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# Medical Image Watermarking with Tamper Detection and Recovery

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**Abstract- This paper discussed security of medical images and reviewed some work done regarding them. A fragile watermarking scheme was then proposed that could detect tamper and subsequently recover the image. Our scheme required a secret key and a public chaotic mixing algorithm to embed and recover a tampered image. The scheme was also resilient to VQ attack. The purposes were to verify the integrity and authenticity of medical images. We used 800x600x8 bits ultrasound (US) greyscale images in our experiment. We tested our algorithm for up to 50% tampered block and obtained 100% recovery for spread-tampered block.**

## I. INTRODUCTION

Security of medical images, derived from strict ethics and legislative rules, gives rights to the patient and duties to the health professionals. This imposes three mandatory characteristics: confidentiality, reliability and availability:

- Confidentiality means that only the entitled persons have access to the images;
- Reliability which has two aspects; Integrity: the image has not been modified by non-authorized person, and authentication: a proof that the image belongs indeed to the correct patient and is issued from the correct source;
- Availability is the ability of an image to be used by the entitled persons in the normal conditions of access and exercise.

Security risks of medical images can vary from random errors occurring during transmission to lost or overwritten segments in the network during exchanges in the intra- and inter-hospital networks. One must also guarantee that the header of the image file always matches that of the image data. In addition to these unintentional modifications, one can envision various malicious manipulations to replace or modify parts of the image, called tampering [1].

The studies that are specifically directed to watermarking of medical images are few. Anand and Niranjan [2] proposed to embed an encrypted version of the Electronic Patient Record (EPR) in the least significant bit (LSB) plane of the image. Miaou et al [3] similarly proposed a LSB technique where the host image authenticated the transmission origin with an embedded message composed of various patient data (e.g. ECG record), the diagnosis report and the doctor's seal. Macq and Dewey [4] proposed a trusted header scheme by embedding the hash of the file header of medical standard image in the image raw data.

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Coatrieux et al [5] proposed Region of Interest (ROI) to preserve the diagnostic zone and Region of Non Interest (RONI) whose integrity need not be preserved and served as the watermark carrier. Wong [6] described a fragile marking technique in which a digest was obtained using a hash function. The image, image dimensions, and marking key were hashed during embedding and used to modify the least-significant bit plane of the original image. This was done in such a way that when the correct detection side information and unaltered marked image were provided to the detector, a bi-level image chosen by the owner (such as a company logo or insignia), was observed. This technique had localization properties and could identify regions of modified pixels within a marked image.

However, Holliman and Memon [7] presented a vector quantization (VQ) counterfeiting attack that could construct a counterfeit image from a VQ codebook generated from a set of watermarked images. To solve the problem of VQ counterfeiting attack, several enhanced algorithms had been proposed [8][9]. Nonetheless, they either failed to effectively address the problem or sacrificed tamper localization accuracy of the original methods [10]. Celik et al [10] then presented an algorithm based on Wong's scheme and demonstrated that their algorithm could thwart the VQ codebook but compromised on the accuracy of localization. Previous researchers working in the area of medical imaging had not included tamper detection and recovery in their work.

In this paper, we propose a watermarking method for image tamper detection and recovery. We are interested in local manipulation such as additional or removal of part of an image. In the next section, an efficient and effective digital watermarking method for image tamper detection and recovery is presented. The method is based on four concepts introduced from the literature: 1) block-based [8]; 2) separating authentication bits and recovery bits [11]; 3) hierarchical [10]; and 4) average intensity as an image feature [12]. The method is efficient as it only uses simple operations such as parity check and comparison between average intensities. It is effective because the scheme inspects the image hierarchically with the inspection view increasing along with the hierarchy so that the accuracy of tamper localisation can be ensured. This scheme can perform both tamper detection and recovery for tampered images. Tamper detection is achieved through a block-based, inspection and recovery of a tampered block and relies on its feature information hidden in another block, which can be determined by a one-dimensional transformation. Using simple operations such as parity checks and average intensities comparison makes our method more efficient compared to the method proposed by Celik et al [10].

