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A Steganographic Method for Transmitting Images Based on Discrete Wavelet Transform Using Three Level and Single Level Wavelet Decomposition

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Abstract— Todays in digital world , computer helps to transforming analog data into digital form before it can be stored or it can be processing. For transmitting digital data internet is the most important communication medium. If any confidential data to be transmitted over the internet , sometime it is possible to copy, destroy or make some changes in confident data by the malicious user. To avoid this various schemes are recently developed. 0ne of the most important way to hide the secure information is the Steganography. It plays an important role to hide the secrete information. In this scheme embedding a secrete data into a cover message and sending it, message is any text, image, audio/video file. Most of the widely used applications area that uses steganography such as copyright protection, internet security, authentication. In this paper propose a new steganographic method for transmitting digital images based on discrete wavelet transform using two different techniques. One using three level wavelet decomposition taking the single plane of cover image for embedding and processing cover image as 4×4 blocks with swapping and another using single level decomposition.

Keywords— Discrete Wavelet Transform, Peak Signal to Noise Ratio, Entropy, Steganoanalysis and Steganography.

I. INTRODUCTION

Steganography is an alternative method for privacy and security. Instead of encrypting, we can hide the messages in other innocuous looking medium (carrier) so that their existence is not revealed. In cryptography, messages are encrypted and only a rightful recipient can decrypt and read the messages. Unwanted user can destroy or modify some data without violating the certain security guaranteed by the cryptosystem. The goal of cryptography is to protect the content of messages and the goal of steganography is to hide the existence of messages into the cover medium. Often, to achieve higher security, cryptography and steganography are used together. To protect the secrete information from unauthorized user both steganography and cryptography techniques are useful.

In digital media steganography is similar to watermarking but both techniques used for different purposes. Steganography used to hide secrete message with high data capacity while digital watermarking focus on robustness of embedded message rather than data capacity. Steganography can be used to exchange secret information in a undetectable way over a public communication channel, whereas watermarking can be used for copyright protection and tracking cogent use of a particular software or media files. Watermarking technology used for protection of intellectual property such as file duplication management, ownership protection, document authentication. Mainly, steganography used for prudent transmission for military purpose, automatic monitoring of radio advertisement, in medical imaging to embed information like patient and physician name, DNA sequence and other particulars [1]. Other application such as : smart video-audio synchronization, secure and invisible storage of confidential information, identity cards to embed individuals details and checksum embedding [2].

For maintaining the confidentiality of valuable information and protecting it from theft or unauthorized user, to protect intellectual property or trade secrets, Steganography can be used. Steganography concerned with embedding of secret message in a cover object in such a way that he xistence of embedded information is hidden The embedding process is sometimes parameterized by a secret key, called stego key. Without knowledge of stego key it is difficult to detect and extract the secret message for an unauthorized person. Secret message embedded into a cover object that object is called a stego object.

This paper present a steganographic method based on discrete wavelet transform using three level and single level wavelet decomposition. This paper is organized as follows. Section 2 briefly discusses the basic idea of steganography system. Section 3 describes the steganography in spatial domain. Section 4 describes steganography method such as Discrete Cosine Transform(DCT), Fast Fourier Transform(FFT) and Discrete Wavelet Transform (DWT) for transmitting images. Section 5 briefly explain the procedure of proposed techniques i.e three level wavelet decomposition and single level wavelet decomposition.. Section 6 represents experimental results of both techniques and statistical analysis of proposed methods. Section 7 gives the conclusion and future scope. Finally in section 8 list of references that are useful for this work.

II. FRAMEWORK OF IMAGE STEGANOGRAPHY

An information hiding system characterized according to three different aspects Security , Capacity and Robustness as shown in following figure 1.

