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An Improved High Capacity and Robust Steganography using Hybrid Wavelet and Scrambling Techniques

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Abstract— Steganography hides the especially survival of a message so that if flourishes it generally attracts no suspicion at all. There are many techniques to carry out steganography on electronic media, most especially audio and image files. In this paper, we proposed a secure steganography scheme hiding a large-size gray image into a small-size gray image with different combination of Discrete Wavelet Transform (DWT) and Integer Wavelet Transform (IWT). Pixel Value Adjustment (PVA) is first performed on cover images. Then both cover and secret image are decomposed into 8x8 blocks. Perform Arnold transforms for secret image to get the scrambled secret image by using a secret key. Apply DWT /IWT on both cover and scrambled secret image. Blending process is applied to both images and compute Inverse DWT/IWT on the same to get the stego image. The extraction model is actually the reverse process of the embedding model. Different combinations of DWT/IWT transform is performed on the scrambled secret image and cover image to achieve high security and robustness. Hybrid transform combination approach and case analysis provided the various hiding environment. Experimental results analyzed and showed the stego-image with perceptual invisibility, high security and certain robustness. All case study cases were tested with various quality metrics, which should be useful for wavelet based research in steganography applications.

Index Terms— Steganography, PVA, DWT, IWT, Fusion process, Image quality metrics.

I. INTRODUCTION

Steganography is a method of hiding data in a coverage file. The steganography technique has to satisfy three requirements viz., (i) Capability measurement is the amount of payload embedded into the cover image. (ii) Imperceptibility is the stego image must be similar to the cover image. (iii) Security is the hidden payload in the cover image should not be disturbed by the noise in the communication channel and also not to reveal to hackers. There must be a tradeoff between the three parameters to have better steganographic technique.

Choosing the hiding medium as the criteria, the steganographic techniques are classified as (i) Text- or linguistic based Steganography uses written natural language to conceal secret information. (ii) Audio Steganography embeds the message into a cover audio file as noise at a frequency out of human hearing range by LSB manipulation, phase coding and echo hiding. (iii) Image Steganography hide the secret message in the images which is nearly impossible to differentiate by human eyes. Based on the data hidden in the pixels directly or in the coefficients obtained after a suitable transform domain leads to spatial domain and frequency domain steganography. Today steganography is mostly used on computers with digital data being the carriers and networks being the high speed delivery channels.

II. STUDY RELATED TO STEGANOGRAPHY

A widely used method of data hiding is replacing the least significant bits (LSB) of the digital image by secret message. The LSB methods generally achieve both high capacity and high imperceptibility. Jessica Fridrich proposed a LSB based high order statistical method for detection of secret message embedded in the digital image[1].

Recently reversible image compression methods have been proposed using IWT. Silvia Torres-Maya has proposed BPCS and IWT based system shows a high data hiding capacity, while keeping high fidelity of a stego image (more than 35 dB of PSNR) [2]. P. Chen and H. Lin have proposed a pattern based image steganography in which first the DWT is performed on the digital image, separates the overlapping blocks and then classifies the wavelet coefficient of these overlapping blocks into a several patterns [3]. Mohamed Ali Bani Younes has proposed a steganographic approach for hiding. This approach hides the least significant bit insertion to hide the data within encrypted image data[4]. Raja.K.B has proposed a novel image adaptive steganographic technique in integer wavelet transform domain [5]. MamtaJuneja has proposed a robust image steganography technique based LSB insertion and encryption [6]. Manjunatha Reddy H.S has proposed an approximation band of the payload and wavelet coefficient of the cover image is fused based an alpha and beta. This method payload capacity increase as the only approximation band of payload is considered [7]. Akhil Khare has proposed DCT based algorithm for hiding the large volume of data in image incurring minimal perceptual degradation [8].

We focus the performance analysis of wavelet transform technique for further research and various application areas like military, medical etc., Shiva Kumar K.B has proposed a performance comparison of multiple transformation technique with error detection and correction coding technique is employed to ensure more reliable communication [9]. Manjunatha Reddy H.S has proposed a performance analysis of IWT and DWT on Non LSB. It is observed that the PSNR values of the best in the case IWT compare to DWT for all image formats[10]. Tanmay Battacharya has proposed a steganographic technique for hiding multiple images in a color image based on DWT and DCT. This Technique gives satisfactory PSNR value to establish the robustness of the work [11]. Since only selected high frequency components are modified for hiding method so there must be constraint on the secret image size.

