Lossless Watermarking in JPEG2000 for EPR Data Hiding

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***Abstract* - With the advances in telemedicine, watermarking for Electronic Patient Record(EPR) data hiding has gained profound importance. Most of the techniques proposed for EPR data hiding are not compression tolerant. In this paper we propose a new lossless scheme wherein the watermarking is done during the JPEG2000 compression process so that both the watermark and the cover image can be recovered as such at the receiving side. The recovered image is the same as that of the decompressed image when no watermarking has been done.**

***Keywords*- JPEG2000, EPR, watermarking, bit-plane**

1 Introduction

With the development in telecommunication, traditional diagnosis is being replaced by e-diagnosis. For the efficient use of the limited channel bandwidth, embedding of EPR data in the cover image is often being used. Several medical image watermarking algorithms have been proposed to meet this as well as the additional requirements of privacy of patient and integrity of EPR and the medical image.

There are three major requirements for EPR data hiding and transmission: (1) The recovery of the EPR should be blind due to the unavailability of the original image, (2) Zero bit-error rate is essential for EPR data, and (3) Imperceptibility should not be compromised for any reason (otherwise, poor diagnosis may result). Most of the watermarking algorithms for EPR data hiding are not compression tolerant. So the data may be lost during transmission over the channel. In this paper we propose a scheme in which the watermarking is incorporated into the procedure of the JPEG2000 coding so that the EPR data is not lost during transmission. The recovered image obtained after watermark extraction is the same as the image obtained when no watermarking has been done. After embedding the data, the JP2 coding generates a watermarked bitstream which is transmitted. At the receiving side, after decoding, the EPR is extracted and the cover image (same as the image to which no watermarking has been done) is reproduced. Hence there is no issue of imperceptibility. The scheme achieves all the three requirements mentioned above and also provides good capacity, which is very important for EPR data hiding.

The rest of the paper is organized as follows: Section 2 gives an overview of the JPEG2000 standard. Section 3 details the proposed watermarking scheme. Results are shown in section 4 and section 5 presents our conclusion.

2 Overview of JPEG2000

JPEG2000 extends the initial JPEG standard to provide increased flexibility in both the compression of continuous tone still images and access to the compressed data. The standard is based on wavelet coding techniques [4],[5],[6]. The JPEG2000 standard allows for both lossless and lossy compression. We use lossy compression as it is more commonly used. Some of the advantages of JPEG2000 standard are its superior low bit-rate performance, robustness to bit-errors, and protective image security.

The JPEG2000 compression standard is composed of the stages as shown in the flow graph in Figure 1. Preprocessing is performed first, which consists of tiling, level offset and irreversible colour transform(only for colour images).Offsetting ensures that the input sample data has a nominal dynamic range centered about zero.

