International Journal of Engineering Research and General Science Volume 3, Issue 5, September-October, 2015
ISSN 2091-2730

Medical Image Watermarking using CGR

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Abstract— Chaos Game Representation (CGR) is used to produce unique images from symbolic sequences, which can serve as signature images of the sequence. In this paper, we pose and answer an interesting question- can we use CGR as a substitution of hashing in medical images? We show that it is possible to generate CGR for medical images as well as can be used to verify the integrity of the image. We go on to show that we can watermark the image using CGR to further verify the confidentiality and authenticity of the medical image.

Keywords— CGR; Watermarking; Compression; Embedding; Extraction; DWT; Authentication.

INTRODUCTION

Medical imaging is the technique of creating visual representations of the interior of a body for clinical analysis and medical intervention. Medical imaging seeks to reveal internal structures hidden by the skin and bones, as well as to diagnose and treat disease. Safety and confidentiality is required for medical images, because critical judgment is done on medical images, which leads to the proper treatment. Privacy protection of medical images has always been an important issue. Medical image communications require a very high level of security for maintaining their communication secrecy. Constant efforts are being made to provide security to ensure (i) medical image transmission cannot be accessed by unauthorized users (confidentiality), (ii) images are not modified during transmission (integrity), and (iii) images have originated from the correct sources to the claimed receivers (authentication) [1]. One effective tool for providing image authentication and source information is digital watermarking. Watermarking, however, is a copyright protection method includes the embedding and extraction process [2]. Extraction process deals with the extraction of secret message or watermark, which is embedded in the medical image. If failure occurs in extraction process the physician would come to know that there has been some kind of tampering with that image, and he would take precaution of not making diagnosis based on that image. However, if the extraction process extracts the correct watermark, physician can continue with diagnosis.

Watermarking is the technique which amends the image information invisibly to implant the watermark. Digital watermarking also has proved to be beneficial in medical imaging. The main role of watermarking in medical imaging is to act as an interface to enhance the protection of its contents, without degrading the quality of data [3]. Its role also extended to the traceability from the origin to the destination. Watermark enhances the security of the image, as it is expected to be a part of the image and at the same time is invisible.

Watermarking techniques can be generally classified into two categories, reversible and irreversible [4]. The main idea behind reversible watermarking is to avoid irreversible distortion in original image , by formulating techniques that can extract the original image exactly. Medical image watermarking is one of the most important fields that need such techniques where distortion may cause misdiagnosis. The reversibly watermarked image is not at all distortion free, but that distorted image is used as a carrier for data to be embedded. and not for diagnosis. The losslessly recovered image is the final one used for diagnosis. Although reversible schemes seem to be adequate for medical images, it must meet all the requirements of image watermarking : imperceptibility, integrity control and authentication. From the literature, the purposes of medical image watermarking are classified into two categories [4]:

1. Tamper detection and authentication
2. Electronic Patient Records (EPR) data hiding.

Tamper detection watermarks are able to locate the regions or pixels of the image where tampering was performed. Authentication watermarks are used to identify the source of the image. EPR data hiding techniques give more importance in hiding high payload data in the images keeping the imperceptibility very high [4]. Depending on the purpose of the watermarking a proper watermarking technique is used accordingly.

In this paper, a new approach for securing medical images and detecting tampering is proposed. Given a medical image, an algorithm named Chaos Game is implemented to generate a unique signature image named Chaos Game Representation images (CGR images). The following section of the paper are organized as follows: The related research works are summarized in Section 2 and 3 describes the proposed CGR method and proposed medical image watermarking technique is described in Section 4. The results and analysis is given in Section 5 and section 6 concludes the paper.

RELATED WORK

Many watermarking schemes were proposed for medical images. Those techniques can be spatial domain techniques, frequency domain techniques, or a combination of the two domains. A security technique based on watermarking and encryption for DICOM is proposed by Mohamed M. AbdEldayem et al. [3] where the original image can be recovered completely. In this paper, a R-S vector is created which is then compressed. A hash value of the image is determined using MD5 hash function. This MD5 hash value along with the compressed R–S vector of the original image are concatenated, and then they are encrypted using AES encryption technique. This watermark is then embedded into the original image. During the extraction process, the exact reverse of the embedding process is performed and the original image is retrieved. Then the hash value of the extracted original image is calculated and is compared with the previous hash value. If they are equal, the image is authenticated, and it has right integrity, else the image is discarded because its integrity is broken. Extended Huffman algorithm is used to decompress the decrypted R–S Vector. The performance of the proposed technique is measured using the performance parameters: Signal to Noise Ratio (SNR), Mean Square Error (MSE), and Bit Error Rate (BER). The experiment results shows that the proposed technique is totally revertible and the original images can be retrieved at the receiver side without any distortion.

