Performance Analysis of Steganography based on 5-Wavelet Families by 4 Levels - DWT

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Abstract
Steganography is the art and science of writing hidden messages in such a way that no one, excluding the sender and deliberated recipient, suspects the message existence , a form of security through obscurity. Steganography techniques can be utilized to images, a video file or an audio file. Typically, steganography is written in characters including hash marking, but its usage within images is also usual. At any rate, steganography secures from pirating copyrighted materials as well as aiding in unauthorized viewing. In this paper, performance analysis of image steganography based on 2 level and 4 level DWT associated to colored images is done. Performance analysis of steganography is done for selecting better wavelet for application by analyzing Peak Signal Noise Ratio(PSNR) of different wavelet families like Haar, Daubechies, Biorthogonal, Reverse Biorthogonal & Meyer wavelet(dmey) on result oriented basis using Matlab environment.

Keywords
Steganography, Discrete Wavelet Transform, Haar, Daubechies, Biorthogonal, Reverse Biorthogonal , Meyer(dmey) , PSNR & MSE

1. Introduction

Steganography is ‘‘covered writing’’. Steganography is the hiding of a secret message within an ordinary message and the extraction of it at its target. Steganography takes cryptography a step farther by hiding an encrypted message so that no one guess it exists. Ideally, anyone scanning your data will fail to know it contains encrypted data.
Four basic characteristics of data hiding are Imperceptibility, Security Capacity and Robustness. Important requirement for Steganography system as follows :

- Security of the hidden communication
- Size of the payload
- Robustness against harmful and unintentional attacks

Figure 1: Processing of Stegnography

Figure 1 shows the basic flow of processes that takes place in image steganography.This paper presents DWT(2-level & 4-level wavelet decomposition)based image steganography. Three different wavelets are used in embedding process of the steganography techniques like Haar, Daubechies ,Biorthogonal ,Reverse bi-orthogonal and Meyer (dmey). It has been observed that wavelets based techniques are most robust as compared to Least Significant Bit (LSB) based techniques. Also, good quality stego-image is obtained using wavelet based techniques. For image quality measurement, Peak Signal to Noise Ratio (PSNR) is used. By analyzing Peak Signal Noise Ratio(PSNR) of different wavelet families like Haar, Daubechies ,Biorthogonal ,Reverse bi-orthogonal and Meyer (dmey) transform, we detect better wavelet for application. The PSNR block computes the peak signal-to-noise ratio, in decibels, between two images. This ratio is often used as a quality measurement between the original and a compressed image. The higher the PSNR, the better the quality of the reconstructed image.
In the next subsequent section 2 we review the literature, section 3 represent discrete wavelet transforms and section 4 represent its families like Haar, Daubechies ,Biorthogonal ,Reverse bi-orthogonal and Meyer (dmey).In section 5 and 6, we give the embedding and extraction formula of proposed DWT. Experimental results are described in section 7 and 8.Conclusion and Future scope is given in section 9.

2. Literature Review

In March 30, 2012, T. Narasimmalou, Allen Joseph .R, proposed that Discrete Wavelet Transform Based Steganography for Transmitting Images. It uses two different techniques to provide security of data and
Provide high peak signal noise ratio value of given input to give a better quality.

In 2013, Abdelfatah A. Tamimi, Ayman M. Abdalla, Omaima Al-Allaf, proposed that Hiding an Image inside another Image using Variable-Rate Steganography. The new algorithm presented in this paper uses a variable number of LSBs from each color of each considered pixel for hiding a secret image. Test results showed that the new

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algorithm keeps the hidden image difficult to detect, as shown by the high PSNR and correlation values for stego images.

3. Discrete Wavelet Transform

A wave is an oscillating function of time or space .A wave is periodic and wavelets are localized waves. They have their energy concentrated in time or space and are suited to analysis of transient signals. The major advantage to using wavelets is that they provide a strong mathematical framework for analyzing functions at various scales. This property makes wavelet-based analysis a powerful tool in image processing. While Fourier Transform and STFT use waves to analyze signals, the wavelets of finite energy used by wavelet Transform. Wavelet transform decomposes a signal into a set of basis functions. These basis functions are called wavelets.

A discrete wavelet transform (DWT) is a sampled wavelet function. The Discrete Wavelet Transform (DWT), which is based on sub-band coding is found to yield a fast computation of Wavelet Transform. It is easy to implement and reduces the computation time and resources required. Rather than calculate the wavelet coefficients at every point, the DWT uses only a subset of positions and scales. This method results in an perfect and more efficient manner of a wavelet transform. The DWT is similar but more adaptable than the Fourier series. The DWT can be made periodic but it can also be applied to non-periodic transient signal.

