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Image Scrambling Using non Sinusoidal Transforms and key Based Scrambling Technique

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ABSTRACT

Nowadays Digital Images find a lot of applications almost in all the fields, for e.g. Information Hiding. Security of these images is very important. Image encryption is one method of providing security to digital images. In this paper we have proposed a method for Image scrambling which is based on a combination of spatial and frequency domain. Four different Non sinusoidal transforms, Walsh , Slant ,Kekre and Haar were used. Three different types i.e Row , Column and Full Transforms of these four transforms were applied for Image scrambling , out of these four Kekre Transform gave the best result

Indexing terms/Keywords

Scrambling; Encryption; Walsh Transform; Slant Transform; Kekre Transform and Haar Transform.

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INTRODUCTION

With the widespread of Digital Image data, over internet it has become very important to provide security to these digital images. One of the method used is Image encryption so that they can be transmitted across network without the attacker been able to see the actual content of it as it is encrypted. There are a lot of methods presented in literature for this purpose. Providing an Image scrambling technique should not only be in spatial domain but should also include transform domain , as we know Transform domain is much robust then the spatial domain to many factors for e.g. noise. In this paper we have presented a method which combines both spatial as well as frequency domain. An encryption technique based on pixels is proposed in[1]. Firstly the image is scrambled using the method of watermarking making it difficult for decoding purpose. Lastly a camouflaged image to vision or the pixels of the true image to get the final encrypted image. The key parameters are encrypted using Elliptic curve cryptography (ECC). The algorithm security, reliability and efficiency is analyzed via experimental analysis. Image security has a wide number of applications specially when some information is to be hidden into a digital image and must be protected from unauthorized access to it. Encryption of Digital images makes security of it possible. As encryption and decryption of digital images consumes lot of time, in [2] considering time as one of the important factor , encryption process is applied over to selected regions in the image, which provides the facility for selective encryption and selective reconstruction of images. The proposed method is compared with traditional methods. The efficiency and advantages of the proposed method over conventional method are discussed.

In [3], firstly textual message is encrypted using a suitable key, to obtain some suitable nonlinear pixel and bit positions about the entire image. As a result, a watermarked image is obtained. Three different image shares are obtained by combining any two components R, G or B of the watermarked image. The key is also divided into three different logical blocks by digits. The key shares are assigned to image shares. Out of the three shares only a combination of two shares will result in the full image or key. At the decryption side , appropriate arrangement of shares of key and image makes the retrieval of hidden data

[4] proposed a novel encryption method called as Bit Recirculation Image Encryption(BRIE). The paper points out that BRIE is not secured enough from attacks. Some defects exists in BRIE, and a know/chosen plaintext attack can break BRIE. Experiments are made to verify the defects and the feasibility of the attack. Security is very important in transmission of digital images and video conferencing. There is a huge increase in the use of digital images in industrial process, security of these images with confidential data from unauthorized access is very important. Advanced encryption standard(AES) is a well known block cipher method , however it is not suitable fro real time applications. In [5] , a modification to AES is been proposed to provide a high level of security and better image encryption. Modification to the method is done by shift row transformation. Experimental results of security analysis are given. The proposed method is highly secured from cryptographic viewpoint. The method is also robust against statistical attacks. A logistic based image encryption techniques is been proposed in [6]. A Haar wavelet is applied over the image to decompose it and decorrelate its pixels into averaging and differencing components. The method produces cipher of the digital image that has good confusion and diffusion properties. The differencing components are compressed using a wavelet transform. Key transmission is done using steganography concept. Tests like NPCR, UACI and PSNR are carried out for experimental analysis.An upgraded method of SD-EI is proposed in [7] called as SD-AEI. The method has three stages. Firstly each pixel is converted to its binary equivalent, In eight bit number , the number of bits equivalent to the length of the password is rotated and reversed. In the second stage extended, hill cipher technique is applied by using evolutionary matrix which is generated by using the same password. In the last stage the whole image is randomized using Modified MSA Randomization encryption technique. The proposed technique is very effective in encrypting any type of image. Experimental results show that the proposed method takes optimal amount of time compared to other traditional techniques. A new invertible two dimensional map is proposed in [8] called as Line Map, for image encryption and decryption. The method maps the digital image to an array of pixels and then maps it back from array to image. A Line Map consists of two maps, a left map and a right map. The drawback of the traditional 2D maps which can be used only for permutation is overcome by Line Map which can perform two processes of image encryption , permutation and substitution simultaneously using the same maps. The proposed method does not have a loss of information, it is also fast and there is no restriction on the length of the security key. An image encryption algorithm based on DNA sequences for Big Images is presented in [9]. The main aim of the method is to reduce the time required to encrypt big images. The method uses natural DNA sequences as keys. Firstly the pixels of the image are scrambled, then the image is confused in the light of scrambling sequence generated by the DNA sequence. Second part involves the process of pixel replacement. The pixel gray values of the new image and the one of the three encryption templates are generated by the other DNA sequence are XORed bit by bit in turn. Experimental results show that the method is feasible and simple.

