An Improved BPCS Image Steganography In Integer Wavelet Transform Domain Using 4x4 Block Size

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Abstract

Steganography is the process that apply secret information in a multimedia carrier, and carrier may be image, audio, and video files but digital images are the most popular because of their high frequency on the Internet. For hiding secret information in images, there exists a large variety of steganography techniques. Different applications have different requirements of the Steganography technique used. For example, some applications may require absolute invisibility of the secret information, while others require a larger secret message to be hidden. Steganography are used in current security techniques by the remarkable growth in computational power, the increase in security awareness by, e.g., individuals, groups, agencies, government and through intellectual pursuit.

Major issues in Image steganography are to increase the payload capacity, imperceptibility of secret information in stego image & increasing the robustness against steganalysisImage Steganography in Wavelet transform domain have higher robustness against statistical attacks compared to spatial domain & image steganography in Discrete Cosine Transform domain. Integer wavelet transform avoid the losses in fraction which happened in discrete wavelet transform so increase the stego image quality compared to image stenography using discrete wavelet transform. BPCS image steganography is depends on Characteristics of human eyes that our human vision system can not perceive any shape information or secret information in a very complicated binary pattern. So all complex bit plane of cover image can be embedded with secret bit plane without affecting the image quality so BPCS method has higher invisibility or robustness against visual attacks & high payload capacity and BPCS image steganography in integer wavelet transform have high robustness statistical attacks also while 4 LSB image steganography have only high capacity but low robustness against visual attacks and statistical attacks.

***Keywords*- Steganography, Hiding, Integer, Wavelet, BPCS**

1. Introduction

cryptography is a the art of writing a secret information to make a message un-understandable for a third party such a way that attacker can not decode the unreadable message and cryptography does not hide the existence of the secret information or communication while in steganography, hiding of guess of stego image is first priority[1].

Anderson proposed a the scheme of Least significant based hiding[2] which it is very easy for implementation but have lowest robustness against statistical attacks. Vijay Kumar and Dinesh Kumar analyzed the imperceptibility in different sub band as cH, cV, CD of Discrete Wavelet Transform (DWT) based image steganography. Experiment & Results shows cD sub-band or diagonal detail coefficients band of DWT gives higher imperceptibility or PSNR compared to other band as cH, cV in DWT based image steganography[3]. Gheorghita Ghinea & Adel Almohammad analysed the advantage & disadvantage of hiding data in coloured & grayscale images and payload capacity & effect of hiding in chrominance component of YCRCB images. According to them image steganography in colour

images have higher robustness against visual attacks compared to data hiding in Gray scale images on same payload capacity[4]. R.O. El. Safy, H.H. Zayed & A. El Dessouki proposed an adaptive data hiding technique using the optimum pixel adjustment algorithm to increase the hiding capacity. In this schemes different number of bits in each integer wavelet coefficient is embedded according to a hiding capacity function in order to maximize the hiding capacity without affecting the invisibility in stego image and this method also minimizes the mean square error by optimum pixel adjustment algorithm. In this paper three different cases of hiding scheme is tested according to requirement by the user according to priority in capacity or invisibility. In decoding side there is no error in the recovered message but stego image have low robustness against statistical attacks such as histogram equalization and JPEG compression [5]. Elham Ghasemi, Jamshid Shanbehzadeh and Bahram ZahirAzami proposed a scheme based on Integer Wavelet Transform and Genetic Algorithm which hide information using a mapping function based on Genetic Algorithm in 8x8 block of wavelet coefficient. According to them Optimal Pixel Adjustment Process and Genetic Algorithm are used to an optimal mapping function to increase the payload capacity with low distortions and to decrease the mean square error respectively but The deficiency of this technique is higher of execution time[6]. Michiharu Niimi, Hideki Noda and Bruce Segee proposed secure BPCS which is more robust against the the visual attack compared to conventional BPCS image steganography in spatial domain. According to them, if hiding of both secret data and conjugation flags into a noisy block using image segmentation and complexity threshold is employed then signature of existing of messages or secret patterns do not visible in the stego-images[7]. Tao Zhang, Zhaohui Li and Peipei Shi concluded in their paper that, in the improved BPCS steganography with dynamic different threshold on different planes for a purpose of higher invisibility & higher robustness against analysis of frequency histogram, the existence of secret information & estimate the embedding threshold value can be analyzed using the partial statistical analysis[8]. Peipei Shi, Zhaohui Li and Tao Zhang proposed a BPCS image steganography scheme based on chaos theory that is more robust against the analysis of existence of secret information with desirable visual imperceptibility & payload capacity[9]. Ramani, Prasad and Varadarajan proposed a the BPCS image steganography using integer wavelet transform in which the secret information embedding is employed in bit planes of integer wavelets Coefficients of sub-band using the Integer Wavelet Transform. For increasing payload capacity without effecting the imperceptibility of the hidden data, the secret data is hidden in IWT coefficient according to the complexity measured in the Bit-Plane. it is a lossless image steganography which use the IWT and BPCS for high data hiding capacity and high imperceptibility. BPCS takes the advantage of human visual system which cannot recognize changes in complex positions of the image[10]. Julio Lopez, Raul Martinez, Mariko Nakhano and Kazuhiko presented an improvement in the Steganalysis method based on statistical moments of wavelet characteristic function. According to this scheme, This Steganalysis method has a low detection of stego image generated by BPCS steganography and this method proposes to use of support vector machine for classification in place of artificial neural network classifier and it is based on the first three moments of characteristic features of the sub bands with the 3-level Haar Wavelet transformation [11]. The Spatial image steganography methods are most applicable in lossless image format, so these method depends on image format[12]. Transform domain image Steganography involves the image transforms & manipulation of algorithms. These techniques embed secret information in more significant areas of the image, that by it is more robust against visual attacks & statistical attacks[14]. In this approaches the embedded message is not lost in conversion between lossy and lossless compression & mostly methods are independent of the image format.

