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A Novel Data Hiding Scheme Based on Fused Adaptive and Non-adaptive Technique

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Abstract: ***Steganography is a technique of hiding the secret information. Steganography hides the existence of the secret data and make the communication undetectable. Secret data can be communicated in an appropriate multimedia carrier such as image, audio or video. Image steganography is extensively used technique. In this technique secret data is embedded within the image. Steganography techniques can be categorized into two groups - adaptive and non-adaptive. Each of these have its strengths and weaknesses. Adaptive steganography embeds the secret information in the image by adapting some of the local features of the image. Non-adaptive steganography embeds secret data equally in each and every pixel of the image. Several techniques have been proposed for hiding the secret data. Least significant bit replacement is the most common method. This is because it is simple and easy to implement. Discrete wavelet transform is also a widely used technique for embedding secret information. This paper propose a novel steganographic approach for hiding the secret data by fusing both adaptive and non-adaptive methods of steganography. This will give a more secure approach for hiding the secret information as the secret embedded image is almost same and totally indistinguishable from the original image by the human eye. Also the retrieved secret image is same as the original secret image. This is proved by means of high values for PSNR and very little values for MSE.***

Keywords—Steganography, Adaptive steganography, Non-adaptive steganography, LSB, DWT, PSNR, MSE.

1. Introduction

Internet is a mainstream communication medium. Still, message transmissions over the internet need to face a few issues, for example, copyright control, information security, and so on. Consequently we need secure secret specialized strategies for transmitting message over the internet. Encryption is a surely understood strategy for security insurance, which alludes to the process of encoding secret data in such an approach, that just the person with the right key can effectively decode it. In any case, encryption makes the message unreadable, and making message sufficiently suspicious to pull eavesdroppers' consideration. Another approach to tackle this issue is to conceal the secret or mystery data behind a cover with the goal that it draws no extraordinary consideration. This strategy of data security is called Steganography (Petitcolas and Anderson,1998; Petitcolas and Katzenbeisser, 2000) in which imperceptible communication happen. The cover could be a digital picture and the cover image after embedding is called stego-image. Attackers don't have the foggiest idea about that the stego-image has concealed mystery information, so they won't mean to get the mystery information from the stego-picture.

2. Literature Review

With the combined support of computer and internet and with the progress of digital signal processing (DSP), theory of information and coding theory, steganography has gone ‘‘digitized”. In this digital world, steganography has created an impression of corporate awareness that has spawned various remarkable applications, as a result its constant development is in no doubt. Cyber offense is supposed to get profit from this digital revolution. For this reason an instantaneous concern is to discover out best possible attacks to carry out steganalysis, and at the same time, ruling out strategies to make stronger the existing steganography strategies against popular attacks like steganalysis.

Cryptography encodes data in such a way that no one can read it, aside from the individual who holds the key. More progressed crypto procedures guarantee that the data being transmitted has not been adjusted in transit. There is some distinction in cryptography and steganography. In cryptography, the covered up message is always visible, however in steganography the covered up message is always imperceptible and thus it does not attracts the intruders.
The contrast features among steganography and cryptography is given in the following table.

Table 1: Steganography versus cryptography

S.No.	*Feature*	*Steganography*	*Cryptography*
1	Carrier file	Image, text, audio, video, etc	Generally text
2	Secret data	Image, text, audio, video, etc	Generally text
3	Key	Optional	Necessary
4	Objective	Secret communication	Data protection
5	Visibility	Never	Always
6	Result	Stego-file	Cipher-text
7	Attack	Steganalysis	Cryptanalysis

