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Analysis and Estimation of Noise in Embedded Medical Images

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Abstract—Patient information is embedded inside the medical images for the storage or transmission, or healthcare applications. In medical image processing, various types of noises corrupt the image quality. There is a need of measure specific noise for a particular image is required for the evaluation of robustness for embedding techniques used for hiding patient information in medical images. It is very important to obtain precise images to facilitate accurate analysis and estimation of noise in embedded medical image. The current work is focused towards studying the effect of specific noise which affect particular medical image. The strength of the medical image is tested by introducing several attacks to the embedded medical images. The statistical quantity measures like peak signal-to-noise ratio (PSNR), signal-to-noise ratio (SNR) and normalized root mean square error (NRMSE) are employed to measure the quality of the output medical image.

Index Terms—Embedding, Healthcare, Medical Image, Noise, Patient Information, Robustness.

I. INTRODUCTION

A Digital Watermark includes data, image or any secret piece of information embedded inside a host image or a video sequence to provide rightful ownership [1] and to prevent misuse of the image, video or data. Further, these techniques extended to carry vital information [2] inside a cover image or video for transmission and reception under privacy. Data Hiding Technique should have the robustness [3], Visual imperceptibility and an Optimal Embedding Capacity [4]. Hiding information inside image or other media in such a way that no-one apart from the sender and intended recipient even realizes there is a hidden information [5-8].

The image with hidden information is transformed from the source. The Receiver side incorporates the watermark extraction process where hidden information is collected at this location. In between the embedding and extraction process, there is communication channel which is predominant with noise which tends to corrupt and degrade the watermarked image. The effects of those channel disturbances [11] can be simulated by addition of noise, rotating the watermarked image and cropping the image which is equivalent to a person trying to destroy the vital piece of hidden information.

In medical image processing, it is very important to obtain precise images to facilitate accurate observations for the given application. Low image quality is an obstacle for effective feature extraction, analysis, recognition and quantitative measurements. Therefore, there is a fundamental need of noise reduction from medical images. There are currently a number of imaging modalities that are used for study of medical image processing. Among the newly developed medical imaging modalities, Magnetic Resonance Imaging (MRI) and Ultrasound imaging are believed to be very potential for accurate measurement of organ anatomy in a minimally invasive way. In this paper, MR image and Ultrasound image are experimented to remove noise. MRI is a powerful diagnostic technique. However, the incorporated noise during image acquisition degrades the human interpretation, or computer-aided analysis of the images. Noise in MR images obeys a Rician distribution. Unlike additive Gaussian noise, Rician noise is signal-dependent and consequently separating signal from noise is a difficult task. Ultrasound imaging is widely used in the field of medicine. It is used for imaging soft tissues in organs like liver, kidney, spleen, uterus, heart, brain etc. The common problem in ultrasound image is speckle noise which is caused by the imaging technique used that may be based on coherent waves such as acoustic to laser imaging.

Medical imaging is a method used to create images of the human body for clinical purposes or medical science. Diagnostic imaging includes a wide variety of scans, examinations and image modalities that are used in the medicine field such as X- Ray, computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound (US) X- Ray, CT, MRI and ultrasound images are widely used in the field of medicine. These images are used for imaging soft tissues in organs like liver, chest, kidney, spleen, uterus, heart, brain etc. Unfortunately, medical images are affected by a various number of noises such as Poisson, Rician, Gaussian and impulse noise (salt and pepper noise).The common problem in these image is noise which is caused by [9, 10] different area.

Embedding patient information inside medical image has attracted attention of researchers nowadays. Instead of focusing on the study of noise on embedded medical image authors attempted to develop a new methodology which includes impact of specific noise on a particular medical image.

The present paper is organized in four sections. Section 1 presents introduction with respect to the embedding the information in the images highlighting the drawbacks. Section 2 presents a detailed methodology adopted by the authors for interleaving of text in images and about noise models. Section 3 deals with statistical parameter used for the method. Section 4 presents results and discussion through tables and visual snapshots. Section 4 presents conclusions followed by references.