## II. METHODOLOGY

We describe the watermarking embedding procedure in this section. Each image is of size M x N pixels where M and N are assumed to be a multiple of eight and the number of grey levels is 256.

### *A. Celik et. al's[10] scheme*

Celik et al. [10] proposed a technique that embedded and extracted a watermark in a multilevel hierarchy. On the lowest level, the image X was partitioned into O x P non-overlapping blocks. At each successive level, the image was partitioned into blocks that in turn were composed of 2 x 2 blocks at the preceding level of the hierarchy.

Although they claimed that their method eliminated the vulnerabilities of Wong's [6] scheme to VQ attack, we found however that the method compromised the accuracy of localization. For example, using ultrasound image of size 800 x 600 pixels, the image was partitioned, resulting in three level hierarchical block structure with smallest block of 200 x 150 pixels as shown in Fig. 1.

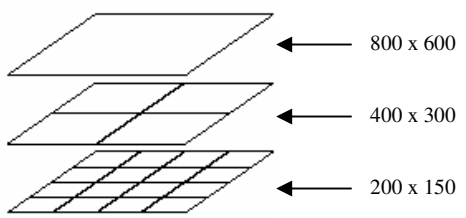



Fig. 1. Partitioning of image size 800 x 600 pixels

### *B. Our scheme: Preparation*

We propose a block of size 8 x 8 for better accuracy of localization, although the scheme allows user to choose the accuracy they want. Our scheme begins by preparing a one to one block mapping sequence A → B → C → D → . . . → A for watermarking embedding, where each symbol denotes an individual block. The intensity feature of block A will be embedded in block B, and the intensity feature of block B will be embedded in block C, etc. Voyatzis and Pitas [13] presented a two dimensional discrete Torus automorphism for creating a unique and random mapping of the pixels within an image. Based on that we use a 1D transformation to get a one-to-one mapping:

$$\vec{B} = [(k \times B) \bmod N_b] + 1, \qquad (1)$$

where $B, \vec{B}, k \in [1, N_b]$ , k is a secret key ( prime number), and $N_b$ is the total number of blocks in the image.

The generation algorithm of the block-mapping sequence is as follows:

- Divide the image into non-overlapping blocks of 8x8 pixels.
- Assign a unique integer $B \in \{1,2,3,..., N_b\}$ to each block from left to right and top to bottom, where $N_b$= (M/8) x (N/8).
- Randomly pick a prime number $k \in [1, N_b]$.
- For each block number B, apply equation (1) to obtain $\vec{B}$, the number of its mapping block.
- Record all pairs of B and $\vec{B}$ to form the block mapping sequence.

TABLE 1
MAPPING OF BLOCKS WITH K=23, 26 AND Nb=40

| **k** | $B$ | 1 | 2 | 3 | 4 | 5 | 6 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **23** | $\vec{B}$ | 24 | 7 | 30 | 13 | 36 | 19 | 4 | 27 | 10 | 33 |
| **26** | $\vec{B}$ | 27 | 13 | 39 | 25 | 11 | 37 | 27 | 13 | 39 | 25 |

Note that the secret key, k, must be a prime in order to obtain a one to one mapping; otherwise, the period is less than $N_b$ and a one to many mapping may occur. Table 1 lists some parts of the mapping sequence generated with Nb=40, k=23 (prime) and 26 (not prime) respectively. In this table, $\vec{B}$ starts to repeat at B=21 when k=26, which is not a prime.

### *C. Our scheme: Embedding*

For each block B of 8x8 pixels, we further divide it into four sub-blocks of 4x4 pixels. The watermark in each sub-block is a 3-tuple (v, p, r), where both v and p are 1-bit authentication watermark, and r is a 7-bit recovery watermark for the corresponding sub-block within block A mapped to B. The following algorithm describes how the 3-tuple watermark of each sub-block is generated and embedded:

- Set the LSB of each pixel within the block to zero and compute the average intensity of the block and each of its four sub-blocks, denoted by avg_B and avg_Bs, respectively.
- Generate the authentication watermark, v, of each sub-block as:

$$v = \begin{cases} 1 & if\ avg\_Bs \geq avg\_B, \\ 0 & otherwise, \end{cases} \qquad (2)$$

- Generate the parity check bit, p, of each sub-block as:

$$p = \begin{cases} 1 & if\ num\ is\ odd, \\ 0 & otherwise, \end{cases} \qquad (3)$$

where num is the total number of 1s in the seven MSBs of avg_Bs.