An image encryption scheme based on JPEG compression tolerant is proposed in [10]. The two main features of the proposed scheme are the decryption algorithm is able to reconstruct the original image even if the encrypted image is JPEG compressed. Secondly the encryption algorithm can be adjusted to produce cipher image with varying perceptual distortion. The proposed method has an advantage that the encrypted image can be compressed and then transmitted across the network thus saving the bandwidth. The proposed method can be used for low level encryption in which the cipher image has a degraded visual quality but reflects the contents of the plain text-image or high level encryption in which the cipher image does not reveal any information about the plain –text image.

NON SINUSOIDAL TRANSFORM

1) Walsh Transform [11]

Walsh transform matrix is defined as a set of N rows, denoted by Wj, for j =0, 1,...., N-1, which have the following properties

i. Wj takes on the values +1 and -1.

ii. Wj[0] = 1 for all j.

iii. $Wj \times Wk^t = 0$ for $j \neq k$ and $Wj \times Wk^t = N$, for j=k.

iv. Wj has exactly j zero crossings, for j = 0, 1,..,N-1.

v. Each row Wj is either even or odd with respect to its midpoint.

Walsh transform matrix is generated using a Hadamard matrix of order N. The Walsh transform matrix row is the row of the Hadamard matrix specified by the Walsh code index, which must be an integer in the range [0... N - 1]. For the Walsh code index equal to an integer j, the respective Hadamard output code has exactly j zero crossings, for j = 0, 1,..., N-1.

2) Slant Transform[12]

The slant transform has its first basis function as constant and second basis function as linear. The Slant vector is a discrete saw tooth waveform decreasing in uniform steps over its length. It is been seen that Slant vectors are suitable for efficiently representing gradual brightness change in an image line. E.g. Television.

Slant Matrix Construction

If S(n) denotes the NxN Slant matrix($N=2^n$),then

$$S(1)=\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix} \quad \ldots(1)$$

The Slant matrix for N=4 can be written as

$$S(2)=\frac{1}{\sqrt{4}}\begin{bmatrix}1 & 1 & 1 & 1\\ a+b & a-b & -a+b & -a-b\\ 1 & -1 & -1 & 1\\ a-b & -a-b & a+b & -a+b\end{bmatrix} \quad \ldots(2)$$

where a and b are real constants to be determined subject to the following conditions:

(i) Step size must be uniform

(ii) S(2) must be orthogonal

The properties of Slant transform are as follows:

i. The Slant transform is real and orthogonal

$S = S^*$, $S^{-1} = S^t$,

ii. It has fast algorithm which is of order

$O(N \log_2 N)$ for NX1 vector

iii. It is very good in energy compaction for television pictures.

3) Kekre Transform [13]

The Kekre transform matrix of dimension NXN is given below:

$$K(x,y)=\begin{bmatrix}1 & 1 & 1 & 1 & 1 & 1\\ -N+1 & 1 & 1 & 1 & 1 & 1\\ 0 & -N+2 & 1 & \cdots & 1 & 1\\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots\\ 0 & 0 & 0 & \cdots & 1 & 1\\ 0 & 0 & 0 & \cdots & -N+(N-1) & 1\end{bmatrix} \quad \ldots(3)$$

The formula for generating the element K(x, y) of Kekre transform matrix is given in the equation below:

$$K(x,y) = \begin{cases} 1, & x \le y \\ -N + (x-1), & x = y+1 \\ 0, & x > y+1 \end{cases} \quad \text{...(4)}$$

The properties of Kekre Transform are as follows:

i. The Kekre transform is real and orthogonal transform.

$$[K][K]^t=[\mu]$$

Where $[K]^t$ is transpose of [K] and [μ] is a diagonal matrix and its elements are given by

$$\mu_{11} = N$$

$$\mu_{ii} = (N-i)(N-i+1)$$

ii. It has a fast algorithm as it contains N(N+1)/2 number of ones and (N-1)(N-2)/2 number of zeros leaving only (N-1) integer multiplications and only (N-1)(N/2) additions for transforming a column vector of dimension Nx1. For a normal matrix transformation we require N^2 multiplications and N(N-1) additions.

iii. The transform of a vector **f** is given by

$$F = [K] f$$

and inverse is given by

$$f = [K]^t[\mu]^{-1} F$$

iv. For image [f] the transform [F] is calculated as

$$[F]=[K][f][K]^t$$

and inverse transform is given by

$$[f]= [K]^t[F_{ij}/\mu_{ij}][K]$$

Where $\mu_{ij} = \mu_{ii}\, \mu_{jj}$

4) Haar Transform [14]

The Haar wavelet is also the simplest possible wavelet. The technical disadvantage of the Haar wavelet is that it is not continuous, and therefore not differentiable. This property can, however, be an advantage for the analysis of signals with sudden transitions, such as monitoring of tool failure in machines.