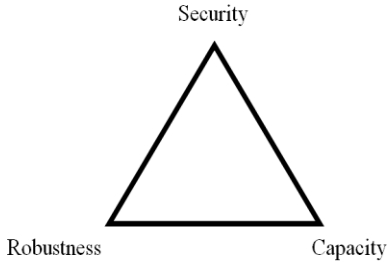


Fig. 1: Information Hiding System Features

Security refers to any unwanted user or attacker unable to detect secret hidden information, capacity refers to amound of data can be hidden in cover medium and robustness to the amount of modification the stego object can withstand before an attacker can destroy any hidden information[3] .

Figure 2 shows the simple representation of generalized framework of steganography system which includes embedding and extraction operation of steganography.

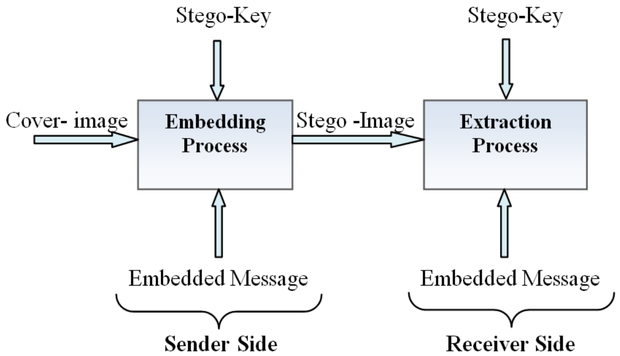


Fig. 2: Generalized Framework of Steganography System

During the embedding operation the secret message is inserted into the cover medium by altering some portion of it. Extraction operation involves reconstruction of secret message from the cover medium. In this example, if the sender wants to send a secret message to the receiver, first sender select ant harmless cover image. Then secret message is embedded inside a cover image and probably uses a stego key and sender gets the stego image. This stego image represents the cover image along with secret image or message embedded inside the cover image. Then sender transmits this stego image to receiver over the public channel for example internet. The stego image can not distinguish from cover image neither by human or by any computer system. The purpose of this system to prevent the serect hidden message from any attacker or any unauthorized party. While at the receiving side receiver gets the stego image they should know the knowledge about the embedding process as well as extraction process and the knowledge about the stego key which is used in the extraction process. With the help of secret key receiver extract the secret image or message. Only sender and receiver should have the knowledge about the stego key. Therefore, most of steganographic systems prompt users to provide a stego key or password when they try to embed information in a cover image.

Steganography technique based on the two approaches i.e spatial domain and frequency domain approach. In spatial domain approach secret message are embedded into least significant pixels of cover image. They are fast but sensitive to image processing attacks. In frequency domain transforming the cover image into the frequency domain coefficients before embedding secret messages in it. The transformation can be either Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) . Though these methods are more difficult & slower than spatial domain. They have an advantage of being more secure and noise tolerant[4]. Now let us discuss the spatial domain and frequency domain approaches.

III. STEGANOGRAPHY IN THE SPATIAL DOMAIN

Spatial domain steganography uses images in spatial domain format for hiding information. This technique encompass bit wise methods that apply bit insertion and noise manipulation to embed information. Data embedding is done by directly replacing data of the image pixel values with secret information[5]. Spatial domain formats can be divided into raster image format and palette based mage formats.

A. Raster Image Format :

In a raster image format, an image is represented in a row-by-row grid of pixels with one or more bytes used to store one pixel depending on bit depth. As a raster image a Windows Bitmap (BMP). The first digital image steganography algorithm developed for raster images was done in spatial domain using LSB coding where the bits are encoded in the cover image by replacing the LSB of pixels. LSB embedding makes use of the small difference created when changing the least significant bit of a byte and is a common, simple approach to embedding information in a cover image.

B. LSB Embedding:

The LSB of some or all of the bytes inside an image is changed to a bit of the secret image. When using a 24-bit image, a bit of each of the red, green and blue colour components can be used, since they are each represented by a byte. The payload capacity can thus be as high as three times the number of pixels in the image. In spatial domain the embedding rate of an algorithm is described as bit per pixel(bpp). LSB embedding in a 24-bit colour image, an embedding rate 3bpp.