Another lossless watermarking scheme for DICOM images is proposed by Osamah M. et al. [4]. This paper is based on a fragile scheme combining two reversible techniques. These techniques are based on difference expansion and protecting the region of interest (ROI) with tamper detection and recovery capability. Here two watermarks are produced where the 1st watermark, which consists of patient's data and the hash message of ROI is embedded into ROI. As a result, an embedding map is produced which will be used to extract the 1st watermark. The map is then combined with recovery information to become a part of the 2nd watermark. This watermark is embedded into RONI. The experiment result shows that the watermarked images have good visual quality in terms of PSNR, with high embedding capacity.

Many works can be seen on investigation into use of CGRs as unique signature images for genomes and also other bio-sequences. The initial proposal of CGR for DNA sequences is made by H. Joel Jeffrey in the paper named Chaos game representation of gene structure in 1990 [5]. In this paper, chaotic dynamic concept is being applied which produces an image of a gene sequence displaying both local and global patterns. This image is named as attractor. Since the DNA sequence is represented using four letters 'a', 'g', 'c', 't', here a square is drawn labeling the four corners with these letters. Then applying the chaos game algorithm , the CGR is generated for the sequence. Each point in the CGR corresponds to exactly one subsequence. This shows a one-to-one correspondence between the subsequences of a gene and points of the CGR. The CGR method thus provides a graphic way of displaying the composition of a sequence.

Another paper named CGR based DNA sequence compression method [6], an efficient way of compressing DNA sequences is proposed where the CGR is used to compress the DNA sequence. This DNA sequence is later reconstructed from the CGR; given the coordinates of the final point in the CGR image. The algorithm is based on trace-back of nucleotides from final CGR coordinates, thereby tracing back the whole genomic sequences and regenerating the complete sequence from the last coordinate. This paper claims that the sequence can be compressed successfully but with a limitation of resolution of the CGR coordinate.

CHAOS GAME REPRESENTATION (CGR)

The 'chaotic dynamical systems' or simply 'chaos' is the field of study in mathematics that studies the behavior of dynamical systems that are highly sensitive to initial conditions—a response popularly referred to as the butterfly effect. Small differences in initial conditions may yield widely diverging outcomes for such dynamical systems. The Chaos Theory is stated as "When the present determines the future, but the approximate present does not approximately determine the future". Chaotic systems are predictable for a while and then 'appear' to become random.

The Chaos Game is an algorithm which allows one to produce pictures of fractal structures [5]. In simplest form, it proceeds as follows [5]:

1. Locate three dots or vertices on a piece of paper. They can be anywhere, as long as they are not all on a line.

2. Label one vertex with the numerals 1 and 2, one of the others with the numerals 3 and 4, and the third with the numerals 5 and 6.

3. Pick a point anywhere on the paper, and mark it. This is the initial point.

4. Roll a 6-sided die. Since in Step 2 the vertices were labeled, the number that comes up on the die is a label on a vertex. Thus, the number rolled on the die picks out a vertex. On the paper, place a mark half way between the previous point and the indicated vertex.

5. Continue to roll the die, on each roll marking the paper at the point halfway between the previous point and the indicated vertex. The result is shown in figure 1.

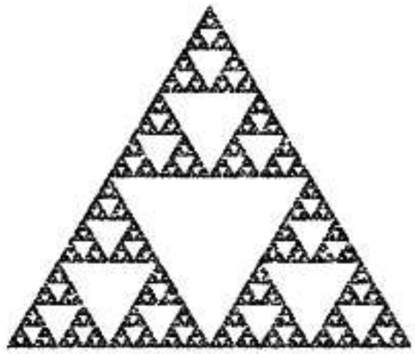

Fig 1: Sierpinski triangle-The Result of the Chaos Game on Three Points.

