

Normalized Correlation Coefficient

In order to show the similarity between the extracted watermark and the original watermark, the NCC is used as a m etric. The equation to calculate NCC is given in (11) in which W (i,j) and $\mathbf{W_1}$(i,j) represents the original and extracted watermark respectively. The value of NCC ranges between 0 a nd 1. For two identical images, NCC value is equivalent to 1 indicating the perfect similarity between them whereas 0 indicates no similarity between them.

$$\mathbf{NCC} = \frac{\sum_{i=1}^{P}\sum_{j=1}^{Q} W(i,j) X\, W_1'(i,j)}{\sqrt{\sum_{i=1}^{P}\sum_{j=1}^{Q} W(i,j)^2}\sqrt{\sum_{i=1}^{P}\sum_{j=1}^{Q} W_1'(i,j)^2}} \quad \text{------ (11)}$$

4.1 Performance analysis of watermarking

In this section, the performance analysis of Visible and Invisible Watermarked Images is presented in detail. The metric UIQI is used to measure the quality of watermarked image is tabulated in Table 2 and corresponding results are shown in Fig.7. UIQI measure is done for two sample cover images.

Table2. UIQI Based Evaluation for Visible and Invisible Watermarked Images

Sample Cover Images	UIQI value for m = 0	UIQI value for m = 1	UIQI value for m = 2
F-16	0.82762	0.93667	0.98738
Lena	0.81307	0.94322	0.98587

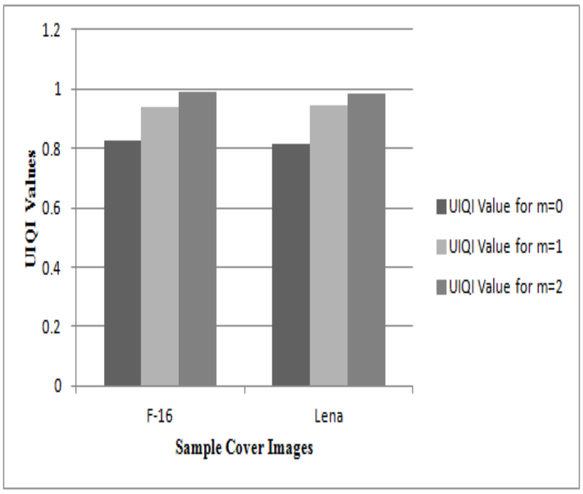

Figure 7. UIQI Based Evaluation for Visible and Invisible Watermarked Images

From the above graph shows that, based on the control parameter different qualities of watermarked images are produced. Better quality is obtained from both visible (m=1) an invisible (m=2) watermarking.

PSNR indicates the quality of image after watermarking. The PSNR measure is done for two sample cover images and compared with the results of M ohanty et al.'s, Tian et al.'s and Santhi et al.'s method, are shown in Table 3. Corresponding results are shown in Fig.8.

Table 3. Comparison of PSNR values for Lena Image with Existing Works

Attack type	Results of Mohanty et al.'s work	Results of Tian et al.'s work	Results of Santhi et al.'s work	Results of Proposed Work
No Attack	35.17	36.08	47.06	49.38
JPEG Compression (60%)	24.69	26.18	32.77	36.40
Median Filtering	25.58	28.63	36.33	38.45
Gaussian Blur	30.43	26.53	32.33	43.52
Resize	26.82	-	38.13	46.64
Low pass filtering	-	-	35.67	41.92
High pass filtering	-	-	40.21	41.37
Cropping	-	-	32.83	34.58

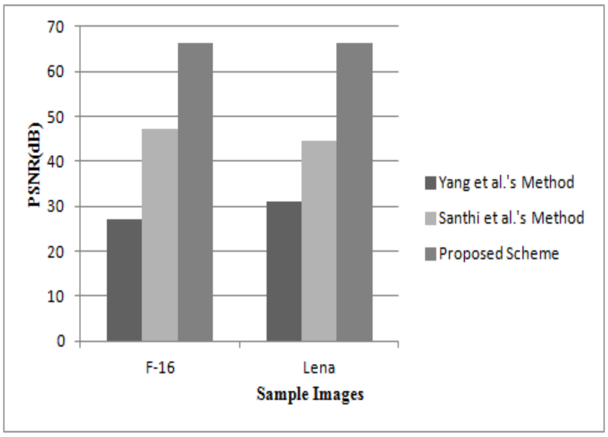

Figure 8 Comparison of PSNR Values for Visible Watermarking (m=1)

There is an improvement in PSNR values for visible (m=1) watermarking is above 15-20% in proposed system.