LSB embedding can be divided into two broad categories: 1) Fixed –size insertion 2) variable –size insertion methods. LSB embedding types depending on the number of LSBs of each byte used for embedding. In fixed –size insertion methods use a fixed number of LSBs to embed the secret in each byte of the cover image and in a variable –size insertion methods use a variable number of LSBs from each byte of the cover image to embed information according to each pixel's suitable for embedding[6]. LSB embedding is a popular image steganography algorithm due to its easy implementation. However, its main drawback of this is to attacker easily detect the embedded information. This technique is also sensitive to image manipulation attack, such as image resizing, cropping and resampling. It is not suitable for lossy image compression. LSB embedding is thus not robust against image manipulation attacks. for statistical attacks using LSB embedding technique ,easy to detect the embedded information.

C. Palette Based Image Format

Palette based images are another popular image file format. This format is commonly used on the Internet. Images such as computer generated graphics, line drawings and cartoons are often stored using palette based images. The GIF i.e Graphical Interchange format is the most widely used palette based image file format. GIF images are indexed images where the colours used in the image are stored in a palette, sometimes it is also referred as colour lookup table. Each colour in the palette is stored as an 8-bit RGB colour. Each palette based image consist of two parts : the palette and the image data. This is a lossless format.

D. LSB Embedding in Palette Based Images

LSB embedding. can be used to hide information in a palette based image with few modifications to the original LSB algorithm. The pixels of a palette based images store indices not colours, changes to the SBs of pixels could result in visual distortion. The least significant bit of a pixel should be changed [7]. If the adjacent palette entries are similar then there is little or non noticeable change, but adjacent palette entries be very dissimilar, the changes should be evident and the hidden information should be visible .The main drawback of LSB embedding in palette based image is the nature of palette based image itself and possible to visual distortion should change the indices.

The optimal parity embedding algorithm was developed by Fridrich J. and Du R. to hide information in palette based images without changes to palette[8].

E. Optimal Parity Embedding

In optimal parity embedding assigns each colours in the colour palette a parity bit (0 or 1) based on that colours red, green and blue values[8]. The parity bit P is calculated as –

$$P=(R+G+B) \bmod 2 \qquad \text{--} \qquad (i)$$

By using optimal parity algorithm whenever a secret message is embedding, a pixel is selected for each message bit and comparison is made between the pixel's parity bit and the message bit. If they are not same, the algorithm determines the closest colour in the palette with the opposite parity. When this colour is found , the index of the pixel is changed to point to the closest colour.

Thus, the information is hidden in the parity bits of the pixels but not in the LSB values of the pixels. Therefore the visual distortion in the image is minimized since pixels are altered to point to similar colours in the palette. An embedding rate 1 bpp can be achieved and the embedded information is not easily detect[8].

IV. STEGANOGRAPHY IN FREQUENCY DOMAIN

The frequency domain based methods such as Discrete Cosine Transform(DCT), Discrete Fourier Transform(DFT),Discrete Wavelet Transform(DWT).

There is need to development of other algorithm for enhanced security. LSB embedding technique has weak resistance to attacks. So to overcome this drawback researchers found a useful way for hiding information in area of the image that are less exposed to compression, cropping and image processing.

A. DCT

In video and image lossy compression i.e JPEG, DCT is used extensively. Each block DCT coefficient quantized using a specific Quantization Table(QT). To embed secret data most of the techniques uses JPEG images. DCT is used to transform successive sub image blocks(8*8) into 64 DCT coefficient. Data is inserted into these coefficients. A single coefficient would affect the entire 64 block pixels[9].

In spatial domain data embedded in the pixels and in transform domain data embedded in the DCT coefficients.

B. FFT

A Fast Fourier Transform introduces a round of errors, therefore it is not suitable for hidden communication. Johnson and Jajodia[7] , thought differently and included it among the used transformation in steganography and

McKeon[10] uses the 2D discrete Fourier Transform (DFT) to generate Fourier based steganography in movies. Steganography using DFT improper for applications.