II. Noise Models

According to the watermarking, an attack is any processing that may mess up detection of the watermark or communication of the information provided by the watermark. The processed, watermarked data is then called attacked data. Robustness against attacks is an important issue for watermarking schemes. Attacks are generally occur during transmission of the watermarking image. There are many major attacks and they are tested in the proposed work.

The main source of noise in digital images arises during image acquisition or during image transmission. Major factors that affecting the amount of noise in the medical image is acquiring images with CCD camera, sensor temperature and light levels. Medical images are corrupted during transmission from source to destination. The principal reason is noise which is interfering in the channel during transmission [12]. The noisy image model is given by

$$N_r(i, j) = I(i, j) + N(i, j) \tag{1}$$

Where $I(i, j)$ the original image pixel is value and $N(i, j)$ is the noise in the image and $N_r(i, j)$ is the resulting noise image. The entire process of the proposed method is given in the form of flowchart in figure 1.

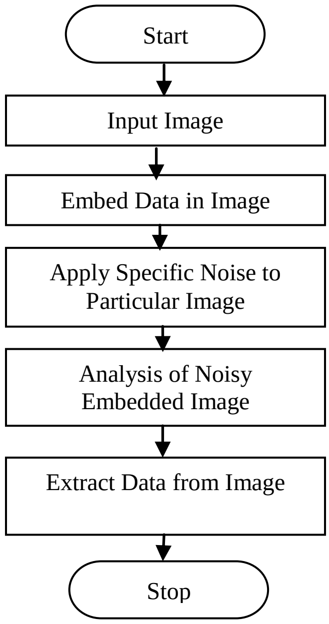


Fig. 1. Flow chart of proposed scheme

Different Noise Model which results in degrading image quality of the specific modality are discussed below.

A. *Poisson noise [X-Ray]*

The noise in X-Ray imaging is sculptural with Poisson noise [14]. X-Ray photons incident on a receptor surface in random pattern and can't force them to be evenly distributed over the receptor surface. One spot of the receptor surface might collect a lot of photons than another spot, even once each the spots are exposed to identical average X-Ray intensity. Using gamma or X-Ray photons most of the image noise is produced by the random behavior of the photons that are distributed within the image. This is known as quantum noise. Every individual photon could be a quantum of energy. It is the quantum structure of the X-Ray beam that makes quantum noise [13].

A Poisson model assume that each pixel x of an image $f(x)$ is drawn from a Poisson distribution of parameter $\lambda = f_0(x)$ where f_0 is the original image to recover. The Poisson density is given as

$$P(f(x) = k) = \frac{\lambda^k e^{-\lambda}}{k!} \tag{2}$$

B. *Rician Noise*

Rician noise which arises from complex Gaussian noise corrupts the MR images. The Rician probability density function for the corrupted image intensity *x* is given by

$$p(x) = \frac{x}{\sigma^2} \exp\left(-\frac{x^2 + k^2}{2\sigma^2}\right) A_0\left(\frac{xk}{\sigma^2}\right) \tag{3}$$

Where *k* is the underlying true intensity, *σ* is the standard deviation of the noise, and A_0 is the Modified zero[th] order Bessel function of the first kind.

C. Speckle Noise

Speckle noise is a granular noise that inherently exists in and degrades the quality of the Ultrasound image. Speckle noise is random and deterministic along with it has negative impact on ultrasound image. The effect of radical reduction in contrast resolution is the key factors in reducing quality of ultrasound image compare to other image modality. According to literature, speckle noise is known as "texture", and may possibly contain useful diagnostic information [15]. In General speckle model is represented as,

$$E(i, j) = I(i, j) * S(i, j) + K(i, j) \quad (4)$$

where $E(i, j)$ is the Noisy image, $I(i, j)$ and $K(i, j)$ is the multiplicative and additive component of the

Speckle noise. Considering multiplicative component and ignoring additive component of the noise, equation (1) is modified as;

$$E(i, j) = I(i, j) * S(i, j) \quad (5)$$

D. Impulse Noise

Impulse noise is frequently encountered in medical image during acquisition, storage and processing. The presence of impulse noise in medical image may be either relatively high or low. Due to this it degrades the image quality and causes some loss of image information details. Salt and pepper is one of the important noises among several types of impulse noise.

a. Salt and Pepper Noise

Salt and pepper noise is a typical form of impulse noise in a medical image which represents itself as randomly occurring white (salt) and black (pepper) pixels. The salt-and-pepper noise is also known as shot noise. Faulty memory locations, malfunctioning pixel elements in the camera sensors, or timing errors in the process of digitization will results in impulse noise. For 8-bit image the typical value for pepper noise is 0 and 255 for salt-noise.

