INFORMED EMBEDDING AND WHITENING FILTER CORRELATOR BASED SPATIAL DOMAIN DATA HIDING TECHNIQUE

Dr. Mehul S. Raval

ABSTRACT

Data hiding is, mainly related to the possibility of perceiving the presence of an object by means of human sight. There are many ways, by which perceptual model can be incorporated into data hiding system to control perceptibility of data. In this work author implements, model for simple adjustment of a global embedding strength, based on cover image. Whitening filter is used at decoder which helps to de-correlate samples of received image, and improve performance of system. Work encompasses Watson perceptual model.

Keywords: Data Mining, Spatial Data, Data Hiding Technique.

1. INTRODUCTION

Major goal to hide an object or a piece of information means to keep it secret and thus perceptually it should be completely transparent. A good knowledge about the characteristics of Human Visual System (HVS) is must. The HVS is one of the most complex biological systems. Many models for HVS have been constructed [1, 3]. Usefulness of exploiting the characteristics of the HVS is valid when data concealment has to be granted with respect to human observers.

Certain observations about the HVS can be generalized like changes are more visible on uniform area than on highly textured region, they are less visible over dark and bright regions, very high energy regions like edges.

There are two different type of perceptibility that may be judged: fidelity and quality. Fidelity is a measure of the similarity between signal before and after processing. quality, on the other hand, is an absolute measure of appeal.

Another possible approach for adapting the data to the cover image is to have a criterion establishing the maximum amount of modification that can be sustained by the cover image. An imperceptibility region around the cover image data set should be defined: any modification, caused by data hiding, bringing the data outside the region will be perceptible, while smaller modifications will not. A level of distortion that can be perceived in 50% of experimental trails is often referred to as Just Noticeable Difference or JND. JND's are sometime employed as a unit for measuring the distance between the two stimuli. Watson [4] defines JNDs as linear multiples of a noise pattern that produces one JND of distortion. Watson proposed a model for measuring the visual fidelity. Watson describes a perceptual model that tries to estimate the number of JNDs between images. This model is far better than Mean Square Error (MSE) at estimating the perceptual effects of noise added to image. Watson proposed a model for adapting the quantization matrices of JPEG still image compression algorithm on a block by block basis, considers also the masking effect. However, author intends to use model for controlling data embedding algorithm.

The importance of including the transmission channel in the evaluation is that the transmission channel can have significant effects on the perceptibility of data hidden. As per the watermarking model of communication noise is superimposed during the transmission. To overcome the noise introduced during transmission one can use FEC.

The detector uses a linear correlator for detection. When a signal is corrupted by an AWGN noise, linear correlation is an optimum method for detection. Multimedia content typically exhibits strong spatial correlations. Image pixels in close proximity to one another typically have similar brightness. A common approach to process correlated data is to first de-correlate the data. De-correlation can be accomplished through the application of whitening filter [5 6], which is designed to eliminate or at least reduce correlation present. Detector in our work employs the whitening filter to exploit above advantages.

2. EMBEDDING ALGORITHM

The encoder is implemented as a state machine. Each message bit to be embedded is represented by pseudo random patterns equal to the image size. The machine begins in state and processes the bits of the input sequence one at a time. The input sequence use eight bit for experimentation. As FSM processes each bit, it gives an output and goes to next state. Out of the FSM is mapped to the unique reference pattern. The reference pattern resulting from a given code word, is then simply the sum of reference pattern for all input bits in FSM. This form of embedding is also known as Trellis Coded Modulation (TCM). Each path in the trellis is assigned a unique reference (watermarking) pattern. The reference pattern is generated using Pseudo Random Number (PRN) generator having a uniform distribution. The reference patterns generated are having one to one relationship with state of PRN generator. All reference patterns are summed to produce the final reference pattern. It is normalized to have zero mean and unit variance before embedding.

The simplest use of a perceptual model during embedding is to automatically adjust embedding strength. Proposed method uses Watson model to decide on a global embedding strength, and it is adjusted to obtain a fixed perceptual distance, as measured by Watson perceptual model.

Watson model defines a frequency sensitivity table as given by Table 1[7]. Each table entry *dct[i,j]* is approximately the smallest magnitude of the corresponding DCT coefficient in a block that is discernible in the absence of any masking noise. Thus a smaller value indicates that eye is more sensitive to this frequency.

This model type of data concealment is relying on the visibility thresholds. It is in fact possible to use optimization techniques for tuning the strength of the watermark signal in the embedding domain in such a way to satisfy the imperceptibility constraint. The main limitation of this approach is that the near frequency and inter-band masking effects are neglected.

