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High Capacity Watermarking Technique for Medical Images Using Fibonacci Decomposition

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Abstract

This paper presents a high capacity watermarking technique in the spatial domain for gray-scale brain MRI. A new scheme, based on Fibonacci decomposition and Knight’s Tour algorithm is proposed in order to increase the hiding capacity for brain MRI. The effectiveness of the proposed scheme is proven by conducting series of experiments with image quality measure matrices namely PSNR and SSIM to allow us to state that the proposed scheme is capable of providing confidentiality to medical images. The experimental results also demonstrate that the proposed scheme has higher capacity compared to other watermarking techniques.

Keyword-Watermarking, Embedding capacity, Brain MRI, Medical images

I. INTRODUCTION

The rapid growth and remarkable evolution of information and communication technologies have brought new challenges in healthcare information systems. The patient’s information is exchanged and transmitted between hospitals and health centers through an open network. Hence, the information has to be properly organized in order to prevent from mishandling and loss of data [1]. Moreover, only a small size of data can be used as to achieve an efficient utilization of communication bandwidth and memory for storage [2]. This is due to the fact that more bandwidth in transmission and more memory space are required when the transmission of image and data is performed separately [2].

The efficiency of memory utilization can be achieved by interleaving medical data over associated digital medical image [1]. Many data hiding techniques have been proposed by various researchers [3, 4]. In [5] a multiple-layer data hiding method in the spatial domain for medical images using a reduced difference expansion (DE) technique to insert the watermark in the LSBs of the expanded differences is proposed. DE technique was also used by [2] where they present two reversible scheme that combine techniques from [6] and [7] for the first scheme, and techniques by [6] integrated with [8] for the second scheme. The obtained experimental results show that the first scheme produces better transparency, while the other scheme has higher embedding capacity. Authors in [9] introduces a modified histogram shifting algorithm to increase the embedding capacity. The algorithm is based on hierarchically partitioning a host image into smaller blocks for data hiding using the histogram shifting method. A data hiding technique based on discrete cosine transform (DCT), where it is able to hide the electronic patient report (EPR) in the quantized DCT coefficients into a watermarked image is presented in [10]. Lastly, [11] proposes an intelligent reversible watermarking technique for medical images. This technique is a block-based hiding technique that use a genetic algorithm (GA) and an integer wavelet transform (IWT).

In this paper a watermarking technique that can be used to enhance confidentiality of medical information is proposed. The proposed method is very high in terms of the payload capacity, with good visual quality. The high capacity is achieved by applying Fibonacci decomposition on host image, while Knight's Tour algorithm is utilized to formulate the position for embedding.

II. PROPOSED METHOD

The proposed high capacity watermarking technique is described in this section. To achieve better performance in terms of capacity and visual quality, the brain MRI is decomposed based on Fibonacci sequence. Such decomposition provides an efficient way in increasing the number of available bit-planes for hiding the watermark.

A. Watermark Embedding Process

As a host image, the brain MRI, I_o, is decomposed into 22 bit-planes based on Fibonacci sequence. The Fibonacci sequence is defined as:

$$f(n) = \begin{cases} 0 & n < 0 \\ 1 & n = 0 \\ f(n-1) + f(n-2) & n > 0 \end{cases} \quad (1)$$

where each element in the sequence is obtained by adding the previous two elements. However, the Fibonacci representation is redundant. Each decimal number can be represented by more than one Fibonacci sequence. Hence, a Zeckendorf's theorem [12] is applied so that each decimal number has a unique representation. Any positive integer can be symbolized as:

$$D = \sum_{i \geq 2} b_i f_i \qquad (2)$$

such that $b_i \in \{0,1\}$ and $b_i b_{i+1} = 0$ for all $i \geq 2$.

The host image is then divided into blocks of 4 × 4 pixels. The blocks are scanned utilizing a Knight's Tour algorithm and categorized into four groups: G1, G2, G3 and G4. Figure 1 depicts the group's position produced by Knight's Tour algorithm.