E. Additive White Gaussian Noise Model Channel Noise

During transmission several types of noises usually degrade the quality of the medical images [15].White noise is the most important type of noise that occurs in communication system and is assumed to be additive. In communication system, it is often assumed that the noise is a stationary additive white Gaussian (AWGN) with power spectral density such that

$$G_n(f) = \frac{N_0}{2} \quad (6)$$

where $G_n(f)$ is spectral density and N_0 is the noise power. As per central limit theorem overall noise can be modeled as Gaussian. AWGN is a random statistical noise in the background of a communication channel. The purpose of hiding the patient information inside the medical image is to transmit diagnosis information of the patient from one clinic to another through open networks. As a result of transmission through the channel, channel noise could get added to the embedded image which could affect the accuracy of recovery of data at the receiver end [11]. To study the effect of channel noise, AWGN noise is generated and added to the embedded image.

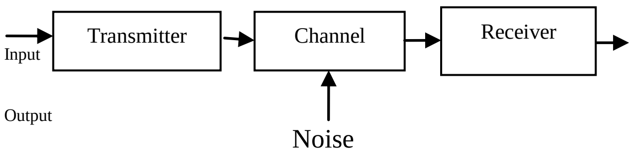


Fig. 2. Communication Channel

III. Performance Parameters

In order to measure the quality of the image at the receiver side, following parameters are used.

A. Mean Square Error (MSE)

The MSE is the cumulative square error between embedded image (image with patient information) and the original image which is defined by

$$MSE = \frac{1}{XY} \sum_{i=0}^{X-1} \sum_{j=0}^{Y-1} \left[I(i, j) - E(i, j) \right]^2 \quad (7)$$

Where, I is the original image and E is the embedded image and X and Y are the dimensions of the images.

B. Peak Signal to Noise Ratio (PSNR):

PSNR is the ratio between maximum possible power of a signal and the power of distorting noise which affects the quality of its representation. It is defined by:

$$PSNR = 20 \log_{10}\left(\frac{\max_f}{\sqrt{MSE}}\right) \quad (8)$$

where $\max_f = 255$ is the maximum intensity value that exists in the original image. A lower value for MSE means lesser error, results in high value of PSNR. Logically, a higher value of PSNR is good. Lower MSE (and a high PSNR), you can recognize that it is a better one.

C. Bit error rate (BER)

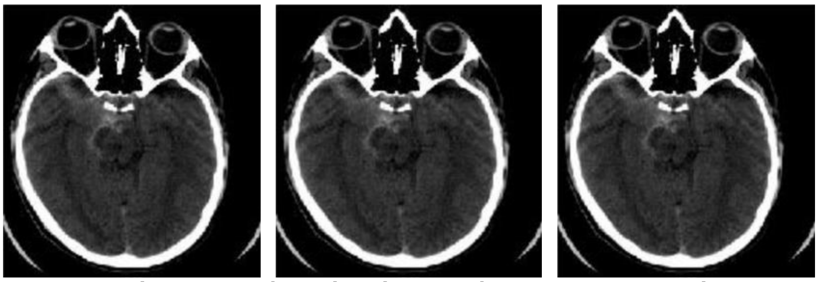
The most meaningful criterion for evaluation of performance of communication systems is the bit error rate (BER).To measure the quality of the proposed algorithm Bit error rate (BER) is determined after the recovery of patient information from the medical image. BER is a measure of how well bits are transferred end-to-end. BER is the ability to receive error-free information, even the medical image is affected by factors such as signal-to-noise and other distortion factors.BER is given by

$$BER = \frac{N_{error}}{N_{bits}} \tag{9}$$

where N_{error} is the number of bits received in error and N_{bits} is the total number of bits received. BER is expressed as ten to a negative power, for example, a transmission might have a BER of 10^{-5}, meaning that on average, 1 out of every 100,000 bits transmitted exhibits an error [4].