This paper presents a new method with various combinations of DWT/IWT for data hiding into the wavelet coefficients of the cover image in order to make best use of the hiding capacity and security to overcome the drawback. In addition, that PVA also gives 1 dB to 2 dB increase in PSNR value. Further this model compared to various quality parameters, which should show the imperceptibility and more secure transmission.

The remaining chapter of the paper will be organized as follows. Chapter three discusses about the methodology used in proposed stenography model and chapter four discuss about the proposed model. Chapter five describes the experimental results and analysis of the proposed steganography method. Chapter six gives the conclusion of the paper and suggests future improvements of the system. References given in the last chapter.

III. PROPOSED WORK

The following session describes the implementation of the encoding and decoding process in a sequential manner. The schematic representation of encoding and decoding process was given in fig. 3. (a) and fig. 3. (b). The proposed algorithm is presented below.

A. Encoding Process and Decoding process

During the encoding process that the cover image and secret image was decomposed into 8x8 pixel blocks. Apply Arnold transforms for secret image by using a secret key to get scrambled secret image. Both cover and scrambled secret image was relocated by DWT/IWT transform domain and then by blending process. Next, IDWT/IIWT was performed to reform the stego image.

The recover stego image was decomposed into 8*8 blocks. Each 8x8 pixel block was reconstructed with DWT/IWT transform domain and followed by blending process. Next, IDWT/IIWT was performed to rebuild the secret image.

We summarize the process step-by-step as follows in the algorithm;

1). Algorithm for encoding process:

Input : Cover image and secret image both are NxN size.
Output : Stego image (NxN size)

Step1: Read the Cover Image **CI** and Secret Image **SEI** file into 2-D array. Apply PVA on **CI.**
Step2: Both CI and SEI are decomposed into 8x8 blocks.
Step3: Perform a 2-D DWT/IWT at level 1 of the image **CI.**
Step4: Extract the approximation co-efficient of matrix LA and detail coefficient matrices LH, LV & LD of level 1of the image **CI**.
Step5: Apply Arnold transformation of SEI uses secret key to get Arnold scrambled secret image **ASSI**.
Step6: Next extract the approximation co-efficient of the matrix LA1 and detail coefficient matrices LH1, LV1 and LD1 of level-1 of the image **SSI**.
Step7: Apply Alpha blending process for on **CI** and SSI to form Blending Image **BI**.
Step8: Finally, perform 2-D IDWT/IIWT on **BI** and form the stego Image **SI.**

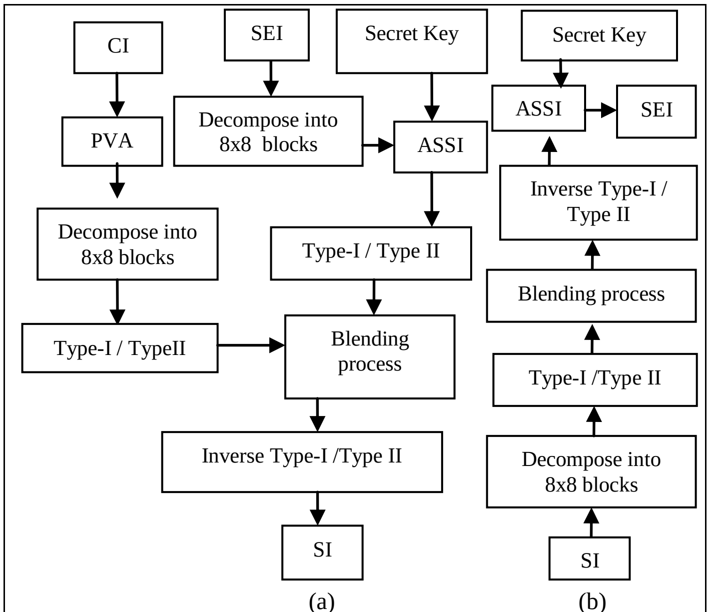


Fig 1. Shows proposed a). Encoding model b).Decoding model (Cover Image-CI, Secret Image-SEI , Type-I : DWT , Type-II: IWT, Stego-image-SI, Arnold Scrambled Secret Image-ASSI)

