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Digital Medical Image Security in Teleradiology using Tamper Localization and Lossless Recovery Watermarking based on LZW lossless compressed Watermark

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Abstract

Digital imaging technology has got its permanent place almost in every field of life. Computed tomography, X-Ray, Magnetic Resonance Imaging, Ultrasound etc. are medical imaging technologies being used for the purpose of medical imaging. Each of the technologies play special role for surgical planning of health recovery process. With the passage of time human needed decentralization of health facilities for easy and better services provision to the far flank areas of the countries. Decentralization of such facilities has become possible due to the usage of modern communication means such as internet. Teleradiology is a health promoting facility based on internet to get access to remotely located radiologist for better analysis of medical images. Teleradiological images are facing security problems due to different noises and unprotected nature of internet channels by giving opportunities to the unauthorized users getting easy access to the communicating medical images data for change of contents according to their own wishes. Medical image data is very sensitive data and do not afford even a bit of change. Surgical decision made on the basis of altered or tampered medical images can lead to non-recoverable loss. To avoid such a big loss there is an intense need of taking such steps making sure the image protection as well as its recovery into its original version. Image tampering occurred in Teleradialogy environment can be covered by using digital watermarking techniques. This research uses Least Significant Bits (LSBs) based digital watermarking technique for content authentication of Ultrasound medical images. The image has two main parts, ROI (region of interest) and RONI (region of non-interes). Usually ROI covers one third part of the image, consisting of image important information. ROI is defined and compressed using more than one lossless compression techniques. Lempe Ziv Welch LZW is a better lossless compression resulting technique due to its good reduction of bits capability and better compression ratio. LZW lossless compressed ROI is inserted into RONI as a watermark. On the recever side the lossless compressed watermarkis retrived decompressed and used for the lossless recovery of tampered areas of the image ROI.

Keywords: Ultrasound medical image security, Teleradiology, ROI, RONI, LZW Lossless Compression.

Introduction

As a part of modern healthcare system, decentralized medical image analysis is playing a key role in the development of health care industry. Teleradiology is a remote medical image processing utility to share a medical expert expertise with those persons that are new in the field or less experienced. Radiological medical imaging is a basic and driving component of Teleradiology. Radiological imaging is performed by using a radiological modality for example computed tomography (CT), nuclear medicine (NM), positron emission tomography (PET), magnetic resonance imaging (MRI), X-Ray and Ultrasound (Us)[1]. Digital technology applications has made possible the transformation of film based images to its digital version for easy manipulation and communication in a simple and faster way. Digital form of images has many advantages such as better quality, easy modification and the copy version same to the original one[2]. Digital technology has added valuable contribution but also resulted in many deficiencies such as digital image contents alteration during its communication. The literature reports that digital watermarking has been used to provide security to different contents especially for digital image in online communication.

In response to a question that what is a watermark can simply be answered as a watermark is a special code, symbol, picture or any other identifying secret code capable of uniquely indentifying, authenticating and recovering a product to its original version in case of tamperoccurances. A visible watermark is a logo or some other picture pasted onto the host images or other multimedia product proving its ownership. For example a particular picture or monogram available on passport, paper currency or machine understandable information code available on a product. The invisible or hidden watermark is some non-visible code used for the product contents authentication such as medical images. The watermark can be detected and extracted by using detection and extraction algorithms. This is very important to make secure digital medical images by developing authentication, recovery mechanisms to prevent the chance of wrong decision making.

Medical data is very sensitive and does not afford even a bit of change. Digital watermarking of images is a technique used to protect the digital images from tampering and perform tampered image recovery as well. Digital watermarking of a multimedia product should be done in such a way that latterly the watermark remains robust to different attacks. The watermark can be detected and extracted by the owner to identify or authenticate the product[3]. The watermarking should not change the perceptual quality of host image and should not be disturbed dut to image processing applications[4]. Generally a watermark and its host mutual processing mathematically can be given as:

$$Xw = F(X, W) \tag{1}$$

The 'X' is an original image to be watermarked, 'F' is the watermarking function or algorithm, 'W' is the watermark and 'Xw' is the watermarked version of the image. Similarly watermark detection and extraction can be given by the mathematical equation as:

$$Wex= D(Xw, [X]) \tag{2}$$

Here 'Wex' is the watermark extracted, 'D' is the function for watermark detection, extraction ,'Xw' is the watermarked image and X represents the original image.[X] shows the optional existence of original image because it presence depends on the watermarking schem used either it is blind or non blind. In case of usage of non blind watermarking schem X presence is necessary otherwise not necessary in blind case watermarking.