IV. RESULTS

This section presents a detailed results and discussion obtained by the authors in the present work. The results are presented through tables and snap shots. Impulse noise and AWGN affect all types of image modality. CT image is chosen for salt and pepper noise a type of impulse noise and MRI for AWGN. The proposed method is applied on more than 100 image modality with different sizes. However the present paper shows one of them of size 128 * 128. MSE, PSNR and BER are the measurable statistical parameters, used to study the quality of interleaved images. These are the important quantitative assessment parameters adopted in the image community. The ASCII codes of the encrypted text shown in Figure 4(b) are broken into bits and interleaved into the Least Significant Bits of the image modality. Different types of attacks are applied on particular image modality which will be affected by specific type of noise. One among that resulting image is shown in Figure 3(b). Figures 3a and 3b exhibits that the visual quality of image is always guaranteed before interleaving and after interleaving Patient information even after adding noise signal into original image. Since LSB of a pixel changes its brightness by one part in 256 interleaved image quality is not degraded which is shown in the figure 3b. It was observed that LSB technique ensure minimum degradation to original image. The PSNR and MSE values were calculated for various image modalities, with and without adding noise to the embedded image. The results obtained for images of different modalities were averaged and tabulated separately for different kinds of attacks. From the table (1) to table (5) it is clear that proposed algorithm will results in minimum MSE and maximum PSNR even when patient information is embedded inside the medical image. High PSNR or a lower MSE [16], indicates an image with minimum degradation. PSNR of the present method for the various attack on specific medical image prove that reconstructed image will match the original image. Similarly, according to the report of [17], a PSNR value in the range 20-40 indicates that the resultant image is a very good match to the original image. In accordance with this report, the results shown in table (1) to table (5) of the proposed algorithms produce PSNR values in the range 30dB to 50dB proving that the proposed algorithms does not degrade the images with the patient information inside the medical image. From the observation of figure 4(a) and 4(b), patient information embedded inside the medical image, is recovered at the receiver with zero BER, which is the most requirements for embedding Techniques.



a Original image b. Interleaved Image with Noise c. Received image

Fig. 3. Data Embedding

THE AIMS HEART FOUNDATION	ÔÅÁt»Æ ÌÓtÅÁ»ÒÔtÂ ÎÖ Í¿»ÔÆ ÎÍ	THE AIMS HEART FOUNDATION
BG Nagar	¼Ät Íãéãó	BG Nagar
Patient Ref.No:63271905	ÐãõëçïõtÒçè˜Íð¯¨¢¡ªž®œ	Patient Ref.No:63271905
Name of the Doctor: Dr. Kumar	Íãîçtðètõêçt¿ðåõðó¯t¿ó˜tÉöîãó	Name of the Doctor: Dr. Kumar
Name of the Patient: Pratham	ÍãîçtðètõêçtÐãõëçïõ¯Ðóãõêãî	Name of the Patient: Pratham
Age: 50 years	»éç¯t¦œtùçãóô	Age: 50 years
Address: 1 st cross, Javaranahalli.	»ææóçôô¯tžtôõtåóðôô”tÈãöãóãïãêãîîë˜	Address: 1 st cross, Javaranahalli.
Case history:	¾ãôçtêëôõðóù¯	Case history:
Date of Admission: 05-08-2010	¿ãõçtðèt»æîëôôëðï¯tœ¦–œ¬–¡œžœ	Date of Admission: 05-08-2010
Result: T Wave inversion	Òçôöïõ¯tÔtØãöçtëïöçóôëðï	Result: T Wave inversion
Diagnosis: Suspected MI	¿ëãéïðôëô¯tÓöôñçåõçætÌÆ	Diagnosis: Suspected MI
Treatment: Sublingual Nitroglycenn.	Ôóçãõîçïõ¯tÓöäîëïéöãîtÍëõóðéîùåçïï˜	Treatment: Sublingual Nitroglycenn.

a. Original Patient Information b. Encoded Patient Informatio c. Decoded patient Information