1.4	1.01	1.16	1.66	2.40	3.43	4.79	6.56
1.01	1.45	1.32	1.52	2.00	2.71	3.67	4.93
1.16	1.32	2.24	2.59	2.98	3.64	4.60	5.88
1.66	1.52	2.59	3.77	4.55	5.30	6.28	7.60
2.40	2.00	2.98	4.55	6.15	7.46	8.71	10.17
3.43	2.71	3.64	5.30	7.46	9.62	11.58	13.51
4.79	3.67	4.60	6.28	8.71	11.58	14.50	17.29
6.56	4.93	5.88	7.60	10.17	13.51	17.29	21.15

Table 1. DCT Frequency Sensitivity Table

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 8 x 8 blocks is brighter. To account for this, Watson model adjust sensitivity table for each block, 'k', according to block dc term as per (1).

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

dct[i,j,k] is luminance masked threshold, *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 (2).

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

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. These thresholds are referred to as slacks. In the experimentation we found that most of the time luminance masked threshold has the highest value and hence slacks were taken equal to *mask[i,j,k]*.The perceptible distance in each term *dist[i,j,k]* is given as (3) below.

$$dist[i, j, k] = \alpha Wm[i, j, k] / mask[i, j, k] \text{-----------------}(3)$$

Wm be the block DCT transform of embedding pattern, α is the embedding strength. The individual errors computed must be pooled into single perceptual distance as in (4).

$$D_{watson}(I, I') = \left(\sum_{i,j,k} |dist[i, j, k]|^p \right)^{1/p} \text{---------------------------}(4)$$

Where Watson recommends a value of $p = 4$.

Thus to set D_{watson} equal to desired perceptual distance, D_{target}, we obtain α as (5)

$$\alpha = D_{target} / D_{watson} \text{--}(5)$$

Finally data is embedded using the following relationship as in (6)

$$I'(i, j) = I(i, j) + \alpha Wm \text{--------------------------------} (6)$$

Where I' is modified cover image and I is original cover image.

3. DETECTION ALGORITHM

Detector plays a very major role in data hiding algorithm. The definition of a reliable procedure to retrieve the information hidden within the host signal is of fundamental importance for proper development of any data hiding system. Author applies the same rule base of FSM at detector which was available at the embedder. The states of FSM are used to generate the reference patterns, used in correlation computations. Linear correlation is optimal detector when a signal is corrupted by AWGN noise. However, if linear correlation is used when the noise is not additive white Gaussian, detection will be suboptimal. Hence we use de-correlating filter, which is designed to at least reduce correlation present. It can be also be used to reduce the cross correlations among signals while preserving other characteristics. To use a whitening filter, F_{wh}, as shown in Table 2, in a linear correlation detector first one should convolve both received cover image (C') and reference pattern (W_r') with F_{wh} and then compute correlation between resulting patterns.

0	0	0	0	0.1	-0.2	0.1	0	0	0	0
0	0	0	0	0.1	-0.3	0.1	0	0	0	0
0	0	0	0	0.2	-0.5	0.2	0	0	0	0
0	0	0	0.1	0.4	-1.1	0.4	0.1	0	0	0
0.1	0.1	0.2	0.4	1.8	-5.3	1.8	0.4	0.2	0.1	0.1
-.2	-.3	-.5	1.1	5.3	15.8	5.3	1.1	-.5	-.3	-.2
0.1	0.1	0.2	0.4	1.8	-5.3	1.8	0.4	0.2	0.1	0.1
0	0	0	0.1	0.4	-1.1	0.4	0.1	0	0	0
0	0	0	0	0.2	-0.5	0.2	0	0	0	0
0	0	0	0	0.1	-0.3	0.1	0	0	0	0
0	0	0	0	0.1	-0.2	0.1	0	0	0	0

Table 2. Whitening Filter used in Detection Algorithm

$Z_{lc}(C',W_r')$ where $C'=C*F_{wh}$ and $W_r'=W_r*F_{wh}$ and * indicates convolution. Z_{lc} signifies the linear correlation. It is then used to determine the output bit as 1 or 0 depending on result of correlation greater than or less than threshold.

4. EXPERIMENTATION AND RESULTS

Experimentation was conducted with various sizes of image varying from 640 x 480 (mansigray.jpg), 256 x 256 (lena.tif) and 128 x 128 (pep128.tif, hetu.tif, merlin128.tif). The embedding strength α is made dependent on cover image making it image dependent. The values of embedding strength are shown in Table 3. Eight bits embedded were of pattern “1 0 1 0 1 0 1 0”.