NCC is regularly used metric for measuring the similarity between the extracted watermark and the original watermark. The NCC measure is done for two sample cover images. Better similarity is obtained from both the visible cases (m=0) and (m=1) watermarking. Table 4 shows that comparison of NCC Values for Lena Image with Existing Works for Invisible Watermarking and corresponding results are shown in Fig. 9.

Table 4. Comparison of NCC Values for Lena Image with Existing Works for invisible watermarking

Attack type	Results of Mohanty et al.'s work	Results of Tian et al.'s work	Results of Santhi et al.'s work	Results of Proposed Work
No Attack	0.9947	0.9984	1.0000	1.0000
JPEG Compression (60%)	0.7930	0.8124	0.9244	0.9463
Median Filtering	0.8373	0.9287	0.7997	0.8452
Gaussian Blur	0.9856	0.8354	0.9820	0.9879
Resize	0.9081	-	0.9860	0.9870
Rotation	-	-	0.6612	0.8144
Low pass filtering	-	-	0.7390	0.7473
High pass filtering	-	-	0.7157	0.7863
Cropping	-	-	0.7342	1.0000

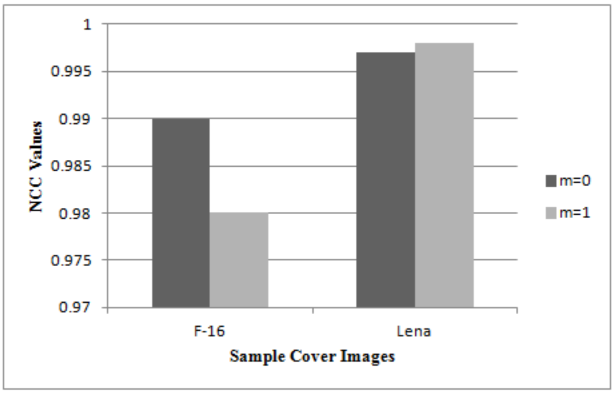

Figure 9. Comparisons of NCC Values for Visible Watermarking

The obtained PSNR and NCC values of proposed work for Lena image is compared with the results of Mohanty et al.'s work and Tian et al.'s work, and santhi et al.'s work . It is proved that the proposed watermarking scheme is better than the other existing methods.

Elapsed time is calculated between the embedding and extraction for both existing and proposed work. The proposed Slant transform is fast computational algorithm because of it matrix formation in the recursive process. It is shown in Table 5 and the corresponding graph is shown in Fig.10.

Table 5 Comparison of Elapsed Time for Embedding and Extraction Watermarking Process

Methods	Elapsed Time Process in Seconds	
	Embedding Process	Extraction Process
Existing Hadamard Transform	5.1342	2.0673
Proposed Slant Transform	2.9440	1.5932

From the table, the time consumption for the slant transform is lower than the existing method.

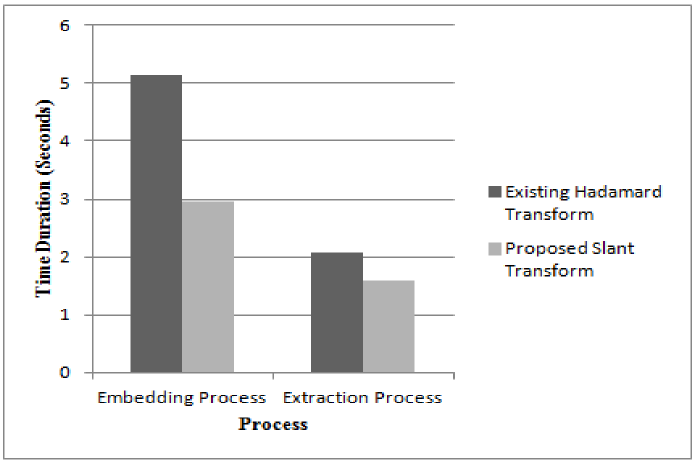

Figure 10. Comparison of Elapsed Time for Watermarking Process

5 Conclusion

An adaptive watermarking method based on embedding and extracting a digital watermark into/from an image is done using a Slant Transform. Slant Transform is mainly used for its robustness against image processing attacks and energy compaction. In this method an adaptive procedure for calculating scaling factor or scaling strength is used in Slant transform. The scaling factor value is controlled by a control parameter. As per the users requirements the inserted watermark may be either visible/invisible based on the control parameter. The results are compared with the existing system. The proposed scheme confirms the efficiency by the experimental result and performance analysis. In future work Slant transform can be implemented for Audio and Video and results are compared with the proposed work.

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