The Haar Wavelets mother wavelet function φ (t) can be described as

$$\varphi(t) = \begin{cases} 1 & 0 \le t < \frac{1}{2} \\ -1 & \frac{1}{2} \le t < 1 \\ 0 & otherwise \end{cases} \quad \text{...(5)}$$

and its scaling function φ (t) can be defined

$$\varphi(t) = \begin{cases} 1 & 0 \le t < 1 \\ 0 & otherwise \end{cases} \quad \text{...(6)}$$

PROPOSED APPROACH

In this paper , we have proposed a novel approach in Transform Domain for Image scrambling. The proposed method makes use of four Non-Sinusoidal Transforms they are Walsh Transform, Slant Transform, Kekre Transform and Haar Transform. For transforming the image from Spatial Domain to Frequency Domain, Row, Column and full Transforms were applied over the image. The Step by Step procedure for Scrambling and De-Scrambling is explained in the section below. For scrambling the image, Key Based Scrambling[15] is used which is a Random numbers generation algorithm using the size of the image as an input. The proposed approach is based on the concept that , if any alterations are done to the transform coefficients, application of inverse transform will surely not result in the original image but a scrambled image. The proposed approach is not limited to a particular scrambling method or a transform, the said approach can make use of any scrambling technique or transform on the image.

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Image Scrambling

Following are the steps used for Image Scrambling

1) Read the image, convert it to grayscale
2) Apply a Transform on the image
3) Transform coefficients which are obtained in step 2 are now scrambled using key based scrambling method.
4) Apply inverse transform on the scrambled transform coefficients obtained in step 3.
5) The image obtained in spatial domain will now be scrambled

The scrambling process is also shown in the Figure 1.

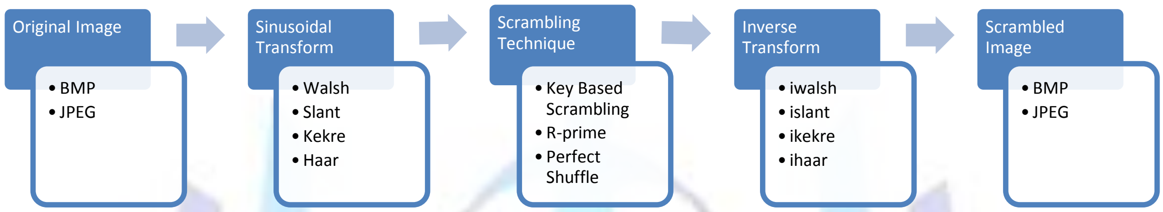


FIG 1: This Different Steps of Scrambling Process

Image Descrambling

The descrambling process is as follows

1) Read the scrambled image
2) Apply the Transform on the image
3) Transform coefficients which are obtained in step 2 are now descrambled using key based descrambling method.
4) Apply inverse transform on the descrambled transform coefficients obtained in step 3.
5) The image obtained in spatial domain will now be original Image

The descrambling process is also shown in the figure

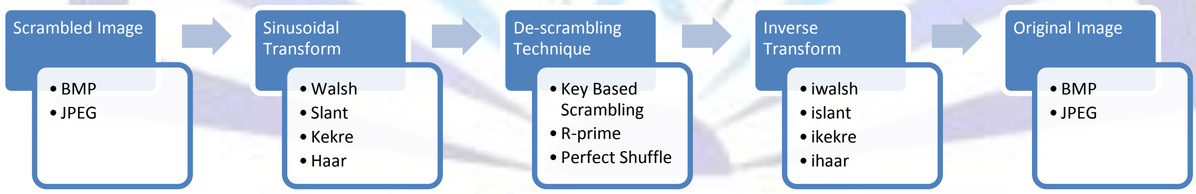


FIG 2: This Different Steps of De-Scrambling Process

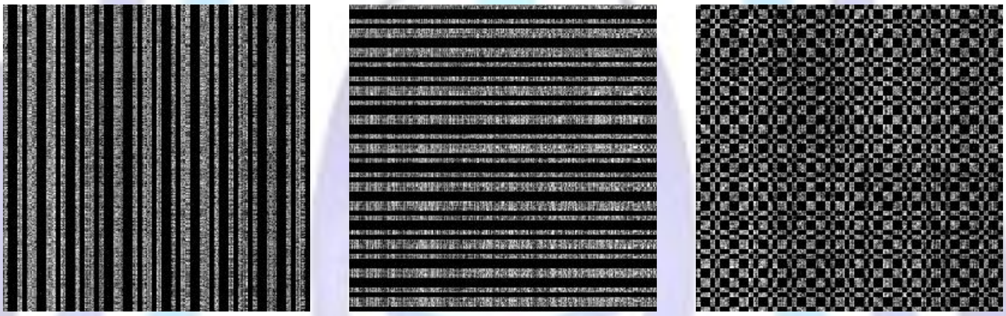
EXPERIMENTAL RESULTS

For Experimental purpose, five images of size 256X256 were used with all the four Non Sinusoidal Transforms. Figure 3(a) shows the Original Image which is a 24-bit color image which is first converted to grayscale as shown in Figure 3(b), Although the proposed method can also be extended on 24-bit color images.