Fig. 4. Encode and Decode of Patient Information Performance Metrics With and Without Attacks on the Watermarked Image

Table 1. Poisson Noise

Image Modality with Size	Embedded Image		Embedded Image with Noise	
	PSNR	MSE	PSNR	MSE
X-Ray 128 *128	71.4101	0.0047	31.1006	50.4684
	71.7218	0.0044	28.9344	83.1077
	71.0842	0.0051	29.4162	74.3800
	71.1902	0.0049	31.7900	43.0605
	63.9979	0.0259	31.8317	42.6487
	71.2622	0.0049	30.2459	61.4450
	70.9638	0.0052	32.1067	40.0323
	71.3541	0.0048	30.6878	55.5014
	71.3913	0.0047	29.9705	65.4687
	71.3355	0.0048	30.4143	59.1089

Table 2. Rician Noise

Image Modality with Size	Embedded Image		Embedded Image with Noise	
	PSNR	MSE	PSNR	MSE
MRI 128 *128	69.321	0.0032	33.676	53.684
	71.362	0.0029	45.047	70.465
	62.065	0.0017	31.276	67.577
	67.256	0.0022	32.726	81.402
	67.406	0.0020	35.993	75.415
	69.790	0.0031	43.401	40.247
	70.329	0.0028	47.620	41.439
	71.432	0.0027	46.378	60.324
	67.472	0.0021	35.069	54.496
	68.529	0.0024	42.418	83.309

Table 3. Speckle Noise

Image Modality with Size	Embedded Image		Embedded Image with Noise	
	PSNR	MSE	PSNR	MSE
ULTRASOUND 128 *128	70.797	0.0050	38.973	8.235
	70.863	0.0053	39.306	7.629
	71.622	0.0045	40.028	6.460
	71.154	0.0051	39.991	6.515
	71.335	0.0040	40.011	6.486
	71.372	0.0047	40.347	6.001
	70.980	0.0052	35.146	9.879
	71.226	0.0049	41.105	5.040
	70.980	0.0052	39.109	7.983
	70.732	0.0055	39.414	7.440

Table 4. Salt and Pepper Noise

Image Modality with Size	Embedded Image		Embedded Image with Noise	
	PSNR	MSE	PSNR	MSE
CT 128 *128	66.261	0.015	49.776	0.684
	66.772	0.013	51.451	0.465
	65.865	0.016	50.517	0.577
	66.792	0.013	52.080	0.402
	71.563	0.004	51.945	0.415
	66.792	0.013	54.202	0.247
	71.563	0.004	51.703	0.439
	66.792	0.013	53.013	0.324
	66.226	0.015	51.170	0.496
	66.792	0.013	53.222	0.309

Table 5. AWGN with Different Variance

Image Modality with Size	Embedded Image		Embedded Image with Noise	
	PSNR	MSE	PSNR	MSE
MRI 128 *128	71.6220	0.0045	29.7750	68.4834
	71.5632	0.0045	29.2232	77.7599
	71.0495	0.0051	28.9994	81.8732
	71.8034	0.0043	29.9259	66.1440
	71.2260	0.0049	29.6415	70.6199
	70.8798	0.0053	29.1763	78.6047
	71.2441	0.0049	28.4067	93.8445
	70.8632	0.0053	28.4435	93.0526
	71.4101	0.0047	29.5752	71.7074
	70.8302	0.0054	29.9637	65.5714

V. Conclusion

This paper has presented a technique of analysis and estimation of noise during embedding patient information inside medical image. Different image modalities like X- Ray, MRI, CT and Ultrasound are used to study the effect noise on specific image. The results from the snap shot conclude that impact of specific noise after interleaving patient data inside the medical image visually agreeable. Robustness of the proposed algorithm is tested and analyzed by applying attacks to the medical image with patient data will not degrade in its quality. Calculating PSNR and MSE between original image and interleaved image with and without noise indicates that proposed algorithm is more resistive to noise attack and embedded patient information is recoverable without any distortion even in the case of attack. From the result it concludes that BER is observed to be zero, since the Patient data is recovered from interleaved image without a single data byte of loss occurred during retrieval time.

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