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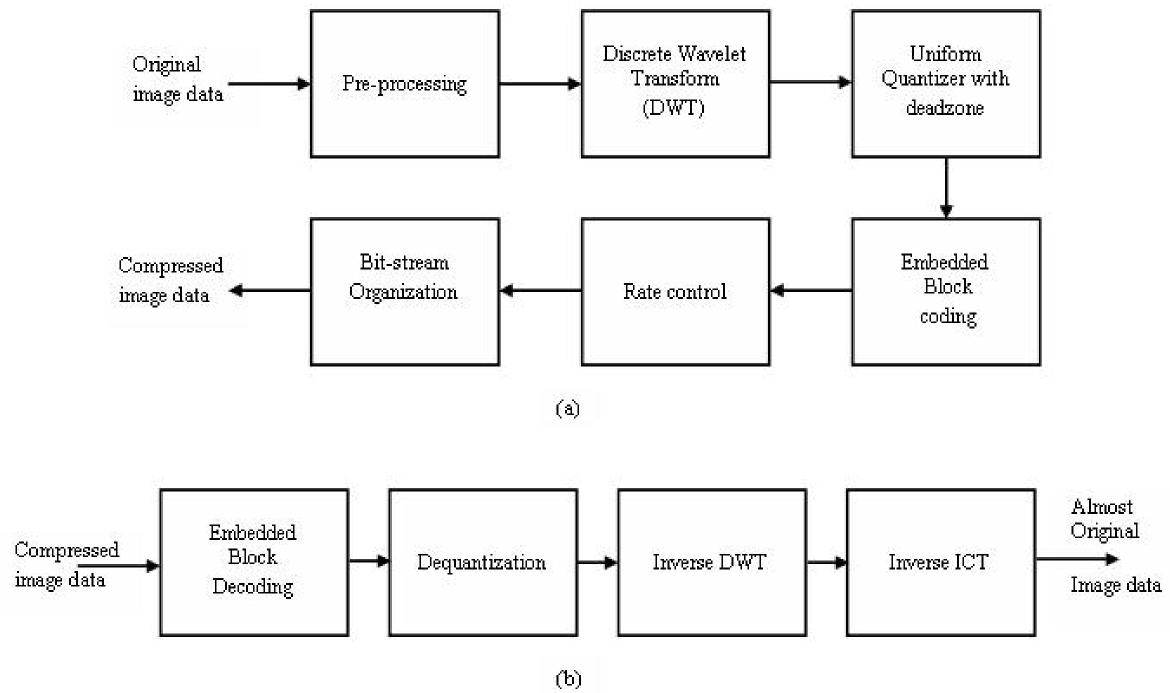

Figure 1: The JPEG 2000 (a) encoding process (b) decoding process

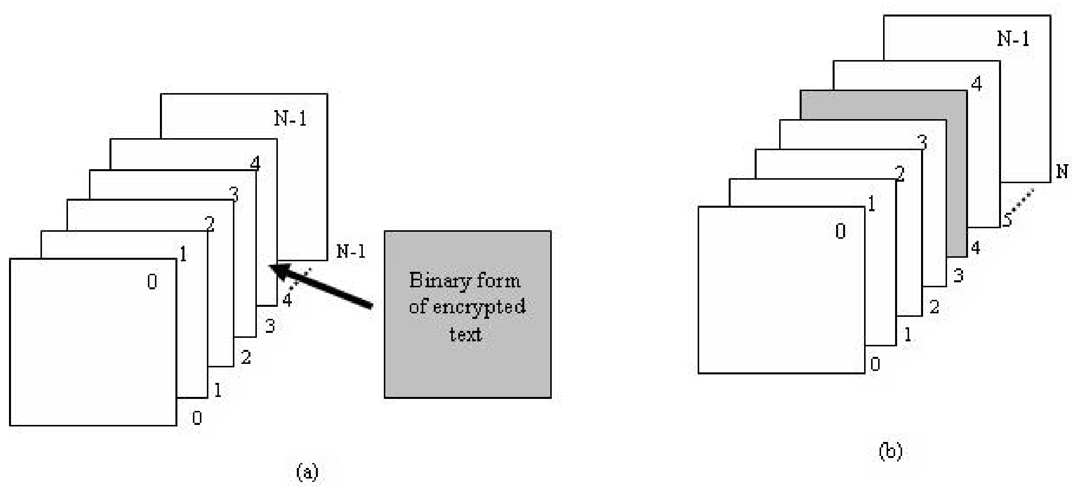

Figure 2: Bit planes of the subband (a) before embedding (b) after embedding

JP2 uses a discrete wavelet decomposition(DWT) to decompose each image tile into its low and high subbands. The first stage of the DWT yields four quadrants :

- **LL:** low subbands for row and column filtering
- **HL:** high subbands for row filtering and low subbands for column filtering
- **LH:** low subbands for row filtering and high subbands for column filtering
- **HH:** high subbands for row and column filtering

In the next stage the same process is repeated with the LL1 subband to obtain the LL2, HL2, LH2 and HH2 subbands. Only the LL subband is further transformed because the high subbands rarely contain any signficant samples. For natural images, usually between 4 to 8 stages of DWT are performed. The number of stages is implementation dependent.