An image 'I' can be represented in its digital format using rows and column, which also give the image size. Every junction of a row and a column of the image, I(x,y) gives a particular pixel address of that image. Where x shows the row while y shows the column idex while f(x,y) gives the pixel intensity. Every pixel value is transferable to its binary contain zeros and ones. The ones show the on bits while zeros show pixel off bits, a pixel intensity is formed by the ones as shown in the figure-1. A pixel value changes directly due to the change in bit value. There are different bits images such as 8-bit (0-255), 9-bit (0-511), 10-bits (0-1023) and so on. The bracketed values show the range of pixel values of indicated images. An image will be looked totally black if all the bits values equal to zeros while will be white/bright if all the bits values equal to ones. If here we consider only a 8-bit image then it can be represented as shown in Figure 1. Another fact if there is some manipulation in most significant bits (MSBs) then the image perceptuality will be highly degraded while it will remain unchanged if this manipulation is restricted only to least significant bits (LSBs). As it has been already mentioned thata medical image data is very sensitive data so we use LSBs for watermark encapsulation during this research because we not only want to communicate watermark but also keep constant the perceptual quality of the image unchangeable.

In this paper we have focussed only on invisible watermark as a digital code. Region of Interest (ROI) of the image is defined, compressed using different lossless compression techniques. LZW compression is pointed out the best one for watermark compression and compressed watermark is embedded into LSBs of RONI. A MATLAB coded algorithm is used for watermark detection and extraction.

Methodology

Basically the existing digital watermarking techniques used for digital image security can be divided into two major groups, transform and spatial domains[5]. Each of the two grouped techniques is totally different regarding watermark embedding and its extraction. Using the frequency domain techniques a watermark is encapsulated into image transformed version. The image transformation is carried out through one of Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) or Discrete Fourier Transform (DFT) techniques. The watermark encapsulation to the image alternative version is complex but having the advantage of more robustness. The watermark robustness guarantees its existence even facing some critical attacks such as scalling, cropping and compression. Invisibility of watermark is another key advantage of this category watermarking as it is spreaded into image in its signal form[6]. The distributed nature of watermark defends it from croppin, scalling and lossy compression of the image[9]. This category watermarking has the speciality of image and other digital products copyright protection[7,8]. It has been also used for digital images contents authentications[10-12].

128	64	32	16	8	4	2	1
--> MSB	. . .	. . .			. . .	. . .	← LSB

128	64	32	16	8	4	2	1
0	1	0	0	1	1	1	1

Pixel value= 64+8+4+2+1
= 79

Figure-1
Eight bits image a particular pixel representation system

On the other hand the spatial domain watermarking techniques have been used to embed watermark into image pixels directly without transformation to any otherversion[13]. The image pixels Least significant bits (LSBs) manipulation technique is well known for this category watermarking. This method is widely used to make the watermarking process simple and preserve the image perceptual qualities. In case of digital medical image watermarking keeping the image perceptuality constant is a basic need. The non robustness of watermark to external attacks is the main disadvantage of this method[14]. To detect and extract the watermark from image some times its original image presence is necessary[15]. The process is called non-blind process if the presence of original image is essential to detect and extract the watermark which has been also termed non-oblivious process in watermarking literature. This process causes miss uses of system resources such as memory and processers to search and keep the original image for every image in the record. This makes the watermarking scheme useless due to such burden on the system. Contrast to non blind the blind or oblivious watermarking does not need the original image to detect or extract the watermark from the watermarked product[16]. This watermarking is preferred to make the process simple and save the system resources.

A number of spatial domain watermarking techniques have been used for medical image security to develop online medical health care systems. Tamper localization and its recovery of medical images is one of such techniques. Many methodologies have been used for this purpose. In one of such methods the image pixels divided into blocks and the average intensity of the blocked pixels is compute to be used for recovery of tampered pixels of the image[17]. However the approximated recovery makes doubtful the recovery[18]. In some techniques the total image is not considered for making it secure and only the important portion known as region of interest is pointed out and taken as watermark to be encapsulated into image. At the receiver side this important information is extracted and used only for that part of image authentication and recovery. A ROI-based reversible watermarking scheme is a good example of this technique[19]. Using the extracted watermark the image important part can be checked for possible tampering, in case of any tamper report the watermark can be used to recover it as the original one[20]. For such recoveries the images are divided into regions of interest and non interest for the ease of watermark definition and its encapsulation and then its recovery to perform effective tamper localization and recovery[21]. It is desired to make the image recovery lossless so the watermark is lossless compressed for its size reduction for easy manipulation of least significant bits. One of such methods is tamper localization and lossless recovery watermarking of medical images[22].