Over the past, various work has been made on steganography. An extremely no doubt understood steganographic technique is the Least Significant Bit (LSB) substitution strategy. It embeds secret information by replacing m LSBs of a pixel with m secret bits specifically[1].To minimize the picture distortion, Chan–Cheng proposed a simple LSB algorithm taking into account optimal pixel adjustment [2] in 2004. Zhang and Wang proposed a algorithm [3] which is represented in (2n + 1)-ary documentation plan. In this plan, just one pixel of n pixels into one group is increased or decreased by 1. In 2006, Jarno Mielikainen [4] proposed LSB matching algorithm for embedding secret or mystery message. Zhang and Wang's plan and Mielikainen's plans [3],[4] had the limited limit for embedding. The purpose of security in LSB-based plans is poor in light of the fact that they just shift the LSB of the picture pixels. An assortment of steganalysis algorithms e.g. RS detector[5] can be utilized to recognize the mystery data effectively. Likewise, all the pixels in the cover picture can't endure equivalent measure of embedding without creating noticeable distortion. Subsequently, it can be effortlessly seen by eavesdropper. To defeat these issues, adaptive strategies for embedding have been proposed [6],[7],[8],[9],[10]. In these techniques, measure of inserting mystery message in pixels is variable. These techniques yield more unnoticeable result than straightforward LSB and other non-adaptive strategies. Adaptive procedures calculate the concealing limit of the cover image by adapting some of the local feature of the cover image.[11],[12]. One adaptive strategy proposed by Wu-Tsai utilizes the distinctive values between two neighboring pixels to locate the quantity of mystery bits to be embedded [13]. A novel steganographic technique proposed by Wu et al. utilizes LSB and pixel values differencing (PVD) strategy. In this algorithm, the pixels situated in the edge areas insert the mystery information utilizing PVD calculation and the pixels situated in the smooth areas embed utilizing 3-LSB algorithm. In 2008, Yang et al. [14] proposed a LSB matching adaptive steganography which utilizes the distinctive values of two continuous pixels in light of bit adjusted LSB technique to recognize edge and smooth regions. In 2009[15] Safy et al. proposed an adaptive method based on integer wavelet transform which gives higher embedding capacity and good imperceptibility. Weiqi et al. in 2010 [16] and Sivaranjani et al. in 2011 [17] have proposed a adaptive image steganography utilizing LSB matching revisited. In these algorithms, edge areas of cover picture have changed and the smooth areas stayed stable. In 2012[18] a robust technique has been proposed by Chirag Sharma and Deepak Prashar. This technique is utilized in the embedding of secret data in such a manner that eavesdropper cannot find it. There is less loss of quality of secret data. In 2013 [19],Yu and Wang proposed a adaptive steganography algorithm in the sparse domain. Again in 2013 a color data hiding scheme was proposed by Hemalatha et al. [20] using Discrete wavelet transform(DWT) and integer wavelet transform. In 2014 [21], Maleki et al. proposed an adaptive and non-adaptive schemes for grayscale pictures taking into account modulus function. Adaptive system uses average difference value of four neighbor pixels and modulus function. The average difference value of four neighbor pixels and a threshold secret key are utilized to determine the edge or smooth range. Additionally, this adaptive strategy can oppose against the RS steganalysis assault. Non-adaptive strategy gives least distortion in the stego-picture.

3. Problem Statement

Several work has been done on LSB and DWT techniques. Both of these techniques have various advantages and disadvantages. These are explained as follows.

3.1 Advantages of LSB-

The advantages of LSB are its easiness to insert the bits of the message clearly into the LSB plane of cover picture and various systems use these techniques. Modulating the LSB does not happen in a human-recognizable distinction in light of the fact that the adequacy of the change is little. In this way, to the human eye, the consequent stego-picture will give off an impression of being unclear to the cover image. The rewards of LSB scheme are:

1)Popularity.
2)Ease of understanding.
3)High perceptual transparency.
4)Low distortion in the image quality.
5)High embedding capacity.

Many commercial software are available which follow this approach. Examples are WebStego, Stego, S-Tools etc.

3.2 Disadvantages of LSB-

Notwithstanding, there are couple of shortcomings of LSB. It is extremely fragile to any sort of filtering and manipulation of the stego-picture. Scaling, rotation, cropping, or lossy compression to the stego-picture will destroy the message. On the other hand, for the concealing limit, the size of data to be hidden depends to the size of the cover image . The secret message must be less than the cover image and accordingly weakens the bandwidth needed to transmit the stego-picture. Another shortcoming is that an assailant can destruct the message by evacuating the whole LSB plane with exceptionally little change in the perceptual nature of the changed stego-picture .

Hence the disadvantages are:
1)Low robustness to malicious attacks.
2)Weak to withstand the noise.
3)Low temper resistance.
4)Slow.