2). Algorithm for decoding process

Input : Stego image and Cover image both are NxN size.
Output : Secret image (NxN size)

Step1: Received the image **SI** and the obtained **SI** is decomposed into 8x8 blocks.
Step2: Perform a 2-D DWT/IWT at level 1 of the **SI**.
Step3: Apply blending process on **SI**
Step4: Next separates the wavelet coefficients and take IDWT/IIWT to reform the **ASSI.**
Step5: Apply Arnold transformation on SSI using secret key to recover secret image **SE1**.

The schematic representation of encoding and decoding process was given in Figure 1a and 1 b.

B. Analysis of Algorithm and Case study of DWT and IWT blend mode:

The following session describes the analysis of proposed algorithm and case study of the blend and combines model. Implementation of the encoding and decoding process by applying DWT or IWT in cover image, secret image and inverse of fusion image is considered. So, we had tried a different combination of secure steganography systems. This case study is very much useful for steganalysis and various applications. This study includes analysis of proposed algorithm and four cases in our proposed model.

1). Analysis of Algorithm

Read the cover image and secret image file into a 2-D array.PVA is applied to both cover image..It is used to prevent the overflow /underflow that occurs when the change values in wavelet co-efficients. Produce the stego image pixel values to exceed 255or to be smaller than zero. This problem can be solved by mapping the lowest 15 gray value levels of the value of 15 and the highest levels of the value 240.

Note that this process gained the 1 dB to 2 dB in Peak Signal to Noise Ratio (PSNR).Transform each block to the transform domain using 2-D Haar DWT / IWT is resulting four subband LL,LH,HL and HH. It is actually the conversion of spatial domain to frequency domain.This process gives safety environment for hiding the data.The important process for combining the both images into one by using fusion process. Apply fusion process for each bands with suitable binding factors alpha and beta.

From our experiments of different values of alpha and beta,we divided the system in Three categories of operation operation depending on the requirements of users. Fusion process, we use the multipliers as followed in (1).

$$\text{alpha}+\text{beta}=1 \qquad (1)$$

Category-1: **1<Alpha>0.5**, traditionally visible secret image or watermark. It is used to Watermarking technique.

Category-2: **0.5<Alpha>0.3**, High security with more visible secret image in stego image. It is not used in hiding technology.

Category-3: **0.3<Alpha>0.001**, Medium security with reasonable high visual quality of steganography. It can select because of acceptable and accurate embedded depth for security.
Note that, we dropped the 1 and 2 category for our experiment. Because it should cause the either visible more or make distortion of the secret image.

2). Case study

In our case study, the various wavelets are like DWT and IWT combination are taken and worked out in our experiment. We mention type I for Haar DWT and Type II for Haar IWT in our experiment. We use the 3-bit binary coding for easily identify the dwt and iwt. For example 0 represent DWT and 1 represent IWT for our experiment. Cover image(CI), Secret image(SI) and Fusion Image(FI) are used in our case study.The following case study gives an idea to implementation of secure mode.

Case-1:

[Reference code =000, CI=Type I, SI=Type I and FI=Type-I]

Step 1: Firstly, take cover image and perform 2-D type-I transform and get the four sub bands.
Step 2: Secondly, taken a secret image and perform 2-D type-I transform and get the four sub bands.
Step 3: Thirdly, apply the fusion process on both transformed image and form a fused image. In this procedure we applied fusion parameter alpha, which is obtained by according to our study in category-2.
Step 4: Finally apply Inverse type-I also obtained a stego image.
Step 5: Receive the stego image and take type-I and use the above Step-1 to form wavelet co-efficient.
Step 6: Perform again the Step3 and get fused image.
Step 7: Regain the secret image by applying the Inverse type-I.

Case-2:

[Reference code =111, CI=Type II, SI=Type II and FI=Type-II]

This case also similar to case 1 and following steps 1 to step 7 apply type-II instead of type –I.