2 . Related Work

2.1 Wavelet Transform

Wavelet transformation is a powerful image processing transform operation which is used widely used feature extraction, compression and de-noising. Wavelet transform represents the signals with small waves, called wavelet, of limited durations. It provides examination of the signal both in frequency.

If $\Psi(t) \in L2(R)$, the basic wavelet, $\Psi(t)$ is defined as

$C\Psi=|\Psi(w)|2w\ dw$

Where $\Psi(w)$ is basic wavelet's Fourier Transform, w is circular frequency. The wavelet transform decompose the image into four sub band of different frequency groups. Coefficient of low frequency sub band is called approximate components which represents the characteristics of a image while coefficients of high frequency sub-band called

detailed components which represents noise and redundancy in a image [14].The two-dimensional wavelet transform is achieved by applying the one-dimensional wavelet transform to the rows and columns of the input image consecutively[15].

2.2 Discrete Wavelet Transform

If O is original image then A, H, V & D is calculated as following which represents the approximation, horizontal, Vertical & Diagonal coefficients of Discrete Wavelet Transform respectively.

Ai,j = (O2i,2j + O2i+1,2j)/2

Hi,j = O2i,2j+1 - O2i,2j

Vi,j = O2i+1,2j - O2i,2j

Di,j = O2i+1,2j+1 + O2i,2j

The Inverse Discrete Wavelet Transform is calculated as following.

O2i;2j = Ai,j - Hi,j/2

O2i,2j+1 = Ai,j - (Hi,j + 1)/2

O2i+1,2j = O2i,2j+1 + Vi,j - Hi,j

O2i+1,2j+1 = O2i+1,2j – Di,j – Vi,j

2.3 Integer Wavelet Transform

Integer Wavelet Transform is used to avoid problems with floating point precision of the wavelet filters. The LL sub-band of Integer Wavelet Transform appears to be a close copy with smaller scale of the original image while LL sub-band of DWT is distorted as shown in Fig[2.2.9]. Lifting Scheme is one of the method for calculation integer wavelet transform. The decomposing Haar filter for integer wavelet transformation [16] can be applied as following.

Si,j= S0,2j +S0,2j+1

Di,j=S0,2j+1 -S0,2j

The Inverse Integer Wavelet Transform is calculated as following:

S0,2i= Si,i- Di,i2

S0,2i+1= S1,1+Di,i+1

2.4 BPCS Image Steganography.

Basic concept of BPCS is depends on Characteristics of human eyes that our human vision system can not perceive any shape information or secret information in a very complicated binary pattern. So all complex bit plane of cover image can be embedded with secret bit plane without affecting the image quality.

