A Comparative Study and Analysis of Quantization Table Modification Effect on JPEG Based Image Steganography

V. Senthooran[1], L. Ranathunga[2], KokSheik Wong[3]

[1,2]Department of Information Technology, Faculty of Information Technology, University of Moratuwa, Sri Lanka

[3]Department of Computer System and Technology, Faculty of Computer Systems and Information Technology, University of Malaya, Sri Lanka

Abstract: ***Imperceptibility and the embedding capacity are the two most important characteristics to be considered in the image based steganographic research studies. In the frequency domain, however, the secret message is first transformed into frequency domain and then the secret messages are embedded in the DCT transformed quantized coefficients. Many researchers have shown that the optimized modified quantization tables in the embedding process in DCT domain significantly reduce the distortion in the quality of stego-images and increase the embedding capacity of stego-image. This paper intends to review and analysis of the performance and efficiency of using optimized quantization tables instead of default JPEG tables within JPEG based image steganography and suggest optimized modified table for data embedding with comparison of previous methods. Data embedding capacity, Mean Square Error(MSE) and Peak Signal to Noise Ratio(PSNR) have been analyzed by modifying quantization tables entry for standard test images and they show the significance performance based on the quantization table modification. In addition to that, we suggest novel technique for data embedding based on quantization table modification.***

Keywords: quantization tables, steganography, JPEG, DCT, stego-image, MSE, PSNR

1. Introduction

Steganography is one of the secure methods of camouflaging secret data in a cover media. This cover media may be a digital image, audio file, or video file. Once the data has been embedded into the cover object, they may be transferred across insecure lines [1]. Now a day's, steganography is generally used on computers with digital data being the covers and networks being the high speed secure delivery channels. Steganography is often mystified with Cryptography because the two are same in the way that they both are used to protect important information. The difference between the two is that, Cryptography encrypts the message so that it cannot be understood. Anyhow, it builds the message suspicious enough to attract hacker's attention. Steganography uses the multimedia as cover medium and hides the secret message within cover medium so that it cannot be observed. There are three different characteristics in information-hiding systems compete with each other. They are embedding capacity, security and robustness. Steganographic capacity is the maximum number of bits that can be hided in a cover image with a minor probability of detection by an unauthorized persons. Therefore, the embedding capacity is likely to be larger than the steganographic capacity [2]. Moreover, the size of the hidden information relative to the size of the cover image is known as embedding rate or capacity [3]. However, Westfield [4] explains the capacity as the size of the hidden message relative to the size of the stego image. Security refers that to hackers failure to detect embedded information and robustness to the amount of modification the stego medium can survive before the hackers can destroy hidden information. The goal of image Quantization modification strategy is to increase the steganographic capacity and enhance imperceptibility [5]. However, steganographic capacity and imperceptibility are related with each other, as embedding larger amount of data reveals more artifacts into stego images and then increases the perceptibility of the hidden information [6]. Further, it is not possible to simultaneously maximize the imperceptibility and the capacity of steganography systems simultaneously [7].

2. Optimization of the JPEG Quantization Table

When considering steganography with JPEG baseline system, image quality and compression ratio are controlled by values in quantization table [8]. Therefore, it is important to find an optimized quantization tables with better image quality than obtained by the JPEG default tables in [9]. Studies in [10], [11], [12], [13], [14] derived some methods for optimizing the JPEG quantization table entries. The connection between quantization table entries and stego image quality was investigated in [10]. In above research work, The quantization table was divided into four bands by frequency. Afterward, each value in each band was altered and then the quality of image was examined. As a result, it was observed that the DC coefficient has an important effect on the image quality while the higher frequency AC coefficients have only a secondary importance. In another part of work, a statistical approach was used in [11] to propose a better quantization table than the default tables of JPEG compression in order to improve the compression ratio. Chang et al. proposed a novel method for designing an image independent JPEG quantization table. He derived a perceptual quantization table by incorporating the human visual system (HVS) with the uniform quantizer. This

