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Block Based Information Hiding using Cosine, Hartley, Walsh and Haar Wavelets

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Abstract

Steganography is the art of hiding information within other information in such a way that it is hard or even impossible to tell that it is there. There are many different carriers for steganography but the most popular is digital images. Typically, the message is embedded within another image known as a cover image, by tweaking its properties. The resulting output, known as a stego-image is engineered such that it is a near identical perceptual model of the cover image, but it will also contain the hidden message. It is this stego-image that is sent between the sender and the receiver. Steganography is a science for invisible communication and play vital role on the network security. To improve the embedding capacity as well as to have minimum distortion to carrier media, we have proposed a method of hiding secret message into the wavelet transformed cover image. In the proposed system we have developed a block based information hiding scheme using DCT wavelet, Hartley wavelet, Walsh wavelet and Haar wavelet transform for providing 62.5% of the embedding capacity. The Experimental results show that, the stego-image is visually indistinguishable from the original cover-image obtained in the proposed method. The paper compares block based information hiding schemes that hide secret message into orthogonal wavelet transforms such as DCT [Discreet Cosine Transform] wavelet, Hartley wavelet, Walsh wavelet and Haar wavelet. Our experimental results show that using DCT wavelet transform for block based information hiding achieve much better results as compared to Hartley wavelet, Walsh wavelet and Haar wavelet.

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Keywords

Steganography, Information hiding, DCT wavelet, Hartley wavelet, Walsh wavelet and Haar wavelet Transform.

1. Introduction

With the rapid development of information technology, security for the confidential information has become challenging issue today. Steganography techniques have been developed in order to achieve the security. Steganography is an art and science of hiding secret information into multimedia such as images, audios or text. The stego media is similar to the cover media hence it is difficult for the hackers to detect the existence of secret message on the cover media. The hidden secret information can be extracted by retrieving algorithm. Image steganography has become an essential and potential field in information hiding for protecting the confidential information.

The three important requirements need to be considered for steganographic model are [1] :

(i) Imperceptibility: means to preserve the details of the cover image when the secret information is being embedded.
(ii) Payload capacity: means the maximum number of bits that can be hidden with an acceptable resultant stego image quality.
(iii) Robustness: is the ability of stego image to retain its contents from attacks.

The steganography techniques are broadly classified into two categories viz., (i) spatial domain and (ii) frequency domain. In spatial domain the secret information is directly embedded into the pixels of the cover image by using 1bit-LSB, 2bit-LSB, Variable bit LSB etc. replacement. Hiding images using LSB substitution techniques can be found in [5]-[11]. But this method has very low robustness to modifications made to the stego-image such as a low pass filtering and compression.[1] In frequency domain [2][3][4]the cover image is transformed into coefficients such as DCT [1], Hartley, Walsh [1], Haar, Wavelets[2], Hybrid Wavelets etc., and the secret data to be embedded is embedded in high

frequency region. The frequency domain embedding process is more secure [2] than the spatial domain [1]. In frequency domain also wavelet transforms are more robust then simple transforms against various attacks as in [1]. Steganography is employed in various applications like copy right control of materials, enhancing robustness of image search engines and smart identity cards, video-audio synchronization, protection of intellectual property, exchange of highly confidential data in a covert manner and bank transactions.

The wavelet transform is applied on the cover image and the secret message image is embedded into lower energy blocks of the transformed cover image [2]. Before embedding, the secret information, it is first normalized and then embedded in to the cover image. Normalizing the secret message image reduces the embedding error [1]. In a normalized version, the pixel values take the values that span a range between 0.0 and 1.0 instead of integer ranges of 0-255 by dividing each pixel value by maximum possible pixel value. This paper compares the performance of various simple wavelet transforms like DCT [12] [16], Hartley [13] [16], Walsh [14] [16] and Haar [15] with respect to minimum distortion in cover image to form the stego image.

2. Image Transforms and Wavelets

2.1. DCT (Discrete Cosine Transform) [12] [16]

The NxN cosine transform matrix C={c(k,n)},also called the Discrete Cosine Transform(DCT),is defined as

$$c(k,n)=\begin{cases}\frac{1}{\sqrt{N}} & k=0, 0\le n\le N-1\\ \sqrt{\frac{2}{N}}\cos\frac{\Pi(2n+1)k}{2N} & 1\le k\le N-1, 0\le n\le N-1\end{cases}$$

-----(1)

The one-dimensional DCT of a sequence {u(n),0≤n≤N-1} is defined as

$$v(k)=\alpha(k)\sum_{n=0}^{N-1}u(n)\cos\left[\frac{\Pi(2n+1)k}{2N}\right]\quad 0\le k\le N-1$$

-----(2)

Where $\alpha(0)=\frac{1}{\sqrt{N}}, \alpha(k)=\sqrt{\frac{2}{N}}\ for\, 1\le k\le N-1$

The inverse transformation is given by

$$u(n)=\sum_{k=0}^{N-1}\alpha(k)v(k)\cos\left[\frac{\Pi(2n+1)k}{2N}\right], 0\le n\le N-1$$

-----(3)