Embedding algorithm in bpcs image steganography:

1. 2D Integer wavelet Transform is applied to cover image matrix I to get wavelet coefficient matrix Iiwt. Wavelet Transform decompose a signal into four Sub Band. LL Sub Band or Approximation Band is a Low frequency wavelet coefficient which are consistent with characteristics of a image. LH, HL, HH Sub Band or Detail component are high frequency wavelet coefficient which contain the edge detail in a signal.
2. Segment integer wavelet transform coefficient matrix Iiwt into 8x8 blocks.
3. Secret key can be used to determine the order of selection of blocks for embedding.
4. For Capacity calculation in a block using BPCS Algo, Convert the each channel of each block into Binary as in table 1.1

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10101111	00100111	01010000	11001010
10100111	00011110	01010000	10111110
10100100	00100110	01011011	10100101
10011011	00100001	01010101	10000110

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Plane8	Plane7	Plane6	Plane5
1001	0011	1100	0010
1001	0010	1001	0111
1001	0000	1101	0010
1001	0010	0100	1010
Plane4	Plane3	Plane2	Plane1
1001	1100	1101	1100
0101	1101	1101	1000

0010 1101 0110 1100

1000 0011 1001 1110

Compute the border length in each plane from lsb plane to msb plane. In each bit plane border length is defined as changes in consecutive bits row wise & column wise. Calculate the complexity in each bit plane which is defined the ratio of border length and total possible border length in 8x8 block. the maximum possible border length in 8x8 block is 112.

C=Total Border Length/Maximum Border Length

Maximum Border for 4x4 block=112

5. Determine the capacity of each block finding its number of bit planes other than Most significant plane possessing a complexity higher than a desired threshold.
6. Determine appropriate complexity threshold for each channel and find the complex planes which have complexity greater than threshold determined in a that channel.
7. Mapping of complex planes is embedded in a particular pixel. Secret data is converted in binary & binary complex planes of each cover block is embedded with secret binary planes.
8. When all channel are embedded, Generate a stego image by computing the inverse integer wavelet transform of embedded wavelet matrix.
9. Generate the stego image by computing the inverse 2D integer wavelet transform.

3. Proposed Work

Concepts of Proposed work: Basic concept of BPCS depends on Characteristics of human eyes that our human vision system can not perceive any shape information or secret information in a very complicated binary pattern. So all complex bit plane of cover image can be embedded with secret bit plane without affecting the image quality so BPCS method has higher invisibility or robustness against visual attacks. Image steganography using Wavelet transform have higher robustness against statistical attacks. Integer wavelet transform avoid the losses in fraction. So BPCS image steganography in integer wavelet transform is high capacity, high robustness against visual attacks & statistical attacks. I have proposed BPCS image steganography in integer wavelet transform domain using 4x4 block size which have higher payload capacity, higher robustness against visual attacks compared to existing BPCS image steganography in integer wavelet transform domain using 8x8 block size.

The embedding and the extracting algorithms are mentioned as following:

Embedding

1. 2D Integer wavelet Transform is applied to cover image matrix I to get wavelet coefficient matrix Iiwt. Wavelet Transform decompose a signal into four Sub Band. LL Sub Band or Approximation Band is a Low frequency wavelet coefficient which are consistent with characteristics of a image. LH, HL, HH Sub Band or Detail component are high frequency wavelet coefficient which contain the edge detail in a signal.
2. Segment integer wavelet transform coefficient matrix Iiwt into 8x8 blocks.
3. Secret key can be used to determine the order of selection of blocks for embedding.
4. For Capacity calculation in a block using BPCS Algo, Convert the each channel of each block into Binary as in table 2.1

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10101111	00100111	01010000	11001010
10100111	00011110	01010000	10111110
10100100	00100110	01011011	10100101
10011011	00100001	01010101	10000110

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Plane8 Plane7 Plane6 Plane5

1001 0011 1100 0010

1001 0010 1001 0111

1001 0000 1101 0010

1001 0010 0100 1010

Plane4 Plane3 Plane2 Plane1

1001 1100 1101 1100

0101 1101 1101 1000

0010 1101 0110 1100

1000 0011 1001 1110

Compute the border length in each plane from lsb plane to msb plane. In each bit plane border length is defined as changes in consecutive bits row wise & column wise. Calculate the complexity in each bit plane which is defined the ratio of border length and total possible border length in 8x8 block. the maximum possible border length in 8x8 block is 112.

C=Total Border Length/Maximum Border Length

Maximum Border for 4x4 block=112

5. Determine the capacity of each block finding its number of bit planes other than Most significant plane possessing a complexity higher than a desired threshold.

6. Determine appropriate complexity threshold for each channel and find the complex planes which have complexity greater than threshold determined in a that channel.