The next step is quantization. The wavelet coefficients are quantized using a uniform quantizer with dead zone. For each subband b, a basic quantizer step size Δ_b is used to quantize all the coefficients in that subband according to

$$q = sign(y) \left\lfloor \frac{|y|}{\Delta_b} \right\rfloor \tag{1}$$

where y is the input to the quantizer, Δ_b is the step size, q is the resulting quantizer index.

Before coding is performed the subbands of each tile are further partitioned into relatively small code blocks such that code blocks from a subband have the same size. Each code block is encoded independendly. Starting from the most significant bit plane with a non zero element, each bit plane is processed in three passes, which are called *significance propagation* , *magnitude refinement,* and *clean-up.* At the same time as embedded block coding is being performed, the resulting bit streams for each code block are organised into quality layers.

The next process is rate control by which the code stream is altered so that a target bit rate is reached. In bit stream organization the compressed data from bit plane coding passes are first separated into packets. One packet is generated for each precinct in a tile (A precinct is a grouping of code blocks within a resolution level).

The decoder basically performs the opposite of the encoder. The code stream is received by the decoder, the coefficients in the packets are decoded and dequantized and the reverse ICT is performed.

3 Proposed Scheme for Watermarking

The data loss in the JPEG2000 compression process occurs during the quantization stage and the rate control stage. The major requirement for EPR data hiding is that these two processes do not alter the embedded EPR so that it can be recovered without error at the receiver side [7],[8]. So we insert the EPR after the quantization process in such a way that the rate control stage *does not* cause any change to it.

Figure 3(a) shows the proposed watermarking scheme. The watermarking is performed after the quantization stage of the JPEG2000 process. The EPR is first encrypted using the equation

$$T_e = t^r - d \tag{2}$$

where t is the input text, T_e is the encrypted text, r and d are constants. r can have a value in the range 1.000 to 1.143 and d can be between 0.0 and 10.0. The first level of security lies in this encryption process.

The encrypted EPR is converted to binary and inserted as an *extra bit plane* to the HL2 and/or LH2 subbands depending on the size of the text. Some of the lower significant bits may be lost in the truncation process of the rate control stage as they have negligible effect on the quality of the image. So to ensure that the watermark(EPR) is not altered during this stage, the binary form of the encrypted EPR is inserted as the *fourth* bit plane of the HL2 and/or LH2 subbands as shown in Figure 2. If the watermark is inserted as higher bit planes, the compression ratio is affected. (This is for an 8-bit image. For 16-bit images, the EPR may be inserted as the 7^{th} or 8^{th} bitplanes to ensure zero data loss during rate control.) After the insertion of the watermark the rest of the JP2 coding process is done and the compressed bit stream is transmitted.

At the receiver side, after decoding, the watermark is extracted as shown in the block diagram of Figure 3(b). The fourth bit plane of HL2 and/or LH2 is taken out (figure 4) and the binary data is converted back to the encrypted text. The HL2 and/or LH2 subbands then are the same as that when no watermarking has been done. The subbands are then dequantized and the inverse DWT operation is performed to recover the original image.

The extracted encrypted text is decrypted using the relation

$$D_e = (T_e + d)^{\frac{1}{r}} \tag{3}$$

where D_e is the decrypted text.