HVS-based quantization table was superior to JPEG default quantization table in terms of the perceptual quality of the reconstructed image as well as the Peak Signal-to-Noise Ratio (PSNR) [12]. In addition to that, a model for generating a JPEG quantization table was proposed in [13] to improve the PSNR of the final image. The quality of the reconstructed image using this quantization table was better than the quality of image when using the default JPEG quantization table. Finally, a general strategy for modeling optimal quantization tables was presented in [14]. This method was designed for adaptive DCT image coding. Moreover, it can be used both for the JPEG image compression standard and for an extension of the JPEG approach to image block sizes other than 8x8 pixels. These techniques produced considerably improved compression performance compared to the default JPEG quantization table. When using an modified adjusted quantization table for JPEG compression provides a reconstructed image with better quality than using the default JPEG table. Therefore, by using such optimized quantization tables, we can either get stego-images with better quality or hide more data while maintaining the stego-image quality.

3. Comprehensive review of quantization table modification techniques

JPEG compression has been widely used in internet and in other applications. Therefore, JPEG based image steganography techniques have been greatly developed. It applies the discrete cosine transformation (DCT) to image which is a commonly used method for frequency transformation [14, 15]. In this JPEG based data hiding scheme, source image samples are grouped into non-overlapped consecutive 8×8 blocks and then each block is transformed by forward DCT into a set of values which are referred as DCT coefficients. The value located in the upper-left corner of the block is called DC coefficient and the other remaining values are called AC coefficients. Although the JPEG standard uses 8x8 quantization tables, it does not identify default or standard values for quantization tables. Choosing the best values in the quantization table is left up to the application. However, the JPEG standard provides a pair of quantization tables (luminance and chrominance) as examples tested and found to generate good results (Fig-1 for luminance) [16]. Ever since this quantization table is broadly used, it will be called the JPEG default quantization table. Trade-off between visual quality and compression rate can be achieved by using a proper quality factor (QF). The quantized DCT (QDCT) coefficients are further encoded into a bit-stream by applying entropy coding [16]. Jpeg–Jsteg is a hiding-tool based on JPEG. In Jpeg–Jsteg scheme, the secret messages are embedded in LSB of quantized DCT coefficients with whose values are not 0, 1, or -1 with zigzag manner [17]. After embedding the secret message in each block, Jpeg–Jsteg uses Huffman coding, Run-Length coding, and DPCM of JPEG entropy coding to compress each block. In this study, Jpeg-Jsteg was implemented by using the scaled and modified default JPEG quantization table (Table 2) which was optimized in Table 3 according to optimization strategy in [14].

Table 1: The default JPEG quantization table

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Chin-Chen Chang, Tung-Shou Chen and Lou-Zo Chung proposed a steganographic method based upon JPEG in [19]. They derived modified 8x8 quantization table in Table 4 which was optimized in Table-5 in order to improve the hiding capacity of Jpeg-Jsteg method. They utilized the middle frequency for embedding in order to achieve better hiding capacity and acceptable stego-image quality. For each quantized DCT block, the least two-significant bits (2-LSBs) of each middle frequency coefficient were modified to embed two secret bits.

Table 2: Scaled Quantization table

8	6	5	8	12	20	26	31
6	6	7	10	13	29	30	28
7	7	8	12	20	29	35	28
7	9	11	15	26	44	40	31
9	11	19	28	34	55	52	39
12	18	28	32	41	52	57	46
25	32	39	44	52	61	60	51
36	46	48	49	56	50	52	50

Table 3: Optimized Quantization table

8	8	8	9	10	10	11	12
8	8	9	10	10	11	12	14
8	9	10	10	11	12	14	15
9	10	10	11	12	14	15	16
10	10	11	12	14	15	16	18
10	11	12	14	15	16	18	20
11	12	14	15	16	18	20	22
12	14	15	16	18	20	22	23

Adel Almohammad, Gheorghita Ghinea and Robert M. Hierons proposed another quantization table method in [19]. They divided the cover image into disjoint blocks of 16 x 16 pixels and derived 16 x 16 modified quantization table (Table 6). In the above mentioned method, for each quantized DCT block, the least two-significant bits (2-LSBs) of each middle frequency coefficients were modified to embed two secret bits. It got better results in terms of capacity and imperceptibility than the previous methods in [17] and [18]. The above mentioned method in [20] was further extended to [20] by applying optimized and modified quantization table (Table 7).

