RELIABLE AND ROBUST TRANSMISSION AND STORAGE OF MEDICAL IMAGES WITH PATIENT INFORMATION

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ABSTRACT

A new method for compact storage and transmission of medical images with concealed patient information in noisy environment is evinced. Digital Watermarking is the technique adapted here for interleaving patient information with medical images. The patient information, which comprises of text data and signal graph, is encrypted to prevent unauthorized access of data. The latest encryption algorithm (Rijndael) is used for encrypting the text information. Signal graphs (ECG, EEG EMG etc.) are compressed using DPCM technique. To enhance the robustness of the embedded information, the patient information is coded by Error Correcting Codes (ECC) such as (7,4) Hamming, Bose-Chaudhuri-Hocquenghem (BCH) and Reed Solomon (RS) codes .The noisy scenario is simulated by adding salt and pepper (S&P) noise to the embedded image. For different Signal to Noise Ratio (SNR) of the image, Bit Error Rate (BER) and Number of Character Altered (NOCA) for text data and percentage distortion (PDIST) for the signal graph are evaluated. The performance comparison based on the above parameters is conducted for three types of ECC. It is elicited that coded systems can perform better than the uncoded systems.

1. INTRODUCTION

Exchange of database between hospitals needs efficient and reliable transmission and storage techniques to cut down cost of health care. This exchange involves large amount of vital patient information such as bio-signals, word documents and medical images. When handled separately using information media like the internet, it results in excessive memory utilization and transmission overheads. Interleaving one form of data such as 1-D signal, or text file, over digital images can combine the advantages of data security with efficient memory utilization [1]. Watermarking is a technique for storing copyright information. In this paper, similar technique is employed to store text and graphical signals in medical images by sharing last bits of pixels. Water marking is broadly classified into two categories one is spatial domain water marking and another is frequency domain watermarking. In spatial domain lower order bits of the image pixels are replaced by the text data without loosing identity of the image [2]. In frequency domain, image is first transformed into frequency domain (DFT, DCT and DWT) and then low frequency components are modified to obtained water marked images [3]. In this paper the information bit streams are interleaved in LSB of medical image. Practical transmission and storage scenarios are far from ideal due to the contamination arising from the presence of noise and other interference. Error Control Coding (ECC) techniques are proposed in this work for enhancing the reliability of transmission and storage in the presence of noise and other interference [4]. Adding Salt and Pepper (S&P) noise to the interleaved image simulates the effects of practical storage and transmission scenario. The reliability and robustness of the patient information is demonstrated using ECC scheme such as (7,4) Hamming codes, BCH codes and RS codes. The performances of various ECC schemes are demonstrated by plotting the BER versus SNR of the S&P noise-corrupted image for both text and signal graph data. Number of characters corrupted in the text can be regarded as a measure of performance of the transmission or storage system. The quality of the signal graph is studied by evaluating percentage distortion in the signal for different values of SNR.

2. THE INTERLEAVING PROCESS

Fig.1 indicates the steps involved in interleaving an image (size: 128x128 pixels) with data file. The information to be stored is encrypted before watermarking to enhance security [5]. This encrypted patient information is coded with error control codes, which make the system robust and reliable. The coded information bit streams are swapped with the least significant bit (LSB) of the grey

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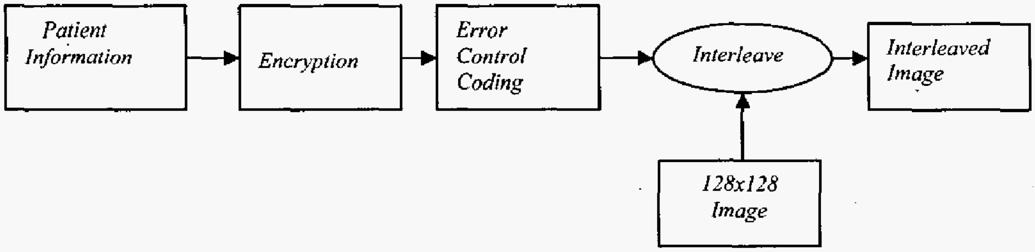
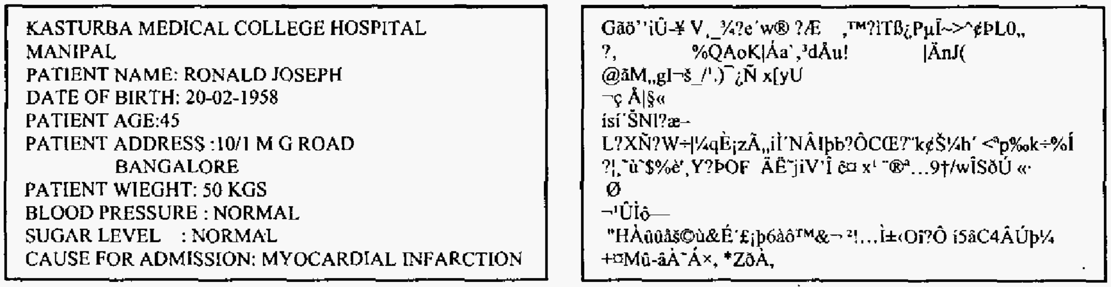


