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Region of Interest-based Tamper Detection and Lossless Recovery Watermarking Scheme on MRI and X-ray Medical Images

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Abstract. The advancement of the technology has introduced many applications that will ease human daily process and improve the way people connect to each other. One of the applications that has been introduced to the user and vastly improve our life is the healthcare system. Health care system allows the medical practitioner to aware of the patient's previous health condition and documents their current. It also allows the medical practitioner to communicate with each other or get some advice from their peers and colleague even if they are far from each other physically. To ensure the authenticity of an image when it is transfer through the health care system, watermarking has been implemented. Through the process of watermarking the images, the authenticity of the images can be ensured. In this study, a ROI-based tamper detection and recovery watermarking scheme has been introduced. The proposed scheme has been tested out on the MRI and XA images. The PSNR value for MRI is 49.09 for the sequential mode and 49.07 in parallel mode. On the other hand, PSNR for XA images is 52.68 in the sequential mode and 52.68 in the parallel mode.

1. Introduction

With the increasingly common in application of healthcare system in a medical facility, communications between multiple medical partitional from different locations has become possible. However, this has brought the issue of medical images authentication to light. Especially when these images were shared between different parties. In certain fields such as military and healthcare, authenticity of the documents received, or transfer is always the one of the most important factors due to their sensitive nature. For example, military often involved with intelligence gathering while the documents transfer via the healthcare system are used often used for the patient's diagnostic.

To enhance and verified the authenticity of the transferred data, digital watermarking has been employed. Digital watermarking is a type of data hiding technology [1]. It allowed the original data to be protected while provide an extra layer of security to the data. Watermarking is often carried out in spatial domain. The intensity of the randomly selected pixel will be modified during the watermarking process[2]. Aforementioned, exchanging medical images or documents between different parties/ hospitals has become more and more common due to the advancement of the technology. Therefore, it has increased the risk of medical images/ documents attacked or modified by third parties. Any tampering that has been done on the medical documents may lead to the false diagnostic of the patients. Medical images such as ultrasound, X-ray, MRI can be easily tampered or modified by using basic image processing tools. Therefore, it is very important to focus on the authenticity of the documents and also increase the difficulties for the documents to be modified. Another important aspect for the watermarking process is its reversibility. The sensitive nature of medical images required the watermark to prove their authenticity. However, they also need to have the ability to recover themselves from the watermarked images as they are required to be view in their original state. Hence, the reversibility of the watermark is highly regarded.

Medical images often been divided into 2 different regions, ROI (region of interest) and RONI (region of non-interest). ROI is the area of images where important data or the diagnosis information is located. On the other hand, RONI often hold less or no significant information. In our previous work, a ROI-based tamper detection and recovery watermarking scheme (ROI-DR) has been proposed [3]. The proposed approach has been tested on the ultrasound medical images. The result proved that the proposed scheme is able to achieve a good result in imperceptibility with peak signal-to-noise ratio (PSNR) values approximately 48dB. The proposed scheme has also show that it is robust enough to fight against various type of tampering. Most importantly, the tampered ROI can be recovered to its original form. The proposed scheme was tested on a ultrasound medical images, while it is able to achieve a good result, it has lead us to one question where if the proposed scheme is able to be applied in other type of medical images such as MRI and X-Ray (XA). In this paper, we will discuss about the application and the result of the proposed scheme when it is applied on different type of medical images. In this paper, past study will be discussed in the section 2, and the methodology used will be discussed in section 3. Section 4 will discuss about the result and the last section will be the summary of this study.