Table 4: Modified Quantization Table

8	6	5	8	1	1	1	1
6	6	7	1	1	1	1	28
7	7	1	1	1	1	35	28
7	1	1	1	1	44	40	31
1	1	1	1	34	55	52	39
1	1	1	32	41	52	57	46
1	1	39	44	52	61	60	51
1	46	48	49	56	50	52	50

Table 5: Optimized Modified Quantization Table

8	8	8	9	1	1	1	1
8	8	9	1	1	1	1	14
8	9	1	1	1	1	14	15
9	1	1	1	1	14	15	16
1	1	1	1	14	15	16	18
1	1	1	14	15	16	18	20
1	1	14	15	16	18	20	22
1	14	15	16	18	20	22	23

Table 6: Modified 16 x 16 Quantization table

16	8	7	6	6	1	1	1	1	1	1	1	1	1	1	1
7	7	6	6	1	1	1	1	1	1	1	1	1	1	1	30
7	6	6	1	1	1	1	1	1	1	1	1	1	1	30	28
6	8	1	1	1	1	1	1	1	1	1	1	1	32	35	29
8	1	1	1	1	1	1	1	1	1	1	1	32	35	32	28
1	1	1	1	1	1	1	1	1	1	1	35	40	42	40	35
1	1	1	1	1	1	1	1	1	1	35	44	42	40	35	31
1	1	1	1	1	1	1	1	1	35	44	44	50	53	52	45
1	1	1	1	1	1	1	1	31	34	44	55	53	52	45	39
1	1	1	1	1	1	1	31	34	40	41	47	52	45	52	50
1	1	1	1	1	1	30	32	36	41	47	52	54	57	50	46
1	1	1	1	1	36	32	36	44	47	52	57	60	60	55	50
1	1	1	1	36	39	42	44	48	52	57	61	60	60	55	51
1	1	1	39	42	47	48	46	49	57	56	55	52	51	54	51
1	1	41	46	47	48	48	49	53	56	53	50	51	52	51	50
1	43	47	47	48	48	49	57	57	56	50	52	52	51	50	50

In this method, the least two-significant bits of each middle frequency coefficients in the quantized DCT blocks by applying quantization table (Table 7) in which middle elements represent values of 1's are modified to hide two secret bits. In addition to that, Jpeg-Jsteg embedding is applied to the lower frequency coefficients (top left part, 14 coefficients, of each block) without using the DC coefficient for embedding. It had been observed that the capacity and stego-image quality of this method with optimized and modified quantization table (Table 7) were better than other methods.

Table 7: Optimized Modified Table

7	7	7	7	7	1	1	1	1	1	1	1	1	1	1	1
7	7	7	7	1	1	1	1	1	1	1	1	1	1	1	17
7	7	7	1	1	1	1	1	1	1	1	1	1	1	17	18
7	7	1	1	1	1	1	1	1	1	1	1	1	17	18	20
7	1	1	1	1	1	1	1	1	1	1	1	17	18	20	22
1	1	1	1	1	1	1	1	1	1	1	17	18	20	22	24
1	1	1	1	1	1	1	1	1	1	17	18	20	22	24	26
1	1	1	1	1	1	1	1	1	17	18	20	22	24	26	28
1	1	1	1	1	1	1	1	17	18	20	22	24	26	28	30
1	1	1	1	1	1	1	17	18	20	22	24	26	28	30	33
1	1	1	1	1	1	17	18	20	22	24	26	28	30	33	36
1	1	1	1	1	17	18	20	22	24	26	28	30	33	36	39
1	1	1	1	17	18	20	22	24	26	28	30	33	36	39	42
1	1	1	17	18	20	22	24	26	28	30	33	36	39	42	45
1	1	17	18	20	22	24	26	28	30	33	36	39	42	45	49
1	17	18	20	22	24	26	28	30	33	36	39	42	45	49	52