3.3 Advantages of Wavelet Theory-

1)Wavelets presents a simultaneous localization in time and frequency domain.
2) Second advantage of wavelets is that, using fast wavelet transform, it is computationally very fast.
3) Wavelets are able to separate the fine details in a signal.
4) A wavelet transform is used to decompose a signal into component wavelets.
5) In wavelet theory, it is often possible to obtain a good approximation of the given function by using only a few coefficients which is the great achievement in compare to Fourier transform.
6) Wavelet theory is capable of revealing aspects of data that other signal analysis techniques miss the aspects like trends, breakdown points, and discontinuities in higher derivatives and self-similarity.
7) It can often compress or de-noise a signal without appreciable degradation.

Advantages of DWT-
1) Higher flexibility: No need to partition the input coding into non-overlapping 2-D blocks.

2) Permit good localization both in time and spatial frequency domain.
3) Good Performance

3.4 Disadvantages of DWT-

1)The expense of computing DWT as contrast to DCT may be higher.
2)The utilization of bigger DWT basis functions or wavelet filters produces obscuring and ringing noise close to edge regions in images or videos.
3)Long compression time.
4)Low superiority than JPEG at less compression rates.

4. Methodology

In order to get rid of the drawbacks of LSB and DWT techniques and to get the advantages of both, a fused approach is proposed in this paper. In this method, both LSB and DWT are used for embedding secret data (which is an image here) in a single cover image. The LSB method is applied on the blue colored pixels and the DWT method is applied on the red colored pixels of the colored cover image. The algorithm is given below-

Step1- Select the secret image.
Step2- Convert this image into one dimensional vector.
Step3- For each value in the vector
    Perform binary conversion of value.
    Take 4 msb bits of every pixel and keep them in the first half of the final secret image.
    Take 4 lsb bits of every pixel and keep them in the second half of the final secret image.
  End.

First half of this secret image will be embedded by blue colored pixels using adaptive LSB technique and second half will be embedded by red colored pixels using non-adaptive DWT technique.

4.1 LSB Replacement Method

LSB replacement embeds a secret message into the cover image by replacing the k LSBs of the cover image with k message bits to arrive at the stego image. In the majority of existing techniques, the choice of embedding places within a cover image depends on a pseudorandom number generator without taking into account the relationship between the image content itself and the size of the secret message. Hence the smooth regions in the cover images will indisputably be contaminated after hiding data even at a low embedding rate, and this will give poor visual quality and low safety, especially for those images with many smooth areas. When considering a 24-bit color image, a bit of every three colors - red, green and blue can be utilized, so in totality 3 bits can be stored in each pixel. For instance, the given grid can be taken as 3 pixels of a 24-bit color image:
(00101101 00011100 11011100)
(10100110 11000100 00001100)
(11010011 10101101 01100011)
When the character B, which is represented in binary form as 01000010, is embedded into the least significant bits of this part of the image with k=1, the resulting grid is as follows:
(0010110**0** 0001110**1** 11011100)
(10100110 11000100 00001100)
(11010011 1010110**0** 01100011)
Here, simply the 3 underlined bits required to be changed according to the embedded message. On an average, just half of the bits in an image will require to be changed to conceal a secret message. Because there are 256 possible intensities of every primary color, altering the LSB of a pixel fallout in small changes in the intensity of the colors. These little changes cannot be perceived by the human sight and therefore the message is effectively hidden. One can still conceal the message in the least as well as second to least significant bit and still not see the dissimilarity. In the above example, consecutive bytes of the image, from the first byte to the end of the message, are utilized to embed the information. This method is very straightforward to detect.

4.2 LSB Using Adaptive Steganography

Adaptive LSB scheme is one in which the embedding can be done into the pixels by adapting some of the local feature of the image. These features can be edge areas, smooth areas, texture, intensity, etc. In computer, digital images are represented as arrays of values. These values represent the intensities of the three colors Red (R), Green (G) and Blue (B), where a value for each of three colors depicts a pixel. Every pixel is a combination of these three color components(R,G and B). In this paper, a hybrid method for data hiding is proposed. In this scheme, the blue pixels which are more in the image (this can be detected by means of histogram) are used to embed 4 bits of secret data and remaining pixels are used to embed 2 bits of secret data.

The algorithm for adaptive LSB is as follows-

Step1: Select the cover image and the secret image to be embedded.
Step 2: Compute the histogram of the blue component.
Step 3: Pick the highest bin from histogram.
Step 4: Generate a location map by index of the bins selected by histogram.
Step 5: Selected index will embed 4 bits of secret data.
Step 6: Rest of the pixels will embed 2 bits of secret data.
Step 7: Write the new image.

