3D Watermarking Secret Direction Scheme for Volumetric DICOM Images

Ajif Y.P. Yusuf, Sajjad Dadkhah, and Mario Köppen

Abstract—This research presents a new method for watermarking multi-frame DICOM medical images viewed as a three-dimensional volumetric with a secret direction. The XY-secret direction is line slicing by using the Bresenham line algorithm, and the t-secret direction is a randomization of the line as a time frame per second by utilizing the Halton series. The line is collected into one frame and then watermarking is embedded by using Discrete Cosine Transform (DCT). The experimental results show that the secret scheme of 3D watermarking direction can ensure the integrity of volumetric DICOM images efficiently.

Research Keywords—Medical Imaging, 3D, Secret Direction, Integrity.

1 Introduction

Image security is one of the most challenging issues when medical images along with patient information are transmitted to the public network. With the service system in obtaining patient medical images gradually expanding with the provision of health care delivery, consideration in image security is no longer limited in transit but also storage. Medical image security can be categorized into three main issues; privacy, authenticity, and integrity [1].

Digital watermarking is a technique for protecting or securing the integrity of medical images. The advantage of using watermarking is to secure authentic information that is visually invisible to the human eye [2].

There has been much research in improving the integrity and authenticity of watermarking techniques, especially in medical images. However, most of them in their applications so far have only one frame in mind and do not offer a satisfying solution to the case of multiple frames, such as X-ray angiography (XA), or intravascular ultrasound (IVUS) [3].

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Digital Imaging and Communication in Medicine (DICOM) is standard for image communica- tion in medicine. The watermarking technique for volumetric DICOM images has been enhanced by several studies [1],[2],[3],[4].

We proposed a new watermark technique with three-dimensional secret directions which is in its application to protecting the authentication of information on multi-frame of the medical image.

2 3D Watermarking Secret Direction Scheme

2.1 3D Watermarking

3D watermarking is watermarking on three-dimensional objects. For this method, view the DICOM medical image frames as three-dimensional structures (Fig. 1). Where the x-axis is represented as a column of Dicom image, the y-axis is represented as

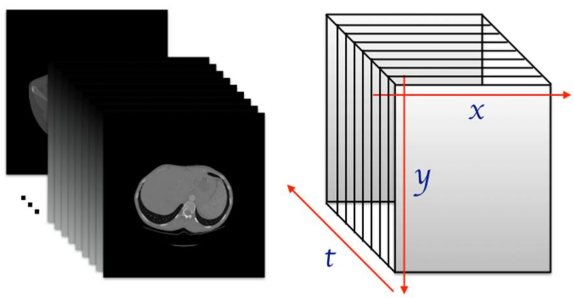


Fig. 1. A series of DICOM images seen as a three-dimensional form.

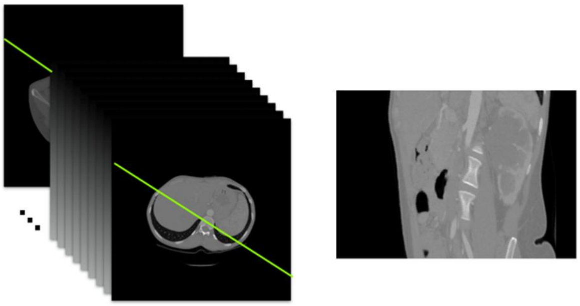


Fig. 2. Point selection (1,32) to (512,433) and the result image of selection point where each row corresponds with the selected line frame by frame.

a row of Dicom image, and the time t-axis is represented as a Dicom series of images per time t. In this study, we will use Dicom images from an abdomen of CT scan with resolution is 512x512x360.

2.2 Secret Direction Scheme

For the XY-secret direction, Bresenham algorithm is used, and for the t-secret direction, the Randomized Halton sequence is used.