4. Color Images

Increasing the capacity of cover images while maintaining imperceptibility is still a challenge on jpeg colour images [20]. Since the significant DCT coefficients of 16x16-pixels blocks are limited, more middle frequency coefficients can be used for embedding. This might increase the embedding capacity and preserve image quality. Neha Batra and Pooja Kaushik were proposed a steganographic method in [21] based upon blocks of 16x16 pixels and modified 16x16 quantization table by using Chang et al. method. However, they divide the cover image into non-overlapping blocks of 16x16 pixels and use larger quantization table in order to improve the embedding capacity in colour images. In the above mentioned method, a new quantization table approach is proposed whose length is twice the standard quantization table. The process results in both DC & AC coefficients of low & mid frequency parts. So there are 136 AC coefficients in quantization table which are set to 1 that can embed secret information. As a result, stego capacity is enhanced. For comparison if we consider test image of 512×512 as an example, chang's [19] method has 26 coefficients, where each coefficient can embed two bits. So, total embedment done is 2×26×512×512/8×8 = 212992 bits. It has been found that capacity which is the amount of information embedding in colour images increases as the number of modified quantized DCT coefficients increases. So more data is embedded using of 16×16 Quantization table (Table 8) compared to 8×8 tables.

8	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	30
1	1	1	1	1	1	1	1	1	1	1	1	1	1	30	28
1	1	1	1	1	1	1	1	1	1	1	1	1	32	35	29
1	1	1	1	1	1	1	1	1	1	1	1	32	35	32	28
1	1	1	1	1	1	1	1	1	1	1	35	40	42	40	35
1	1	1	1	1	1	1	1	1	1	35	44	42	40	35	31
1	1	1	1	1	1	1	1	1	35	44	44	50	53	52	45
1	1	1	1	1	1	1	1	31	34	44	55	53	52	45	39
1	1	1	1	1	1	1	31	34	40	41	47	52	45	52	50
1	1	1	1	1	1	30	32	36	41	47	52	54	57	50	46
1	1	1	1	1	36	32	36	44	47	52	57	60	57	55	47
1	1	1	1	36	39	42	44	48	52	57	61	60	60	55	51
1	1	1	39	42	47	48	46	49	57	56	55	52	61	54	51
1	1	42	46	47	48	48	49	53	56	53	50	51	52	51	50
1	45	46	47	48	48	49	57	56	56	50	52	52	51	51	50

Table 8: Optimized Modified Quantization table

The visual compassion varies from person to another person and it changes over time in everyone. So that different listeners will behave differently [6]. Consequently, most researchers use Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) criteria to measure the quality of mage coding and compression [9]. The PSNR and MSE for an NxN gray-level image are defined as follows.

$$PSNR = 10.\log_{10}\frac{255^2}{MSE}db$$

$$MSE = \left(\frac{1}{N}\right)^2 \sum_{i=1}^{N}\sum_{j=1}^{N}\left(X_{ij} - \overline{X_{ij}}\right)^2$$

X_{ij} : The pixel values of the cover image.

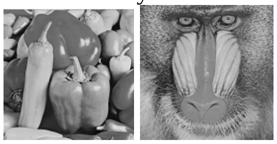
$\overline{X_{ij}}$: The pixel values of the stego-image.

