Using Perceptual Criteria in Enhancing Capacity of Quantization Based Data Hiding Technique for Gray Scale Images

Mehul. S. Raval, *Member, IEEE*
Department of Electronics & Communication Engineering,
Sarvajanik College of Engineering and Technology, Dr. R.K.Desai Marg, Athwalines, Surat, Gujarat, 395001 India
Phone: 0261-2240148; fax: 0261-2240145 e-mail: mehul@ieee.org).

***Abstract*— Using scalar quantization, Quantization Index Modulation (QIM) based methods are perceived to give exceptional data hiding capacity. It is also possible to add local perceptual criteria within cover image coefficients for improving upon the data hiding capacity. In this work, author considers an implementation of this idea to improve upon the data hiding capacity of the conventional QIM method. Author calls this implementation as "Adaptive Perceptual QIM" implementation. The results of experiments suggest that work succeeded in improving upon the bit carrying capacity of simple QIM implementation.**

***Index Terms*— Data Hiding, Human Visual System, Quantization Index Modulation, Scalar Quantization**

I. Introduction

In QIM schemes proposed by Brian Chen and Gregory W. Wornell [2], data hiding is achieved through the quantization of transform domain coefficients according to set of predefined quantizers. The data to be hidden modulates the quantizer index. In order not to introduce a perceptually significant distortion, each quantizer must be fine enough. J. M. Barton et.al [1], K. Tanaka et.al[7], M. D. Swanson et.al[6] worked on a low-bit modulation, where the least significant bit in the quantization of the host signal are replaced by a binary representation of the embedded signal. It utilizes an embedding algorithm that maps the cover image and data to be hidden into a composite signal subject to some distortion constraint. J. A. O'Sullivan et.al[4] developed the information theoretic results for digital watermarking with which the QIM implementation can be compared. QIM methods are provably better than additive spread spectrum and generalized least significant bit methods for large capacity.

In order to further improve upon the capacity of the QIM implementation, it should also be possible to add the local perceptual criteria as suggested by A. B. Watson[8]. Watson proposed a model for adapting the quantization matrices of JPEG still image compression algorithm on a block by block basis, and considered masking effect as well. C.I.Podilchuk et.al [5] used visual models and investigated the results of the image adaptive watermarking scheme. R B Wolfgang et.al [9] proposed image adaptive watermarks for Discrete Cosine Transform (DCT) and Discrete wavelet Transform (DWT). They utilized the Watson perceptual model for investigations. They suggested both blind and informed decoding. But the main disadvantage with the Watson implementation is that set of equations are required at the decoder and if possible the original image, for detection as well.

II. Implementation

In this implementation author has utilized the conventional standard JPEG quantization table instead of DCT Frequency Sensitivity Table suggested by Watson for adaptation. Author has normalized the JPEG table by scaling a factor of 11.42 to obtain the similarity with DCT Frequency Sensitivity Table proposed by Watson. Image adaptation is also implemented by selecting coefficients for embedding of the data, which can survive JPEG compression. Author also adapts the JPEG quantization table for a given quality factor before embedding the data. This will help in preparing better against and JPEG compression attack in advance. It will lead to better "resistivity" against JPEG compression attacks for a given or better quality factors.

A. Embedding algorithm

Define JPEG quantization matrix of a desired quality factor so that data can resist any attack with similar or higher quality factor. (JPEG adaptation). Adapt the cover image by computing the masks based on Watson method. Use the JPEG quantization table instead of standard frequency sensitivity table.

Watson method implements the equations as follows. Luminance adaptation refers to the fact that a DCT coefficient can be changed by a larger amount before being noticed if the average intensity of block is brighter. To account for this, Watson model adjust sensitivity table for each block, 'k', according to block dc term as per following equation (1).

$$dct[i,j,k] = dct[i,j] * (I[0,0,k] / I[0,0])^{a} \qquad (1)$$

Where dct[i,j,k] is luminance masked threshold, dct[i,j] is JPEG quantization table value for DCT coefficient at values (*i,j*), a is a constant with a suggested value of 0.649, I[0,0,k] is the DC coefficient of the Kth block in the original image, and I[0,0] is the average of the DC coefficients in the image. The luminance masked threshold, is subsequently affected by contrast masking. Contrast masking resulting in a masking threshold, mask [i, j, k], given by following equation (2)

$$mask(i,j,k) = \max\left\{dct[i,j,k], \left|I[i,j,k]\right|^{w[i,j]}, dct[i,j,k]^{1-w[i,j]}\right\} \quad (2)$$

Where w[i,j] is a constant between 0 and 1 and we have used value as 0.7 for all i and j as suggested by Watson. The final threshold mask [i,j,k] estimate the amounts by which individual terms of the block DCT may be changed before resulting in one JND. Each mask will be multiplied with its corresponding DCT coefficients before QIM implementation.