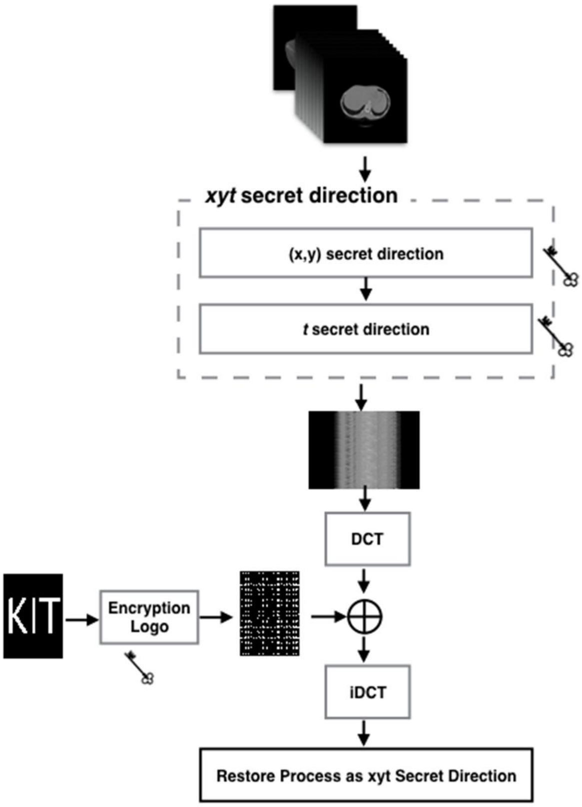


Fig. 3. 3D watermarking secret direction scheme.

2.2.1 Bresenham Algorithm

Bresenham algorithm is an algorithm for drawing an approximate line. This algorithm was proposed by Jack Elton Bresenham in 1962 [5].

At first, choose two endpoints of line from (X0,Y0) to (X1,Y1). Calculate dx=X1- X0, dy= Y1- Y0, D=2dy-dx, then start with x= X0, y= Y0 until x= X1 to plot (x,y), repeat incrementing y by 1 and reducing D by 2dx as long as D>0, unreasing D by 2dy, plot next (x,y) ,etc.

2.2.2 Randomized Halton Sequence

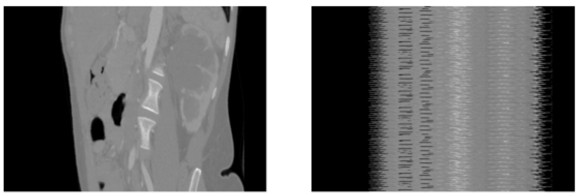
Encrypt the watermark logo using the Halton Sequence for the first step of pre-watermarking. The Halton Sequence is a well-known multi-dimensional low-discrepancy sequence that can be relied upon to encrypt the watermark logo [1].

The Halton sequence is a sequence that is obtained by breaking the unit interval continuously based on chosen parameter-p.

For example, if we choose p=2; it will generate the sequence by breaking the unit interval by 2 continuously until the number of sequence values that we want is reached. The first unit interval (0,1) and the first number of sequence is 1/2. The second interval is (0,1/2) and the second number of sequence is 1/4. The third interval is (1/2,1) and the third number of sequence is 3/4. It is performed repeatedly until the number of sequence values that we want is reached.

We are increasing the parameter p with not simple point like a decimal point, for example, p=3.42. Because we want to increase the level of security. So that, it will generate the sequence by breaking the unit interval by 3.42 continuously.

The picture below is a frame which is sample how Halton sequence works to get t-dimension becomes scrambled in a reproducible way, once p is known.



(a) (b)

Fig. 4. (a) Before Randomized Halton Sequence and (b) After Randomized Halton Sequence with parameter p=3.42.

3 METHODOLOGY

Embedding the watermark logo will be done after the message encryption process, the line slicing process on the XY-secret direction and the method of randomizing the line to get the t-secret direction. It aims to secure messages or watermark logos into levels challenging to detect.

Slicing process by selection point for (x, y) secret direction is the second step in the pre-watermarking process. Using the Bresenham Algorithm in determining pixel selection to form a line extending over the DICOM image per-time t. In this experiment will be executed five types of image slicing.