This original CGR algorithm is later used to produce pictures revealing patterns in DNA sequences [6]. Even though the technique is first proposed for DNA sequence, it is now being used for sequence of arbitrary symbols. Basically, the whole set of frequencies of the words found in a given genomic sequence can be displayed in the form of a single image in which each pixel is associated with a specific word [8]. CGR acts as a means to visualize the non-randomness of genomic sequence by using the concept of chaotic dynamical systems. Since a genetic sequence can be treated formally as a string composed from the four letters 'a', 'c', 'g', and 't', a square is drawn with each of the four corners of the square labeled as 'a', 'c', 'g', or 't' [5]. For plotting a given sequence, it is started from the centre of the square. A nucleotide is represented as one point in the square [6]. The first point plotted halfway between the centre of the square and the corner corresponding to the first nucleotide of the sequence and successive points plotted halfway between the previous point and the corner corresponding to the base of each successive sequence site.

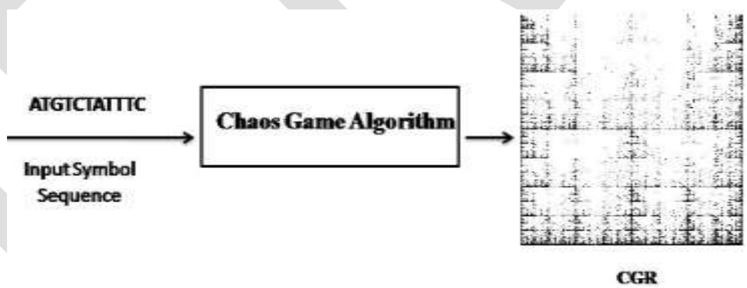

Fig 2: Chaos Game Representation process.

In this paper, we use this algorithm to generate CGR for medical images which may act as the unique signature image for the corresponding medical image. Consider a binary sequence 1110010100101011010100101.... To derive a Chaos Game Representation of this sequence, a square is first drawn to any desired scale and corners marked 00,01,10 and 11. Here the sequence is taken as two-digit pattern. For plotting a given sequence, we start from the centre of the square [6]. The first point is plotted halfway between the centre of the square, and the corner corresponding to the first number of the sequence, and successive points are plotted halfway between the previous point, and the corner corresponding to the base of each successive numbers. Fig 3 shows all segments in a CGR square.

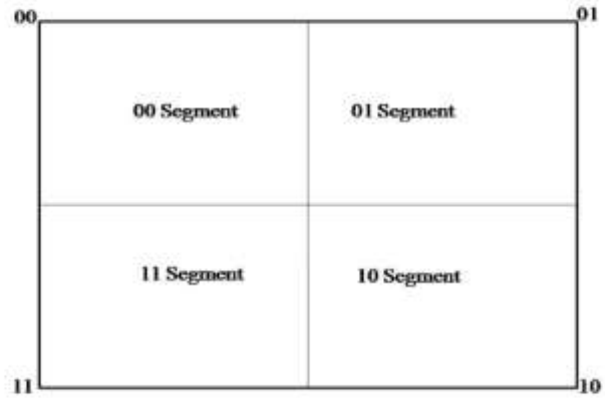

Fig 3: Segments in a CGR Square

The general steps for plotting a given sequence are concluded below [6].

1. Select the first number from the given sequence.
2. Calculate the midpoint between the centre and the corner corresponding to the first number (xN, yN). Let the midpoint be (xi, yi). Let (xc, yc) be the co-ordinates of the midpoint of the square. Then
   xi = (xc+ xN)/2 and yi= (yc+ yN)/2

3. Do the following steps until all the numbers are processed: Read the next number in the sequence. Calculate the midpoint between the current point (xi, yi) and the corner corresponding to the newly read number:
   xi+1 = (xi+ xN)/2 and yi+1 = (yi+ yN)/2.

We will demonstrate this basic idea with a toy example. Let us plot the sequence 11011010 into the CGR square. Points are marked within the square corresponding to the bases in the sequence, as follows:

1) Plot the first point X1, halfway between the center of the square X0, and the 11 corner.
2) The next point X2 is plotted halfway between X1 and the 01 corner.
3) The next point X3 is plotted halfway between X2 and the 10 corner.
4) The next point X4 is plotted halfway between X3 and the 10 corner.

The final CGR is given in Fig. 4.

Fig 4. Plot of CGR points for the sequence "11011010"

A CGR has many interesting properties. Every binary-sequence has a unique CGR [7]. In fact every number in a sequence will have a corresponding unique point in the CGR. Every point on the CGR is a representation of all the numbers in the sequence up to that point. Each sub-square in a CGR has a special significance. If we divide the CGR into four quadrants, then the top right corner will contain points representing sub-sequences that end with 01, as a midpoint between any other point in the square and the 01-corner has to fall in this quadrant.