7. Mapping of complex planes is embedded in a particular pixel. Secret data is converted in binary & binary complex planes of each cover block is embedded with secret binary planes.

8. When all channel are embedded, Generate a stego image by computing the inverse integer wavelet transform of embedded wavelet matrix.

9. Generate the stego image by computing the inverse 2D integer wavelet transform. Extracting

1. Compute the 2D integer wavelet transform Iiwt of the stego image Istego as mentioned in above section 2.2.

2. Segment integer wavelet transform coefficient matrix Iiwt into 8x8 blocks.

3. Use Secret key to determine the order of selection of blocks for embedding.

4. Use particular pixel of block to determine the embedded planes.

5. Extract the embedded plane of the block and Extract the message bits.

6. Construct the message from extracted bits.

Steganography in wavelet domain should be in those regions where Human Vision System is less sensitive[10]. For this we can adapt the amount of embedded data in each block of wavelet transform domain with a measure of noisiness in that region. We use the bit-plane complexity segmentation (BPCS) as the measure of noisiness as . Each RGB component of a 24-bit bitmap image is an 8-bit value that changes from 0 to 255. In each color plane, the value zero represents the mentioned indarkest shade of that color, where the brightest shading corresponds to the 255 value. Figure 2 shows a 4□□4 test image with the RGB values shown in Table I. Therefore, the R channel is decomposed as indicated in Table II. Now, the bit plane segmentation, visualized in Figure 3, results in eight binary planes for R channel, as shown in Table III. As a benchmark to measure the amount of noisiness of a bit plane, we use the black and white border image complexity defined by Kawaguchi [8]. Based on the definition, the complexity for a black and white border P (equivalent to our segmented plane) is the ratio of the number of total B-W changes in the plane to its maximum possible value, denoted as $\alpha(P)$, where $0<\alpha(P)<1$.

Following measuring the complexity of each plane, we compare the complexity to a threshold to decide if it is a noisy plane. This threshold is to compromise between capacity and imperceptibility. We segment each channel of wavelet transform representation into 8□8 blocks with pixel values changing from 0 to 255. For each block, we construct the relevant 8-bit planes and compare the bit plane complexity with threshold from the MSB bit plane to the LSB bit plane. Once the first plane with a complexity higher than the threshold is found, we decide on the number of bits that can be embedded in the block pixels. As an example, we can embed five bits of message in the five LSBs of each pixel of the block, if the fourth plane is the first one with a complexity higher than the threshold. For each RGB channel, the threshold is adjusted adaptively according to:

Cth □*Cin* □*C*max (1)

where *Cin* is the parameter to compromise between capacity and imperceptibility ranging from zero to one, *Cmax* denotes the maximum complexity in the relevant channel, and *Cth* is the comparative threshold used for making decision on the planes of that channel.

4 .Experiments & Results

In our experiments 4 different images, mostly in research papers of image steganography, is used for test. All four images are 256x256 bitmap RGB colored image of pixel depth 24 which named F15.bmp, Pepper.bmp, Leena.bmp, Baboon.bmp as shown in figure[5.1-5.4]. The algorithm presented in chapter 4 is implemented with slightly difference in step no 2 with 2x2 block size segmentation & 8x8 size segmentation also which is called 2x2 block BPCS image steganography & 4x4 block BPCS image steganography respectively while proposed work is called 4x4 block BPCS image steganography in this dissertation. In 2x2 block BPCS image steganography & 8x8 block BPCS image steganography, maximum possible border length or maximum possible bit pattern is 4 & 112 while in proposed 4x4 block BPCS image steganography it is 24. Experiments are run with different desired threshold from 0.3 to 0.8. The pay load capacity is shown is result is maximum information which can be replaced with secret information which unit is average bits per pixel & PSNR is calculated on same payload capacity in 2x2 BPCS, 8x8 BPCS & proposed 4x4 BPCS technique which unit is dB.

4.1 Measurement Matrices

Measurement units of Quantity of secret information, imperceptibility & robustness against first order statistical attacks are defined as following.

1. Payload Capacity: Payload Capacity is defined the part of cover image possible to embed with secret information. It is measured either in average bits per pixel or in percentage of cover image.

2. Imperceptibility: Quality of stego image after the embedding of secret information for robustness against visual Attacks is called imperceptibility of secret information which is proportional to PSNR (Peak Signal to Noise Ratio) as defined in following equation.