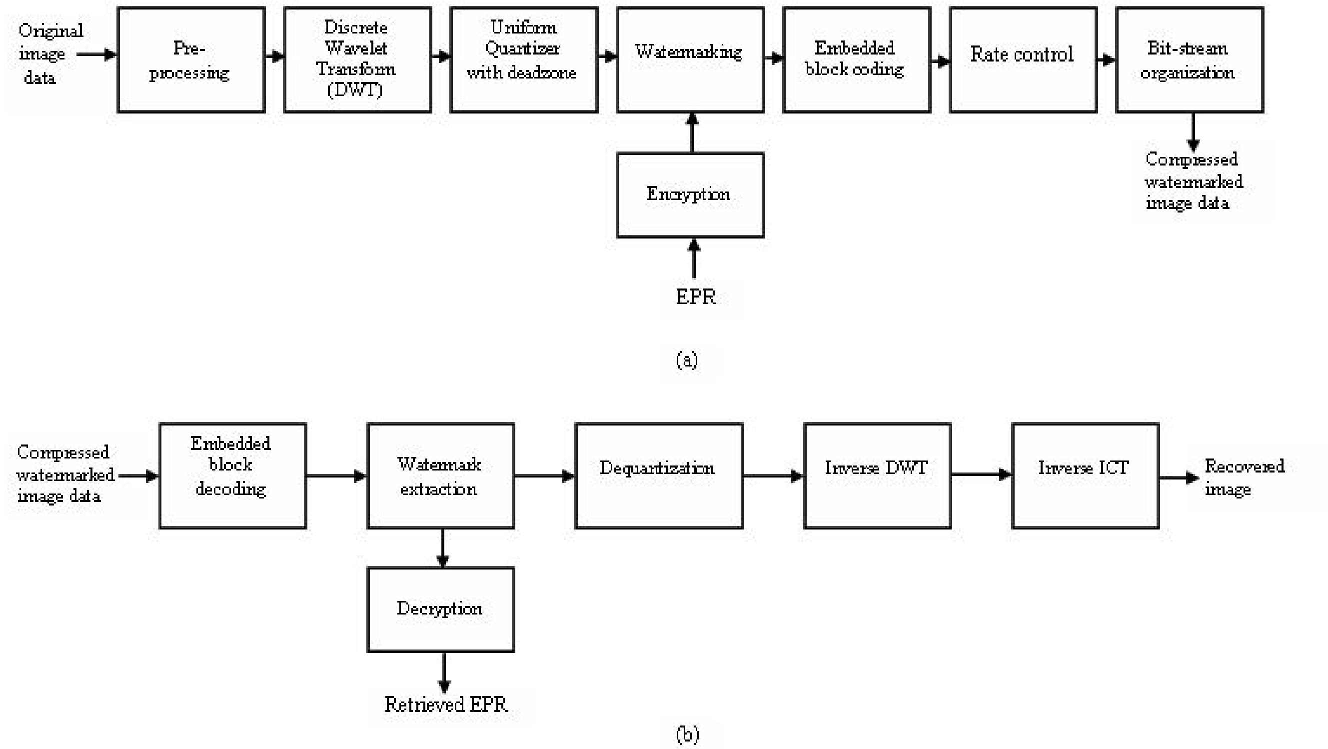

Figure 3: Proposed watermarking scheme (a)Embedding (b)Retrieval

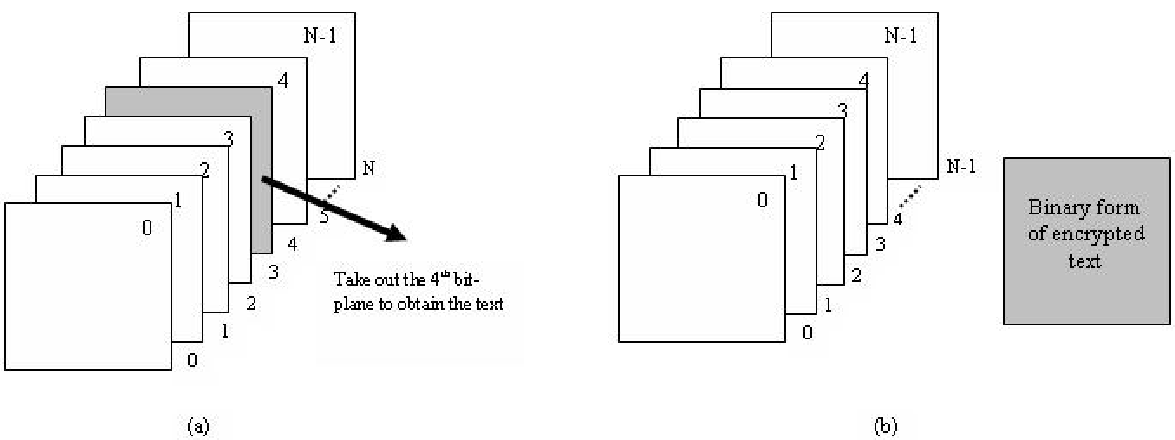

Figure 4: Bit planes of the subband (a) before extraction (b) after extraction

4 Results

For a 512×512 image, a maximum of 4096 characters (one character is represented by 8 bits) can be embedded. Since the watermarking scheme is entirely lossless, the recovered image is the same as the image obtained when no watermarking has been done. An NRMSE of 0 and a PSNR of ∞ are thus achieved. Table1 shows the results of evaluation of various watermarking parameters [9].

Metric	Equation	Value
%NRMSE	$\sqrt{\dfrac{\sum_{y=0}^{N-1}\sum_{x=0}^{M-1}[I(m,n)-\tilde{I}(m,n)]^2}{\sum_{n=0}^{N-1}\sum_{m=0}^{M-1}[I(m,n)]^2}}\times 100$	0
PSNR	$MN\dfrac{\max_{m,n} I^2(m,n)}{\sum_{m,n}[I(m,n)-\tilde{I}(m,n)]^2}$	∞
NC	$\dfrac{\sum_{m,n} I(m,n)\tilde{I}(m,n)}{\sum_{m,n} I^2(m,n)}$	1
SC	$\dfrac{\sum_{m,n} I^2(m,n)}{\sum_{m,n} \tilde{I}^2(m,n)}$	1

Table 1: Results of Evaluation

