Image Steganography Technique Using Daubechies Discrete Wavelet Transform

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Abstract: The world in modern days is being more and more tied up to the use of technology for facilitating day to day tasks. In this regard, information security is turning to be great challenge when sending information from one place to another with the aid of technology. Steganography is one of the techniques for the safe transmission which involves hiding information generally with other information that only the receiver will know. In this research, steganography technique using Daubechies Discrete Wavelet Transform (DWT) is implemented. First the cover image is transformed using Daubechies DWT and secret information is embedded in coefficients of Daubechies DWT which gives stego image. Reverse process is applied to obtain secret information from stego image. The performance of the proposed approach is evaluated using PSNR and MSE. Also analysis is done to find the best sub-band to hide information among different sub-bands of Daubechies DWT.

Keywords: Stego Image; Discrete Wavelet Transform (DWT); Peak Signal to Noise Ratio (PSNR); Mean Square Error (MSE)

1. Introduction

Transmission of information from one place to another always has potential threats of being leaked before it reaches the destination. Especially when one has to transmit secure and confidential message, this risk is always high. To address these threats, people always seek and invent technologies for securely transmitting messages. One of the techniques is information hiding.

There are many techniques of information hiding including cryptography, watermarking and steganography. Cryptography is art of protecting information by transforming or encrypting it into an unreadable format, called cipher text. Only those who possess a secret key can decipher or decrypt the message into plain. Watermarking is a pattern of bits inserted into a digital image, audio or video file that identifies the file's copyright information (author, rights, etc.)

Steganography is an art of covert communication in which a secret message is communicated by hiding it in a cover file, so that the very existence of the secret message is not detectable. The cover file can be image, audio or video; the most commonly being the image files.

Steganography dates back to ancient Greece, where common practices consisted of etching messages in wooden tablets and covering them with wax, and tattooing a shaved messenger's head, letting his hair grow back, and then shaving it again when he arrived at his contact point.

The advantage of steganography over cryptography alone is that the intended secret message does not attract attention to itself as an object of scrutiny.

Plainly visible encrypted messages no matter how unbreakable will arouse interest, and may in themselves be incriminating in countries where encryption is illegal. Thus, whereas cryptography is the practice of protecting the contents of a message alone, steganography is concerned with concealing the fact that a secret message is being sent, as well as concealing the contents of the message.

2. Related Theory

A. Discrete Wavelet Transform

The wavelet domain is growing up very quickly. Wavelets have been utilized as a powerful tool in many diverse fields, including approximation theory; signal
processing, physics, astronomy, and image processing. A wavelet is simply, a small wave which has its energy concentrated in time to give a tool for the analysis of transient, non-stationary or time-varying phenomena. A signal can be better analyzed if expressed as a linear decomposition of sums of products of coefficient and functions. A two-parameter system is constructed such that one has a double sum and coefficient with two indices. The set of coefficients are called the DWT of a signal.

The DWT splits the signal into high and low frequency parts. The high frequency part contains information about the edge components, while the low frequency part is split again into high and low frequency parts which is shown in figure 2 [1].

The high frequency components are usually used for steganography since the human eye is less sensitive to changes in edges [2]. In two dimensional applications, for each level of decompositions, we first perform the DWT in the vertical direction, followed by the DWT in the horizontal direction. As we can see in figure 3 [2], after the first level of decomposition, there are four sub-bands: LL, LH, HL and HH.

![Figure 2: Block Diagram of 1-Step 2-D DWT](image)

**Figure 2: Block Diagram of 1-Step 2-D DWT**

**C. 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 \( \pi \). The Daubechies wavelet transforms are defined in the same way as the Haar wavelet transform—by computing 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. For the Daubechies wavelet transforms, the scaling signals and wavelets have slightly longer supports, i.e., they produce averages and differences using just a few more values from the signal. This slight change, however, provides a tremendous improvement in the capabilities of these new transforms. The names of the Daubechies family wavelets are written dbN, where N is the order, and db the "surname" of the wavelet.

**D. Peak Signal to Noise Ratio (PSNR)**

It is the measure of reconstruction of the transformed image. This metric is used for discriminating between the cover and stego image which is given by equation 1 [13].

\[
PSNR = 10\log_{10}255^2/MSE
\]

**E. Mean Square Error (MSE)**

It is one of the most frequently used quality measurement technique followed by PSNR. The MSE
can be defined as the measure of average of the squares of the difference between the intensities of the stego image and the cover image. It is popularly used because of the mathematical tractability it offers. It is represented in equation 2 [13].

\[
MSE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} (f(i,j) - f'(i,j))^2
\]  

(2)

**F. Cover Image**

It is defined as the original image into which the required secret message is embedded. It is also termed as innocent image or host image. The secret message should be embedded in such a manner that there are no significant changes in the statistical properties of the cover image. Good cover images range from gray scale image to colored image in uncompressed format.