4 PERFORMANCE ANALYSIS AND EXPERIMENTAL RESULTS

The experimentation has been carried out using MATLAB R2016b platform with CPU of 1,6GHz intel core i5 and RAM of 4 GB. The DICOM images are images of abdomen that are downloaded for free at https://www.dicomlibrary.com/ with a resolution of 512x512x360. The resolution of the logo is 64x45.

To evaluate the performance of the proposed watermarking, peak signal to noise ratio (PSNR) is used. Higher values of PSNR means the better quality of the tested image. The following equation below is the PSNR formula:

$$PSNR = 10.\,log\left(\frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - W(i,j)]^2\right) \quad (1)$$

Where m and n are the dimension of the monochrome image of I and W. I denotes the original image and W denotes the image watermarked.

To get the comparison of the better PSNR value, we are dealing with 5 types of selection point;

1. Point selection Type 1: (1,1) to (512,512),
2. Point selection Type 2: (51,1) to (335,512),
3. Point selection Type 3: (352,1) to (352,512),
4. Point selection Type 4: (1,32) to (512,433),
5. Point selection Type 5: (1,105) to (512,105).

All of selection types is illustrated in Fig.5. And it is running for 360 frames. As a result, we get different values of the PSNR.

The average PSNR of point selection type 1 is 90.33% per frame. The average PSNR of point selection type 2 is 86.01% per frame. The average PSNR of point selection type 3 is 90.96% per frame. The average PSNR of point selection type 4 is 86.18% per frame. The average PSNR of point selection type 5 is 91.5% per frame. The obtained of the PSNR values indicate that easy slicing as shown in point selection type 1, type 3, and type 5 will get the result above 90%.

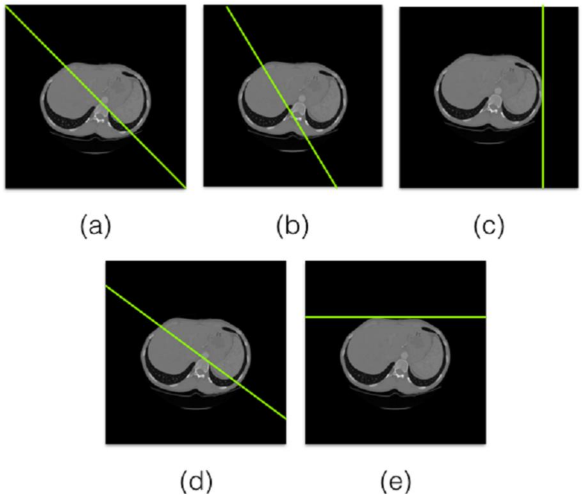


Fig. 5. The point selection of every types; (a) Type 1, (b) Type 2, (c) Type 3, (d) Type 4, (e) Type 5.

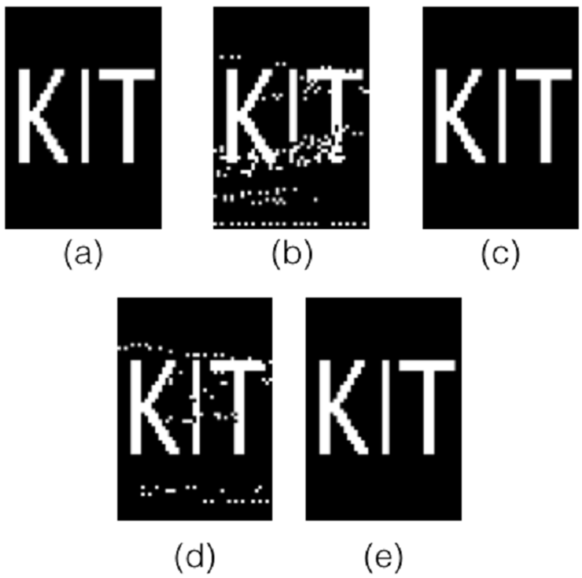


Fig. 6. Decryption of the logo for all types; (a) Type 1, (b) Type 2, (c) Type 3, (d) Type 4, (e) Type 5.