Discrete Wavelet Transform (DWT) performs repeated procedure at each step given as follows:

- Filter the image by 2D-lowpass and high pass filter
- Sub-sample the results by factor 2
- Decompose the image into 4 sub-bands (LL, LH, HL,HH) Huge decrease in entropy in high-frequency bands (LH, HL,HH)

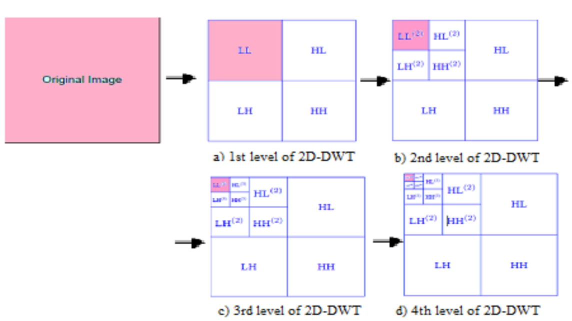

Figure 2: Image Decomposition

In wavelet transforms, original signal is divided into frequency resolution and time resolution contents by using a cutting window. This window is known as “Mother Wavelet”. The problem here is that cutting the signal corresponds to a convolution between the signal and the cutting window. The signal will convolve with the specified filter coefficients and gives the required frequency information. The decomposition of Leena image up to 4th level of DWT is as shown in fig.3.

Figure 3: Decomposition of Leena Image

4. Wavelet Families

There are a number of basis functions that can be used as the mother wavelet for Wavelet Transformation. Since the mother wavelet generates all wavelet functions used in the transformation through translation and scaling, it determines the resulting Wavelet Transform characteristics. Hence, the particular application details should be taken into account and the appropriate mother wavelet should be chosen in order to use the Wavelet Transform effectively. Here the performance analysis is done for DWT’s different wavelets.

4.1 Haar Wavelet

Haar wavelet is one of the oldest and simplest wavelet. Hence, any discussion of wavelets starts with the Haar wavelet. It is also the symmetric wavelet. In discrete form Haar wavelets are related to a mathematical operation called the Haar transform. The Haar transform works as a prototype for all other wavelet transforms. In mathematics, the Haar wavelet is a sequence of rescaled "square-shaped" functions which together form a wavelet family or basis. Wavelet analysis is homogeneous to Fourier analysis in that it allows a target function over an interval to be represented in terms of an orthonormal function basis . It represents the same wavelet as Daubechies db1. The Haar wavelet transform has a number of advantages such as it is conceptually fast,simple, memory efficient, since it can be calculated in place without a temporary array. The technical disadvantage of the Haar wavelet is that it is uncontinuous, and therefore undifferentiable. This property can, however, be an advantage for the analysis of signals with sudden transitions including monitoring of tool failure in machines.

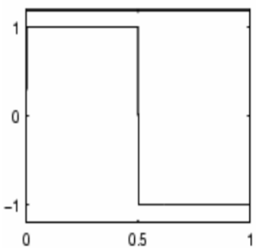

Figure 4.1 Haar Wavelet

4.2 Daubechies Wavelet

Daubechies wavelets are the most popular wavelets. They represent the foundations of wavelet signal processing and are used in various applications. These are also called Maxflat wavelets as their frequency responses have maximum flatness at frequencies 0 and π. The Daubechies wavelet transforms are defined in the same way as the Haar wavelet transform by computing the running averages and differences via scalar products with scaling signals and wavelets the only difference between them consists in how these scaling signals and wavelets are defined. Ingrid Daubechies, one of the brightest stars in the world of wavelet research, originated what are called compactly supported orthonormal wavelets — thus making discrete wavelet analysis practicable. Daubechies-2 wavelet transform used for improving clustering quality and the privacy measure of data.The names of the Daubechies family wavelets are written `dbN`, where `N` is the order, and `db` the "surname" of the wavelet. The `db1` wavelet, as previously mentioned, is the same as `Haar` wavelet. Here are the wavelet functions of the next nine members of the family:

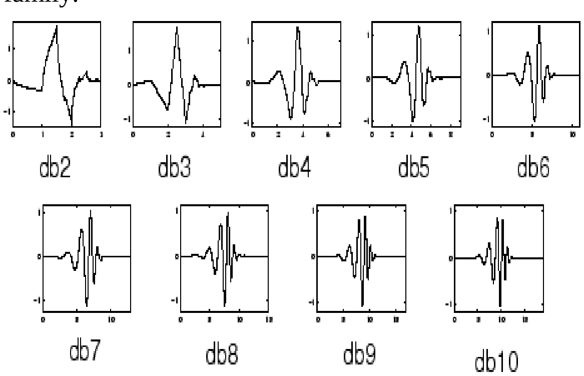

Figure 4.2: Daubechies Wavelet Family

4.3 Biorthogonal Wavelet

A biorthogonal wavelet is Proposed by Cohen (1992). A biorthogonal wavelet is a wavelet where the associated wavelet transform is invertible but not surely orthogonal. Designing biorthogonal wavelets allows more degrees of freedom than orthogonal wavelets. One extra degree of freedom is the possibility to produce symmetric wavelet functions. This family of wavelets display the property of linear phase, which is required for signal and image reconstruction. Interesting properties are derived by using two wavelets, one for decomposition (on the left side) and the other for reconstruction (on the right side) instead of the same single one.

4.4 Reverse Biorthogonal Wavelet

The family of Reverse Biorthogonal is symmetric and orthogonal. The property of symmetry ensure that they have linear phase characteristics. This type of base wavelet constructed by spline method(Cohen et al.1992).In practice this wavelet used for surface profile filtering in manufacturing process monitoring & diagnostics.

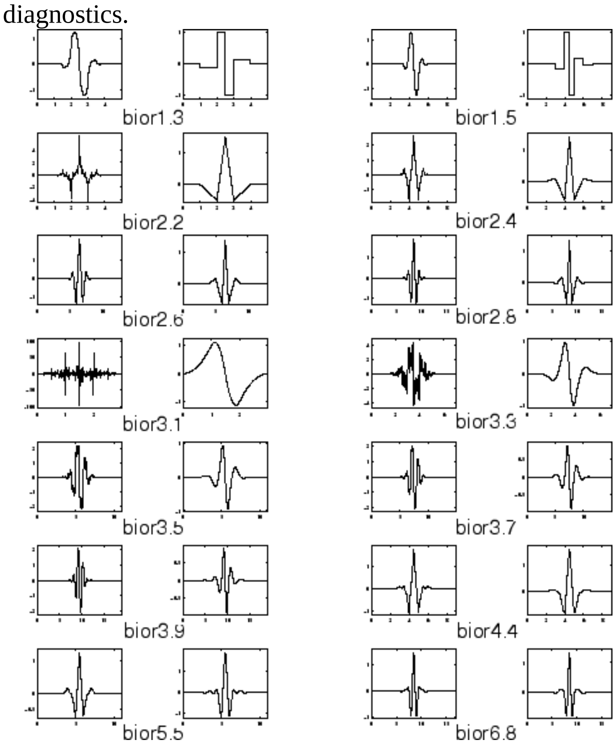

Figure 4.3: Biorthogonal Wavelet Family

4.5 Meyer Wavelet(dmey)

The Meyer wavelet(dmey) which is an infinitely regular orthogonal and symmetrical wavelet, named after another one of the Originators of the field, Yves Meyer. The Haar and Daubechies are compactly supported orthogonal wavelets. These wavelets along with Meyer wavelets(dmey) are capable of perfect reconstruction.. Reconstructed images quality is measured by the peak signal noise ratio, which is obtained by maximum discrete Meyer wavelet(dmey).The Meyer wavelet and scaling function are defined in the frequency domain.

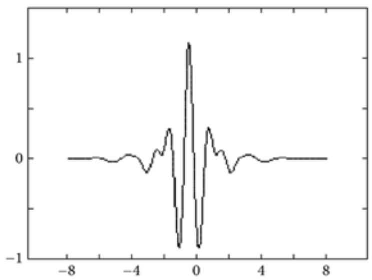

Figure 4.4: Meyer Wavelet

5. Implementation of Proposed Method 1

5.1 Procedure for Embedding using 2-Level Wavelet Decomposition :

1. Perform 2 level 2D-Haar DWT decomposition as follows:
   a) Take the cover image (JPEG) (512 x512) and its green plane alone and perform first level 2D-DWT on the image to obtain approximation 1 coefficient (LL 1),horizontal 1 coefficient (HL 1), vertical 1coefficient (LH 1), diagonal 1 coefficient (HH1) respectively.
   b) Take the approximation 1 coefficient (LLl) and perform second level 2D-DWT on the image to obtain approximation 2 coefficient (LL2), horizontal 2 coefficient (HL2),vertical 2 coefficient (LH2), diagonal 2 coefficient (HH2) respectively.