5. Discussion

In this paper, we have studied various quantization table modification techniques and implemented some of the methods in [17], [18], [19], [20] found in literature which were developed by different researchers by applying default and optimized quantization tables and analyzed the obtained experimental results as well as results found in literature. Based on the experimental results, we have seen the following observations. The comparison of visual quality between the Chin-Chen Chang, Tung-Shou Chen, Lou-Zo Chung method [18] and Jpeg–Jsteg [17] are observed in the 256 x 256 cover images (Lena, Baboon, Girl, and Boat). It is observed that the stego-images of those methods are almost identical with the Jpeg–Jsteg and moreover they are identical to original images by measuring related MSE and PSNR. The message capacity of that Chin-Chen Chang, Tung-Shou Chen, Lou-Zo

Chung method [18] is larger than of Jpeg–Jsteg and the image quality of the method is acceptable. Further, Adel Almohammad, Gheorghita Ghinea, Robert M. methods [19] , [20] are implemented and compared with previous scheme in [17],[18] by applying to the same image set with 512x512 pixels.

Lena Tiffany Couple



Peppers Baboon

Source:http://www.imageprocessingplace.com/root_files_V3/image_databases.htm

Effectiveness of optimized quantization tables are evaluated through the Table 9 and Table 10. We have simply modified and implemented Jpeg-Jsteg [17], Chin-Chen Chang, Tung-Shou Chen and Lou-Zo Chung [18], Almohammad, Gheorghita Ghinea, Robert M. [19] , [20] methods with default quantization tables (Table 2, Table 4, Table 6) and optimized quantization tables(Table 3, Table 5, table 7). Table 1 shows the capacity (bits) of the cover images using these three methods once with the default quantization tables in FIG-1 and once with the modified quantization tables in FIG-2, FIG-3, FIG-4, and FIG-5 respectively. Table 1 and Table 2 shows the embedding capacity of the cover images and quality of stego-images for all stego-images produced was considerably improved when the optimized quantization tables were applied instead of the default ones used in JPEG.

Table 9: Capacity of steganographic methods (Bits)

Method	Lena	Tiffany	Couple	Pepper	Babbon
Jsteg(Table 2)	21917	20939	31006	21041	51554
Jsteg(Table 3)	21607	21590	33508	20395	68373
Chang(Table 4)	212992	212992	212992	212992	212992
Chang(Table 5)	212992	212992	212992	212992	212992
Almohammad (Table 6)	247808	247808	247808	247808	247808
Almohammad (Table 7)	255558	255283	257298	256066	258977

Table 10: The quality of stego-images, PSNR (db)

Method	Lena	Tiffany	Couple	Pepper	Babbon
Jsteg(Table 2)	33.76	32.85	31.8	32.71	27.92
Jsteg(Table 3)	34.8	34.4	33.4	33.8	30.6
Chang(Table 4)	36.92	35.39	35.2	34.9	29.8
Chang(Table 5)	37.91	37.38	37.03	36.11	35.04
Almohammad (Table 6)	37.56	36.41	36.3	35.32	32.49
Almohammad (Table 7)	37.1	35.97	35.82	35.05	32.51

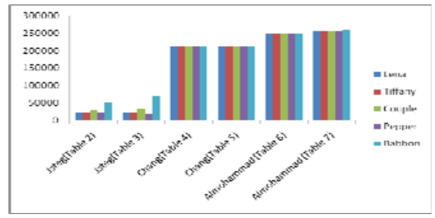


Figure 1: The capacity analysis of steganographic methods (Bits)

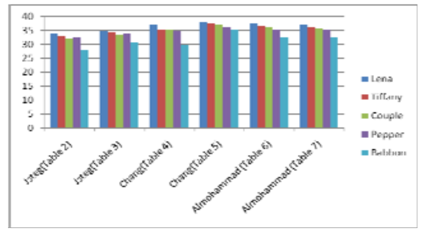


Figure 2: The quality analysis of stego-images, PSNR (db)

In Neha Batra and Pooja Kaushik scheme, four colour images, each of 256 x 256 and 512 x 512 pixels were used as test images by researchers. These cover images are Lena (1), Peppers (2), Jet (3), Baboon (4).The following results related to embedding capacity and imperceptibility were analyzed below by using quantization Table8.