**G. Stego image**

It is the final image obtained after embedding the secret information (in a form of image, text, audio etc.) into a given cover image. It should have similar statistical properties to that of the cover image.

3. Related Works

There are many steganography techniques which are capable of hiding data within an image. These techniques can be classified into two categories based on their algorithms: (1) spatial domain based techniques; (2) transform domain based techniques. The spatial domain based steganography technique use either the LSB or Bit Plane Complexity Segmentation algorithm. The most widely used technique to hide data is the usage of the LSB [5]. The existing techniques are mainly based on LSB (Least Significant Bit) where LSBs of the cover file are directly changed with message bits. S. M Karim et al. [6] has proposed a LSB technique for RGB true color image by enhancing the existing LSB substitution techniques to improve the security level of hidden information. LSB matching image steganography and edge adaptive scheme was proposed which can select the embedding regions according to the size of secret message and the difference between two consecutive pixels in the cover image. In [7] designing of robust and secure image steganography based on LSB insertion and RSA encryption technique has been used.

M. A. Ahmed et al. [8] proposed a method in which a message hidden inside an image by using the Least Significant Bit technique and after creation of the hidden message, the image will pass it in hash function to obtain hashing value using the MD5 technique. In [9] a hash based approach proposed for secure keyless steganography in lossless RGB images that an improved steganography approach for hiding text messages in lossless RGB images.

Transform domain techniques embed secret information in a transform space of the signal means the process of embedding data in the frequency domain of a signal to make them more robust to attack such as adding noise, compression, cropping, some image processing etc[10]. Many transform domain variations exist. One method is to use the Discrete Cosine Transformation (DCT) as a vehicle to embed information in image. Another method would be the use of wavelet transforms. Advantages of transform domain include higher level of robustness against simple statistical analysis.

JSteg sequentially replaces the LSB of the non-zero quantized DCT coefficients with secret message bits whereas in JPHide the quantized DCT coefficients are not selected sequentially but selected randomly by a pseudo-random number generator [10]. F5 comes after a series of F3 and F4 [11]. F5 steganographic algorithm was introduced by Westfield and it embeds message bits into randomly chosen DCT coefficients. The F5 algorithm employs matrix embedding that minimizes the necessary number of changes to hide a message of certain length.

The discrete wavelet transform (DWT) method is favored over the DCT method in steganography because DWT provides better image resolution at various levels. DWT converts spatial domain information to the frequency domain information and it clearly partitions the high-frequency and low-frequency information on a pixel by pixel basis [12]. Wavelets are mathematical functions that divide data into frequency components, which makes them ideal for image compression. Haar wavelet transform is the widely used wavelet transform due to the simplicity in implementation [13].

4. Methodology

A. **Algorithm for Embedding Process**

1. Get cover image and secret image.
2. Calculate daubechies wavelet transform of the cover image.
3. Embed the pixel values of secret image into the wavelet coefficients. This is done in following method.
   i. Select any two bands (i.e. HL/HH or LH/HH or HL/LH).
   ii. Get the secret information (image).
   iii. Get lower four bits of secret information and embed into the lower
four bits of wavelet coefficients of one of the band selected.
iv. Get higher four bits of secret information and embed into the lower four bits of wavelet coefficients of other band selected.
5. Stego image is generated.

B. Algorithm for Extracting Process
1. Get stego image.
2. Calculate daubechies wavelet transform of the stego image.
3. Obtain the coefficients of the selected band where the pixel value of secret image is hidden.
4. Extract the pixel values of secret image from wavelet coefficients. The extraction is done in the following method.
   i. Get coefficients from one of the selected bands of wavelet.
   ii. Obtain lower four bits of the coefficients.
   iii. Get coefficients from other selected bands of wavelet.
   iv. Obtain lower four bits of the coefficients.
   v. Combine this four bits with the four bits obtained in (ii) by making this four bits as higher bits and other four bits as lower bits.
5. Secret image is generated.

5. Experiment and Evaluation

A. Simulation Parameters
- Coding Platform: Matlab
- Cover and Secret Image: 8-bit grayscale
- Cover Image size: 512 X 512
- Secret Image size: 128 X 128

B. Comparison of different bands of Daubechies wavelet transform for embedding secret image

5 different secret images and 30 different cover images are taken and secret image is embedded in different combination of bands (horizontal/diagonal, vertical/diagonal and vertical/horizontal) and performance is evaluated in terms of mean square error (MSE) and peak signal to noise ratio (PSNR).