Note: NRMSE - Normalised Root Mean Square Error, PSNR - Peak Signal to Noise Ratio, NC - Normalised Cross Correlation, SC - Structural Content. I(m,n) represents a pixel, whose coordinates are (m,n) in the original, undistorted image and Ĩ(m,n) represents a pixel, whose coordinates are (m,n), in the watermarked image.

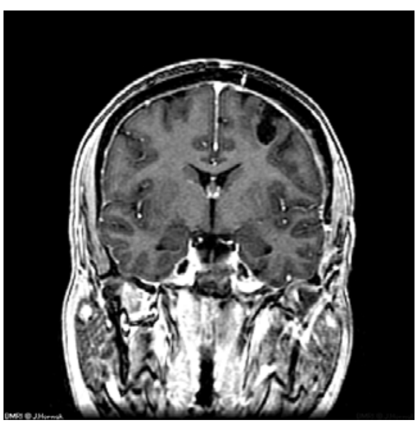

Figure 5: Image when no watermarking has been done

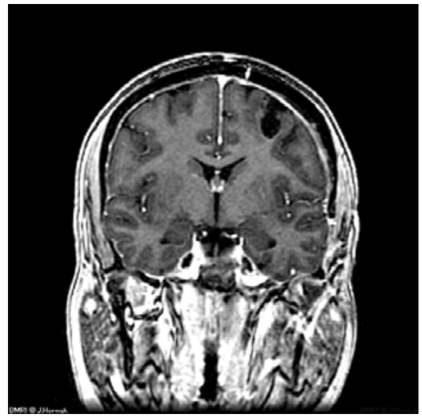

Figure 6: Recovered image when watermarking has been done

5 Conclusion

A lossless watermarking scheme for EPR data hiding in JPEG2000 domain has been proposed. The method allows the simultaneous storage and transmission of EPR and the medical image and the lossless retrieval of the EPR at the receiver. The recovered image obtained after watermark extraction is the same as the image obtained when no watermarking has been done. Encryption of EPR is done to provide additional security. The proposed scheme also has very good capacity, which is important for EPR data hiding.

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