Fig. 1. Block diagram of interleaving process.



```
KASTURBA MEDICAL COLLEGE HOSPITAL
MANIPAL
PATIENT NAME: RONALD JOSEPH
DATE OF BIRTH: 20-02-1958
PATIENT AGE:45
PATIENT ADDRESS :10/1 M G ROAD
        BANGALORE
PATIENT WIEGHT: 50 KGS
BLOOD PRESSURE : NORMAL
SUGAR LEVEL   : NORMAL
CAUSE FOR ADMISSION: MYOCARDIAL INFARCTION
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a) Original Text

```
Gãö''iÛ-¥ V,_¾?e´w® ?Æ   ,™?ìTß¿PµÏ~>^¢ÞL0„
?,          %QAoK|Áa`,³dÅu!          |ÄnJ(
@ãM„gl¬š_/'.)¯¿Ñ x[yU
¬ç Å|§«
ísí´ŠNl?æ–
L?XÑ?W÷|¼qÈ¡zÃ„iÌ´NÂlþb?ÔCŒ?¨k¢Š¼h' <ªp‰k÷%Í
?¦,¯ù¨$%è',Y?ÞOF  ÄË¨jiV'Î ê¤ x¹ ¯®ª…9†/wÎSðÚ «·
 Ø
¬¹ÛÌô—
 "HÀûûåš©ù&É´£¡þ6àô™&¬ ²!…Ì±‹Oï?Ô í5âC4ÂÚþ¼
+¤Mû-âÀ¯Á×, *ZðÀ,
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b) Encrypted Text

Fig. 2. Encryption Results.

scale bit by bit. Each bit of the code thus replaces LSB of one pixel in the image. This cycle of interleaving coded bits in consecutive pixels is repeated to include all the bit streams. The LSB of the pixel is chosen for data interleaving because, the resulting degradation of image is minimal.

2.1: Encryption of the text file

The information to be stored is encrypted before watermarking to enhance the security. Highly secured algorithm called as Advanced Encryption Standard (AES), which is developed by National Institute of standards and Technology, is used for the encryption of text data. This algorithm is also called as Rijndael algorithm, which is designed by John Daemen and Vincent Rijmen. Rijndael's key length is defined to be either 128, or 192 or 256 bits in accordance with the requirements of the AES. [6]. Figure 2(a) and 2(b) shows the original patient data and the encrypted data respectively.

2.2 Encryption of Bio-signal graph:

Analog ECG is usually recorded on magnetic tape (Holter). To store it in the digital form, the ECG signal is sampled at a suitable rate so as to retain relevant details of peaks, troughs and frequency. The sampled signal is converted into digital form, whose dynamic range is determined by the word length of ADC output. The Differential Pulse Code Modulation (DPCM) technique is extensively used to reduce the dynamic range of the signal. The DPCM is used here for encrypting the ECG signal. The differential error output (which is random and uncorrelated) is used as the encrypted version of the original signal. The DPCM is a predictive coding technique [7] where in the present sample x_n in a signal is expressed as a sum of linearly weighted past sample x_{n-1} and error signal e_n and $x_n = px_{n-1} + e_n$ (1)

The predictor coefficient p is determined by the least square technique, as $p = {r(1)}/{r(0)}$

Where, $r(m) = \sum_{n=0}^{N-1-m} x_n x_{n+m}$

The differential error e_n is stored along with the first sample x_0 and the linear predictor coefficient p. The ECG signal x_n can be reconstructed from the error signal by auto-regression technique (Eq. (1)). Thus, the symbol pair (p, x_0) forms the key for the encrypted ECG signal e_n. This quantized e_n is interleaved with the LSB of image DCT/DWTs. As the dynamic range of the error signal e_n is very small, it is coded with only 4 bits. Figure 3 shows the results of this process.