C. DWT

Today's the wavelet domain is growing up very quickly. Wavelet has been utilizes as a powerful tool in many application field. Such as applications based on signal processing, physics, astronomy and image processing. Steganography in the transform domain involves the manipulation of algorithms and image transformation. These methods hide messages in more significant areas of the cover image, so making it more robust.

In Discrete Wavelet Transform domain the hidden message can be correctly identified at each resolution, when it is subjected to distortion from compression. In wavelet transform, the original 1-D,2-D and 3-D signals is transformed using predefined wavelets. The wavelets are orthogonal, orthonormal or biorthogonal, scalar or multiwavelets[11].

In this paper a steganographic methods using Discrete Wavelet Transform for transmitting digital images is propose because, DWT allows the use of long time intervals where we want more precise low-frequency information, and shorter regions where we want high-frequency information. The DWT consists in splitting the signal $x[n]$ in low and high frequencies using a lowpass and a highpass filter respectively. In DWT based steganography the information is stored in the wavelet coefficients of an image, instead of changing bits of the actual pixels. Two different techniques are proposed one using single level wavelet decomposition and another using three level wavelet decomposition. The extension of one-dimensional analysis is multi-resolution analysis based on two-dimensional wavelet transform. If $\varphi(x)$ and $\psi(x)$ stand for one dimension scale function and wavelet function respectively, the following one two-dimensional scale function and three two dimensional wavelet functions comprise the foundation of two-dimensional wavelet transform.

$$\left.\begin{aligned} \varphi(x, y) &= \varphi(x)\,\varphi(y) \\ \Psi_H^V(x,y) &= \varphi(x)\,\psi(y) \end{aligned}\right\} \quad \text{--- (ii)}$$

$$\left.\begin{aligned} \Psi^H(x,y) &= \psi(x)\,\varphi(y) \\ \Psi^D(x,y) &= \psi(x)\,\varphi(y) \end{aligned}\right\} \quad \text{--- (iii)}$$

Following L-level decomposition of the image f(x,y), we obtain approximation and three detail transform coefficients

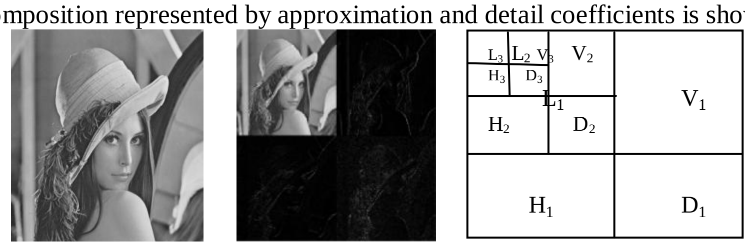
$$A_L f(x,y) = \{f(x, y), \varphi_L(x, y)\} \quad \text{--- (iv)}$$

$$D_H^V f(x,y) = \{f(x, y), \Psi_L^V(x,y)\} \quad \text{--- (v)}$$

$$D_L^H f(x,y) = \{f(x, y), \Psi_L^H(x,y)\} \quad \text{--- (vi)}$$

$$D_L^D f(x,y) = \{f(x, y), \Psi_L^D(x,y)\} \quad \text{--- (vii)}$$

The cover image decomposition represented by approximation and detail coefficients is shown in figure 3.



(a) (b) (c)

a) Image Lena.bmp, b) Result of decomposition, c) Structure of decomposition.

Fig. 3: Image Decomposition by DWT.

In DWT based steganography method contains embedding and extraction process. Following figure 4 and figure 5 shows the block diagram of three level DWT embedding process and extraction process respectively. In this embedding process embed the secret image or stego image on to the cover image using three level wavelet transform. The cover image is made up of three channels Red(R), Green (G), Blue (B). And for embedding we are dealing with G channel. In extraction process reconstruct the original secret image SI.