2. Literature review

To address the authentication issue of the medical images, watermarking has been implemented. Through the implementation of watermarking in the medical images, unauthorized modification can be prevented. During the watermarking process, tampered localization was able to detect and locate modification of pixel values of the image. It is also able to deduct the motivation of a tampering process and if the modification is legitimate. Liew [4] proposed a tamper localization and recovery scheme by dividing the image into ROI and RONI. ROI is the significant part of medical images that used by doctors to diagnose the patient, and RONI is the area outside the ROI. The original Least Significant Digits (LSBs) that are removed in watermark embedding process were stored in RONI after compression. Gran [5] proposed a watermarking scheme that uses lossless compression which allows larger ROI to be used. These researches that has been mentioned were conducted on a single frame ultrasound image which is impractical in the real world. Therefore, digital watermarking on multi-frames medical images is proposed. However, several researches have proven that a multi-frames watermarking required a longer processing time. To speedup multi-frames watermarking processing time, a parallel computation in multicores watermarking processing on medical images is introduced.

Recent research about parallel processing has demonstrated its potential in improving medical image processing performance [6]. Parallel processing or computing is a type of computation approach that allows multiple processes or calculations to be carried out simultaneously. This approach is based on the concept of separating a complicated process into a few smaller processes. These smaller processes will then be solved concurrently. Parallelism has been employed for many years, mainly in high-performance computing (i.e., supercomputers such as Cray, and PC- based cluster and grid computing), but the more recent rise of multicore processor technology such as Intel Quad-Core technology has allow server or similar system to take advantages of its processing power [7]. The advantages of the parallel computing have attracted the researcher to implement parallel processing into the watermarking process. Hosny, Darwish, Li and Salah [8] proposed an approach of that make use of the parallel multi-core CPU and GPU for a fast and robust medical image watermarking. The result has shown that the application of parallel multi-core CPU and GPU has resulted in a huge amount of time reduction in the overall watermarking process. Glowacz and Pietroń [9] has proposed a watermarking algorithm by exploring the mixed CPU and GPU processing approach. It has been discovered that parallelization played an important part in the reducing the computation time by making an optimal use of the resources.

While the previous methods address the issue of speed in a watermarking process, there is other issue that has not been addressed. Medical images often are very sensitive in nature. Hence, the originality of the images needed to be preserved. Therefore, reversibility has become one of the important factors in the watermarking process. In certain area, modification in the images are not allowed regardless of the size and type of modification. Any form of modification will affect the authenticity of the images hence render the images to be unusable [10]. The main objective of reversible watermarking is to embed the information without any kind of distortion. Catalin and Coltuc[11] proposed a local prediction based reversible watermarking. This reversible watermarking provides a good result. However, it requires extra computing cost for each pixel a least square predictor in a square block center on the pixel. Hence, a longer processing time is required. Later, Catalin and Coltuc [12] revisit a previous reversible watermarking scheme proposed earlier. The adaptive pixel paring consider only pixels with similar predictions errors is introduced. By increasing the number of pixel pairs where both the pixels are embedded and decrease in the number of shifted pixels, the proposed watermarking scheme were able to outperforms the state-of-art low embedding bit rate schemes. Pakdanan and Saryazdi [13] has proposed a reversible watermarking based on error prediction in Hadamard domain. The proposed method divides the original image into block and transform them to Hadamard domain. Value of error between the original and the predicted coefficient is computed. Proposed method shows that it provides a higher capacity and quality as compared to other well-known methods.

3. Methodology

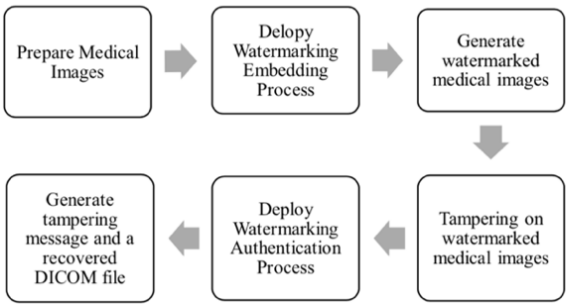

Figure 1. Watermarking process flow

Figure 1 shows the process flow of the proposed watermarking scheme. The proposed watermarking scheme will be implemented in both sequential and also parallelly in order to speed up the watermarking process. When the process is carried out parallelly, the watermarking scheme will subdivide the medical images based on the number of core available and hence perform the all the watermarking process in parallel. This process is shown in Figure 2.