Table 1: Calculation of MSE and PSNR at different bands with roses.jpg as secret image

<table>
<thead>
<tr>
<th>Cover Image</th>
<th>roses (Secret Image)</th>
<th>horizontal/diagonal</th>
<th>vertical/diagonal</th>
<th>vertical/horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MSE</td>
<td>PSNR</td>
<td>MSE</td>
</tr>
<tr>
<td>lina1</td>
<td></td>
<td>227.0067</td>
<td>24.5704</td>
<td>223.0057</td>
</tr>
<tr>
<td>image11</td>
<td></td>
<td>2538.8</td>
<td>14.08452</td>
<td>2664.4</td>
</tr>
<tr>
<td>image2</td>
<td></td>
<td>1111</td>
<td>17.67366</td>
<td>1124.1</td>
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<tr>
<td>test</td>
<td></td>
<td>405.8065</td>
<td>22.04761</td>
<td>424.1797</td>
</tr>
<tr>
<td>chess</td>
<td></td>
<td>208.5411</td>
<td>24.93889</td>
<td>223.9547</td>
</tr>
<tr>
<td>aa</td>
<td></td>
<td>189.594</td>
<td>25.35256</td>
<td>201.1265</td>
</tr>
<tr>
<td>drape</td>
<td></td>
<td>553.144</td>
<td>20.70246</td>
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<tr>
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<td>25.14283</td>
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<tr>
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<td>24.75348</td>
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<tr>
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<td>rose</td>
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<td>176.1932</td>
<td>25.67091</td>
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<td>1730.11</td>
<td>15.75009</td>
<td>1898.6</td>
</tr>
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</table>

In table 1, out of 30 tests, 26 give less mean square error and hence more peak signal to noise ratio in horizontal/diagonal band and 4 give less mean square error in vertical/diagonal band.
In Table 2, out of 30 tests, 16 give less mean square error and hence more peak signal to noise ratio in horizontal/diagonal band, 12 give less mean square error in vertical/diagonal band and 2 in vertical/horizontal band.

In Table 3, 19 give less mean square error and hence more peak signal to noise ratio in horizontal/diagonal band and 11 give less mean square error in vertical/diagonal band.
In Table 4, out of 30 tests, 20 give less mean square error and hence more peak signal to noise ratio in horizontal/diagonal band and 10 give more mean square error in vertical/diagonal band.

In Table 5, out of 30 tests 17 give less mean square error and hence more peak signal to noise ratio in horizontal/diagonal band and 13 give less mean square error in vertical/diagonal band.

In above five tables, out of 150 tests, 98 give less mean square error in horizontal/diagonal band, 50 give less mean square error in vertical/diagonal band and 2 give less mean square error in vertical/horizontal band. Horizontal/diagonal band has slightly more images with less mean square error and vertical/diagonal band also contains significant number of images with less mean square error.
mean square error. Hence, it can be concluded that diagonal band contains less information of an original image and can be used to embed the secret information with less distortion in original image.

**C. Comparison of Haar and Daubechies Wavelet Transform**

Five different secret images and 20 different cover images are taken and performance of Haar and Daubechies wavelet transform is compared on these images in terms of mean square error.

In figure 4, there are 17 cover images out of 20 images where the mean square error of Daubechies wavelet transform is less than Haar wavelet transform. In figure 5, there are 17 cover images out of 20 images where the mean square error of Daubechies wavelet transform is less than Haar wavelet transform.

In figure 6, there are 17 cover images out of 20 images where the mean square error of Daubechies wavelet transform is less than Haar wavelet transform.

In figure 7, there are 17 cover images out of 20 images where the mean square error of Daubechies wavelet transform is less than Haar wavelet transform.

In figure 8, there are 17 cover images out of 20 images where the mean square error of Daubechies wavelet transform is less than Haar wavelet transform.
In above 5 cases, a total of 87 out of 100 tests give less mean square error in Daubechies wavelet transform than Haar wavelet transform. Hence it can be concluded that Daubechies wavelet transform gives better quality of secret image extracted from stego image.

D. Daubechies Wavelet Transform of some images

Figure 9: (a) Cover Image (image12) (b) Stego Image (c) Wavelet Transform of an image (d) Original Secret Image (e) Extracted Secret Image

5. Conclusion and Future Works

In steganography, secret information is to be embedded in such a way that it doesn’t make significant change to cover file. In this research, Daubechies discrete wavelet transform technique is used to embed the secret information and different tests have been performed. Different results show that diagonal band of wavelet transform carries less information of original image and hence coefficients of this band can be used to embed the secret information without much change to an original image. Instead of taking single band, embedding secret information in combination of bands such as vertical/diagonal or horizontal/diagonal band gives better result in terms of MSE.

Also the performance of Daubechies DWT and Haar DWT is evaluated in terms of PSNR and MSE. Different tests show that Daubechies DWT gives less MSE and hence more PSNR compared to Haar DWT.

In future, same tests can be done for color image and better embedding algorithm can be used to improve the performance.

References