Algorithm for extraction:

Step 1: Read the image.
Step 2: Restore the histogram of the original image by location map.
Step 3: Extract 4 lsbs bits from the location map values .And extract 2 bits from the remaining pixels.
Step 4 : Write the image.

4.3 Discrete Wavelet Transform Scheme

The wavelet transform (WT) has gained widespread acceptance in signal processing and image compression. Because of their inherent multi-resolution nature, wavelet-coding schemes are especially suitable for applications where scalability and tolerable degradation are important. Recently the JPEG committee has released its new image coding standard, JPEG-2000, which has been based upon DWT. Wavelet transform disintegrates or decomposes a signal into a set of basis functions. These basis functions are called wavelets. Discrete wavelet transform (DWT),transforms a discrete time signal to a discrete wavelet representation.

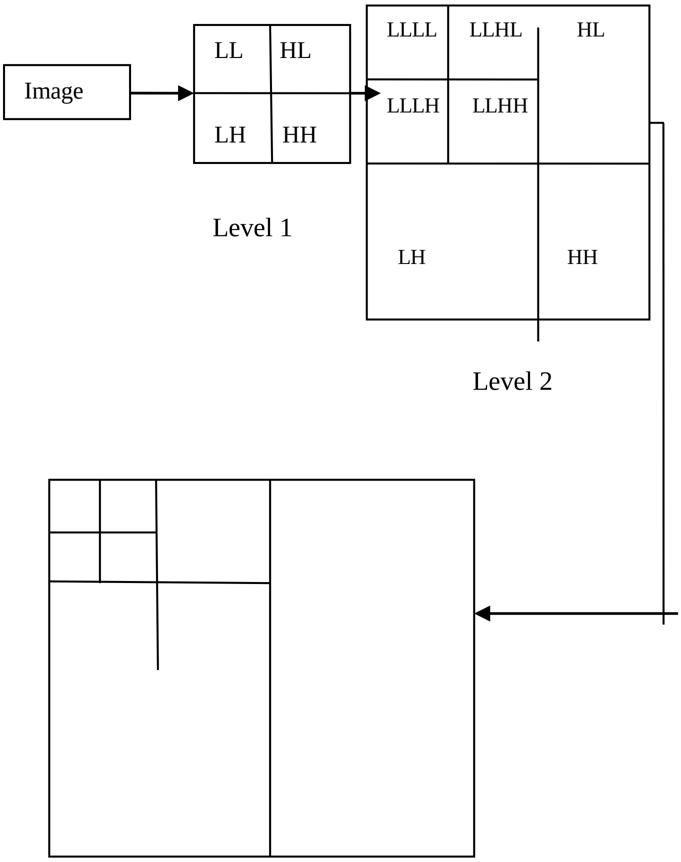

Figure 1: 2D DWT for image

Most recent researches are intended for the use of DWT because it is used in the new image compression format MPEG4 and JPEG2000, examples of using DWT can be found in [15]. In [15], the secret message is embedded into the high frequency coefficients of the wavelet transform while leaving the low frequency coefficients subband unchanged. Some mathematical operations are done on the secret messages before embedding. These procedures and a well made mapping table keep the messages away from stealing, destroying from unintended users on the internet and hence provide agreeable security. The advantages of transform domain techniques over spatial domain techniques are their high ability to bear noises and some signal processing operations but they are computationally very complex and slower. Here, DWT is applied on the red colored pixels of the cover image to embed secret data.

The algorithm for embedding using DWT is as follows-

Step 1 – Select the cover and secret image.

Step 2- Perform DWT decomposition of both the images.

Step 3- Applying following equation in each component

Component of embedded image =

k*(component of cover image)+
q*(component of secret image)

Step 4 - Applying inverse DWT on the new components.

Step 5- Retrieve embedded image.

Step 6- End.

k, q - Scaling factors for the original image and secret image respectively.

The algorithm for extraction is as follows-

Step1- Select the stego-image.

Step 2- Perform DWT decomposition of the secret image.

Step 3- Applying following equation in each component

Component of secret image=

$$\frac{\text{(component of embedded image} - \text{k * component of cover image)}}{q}$$

Step 4- Perform IDWT decomposition on retrieved secret image.