Case –3:

[Reference code =101, CI=Type II, SI=Type I and FI=Type-II]

We follow the case 1 step1 and step 2 only apply type II instead of type I. Final step apply type II instead of type I.

Case-4:

[Reference code =010, CI=Type I, SI=Type II and FI=Type-I].

We take the case 1 step1 and step2 applies type II instead of type I. Then Step 4 applies type -II instead of type I.

Our analysis, the other combination cases also consider in our study but this should not get the clear stego image and secret image. In our first case and second case provides high visual quality of stego image. The third case provides medium visual quality and fourth one provides reasonable visual quality of stego image. The other cases give worst visual quality of stego image. Even though these are all bad, we consider some cases are considered for various applications. In these cases we apply noise filters to remove the noises.

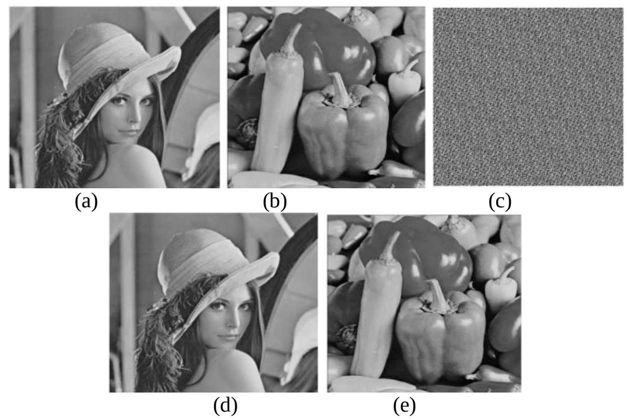


Fig.2. Shows (a) cover image, (b) secret image, (c) Scrambled secret image,(d) stego image, (e) Extracted secret image.

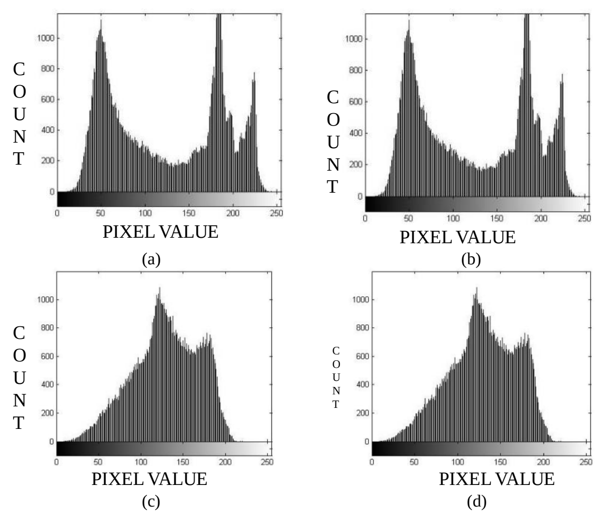
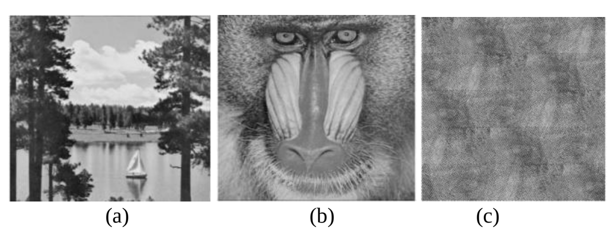


Fig 3. Shows the Histogram plot of (a) cover image (b) stego image (c) secret image (d) recovered secret image.



(d) (e)

Fig.4. Shows (a) cover image, (b) secret image, (c) Scrambled secret image,(d) stego image, (e) Extracted secret image.