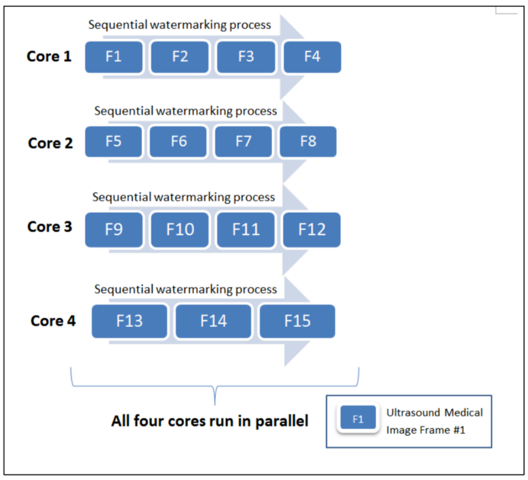

Figure 2. Multi-frame watermarking scheme

Three different type of medical images are selected in this study, MRI, XA and CT scan. While these medical images are different in nature, they are all 8 bits per pixel. The properties of these images is shown in Table 1.

Table 1. Medical Images Properties

Medical Image Sample	Image dimension in pixels	Bits per pixel	Number of frames	ROI size definition [x, y, width, height]
MRI.dcm	640 x 476	8	16	[132, 135, 284, 149]
XA.dcm	512 x 512	8	12	[140, 127, 226, 149]
CT.dcm	512 x 512	8	1	[135, 124, 206, 168]

The entire watermarking and authentication process started with the image preparation process. Each medical image is divided into one main section of ROI and 5 different sections for RONI. ROI and RONI will be predefined before the start of watermarking embedding process. ROI is the section where it holds the important information about the image where RONI is basically contained less to none information.

The main process of the watermarking embedding is adding ROI bits into RONI area to produce a watermarked medical image. These added bits will later be used in the watermarking authentication process.