G2	G4	G3	G1
G3	G1	G2	G4
G4	G2	G1	G3
G1	G3	G4	G2

Figure 1 Example of the group's position produced by Knight's Tour algorithm

The embedding technique begins with G1's group where the watermark is embedded in each pixel of G1's group. For each selected pixel, if the Zeckendorf's condition is fulfilled, the watermark is inserted, otherwise the following pixel of current group is considered. All blocks are traversed before moving to the next group of pixels. Figure 2 illustrates the Knight's Tour on a block of 8 × 8 pixels.

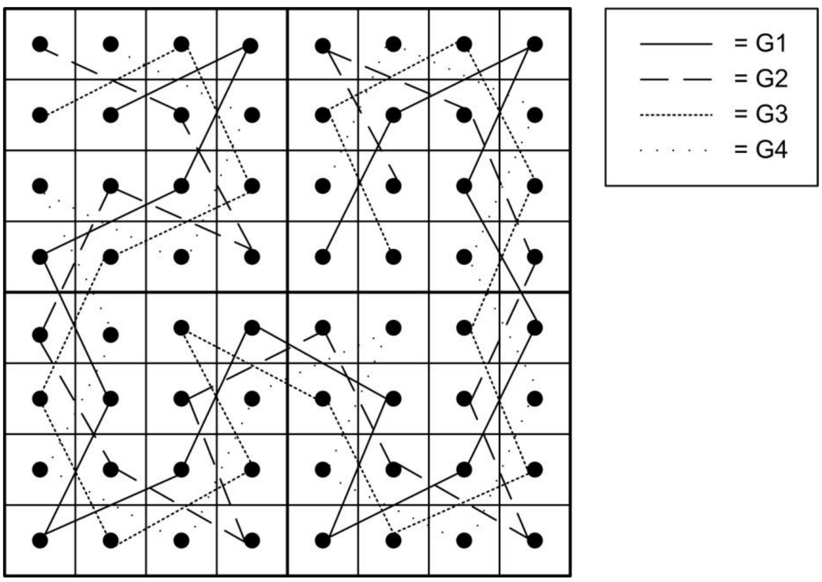

Figure 2 A Knight's Tour on a block of 8 × 8 pixels

Once the entire watermark is inserted in the host image, a watermarked image is reconstructed by recompose to its original form, which in the binary domain.

B. Watermark Extracting Process

For extracting the watermark, the proposed scheme only requires the size of the watermark. The host image and any of its characteristics are not required. Similar with the embedding process, the watermarked image is firstly decomposed into 22 bit-planes using Fibonacci sequence. Afterwards, the watermarked image is divided into blocks of size 4 × 4 pixels. By using the Knight's Tour algorithm, the watermark is extracted from the selected pixel. The extraction process is only performed if the selected pixel fulfils the Zeckendorf's condition. This process is repeated until the whole watermark is retrieved.

III. EXPERIMENTAL RESULTS

A set of 5 brain MRI images, which are in grayscale Digital Imaging and Communications in Medicine (DICOM) format are used to test the proposed scheme. The images are represented by 16-bit depths with size of 256 × 256 pixels. A random image of hospital's logo is chosen as the watermark.

The proposed scheme is evaluated based on embedding capacity and visual quality. Peak signal-to-noise ratio (PSNR) is utilized to measure the quality of embedded images. PSNR is defined as:

$$PSNR = 10 * \log_{10}\left(\frac{MAX_I^2}{\frac{1}{m*n}\sum_{i=0}^{m}\sum_{j=0}^{n}\left[I(i,j) - K(i,j)\right]^2}\right) \quad (3)$$

where I is the host image, K is the watermarked image, MAX_I is the maximum intensity of I.

