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Comparison of Arnold and Matrix Rotation Using DWT Image Steganography

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Abstract: A new method for transform domain image steganography is introduced in this paper. The proposed steganography algorithm works on the (DWT) Discrete wavelet transform with Haar Wavelet coefficients of the original image to embed the secret data (image). As compared to current transform domain data hiding methods, this scheme can provide a less noise in stego image for data hiding without sacrificing the cover image quality. This is achieved through maintaining the pixels of hiding image when scramble. This improvement to capacity-quality trading-off interrelation is analyzed in detailed and experimentally illustrated in the paper.

Index Terms: Image Steganography, Arnold Transformation, DW Transformation, Matrix Rotation, comparison, Advance Steganography, Security of Data, Haar Wavelet

1 Introduction

Information hiding is an old but interesting technology. Steganography is a branch of information hiding in which secret information is added behind the other information. The word steganography in Greek means "covered writing" (Greek words "stegos" meaning "cover" and "grafia" meaning "writing") .As we performed this experiment with DWT haar wavelet transformation, first of all I would like to define wavelet. It is a small wave which oscillates and decays in the time domain. The Discrete Wavelet Transform (DWT) is a relatively recent and efficient technique in image hiding. In this paper, DWT technique has been used for image steganography. This method transforms the object in wavelet domain, processes the coefficients and then performs inverse wavelet transform to represent the original format of the stego object with less loss in recovered image.

Steganography is basically of two types which are implemented on i.e. spatial domain & frequency domain. In spatial domain, processing is applied directly on the pixel values of the image and in frequency domain, pixel values are transformed and then processing is applied on the transformed coefficients

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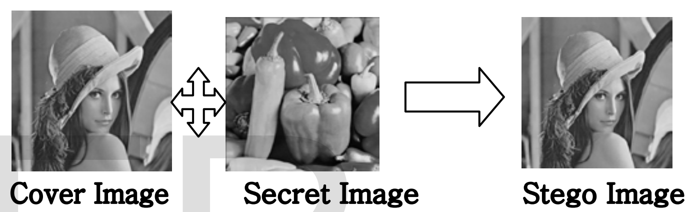

Fig 1.Principles of Steganography

2 Related Work

There are so many types of image steganography done before and lots of efforts have been made on it. Like

1. **Least significant bit substitution technique** (LSB): In this, the least significant bits of the cover image are used to conceal the message. The simplest of these techniques is LSB replacement. This steganography flips the last bit of each of the data values to reflect the message that needs to be hidden.

2. **Discrete Cosine Transform technique** (DCT): Discrete Cosine Transform (DCT) attempts to decorrelate the image data. After decorrelation each transform coefficient can be encoded independently without losing compression efficiency

3. **Discrete Wavelet Transform technique** (DWT): Recent researches are using discrete wavelet transform (DWT) with Arnold Transform by which we can scramble any image. But by using Arnold Transform we cannot exceed value of Alpha used in alpha blending more than 0.05.Other than that by using Arnold Transform, timing of steganography is more and high noise level in stego image when value of alpha go high.

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We tried to hide image with the discrete wavelet coefficients with one another image scrambling technique called Matrix Rotation Technique. In addition, the Matrix Rotation transformation performed system security. This has improved not only Noise level of stego image but also has reduced the timing for conversion even with more value of Alpha (more than 0.05).Peak Signal to Noise Ratio has been increased in Matrix Rotation in comparison to Arnold Transformation.

Except it when we measured PSNR of Recovered Secret Image its PSNR Value was also high in case of Matrix Rotation Method. Which shows that recovered image in term of Matrix Rotation Transformation Method is better in quality than in Arnold Transformation.

One main and important advantage which we noticed is that Arnold Transformation only works in Gray Scale Image But this single Matrix Rotation Transformation Method Works with Gray Scale as well as Colored Images. So we can use it in Dual Form. A single technique for both Grayscale and Colored images is seemed to be good and efficient method.

We tried to compare these two techniques and got some results which have been represented in this paper.

3 Similarities between Matrix Rotation and Arnold Transformation

3.1 DWT Transformation with Haar Wavelet

In both the types DWT is being used. Discrete wavelet transforms is the technique to convert the image in spatial domain to frequency domain, where the wavelet coefficients so generated, are modified to conceal the image. In this kind of transformation the wavelet coefficients separates the high and low frequency information on a pixel to pixel basis. The DWT approach applied in the proposed work is the 'Haar DWT'. In this transform, time domain is passed through low-pass and high pass filters and the high and low frequency wavelet coefficients are generated by taking the difference and average of the two pixel values respectively. The operation of Haar DWT on the cover image results in the formation of 4 sub-bands, namely the approximate band (LL), horizontal band (HL), vertical band (LH) and the diagonal band (HH). The approximate band contains the most significant information of the spatial domain image and other bands contain the high frequency information such as edge details. Thus, the DWT technique describes the decomposition of the image in four non overlapping sub-bands with multi-resolution. This process can be iterated on one of the sub-band of first level DWT to get the further second level sub bands for better results.