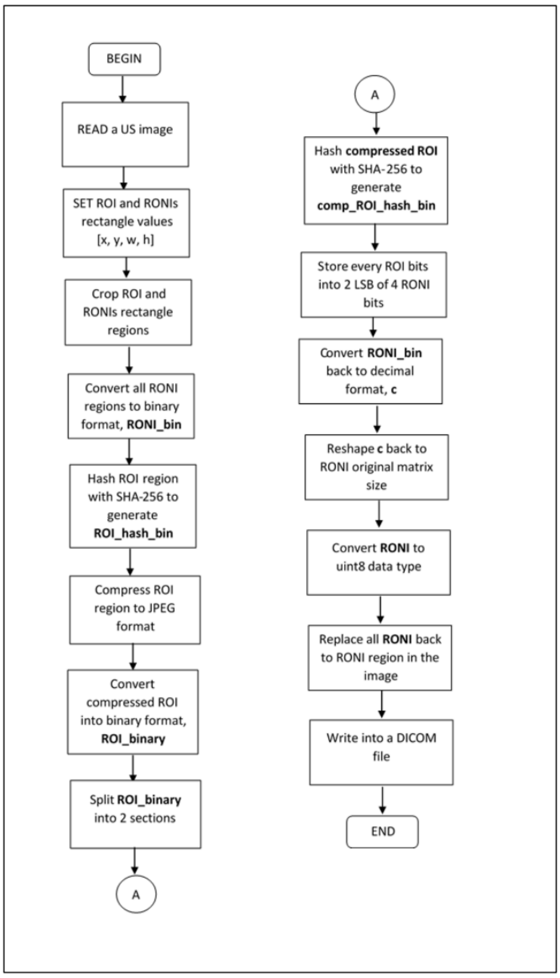

Figure 3. Proposed watermarking embedding process

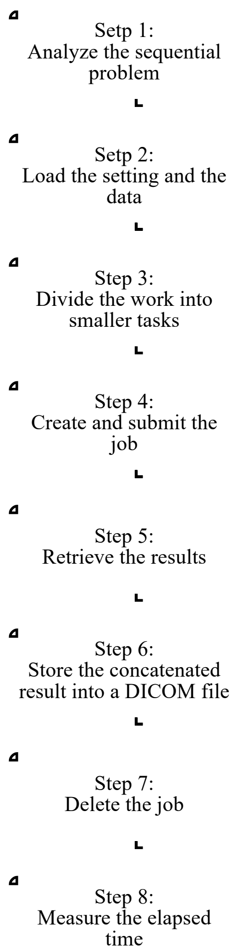

Figure 4. Main algorithm flow of parallel watermarking process

Figure 3 shows the proposed watermarking embedding process. RIO region was hashed with SHA-256 and stored as ROI_hash in ROI 3. This process is carried out in both parallel and sequential modes. The multi-frame ultrasound medical images were loaded into a quad-core processor. While these

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images were loaded into different core, the sequential watermarking process will be carried out in each core parallelly. The main algorithm for the parallel watermarking is shown in Figure 4. The methodology of this study was described in details in our previous work [3] .

4. Result

In our last study, the proposed scheme has been deployed onto the ultrasound medical images. To test our proposed approached with different type of images, the scheme is carried out on the MRI and XA images. The PSNR and MSE values after the watermarking process for the MRI and XA are shown in Table 2 and Table 3.

Table 2. PSNR and MSE Value after ROI-DR multi-frames watermarking embedding process on MRI image

ROI-DR Multi-Frames Watermarking Embedding Process				
MRI.dcm	**Sequential mode**		**Parallel Mode**	
Frame_No	**PSNR**	**MSE**	**PSNR**	**MSE**
1	49.34	35.64	49.00	37.45
2	49.00	37.45	49.00	37.45
3	49.11	35.11	49.11	35.11
4	49.12	35.51	49.12	35.51
5	49.06	34.51	49.06	34.51
6	49.02	34.79	49.02	34.79
7	49.01	35.85	49.01	35.85
8	49.07	36.39	49.07	36.39
9	49.02	35.86	49.02	35.86
10	48.96	35.65	48.99	35.69
11	49.10	36.09	49.10	36.09
12	49.15	36.21	49.15	36.21
13	49.15	36.31	49.16	36.33
14	49.10	36.88	49.10	36.88
15	49.10	37.50	49.10	37.50
16	49.11	37.42	49.11	37.42
Average	**49.07**	**36.07**	**49.07**	**36.19**

Table 3. PSNR and MSE Value after ROI-DR multi-frames watermarking embedding process on XA image

ROI-DR Multi-Frames Watermarking Embedding Process				
XA.dcm	**Sequential mode**		**Parallel Mode**	
Frame_No	**PSNR**	**MSE**	**PSNR**	**MSE**
1	52.70	38.96	52.70	38.96
2	52.69	39.54	52.69	39.54
3	52.65	39.69	52.65	39.69
4	52.65	39.80	52.65	39.80
5	52.65	39.74	52.65	39.74
6	52.72	39.93	52.72	39.93
7	52.68	39.90	52.68	39.90
8	52.69	39.87	52.69	39.87
9	52.69	39.87	52.69	39.87
10	52.71	239.90	52.71	39.90
11	52.68	39.89	52.68	39.89
12	52.67	39.86	52.67	39.86
Average	**52.68**	**39.75**	**52.68**	**39.75**

Based on the result it can be concluded that the PSNR values for MRI and XA are both well above the minimum acceptable PSNR value which is 30dB. When the two group of images were compared, it can be notice that PSNR value for the XA is better than the PSNR value for MRI. One of the reasons for this is the ROI size for XA is smaller than the ROI size of the MRI. Hence, there are fewer embedding bits in the RONI.

Table 4 Speedup Factor for ROI-DR multi-frames watermarking embedding process on different medical images modalities

Medical Image Modalities	Number of frames	Elapsed time (seconds)		Speedup factor= Sequential / Parallel
		Sequential	Parallel	
MRI	16	16.57	18.50	0.90
XA	12	10.94	16.10	0.68
US	15	14.30	12.60	1.14

Table 4 shows the speedup factor for DOI-DR multi-frames watermarking embedding process on different medial images modalities. The speedup factor is calculated by dividing the elapsed time of the process in the sequential mode with the parallel mode. The result shows the speedup factor for MRI and XA is smaller than 1. This result might due to the frame size of the MRI and XA as it is smaller than an ultrasound image. Therefore, they are unable to take advantages the proposed multi-frames watermarking scheme.