Step 5- Write the final retrieved secret image.

5. Results and Calculation

5.1 Mean Square Error(MSE)

The MSE of an estimator calculates the average of the squares of the errors, that is, the distinction between the estimator as well as what is expected. MSE is a risk function, linking to the normal estimation of the squared error loss or quadratic loss. In statistical modeling, the MSE is utilized to focus to what degree the model does not fit the information, or whether evacuating certain terms could rearrange the model in gainful ways. The MSE provides a method for picking the best estimator: a negligible MSE regularly, however not generally, demonstrates minimal variance, and subsequently a good estimator.

If $\hat{X}$ is a vector of n predictions, and X is the vector of the true values, then the (estimated) MSE of the predictor is:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(\hat{X}_i - X_i\right)^2 \qquad (1)$$

5.2 Peak Signal to Noise Ratio(PSNR)

PSNR, is a term for the proportion among the most possible power of a signal and the power of ruining noise that influences the trustworthiness of its representation. PSNR is generally spoken in terms of the logarithmic decibel measure. PSNR is used to gauge the excellence of rebuilding of lossy compression codecs. The signal for this situation is the original information, and the noise is the fault obtained by compression. PSNR is an estimation to human being perception of rebuilding excellence. In spite of the fact that a superior PSNR by and large demonstrates that the recreation is of superior class, it might be not true always. Individual must be amazingly watchful with the extent of legitimacy of this metric; it is just convincingly legitimate when it is utilized to analyze results from the same codec (or codec sort) and same content .

The PSNR is defined as follows-

$$PSNR = 10.\log_{10}\left(\frac{MAX_i^{\,2}}{MSE}\right) \qquad (2)$$

Where MAX_i is the maximum possible pixel value of the picture. For color pictures, the definition of PSNR is the similar apart from the MSE is the total over all squared value differences divided by image size and by three. In this paper, we have used color images of Lena, Mandrill, Peppers and Barbara as cover images and the grayscale image of Tiffany as the secret image. The cover images are of size of 512x512 and the secret image is of size 128x128.

MSE and PSNR of original versus stego-image are as shown in the table 2.

Table 2

Cover image	Secret image	MSE	PSNR
Lena	Tiffany	0.22779	54.5895
Mandril		0.16253	56.0555
Peppers		0.17809	55.6584
Barbara		0.1737	55.7668

When attack with rotation is applied on the original image the values of MSE and PSNR are shown in the table 3 as follows.

Table 3

Cover image	Secret image	MSE	PSNR
Lena	Tiffany	0.22778	54.5896
Mandrill		0.16253	56.0555
Peppers		0.17809	55.6584
Barbara		0.17369	55.767

When attack with noise is applied to the original image the values of MSE and PSNR are as follows-

Table 4

Cover-image	Secret image	MSE	PSNR
Lena	Tiffany	0.21464	54.8478
Mandrill		0.16206	56.0681
Peppers		0.17822	55.6552
Barbara		0.15913	56.1474

The images of Lena, Mandrill, Peppers and Barbara are as shown below in figure 2.

Lena

Mandrill

Peppers

Barbara

Figure 2: Cover images of Lena, Mandrill, Peppers and Barbara

The secret image of Tiffany is shown in figure 3 below.

Figure 3: Secret image of Tiffany

The retrieved secret image of Tiffany is shown below.

Figure 4: Retrieved secret image of Tiffany

The following graph shows the Image versus MSE of the 512x512 images for the three cases –

1)Without attack,

2)Attack with rotation,

3)Attack with noise.

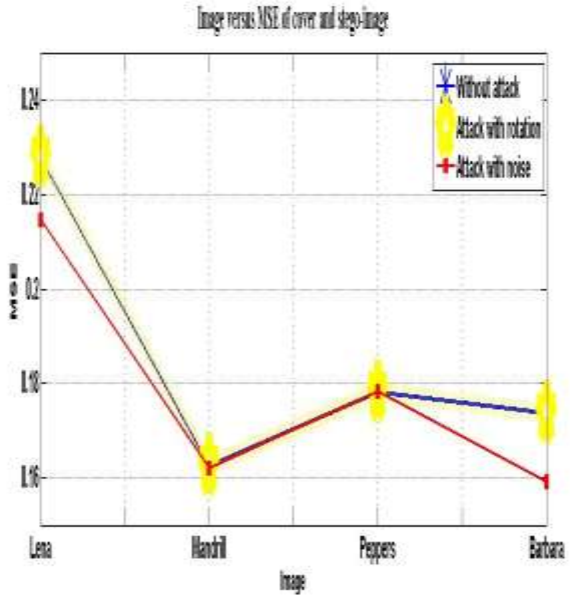

Figure 5

Similarly, the following graph shows the Image versus PSNR of the original and stego-image when we take the same cover images of size 512x512 and secret image of size 128x128 for the same three cases.

