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Robust Steganography over Noisy Channel

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Abstract*: Steganography is accomplished by frequency or spatial domain. In spatial domain method, the important data are inserted directly into the image's pixels. Alternatively, the coefficients of the image frequency transform like DCT are used to carry the important data. Robustness in the presence of a noise is important. In this paper, the robustness over a noisy channel with noise like Added White Gaussian Noise (AWGN), salt and pepper noise and Speckle noise is investigated. The bit error rate is used for system evaluation. Simulation outcomes demonstrate that the frequency based model is stronger than spatial method against channel noise. Moreover, robustness is enhanced via using error correction.

Keywords: Steganography; Robustness; Noise; AWGN; salt and pepper, Speckle.

I. INTRODUCTION

Important data can be concealed unnoticeably in an image [1]. The hiding model is shown in Figure 1, where the significant data W concealed in the image C. The watermarked image I is passed over a channel. At the receiving end, the critical data is extracted. The system is realized via spatial [2] or frequency techniques [3].

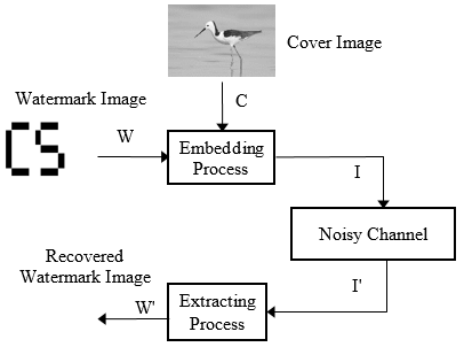

Fig. 1.Steganography Model

The impact of the LSB on the image is negligible because of using a bit with a small value. On the other hand, the discrete cosine transform (DCT) coefficients used to hide secret message bits. Figure 2 shows the 2D DCT coefficients where the components are divided into three groups low, middle and high [4].

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The middle components are nominated to carry the watermark because they are not affected by compression.

In this paper, the robustness of different methods is evaluated over a noisy channel. Furthermore, the robustness is improved by convolution encoder and Viterbi decoder [5].

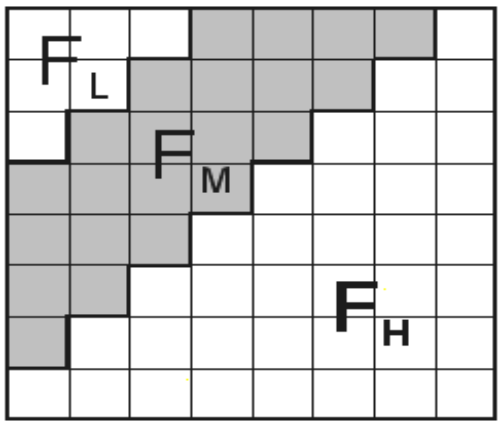


Fig. 2.The 2D DCT

II. PERFORMANCE OVER NOISY CHANNEL

Here, the robustness of the concealing methods are evaluated with different type of noise such as Added White Gaussian Noise, Salt and Pepper Noise and Spike Noise. For evaluation the PSNR is computed as following

$$PSNR = \frac{10\log_{10}(255)^2}{\frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left[I(i,j)-I'(i,j)\right]^2} \quad (1)$$

where M and N denote the image size.

Also, the received data quality is quantified by the bit error rate as follows

$$BER = \frac{\sum_{i=0}^{K-1}\sum_{j=0}^{L-1}\left[W(i,j)\oplus W'(i,j)\right]}{KL} \quad (2)$$

A. Performance over AWGN channel

The Additive Gaussian noise adds a noise to an image intentionally to corrupt the image or it may occurs during the signal acquisition due to sensor noise or electronic circuit noise. The LSB (Figure 3) is evaluated for different noise level. The results are illustrated at Table 1 and show that LSB is fragile against the AWGN noise. Alternatively, the DCT (Figure 4) is used and results shown at Table 2 indicate the superiority of the DCT over the LSB in attaining more robustness.

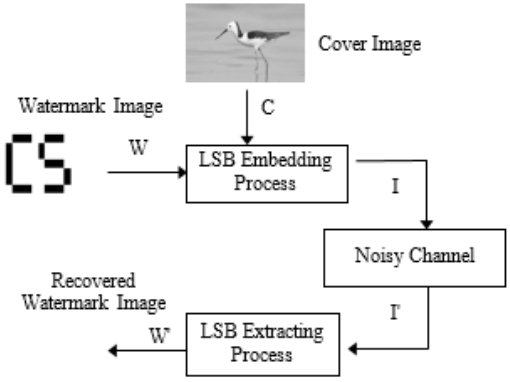
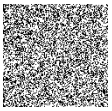
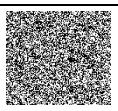
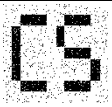
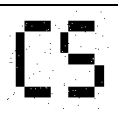
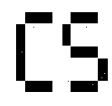