LL	HL
LH	HH

Fig 2.Sub bands formed after applying Haar Wavelet

$$\left[\begin{array}{cc|cc} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ \hline a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{array}\right] = \begin{array}{c|c} A_{11} & A_{12} \\ \hline A_{21} & A_{22} \end{array} \quad \text{or} \quad \left[\begin{array}{c|c} HAH^T & HAG^T \\ \hline GAH^T & GAG^T \end{array}\right]$$

Fig 3.Calculation under Sub bands of Haar Wavelet

Where
HAHT gives the average of the elements
HAGT can be viewed as for vertical differences
GAHT can give as for horizontal differences
GAGT can be viewed as differences along the diagonal

3.2 Alpha Blending

Alpha Blending is the process of combining an image with a background to create the appearance of partial or full transparency. In order to combine two image elements correctly, it is necessary to keep a pixel ratio same for each element. There is some other blending method too but this is the simplest method we have.

Fig 4.Result of Alpha Blending (Combination of two images)

4 Comparisons between Arnold Transformation and Matrix Rotation Transformation

4.1 Arnold Transformation

Arnold transform was advanced by Russia mathematician named Vladimir I. Arnold. This transformation is applied widely in digital image scramble because of its periodicity. But it waste lots of time when we used its periodicity to get the anti-Arnold transformation algorithm, especially when it used in the picture with big degree.

For an N×N image, two-dimensional Arnold transform is defined as under

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 1 & 2 \end{pmatrix} \cdot \begin{pmatrix} x \\ y \end{pmatrix} \pmod{N}$$

And then we apply inverse Arnold Transformation which takes lot of time to recover original image.

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4.2 Matrix Rotation Transformation

In this method presented in paper, rather than multiply matrix of pixels with any module or with any other matrix. We simply convert image pixels into matrix form then shuffle this matrix so image pixels distributed randomly and image break in unidentified pattern. Like

Fig 5.Original Image

Fig 6.Scrambled Image

Above images gives the brief idea how matrix rotation works. In original working of matrix rotation is different as it works with pixels of image. But with above pictures we can only get idea how an image scrambled.

5 Result Analysis

We tried to find out many factors like PSNR,MSE,NC,MD .Here I am showing two major factor which effect any image quality that are PSNR and MSE.

Peak Signal-to-Noise Ratio, often abbreviated PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale.

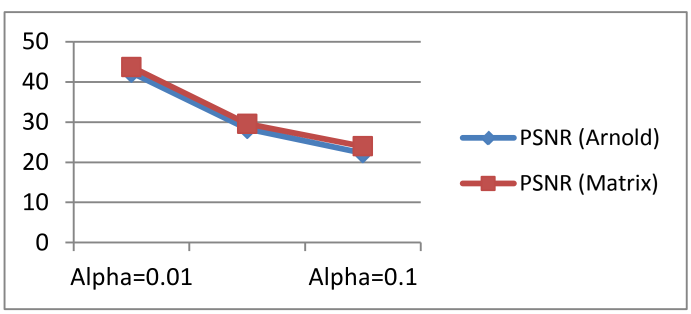

Fig 7.Comparison of PSNR Values of Both Transformations

We can calculate $PSNR = 10\frac{\log_{10}(255^2)}{MSE}db$

Mean squared error (MSE) is one of many ways to quantify the difference between values implied by an estimator and the true values of the quantity being estimated. MSE is a risk function, corresponding to the expected value of the squared error loss or quadratic loss. MSE measures the average of the squares of the "errors." The error is the amount by which the value implied by the estimator differs from the quantity to be estimated. The difference occurs because of randomness or because the estimator doesn't account for information that could produce a more accurate estimate

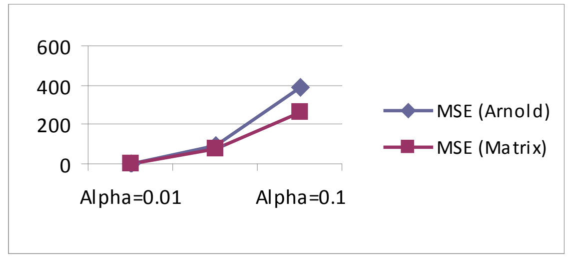

Fig 8.Comparison of MSE Values of Both Transformations

We can calculate $MSE = \frac{1}{MN}\sum_{j=1}^{M}\sum_{j=1}^{N}(X_{j,k} - X'_{j,k})^2$

From Fig 7 and 8, it has been confirmed that PSNR ratio of Matrix rotation is more that means its Stego image is clearer to its original image with less noise in image. And on the other side MSE value of Matrix Rotation is less which means Noise is less in Matrix Rotation method in comparison with Arnold Transformation.