- From the mapping sequence generated in the preparation step, obtain block A whose recovery information will be stored in block B.
- Compute the average intensity of each corresponding sub-block As within A, and denote it avg_As.

- Obtain the recovery intensity, r, of As by taking 7 MSB in avg_As. Seven bits is used as we are using one bit for watermarking .
- Embed the 3-tuple watermark (v, p, r), 9 bits in all, onto the LSB of of each pixel in a 3x3 block within Bs as shown in fig. 2, where r1 is the MSB, e.g. if the intensity of As is 155, r1, r2, r3, r4, r5, r6 and r7 is 1, 0, 0, 1, 1, 0 and 1 respectively.

| | | |
|---|---|---|
| v | p | r1 |
| r2 | r2 | r4 |
| r5 | r6 | r7 |

Fig.2. Watermark positioned in the LSB of 3x3 block

### D. Our scheme: Tamper Detection

The test image is first divided into non-overlapping blocks of 8x8 pixels, as in watermarking embedding process. For each block denoted as $\vec{B}$, we first set the LSBs of each pixel in $\vec{B}$ to zero and compute its average intensity, denoted as avg_$\vec{B}$. We then perform 2-level detection. In level-1 detection, we examine each 4x4 sub-block within one block. In level-2 detection, we treat an 8x8 block as one unit. Level-3 detection is for VQ attack resilience only. The procedure of our hierarchical tamper detection scheme is describe in the following:

*Level-1 detection*.

- For each sub-block $\vec{B}_s$ of 4x4 pixels within the block $\vec{B}$, perform the following steps:
- Extract v and p from $\vec{B}_s$.
- Set the LSBs of each pixel within each $\vec{B}_s$ to zero and compute the average intensity for each sub-block $\vec{B}_s$, denoted as avg_$\vec{B}_s$.
- Count the total number of 1s in avg_$\vec{B}_s$ and denote it as $P_s$.
- Set the parity check bit p' of $\vec{B}_s$ to 1 if $P_s$ is odd, otherwise, set it to 0.
- Compare p' with p. If they are not equal, mark $\vec{B}_s$ as tampered and complete the detection for $\vec{B}$s.
- Set the algebraic relation v'=1 if avg_$\vec{B}_s$>=avg_$\vec{B}$, otherwise, set it to 0.
- Compare v' with v. If they are not equal, mark $\vec{B}_s$ as tampered and complete the detection for $\vec{B}_s$; otherwise mark it valid.

*Level-2 detection*.

For each block of size 8x8 pixels, mark this block tampered if any of its sub-block is marked tampered; otherwise mark it valid.

*Level-3 detection*.

For each valid block $\vec{B}$ of size 8x8 pixels, perform the following steps:

- Find the block number of block C, where block C is the one in which the intensity feature of block $\vec{B}$ is embedded.
- Locate block C.
- If block C is marked tampered, assume block $\vec{B}$ is valid and complete the test.
- If block C is valid, perform the following steps:
- Obtain the 7-bit should-be intensity of each $\vec{B}_s$ by extracting the LSBs from each pixels in the corresponding block within block C, padding one zero to the end to make an 8-bit value.
- Compare with avg_$\vec{B}_s$ and mark $\vec{B}$ tampered if they are different.