2.3 Error Correcting codes for patient information

The theory of error detecting and correcting codes is that branch of mathematics, which deals with reliable transmission, and storage of data. Information media is not 100% reliable in practice, in the sense that, noise (any form of interference) frequently causes the data to be distorted. To deal with this undesirable but inevitable situation, some form of redundancy is incorporated in the original data. With this redundancy, even if the errors are introduced (up to some tolerance level), the original information can be recovered, or at least the presence of errors can be detected. The increasing reliance on digital communication and the emergence of digital computer as an essential tool in a technological society have placed ECC in a most prominent position. To enhance the reliability and robustness of the watermarking, patient information is coded by ECC. In this paper, we propose the use of an important class of ECC called as block code for enhancing the reliability of transmission and storage of the type of messages dealt with in this work. A comparative study of the objective parameters (BER, NOCA, PDIST) is demonstrated for (7,4) Hamming, BCH and RS codes

2.3.1. (n,k) Hamming Code

Hamming codes were the first class of linear codes devised for error correction and detection [8]. The single error correcting and double error detecting Hamming codes are characterized by the following parameters.

Code length: n=2^m-1
Number of Information bits: k=2^m-m-1
Number of parity check symbols: n-k=m
Error correcting capability: t=1;

In (7,4) Hamming code, four a message block of four bits is combined with three parity check bits to form a code word of length seven. Exact details of formation of the code word could be found in [8].

2.3.2 (n,k) Bose-Chaudhuri-Hocquenghem (BCH) code

BCH code is a cyclic code [8] and is a subclass of linear block codes. For any positive integer m and t (t<2^{m-1}), there exists a BCH code with following parameter [8].

Block length n=2^m-1
Number of parity-check digits: n-$k \leq mt$
Minimum distance: $d \geq 2t$+1;

Clearly this code is capable of correcting any combination of t or fewer errors in a block of n bits. Such BCH codes are aptly called as *t-error-correcting* BCH codes [8].

2.3.3 (n,k) Reed Solomon (RS) code:

The RS block code is organized on the basis of groups of bits. Such a group of bits are referred to as symbol. Each symbol can be considered to be non-binary symbol, which indicates that we are dealing with m bit symbol [8]. Since we deal only with symbols we must consider that if an error occurs even in a single bit of a symbol, the entire symbol is in error. RS code has following characteristics

Block length: n=2^m-1
Number of parity digits: n-k = 2t
Minimum distance: d = 2t + 1

This can correct combination of t or fewer errors. As it was in the case of BCH codes, such RS codes, which correct t or fewer errors, are aptly called as *t-error-correcting* RS code.

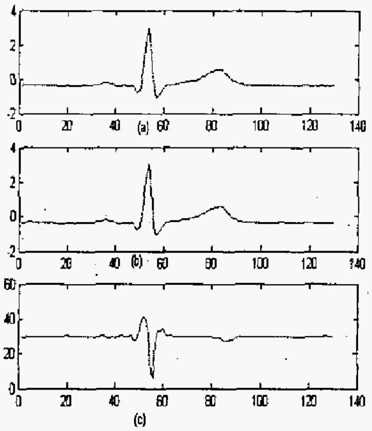
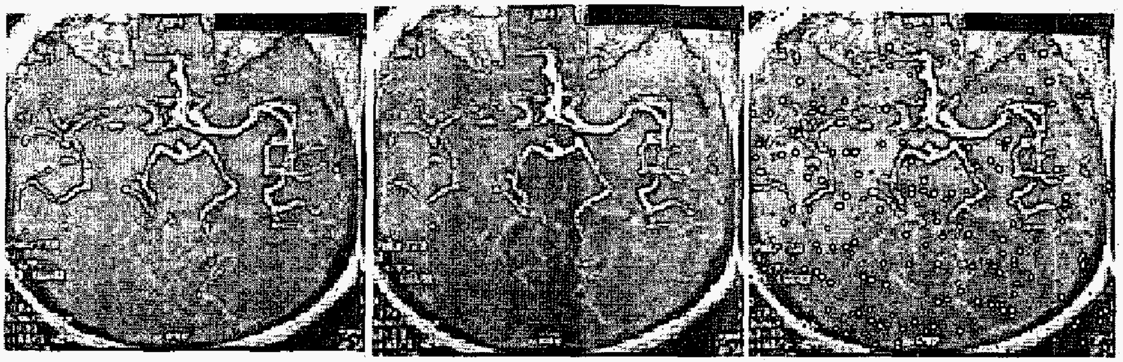