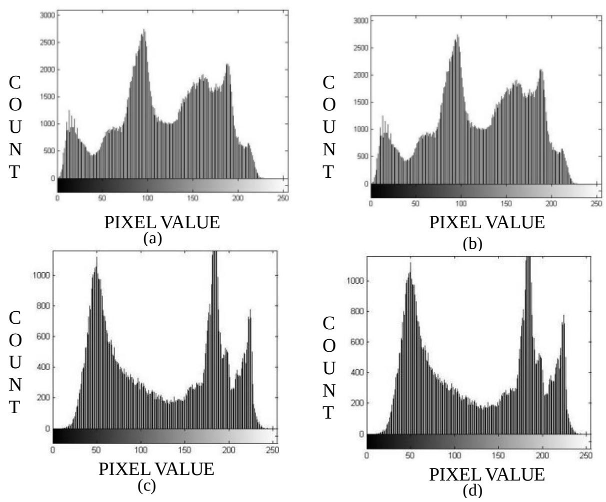


Fig 5. Shows the Histogram plot of (a) cover image (b) stego image (c) secret image (d) recovered secret image.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

To evaluate the performance of the proposed method by using Matlab R2010a, 7.10 version. In our experiment, we have tested 200 general example images and tested into our proposed algorithm. We have taken two images cover image lena.jpg (512x512) and secret image chilli.jpg (512x512) are considered as for our experiment. First of all, we experiment with both images dimension of 512×512. Then second experiment we use cover image of 512x512 size and then secret image resize of 1024x1024 size. We tested the various alpha values in between ranges from 0.05 to 0.01.

Fine tuning the embedding strength factor using alpha and improve the quality level of stego-image. Then, we tested full secret load 600x600 was embedded into 300x300 size, which is obtained by apply 2 level DWT/IWT. The 2nd level of DWT also performed but the approximation band is not clear on the level. These corresponding Images are shown Fig 2 to Fig 5. The histogram of cover and stego imag set with PVA, which indicate the less distortion occurs in the stego image.

A. Image quality metrics

The good visual quality of stego images (i.e. Images embedded with a secret image) is the most important property of a steganography system because it is hard to detect by detectors. We use Peak Signal to Noise Ratio (PSNR) to measure the distortion between an original cover image and stego image.

TABLE-1
COMPARISON OF VARIOUS QUALITY MEASUREMENTS ON COVER IMAGES(300 X300)- LENA.JPG AND SECRET-IMAGE (600X600)-CHILLY.JPG WITH STEGO IMAGE

Cover-image (Forward)	Secret-image (Forward)	Fused-image (Inverse)	MSE	PSNR	NCC	AD	SC	MD	NAE
DWT0	DWT0	DWT0	3.2325	43.30	1.0083	1.4059	0.9835	1.4190	0.0126
DWT0	DWT0	IWT1	1.7582	5.6820	2.0012	-123.26	0.2475	63.62	1.0195
DWT0	IWT1	DWT0	0.7839	49.188	0.9938	0.6466	1.0125	2.1725	0.0060
DWT0	IWT1	IWT1	1.659 $x10^4$	5.930	1.9722	-119.15	0.2549	67.165	0.9857
IWT1	DWT0	DWT0	4.25 $x10^3$	11.845	0.5084	58.416	3.7377	217.42	0.4891
IWT1	DWT0	IWT1	18.0036	35.57	1.0240	-3.6475	0.9532	2.9945	0.0306
IWT1	IWT1	DWT0	4.49 $x10^3$	11.607	0.4939	60.46	3.9561	219.94	0.5054
IWT1	IWT1	IWT1	1.5935	46.107	0.9952	0.4410	1.0097	4.9780	0.0082

(MSE= Mean Square Error) , (PSNR= Peak Signal To Noise Ratio) , (NCC= Normalized Cross Correlation),(AD=Average Difference) , (SC=Structural Content) , (MD=Maximum Difference) , (NAE=Normalized Absolute Error).

TABLE-2
COMPARISON OF VARIOUS QUALITY MEASUREMENTS ON COVER IMAGES(300 X300)- LENA.JPG AND SECRET-IMAGE (300X300)-CHILLY.JPG WITH STEGO IMAGE