PROPOSED SCHEME

In the proposed scheme, the medical image integrity for medical images based on reversible watermarking is proposed. Here, the concept of CGR is being implemented in medical images especially on X-ray images. For any given medical image, the CGR is generated and this CGR is watermarked into the corresponding medical image itself [3]. Later on, during transmission the watermarked image is being transmitted and at the receiver site, the watermark and the original image is extracted. From the original image, the CGR is again generated and is compared with the watermarked CGR. If they are equal, then the image is not modified and is validated, otherwise the two CGRs are different, therefore the image was modified [3], and it is no longer authenticated. Here, the DWT watermarking technique is used to watermark the image. The watermark embedding and extraction process are shown.

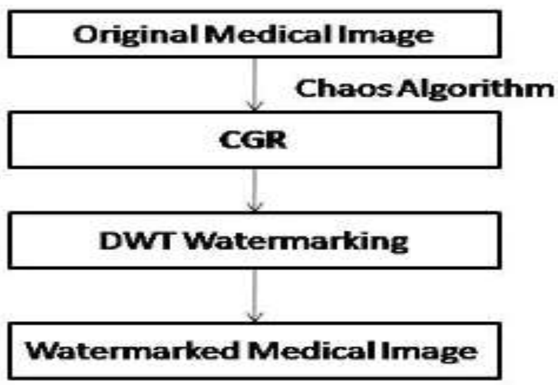

Fig 5. Proposed Scheme- Embedding Process

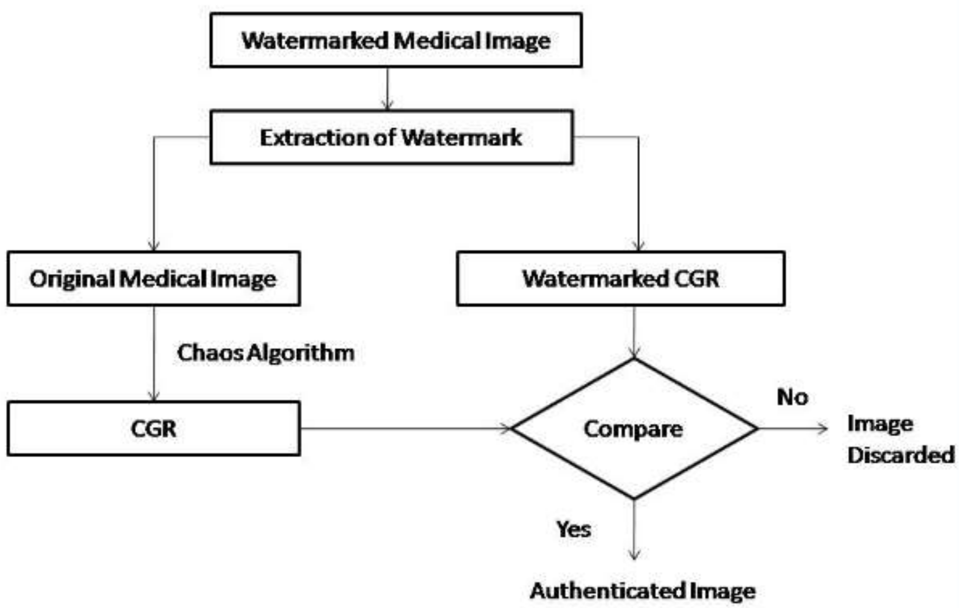

Fig 6. Proposed Scheme- Extraction Process

RESULTS AND ANALYSIS

The proposed CGR-based medical image watermarking algorithm has been applied against different type of medical image such as, CT scan, MRI, X-Ray and Ultrasound. We have tested the system over different size of medical images like 320 X 256, 384 X 384, and 512 X 512. The CGRs, are then embedded as the watermark into the original medical image. The extracted CGR and the computed CGR are compared at the receiver side using the statistical measures MSE, RMS, PSNR and correlation coefficient.

CONCLUSION

In this paper, a unique way of securing medical images using CGR is proposed. This technique provides image integrity service as the CGR involves treating an image as an abstract string of numbers. Here, the CGR algorithm has been used as a substitution of hashing algorithm. The generated CGR i watermarked into the medical image using DWT watermarking algorithm. Since DWT is a reversible watermarking method, the original medical image can be retrieved at the receiver side without any distortion.

As a future work, the proposed technique can practically be included within the medical information systems to provide medical image integrity, system authentication and confidentiality. Other revertible watermarking methods can be proposed to increase the amount of embedded data.

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