a) Original Image **(b) Gray Image**

FIG 3:

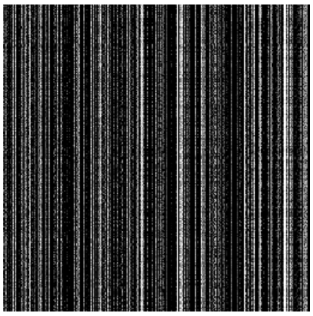
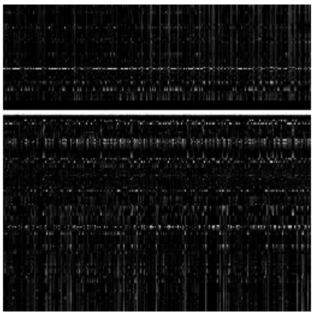
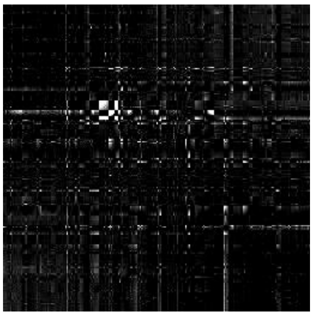
The experimental results shown below are as follows. Figure 4(a-c) shows the scrambled images obtained for walsh row,column and full transform. Figure 4(d-f) shows the descrambled images obtained for walsh row, column and full transform. Similarly Figure 5(a-c) shows the scrambled images obtained for slant row,column and full transform, Figure 5(d-e) shows the descrambled images obtained for slant row, column and full Transform. Figure 6(a-c) shows the scrambled images obtained for kekre row,column and full transform, Figure 6(d-e) shows the descrambled images obtained for kekre row, column and full Transform. Figure 7(a-c) shows the scrambled images obtained for Haar row,column and full transform, Figure 7(d-e) shows the descrambled images obtained for Haar row, column and full Transform.



(a)Walsh Row Transform Scrambled **(b)Walsh Column Transform Scrambled** **(c)Walsh Full Transform Scrambled**

(d) Walsh Row Transform Descrambled **(e) Walsh Col Transform Descrambled** **(f) Walsh Full Transform Descrambled**

FIG 4.

(a)slant Row Transform Scrambled

(b) slant Column Transform Scrambled

(c) slant Full Transform Scrambled

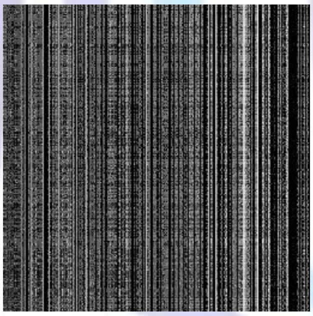
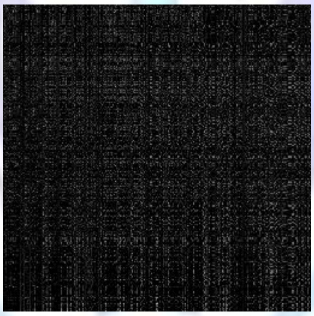
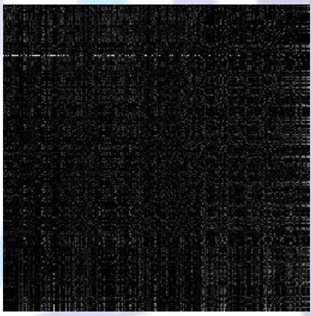


(d) slant Row Transform Descrambled

(e) slant Col Transform Descrambled

(f) slant Full Transform Descrambled

FIG 5.

(a)kekre Row Transform Scrambled

(b) kekre Column Transform Scrambled

(c) kekre Full Transform Scrambled



(d)kekre Row Transform DeScrambled

(e) kekre Column Transform DeScrambled

(f) kekre Full Transform DeScrambled

FIG 6

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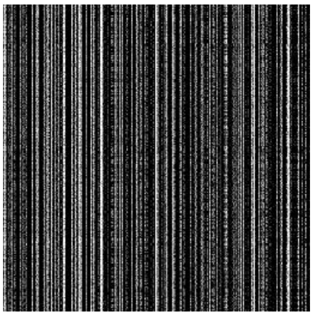
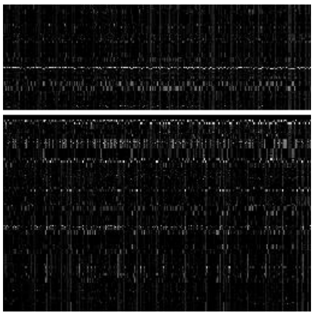
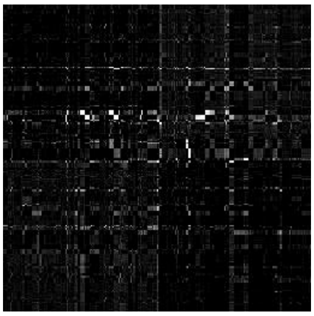


(a)Haar Row Transform Scrambled



(b) Haar Column Transform Scrambled



(c) Haar Full Transform Scrambled

(d)Haar Row Transform DeScrambled

(e) Haar Column Transform DeScrambled

(f) Haar Full Transform DeScrambled

FIG 7

Observations

As can be seen from the figures 4(a-c), 5(a-c),6(a-c) and 7(a-c), the proposed method gives a good scrambling effect on the original image for all the four Non Sinusoidal Transforms. For evaluation of all the Transforms two parameters are been used, Average correlation between rows and columns in the original image and the scrambled image obtained by applying row transform, column transform and full transform. The second parameter used is the energy distribution in original image , row ,column and full transform image coefficients and scrambled images obtained by row, column , full transform in spatial domain.