Cover-image (Forward)	Secret-image (Forward)	Fused-image (Inverse)	MSE	PSNR	NCC	AD	SC	MD	NAE
DWT0	DWT0	DWT0	0.5498	50.7286	0.9986	-0.0376	1.0027	1.8700	0.0051
DWT0	DWT0	IWT1	1.6921 $x10^4$	5.8846	1.9819	-120.53	0.2524	67.63	0.9970
DWT0	IWT1	DWT0	0.7841	49.1872	0.9938	0.6466	1.0125	2.1835	0.0060
DWT0	IWT1	IWT1	1.6596 $x10^4$	5.9308	1.9723	-119.15	0.2549	67.620	0.9857
IWT1	DWT0	DWT0	4.4099 $x10^3$	11.6865	0.4987	59.785	3.8814	219.08	0.5000
IWT1	DWT0	IWT1	2.9633	43.4131	1.0049	-0.9244	0.9902	4.9835	0.0113
IWT1	IWT1	DWT0	4.4909 $x10^3$	11.6074	0.4939	60.469	3.9561	219.94	0.5054
IWT1	IWT1	IWT1	1.6003	46.0880	0.9952	0.4395	1.0097	4.9780	0.0082

(MSE= Mean Square Error) , (PSNR= Peak Signal To Noise Ratio) , (NCC= Normalized Cross Correlation),(AD=Average Difference) , (SC=Structural Content) , (MD=Maximum Difference) , (NAE=Normalized Absolute Error).

1).Imperceptibility:

The PSNR and MSE of cover verses stego image respectively, the definitions are as follows in (2) and (3)

$$\mathrm{PSNR} = 10\frac{\log_{10}(255)^2}{\mathrm{MSE}}\mathrm{dB} \qquad (2)$$

Where

$$MSE = \frac{1}{MN}\sum_{j=1}^{M}\sum_{k=1}^{N}(x_{j,k} - x'_{j,k})^2 \qquad (3)$$

Where MSE is the mean square error representing the difference between the original cover image x sized M x N and the stego image x' sized M x N, and the $x_{j,k}$ and $x'_{j,k}$ are pixel located at the j^{th} row the k^{th} column of images x and x', respectively. A large PSNR value means that the stego image is most similar to the original image and vice versa. The other

Image quality parameters normalized cross correlation, average difference, structural content, maximum difference and normalized absolute error are taken for our experiment.

Normalized cross correlation (NCC) is defined as in (4).

$$NCC = \sum_{j=1}^{M}\sum_{k=1}^{N}(x_{j,k} - x'_{j,k}) \frac{1}{\sum_{j=1}^{M}\sum_{k=1}^{N}(x_{j,k})^2} \quad (4)$$

Average difference (AD) is defined as in (5).

$$AD = \sum_{j=1}^{M}\sum_{k=1}^{N}(x_{j,k} - x'_{j,k})/MN \quad (5)$$

Structural content (SC) is defined as in (6).

$$SC = \sum_{j=1}^{M}\sum_{k=1}^{N}(x_{j,k})^2 / \sum_{j=1}^{M}\sum_{k=1}^{N}(x'_{j,k})^2 \quad (6)$$

Maximum difference (MD) is defined as in (7).

$$MD = Max(|x_{j,k} - x'_{j,k}|) \quad (7)$$

Normalized absolute error (NAE) is defined as in (8).

TABLE3.SHOWS DIFFERENT STATISTICAL ATTACKS WITH RESPECT TO COVER IMAGES(512 X512)- LENA.JPG AND SECRET-IMAGE CHILLY.JPG (1024x1024) FOR ROBUSTNESS CHECKING

Statistics Attacks	Variance	Case 1	Case2	Case 3	Case 4
Image Contrast	0.04	42.6713	45.4783	34.9413	48.5593
	0.06	42.6346	45.4416	34.9046	48.5226
	0.08	42.5147	45.3217	34.7847	48.4027
	0.1	42.2639	45.0709	34.5339	48.1519
Image suppression	0.04	42.7048	45.5118	34.9748	48.5928
	0.06	42.0491	44.8561	34.3191	47.9371
	0.08	41.2687	44.0757	33.5387	47.1567
	0.1	40.4341	43.2411	32.7041	46.3221
Image rotate	0.5	43.30	46.107	35.57	48.188

$$NAE = \sum_{j=1}^{M}\sum_{k=1}^{N}|x_{j,k} - x'_{j,k}| \Big/ \sum_{j=1}^{M}\sum_{k=1}^{N}|x'_{j,k}| \quad (8)$$

The original cover image x sized M x N and the stego image x' sized M x N, and the $x_{j,k}$ and $x'_{j,k}$ are pixel located at the j^{th} row the k^{th} column of images x and x', respectively.