2.2. Hartley Transform [13][16]

The Discrete Cosine Transform (DCT) utilizes cosine basis functions, while Discrete Sine Transform (DST) uses sine basis function. The Hartley transform utilizes both sine and cosine basis functions. The discrete 2-dimensional Hartley Transform is defined as [7]

F(uv)= $\frac{1}{N}\sum_{x=0}^{N-1}\sum_{y=0}^{N-1}f(x,y)Cas\left\{\frac{2\pi}{N}(ux+vy)\right\}$

-----(4)

Inverse discrete 2-dimensional Hartley Transform is,

f(x,y)= $\frac{1}{N}\sum_{u=0}^{N-1}\sum_{v=0}^{N-1}F(u,v)Cas\left\{\frac{2\pi}{N}(ux+vy)\right\}$

-----(5)

where, $Cas\theta=\cos\theta+\sin\theta$

2.3. Walsh Transform [14][16]

Walsh transform matrix is defined as a set of N rows, denoted Wj, for j = 0, 1, ..., N - 1, which have the following properties[10]

- Wj takes on the values +1 and -1.
- Wj[0] = 1 for all j.
- Wj xWkT =0, for j ≠ k and Wj xWKT Wj has exactly j zero crossings, for j = 0, 1, ...N-1.
- Each row Wj is even or odd with respect to its midpoint.
- Transform matrix is defined using a Hadamard matrix of order N. The Walsh transform matrix row is the row of the Hadamard matrix specified by the Walsh code index, which must be an integer in the range [0... N-1]. For the Walsh code index equal to an integer j, the respective Hadamard output code has exactly j zero crossings, for j = 0, 1... N - 1.

2.4. Haar Transfrom [15]

The Haar wavelet's mother wavelet function φ (t) can be described as

$$\varphi(t)=\begin{cases}1\ ,0\le t\le\frac{1}{2}\\ -1\ \ ,\frac{1}{2}\le t\le 1\\ 0\ \ ,Otherwise\end{cases}$$

-----(6)

And its scaling function $\varphi(t)$ can be described as,

$$\varphi(t) = \begin{cases} 1 \ ,0 \le t \le 1 \\ 0 \ ,Otherwise \end{cases} \qquad \text{-----(7)}$$

2.5. Wavelets [17]

The first step is to select the transform for which the wavelet need to be generated i.e. let's assume "4 x 4 Walsh transform as shown in Figure 2.1". The procedure of generating 16x16 Walsh wavelet transform from 4x4 Walsh transform is illustrated in Figure 2.2.

1	1	1	1
1	1	-1	-1
1	-1	-1	1
1	-1	1	-1

Figure: 2.1 4x4 Walsh Transform Matrix Figure

	1st column of W4 Repeated N=4 times				2nd column of W4 Repeated N=4 times				3rd column of W4 Repeated N=4 times				4th column of W4 Repeated N=4 times			
1 to 4 rows	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1
	1	1	1	1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1
	1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	-1
5 to 8 rows	1	1	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	1	1	-1	-1	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	1	1	-1	-1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	1	1	-1	-1
9 to 12 rows	1	-1	-1	1	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	1	-1	-1	1	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	1	-1	-1	1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	1	-1	-1	1
13 to16 rows	1	-1	1	-1	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	1	-1	1	-1	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	1	-1	1	-1	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	1	-1	1	-1

Figure: 2.2 Generation of 16x16 Walsh wavelet transform from 4x4 Walsh transform

Wavelets for other transforms can also be generated using the same procedure.

3. Proposed Information Hiding System

Wavelet transforms like DCT wavelet, Hartley wavelet, Walsh wavelet and Haar wavelet are applied on the full cover image. The entire wavelet transformed cover image is then divided in 16 non-overlapping blocks [1]. The energy of each block is computed and ten blocks of lower energy[2] are selected to embed the normalized secret message into these blocks to achieve 62.5% embedding capacity. A conceal plan is generated of the size 4x4 which has information about where the secret message is hidden, the block containing the hidden message is marked by '1' and rest of the blocks are marked by 0 as shown in Figure 3.1 . The conceal plan size is minimized to 4x1 by converting each row of conceal plan into its decimal equivalent and then normalizing it. Then a lower energy block is selected in which this minimized normalized conceal plan is embedded which is known only by the sender and the receiver. The inverse wavelet transform is applied to get the Stego image and the reverse is applied to obtain the hidden secret message.