Fig. 3.LSB Model

Table- I: LSB over AWGN noise channel

PSNR	I'	W'	BER
10			0.45
50			0.45
53			0.3
60			0.06
70			0.006
80			00006

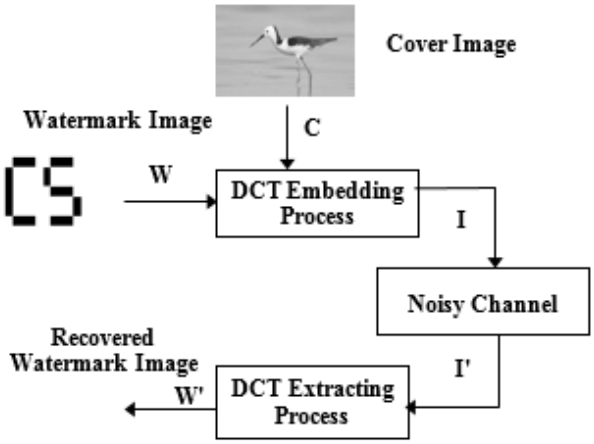
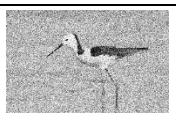
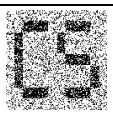
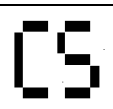
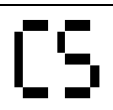


Fig. 4.DCT Model

Table- II: DCT over AWGN noise channel

PSNR	I'	W'	BER
10			0.37
15			0.23
20			0.08
25			0.0053
28			0.00013
30			0.000007

B. Performance over Salt and Pepper channel

The salt and pepper noise is presented as randomly happening of white and black pixels in an image. it could happen due to errors in data transmission or intentionally by an attacker to destroy the watermark [6]. The robustness of the embedding methods in presence of salt and pepper noise is illustrated at Table 3 and Table 4. Bothe methods have similar performance and the salt and pepper has less impact on the watermarked image compare to the AWGN noise.

Table- III: LSB over salt and pepper noise channel

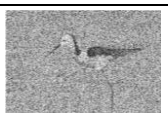
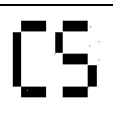
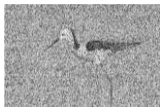
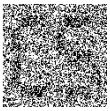
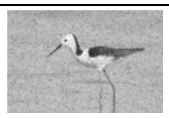
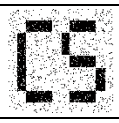
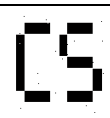
PSNR	I'	W'	BER
10			0.2
15			0.05
20			0.01
35			0.0006

Table- IV: DCT over salt and pepper noise channel

PSNR	I'	W'	BER
10			0.4
15			0.2
20			0.07
35			0.001

C. Performance over channel with Speckle noise

The speckle noise degrades the image quality by distributed random noise with mean zero and variable variance. It happens in imaging systems like laser, ultrasound and synthetic aperture radar images[7]. The result depicted at Table 5 displays the weakness of the LSB method at the presence of the Speckle noise. Oppositely, the result depicted at Table 6 demonstrates the effectiveness of the DCT method to obtain better BER.

Table- V: LSB over speckle noise channel

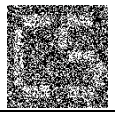
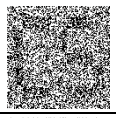
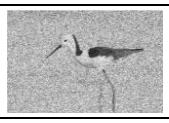
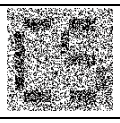
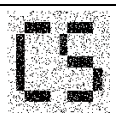
PSNR	I'	W'	BER
50			0.63
52			0.4
55			0.15
63			0.015

Table- VI: DCT over speckle noise channel

PSNR	I'	W'	BER
12			0.33
19			0.1
24			0.01
28			0.0002

III. ROBUST STEGANOGRAPHY

The system strength is improved by facilitating the errors correction (Figure 5) [8]. The convolutional encoder (Figure 6) is used to encode watermark bits. The encoder uses n-bit symbol to encode m-bit input. The encoder is classified based on the code rate and the constraint length CL. The Viterbi decoder is used to get the watermark W' at the receiving point.

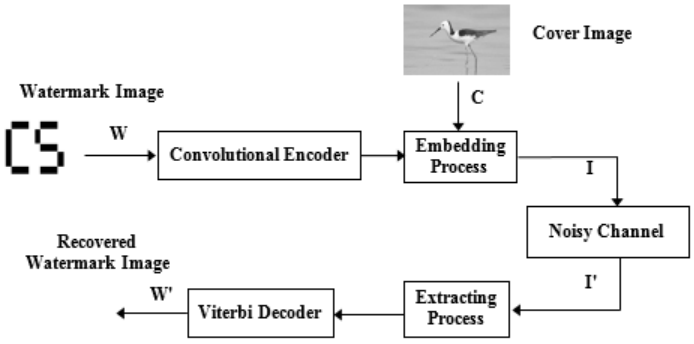


Fig. 5.Robust Model

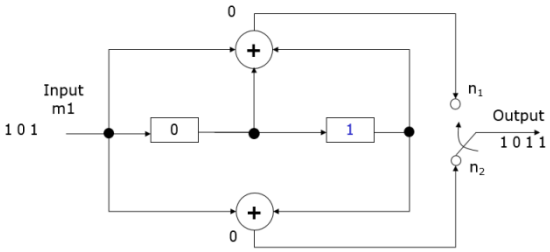


Fig. 6.Encoder

A. Performance over AWGN channel

Figure 7 shows the results for the LSB method where the CL is set to 3 and different rate values. Despite using the errors correction, LSB is weak against the AWGN noise. In contrast, the result at Figure 8 illustrates that the DCT method benefits from the proposed model to enhance the system robustness. The extensive experiments show that the system will achieve stronger robustness with higher R and CL[9].