TABLE4
SHOWS DIFFERENT STATISTICAL ATTACKS WITH RESPECT TO COVER IMAGES(512X512)- LENA.JPG AND SECRET-IMAGE CHILLY.JPG (512X512) FOR ROBUSTNESS CHECKING

Statistics Attacks	Variance	Case 1	Case 2	Case 3	Case 4
Image contrast	0.04	50.0999	45.4593	42.7844	48.5585
	0.06	50.0632	45.4226	42.7477	48.5218
	0.08	49.9433	45.3027	42.6278	48.4019
	0.1	49.6925	45.0519	42.3770	48.1511
Image suppression	0.04	50.1334	45.4928	42.8179	48.5920
	0.06	49.4777	44.8371	42.1622	47.9363
	0.08	48.6973	44.0749	41.3818	47.1559
	0.1	47.8627	43.2221	40.5472	46.3213
Image rotate	0.5	50.7286	46.0880	43.4131	49.1872

The other image quality measurements are compare to cover image and stego image with secret image were measured in terms of error ratio. The summary of the image quality measurements with the corresponding result of the images used in our study has been illustrated in Table 1 and Table 2.

The image quality factors MSE, PSNR and other quality measurement are observed. The effectiveness of the stego image formation proposed has been studied by calculating MSE and PSNR for the two digital images. The result data shows that for less MSE and High PSNR value. Embedding capacity of the proposed method has been computed which is better than the most cases compared to the existing methods. The MSE and PSNR value is also better than existing methods after embedding of secret image in various coefficients of the cover image. Further, steganalysis to compare the quality of recovered secret image with secret image. The best quality stego image formed by the other image quality metrics followed in the ranges. Normalized cross correlation (NCC) is observed ranges from 0.99 to 1.00. Average Difference (AD) is observed ranges from -0.3 to 0.7. Structural content (SC) is observed ranges from0.97 to 1.01. Maximum Difference (MD) is observed ranges from 1.5 to 3.5. Normalized Absolute Error (NAE) is observed from 0.006 to 0.01.

Inference: Optimal level of PSNR ranges from 35db to 45 dB and MSE is as less as possible.

2).Robustness:

Robustness is a measure of immunity of steganography against attempts to image modification and manipulation like compression, filtering, rotation, scaling, cropping etc. We are handling various attacks in the stego image and recover the secret image.The contrast attack and suppression can be performed in the stego image with a different variance value. We can rotate anti-clockwise and clockwise rotating various small deviation angle. Next filtering and speckle noise attacks can be generated , it is tested with small variance value. The resultant values are shown in table 3 and table 4. The PSNR value is tolerable against image processing and recover the secret image.

3).Capacity:

The payload is the number of bits to be embedded in the cover image i.e., Same size and compressed secret image hide into cover image. Scrambling technique used for Arnold Transform with secret key given more security to our model. Any unauthorized person taken the stego image and recover only scrambled image. So without key they should not see the secret message. Blending process gives a depth value that provided a hiding place for secret wavelet coefficients. We achieved more over same size of secret image is embedded.

It is hard for the Human eyes to distinguish between original cover image and stego image when the PSNR ratio is larger than 30dB. We gained PSNR value nearly This model should examine the Haar wavelet with DWT and IWT with high security for testing in various cases.

VI. CONCLUSION

In this paper, we proposed a simple DWT and IWT scheme in spatial domain for digital images by using fusion embedded strategy. The PVA also carried out in this paper it can also gain up to 2 dB in PSNR value. This blend combination approach is capable of achieving more security, imperceptibility and certain robustness. According to our study of alpha and beta multiplier gave deep depth value to hide the secret image. The proposed model has embedded full and double payload (a secret image) for testing the strength of the algorithm. The simulation and results of the analysis identify the safety environment to hide the secret image into cover image. The various case studies with image quality metrics are very much useful for various applications and steganalysis.

In future, this model should be extended to apply in to medical image and report transaction process.

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