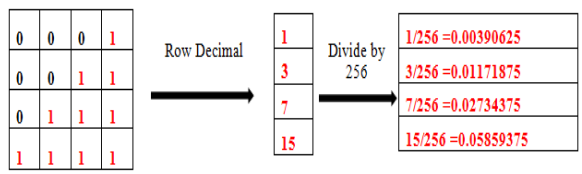

Figure: 3.1 Minimizing and Normalizing the conceal plan

3.1 Embedding Algorithm

1. **Cover Image Transformation.**
   Apply wavelet transform on the color image of size 256x256.
2. **Block division and Energy calculation of transformed Cover Image.**
   Divide the wavelet transformed cover image into block size of 64x64 and calculate the energy of each block.
3. **Message Images (Secret Messages) Normalization.**
   In all the secret message each pixel value is divide by 256 to minimize the embedding error.
4. **Generation of Conceal Plan.**
   For embedding 62.5% of the cover image capacity 10 blocks with minimum energy are marked with 1 and rest by 0 as in Figure 3.1.
5. **Minimizing the size of Conceal Plan and Normalizing it.**
   Each row of a conceal plan is converted to its decimal equivalent and divided by 256 to normalize it.
6. **Embedding secret normalized message as per Conceal Plan.**
7. **Embedding Conceal Plan.**

8. **Obtaining Stego image by taking inverse wavelet transform on modified Cover image.**

3.2 Extraction Algorithm

1. **Transformation of Stego Image.**
   Apply wavelet transform on stego image
2. **Retrieving and regeneration of Conceal plan.**
   Obtain the minimized conceal plan and convert each digit into its binary equivalent to obtain the original conceal plan.
3. **Retrieving Secret message blocks as per Conceal plan.**
4. **De-normalization of Retrieved Secret message.**
   Multiply each pixel of the obtained message by 256 to de-normalize and obtain the original secret message.

4. Result and Discussion

These are the experimental results of the images shown in figure 4.1 used as secret message and figure 4.2 used as cover image which were carried out on DELL N5110 with below Hardware and Software configuration.

Hardware Configuration:

1. Processor: Intel(R) Core(TM) i3-2310M CPU@ 2.10 GHz.
2. RAM: 4 GB DDR3.
3. System Type: 64 bit Operating System.

Software Configuration:

1. Operating System: Windows 7 Ultimate [64 bit].
2. Software: Matlab 7.14.0.739 (R2012) [64 bit].

Our experimental results shows that by embedding 62.5% of the Cover image information as in Figure 4.2 with Secret Message image as in Figure 4.1 in various wavelet transforms like DCT wavelet, Hartley wavelet, Walsh wavelet and Haar wavelet. DCT wavelet gives the least MSE(Mean Squared Error) between the Cover Image and the Modified Cover Image i.e. Stego Image as in Figure 4.3 and Table 4.1 . Total four Secret Message Image (Left to Right and Top to Bottom, Image1 128x128, Image2 64x128, Image3 128x64 and Image4 64x128) were embedded into the Cover image (Left to Right and Top to Bottom, Image1, Image2, …..,Image6) of size 256 x 256.

Figure: 4.1 Test Bed of Secret Message

Figure: 4.2 Test Bed of Cover Image

As shown in Table 4.1 and in Figure 4.2, Image1 has more granularity as compared to all other images and Image5 has less granularity as compared to all other images, so more the granularity of the image greater is the MSE value between the cover image and the stego image and viz.

5. Conclusion and Future Work

This paper proposes a information hiding technique using wavelet transforms. Information hiding using DCT wavelet, Hartley wavelet, Walsh wavelet and Haar wavelet transforms have been implemented. The paper compares the result of DCT wavelet, Hartley wavelet, Walsh wavelet and Haar wavelet transforms respectively. Our experimental results

proves that steganography amoung DCT wavelet, Hartley wavelet, Walsh wavelet and Haar wavelet transforms and for 62.5% embedding, DCT wavelet gives the least MSE. If the image used as cover image is having lower granuality then the MSE will be minimum.Our next research step could be to test hybrid wavelets for information hiding and to test them against various attacks like Histogram Equalization, Brightness, Salt and Pepper noise, Cropping etc.

Table: 4.1 Results obtained by embedding in DCT wavelet, Hartley wavelet, Walsh wavelet and Haar wavelet.

Cover Image	DCT Wavelet MSE	Hartley Wavelet MSE	Walsh Wavelet MSE	Haar Wavelet MSE
Image 1	158.6695	247.7746	357.799	379.4977
Image 2	48.6527	90.5984	113.6936	135.9397
Image 3	87.2695	149.6355	193.5298	199.1639
Image 4	27.2487	64.9407	75.2895	77.8355
Image 5	7.9113	23.6729	33.2892	39.6337
Image 6	34.6714	51.0223	72.9719	74.589
Average	60.73718	104.6074	141.0955	151.1099

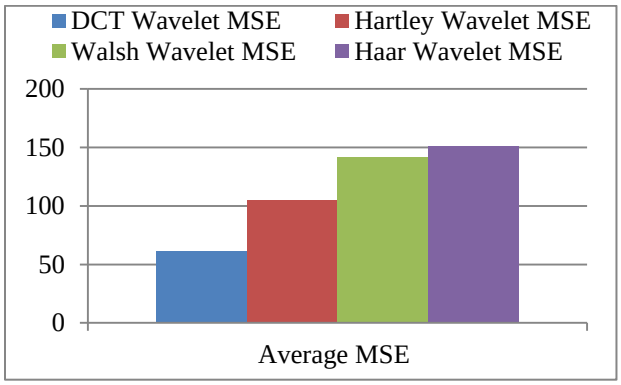

Figure: 4.3 Average MSE of Cover Image w.r.t Stego Image

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