The reason behind choosing these two parameters for experimental analysis is that, A image in spatial domain is highly correlated due to which a human eye can perceive the details of the image, when a transform is applied over a image it de-correlates the pixels. The aim in Image scrambling is to reduce the correlation between the pixels to make it unreadable. The proposed method is a combination of both spatial as frequency domain. As can be seen from Table No 1, slant row transform gives a reduction in correlation in Lena , pepper and cartoon images, Row Haar transform gives a reduced correlation in pepper image, whereas kekre row, column and full transform gives a reduction in correlation in all the five images tested.

The energy distribution in Original Image, Row, column and full transform image coefficients and row, column and full transform images are shown in Figure 8 to Figure 11.

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TABLE 1: Average Row and Average Column correlation obtained in Row Transform , Row Transform scrambled , Column Transform , Column Transform Scrambled , Full Transform and Full Transform scrambled images for Walsh, Slant, Kekre and Haar Transforms

	Original Image : Lena Row: 0.8439 Col:0.6937					
Transforms	**Row Transform**	**Row Transform Scrambled**	**Column Transform**	**Column Transform Scrambled**	**Full Transform**	**Full Transform Scrambled**
Walsh	Row: 0.9947 Col:0.2088	Row: 0.3520 Col:0.3283	Row: 0.1938 Col:0.9928	Row: 0.4249 Col:0.3380	Row: 0.2026 Col: 0.2351	Row: 0.4692 Col:0.3829
Slant	Row:0.8916 Col: 0.3899	Row: 0.8429 Col:0.2065	Row: 0.3303 Col: 0.9931	Row: 0.6336 Col:0.8118	Row: 0.4060 Col:0.4289	Row: 0.6272 Col:0.5867
Kekre	Row: 0.9924 Col:0.7046	Row: 0.8102 Col:0.2284	Row: 0.7884 Col:0.9924	Row: 0.2517 Col:0.9359	Row: 0.8944 Col:0.8831	Row: 0.2515 Col:0.2848
Haar	Row: 0.9122 Col:0.1969	Row: 0.8345 Col:0.2048	Row: 0.2382 Col:0.9928	Row: 0.6088 Col:0.6960	Row: 0.2466 Col: 0.2794	Row: 0.5935 Col:0.5548

	Original Image : Pepper Row: 0.8891 Col: 0.8468					
Transforms	**Row Transform**	**Row Transform Scrambled**	**Column Transform**	**Column Transform Scrambled**	**Full Transform**	**Full Transform Scrambled**
Walsh	Row: 0.9940 Col: 0.1990	Row: 0.3498 Col:0.3344	Row: 0.1965 Col: 0.9929	Row: 0.3368 Col: 0.3353	Row: 0.2415 Col: 0.2686	Row: 0.4102 Col:0.4171
Slant	Row: 0.9153 Col:0.5000	Row: 0.7708 Col: 0.2248	Row: 0.3037 Col:0.9922	Row: 0.6537 Col:0.7370	Row: 0.4033 Col:0.4236	Row: 0.6477 Col:0.5913
Kekre	Row: 0.9933 Col:0.8470	Row: 0.7393 Col: 0.2306	Row: 0.8334 Col:0.9927	Row: 0.2766 Col: 0.8963	Row: 0.9300 Col:0.9159	Row: 0.2808 Col:0.2462
Haar	Row: 0.9381 Col:0.2251	Row: 0.7748 Col:0.2226	Row: 0.2202 Col:0.9923	Row: 0.6153 Col:0.6225	Row: 0.2963 Col: 0.3150	Row: 0.6205 Col: 0.5891

	Original Image : Cartoon Row: 0.8027					**Col:0.8070**
Transforms	**Row Transform**	**Row Transform Scrambled**	**Column Transform**	**Column Transform Scrambled**	**Full Transform**	**Full Transform Scrambled**
Walsh	Row: 0.9951 Col:0.2066	Row: 0.3754 Col:0.4798	Row: 0.2734 Col:0.9954	Row: 0.4359 Col:0.4656	Row: 0.3931 Col:0.2410	Row: 0.4824 Col:0.5344
Slant	Row: 0.8822 Col:0.4816	Row: 0.8810 Col: 0.2522	Row: 0.3171 Col:0.9954	Row: 0.6384 Col:0.8893	Row: 0.3923 Col:0.3992	Row: 0.7195 Col:0.6217
Kekre	Row: 0.9942 Col: 0.7956	Row: 0.8522 Col: 0.2878	Row: 0.7676 Col:0.9953	Row: 0.2629 Col: 0.9591	Row: 0.9577 Col:0.9247	Row: 0.3787 Col:0.3010
Haar	Row: 0.9252 Col:0.2525	Row: 0.8542 Col:0.2626	Row: 0.2592 Col:0.9956	Row: 0.6063 Col:0.8189	Row: 0.3065 Col: 0.2804	Row: 0.6822 Col:0.6449