The average of time consumption to run proposed watermarking all types was 0.21 seconds per frame.

Fig.7 illustrates watermarked medical image using the proposed algorithm. From top to bottom is the 1st frame, the 195st frame and the 360st frame.

The primary thing to note in this method is the

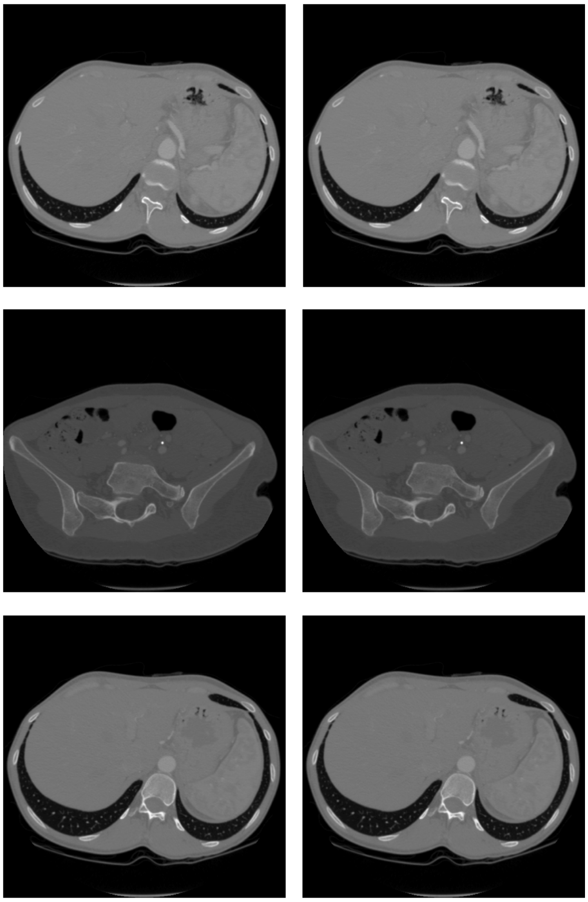


Fig. 7. The left-side is the original medical image and right-side is the image watermarked by the proposed method.

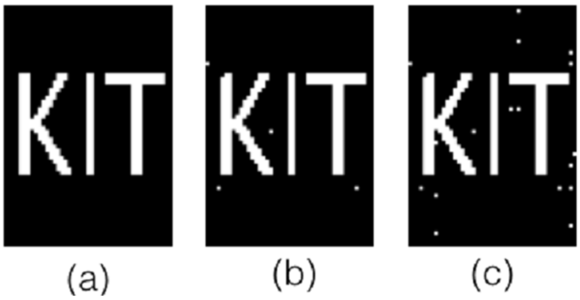


Fig. 8. JPEG compression by Q=30; (a) Original logo, (b) On one frame, (c) On ten frames.

secret direction applied to all frames. Thus, in case of an attack on one frame, it is robust regarding proving the logo watermarked. That is because each frame is drawn only one line across. To test the robustness of the DICOM watermarked, JPEG compression with quantization 30 (Fig.8) and rotation 100 (Fig.9) are used.

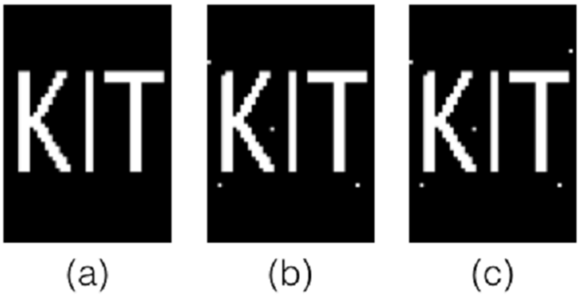


Fig. 9. Rotation 10° ; (a) Original logo, (b) On one frame, (c) On ten frames.

5 Conclusions

In this paper, we presented 3D watermarking secret direction scheme for volumetric DICOM Images. The experimental results show good PSNR values and with a very efficient time. This research uses only one direction and should be improved in many directions to compare it.

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