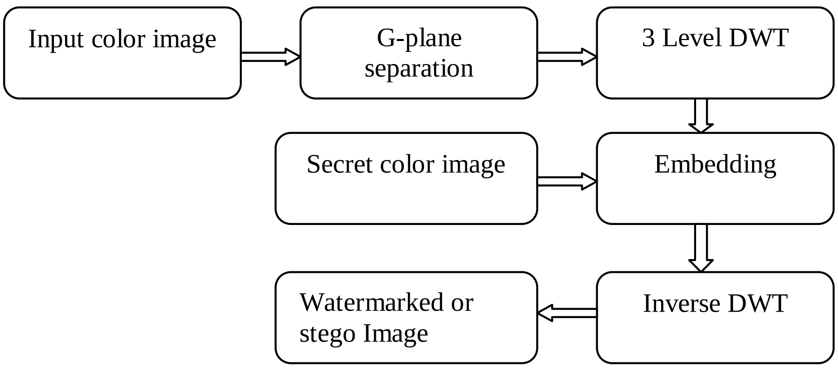


Fig 4: Embedding process using three level DWT

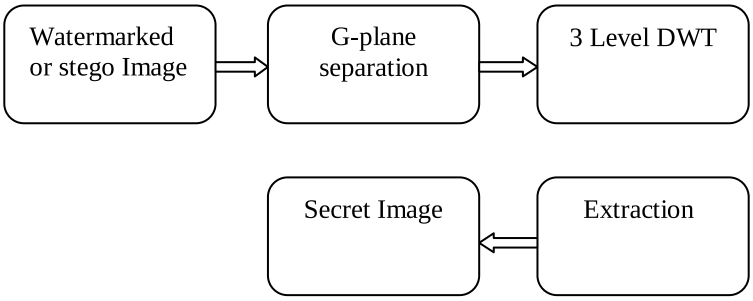


Fig 5: Extraction process using three level DWT

V. IMPLEMENTATION OF PROPOSED METHODS

This section describes the proposed method in frequency domain such as discrete wavelet transform (DWT). There are two different techniques are proposed one using three level wavelet decomposition by applying 2D Haar DWT and another using single level wavelet decomposition by applying Daubechies DWT.

A. Proposed Method 1- Three Level Wavelet Decomposition using 2D-Haar.

l. Perform three level 2D-Haar DWT decomposition as follows:

a) Take the JPEG cover image (CI) (512 x512) and its green plane alone and perform first level 2D-DWT on the image to obtain approximation 1 coefficient (LL1), horizontal 1 coefficient (HL1) and vertical 1 coefficient (LH1), diagonal 1 coefficient (HH1) respectively.

b) Take the approximation 1 coefficient (LLl) and perform second level 2D-DWT on the image to obtain LL2, HL2, LH2 and HH2 respectively.

c) Take the approximation 2 coefficient (LL2) and perform third level 2D-DWT on the image to obtain LL3, HL3, LH3 and HH3 respectively.

2. Take the secret image (SI) and turn it into black and white.

3. Perform Embedding process as follows:

a) Assume an embedding coefficient of value of $\alpha = 0.05$.

b) Process on LL3 block by block (4x4).

c) Process the secret image block by block (4X4).

d) To obtain the secret image block (4x4) following formula is used which is basically swapping,
SI block = {(1- α) * LL3 intensity value} +
{α * SI intensity value}

4. Perform three level 2D-Haar Inverse DWT (IDWT) for reconstruction to obtain the stego image.

5. Perform Extraction process as follows:

a) Perform three level 2D-Haar DWT decomposition on the stego image as well the cover image.

b) Process LL3 of the stego image and cover image block by block (4x4).

c) Assume an embedding coefficient of value of $\alpha = 0.05$.

d) To get the image blocks of the secret image (4x4) following formula is used,
SI block = {LL3 intensity value of stego image – {(1- α) * LL3 intensity value of the CI}}/ α.