Data compression is performed to reduce the data size to facilitate its operations such as exact recovery, speedy transfer, reduction of communication bandwidth and storage. There are two main modes of compression, lossless and lossy. Using lossless compression data size can be reducedto the data size upto one to ten times of the original having the capability of original version recovery of the compressed data. On the other handlossy compression mode reduce the data size upto fifty times the original on the cost of losing important part of data[23,24]. Figure-2 shows the general sketch of data compression and decompression.

In this paper our focus is on a watermark lossless compression based spatial domain watermarking of Ultrasound digital medical image to keep the distortion low or negligible. Here an Ultrasound image as shown in figure-3, of 480x640 sizes is read from the image database. ROI of size 100x100 as a watermark is selected automatically using the x, y coordinate system. Rest of image other than ROI is taken as RONI. To minimize the distortion up to negligible extent the watermark is compressed using lossless compression techniques illustrated in table-1, is encapsulated into RONI pixels LSBs using MATLAB based developed algorithm which results a watermarked image can be seen in figure-4. The same algorithm is used for watermark detection and extraction process. In this work we have used lossless compression of watermark to reduce watermark payload. It makes sure the image lossless recovery because using watermark lossless compression and its decompression. The US images are monochrome means colourless and do not need additional effort for their colour compression. The lossless compression of radiologic images should not be visually degraded for better diagnostic purposes[25].

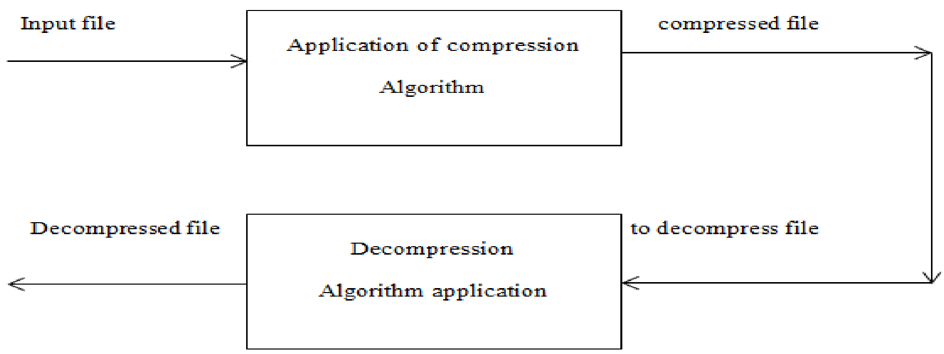

Figure-2
Watermark compression and decompression algorithms

Table-1
Comarision of watermark lossless compression using different techniques

Compression technique	Compression mood	No of ROI bytes before compression	No. of bytes after compression	Time taken in sec: during compression	Compression ratio
Png	Lossless	8281	4105	0.065	0.495
GIF	- - -	8281	7466	0.016	0.901
JPG	Lossless	8281	1559	0.008	0.188
Jpeg2000-j2c	Lossless	8281	2956	0.010	0.357
Jpeg2000-jp2	lossless	8281	3041	0.005	0.367
Jpeg2000-j2k	Lossless	8281	2956	0.004	0.357
LZW	Lossless	8281	600	0.003	0.007

Analyzing the above table each field gives the required information showing the details of the best compression techniqueto be used in image watermarking. The compression ratio is the ratio between compressed and non-compressed versions of watermark. Compression ratio and time taken during compression are the important parameters to be considered for the selection of best compression technique. From the above listed records LZW is the most feasible technique to be used during this watermarking.

The quality of image after watermark extraction is the main factor considered to measure the reconstruction quality of an image. Peak signal to noise ratio (PSNR) is used to calculate the qualities of the original image and the noise induced images during image compression or watermarking. A watermarked medical image perceptually non degradation indicates better and reliable watermarking. PSNR is an important parameter used to measure the image quality of the reconstructed image after its watermarking. PSNR is an engineering term measured in a unit called decibel (dB) during calculations. The greater value of PSNR represents high reconstructed quality while low value shows the low reconstructed quality. The PSNR value equal to 30 dB or above is considered good qualities of the images. Mean square error (MSE) is a base for PSNR calculation is given by;

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]2 \quad (3)$$

The values m, n are rows and columns of image represented as a matrix and I is the image before compression while K is the approximated noise induced during compression. The watermarked and recovered images quality is measured by the PSNR calculation given by the formula.

$$PSNR = 20.\log 10\ (\mathrm{MAX\ I}) - 10\ \log 10\ (\mathrm{MSE}) \quad (4)$$

Here 255 is MAX I, highest possible numeric value for a pixel because we are using 8-bit ultrasound image.