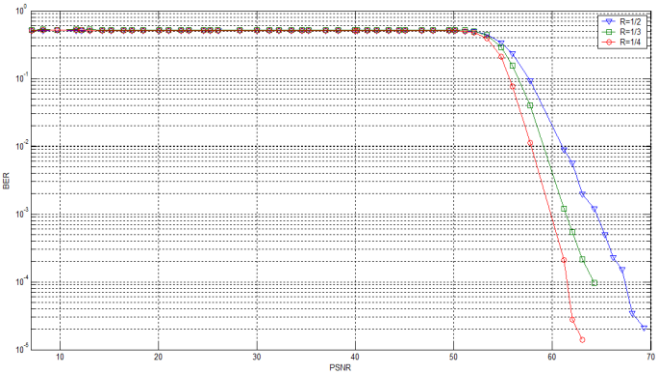


Fig. 7.LSB with CL=3

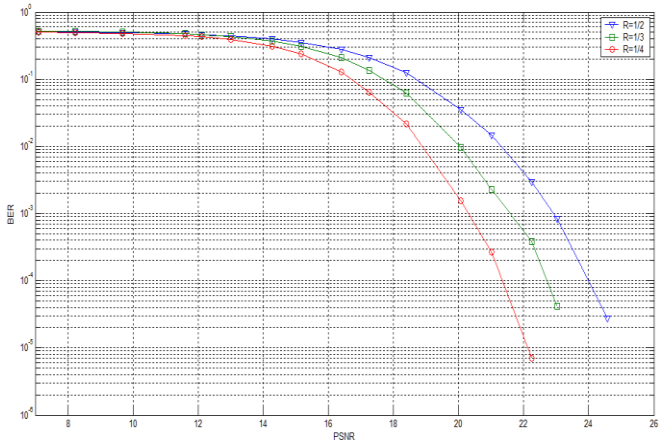


Fig. 8.DCT with CL=3

B. Robustness against Salt and Pepper noise

The evaluation results at Table 7 and Table 8 demonstrate that the embedding methods robustness against the salt and pepper noise is improved by employing the errors detection and correction capability where the robustness is improved significantly.

Table- VII: Robust LSB over salt and pepper noise channel

PSNR	LSB BER	Proposed BER
15	0.0493	0.0103
17	0.0319	0.0019
20	0.0150	0.0003
35	0.0006	0.0000

Table- VIII: Robust DCT over salt and pepper noise channel

PSNR	DCT BER	Proposed BER
20	0.0722	0.0210
24	0.0145	0.0005
26	0.0015	0.000

C. Robustness against Speckle noise

Similarly, the proposed system enhanced the secret data hiding robustness in the presence of the Speckle noise. The evaluation results at Table 9 and Table 10 validates the importance of the proposed system in making the embedding methods more robust.

Table- IX: Robust LSB over speckle noise channel

PSNR	LSB BER	Proposed BER
50	0.6390	0.4941
55	0.1565	0.2153
57	0.0914	0.0688
63	0.0154	0.0018

Table- X: Robust DCT over speckle noise channel

PSNR	DCT BER	Proposed BER
17	0.1492	0.1771
19	0.0808	0.0435
24	0.0103	0.0008
28	0.0002	0.000

D. Robustness over channel with multiple noise

Here, the robust proposed system is evaluated in the presence of multiple noise types. Table 11 exhibits the performance of the DCT over channel with different types of noise, while, Table 11 demonstrates the advantage of using the proposed robust method to protect the covered data.

Table- XI: DCT over noisy channel

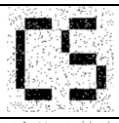
Noise variance & density	PSNR	W'	BER
AWGN=0.0001 S&P=0.02 Speckle =0.001	21		0.0512
AWGN=0.0001 S&P=0.01 Speckle =0.001	24		0.0226

Table- XII: Robust DCT over noisy channel

Noise variance & density	PSNR	W'	BER
AWGN=0.0001 S&P=0.02 Speckle =0.001	21		0.0065
AWGN=0.0001 S&P=0.01 Speckle =0.001	24		0.001

IV. CONCLUSION

In this paper, the performance of the spatial domain and the frequency domain data hiding methods over a noisy channel are evaluated for different type of noise. The results show that the spatial domain is very weak against the noisy channel. In contrast, the frequency domain method demonstrates better robustness. Moreover, the system robustness is boosted by using the proposed model of using the convolutional encoder and Viterbi decoder for error correction. Simulation results illustrate the efficiency of the proposed robust data hiding model by achieving better BER over a noisy channel.

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