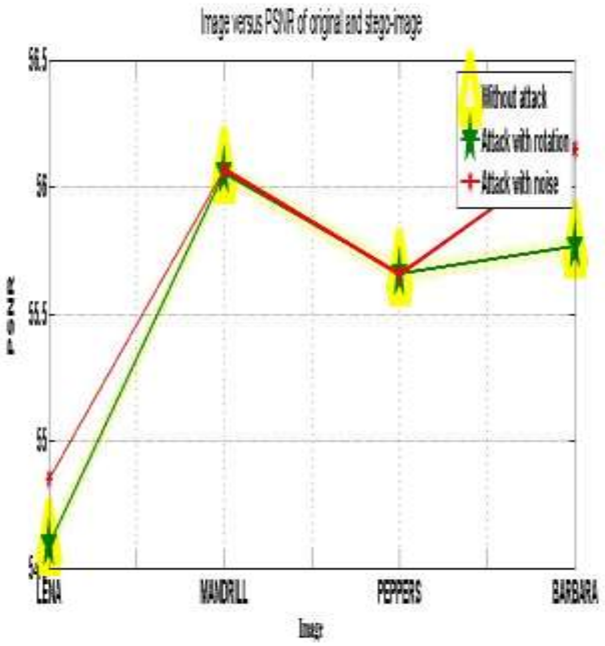

Figure 6

PSNR values are high that shows high efficiency of our data hiding method. The graph of figure 2 shows that when attack is applied on the original image, the MSE between the original and the stego-image remains nearly same and this is very little, and there is actually no increase in it by applying attacks. The graph of figure 3 shows that PSNR is more than 54.5 which is excellent. These results shows that there is no any visual difference between the original and the stego-image. Hence intruders will not be able to identify that something secret is going to be sent. Also the retrieved secret image and the original secret image are approximately same.

Following the sequence of experiments performed on images in MATLAB, we have find out that our proposed method is better than LSB technique because it is more robust to Rotation, cropping and noise attacks and there are small number of frequency components lost in the stego-image. To measure the efficiency of the technique, the performance metrics are measured. The quality of the stego-image and retrieved secret image is measured by the PSNR and MSE. PSNR is given only to provide us a rough estimate of the quality of the stego-image and secret image. By using equation 1 and 2 we have calculated MSE and PSNR values. The results shows the high value of PSNR ranging from 54.5 to 56.14 db (decibel). This shows that the proposed method is capable enough to handle attacks.

6. Conclusion

In the emergent field of multimedia technology, the area of steganography has major significance but still there is a need to safeguard the digital data since intruders are finding various means to copy secret information and use it criminally. The technique proposed in this paper is useful in embedding of secret information in such a way such that intruder cannot find it effortlessly and there is less loss of quality after the embedding of secret information inside the images. A number of strategies have been proposed for steganography. A fused approach using adaptive and non-adaptive methods of steganography has been presented here. With various experiments and results we conclude that that effect of attacks on secret data represented by means of MSE and PSNR seems to be negligible. MSE and PSNR of original and stego-image is comparatively better than other similar fused approaches. Error rate of retrieved secret image and original secret image is very less. Execution time is less. Time complexity of algorithm is less than other algorithms. However our proposed technique is more robust than LSB Technique thus provide better results in case of copyright protection and ownership identification. The performance of our proposed data hiding scheme is evaluated with common image processing attacks such as additive noises, rotation. Experimental results demonstrates that this data hiding technique is robust against those attacks.

7. Future Scope

The above work can be extended by taking colored secret image instead of grayscale image. Discrete Cosine Transform(DCT) can be used. Also, Single valued decomposition (SVD) can be used. We can combine encryption for more security with the above technique. Again the above work can be extended to video steganography.

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