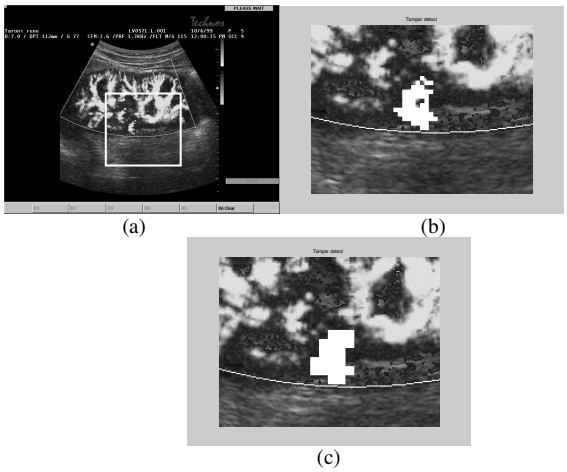
### E. Our scheme: Image Recovery

After the detection stage, all the blocks are marked either valid or tampered. We only need to recover the tampered blocks and leave those valid blocks as they are. For convenient, we call the tampered block, block B and the block embedded with its intensity, block C. The restoration procedure for each tampered block is described as follows:

- Calculate the block number for block C.
- Locate block C
- Obtain the 7-bit intensity of each sub-block within block B, padding one zero to the end to make an 8-bit value.
- Replace the new intensity of each pixel within the sub-block with this new 8-bit intensity.
- Repeat step 3 and 4 for all sub-blocks within block B.

## III. RESULTS

We carried out two experiments to test our algorithms. We watermarked our test image with peak signal to noise ratio of 54.8 dB. In the first experiment, we tampered a watermarked image by adding a clone of part of the original image as in Fig. 1 (a). Level-1 detection left some areas undetected as seen in Fig. 3(b). 100% tamper was detected using level-2.



(a) (b)

(c)

Fig. 3. (a) Tampered image (b) level-1 detection with some areas undetected (c) level-2 with 100%detection

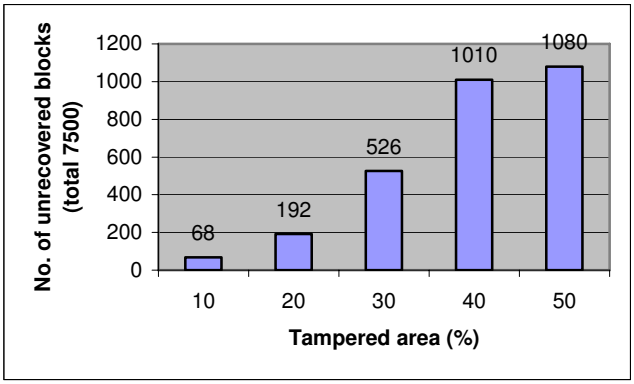



Fig.4. Unrecovered blocks for single tampered block

We used spread tampering and single block tampering ranging from 10% to 50% of the image as shown in Fig. 5 with k=3739 for our second experiment to determine recovery rate of our method. Our results showed that we could recover all tampered areas for spread-tampered blocks and the result for single tampered block is shown in Fig. 4.

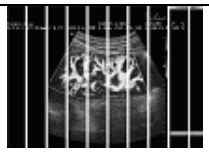
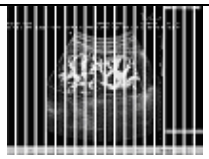
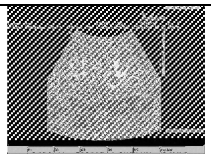
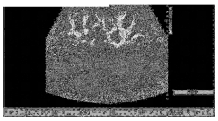
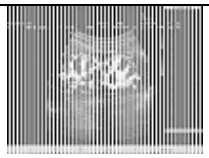
| Tamper rate | Spread Tampered blocks | Single tampered block |
|---|---|---|
| 10% |  |  |
| 20% |  |  |
| 30% |  |  |
| 40% |  |  |
| 50% |  |  |

Fig.5. Tampered Images

## IV. CONCLUSION

This paper discussed the security of medical images and reviewed some work done on them. We also proposed a watermarking scheme that could detect tamper and recover the image. The purposes were to verify the integrity and the authenticity of the images. The experimental results demonstrated that the precision of tamper detection and localization was close to 100% after level-2 detection. We achieved 100% recovery rate for spread tampered blocks and more than 86% for a less than half tampered image in a single tampered block.

By keeping a low distortion level, thus intact watermarked images, these images could also be used for other general purposes unrelated to patient care such as teaching or display in medical museums for students.

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