2. Take the secret image and turn it into black and white.
3. Perform Embedding as follows:
   a) Assume an embedding coefficient of value of 0.05
   b) Process LL2 block by block (4x4)
   c) Process the secret image block by block (4X4).
   d) The following formula is used to obtain the secret image block (4x4) which is basically swapping, secret image block =LL2 + (Embedding co-efficient x secret image intensity value)

4. Perform 2 level 2D- inverse DWT for Reconstruction which is the inverse process of 2 level 2D-DWT decomposition in order to obtain the stego image
5. Calculate the PSNR in order to check for the visual quality of the stego image.
   - To compute the PSNR, the block first calculates the mean-squared error using the following equation:

$$MSE = \frac{\sum_{M,N} [I_1(m,n) - I_2(m,n)]^2}{M * N} \quad (1)$$

   In the above equation, *M* and *N* are the number of rows and columns in the input images, respectively.

   - Then the block computes the PSNR using the following equation:

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \quad (2)$$

In the previous equation, *R* is the maximum fluctuation in the input image data type. Consider an example, if the input image has a double-precision floating-point data type, then *R* is 1. If it has an 8-bit unsigned integer data type, *R* is 255, etc.
The *Mean Square Error (MSE)* and the *Peak Signal to Noise Ratio (PSNR)* are the two error metrics used to compare image compression quality. The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error. The lower the value of MSE, the lower the error.
The above mentioned procedure can be perform for Daubechies ,Bi-orthogonal,Reverse Biorthogonal and Meyer wavelets(dmey).

5.2 Procedure for Extracting using 2 - Level Wavelet Decomposition:

a) Conduct 2 level 2D- Haar DWT decomposition on the stego image as well the cover image as we did in the embedding procedure.
b) Calculate the PSNR for the decomposed stego image as well as the cover image for finding out in which sub-band the secret image has been embedded. On examining we will find it out to be LL2
c) Process LL2 of the stego image block by block (4x4).
d) Process LL2 of the cover image block by block (4x4).
e) Assume an embedding coefficient of 0.05
f) Use the formula which follows to get the image blocks of the secret image.

secret image block = (LL2 intensity value of stego image – LL2 intensity value of the cover image) / embedding coefficient

6. Implementation of Proposed Method 2

6.1 Procedure for Embedding using 4-Level Wavelet Decomposition :

1. Perform 4 level 2D-Haar DWT decomposition as follows:
   a) Take the cover image (JPEG) (512 x512) and its green plane alone and perform first level 2D-DWT on the image to obtain approximation 1 coefficient (LL 1),horizontal 1 coefficient (HL 1), vertical 1coefficient (LH 1), diagonal 1 coefficient (HH1) respectively.
   b) Take the approximation 1 coefficient (LLl) and perform second level 2D-DWT on the image to obtain approximation 2 coefficient (LL2), horizontal 2 coefficient (HL2),vertical 2 coefficient (LH2), diagonal 2 coefficient (HH2) respectively.
   c) Take the approximation 2 coefficient (LL2)and perform third level 2D-DWT on the image to obtain approximation 3 coefficient (LL3), horizontal 3 coefficient (HL3),vertical 3 coefficient (LH3), diagonal 3 coefficient (HH3) respectively.
   d) Take the approximation 3 coefficient (LL3)and perform forth level 2D-DWT on the image to obtain approximation 4 coefficient (LL4), horizontal 4 coefficient (HL4) ,vertical 4 coefficient (LH4), diagonal 4 coefficient (HH4) respectively.
2. Take the secret image and turn it into black and white.
3. Perform Embedding as follows:
   a) Assume an embedding coefficient of value of 0.05
   b) Process LL4 block by block (4x4)
   c) Process the secret image block by block (4X4).
   d) The following formula is used to obtain the secret image block (4x4) which is basically swapping,
   secret image block =LL4 + (Embedding coefficient x secret image intensity value)
4 . Perform four level 2D- inverse Haar DWT for reconstruction which is the inverse process of four level 2D Haar – DWT decomposition in order to obtain the stego image
5. Calculate the PSNR in order to check for the visual quality of the stego image by using above mentioned formula.