Sr. No.	Image (Size)	α
1.	mansi.jpg 640 x 480	0.0025
2.	Hetu.tif 128 x 128	0.0054
3.	lena.tif 256 x 256	0.0039
4.	cat256.tif 256 x 256	0.0044
5.	Merlin128.tif 128 x 128	0.0057
6.	pep128.tif 128 x 128	0.0054
7	taylor128.tif 128 x 128	0.0051

Table 3. Embedding Strength for various types of Image

As visualized from the Table 3 embedding strength α is kept low, resulting in excellent perceptual transparency for message embedded cover image. The watermarked image is subjected to JPEG compression, noise addition, intensity adjustments, histogram equalization. Against all set of attacks all embedded eight bits has been recovered. The perceptual quality is seen from Fig.1, in which both original cover image (mansigray.jpg) and embedded cover image is zoomed several times.

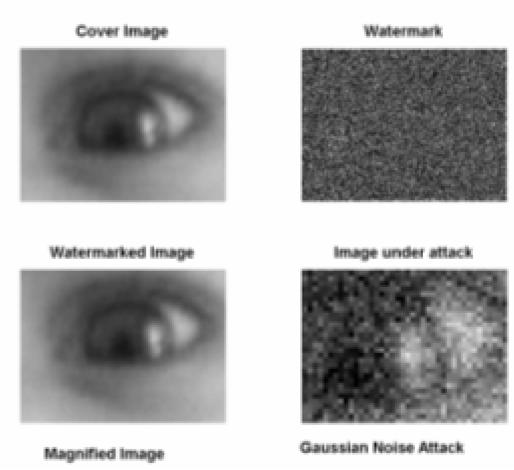

Fig.1 Perceptual transparency cover image

Images are subjected to various type of noise addition like Gaussian noise with zero mean and 0.01 variance as shown in Fig.1 and Fig2. The recovery against more severe noise attacks is also possible but it will significantly distort the perceptual quality of the data embedded image and hence reducing the value of image.

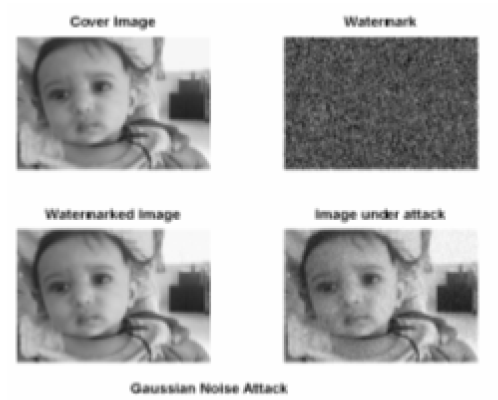

Fig.2 Image subjected to Gaussian Noise

Salt and pepper noise is added with a noise density of 0.05 and it is seen will "turn on and turn off" the pixel value.

Fig3. Cover Image subjected to Salt and pepper Noise

Speckle noise is type of multiplicative noise added to the image I, using the equation I = I + n*I, where n is uniformly distributed random noise with mean 0 and variance V. The default for V used is 0.04.

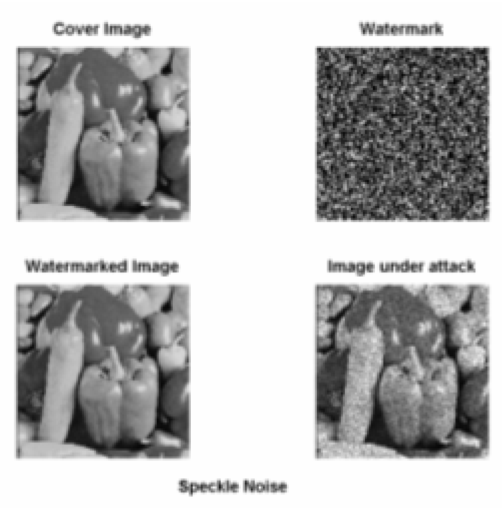

Fig 3. A Image subjected to Speckle Noise

Fig.3 shows the image corrupted with salt and pepper noise and Fig 3A shows image corrupted with speckle noise. Against all types of noise attacks algorithm has been able to recover 8 bit embedded in message faithfully.

Images are also subjected to various image intensity attacks like histogram equalization, gamma adjustment with value greater than (Darker resulting image) and less than one (Brighter resulting image) as shown in Fig 4, to Fig.7.