Table 11: Comparison of hiding capacity, MSE and PSNR

Image	Pixels	Capacity	MSE	PSNR
Lena	256x256	69632	0.0981	58.2122
	512x512	278528	0.0251	64.1282
Pepper	256x256	69632	0.0931	56.9715
	512x512	278528	0.025	62.2132
Jet	256x256	69632	0.1771	55.6473
	512x512	278528	0.0324	63.0185
Baboon	256x256	69632	0.0944	58.3766
	512x512	278528	0.024	64.3199

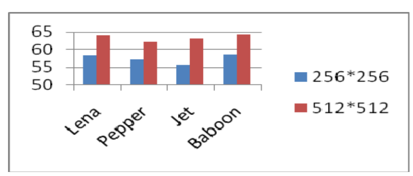


Figure 3: PSNR Comparison based on image size

Table 12: Comparison of steganography capacity

Method	Lena	Baboon
Neha Batra	184757 bits	184757 bits
Chang Method	141284 bits	141284 bits
Jpeg-Jsteg	49798 bits	53142 bits

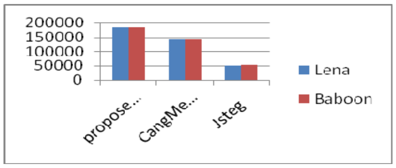
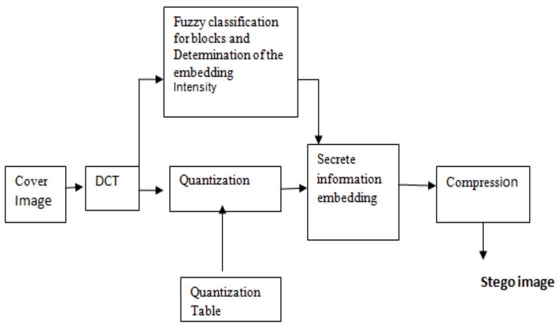


Figure 4: Comparison of embedding capacity pixel images

6. Future plan and proposed method

We suggest an idea that classifies the RGB image into non overlapped DCT blocks based on fuzzy theory to determine the embedding strength of each blocks and then derive the relationship between the color intensity values and modification of the threshold value in quantization table entry for data embedding in different image blocks without degrading the image quality. The rough sketch of diagrammatic description is illustrated as follows



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7. Conclusion

This paper presented a comprehensive review of how quantization table modification effect influence on embedding capacity and imperceptibility of jpeg based image steganographic system with experimental results by applying default and optimized quantization tables which were reviewed in literature. It was observed that steganographic method which use optimized quantization table can be embedding noticeably more secrete information than the methods which use default quantization table. Further, quality of steganographic technique which are occupying optimized quantization table was better than default quantization table. Anyhow, determining the optimized quantization table for image steganography is still challenge. In future, we fuzzy based idea proposed for gray or colour images based on embedding strength by applying quantization table modification to investigate both requirements of image steganographic system.

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Author Profile

V.Senthooran received the B.Sc (Hons) degree in Computer Science from University of Jaffna, Srilanka in 2006 and he is pursuing MPhil research work at University of Moratuwa with the title of "Adaptable Algorithms for Image Steganography" under the supervision of **Dr. Lochandaka Ranathunga** from University of Moratuwa and **Dr. Wong Kokshiek** from University of Malaya.

Dr. Lochandaka Ranathunga received B. Sc Sp (Hons), M. Sc, PGDip in DEd.(IGNOU), PhD (Malaya), MIPSL, MCSSL and he is presently working Lecturer and Head of the Department of Information Technology, Faculty of Information Technology, University of Moratuwa.

Dr. Wong KokShiek received B. Sc (Mathematics and Computer Science, MSc (Mathematics) MSc (Computer Science) in) (Utah State University, USA) and Deng (ShinshuUniversity,Japan) and presently working as Senior Lecturer in Department of Computer Systems and Technology, Faculty of Computer Science & Information Technology, Information Technology, University of Malaya.