Procedure for Extracting using 4- Level Wavelet Decomposition :

a) Perform four level 2D- Haar DWT decomposition on the stego image as well the cover image as we did in the embedding procedure.
b) Calculate the PSNR for the decomposed stego image as well as the cover image for finding out in which sub-band the secret image has been embedded. On examining we will find it out to be LL4
c) Process LL4 of the stego image block by block (4x4).
d) Process LL4 of the cover image block by block (4x4).
e) Assume an embedding coefficient of 0.05
f) Use the formula which follows to get the image blocks of the secret image.
   secret image block = (LL4 intensity value of stego image – LL4 intensity value of the cover image) / embedding coefficient

7. Experimental Result of Proposed Method 1

7.1 Embedding and extraction results using 2 level 2D-Haar DWT:

Figure 5: Stego Image with Secrete Image embedded on Original Image

Stego Image with secret Image embedded on the original Image is shown in figure 5. PSNR value after embedding for the 2 level -2D Haar DWT is 86.5001 db.

Figure 5.1: Screenshots of Result of 2 level 2D-Haar DWT

By same procedure we show PSNR value for Daubechies , Bi-orthogonal, Reverse Biorthogonal and Meyer wavelets(dmey).

The table 1 below lists the image quality(PSNR) in dB for the cover images after embedding for different wavelet families such as Daubechies ,Bi-orthogonal, Reverse Biorthogonal and Meyer wavelets(dmey). These results were obtained using MATLAB using simulink.

Table 1 :Image Quality (PSNR) in dB of the Cover Image by 2 level of different Wavelets after Embedding

S.No	Wavelet	MSE	PSNR	Ext Logo Quality
1	haar	1.46E-04	86.5001	good
2	db5	1.45E-04	86.5218	good
3	bior 1.3	1.45E-04	86.5058	good
4	rbio 1.3	1.46E-04	86.4988	good
5	dmey	1.31E-04	86.9695	bad

8. Experimental Result of Proposed Method 2

8.1 Embedding and extraction results using 4 level 2D- Haar DWT:

Stego Image with secret Image embedded on the original Image is shown in figure 5.PSNR value after embedding for the 4 level -2D Haar DWT is 98.3346 db.

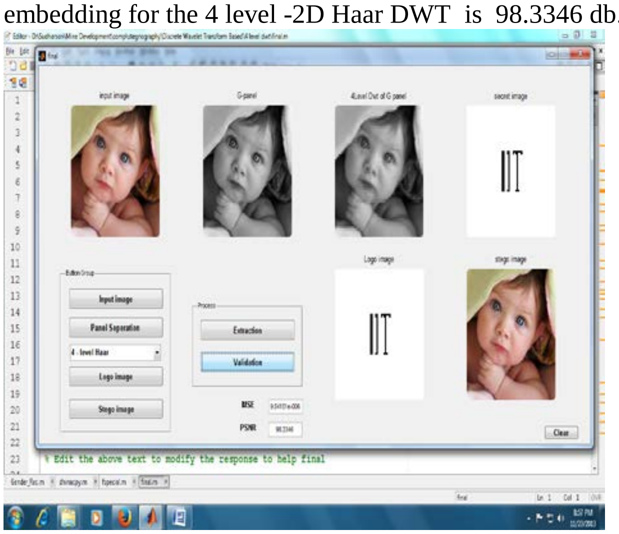

Figure 5.2: Screenshots of Result of 4 level 2D-Haar DWT

The table 2 below lists the image quality(PSNR) in dB for the cover images after embedding for only Haar wavelet .

Table 2:Image Quality (PSNR) in dB of the Cover Image by 4 level Haar wavelets after Embedding

S.No	Wavelet	MSE	PSNR	Ext logo quality
1	Haar	9.54E-06	98.3346	Very good

9. Conclusion and Future Work

In this paper we discuss the important quality peak signal-to-noise ratio for different wavelet in DWT (discrete Wavelet transform). In this paper we using two technique of 2-level and 4-level discrete wavelet transform for hiding images has been proposed and implemented. This is done in MATLAB using simulink. Different wavelets analysed here are Haar,

Biorthogonal, Reverse Biorthogonal, Daubechies,and Meyer(dmey).Results provide a good reference for application developers to choose a good wavelet compression system for their application, with this result we conclude that 4-level Haar DWT has better PSNR as compared to 2-level Haar DWT and also provide best quality of image.

In Future we modified embedding & extraction formula for hiding audio data in cover image by using 2 level & 3 level wavelet decomposition of 3D-DWT which can be considered as a combination of three 1D DWT in the x, y and z directions and shows better performance in terms of both capacity and security.

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