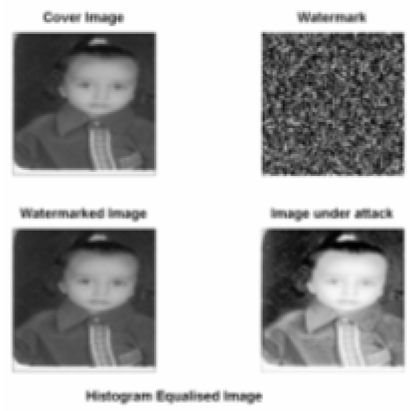

Fig. 4. Histogram Equalization

Histogram equalization enhances the contrast of image by transforming values in an image, so that histogram of output image matches a specified histogram.

Fig.5 Histogram equalization for lena image

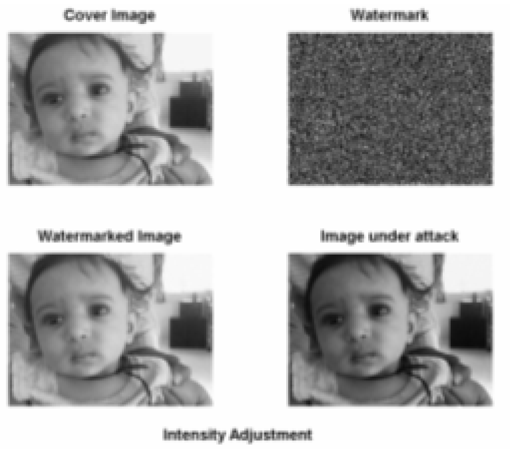

Fig. 6 Gamma adjustment with resulting darker image

Gamma specifies the shape of the curve describing the relationship between the values in input and output image. If gamma is less than 1, the mapping is weighted toward higher (brighter) output values. If gamma is greater than 1, the mapping is weighted toward lower (darker) output values.

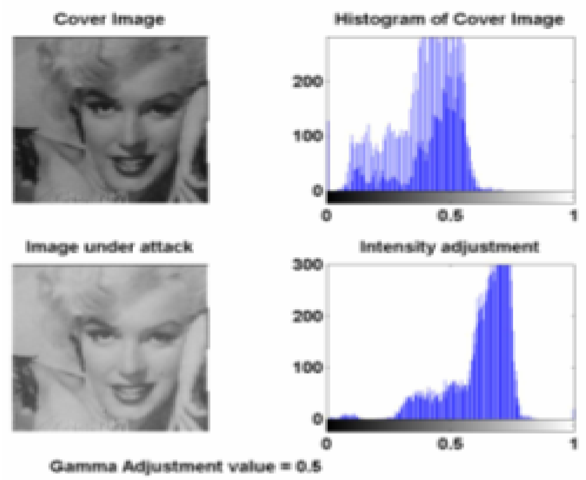

Fig.7 Gamma value adjusted resulting in brighter image

For all types of intensity attacks algorithm successfully recovers message bits embedded in the cover image.

To test the resistance of image against standard JPEG compression, taylor128.tif image is JPEG compressed with quality factor of Q = 60 to successfully recover the message bits. The result is evident in Fig.8

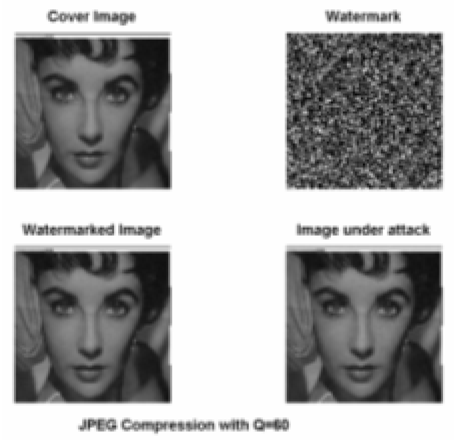

Fig.8 Recovery of message against JPEG compression with Q=60

If the quality factor of JPEG is further reduced then the recovered bits had error. If one applies embedding in rotation and scaling invariant domain than it is possible to have robustness against rotation and scaling attacks making method immune to vary large set of attacks.

5. CONCLUSION

The method is successful in hiding the data with excellent perceptual quality of cover image. The payload of the system is kept low to improve upon the robustness characteristics although one would like to visualize this system as data hiding technique rather than watermarking technique. Despite of embedding in "Random work", for all the image intensity attacks, noise attacks and JPEG compression (for some images and limited quality factor) algorithm is able to successfully recover the embedded message. One is using word "Random Work" due to different type and size of cover image used to embed the data in them. Performance improvement is also visible due to usage of whitening filter at the detector.

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