In order to test the robustness of the medical images towards any tampering, the MRI, XA and CT has been tampered. This process was completed by adding "Paper and Salt" noise to the ROI. A portion of the images has been cloned and flipped vertically into the ROI.

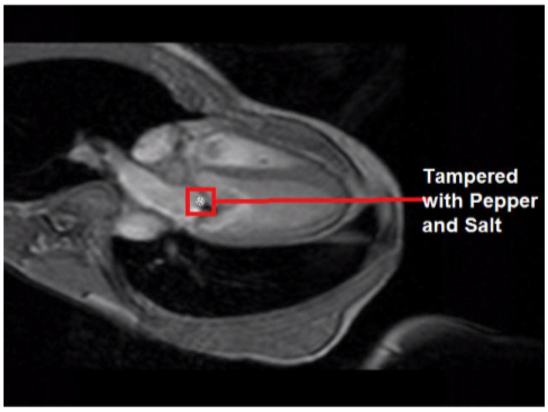

Figure 5 Watermarked MRI tampered by "Pepper and Salt" noise

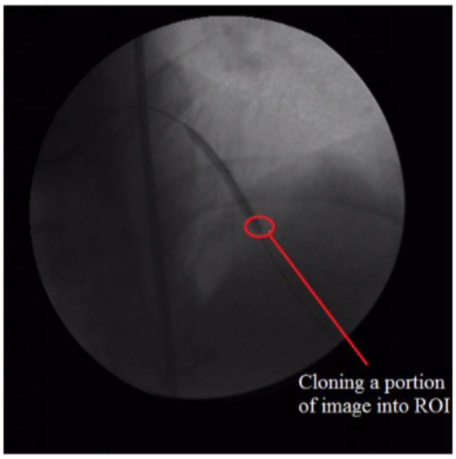

Figure 6 Watermarked XA tampered by "Pepper and Salt" noise

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Figure 7 Watermarked CT tampered by "Pepper and Salt" noise

The time needed for the authentication process has been recorded. In Table 5, it can be noticed that the elapsed time in the watermarking authentication process for different medical images is very efficient which only took less than 0.5 seconds. At the same time, it is also able to detect any form of tampering and recovery regardless of the image type. However, it has been discovered that the elapsed time for the parallel watermarking authentication process is quite high which render it not suitable to be adapt. This might largely due to the frame size of the medical image that are too small to take advantages of the parallel watermarking process.

Table 5. Speedup factor for ROI-DR multi-frames watermarking authentication process on different medical images

Measurement	Result			
	MRI	XA	CT	US
Elapsed time in watermarking authentication process (seconds)	0.46	0.29	0.43	0.34
Able to detect tampering	Yes	Yes	Yes	Yes
Able to produce exact ROI recover	Yes	Yes	Yes	Yes
Able to generate a recovered DICOM file	Yes	Yes	Yes	Yes

Table 6. Speedup factor for ROI-DR multi-frames watermarking authentication process on different medical images

Medical Image Modalities	Number of frames	Elapsed time (seconds)		Speedup factor= Sequential / Parallel
		Sequential	Parallel	
MRI	16	3.28	16.90	0.19
XA	12	1.69	12.70	0.13
US	15	5.70	9.30	0.61

5. Conclusion

The proposed scheme similarly is able to receive a fast authenticating result when it is applied to different medical images. The robustness of the proposed scheme was also been tested and has been proven to be able to detect any tampering and has the ability to recover the ROI. However, due to the small size of the MRI and XA, the elapsed time for the parallel watermarking scheme are quite high.

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The small size of these images does not allow them to take advantages of the parallel processing. Future study needs to be carried out in order to investigate this issue.

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