Meanwhile, an improved method, known as structural similarity (SSIM), is used to compute the similarity between host image and watermarked image. This is due to the fact that conventional method such as PSNR is proven to be incompatible with human visual system (HVS) [13]. SSIM will return a decimal value between 1 to -1, and two images are said to be identical if the value of SSIM equals to 1. SSIM is given by the following equation:

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\,\mathrm{cov} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad (4)$$

where μ_x and μ_y denote the host image and watermarked image, respectively; σ_x^2 and σ_y^2 denote the variance of μ_x and μ_y, respectively; *cov* denotes the covariance of μ_y;

$c_1=(k_1L)^2$; $c_1=(k_1L)^2$ are two variables to stabilize the division with weak denominator; L denotes dynamic range of μ_x; k_1 = 0.01 and k_2 = 0.03 by default.

Table I and Fig 3. show the results retrieved from embedding process. The visual quality of the proposed scheme is tested with different embedding capacities (0.2 – 2.0 bpp).

TABLE 1 Visual Quality and Similarity Measure Using PSNR and SSIM (Embedding Capacity= 2.0 bpp)

Host Image	Watermarked Image	PSNR	SSIM
Brain MRI 1	MRI1	88.6318	1
Brain MRI2	MRI2	88.5219	1
Brain MRI3	MRI3	88.6698	1
Brain MRI4	MRI4	88.5362	1
Brain MRI5	MRI5	88.6069	1

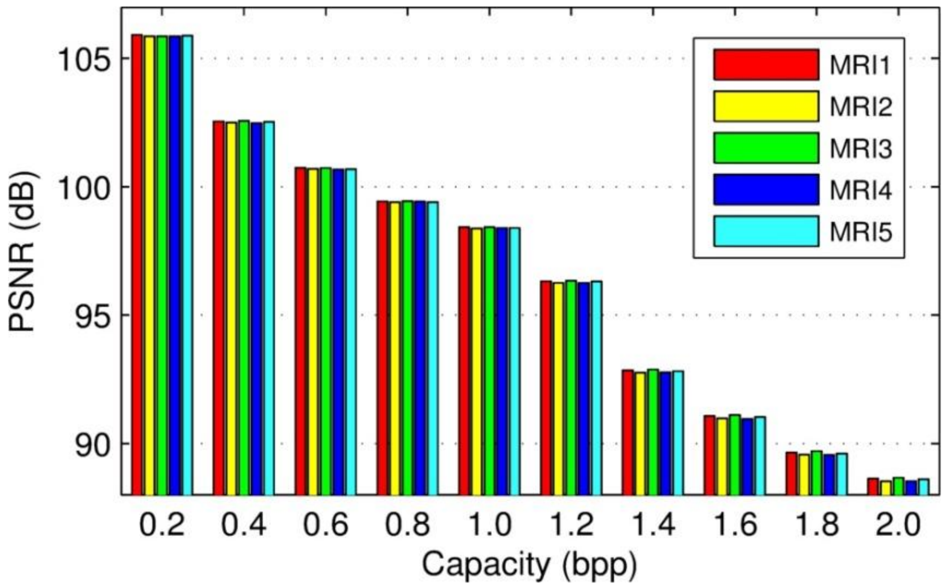

Figure 3 Relationship between PSNR and embedding capacity (bpp) for watermarked images

As can be seen in Figure 3, the visual quality of watermarked images degraded as the capacity increase. However, the proposed scheme still capable in producing high PSNR value despite of the expansion of watermark's size. The PSNR values rose to more than 88 dB with embedding capacity of 2.0 bpp.

Meanwhile, the proposed scheme is proven to be visually imperceptible as all SSIM value equal to 1.

IV. Conclusion

The proposed scheme presents a blind watermarking technique for brain MRI. Experimental results indicate that the proposed scheme outperforms other watermarking techniques with higher embedding capacity while retaining good visual quality It can be used to hide a large size of data as it can provides capacity up to 2.0 bpp. Therefore, a watermarking technique based on Fibonacci decomposition will be a promising technique in order to increase the embedding capacity of medical images.

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