	Original Image : Baboon Row: 0.7179					**Col:0.6935**
Transforms	**Row Transform**	**Row Transform Scrambled**	**Column Transform**	**Column Transform Scrambled**	**Full Transform**	**Full Transform Scrambled**
Walsh	Row: 0.9932 Col:0.2117	Row: 0.3331 Col:0.3686	Row: 0.2436 Col:0.9937	Row: 0.3087 Col:0.3147	Row: 0.2564 Col:0.2250	Row: 0.3766 Col: 0.4097
Slant	Row: 0.7745 Col:0.4015	Row: 0.8865 Col:0.2220	Row: 0.2910 Col:0.9937	Row: 0.4912 Col:0.8591	Row: 0.3603 Col:0.3813	Row: 0.4948 Col:0.5261
Kekre	Row: 0.9875 Col: 0.6756	Row: 0.8610 Col: 0.2429	Row: 0.6758 Col:0.9934	Row: 0.2563 Col:0.9601	Row: 0.8523 Col:0.8342	Row: 0.3000 Col: 0.2667
Haar	Row: 0.8299 Col: 0.1984	Row: 0.8725 Col:0.2215	Row: 0.1940 Col:0.9937	Row: 0.4702 Col: 0.7401	Row: 0.2026 Col:0.2035	Row: 0.4734 Col: 0.4943

Transforms	Original Image : Lotus Row: 0.8163 Col:0.8461					
	Row Transform	**Row Transform Scrambled**	**Column Transform**	**Column Transform Scrambled**	**Full Transform**	**Full Transform Scrambled**
Walsh	Row: 0.9857 Col:0.1934	Row: 0.2906 Col: 0.4174	Row: 0.2093 Col:0.9885	Row: 0.3509 Col:0.3108	Row: 0.2333 Col:0.2295	Row: 0.3844 Col:0.4271
Slant	Row: 0.8693 Col:0.4610	Row: 0.6497 Col:0.2216	Row: 0.3401 Col:0.9858	Row: 0.5389 Col:0.5948	Row: 0.4066 Col:0.4098	Row: 0.5541 Col: 0.5805
Kekre	Row: 0.9796 Col:0.8487	Row: 0.6158 Col:0.2260	Row: 0.8196 Col:0.9892	Row: 0.2323 Col:0.7988	Row: 0.9242 Col:0.8973	Row: 0.2528 Col: 0.2409
Haar	Row: 0.8871 Col:0.2111	Row: 0.6503 Col:0.2331	Row: 0.2210 Col: 0.9847	Row: 0.5430 Col:0.5760	Row: 0.2869 Col:0.2730	Row: 0.5479 Col: 0.5605

The Figure 8 – Figure 11 shows the blockwise cummulative energy in the transform coefficients after applying row transform, column transform and full transform. Energy in the coefficients is calculated by dividing the image in to blocks. The first block is of size 2x2, the second block considered is 4X4 which includes the first block and an increase in the block size by 2 and so on.