PSNR = 10*logP2MSE

MSE = x=1My=1N(Sxy- Cxy)

Where P:-Max. Value in Cover Image

Sxy: pixel value at xy position in Stego Image

Cxy : pixel value at xy position in Cover Image.M & N are the pixels in rows & column of Cover image respectively.

3. Robustness against statistical attacks: First order Steganalysis can be obtained by analysis of frequency histogram. A normal image have a smooth frequency histogram while in frequency histogram of mostly stego images have peaks & not smooth. For higher robustness stego image should have smooth frequency histogram & minimum deviation from original frequency histogram.

sno	Threshold	F15	Pepper	Leena	Baboon
1	0.3	11.4	11.8	12.1	14.6
2	0.4	14.6	10.6	11.2	14.1
3	0.5	9.1	9.4	10.1	12.9
4	0.6	7.9	8.2	8.9	11.5
5	0.7	5.9	6.1	4.6	7.6
6	0.8	2.2	2.3	0.9	1.9

S. no	Threshold	F15	Pepper	Leena	Baboon
1	0.3	18.5	18.1	19.5	16.1
2	0.4	19.8	20.1	22.4	16.9
3	0.5	22.5	23.2	25.1	19.1
4	0.6	24.9	26.3	27.5	22.1
5	0.7	29.4	30.5	32.9	25.9
6	0.8	35.9	36.8	40.6	33.8

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sno	Threshold	F15	Pepper	Leena	Baboon

1	0.3	12.5	12.9	13.3	15.6
2	0.4	11.3	11.7	12.3	14.0
3	0.5	10.2	10.5	11.0	12.8
4	0.6	8.8	9.1	9.7	12.3
5	0.7	6.6	6.6	5.2	8.2
6	0.8	2.5	2.7	1.3	2.9

1	0.3	15.9	15.5	16.9	14.1
2	0.4	17.3	17.8	20.1	14.4
3	0.5	20.1	20.9	22.8	16.7
4	0.6	22.1	23.8	24.9	19.7
5	0.7	26.9	28.1	29.3	23.1
6	0.8	32.1	33.4	37.5	30.7

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S. no	Threshold	F15	Pepper	Leena	Baboon
1	0.3	22.1	21.8	23.1	19.9
2	0.4	23.4	24.1	26.2	20.5
3	0.5	26.2	27.1	28.7	22.8
4	0.6	28.7	22.1	30.9	25.6
5	0.7	32.9	33.9	35.9	28.8
6	0.8	38.8	39.2	42.8	37.4

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sno	Threshold	F15	Pepper	Leena	Baboon
1	0.3	9.8	10.1	10.3	12.8
2	0.4	8.9	9.4	9.6	12.2
3	0.5	7.7	8.3	8.5	11.1
4	0.6	6.8	7.4	7.4	9.9
5	0.7	4.9	5.6	3.8	6.7
6	0.8	6.7	2.1	0.8	1.7

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sno	Threshold	F15	Pepper	Leena	Baboon

5. Conclusion

Imperceptibility, Payload capacity & robustness always issues of image steganography. Experiments are done in different images. The Results of experiments shows that proposed BPCS image steganography technique in integer wavelet transform domain using 4x4 in block size have higher payload capacity, higher robustness against visual attacks compared to BPCS image steganography using 8x8 block size in integer wavelet transform domain. Using the mathematical analysis of example shown in favour of proposed work It is concluded that in BPCS image steganography using low block size (ex. 4x4 block size, 2x2 block size), actual bit planes of complex bit pattern is replaced with secret information while in higher block size method(ex. 8x8 block size) some bit planes which have a complex bit pattern is not used for embedding which reduce the pay load capacity & some planes of non complex bit pattern is used for embedding which reduce the imperceptibility. It is also seen from results that proposed technique is more robust against first order statistical attacks because it have a frequency histogram with less peaks & more smoothness compared to 8x8 block size BPCS method. So the proposed BPCS image steganography using 4x4 block size in integer wavelet transform is more efficient than existing 8x8 block size BPCS image steganography in integer wavelet transform. But 2x2 is not efficient than 4x4 & 8x8 block size image steganography. In 2x2 BPCS 25% pixels values is changed for capacity hiding & while in 8x8 BPCS & In 4x4 BPCS image steganography capacity hiding changes 1.56% of pixels & 6.25% of pixels respectively. So in 2x2 BPCS Mean square error is encountered more than 8x8 BPCS & 4x4 BPCS

method on same payload capacity. So 2x2 BPCS technique have low imperceptibility & low payload capacity.

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