6. Calculate RMSE and PSNR values in order to check for the visual quality of the stego image.

B. Proposed Method 2- Single Level Wavelet Decomposition using 2D- Daubechies

l. Take the cover image and the secret image and take the Red (R) plane separately and perform single level 2D-Daubechies DWT decomposition on the cover image as well as the secret image.

2. Assume an embedding coefficient of value ranging from 0 to l, if the value of α is large then it increases robustness and if it is small then increase transparency.

3. To find the approximation coefficient, horizontal coefficient, vertical coefficient and diagonal coefficient of the stego image use the following formula:
Approximation coefficient of Stego image =
{{(1- α) * Approximation coefficient of CI} + {α * Approximation coefficient of SI}}
Similarly, the same formula is used for the horizontal coefficient, vertical coefficient and diagonal coefficient of the stego image.

4. Perform single level 2D- Daubechies inverse DWT decomposition on the calculated approximation, horizontal, vertical and diagonal coefficients of the R plane of the stego image.

5. The above mentioned procedure is done for the Green(G) plane and Blue(B) plane separately and concatenate
Red (R), Green (G) plane and Blue (B) plane to get the stego image.

6. Perform Extraction process as follows:

a) Take the cover image and the stego image and take the Red (R) plane separately and perform single level 2D Daubechies DWT decomposition on the cover image as well as the stego image.

b) To find the approximation coefficient, horizontal coefficient, vertical coefficient and diagonal coefficient of the secret image use the formula:

Approximation coefficient of SI =
{Approximation coefficient of stego image - (1-α) * Approximation coefficient of stego image}/α.
Similarly, the same formula is used for the horizontal coefficient, vertical coefficient and diagonal coefficient of the stego image.

c) Perform single level 2D- Daubechies inverse DWT decomposition on the calculated approximation, horizontal, vertical and diagonal coefficients to get the approximation, and horizontal, vertical and diagonal coefficients of the secret image of the R plane.

d) The above mentioned procedure is done for the Green (G) plane and Blue (B) plane separately and concatenates Red (R), Green (G) plane and Blue (B) plane to get the secret image.

7. Finally, calculate RMSE and PSNR values in order to check for the visual quality of the stego image.

VI. EXPERIMENTAL RESULTS

For visual evaluation, consider natural appearance of secret image. This section present the experimental result of the proposed method. The quality of stego image produced by the proposed method has been tested exhaustively based on various image similarity metrics namely RMSE and PSNR.

A. Embedding and Extraction results using Three Level 2D Haar DWT

Cover image is shown in figure 6 and secret image before embedding is shown in figure 7, after three level decomposition using 2D Haar DWT is shown in figure 8. Stego image with secret image embedded on cover image is shown in figure 9 and the extracted secret image is shown in figure 10.

Fig 6: Cover Image

Fig 7: Secret Image

Fig.8: Cover image after Three Level Decomposition using 2D Harr DWT

Fig. 9: Stego image with secret image embedded on cover image

Fig 10: Extracted secret image

B. Embedding and Extraction results using Single Level 2D –Daubechies DWT

1- Level decomposition using 2D Daubechies DWT Shown in figure 11. Stego image with secret image embedded on cover image is shown in figure 12 and the extracted secret image is shown in figure 13.

Fig. 11: Cover image after Single Level Decomposition using 2D Daubechies DWT

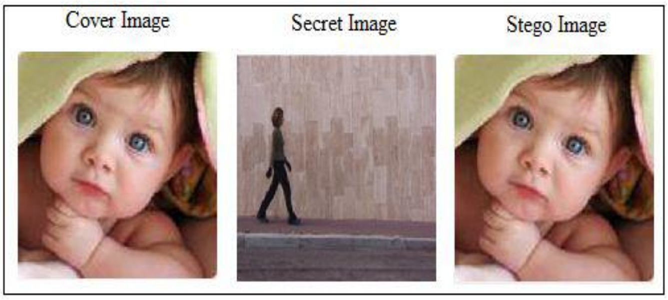


Fig. 12: Stego image with secret image embedded on cover image

Fig 13 : Extracted secret image

C. Stastical Analysis

In addition to the visual analysis, extended investigation to a quantitative analysis. The performance of the proposed technique can be measured by calculating the image quality parameter such as RMSE and PSNR , Entropy and Mean value of the stego image. Table-I and table-II shows the performance of proposed method1 and method2 respectively.