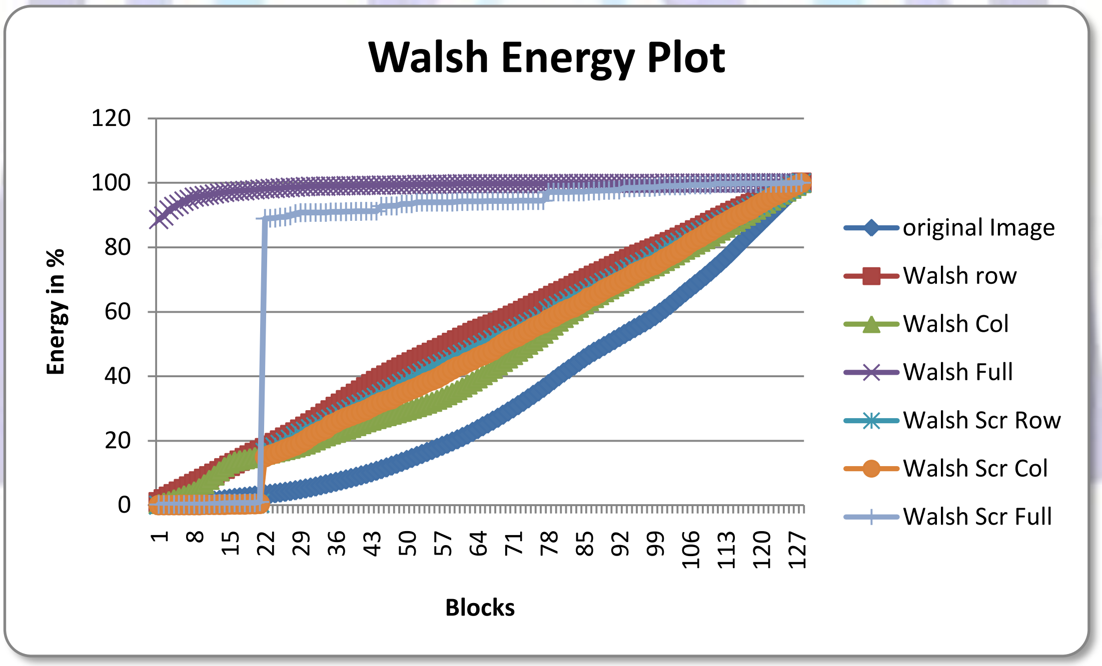

FIG 8: Block wise Energy obtained in original, Walsh row, Walsh column, Walsh full, Walsh row scrambled, Walsh Column Scrambled, Walsh Full scrambled

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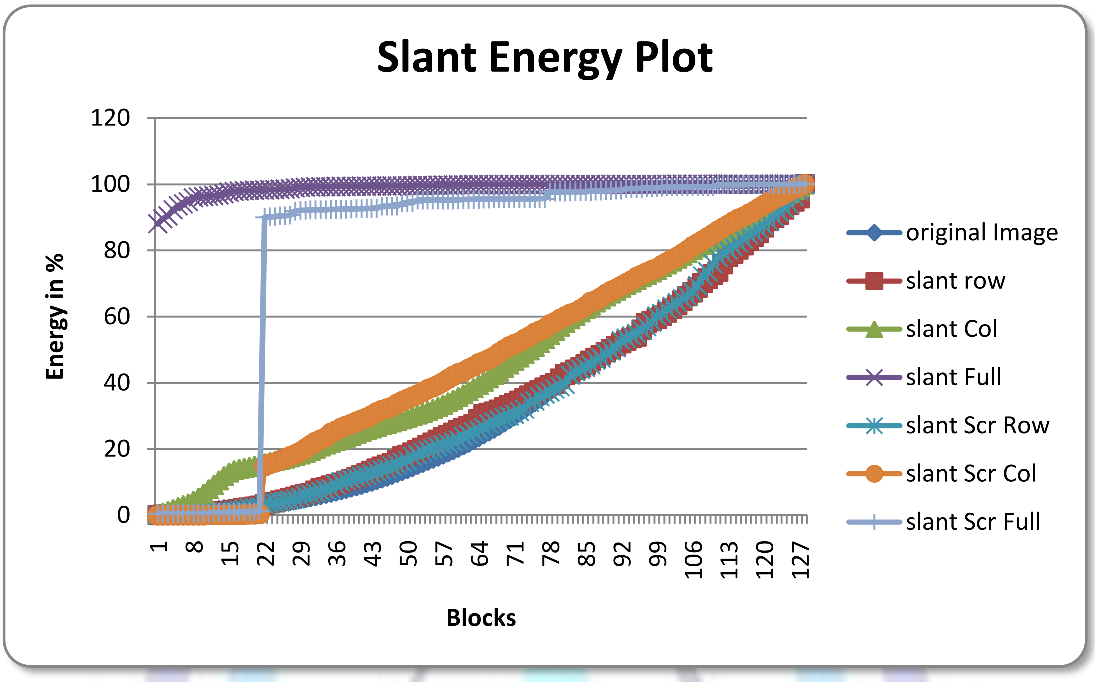

FIG 9: Block wise Energy obtained in original, Slant row, Slant column, Slant full, Slant row scrambled, Slant Column Scrambled, Slant Full scrambled