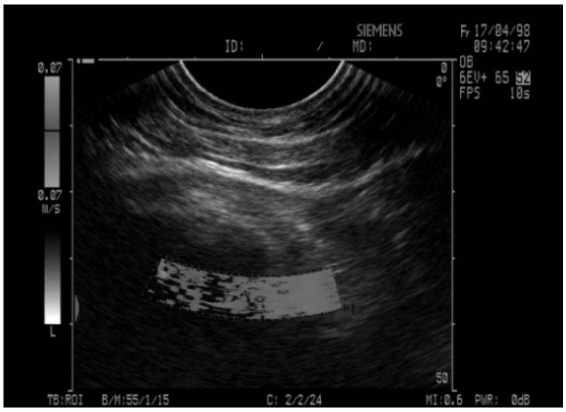

Figure-3
Original Ultrasound image

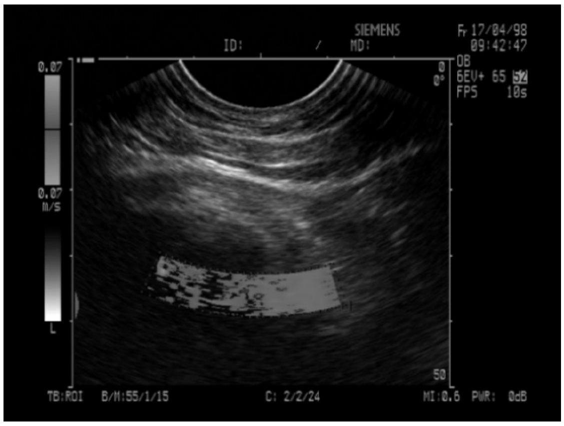

Figure-4
Watermarked Ultrasound image

Results and Discussion

The above displayed figures using MATLAB based algorithm illustrate the perceptual qualities of the image after and before watermark insertion. Figure-3 is the original Ultrasound image before watermarking while figure-4 represents the watermark inserted image. According to one of the watermarking main requirements of medical images both the original and watermarked versions of the image should be same perceptually and the image should not degraded. An ultrasound image of 480 * 640 sizes is read as shown in figure-3, its ROI is selected as watermark, using x,y coordinate system (specifying the included pixels of the image in rows and columns). A watermark is written into a file while compressing it by a number of lossless compression techniques. LZW technique is the best one based on good compression ratio, more bytes reduction and is encapsulated to image pixels at least significant bits resulting into a watermark encapsulated image. One cannot notice any change in the original and watermarked images, fulfilling a watermark embedding rule. The developed algorithm is capable of detection and extraction of watermark from watermarked image.

Conclusion

MATLAB R2010a, Windows 7 Professional and HP ® Core (TM) i7-3770 CPU Intel @3.40GHZ were used for the experiments. The scientific research progress has been noted with the passage of time in different fields including online digital image security. This progress has well contributed in the development of medical imaging technologies. The authentication of PACS medical images is important for accurate and timely medical decision making process. This is only possible by making the images secure not to be affected by the noisy communication channels and by keeping away from hackers access, in case of happening any tamper its localization and lossless recovery is possible using watermarking technique. Digital watermarking is a technique being used for this purpose for the last two decades. Digital watermarking is used for the secure communication of digital multimedia products as an improved version of steganography used for the messages secure communication only. In this article we have focused on the digital watermarking of Ultrasound medical images. The image was divided into ROI (region of interest) and RONI (region of non interest). ROI is the most important part of the image for the diagnostic point of view while RONI is the outside part around ROI. The ROI was lossless compressed using different techniques and LZW compression was selected as the best of all on the basis of more bytes reduction and good compression ratio. The compressed watermark was embedded into least significant bits (LSBs) of RONI without the degradation of image perceptual qualities. Lossless compression of watermark ensures the its exact recovery from the watermarked image and recovery of tampered ROI of the images. The manipulation of pixels LSBs of the image keeps constant the image perceptuality and diagnostic qualities as well.

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