1. RMSE (Root Mean Squared Error)

RMSE is a frequently used measure of the difference between values predicated by a model and the values actually observed from the thing being modeled. Calculate the root mean square error of the corresponding pixels in the reference image I and the extracted image F.

$$RMSE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[I(i,j) - F(i,j)]^2}{M * N} \quad \text{--(viii)}$$

2. PSNR (Peak Signal to Noise Ratio)

The PSNR is the ratio between a signal's maximum power and power of the signal's noise. The PSNR is the most commonly used as quality of reconstruction of extracted image. It is estimated in decibel(dB) and it is defined as,

$$PSNR = 10log_{10}\left(\frac{255^2}{RMSE}\right) \quad \text{--(ix)}$$

Where, 255 is the maximum pixel value of the image when the pixels are represented using 8-bit per samples.

The experimental results are analyzed based on the combination RMSE and PSNR.

3. ENTROPY

The entropy of an image is a measure of information content. The entropy of an image is a statistical measure of randomness that can be used to characterize the texture of the input image. It represents richness of information content in an image. The value of entropy should be large for better information in an image.

Shannon defined the entropy H of a discrete random variables X and Y. Define the conditional entropy of two events *X* and *Y* taking values x_i and y_j respectively, as-

$$H(X \mid Y) = \sum_{i,j} p(x_i, y_j) \log \frac{p(y_j)}{p(x_i, y_j)} \quad \text{--(x)}$$

where $p(x_i, y_j)$ is the probability that $X = x_i$ and $Y = y_j$.

4. MEAN

The mean represents the average of pixel values of an image. So, the value of Mean should be high for better contrast in an image.

$$\mu = \frac{1}{N}\sum_{i=0}^{N-1} Xi \quad \text{-- (xi)}$$

The signal is contained in X_0 through X_{N-1} , i is an index that runs through these values and μ is the mean or average of pixel values.

Table 1: RMSE, PSNR, ENTROPY, MEAN values for the different cover and secret images using Three Level Decomposition.

Cover image	**Secret image**	**Three Level DWT**			
		RMSE	PSNR	ENTROPY	MEAN
Baby	Tree	6.5613	31.790	7.8463	123.776
Man	IIT	8.74571	29.2949	7.4131	158.4646

Table 2: RMSE, PSNR, ENTROPY, MEAN values for the different cover and secret images using Single Level Decomposition.

Cover image	**Secret image**	**Single Level DWT**			
		RMSE	PSNR	ENTROPY	MEAN
Baby	Tree	1.3187	46.92	7.8338	125.98
Man	IIT	1.2118	47.33	7.2490	161.89

VII. CONCLUSION AND FUTURE SCOPE

In this paper, a new image data hiding technique based on DWT has been proposed. The stego-image is looking perfectly intact with has high PSNR value and low RMSE value. Hence, an unintended observer will not be aware of the very existence of the secret-image.

In this paper two different techniques proposed and implemented for data hiding namely-

1. Using thee level discrete wavelet transform and
2. Using single level discrete wavelet transform

The extracted secret image is perceptually similar to the original secret image. The file size of cover image and stego image will not be different too much. The advantage of steganography over the cryptography is it does not raise any suspicion and message can not be exchanged over the communication channel. Using this technique in transform domain the embedding capacity is better than other existing techniques. The relative analysis between the proposed methods the other existing techniques has shown the pre-eminence of the proposed technique.

In future work, the steganography can also be used to enforce on a digital medium. For example, steganography can be used to hide information in a music/audio file or in a video file. When an unauthorized user plays the file, the information can be extracted and checked against the permission for that file.

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