Fig. 3. Results of DPCM techniques: a) Original signal b) Reconstructed ECG signal C) Error signal

The patient information such as text data and bio-signal graph is encoded with (7,4) Hamming code, (15,3) and (15,7) BCH codes, (15,3) and (15,5) RS codes and their respective performance is demonstrated. The coded patient information is embedded in medical image and needs to be transmitted or stored. To simulate the effects of noise which is inevitable in practical transmission and storage scenarios, S&P noise is added to the embedded image, which will impart both random and burst error in the extracted patient information. This extracted patient information is decoded using ECC and decrypted using the same key and algorithm that is used for the encryption. Any image restoration technique [9] can now be implemented to alleviate the effects of noise in the image without having to worry about loss of interleaved text in the process of restoration.

3 RESULTS

The patient information, which includes both text data and bio-signal graph, are encrypted using the algorithm explained above. A MRI of size 128X128 is used for the interleaving process. The encrypted patient information is broken into bit streams and coded with ECC. These code words are embedded into the image as explained in the interleaving process. As mentioned earlier, adding S&P



a) Original Image b) Interleaved Image c) Noisy Image

Fig. 4. MRI Image

noise of various densities simulates the noisy transmission and storage scenario. The Signal to noise ratio (SNR) is computed for the noisy image. This is given in (2)

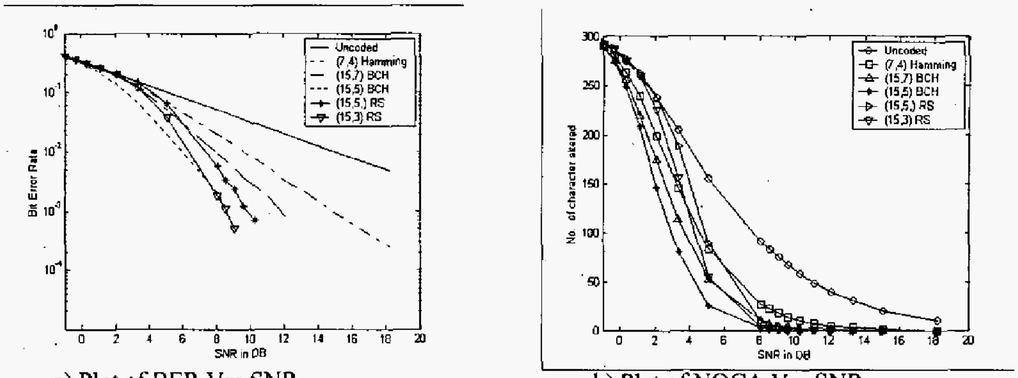
$$SNR = 10\log 10\left[\frac{\sum_{x=1}^{M}\sum_{y=1}^{N}(f(x,y))^2}{\sum_{x=1}^{M}\sum_{y=1}^{N}[f(x,y)-f_n(x,y]^2}\right]\text{dB} \quad (2)$$