Then we checked the Intensity level of Stego image in both cases. It showed that in Arnold Transformation, dark level is more than Matrix Rotation which means Matrix Rotation Picture is clearer. Intensity Histogram is given below;

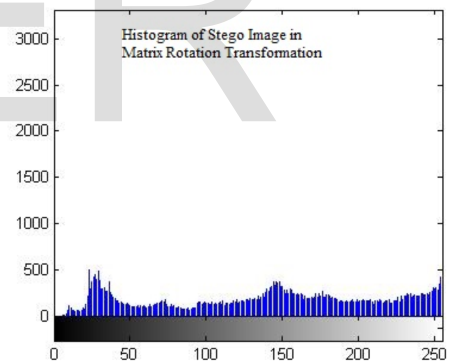

Fig 9.Histogram of Stego Image for Matrix Rotation Method

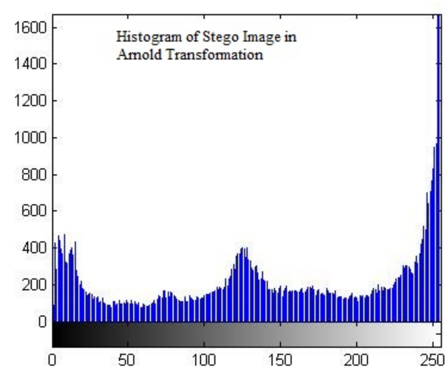

Fig 10.Histogram of Stego Image for Arnold Method

5.1 Comparison of Various Image Parameters for Different Value of Alpha

There are various other image parameters factors such as

Normalized cross correlation (NCC)

$$NCC = \sum_{j=1}^{M}\sum_{k=1}^{N}(X_{j,k} - X'_{j,k})\frac{1}{\sum_{j=1}^{M}\sum_{k=1}^{N}(X_{j,k})^2}$$

Average difference (AD)

$$AD = \sum_{j=1}^{M}\sum_{k=1}^{N}(X_{j,k} - X'_{j,k}) / \mathrm{MN}$$

Structural content (SC)

$$SC = \sum_{j=1}^{M}\sum_{k=1}^{N}(X_{j,k})^2 / \sum_{j=1}^{M}\sum_{k=1}^{N}(X'_{j,k})^2$$

Maximum difference (MD)

$$MD = Max(\left| X_{j,k} - X'_{j,k} \right|)$$

Normalized absolute error (NAE)

$$NAE = \sum_{j=1}^{M}\sum_{k=1}^{N}\left| X_{j,k} - X'_{j,k} \right| / \sum_{j=1}^{M}\sum_{k=1}^{N}\left| X'_{j,k} \right|$$

After comparing various other Factors at different alpha values and different image pixels we got these results:

TABLE 1
COMPARISON OF NC, NCC, AND AD

Method	Cover Image	Secret Image	Value of Alpha	NC	NCC	AD
Matrix Rotation	car.tiff 2560*1600	Cycle.tiff 630*420	0.1	0.9488	1.0489	13.2236
Arnold	car.tiff 2560*1600	Cycle.tiff 630*420	0.1	0.9171	1.0869	18.0967
Matrix Rotation	grass.tiff 300*168	Marbles.tiff 1600*900	0.1	0.9182	1.0766	7.2479
Arnold	grass.tiff 300*168	Marbles.tiff 1600*900	0.1	0.9106	1.0877	7.198
Matrix Rotation	car.tiff 2560*1600	Cycle.tiff 630*420	0.01	0.9933	1.0067	1.5048
Arnold	car.tiff 2560*1600	Cycle.tiff 630*420	0.01	0.9913	1.0087	1.8097
Matrix Rotation	grass.tiff 300*168	Marbles.tiff 1600*900	0.01	0.9924	1.0075	0.6957
Arnold	grass.tiff 300*168	Marbles.tiff 1600*900	0.01	0.9912	1.0088	0.7198

TABLE 2
COMPARISON OF SC, MD, AND NAE

Method	Cover Image	Secret Image	Value of Alpha	SC	MD	NAE
Matrix Rotation	car.tiff 2560*1600	Cycle.tiff 630*420	0.1	0.9045	26	0.0811
Arnold	car.tiff 2560*1600	Cycle.tiff 630*420	0.1	0.8438	25.5	0.1109
Matrix Rotation	grass.tiff 300*168	Marbles.tiff 1600*900	0.1	0.8529	26	0.1572
Arnold	grass.tiff 300*168	Marbles.tiff 1600*900	0.1	0.8372	25.5	0.1561
Matrix Rotation	car.tiff 2560*1600	Cycle.tiff 630*420	0.01	0.9867	3	0.0092
Arnold	car.tiff 2560*1600	Cycle.tiff 630*420	0.01	0.9828	2.55	0.0111
Matrix Rotation	grass.tiff 300*168	Marbles.tiff 1600*900	0.01	0.9851	3	0.0151
Arnold	grass.tiff 300*168	Marbles.tiff 1600*900	0.01	0.9826	2.55	0.0156

4 CONCLUSION

After getting all the above results we can say that by using Matrix Rotation Transformation, we can have better values of image in terms of various factors of image in less time as compared to Arnold Transformation. And this is the one of the methods with which we can stego the gray scale as well as colored image with a single technique. In future this method can be tested with other wavelet transform techniques with various image quality measurements and with more fast simulation.

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