Find the number of candidate embedding DCT coefficients. Only selected coefficients from this band would be used for embedding (Image Adaptation). Fig.1 shows dotted coefficients that are having potential for embedding per block of 8 x 8.

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Fig. 1: Potential DCT Coefficients for Embedding

Generate a randomly generated bit stream to be hidden (8 x 8) consisting of ones and zeros. We are using random collections of bits instead of using the recognizable pattern as data to be hidden. Get an 8x8 block of a cover image and take its forward DCT. Divide it by JPEG quantization matrix as obtained earlier for a given quality factor.(JPEG adaptive ness). Take the coefficient from the block and if '1' is to be hidden so quantize it to an odd value. If '0' is to be hidden quantize it to an even value. QIM implementation is done with step size of 1. Also do not embed into the coefficient that would quantize to zero. Quantized DCT block is multiplied again JPEG quantization matrix and Inverse DCT transform is taken. Count the numbers of bits encoded and various parameters like similarity factors.

B. *Detection Algorithm*

Blind detection is done and thus original image for detection is not required. Watson equation computation is not required at the detector. Block processing is done and after taking DCT transform for 8 x 8 blocks, it is to be checked that if the coefficient is even, the hidden bit is '0' else if the coefficient is odd, the hidden bit is '1'. Computation of errors is done by comparing recovered bit pattern with original bit pattern embedded. We compute false positive errors and false negative errors and bits recovered. False positive error occurs when detector incorrectly indicates presence of data. A False negative error occurs when detector incorrectly indicates the absence of data.

III. Testing and Results

Implementation of simple QIM scheme is also done on the above lines but without Watson perceptual criteria implementation. Testing is done with set of gray scale images which are varying in size from 512 x 512, 800 x 640, 736 x 496 and texture. As a pilot test case JPEG quantization matrix pertaining to quality factor of 50 is selected. The result of the testing is shown in following Fig. 2 with Q = 50.

It is difficult to incorporate the human response into the mathematical design procedure and so after extracting the watermark we need to measure its similarity with respect to embedded watermark sequence W and so a similarity factor (SF) defined by Chiou-Ting Hsu et.al [3] is adopted.

$$SF = \sum_i \sum_j f(i,j) f'(i,j) / \sum_i \sum_j [f(i,j)]^2 \quad (3)$$

f'(i,j) is the modified pattern, *f(i,j)* is original pattern. Thus similarity factor is a cross correlation normalized by an original pattern.

Original Image | Simple QIM Implementation | Adaptive Perceptual QIM Implementation

Fig.2 Comparison of Simple and Perceptual QIM Implementation for Q=50

The Table I list computation of errors, similarity factor for cover images, and total number of bits embedded in cover image, false positive and false negative errors for various test images. Fig. 3 compares number of effective bits embedded for perceptual and simple QIM schemes. Table II shows effects on increase in quality factor on JPEG compression.

TABLE I
LISTING OF PARAMETERS FOR ADAPTIVE PERCEPTUAL AND SIMPLE QIM

Test Images	Adaptive perceptual QIM implementation					Simple QIM implementation				
	No. Bits embedded	SFC	Error	False -ve error	False +ve error	No. Bits embedded	SFC	Error	False -ve error	False +ve error
Cameraman	17657	0.9994	73	1	9	16732	0.9997	3	0	0
Lena	22874	0.9987	10	1	1	22228	0.9995	0	0	0
Mandrill	29589	0.9970	2	0	0	27921	0.9993	56	1	1
Beach	88391	0.9946	1196	42	196	84436	0.9989	62	0	4
Balloons	35234	0.9919	1184	71	235	32565	0.9991	47	1	1
Waterfall	79013	0.9888	1639	61	272	75321	0.9989	250	5	18
Waves1	56647	0.9978	0	0	0	52268	0.9996	5	0	0
UN	51818	0.9900	405	9	57	49419	0.9987	1	0	0
Mountains	28594	0.9988	13	1	3	27755	0.9995	26	1	2