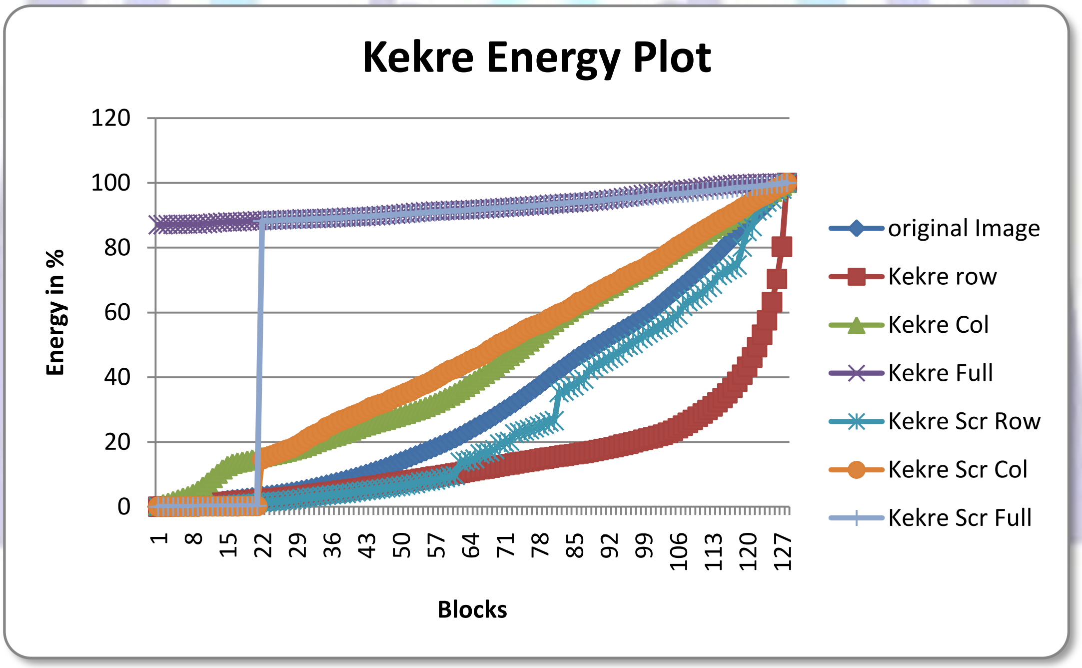

FIG 10: Block wise Energy obtained in original, kekre row, kekre column, kekre full, kekre row scrambled, kekre Column Scrambled, kekre Full scrambled

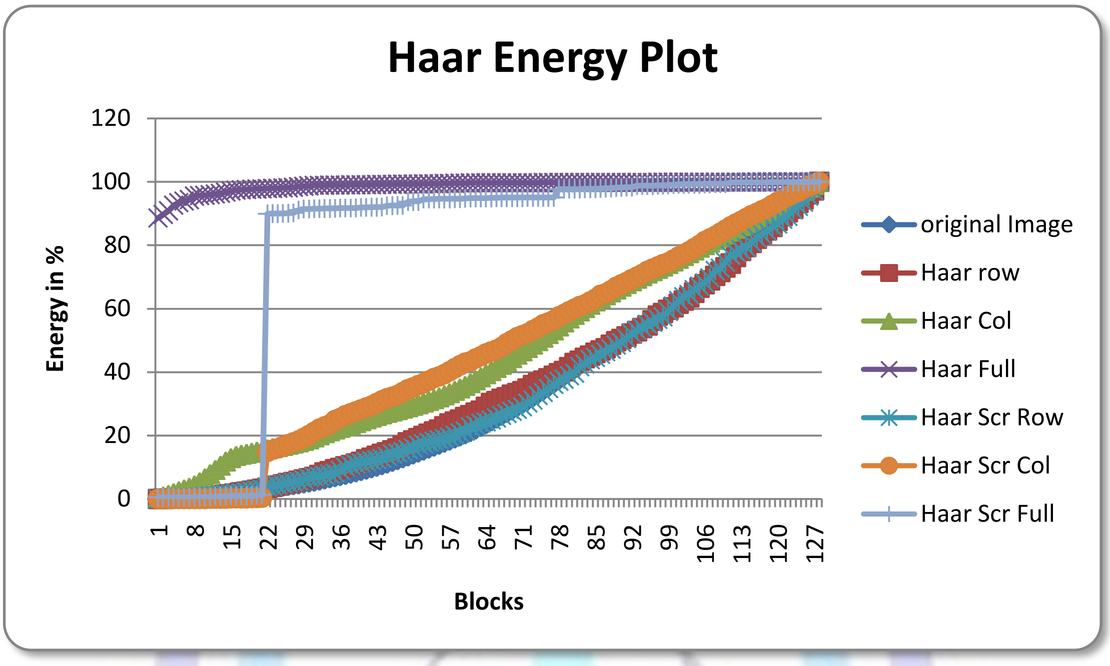

FIG 11: Block wise Energy obtained in original, Haar row, Haar column, Haar full, Haar row scrambled, Haar Column Scrambled, Haar Full scrambled

CONCLUSION

In this paper we have proposed a method for Image scrambling which is based on a combination of spatial and frequency domain. Four different Non sinusoidal transforms, Walsh , Slant ,Kekre and Haar were used. Three different types i.e Row , Column and Full Transforms of these four transforms were applied for Image scrambling , out of these four Kekre Transform gave the best result. To some extent Slant row transform also gave good result for Lena ,pepper and cartoon and Haar row transform for pepper image. Energy distribution were found similar in all the four non sinusoidal transforms with Original image, Row , column transformed image and Row scrambled image having a linear increase, whereas energy was found to be in the range of 80% in Full Transformed image in the initial blocks and then a small increase till the last block in the image. In the Full transform scrambled image , energy was very less approx to 0 and then a sudden increase in the energy after 22^{nd} block of the image. This energy distribution in the scrambled image shows a common property for all the full transforms which can be very useful to check whether the image is scrambled.Thus we can conclude that we have successfully presented a scrambling technique which is combining both spatial as well as frequency domain and used average correlation between rows and columns as a measure for experimental analysis along with energy distribution.

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