Where $f(x, y)$ is Interleaved Image and $f_n(x,y)$ is noise corrupted image [9]. This is the quantitative measure; a class of criteria used often called the mean square criterion. Figure 4a, 4b and 4c shows original, interleaved and Noise corrupted MRI image respectively. As an objective measure for the quality of the de-interleaved or extracted text data and signal graph, BER, NOCA and PDIST is evaluated. BER gives the amount of error in the recovered patient information as compared to original information embedded in the image before transmitting of storing in noisy environment. NOCA will provide the number of text altered in recovered text data as compared to original embedded text data. The quality of the recovered bio-signal graph is evaluated using a quantitative measure called as percentage distortion, which will show the amount of distortion in the recovered signal as compared to the embedded signal before transmission or storage. These objective parameters are evaluated for various SNR. The robustness and reliability of the transmission and storage system is demonstrated for three types of ECC ((7,4) Hamming, BCH, and RS). Depending on the error correcting capability the performance of the BCH codes are tested for (15,5) and (15,7) BCH codes. Similar testing is done for RS code using (15,3) and (15,5) RS codes. Higher the error correcting capability better will be the performance.

Fig. 5 and 6 indicates the performances for both coded and uncoded system in noisy environment for various SNR values. This also provides the evaluation of BER, NOCA and PDIST respectively in the recovered patient information for the three types of ECC referred to in the previous section. The plots show that low BER is obtained for the coded system especially BCH and RS codes, which are also observed to give better performance compared to the (7,4) Hamming codes. Similar results are shown for NOCA. It is seen that less number of characters are altered on an average if we encode the patient information with ECC and then interleave or embed in the medical image. The percentage distortion is also found to be less for encoded systems compared to the uncoded systems. The plots in Figures 5.a and 5.b show the performance of ECC on text data in the form of BER and NOCA respectively against various SNR values. Similar plot for the bio-signal is shown in figures 6.a and 6.b where, BER and PDIST is plotted as a function of SNR. Since the error correcting capability of (7,4) Hamming code is just one, its performance is inferior to the other two types of codes which have larger error correcting capabilities. Comparison of the results of (15,3) and (15,5) BCH codes reveal that the former is found to be the best because of the better error correcting capability. Similar conclusions can be drawn from a comparison of the results for the (15,3) and (15,5) RS codes. It is evinced that maximum tolerable noise level is 8dB, beyond which performance is unacceptably poor.

4 CONCLUSION

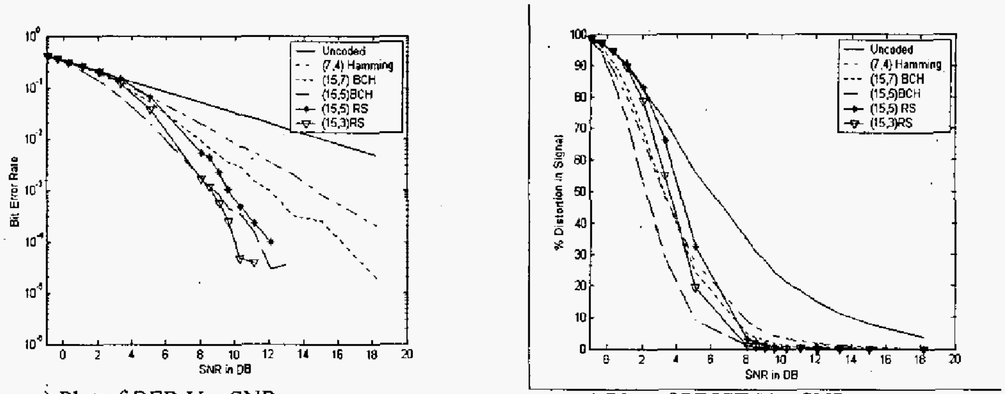
A practical method based on the use of ECC for reliable and robust transmission and storage of medical images with concealed patient information is demonstrated. The patient information is coded with ECC to make it less susceptible to noise introduced during transmission or storage. A comparative study of three coding techniques namely (7,4) Hamming code, BCH code, and RS code is demonstrated for various levels of S&P noise. It is seen that even though ECC will correct the errors introduced in patient information, there is limit for the error correction. Beyond some level of SNR value, the information is completely lost. Our results are encouraging enough to make investigations on more powerful ECC techniques to make the system more reliable and robust worth pursuing.



a) Plot of BER Vss SNR

b) Plot of NOCA Vss SNR

Fig. 5. Results for text data



a) Plot of BER Vss SNR

a) Plot of PDIST Vss SNR

Fig. 6. Results for bio-signal graph

The Convolution codes, a different class of ECC compared to block codes could as well be used to encode the patient information. This is a future work.

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