TABLE II
Effect of Increasing Quality factor

Adaptive perceptual QIM implementation						Simple QIM implementation					
Quality Factor	No. Bits embedded	SFC	Error	False -ve error	False +ve error	Quality Factor	No. Bits embedded	SFC	Error	False -ve error	False +ve error
50	22874	0.9987	10	1	1	50	22228	0.9995	0	0	0
55	27057	0.9995	0	0	0	55	26976	0.9994	0	0	0
60	27385	1	0	0	0	60	27172	0.9996	0	0	0
65	27429	1	0	0	0	65	27177	0.9997	0	0	0
70	27400	1	0	0	0	70	27181	0.9999	0	0	0

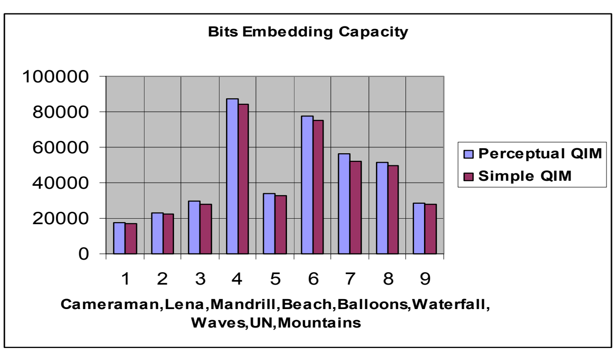

Fig.3 Comparison of Effective Numbers of Bits embedded for Simple and Perceptual QIM

We observe the effect of increasing the quality factor of JPEG compression on various parameters like total number of bits embedded in cover image, errors, false positive and false negative errors and similarity factors for single cover image. The experimentation was carried out with image Lena (512 x 512). Table II shows result of this experimentation. Fig.5 indicates the Graph of Number of Bits embedded for Simple and Perceptual QIM implementation for image Lena based on Table II.

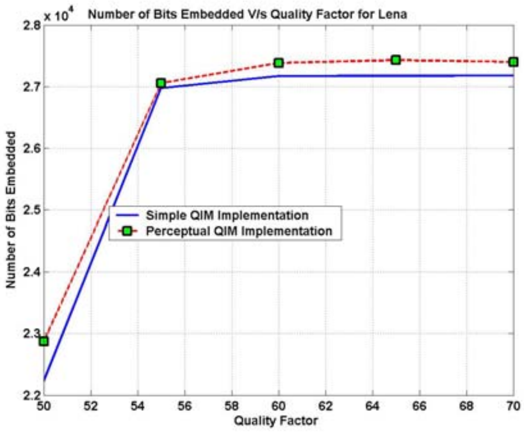

Fig.5 Graphs of Number of Bits embedded for Simple and Perceptual QIM implementation for Image Lena.

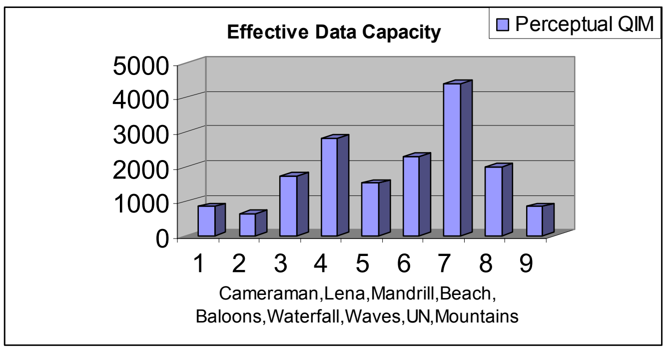

Fig.6 Effective Increase in Numbers of Bits embedded for Perceptual QIM as compared to Simple QIM

IV. CONCLUSION

It is evident from the experimentation that implementing perceptual criteria based QIM leads to higher number of bits being embedded into the cover image. This is shown in Fig.6 which indicates effective increase in capacity of cover images for bit embedding. These results are for Adaptive Perceptual QIM implementation with JPEG Q=50 and upon various test images as listed in Fig 2. We do not require knowledge of the Watson equations at the decoder making it simpler. The similarity factor between the original image and embedded information cover image is excellent and more or less similar for both simple as well as adaptive perceptual QIM implementation. As evident from the Table I the errors for the perceptual QIM can be brought down by implementation of error control coding.

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